Regulated Slow Steaming in Maritime Transport

An Assessment of Options, Costs and Benefits

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Preface

This report has been written by CE Delft, the ICCT and Professor Mikis Tsimplis for Transport and Environment and Seas at Risk. Funding was kindly provided by Climateworks and the Umweltbundesamt. The views expressed are those of the authors, not necessarily of the clients. Conversely, the authors do not necessarily advocate regulated slow steaming as an instrument to reduce greenhouse gas emissions from ships.

Jasper Faber

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Summary

The Clean Shipping Coalition (CSC) has proposed speed limits in the shipping sector as 'the key to the fast and efficient reduction of greenhouse gas emissions from ships' (MEPC 61/5/10). It has proposed to the International Maritime Organization's Marine Environment Protection Committee (IMO MEPC) to discuss mandatory speed controls.

Currently, fleet average ship speeds vary as the shipping sector adapts to changing market circumstances. In recent years, speeds have been reduced in a response to an increasing supply of ships, a slower increase in demand for maritime transport and rising fuel prices.

Regulated slow steaming could be introduced at various levels. A global regime would potentially have the largest impact on speed and emissions, a regional initiative, e.g. in the EU, would have a smaller impact. Regulated slow steaming in the Arctic could prevent an increase in black carbon (BC) emissions in the Arctic as shipping activity increases as a result of the opening of sea routes; BC has a particularly strong climate effect when deposited on snow or ice.

This report, written at the request of the several members of the CSC, studies the impacts of vessel speed on emissions, technical constraints and other experiences with slow steaming and current speed regulations. Moreover, it analyses the legal feasibility of regulated slow steaming, the feasibility of implementation, possible policy designs, and the associated social costs and benefits of such an approach.

Environmental impacts of slow steaming

As a rule of thumb, engine power output is a third power function of speed. Hence, when a ship reduces its speed by 10%, its engine power is reduced by 27%. Because it takes longer to sail a given distance at a lower speed, the energy required for a voyage is reduced by 19% (a quadratic function).

Within most speed ranges, fuel consumption and consequently emissions of carbon dioxide and sulphur oxides are reduced in line with the energy consumption. Only at very low speeds, the amount of fuel needed to provide a unit of output energy may increase somewhat, although this can be prevented by derating the engine.

The emissions of nitrogen oxides are reduced in line with the fuel consumption unless the engine load becomes very low. Below a certain engine dependent load, the absolute quantity of nitrogen oxide emissions is reduced, but less than fuel consumption.

There is still much uncertainty about the relation between engine load and emissions of black carbon. The available scientific evidence suggests that black carbon emissions will be reduced in line with fuel consumption until the engine load becomes very low.

In sum, slow steaming reduces all shipping air emissions. The environmental impacts of slow steaming are independent of whether ships slow down voluntarily or are required to do so by law.

Legal feasibility

The legal feasibility of regulating ship speed depends on where and how the speed control is imposed.

Compulsory slow steaming can be imposed by a State on the ships flying its flag. For such ships the flag State has prescriptive and enforcement jurisdiction. Under a global agreement, Port States would also have the right to impose speed controls on ships flying the flag of non-party States.

For a regional speed control, the situation is more complex. Imposing slow steaming only on ships flying a flag within the region would risk distorting the market and, given the relative ease of changing flag, also risk eroding environmental impacts.

However, a coastal State can impose slow steaming on all ships as conditions for entry into its ports. Such a measure can be enforced on the basis of the presence of the ship in that port. Issues relating to the extraterritorial character of speed controls at the high seas or the Exclusive Economic Zone (EEZ) are likely to arise but, it is our view, because they are imposed as conditions for entry to a port the fact that they dictate behaviour in areas outside the enforcement area of the coastal State is not a restriction in exercising enforcement rights because they are of no effect unless where a ship voluntarily visits the port of the coastal State.

Feasibility of implementation

The feasibility of implementation depends on whether speed can be accurately monitored, both by the ship and the regulator, and whether a regulated speed can be set.

(S-)AIS systems, which most ships are required to have on board, allow both the ship and the regulator to monitor speed over ground. Moreover, independent verification of the average speed on a voyage is possible by inspecting logbook entries of when a ship leaves one port and enters another. There are no restrictions on the use of (S-)AIS data by regulatory parties.

A regulated speed that is dependent on ship size and type is preferable to a single speed for all ships, mainly because the latter would distort the competitive market between ship types. Ship-specific speeds could be monitored based on self-reporting of verifiable data.

Technical constraints

Many shipping companies have experience with slow steaming in recent years. Even at very low engine loads, they have encountered only a few problems and these problems could be surmounted by small changes to operational procedures. Hence, it appears that there are very few technical constraints to slow steaming.

For new ships, we have not identified constraints to lowering the design speed. There are constraints to the power of ships, related to the ships ability to manoeuver safely in adverse conditions, but ships can be equipped with redundant power, albeit at a cost. The decision becomes an economic consideration rather than a technical constraint. Ships designed for slower speeds may have a higher block coefficient. As a result, the third power relation between speed and engine power cannot be taken for granted for new ships.

Industry responses

As noted above, many ships have slowed down in the past years. As a consequence, industry players like shipping companies, logistics service providers, ports and shippers all have recent experience with slow steaming. Based on a limited survey, it appears that shipping companies and shippers have been most affected. These parties also have the strongest opinions about a regulated speed reduction.

Shipping companies face a constant need to manage their fleet size and available capacity while reducing their fuel costs where possible. Speed as a variable allows them to better manage these factors. The concept that slow steaming leads to a 'greener' supply chain is a well understood (if unintended) benefit, but carriers will likely return in large part to pre-2007 speeds when market conditions change and more capacity is required. Regulated speed reduction would restrict the degree of freedom that the shipping companies have in responding to changing market circumstances.

Shippers have been affected by slow steaming as they have had to build up their inventory levels and adjust their supply chains. They recognise the benefits of being able to market the use of 'green' shipping practices but do not feel that they have a consistent way to evaluate, communicate, and compare slow steaming with other tools to achieve similar goals.

In our limited survey, there was near universal opposition to the concept of mandatory speed limits. Reduced market flexibility was the primary reason for this. There was also confusion as to why a mandatory scheme would be required as opposed to a carbon levy or voluntary program. Some participants noted that their strong opposition was directed at a theoretical and undefined program. More definition and accommodation of their chief concerns may ameliorate some of the dissent. The success of any mandatory policy will be in its administrative, implementation and enforcement details. A mandated program must be clear, fair, and include a reasonable process for determining appropriate speeds and scope of application.

Design of a global regulated slow steaming regime

The main aim of global regulated slow steaming would be to reduce CO_2 emissions from shipping.

The development of a global regime for compulsory slow steaming provides the most difficult to achieve but least difficult to implement legal option. A general agreement on maximum speeds for each type of vessel approved by the IMO's navigation committee and the MEPC would give global consent to such measures. This will reduce the risk of legal claims against regulated slow steaming. Building consensus within the IMO would be a necessary prerequisite.

The speed restriction should be expressed in average speed over ground so that it can be monitored and verified; and be dependent on the ship type and possibly size in order to limit distortions of competition.

In a global system, enforcement would be both through flag State and port State control. The responsible entity can in that case be the ship owner. In case the owner is not the operator of a ship, he can contractually pass on the obligation to respect the speed restriction to the operator.

Enforcement of global regulated slow steaming would be organised using flag State obligations and port State rights. Flag States that would be a party to a convention would take on the obligation to enforce the speed restriction on

ships flying their flag. In addition, port States which are party to a convention would have the right to inspect any ship in their port for compliance. Compliance can either be demonstrated by a certificate from the flag State or a compliance report on board of the ship in case she is registered in a non-party State.

The time to introduction depends on whether a new convention is needed or whether regulated slow steaming can be introduced as a revision to an existing convention. Recent experience within IMO suggests that a new convention may take 18-24 years from the time the issue is first raised until its entry into force. An amendment of an existing convention may take 5-15 years.

Design of an Arctic regulated slow steaming regime

The main aim of regulated slow steaming in the Arctic would be to reduce BC deposition on ice and snow in the Arctic.

Imposing speed restrictions in the Arctic can be done unilaterally by one or more States, as conditions for entry into their ports or by including speed restrictions in the Arctic as part of the, under development, Polar Code or finally by imposing such restrictions as an Associated Protective Measure within the designation of an Arctic PSSA.

The geographical scope of a speed restriction in the Arctic ensures that the aim of the regulated slow steaming regime is met, i.e. to reduce black carbon emissions from ships and/or deposition of these emissions in the Arctic. In case of the narrow aim, i.e. reduce *emissions* of black carbon from ships in the Arctic, the geographical scope would be confined to the Arctic. If the aim of the Arctic slow steaming regime is broader, i.e. to reduce *deposition* of black carbon from ships in the Arctic, the geographical scope needs to be larger than the Arctic itself.

The required speed would be an average speed within the geographical scope. A single speed for all ships, regardless of type or size, would be easier to monitor and enforce, but could have negative impacts on the competitive market between different ship types in the future.

Under the Arctic regulated slow steaming regime, ships would need to comply with the speed restrictions when sailing in the geographical scope of the area where restrictions are imposed. This means that they would be required to report: time of entrance in the geographical scope; time of exit of the geographical scope; route and distance sailed within the geographical scope; average speed in the geographical scope. Regulators can monitor speed using (S-)AIS.

The enforcement of an Arctic speed restriction could be organised by refusing entry to ports of contracting States to ships that cannot demonstrate compliance with the regulated slow steaming regime.

The designation of a PSSA typically takes a few years.

Design of a European regulated slow steaming regime

Speed restrictions on ships sailing to EU ports could be introduced in order to reduce the climate impact of ships sailing to EU ports.

As argued above, a speed restriction on voyages to EU ports would need to be adopted as a condition of entry into an EU port. This may raise issues of extraterritorial impact of EU law.

This report argues that a regulated slow steaming regime imposed on the high seas are not a violation of the exclusive rights of the flag State because they are not enforceable unless the ship voluntarily chooses to enter the port of the State imposing such controls. Thus it is submitted that speed restrictions on ships imposed as conditions for entry in the EU Member State ports are legally feasible. They are easier to justify when compliance is demanded for voyages to and from Member States. The port State has, in our view, jurisdiction to enforce such measures. Thus it is a matter for the national legislator whether the enforcement jurisdiction of the port State should be exercised against foreign ships violating such regulations.

The geographical scope could either include all ships sailing to EU ports or ships sailing between EU ports.

In order for the speed restriction to be enforced, ships should report their average speed within the geographical scope to the regulator upon entering a port. If a ship can ascertain that it will continue to sail in Europe, the per voyage reporting requirement could be relaxed in order to reduce the administrative burden.

Enforcement of a regional speed restriction would ultimately take place by refusing ships that have sailed above the limit entry to EU ports.

An European Directive would take several years to be prepared and at least two years to be agreed upon by the Council and Parliament.

Costs and benefits of regulated slow steaming

Regulated slow steaming would have costs and benefits to the society. Based on a literature review and a stakeholder consultation, this report identifies the following items.

- direct costs:
  - costs of building and operating additional ships (including fuel);
  - costs of ship and engine modifications;
  - higher inventory costs for maritime cargo;
  - monitoring costs;
- direct benefits:
  - fuel savings;
- indirect costs:
  - adjustment of logistical chains;
  - less innovation in energy saving technologies;
- external benefits:
  - lower emissions of CO2, NOx, SOx and BC;
  - fewer whale strikes;
  - higher emissions associated with ship building.

The balance of costs and benefits depends on the stringency of the speed restriction, fuel prices, and the type of speed restriction, amongst others. This report has assessed them in two cases: for a global speed restriction and for a speed restriction on ships sailing to EU ports.

Costs and benefits of a global regulated slow steaming regime

A global regime which limits the average speed of ships to 85% of their average speed in 2007 would have benefits that outweigh the costs by USD 178 - 617 billion in the period up to 2050, depending on future fuel prices. This result takes into account social costs and benefits as defined above. The main costs are the purchase of additional ships and the main benefits are reduced net fuel expenditures. To put the benefit in perspective, the net present value of

the baseline fuel costs of the shipping sector until 2050 are projected to be USD 5,900 billion in a base fuel price scenario

The results are sensitive to fuel price projections; higher fuel prices result in larger benefits, lower fuel prices in lower benefits. The results are also sensitive to the discount rate used, although in most cases, a change in discount rate does not change the sign of the net costs or benefits.

Costs and benefits of a European regulated slow steaming regime

A regime in which all ships arriving in European ports would need to reduce their speed to 85% of their 2007 average would on balance either have a cost of USD 1 billion or net benefits of up to USD 74 billion, again depending on fuel prices. In the base and high fuel price scenarios, the benefits outweigh the costs, but not in a low fuel price scenario

Conclusion

Slow steaming has significant environmental benefits. Mandatory slow steaming may, depending on the stringency of the speed restriction, also have economic benefits. The economic benefits are larger for ships that spend a large number of days at sea.

Slow steaming is already widely practiced as a result of changed market circumstances. If markets would revert to the pre-2008 situation, the chances are that ships will speed up again. Experiences with slow steaming vary across stakeholders. Typically, shipping companies have benefited from slow steaming while shippers have had to adjust to the new situation, e.g. by increasing their inventory levels.

Mandatory slow steaming is legally feasible either under a global agreement or unilaterally as a condition of entry to a port.

1 Introduction

The Clean Shipping Coalition (CSC) has presented a proposal on mandatory speed limits for ships to the International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC): 'Speed Reduction – the key to the fast and efficient reduction of greenhouse gas emissions from ships' (MEPC 61/5/10). The proposal contained references to evidence showing that speed reduction can result in considerable reductions in fuel use and CO_2 emissions, and to speed restrictions in other transport sectors. The proposal argued that speed reduction should be pursued by the IMO as a regulatory option in its own right and not just as a possible consequence of other instruments.

The discussions at MEPC led to the conclusion that speed considerations would be addressed indirectly through other instruments and that no further investigation of speed reductions as a separate regulatory path was needed. Still, it was noted that if speed restrictions would be imposed on ships, "different limits would be needed for different ships types and (…) the legal and enforcement aspects as well as the practicalities of the measure should (…) be investigated" (MEPC 61/24).

Transport and Environment (T&E) and Seas at Risk, both members of the CSC, want to develop the various policy options further in order to shed more light on the importance of speed and its relation with emissions and abatement options and to investigate whether regulated slow steaming is practically and legally feasible. They also want to address the comments raised in MEPC 61. To this end, they have asked CE Delft, the ICCT and Mikis Tsimplis to study the feasibility, costs, legal aspects and benefits of regulated slow steaming in more detail, taking into account considerations raised at MEPC.

1.1 Study objective

The objective of this study is to design the regulated slow steaming policies and assess their costs and benefits.

In particular, the project aims to:
- design regulated slow steaming policy instruments, taking into account:
  - legal aspects of prescriptive and enforcement jurisdiction;
  - current industry practices and other relevant factors;
  - feasibility of implementation;
  - safety aspects;
  - potential differentiation among ship types and sizes.
- quantify the costs and benefits as a function of two selected options.

1.2 Types of regulated slow steaming regimes

Speed restrictions can, in principle, be introduced at various levels and for different purposes. This report assesses slow steaming regimes introduced globally under an IMO treaty, regionally as a specific measure for a Particularly Sensitive Sea Area (PSSA) in the Arctic, and regionally in the EU. It also assesses regulated slow steaming introduced in order to reduce greenhouse gas (GHG) emissions (at a global or regional level), to reduce black carbon (BC) emissions (only in the Arctic, where BC is a particularly strong short lived

climate forcer) and in order to reduce air pollutant emissions (only in a regional scheme).

Hence, six possible regulated slow steaming regimes are studied:

1. **Global:**
   a **Global treaty for all ships**. This would require a new convention, probably under IMO, which would be enforced through flag and port States as are all IMO conventions. Likely, support from a few large registries would be needed.
   b **Global treaty for existing ships where the speed will be restricted to the average speed of new ships that have a lower speed because of the EEDI regulation.**
2. **To reduce black carbon deposition in the Arctic**. This could be either a global treaty or enforced as a condition of entry in a port.
3. **EU:**
   a **EU agreement for all ships in EU territorial waters as a condition of entry in EU ports**. Could be one speed for all ships or variable for different ship types. Since the emissions in EU territorial waters are a small share of total emissions, the climate benefits of this option would be limited. A special case of this regime is a restriction on speed when approaching harbours.
   b **EU agreement for all ships sailing between EU ports as a condition of entry in EU ports**. Since a little over half of the emissions on voyages to EU ports are from intra-EU voyages (i.e. from one port in the EU directly to a second port in the EU), there could be a significant benefit in CO_2 emissions as well.
   c **EU agreement for all ships arriving in EU ports as a condition of entry in EU ports**. This regime would apply to all ships, regardless from where they have sailed, and not just to ships sailing from other EU ports. The main benefits would be reduced air pollution and reduced GHG emissions.

1.3 Report outline

Chapter 2 presents current slow steaming practices based on a literature survey and a series of interviews with stakeholders. Legal aspects and practical issues relating to the feasibility of implementation of regulated slow steaming are discussed in Chapter 3. Chapter 4 presents a detailed design of the different types of regulated slow steaming regimes. For a global speed limit and a speed limit for ships sailing to EU ports, a social cost-benefit analysis is presented in Chapter 5. Chapter 6 concludes.

2 Slow steaming: current practises, advantages and disadvantages

2.1 The impact of slow steaming on emissions

The worldwide shipping fleet was responsible for 1,046 million tonnes, or 3.3% of total global emissions of CO_2 in 2007, a figure that, barring substantial regulatory intervention, is expected to grow nearly threefold by 2050 (Buhaug et al., 2009). Ship engine exhaust products are the overwhelming source of both GHG emissions and the conventional air pollutants that are a primary concern for air quality and human health. As described in Section 5, fuel use decreases exponentially as ship speed decreases, leading to substantial cost and CO_2 savings. CO_2 reductions are directly proportional to fuel savings, varying only by a few per cent depending on what type of fuel is being used.

Even though decreased fuel use will lead to decreases in CO2 and SOx emissions simply because of mass balance, relative emissions of conventional air pollutants have a more complicated relationship with speed. Ship engines are designed for optimal combustion at specific loads near the high end of their rated power. Reducing load, as occurs with slow steaming, leads to less optimal combustion and an increase in specific fuel consumption, the amount of fuel consumed per unit of power produced. So at lower speeds, even though a ship uses less fuel to go the same distance, it requires more fuel per unit of power delivered by the engines because combustion is not optimal.

Sub-optimal combustion that produces proportionally less power also generates proportionally higher emissions of pollutants like particulate matter (PM) and Nitrous Oxides (NO_x), which are the primary constituents of diesel exhaust linked to human health concerns. These pollutants are also linked to climate forcing effects due to the black carbon fraction in the case of PM and the effect on ozone in the case of NO_x. Because of their relative complexity, emissions of black carbon and NO_x are explored in more detail in the following sections.

2.1.1 The impact of slow steaming on fuel use and CO_2 emissions

As a rule of thumb, engine power is related to ship speed by a third power function. This means that a 10% reduction in speed results in an approximate 27% reduction in shaft power requirements. However, a ship sailing 10% slower will use approximately 11% more time to cover a certain distance. If this is taken into account, a new rule of thumb can be drafted stating that per tonne mile, there is a quadratic relation between speed and fuel consumption, so that a 10% decrease in speed will result in a 19% reduction in engine power.

The rule of thumb has an implication for regulated slow steaming policies. Because both the third power and the square relation are convex functions, sailing at a constant speed requires less fuel than sailing part of the voyage at a higher speed and part of the voyage at a lower speed, even while the average speed may be the same.

The rule of thumb has a limited applicability due to the fact that the specific fuel consumption of engines (i.e. the amount of fuel used to generate 1 kWh of power) varies with the engine's load. However, if engines are to be operated at lower loads continuously, they can be derated so that their SFC remains constant or improves.

In examining this relation, 2-stroke and 4-stroke engines should be distinguished due to different operational principles of the engines. In general, 4-stroke engines are used in smaller ships and 2-stroke engines in larger ships. Typical engine applications are:

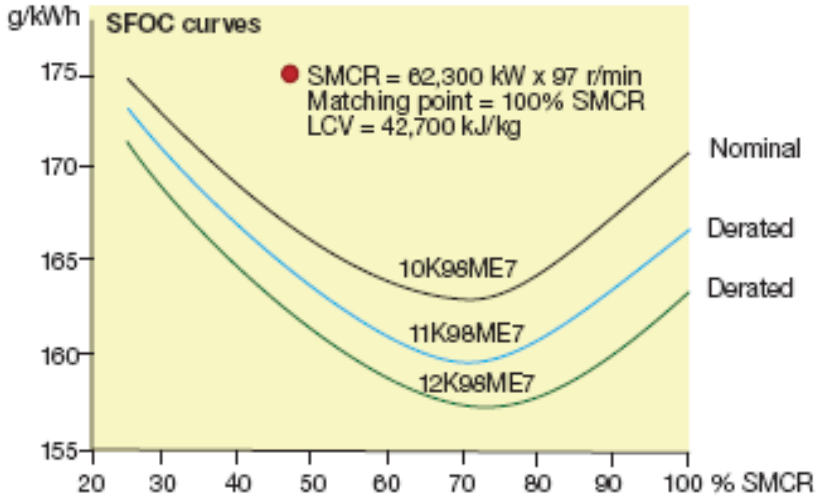
- 4-stroke: Container feeder, multipurpose vessel, passenger vessels, small bulker and tanker.
- 2-stroke: Container vessel panamax and post-panamax, large bulker and tanker.

Between engine loads of 100% maximum continuous rating (MCR) and 50% MCR the variation is within 3% of the lowest consumption, e.g. at 2-stroke 190 g/kWh and 4-stroke 200 g/kWh. So at these loads, the rule of thumb can be applied without resulting in major discrepancies. At 25% MCR the specific fuel consumption increases to about 10-15% above optimum specific fuel consumption. In other words, the engine uses 10-15% more fuel per unit of power. Below 25% MCR, only few consumption data are available with increases between 40 and 100% compared to optimum. So at these loads, the rule of thumb cannot be applied.

From test bed data one can generalise for operation at 25% MCR an increase of specific fuel consumption of about 10% for 2-stroke (190 g/kWh to 209 g/kWh) and 15% for 4-stroke engines (200 g/kWh to 230 g/kWh).

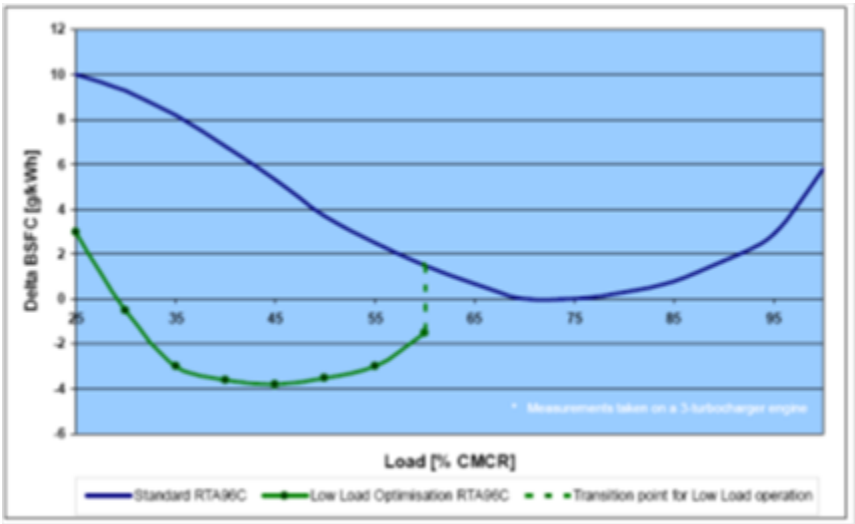
Figure 1 and Figure 2 are showing the variations of fuel consumption depending on engine load. The displayed values are for ideal engines taken from manufacturers' brochures, with effects of optional retrofits for slow steaming.

Figure 1 **Example of the relation between engine load and specific fuel oil consumption for a 2-stroke engine**



Source: MAN.

Figure 2 **Example of the relation between engine load and specific fuel oil consumption for a 2-stroke engine**



Source: Wärtsilä.

From a technical point of view, a ship operating on slow steaming is most probably operating in so-called 'off-design conditions'. Sailing in off design conditions the following disadvantages are likely to occur:

- The heat recovery systems possibly lose their efficiency. E.g. the output of the exhaust gas boiler may not be sufficient and therefore an oil boiler must be use to generate sufficient heat on-board.
- Loss of turbo charger efficiency.
- Loss of propeller efficiency.
- Increased fouling of hull and propeller due to reduced velocity and hence reduced flow velocities. Some antifouling systems need minimum velocities to 'wash-off' fouling.
- Auxiliary systems may work in off-design conditions to compensate e.g. the loss of heat recovery and turbo chargers. Often these systems are not designed for continuous operation and an increased maintenance as well as failure may occur.
- Increased lubrication oil demand.
- Due to sailing in off-design conditions the level of vibrations can increase.
- At variable pitch, propeller cavitation on the pressure side of the propeller can occur.

Most of the above mentioned disadvantages can be overcome by retrofits. Others could possibly be neglected because they will not cause damages or restrict operations, such as the loss of propeller efficiency. I.e. a propeller may not work at its design point sailing slow steaming, however, the propeller will not be damaged (fix pitch propellers), even if another propeller designed for slow speed would be more efficient. An absolute fuel oil consumption reduction can be measured anyway.

However, some components are more critical: for example auxiliary blowers that are needed to start turbocharged 2-stroke engines. A continuous operating of the auxiliary blowers because of a decreased efficiency of the turbocharger will increase the frequency of failure of these components. If all auxiliary blowers are broken it is not possible to start the main engine, which is a serious safety issue. A spare auxiliary blower in the store of the ship could be reasonable.

2.1.2 Black Carbon Emission Factors

There is a limited number of publications that analyse the emission factor (EF) of Black Carbon (BC). The data presented in these publications give insight into the emission profile of different engines with various sulphur levels and engine loads. In this review, we summarise relevant research, examine their differences, clarify the warming potential of BC with other particulate diesel matters, and conclude with future research needs for the EF of BC.

Pollutants that contribute significantly to climate forcing, but over much smaller time scales than CO_2, have been defined collectively as short-lived climate forcers (SLCFs). Among different types of SLCFs, BC is gaining increasing attention in shipping. BC is in particular damaging in the Artic area by substantially reducing the surface albedo. While significant research is underway to establish the extent of BC emissions and their overall effect on climate, assigning a firm value to warming effects would be premature. Instead, this section describes the current state of understanding of BC emission factors and global warming potential in order to illustrate relative impacts.

To quantify the impact of BC, both test bed studies and field observations have been carried out. In a test bed study, Petzold et al. (2008) estimate a seven-cylinder 4-stroke marine diesel engine under different engine loads and find that the EF of BC varies greatly under different engine loads. Importantly, they find the EF increases significantly when the engine load declines to 25%. Petzold et al. (2010) examine the EF of BC from a Medium Speed Diesel engine (MSD) and compute the EF at about 174 mg/kg fuel. It is similar to the estimate of Shiha et al. (2009) who calculate the EF at around 180 mg/kg fuel. On the other hand, Lack et al. (2008, 2009) contend that the EF is independent from the engine load based on their field observations. Their work shows that the EF is related to the energy efficiency of the MSD engine. More recently, Ristimaki et al. (2010) shows a strong inverse relationship between the sulphur level and the EF. This is contrary to the findings of Lack et al. (2011) who argue that BC emissions decrease with the fuel sulphur level. Emissions related to fuel sulphur content is especially important as more ships around the world will begin using lower sulphur fuels to comply with voluntary and mandatory fuel quality programs.

Despite the differences, recent inventory works largely use a single EF. Corbett et al. (2010), for example, use 350 mg/kg fuel to estimate the BC inventory in the Arctic in 2030. Dalsøren et al. (2009) use 180 mg/kg fuel to map the global GHG inventories. Given the vastly different estimates and great uncertainties, using a single EF may create difficulties in accurately computing emission inventory (Table 3).

2.1.3 Agreement: EF of different engine types and different energy efficiencies

Based on literature that we reviewed, there is a general consensus that both the engine type and the energy efficiency play important roles in determining the EF of BC. For example, Lack et al. (2008) report significantly higher EF for MSD which is two times as high as the EF for High Speed Diesel engine (HSD) and Slow Speed Diesel engine (SSD). Petzold et al. (2010), Lack et al. (2008), and Shiha et al. (2008) all find that higher engine efficiency reduce the EF of BC.

However, their estimates for the EF contain differences, and sometimes vastly, as indicated in Table 3. For SSD engine, the EF from Lack et al. (2008) is one magnitude higher than the EF from Agrawal et al. (2010). Another difference is the role of the engine load. Lack et al. (2008) argue that the

engine load does not influence the EF of BC. This is in contrast with Petzold et al. (2010), whose test bed study shows that lower engine loads would be counterproductive to reducing BC. A more recent difference emerges as scientists look into the effect of low sulphur fuel on the EF of BC. Ristimaki et al. (2011) find that the sulphur level increases the EF of BC in a significant manner. Lack et al. (2011), however, claim the low sulphur levels cut the EF in half (Table 3). Their work is significant in the context of the policy debate regarding the climate change effect of low sulphur fuel mandates within Emission Control Areas and around the globe.

So while substantial uncertainty still exists and investigation is on-going, it can generally be concluded that reduction in speed will lead to reduction in black carbon emissions when going from higher speeds to medium speeds. At the lowest speeds, studies indicate there may be a threshold at which slow steaming is counterproductive to reducing black carbon emissions.

Table 1 Emission factors of BC in various studies

	Emission factor (mg/kg fuel)	Engine type	Engine load (%)	Other note
Lack et al. (2008)	380	Tanker (SSD)	40-100	With various sulphur levels
	800	Container (SSD)	40-100	
	400	Cargo Carriers (SSD)	40-100	
	380	Bulk Carriers (SSD)	40-100	
	970	Tug Boats (MSD)	30-70	
	360	Passenger Boats (HSD)	40-100	
Lack et al. (2011)	130	SSD		0.07%
	220	SSD		3.15%
Petzold with 2.21% HFO	75	MSD	100 (cold)	With 2.21% HFO
	70	MSD	110	
	57	MSD	85	
	72	MSD	50	
	204	MSD	25	
	367	MSD	10	
	58	MSD	100 (warm)	
Agrawal et al.*	39	SSD		With 3.01% HFO
	100	SSD		
	44	SSD		
Shina	180			
Petzold with 2.21 HFO	174	MSD	85	With 2.45% HFO
Corbett	350			

HFO = Heavy fuel oil.

LSF = Low sulphur fuel.

*The EF was calculated from g/kWh to mg/kg fuel, assuming a SFOC of 180 g/kWh.

2.1.4 Particulate matter, elemental carbon and black carbon

Not only the EF of BC remains unresolved, there are often confusions among PM, EC and BC. Sometimes, the terms PM, EC and BC are used interchangeably, but strictly speaking, they are different in a number of ways. PM is a mix of non-volatile and semi-volatile compounds that were not fully combusted or that are produced during combustion process at high temperature and pressure. PM often comprise of ash, water, elemental carbon and organic materials.

Elemental carbon is defined using thermal measurement methods, while black carbon is defined using optical measurements. The chemical constituents are similar, but not identical. Elemental carbon volatizes at 550 °C. Black carbon is a solid carbonaceous particle that strongly absorbs light. Some climate researchers have proposed a definition based on a particular wavelength of light which black carbon is particularly well suited to absorb. But there is no universal standard. It is safe to say that all elemental carbon is black carbon. However, the opposite is not necessarily true. Some strongly absorbing black carbon particles may start out as organic carbon, and under certain conditions transition to elemental carbon (Bond and Bergstorm, 2009; Moosmuller et al., 2009).

2.1.5 Radiative forcing, GWP and GTP

Integrated climate change knowledge depends in part upon jointly understanding GHGs together with their warming potentials. To quantify the effects of various air pollutants, some metrics have to be determined beforehand. One of the most used concepts to investigate potential climate change impacts of air pollutant is the radiative forcing (RF) (IPCC, 2001). The key assumptions for using RF are that the global mean forcing is related to the equilibrium global mean surface temperature change and that the climate sensitivity can be considered to be constant and independent of the forcing applied for homogeneously distributed forcing (Hanson et al., 2000).

Such a value of RF cannot fully illustrate what would happen in the future to the global warming as a result of emissions. Forward-looking metrics are used for formulation of policy and for assigning CO_2-equivalent (CO_2-e) emissions. Metrics such as the Global Warming Potential (GWP) and the Global Temperature change Potential (GTP) examine the marginal impacts of a unit emission of a radiatively active species compared to that of CO_2 (Shine et al. 2005). The GWP for a gas is the ratio of the cumulative, globally-averaged RF over a specified time horizon produced by a unit-mass emissions impulse of that gas to that due to a unit-mass impulse of carbon dioxide. In the policy context, the GWP has become the de facto standard for estimating. The relative effectiveness of reducing emissions of different greenhouse gases are therefore at the center to evaluate approaches to GHG mitigation (IPCC, 1995). The attraction of GTP is that it requires essentially the same inputs as the GWP but reflects the response of the global-mean surface temperature (Shine et al., 2005). It is also further down the cause and effect chain from emissions to impacts (Derwent et al., 2008). Therefore it provides a different perspective to evaluate the relative importance of emissions of different species and how it changes over time. Table 4 shows the GWP and GTP of BC and some other emissions (ICCT, 2009 #175)(Shine, 2005 #176)(IPCC, 2001 #238).

Table 2 The GWP and GTP of some emissions

	GWP		GTP	
	H=20	H=100	H=20	H=100
Sulphate	-140	-40	-41	-5.7
BC	1,600	460	470	64
OC	-240	-69	-71	-10
CO_2	1	1	1	1

2.1.6 NO_x emission factor

Unlike BC, the EF of NO_x is relatively well understood. Entec (2002) examines different groups of engines and fuels at sea and in port, and estimates the EF for each group (Table 5, Entec, 2002). The Entec study has been widely cited and considered one of the most comprehensive studies on the NO_x EF to date (Buhaug et al., 2009; Cooper and Gustafsson, 2004).

Table 5 indicates that the engine plays a pivotal role in determining the EF of NO_x. The SSD has the highest EF, followed by the MSD. ST has the lowest EF and the GT has the second lowest. On the other hand, the fuel type has little to do with the EF of NO_x. The EF only marginally changes when fuel quality is downgraded from MGO to MDO and then to RO. The finding has been confirmed by other studies as well (Buhaug et al., 2009).

Table 3 The EF of different engine and fuel combinations

Engine type/Fuel type	NO_x EF in ME at Sea (g/kg fuel)	NO_x EF in port (g/kg fuel)	NO_x EF in AE (g/kg fuel)
SSD/MGO	91.9	66.7	
SSD/MDO	91.9	66.7	
SSD/RO	92.8	67.4	
MSD/MGO	65.0	47.5	51.3
MSD/MDO	65.0	47.5	64.1
MSD/RO	65.7	47.9	64.8
HSD/MGO	59.1	43.0	50.2
HSD/MDO	59.1	43.0	50.2
HSD/RO	59.6	43.6	51.1
GT/MGO	19.7	9.1	
GT/MDO	19.7	9.1	
GT/RO	20.0	9.2	
ST/MGO	6.9	5.0	
ST/MDO	6.9	5.0	
ST/RO	6.9	5.1	

Source: Entec and authors' calculation.
ME = Main Engine.
AE = Auxiliary Engine.
SSD = Slow Speed Diesel.
MSD = Medium Speed Diesel.
HSD = High Speed Diesel.
GT = Gas Turbine.
ST = Steam Turbine.
MGO = Marine Gas Oil.
MDO = Marine Diesel Oil.
RO= Residual Oil.
None of Auxiliary Engine in the Llodys used by Entec were of SSD, GT nor ST engine type.
EF in g/kg fuel is calculated by the authors based on EF in g/kWh and SFOC.

Written in 2002, Entec does not consider the gradually tightening NO_x standards beyond 2008 when Tier II and Tier III come into effect. Because the engine with Tier III standard is five times as efficient as the engine with Tier I standard (Table 6), such an omission is significant. To fill the gap, Buhaug et al. (2009) take into consideration the global Tier II standard and the Tier III standard in the Emission Control Area, and estimate the weighted average EF for the global fleet in 2020 and 2050 (Table 7, Buhaug et al., 2009). Under the best scenario, the EF of NO_x in 2020 will be 10% more stringent than the Tier II standard. Much of the improvement relies on the phase-in of LNG and the gradual retirement of old engines.

Table 4 **Estimated NO_x emission factor by emission standard and engine type (g/kg fuel)**

	Tier 0	Tier I	Tier II	Tier III
SSD	90	78	66	18
MSD	60	51	41	12
LNG	6	6	6	6

Table 5 **IMO forecast of EF in 2020 and 2050**

	A1B	A1F	A1T	A2	B1	B2
2020	61.0	61.0	59.8	61.0	59.8	59.8
2050	49.1	49.1	45.0	49.1	45.0	45.0

Although Buhaug et al. (2009) assess the effect of speed reduction on fuel consumption, they do not examine whether speed reduction will change the EF of NO_x. Alternatively, Buhaug et al. (2009) implicitly assume that the impact of speed reduction is negligible when they forecast NO_x emissions in 2020 and 2050. Agrawal et al. (2008) confirm this assumption when ships reduce the engine load from 70% (at operational speed) to 60%. However, if ships go even slower, Agrawal et al. (2008) find the EF begins to fluctuate significantly. For example, when the ship continues to reduce the engine load to 27%, the EF drops another 8%. When the ship further cuts the engine load to 8% (equivalent to less than 12 knots), the EF increases almost 25% from the lowest level or 10% from the operational speed level (Table 8, Agrawal et al., 2008).

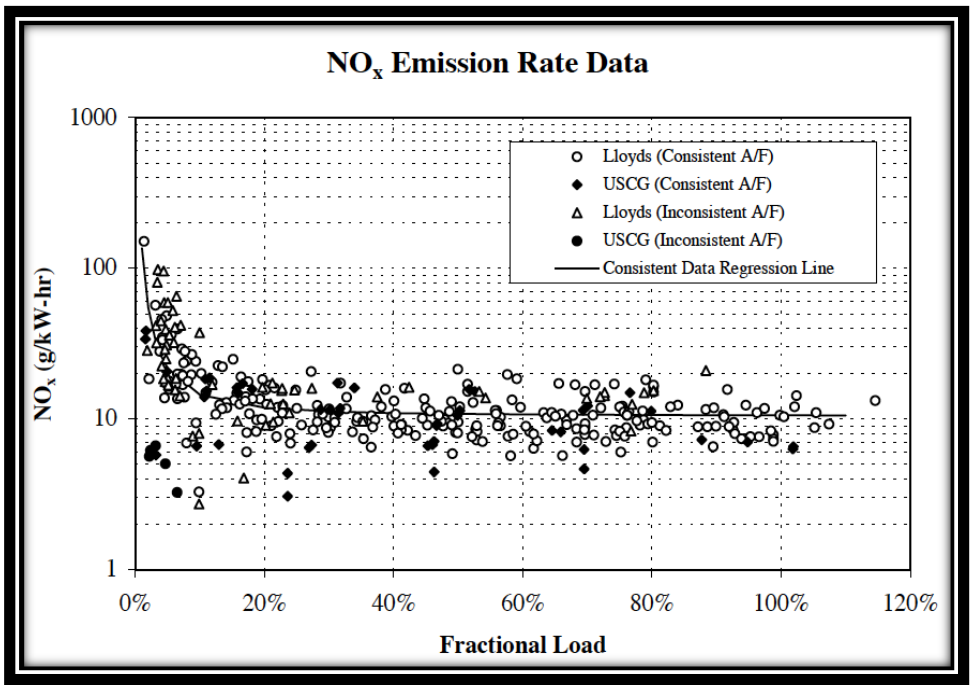
Table 6 **The EF of NO_x in different engine loads**

Agrawal et al.	Load (%)	NO_x (g/kwh)
	8	20.96
	27	15.84
	52	16.4
	63	17.85
	70	18.89

Source: Agrawal et al. (2008).

Such a relationship between the engine load and the EF of NO_x has been partly confirmed by other studies, but they disagree which engine load can achieve the lowest EF. For example, EPA (2000) examines more than 200 data points and finds the EF becomes flat when the engine load reaches 40% (Figure 6, EPA, 2000). Rattenbury (2008) finds that comparing to the 100% load case, the overall quantity of NO_x increases at 75% load but declines at 25% load.

Figure 3 The engine loads and the EF of NO_x



It should be noted, however, when the NO_x emission value is certified for an engine, the EF is a weighted average over 25, 50, 75, and 100% engine load. This will enable engine tuning to further reduce the engine load without sacrificing the NO_x efficiency.

2.1.7 Conclusion and future research

Although the continuing growth in global shipping and the emission of BC gives rise to increasing concern about the potential effect on global climate, the scientific community has yet to reach a consensus on the relationship between the BC and the fuel quality and between the BC and the engine load. Importantly, in the short term, speed reduction requires the change of the engine load from the designed level, which may or may not change the BC based on most recent research. For long-term implementation, engines can be de-rated to mitigate these effects. It is also worth noting that the uncertainties over the EF of BC emphasise the difficulty in applying a single EF to all shipping. Therefore more research is needed to provide better resolution. Special attention should be paid to the question of whether the engine load and the sulphur level may significantly alter the EF of BC. There is a continued need to measure EFs from different marine vessels, engines, and engine loads to improve the existing emission inventory and accurately model the impacts of marine traffic on regional and global air quality.

Compared with the EF of BC, the EF of NO_x is relatively well known. Comprehensive studies have been done to analyse the EF of NO_x based on engines and engine loads. It has been found that the SSD has the highest EF of NO_x followed by the MSD. ST has the lowest EF of NO_x followed by the GT. With the gradual phasing-in of the new NO_x standards, the EF of NO_x is expected to decrease even further.

The EF of NO_x falls when the engine load is reduced - up to a point. In super slow steaming, it is generally agreed that the EF may increase. Since the EF of NO_x is certified by a weighted average over different engine loads, engine tuning can be used to reduce the engine load without increasing the EF of NO_x.

2.2 Overview of current slow steaming practices and regulations

2.2.1 Current practices

Over the past years, ships have slowed down as a response to higher fuel prices and lower freight rates (UNCTAD, 2011). Many shipping lines have reduced their speeds while other shipping segments such as bulkers and tankers also appear to have slowed down. Lacking statistics on ship speeds, it is hard to evaluate the extent to which ships have slowed down and the impacts on emissions.

De Kat (2011) has reported that average main engine loads of Maersk Line owned ships have decreased from around 57% in 2007 to 35% in 2010, suggesting an average speed reduction of 15%.

Devanney (2011) claims that "almost all big tankers and bulk carriersare steaming at average speeds of 11 or 12 knots — considerably less on the ballast leg". According to the same study, if charterparties would not preclude ships from doing so, they would also sail slower on the loaded leg. Devanney does not cite any sources for his assertion. Since large tankers and bulkers sailed 13-14 knots in 2007 (Buhaug et al., 2009), they may have reduced their speed by some 15% on their ballast legs.

PWC (2011) claims that between 2008 and 2011, ships have reduced their speed by 15% on average, citing 'AIS live satelite datastreams'. How exactly this average is calculated is not clear from the report. Moreover, it is not likely that AIS data with global coverage was available for 2008. The 15% fleet average speed reduction is higher than the reduction claimed by Devanney (2011) and would imply that all ships have slowed down to the same extent as Maersk Line owned ships have.

Although there is hardly any reliable basis, the authors have the impression that container ships may have slowed down in line with the Maesk Line reduction, or somewhat less, and that other ship types have slowed down less. A fleet average speed reduction would be lower than 15%. As this speed reduction has been driven by market changes, it will likely be reversed if market conditions change: an increase in freight rates, a decrease in fuel prices, or a smaller supply of ships will probably result in a speed increase.

2.2.2 Mandatory speed reduction to avoid right whale strike

The North Atlantic right whale *Eubalaena glacialis* whose habitat ranges from Florida to the Bay of Fundy in Canada, is one of the most endangered large whale species in the world. The number has diminished considerably despite legal protection since the 1930s (Vanderlaan et al., 2009). The number of right whales lingers around 350 individuals. Most documented right whale injuries and deaths are attributable to ocean-going vessel strikes. Due to the higher speed and larger size of ships and growing ship activities, the number of reported vessel strikes has increased approximately three-fold since the 1970s (NOAA, 2010). If population growth, death rates and ship strike rates follow recent trends, it is likely that the species will become extinct within 200 years (Silber and Bettridge, 2010). Thus, minimising the probability of vessel strikes to right whales is important for the recovery of this endangered species.

The United States National Marine Fisheries Service (NMFS) under the National Oceanic and Atmospheric Administration (NOAA) is responsible to manage whale populations. Since the right whale is listed in the Endangered Species Act (ESA), the NMFS has to develop a recovery plan and reduce incidental strikes to the whale (Firestone, 2009).

To protect the right whale and to restore the species, NMFS, under the ESA, issued a final rule that required vessels larger than 65 feet in length to travel at 10 knots or less in certain times and locations (termed: 'Seasonal Management Areas', or SMA) of right whale occurrence (NOAA, 2010; Silber and Bettrigde, 2009). NMFS also initiated a program called 'Dynamic Management Areas' (DMA) in areas where right whales are observed outside SMAs, whereby temporary zones are created and vessels are requested (but, not required) to either navigate around the zone or travel through it at 10 knots or less. The NMFS is taking charge of monitoring the effectiveness of the restrictions by assessing compliance with the vessel speed limits as well as adherence to associated voluntary measures. The Automatic Identification System (AIS) technology provides a precise and accessible way to do so (Silber and Bettridge, 2010).

Currently, there is a mandatory speed reduction zone, called Mid-Atlantic Seasonal Management Areas, ranging from the US Atlantic Seaboard that corresponds to right whale occurrence. Exempted from the rule are US government vessels that are expected to adhere to guidance provided under ESA Section 7 consultations and State law enforcement vessels engaged in search and rescue or law enforcement activities. The rule is valid for five years, beginning from January 2009. During this period, scientists will assess the rule's effectiveness before the rule expires in 2013.

The office of Law Enforcement in NOAA is responsible for enforcing this rule under the authority of the ESA. Ships violating the speed reduction zone can be prosecuted either criminally or civilly, with current open cases being prosecuted civilly only. Those are prosecuted by attorneys from the office of General Counsel for Enforcement and Litigation. The maximum civil penalty for violating the ESA is USD 25,000. The maximum criminal penalty is USD 50,000 and/or imprisonment for not more than one year.

As at November 2010, NOAA had charged seven vessels for allegedly violating seasonal speed limits since the rule was enacted.

The co-benefit of reducing fuel consumption and Greenhouse Gas while avoiding the strike was mentioned but not quantified by some literature (Firestone, 2009).

2.2.3 Speed reduction policies in US West Coast ports

Three ports in California have introduced voluntary speed reduction programmes with the objective to reduce air emissions near these ports. They are the Port of Los Angeles (POLA), the Port of Long Beach (POLB), and the Port of San Diego (POSD). Details of these programmes are discussed in subsections below. The California Air Resource Board has performed useful analyses of potential mandatory speed reduction in the US West Coast. Its analysis is also summarised.

The Port of Los Angeles

The Port of Los Angeles (POLA) established its voluntary vessel speed reduction program (VSRP) in 2001 as a measure contributing to the region's ozone reduction goals in the 2003 State Implementation Plan for Marine Vessel Emissions Control Strategies. This program was jointly initiated with the POLB and implemented in cooperation with the U.S. Environmental Protection Agency, the California Air Resources Board, the South Coast Air Quality Management District, the Steamship Association of Southern California and the Pacific Merchant Shipping Association. The Marine Exchange of Southern California, which maintains ship traffic data through the cooperation with US Coastal Guard, supplies both ports with vessel speed data. Under the VSRP,

ships calling at the ports are asked to reduce their speed to 12 knots or less within a 20-mile radius of the ports of Los Angeles and Long Beach (POLA, 2009; Ross and Associates Environmental Consulting, 2009).

In June 2008, the POLA adopted a vessel speed reduction incentive program (VSRIP) (We have not been able to identify incentives provided prior to 2008). The VSRIP provides compliant vessel operators the equivalent of 15% discount of the first day of dockage, per vessel unit. This policy applies to all of the vessels berthing at POLA and mirrors some aspects of the POLB Green Flag Program described in Section 2.2. In September 2009, the VSRIP was expanded to 40 nautical miles (nm). Vessels compliant with the expanded VSRIP receive a refund of 30% of their first day dockage (POLA, 2009). No emission reduction effect has been quantified since the VSRIP went into effect, but it was estimated that the speed reduction program saved more than 100 tons of nitrogen oxide (NO_x) in the first quarter of 2005. This translates into an average daily savings of 1.1 ton of NO_x (POLA, 2005).

The Port of Long Beach

Besides the VSRP, the Port of Long Beach (POLB) has implemented a Green Flag program to reduce ship emissions near port with remarkable success. The Green Flag Program provides incentives for continued observance of the voluntary vessel speed reduction program by asking vessel operators to slow down to 12 knots or less within 40 nm of Point Fermin (near the entrance to the Harbor).

The Green Flag Program first began in January 2005. Under this program, individual vessels that dock at the Port of Long Beach earn a Green Flag Environmental Achievement Award when they attain 100% compliance with the voluntary vessel speed reduction program for a 12–month period. From January 2006, carrier lines that achieve a 90% or better compliance rate in a 12–month period were eligible for a 15% reduced dockage rate (Green Rate) in the following year. From January 2008, the Long Beach Board of Harbor Commissioners expanded the slowdown zone to 40 nm for additional pollution reductions.

As the incentive of this expanded project, ships can earn the 'Green Plus Rate' of 25% reduction on dockage fees paid to the Port of Long Beach if they slow to 12 knots from 40 nm; or the standard 'Green Flag Rate' of 15% reduction, for slowing from 20 nm (POLB, 2009).

By reducing the speed, ships burn less fuel and emit less air pollutants. Since the program began in 2006, the number of vessels slowing down has increased from 76 to 94% since 2008. The number of vessels now slowing down in the 20 to 40 nautical mile zone has increased from 40% in 2008 to 75% by March 2009. In 2008, POLB estimated that the program reduced 678 tonnes a year of NO_x, 453 tonnes of sulphur oxides (SO_x), 60 tonnes of diesel particulate matter (PM), and more than 26,000 tonnes of CO_2 equivalent (Ross and Associates Environmental Consulting, 2009; POLB, 2009).

In 2009, ocean carriers saved an estimated USD 1.6 million in fees while helping reduce air pollution. The Port will award about USD 2.5 million in dockage savings in 2010 and anticipates awarding as much as USD 4 million in 2011. Because of the success of the program, the POLB has been awarded the US Environmental Protection Agency's (EPA) Clean Air Excellence Award for its Green Flag Program.

No cost effectiveness analysis has been done for the Green Flag Program in POLB. A simple calculation shows that if only the NO_x reduction is considered,

the cost of reducing is USD 2,360 per ton for the Green Flag Program. The cost is lower than the estimated cost of the Emission Control Area and much lower than the cost of regulations for light duty gasoline/diesel engines.

The Port of San Diego

Beginning March 1, 2009, the Port of San Diego requested that operators of cruise and cargo ships reduce ship speeds when entering and leaving San Diego Bay. The speed limit is 12 knots for cargo ships and 15 knots for cruise ships. The vessels were asked to observe this speed limit when travelling in an area that extends 20 nautical miles seaward from Point Loma. The difference in the speed limits is based on differing engine fuel efficiencies. In order for a vessel operator to be deemed compliant, they must practice the voluntary speed limit for 90% of the operator's total vessel visits. This includes travelling both to and from the Port (POSD, 2009).

The first quarter results for April through June 2009 showed that 86% of all cruise ships visiting the Port complied with the speed reduction request, and 53% of cargo vessels complied. During that quarter, the speed reduction resulted in an estimated 10% reduction in emissions from participating vessels. Second quarter results from July through September 2009 showed a slight decrease in vessel participation (POSD, 2009).

No financial incentive is committed. Instead, vessel operators with at least 90% compliance for 12 consecutive months (i.e. 90% of an operator's vessels calling at the Port voluntarily reduce their speed) will be recognised for their successful participation in the program. In addition, the Port will distribute a quarterly report to vessel operators, the general public, the media, and the Board of Port Commissioners. Because the voluntary speed reduction is just beginning, little data is available as to how effective the program is.

Californian Air Resources Board

The Air Resources Board of California (CARB) analysed vessel speed reduction at 24 nm and 40 nm from Californian ports, respectively. Assuming all ships reduce speed to 12 knots, CARB found that the speed reduction could reduce PM, NO_x, SO_x and CO_2 (Table 7). CARB also compared emission reduction for different ports in 2008 and 2012, which is shown in Table 8 (CARB, 2009). Table 7 shows that overall emissions from five ports listed in Table 8 fall substantially after the speed reduction. For example, if all ships were required to reduce speed to 12 knots 40 nm outside ports, the emissions of PM, NO_x, SO_x and CO_2 would be reduced by 31, 36, 29 and 29% respectively.

Table 7 **Projected Emission savings (tonne per day) for different scenarios in 2008**

	Without VSR (24 nm)	With VSR all traffic (24 nm)	With VSR port only (24 nm)	Without VSR (40 nm)	With VSR all traffic (40 nm)	With VSR all port only (40 nm)
PM	5.1	4.2 (-18%)	4.6 (-10%)	8.9	6.1 (-31%)	7.8 (-12%)
NO_x	53	42 (-21%)	48 (-9%)	98	63 (-36%)	83 (-15%)
SO_x	45	39 (-13%)	42 (-7%)	73	52 (-29%)	64 (-12%)
CO_2	3,130	2,720 (-13%)	2,930 (-6%)	4,810	3,430 (-29%)	4,250 (-12%)

Source: CARB.

Note: VSR = Vessel Speed Reduction.

All Traffic includes ships departing and arriving ports as well as transit.

Table 8 Emission reductions (tonne per day) for 12 knot maximum speed in different ports

	PM_{10}	NO_x	SO_x	CO_2
2008				
LA/LB	0.07	1	0.6	41
San Diego	0.04	0.5	0.3	21
Bay Area	0.4	4.6	2.7	167
Hueneme	0.4	4.8	2.8	180
Total	0.9	11.2	6.4	409
2012				
LA/LB	0.01	1.1	0.03	46
San Diego	0.008	0.6	0.01	23
Bay Area	0.07	5.4	0.1	187
Hueneme	0.09	6	0.1	201
Total	0.18	13.1	0.24	457

Source: CARB.

Note: Smaller reductions at LA/LB are due to the existing VSR program. San Diego also has less emission reduction benefit likely due to the types of ships coming into port which tend to have slower average speeds, such as tankers.

In addition, CARB conducted a survey of ship owners on their opinions about speed reduction near ports. Most vessel operators indicated that their operating costs increased when complying with speed reduction. The survey showed an average vessel weighted daily cost from USD 250 to USD 600 assuming a one-hour delay. This range included on-board labour and maintenance but did not include any fuel costs or savings. Most vessels indicated they would speed up outside the speed reduction zone to maintain their schedule. Many indicated that they would speed up by at least ½ knot or more. About half of the vessels indicated that they may change their route or consider rerouting if speed reduction was implemented in the south bound channel. About 75% of the respondents indicated that they would comply with a voluntary speed reduction program. Vessel owners indicated that reducing port fees was the most important incentive for a speed reduction program (CARB, 2009).

2.2.4 Summary of the speed reduction policies near ports

In summary, speed reduction has proven to be an effective approach to reducing emissions from ships and improving air quality near ports in California. Speed reduction can reduce CO_2, NO_x, PM and SO_x in a substantial manner, as high as 35% for various emissions. The ports of LA and LB have extended their speed reduction zones from 20 nm to 40 nm.

However, as the CARB survey shows, in local systems it is likely that ship operators speed up outside the speed reduction zones to catch up with their schedule. This means that fuel use and CO_2 emissions over the entire voyage are likely to increase. While this may not be a reason for concern for emissions that cause local damage, such as NO_x, it means that local speed reduction policies are ineffective in order to reduce climate impacts. Speed reduction policies may in this context also increase operational costs.

2.3 Stakeholder reactions to slow steaming

2.3.1 Introduction

During late summer, 2011, the ICCT and CE Delft conducted a survey of 16 individuals representing companies and industries that may be affected by either voluntary or mandatory slow steaming policies for ocean-going vessels (OGVs). The intention of this survey was to elicit common themes and reactions that could inform further inquiry into slow steaming as either a mandatory or voluntary tool. The limited timeframe and funding for the project did not permit a statistically representative survey, but identifying and better understanding key stakeholder concerns is central to evaluating the viability of mandated speed restrictions. Therefore, a more limited approach was chosen that would still function to elicit central ideas and highlight common concerns.

For the purposes of this limited study, the report authors developed a survey template and administered the survey either electronically or in person to selected participants. The survey template used for this report is attached in Section 5.6. The two pages of survey questions reflect a best effort to balance a limited number of questions with sufficient depth that clear opinions and useful information would emerge. The original intention was to limit the survey to 6 individuals. After conducting several surveys, converging ideas for the industry did not seem discernible from the personal opinions of the participants for all of the questions, so additional surveys were added with much more satisfactory results.

According to the preference and availability of the participants, about half of the surveys were administered in person as interviews and others were filled in and returned electronically. In-person surveys tended to be more consistent in the extent and quality of the response because participants could either ask clarifying questions or felt compelled to elaborate on initial reactions. Written survey responses varied more widely, from a few that were largely one word or one-sentence answers to several that amounted to several pages of text. In nearly all cases, surveys took between 30-60 minutes to respond to.

Survey participants were chosen based on their status in a major company and ability to understand the implications of various policy options for their organisation. To allow them to speak candidly, the names of the participants and their organisations are not identified. Their expressed views are based on their professional opinions and do not necessarily represent the views of the organisations they represent.

Sixteen survey participants were chosen from major operators in four general categories described below. Company examples associated with the categories are not necessarily companies that participated in this survey:

1. Third-Party Logistics (3PL) Operators: These companies specialise in providing full-service cargo logistics services, they may occupy smaller intermediary roles in the logistics chain. Examples of 3PL's include Kuehne-Nagel, Expediters International, DHL.
2. Steamship Lines: Responsible of the operation of steamship fleets; also called 'ocean carriers,' 'carriers' or 'lines.' Examples of steamship lines include Maersk, Evergreen, CMA-CGM, Matson, etc.
3. Shippers and Beneficial Cargo Owners (BCO's): These refer to either the manufacturer of the cargo being shipped (shipper) or the future owner of the cargo that is being carried by the vessel (BCO). This category includes many industries that are associated with major brands like Nike, IKEA, Target, and Wal-Mart.

4. Major Port Authorities: Ports that have or may have air quality concerns or other reasons to consider slow steaming programs. Examples include the Port of Los Angeles, Virginia Port Authority, Port of Rotterdam, etc.

To capture the range of opinions while summarising key points in significant categories, survey results are discussed in three different sections:

1. A general overview of responses: This section is a 'broad brush' look at the survey answers and themes without getting into specific details.
2. A compilation of common points made in the course of the surveys according to the most significant themes that emerged. This section compiles specific details and ideas about slow steaming and mandatory programs with more limited structure and analysis.
3. A summary of key points both overall and for each of the industry categories that participated in the survey. This section combines the specifics in the second section with the broad themes of the first section in order to arrive at key summary points.

Because of the nature of this survey, no statistical or mathematical compilation methods are used in this overview. As such, many details and explanations may be incomplete or lacking – largely reflecting the limitations of the source material but also as an effort not to make the work appear more conclusive or certain than it is meant to be. The intention of this work is to promote discussion and further investigation of issues that may be crucial to appropriate policy development.

2.3.2 Survey structure and general responses

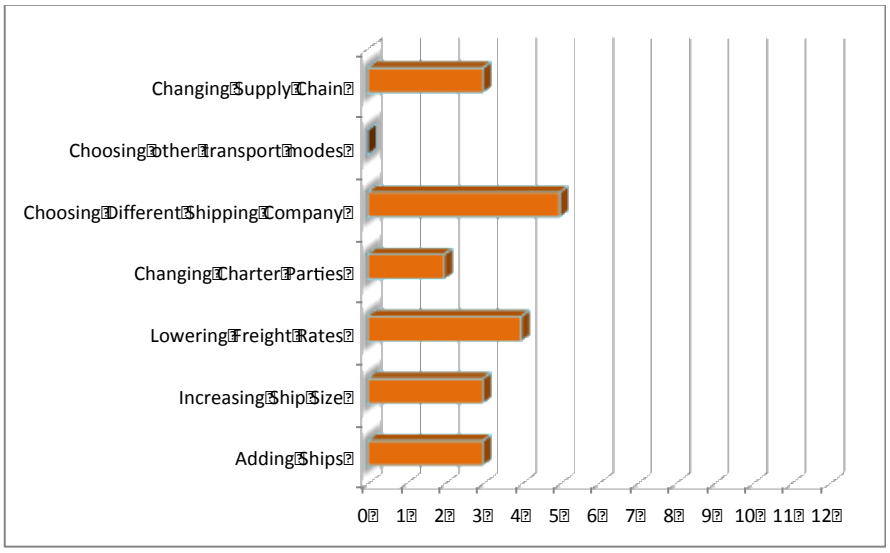
The survey was structured to elicit both a current level of understanding of the survey issues and explore the potential positive and negative effects of voluntary and mandatory slow steaming programs. The responses were gathered in four main categories that frame the discussion in this section.

Industry experience with slow steaming

The 'industry experience' section included both an open-ended question about the participants' experience and a series of questions about specific changes in operations that may have been chosen as strategies to manage slow steaming ships. For the open-ended question, the survey revealed that participants were all familiar with the concept of slow steaming and how it does or might affect their specific industry. While this may be partly aided by preceding text in the survey that describes some general benefits and considerations, responses clearly conveyed both knowledge and interest in the subject. 'Experience' answers generally broke along two categories: participants who were concerned about both direct and indirect changes to market and logistic dynamics, and participants who were concerned about the direct impact on the logistics and costs of the ship-side operations.

Simplified answers to the 'specific responses to slow steaming' questions from the 'experience' section are summarised in Figure 4. Most responses in these sections were simply 'yes,' when applicable, with occasional explanation and frequent abstention. Compared to the two other 'series' questions in the survey, this set of questions generated lower numbers of total responses because the individual measures described are specific to a more limited portion of the industries surveyed. Total 'yes' responses exceed the total number of survey participants because individuals could select multiple responses.

Figure 4 **Participants responding 'yes' when asked whether they have adopted a particular measure in response to current slow steaming practices**



Benefits and disadvantages of slow steaming

Following questions in the previous section that establish the level of understanding of slow steaming, two subsequent sets of questions explored the perceived or realised benefits of slow steaming for the participants as well as the disadvantages. Compiled in a similar manner to the results in Figure 4, Figure 5 and Figure 6reveal some underlying trends in responses. For instance, data shown in Figure 5reveals a very clear understanding of the environmental benefits of slow steaming with less consensus on logistic benefits. While the specific benefits are based on real experience, they do not produce equal benefits for all parts of the logistic chain. In fact, any savings generated from slow steaming are not passed on to cargo owners (see 'key points' in the following section), according to survey responses.

Figure 5 **Participants responding 'yes' when asked about specific benefits of voluntary slow steaming**

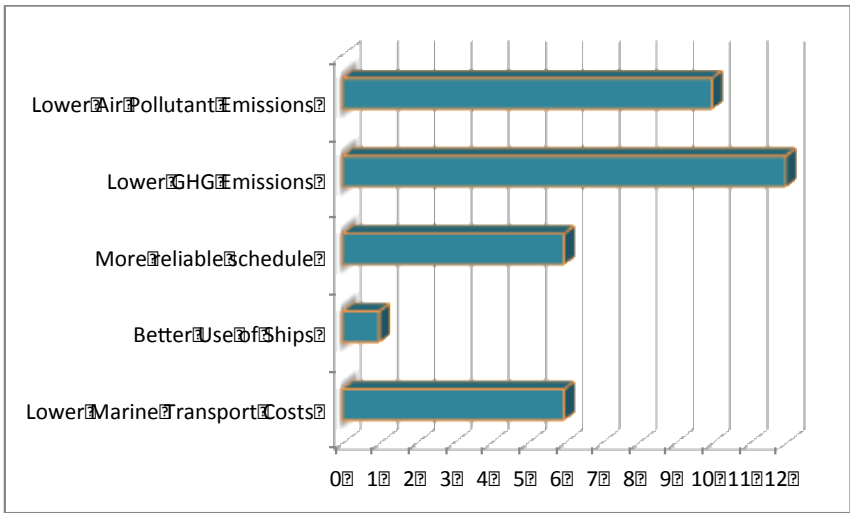
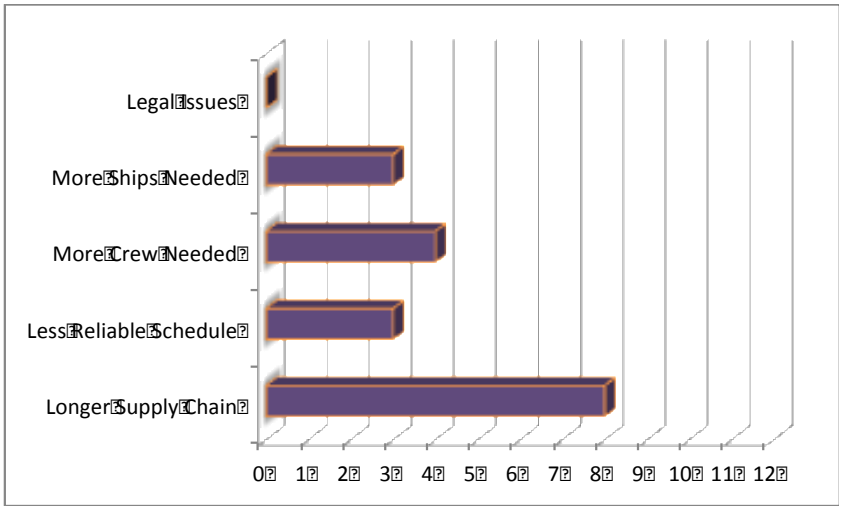


Figure 6illustrates a similar trend as seen in the logistic-related questions of Figure 5. Different companies experience different effects from slow steaming. While logistics companies may not directly care whether more crew or ships are needed, carriers having to pay for these added costs certainly do.

On the other hand, a longer supply chain affects almost every part of the industry. Interestingly, nobody thought that legal issues were a concern with voluntary slow steaming. As one participant noted, this is likely because conditions of freight carriage are negotiated before transport.

Figure 6 **Participants responding 'yes' when asked about specific disadvantages of voluntary slow steaming**



Comparisons of benefits from mandatory and voluntary slow steaming

The balance of the survey asked more open-ended questions that either did not lend well to 'yes or no' answers or were compelling enough that participants offered more detailed explanations. Two sets of two questions compared mandatory and voluntary slow steaming for either their relative benefits (first set) or relative drawbacks (second set). The first question in each set asked participants to describe what they see as the common benefits or disadvantages of the schemes while the second question asked to specifically comment on the exclusive attributes of mandatory programs as they differ from voluntary schemes.

For the first set of these questions, many participants' answers sought to make clear that many of the benefits that are now seen with voluntary slow steaming would be largely lost in a mandatory program. By the second set of questions describing disadvantages, many of the participants felt that the questions were becoming redundant, but almost all maintained strong opinions on the difference between mandatory and voluntary schemes. By far the most consistent issue raised in differentiating the two schemes was imposition of constraints and the resulting loss of flexibility that would inevitably accompany a mandatory scheme. The general feeling was that slow steaming emerged due to market forces that required a quick response mechanism for a sudden shift in market conditions.

With the economic downturn (2007), the sudden convergence of rising fuel prices and decreased demand created a need to artificially reduce capacity in the marketplace. While not immediately optimal, slow steaming offered a mechanism for immediate cost and capacity controls that saved money for carriers in the short-term. Practitioners gradually began to balance how and when slow steaming was used and other parts of the industry came to plan around the availability of both slow steaming and standard speed operations. Participants noted that this advent of slow steaming ultimately created a

desirable alternative in the market, but the environmental benefits noted earlier in the survey are almost entirely irrelevant to the business decision.

Towards the end of this series of questions, several participants began noting that relative advantages and disadvantages were actually difficult to discern in the absence of a well-described program. Many of the potential disadvantages (and advantages) could be removed or enhanced depending on how a program is implemented. The issue of how flexible the program would be is at the center of the distinction, but other factors were also considered important. Of these factors, administration, management and enforcement were major unknowns that would affect program viability. Similarly, how speeds are set, who and what routes they affect, and generally how the competitive landscape would be altered were issues that seemed so complicated that envisioning a viable mandatory system was very difficult.

Industry responses to mandatory programs

The final survey section, 'Industry Responses,' is a series of open-ended questions intended to allow participants to describe how their organisation would respond to changes in the current practice of slow steaming. The questions covered changes due solely to market conditions and changes due to implementation of a mandatory program. In general, the participants reiterated earlier points that the market conditions drove the move to slow steaming and indicated that it would also motivate vessels to speed up when conditions improved.

On the other hand, the quick adoption of slow steaming also forced carriers to be more sophisticated about how they manage ship efficiency. This sophistication caused what are seen to be permanent changes in how ships are operated (reinforced by the recent 'Ship Energy Efficiency Management Plan' (SEEMP) requirement passed by the IMO), and created a lasting space in the market for a slow steaming option. Regardless of how market conditions rebound, there will always be retailers and manufacturers who value price over speed. And, as long as capacity exceeds demand, slow steaming will be used as a means to curb costs.

The main sentiment in this section is a generally negative view of mandatory slow steaming. While some of this response was tempered by acknowledgement that the 'devil is in the details,' participants' answers indicated that they could not envision any mandatory program that would not lead to significant market distortions. On the other hand, when prompted to consider the effects of the recent Energy Efficiency Design Index (EEDI) regulation and the potential for a mandatory program to 'level the playing field,' there was some acknowledgement that mandatory programs could have merit in this regard alone, but the overall effect of mandates would still be negative for most of the participants.

2.3.3 Summary of key points by common themes

The variety of stakeholders, operations, and interpretation of the questions in the survey led to a similarly wide variety of exposition and insight into various aspects of existing and future slow steaming practices. This section seeks to convey more detailed responses by sorting key points according to general themes without substantial interpretation.

Reactions to (voluntary) slow steaming

Market forces

- Slow steaming is a practice that is currently tied to the economic downturn:
  - It is mainly a function of the need to reduce tonnage and fuel costs.
  - It did not exist prior to 2008 but has become (likely inextricably) part of the lexicon of strategies.
  - When the economy recovers, many ships would return to normal speeds in order to maintain system capacity.
- Slow steaming benefits differ by:
  - vessel type and service;
  - vessel route;
  - actual and relative speed difference.
- Shippers/customers drive 3PL's to both acknowledge and seek carriers that have 'green' practices such as slow steaming. Slow steaming is currently often cited in manufacturers' and retailers' corporate social responsibility (CSR) plans, but no consistent program exists to convey and compare these values.
- All parties recognise the air quality and GHG benefits of slow steaming, but these are not motivators except to the extent that they contribute to CSR goals.
- Slow steaming requires more inventory (i.e. cargo tied to market demand) to keep stocks flowing on a larger number of ships in the logistic chain.
- The general cost structure for shipping tends to be a balance of
  - freight rates;
  - fuels costs;
  - carrying costs (driven by interest rates);
  - operating costs.
- As long as interest rates are low, the incentive to increase speed (and maximise ship utilisation) is diminished.
- Competition has kept freight rates low – often lower than operating costs (which are mainly fuel and carrying cost) as carriers seek to maintain (or grow) market share.
- Shippers feel that carriers are colluding to keep freight rates as high as possible by reducing volumes – slow steaming is one tactic for reducing overall available capacity.
- Per TEU (or unit) efficiency is a market driver that inherently favors larger ships but not necessarily slow steaming.

Logistical issues

- Flexibility is crucial:
  - The system takes time to optimise over modes, services, and fluctuating market conditions.
  - Some specialty cargoes will always require faster ships.
- Stocks/volumes must be increased with increased transit times:
  - Requires good communication, so gradual transition is best.
  - Slow steaming costs manufacturers more due to additional in-transit storage costs.
  - Logistics providers will (and do) work with available options, and slow steaming is one variable in a long list of issues to manage.
- 'Steady steaming' can be equally as important as 'slow steaming' in maximising efficiency. Carriers need to be able to maintain an appropriate speed that is tailored to conditions at sea and safety near land.

- Slow steaming allows ‘reserve speed’ to be available during a voyage to increase reliability and on-time arrival.
- There are no perceived legal concerns with slow steaming because conditions of carriage are negotiated before transport.

Reactions to mandatory slow steaming

- ‘Slow steaming’ and ‘mandatory scheme’ must be better defined. It is difficult to make a real judgment without a detailed program proposal.
- Mandatory slow steaming could create a level playing field in theory, but it is not clear that this would work in practice.
- Mandatory speed restrictions would decrease competition by removing one of three key variables (Speed) that drive industry competition (the other two are Reliability and Price).
- Mandates would have to be done in a way that:
  - minimises added cost and administrative burden;
  - maintains operational flexibility as much as possible (carbon levies may be as effective, voluntary/incentivised schemes are almost unanimously preferred – some 3PL’s are ambivalent);
  - ultimately defers to captain’s prerogative to select speeds that best protect crew and cargo; must be tailored to regionally appropriate safe speeds.
- Mandates are broadly opposed by surveyed industry, though a more defined program that accommodates key issues may be more acceptable.
- Potential for modal shift: marine is just one part of the larger supply network that includes other modal options. If shipping price, reliability or schedule is altered for mandates or any other reason, shippers will look to other parts of the supply network to balance their needs.
- Enforcement must be consistent worldwide
  - There is significant skepticism that this is possible or that a mandatory system could be appropriately tailored.
  - The prospect of an additional record keeping and reporting burden is off-putting.
- It is not clear how speed restrictions would or could be set, who would set them and why, where and when they should be enforced. In general, mandates seem to have too many variables to be effective.
- Mandatory slow steaming would effectively reduce the total capacity available which may create a capacity shortage if the market rebounds.
- A ‘carbon levy’ is widely considered both preferable to mandatory slow steaming and potentially as effective at creating the desired results without imposing ‘arbitrary’ restrictions on shipping that reduce service options and flexibility.
- The relative potential of voluntary or incentivised programs needs to be evaluated before a case can be made for mandatory programs.
- Mandatory slow steaming for older, non-EEDI ships could mend some ‘distortions’ created as newer ships that are designed for slow steaming begin to penetrate the fleet.
- Speed as a variable in logistic decisions equates to flexibility, resilience and the ability to respond to changing market conditions most effectively. Restrictions on speed reduce these. Mandatory slow steaming would decrease the ‘value proposition’ of ship transportation by narrowing its potential.
- ECA requirements are forcing some design changes to ships. There is a general need to evaluate and understand the potential compounding effects of mandatory slow steaming with other current and emerging GHG and air quality regulations.

2.3.4 Summary and conclusions

Despite the wide variety of comments and opinions that accompanied the survey questions, responses from major industry sectors often followed consistent themes. Many of these themes are alluded to in the previous two sections, but this final section briefly summarises key themes, perspectives, and conclusions by the four participating industry sectors queried for the survey. A general set of conclusions summarises the survey.

Conclusions by Sector:

Ocean Carriers

Drivers for ocean carriers are purely economic and reflect the need to balance forces that affect their ability to compete in the marketplace. Carriers face a constant need to manage their fleet size and available capacity while reducing their fuel costs where possible. Speed as a variable allows them to better manage these factors. They strongly value the ability to control speed because it is an efficient means to control costs, manage schedules, and maintain competitive operations. The concept that slow steaming leads to a 'greener' supply chain is a well understood (if unintended) benefit, but carriers will likely return in large part to pre-2007 speeds when market conditions change and more capacity is required. Carriers are resistant to mandates for pragmatic reasons. They perceive that mandates would decrease flexibility, increase administrative burdens, and potentially affect their competitiveness.

Third-Partly Logistics Operators (3PLs)

The 3PL seems to have no real driver when it comes to slow steaming. 3PLs are aware of the environmental benefits of slow steaming and may be asked by customers to consider it as a factor in choosing carriers. In general terms, the business of a logistics service provider is to constantly adapt to changing conditions, so slow steaming – whether voluntary or mandatory – is just another variable for them to consider among many others. The types of factors that require adaptation by 3PLs (and others) include lengthening of the supply chain, less flexibility to manage delays, consideration of other transport modes, and additional management to ensure efficient connections.

Ports

In general, shipping ports are driven by both the needs of their customers – mainly ocean carriers – and the needs of the local communities and government that oversees their operations. With mandatory slow steaming these two factions may have conflicting values, requiring port authorities to find an appropriate balance. Some ports have successfully achieved this balance with voluntary or incentivised slow steaming programs. Mandatory programs, especially if driven by regional or national governments, would relieve the ports from the burden of being intermediaries and allow them to act as a more neutral advisor in policy development. Participant ports in this study show a clear awareness of both environmental and economic factors involved in slow steaming and add a concern over locally-specific issues like the ability to maintain safe navigation speeds.

Cargo Owners

Having been more removed than other participants from discussions about slow steaming over recent years, cargo owners' responses suggested some confusion about the environmental benefits of slow steaming. Their drivers were mainly increased costs due to the need to maintain a larger inventory and related factors. Cargo owners are often in conflict with carriers whom they see using slow steaming as a means to artificially reduce capacity and drive up freight rates. Respondents believe they are paying surcharges for fuel when costs increase and that slow steaming does not have a direct economic

benefit for them in many cases. Cargo owners recognise the benefits of being able to market the use of 'green' shipping practices but do not feel that they have a consistent way to evaluate, communicate, and compare slow steaming with other tools to achieve similar goals.

2.3.5 General conclusions on regulated slow steaming

While survey participants offered a wide variety of input and perspectives, a few broad conclusions can reasonably be drawn. First, there was near universal opposition to the concept of mandatory slow steaming. Reduced market flexibility was the primary reason for this. There was also confusion as to why a mandatory scheme would be required as opposed to a carbon levy or voluntary program. Some participants noted that their strong opposition was directed at a theoretical and undefined program. More definition and accommodation of their chief concerns may ameliorate some of the dissent. The success of any mandatory policy will be in its administrative, implementation and enforcement details. A mandated program must be clear, fair, and include a reasonable process for determining appropriate speeds and scope of application.

2.4 Other impacts

2.4.1 Impact of slow steaming on congestion in busy straits

It has been claimed that slow steaming could result in increased congestion in busy straits. The relation between congestion and speed is ambiguous, however. In the Straits of Malacca and Singapore, for example, slower speeds are associated with congestion by some authors (Rusli, 2010). However, others point out that a doubling of traffic could occur without reducing speed, suggesting that at current traffic levels, even in the heavy traffic of the Strait of Singapore, there is no relation between speed and congestion (Ho, 2010). In fact, oil tankers in the Straits of Singapore and Malacca are required to slow down in order to reduce the risk of collisions (MPA Singapore, 2006). If other ship types would be required to use the same speed, congestion could potentially be reduced.

2.4.2 Impact of slow steaming on demand for new ships

When ships slow down, more ships are needed to deliver the same amount of transport work (conversely, and in the absence of speed restrictions, when transport demand is low, ships tend to slow down). As a first approximation, a speed reduction of x% requires a 1/(1-x%) larger fleet to achieve the same transport performance.

Taking into account that slow steaming only affects the time ships spend at sea, and not in port, the relation between fleet size F and speed reduction Δs is given by IMarEST (2010):

$$F_1 = F_0 \left(\frac{\frac{DAS}{1-\Delta s} + (365 - DAS)}{365} \right)$$

Where
F_0 – the number of vessels of ship type and size category in the fleet
DAS – days at sea per year for ship type and size category
Δs – speed reduction as % of the baseline speed.

Hence, in general, slow steaming, whether market-driven or driven by regulation, increases the demand for new ships. The situation is different

when there is a large oversupply of ships. In that case, slow steaming will probably first result in laid-up ships being activated and only if that's not enough, additional ships will be added to the fleet (CE Delft and Germanischer Lloyd, 2009).

2.4.3 Impact of slow steaming on demand for seafarers

A larger number of ships would result in a higher demand for seafarers, more or less in line with the fleet size increase.

Several studies indicate that in 2010, supply of and demand for seafarers is roughly in balance (Bimco and ISF, 2010; JITI and Nippon Foundation, 2010). Forecasts are that, depending on economic growth, supply and demand will remain balanced or that demand will grow faster. Regulated slow steaming would increase demand and, if this segment of the labour market is efficient, may lead to an increase in wages.

3 Exploration of regulatory approaches

3.1 Legal aspects of *mandatory* slow steaming

Customary international law and the 1982 United Nations Law of the Sea Convention (UNCLOS) provide the general legal framework within which the legality of mandatory slow steaming is to be assessed. International law, and in particular international environmental law is a flexible, dynamic and developing legal area which should not be approached as a rigid frame which *a priori* prohibits new approaches to environmental protection but rather a framework that can facilitate the development of appropriate measures in a way consistent with well established constraints protecting the rights of other States and ensuring non-discriminatory treatment between States.[1]

The speed by which a ship travels is a navigational matter dictated by safety of navigation considerations, including pollution avoidance, but also by commercial factors and the oceanic and atmospheric conditions. It is usually left to the discretion of the master who is under an obligation under the Collision Regulations[2] to ensure that the ship proceeds with safe speed[3].

UNCLOS outlines the rights and obligations of States in relation to their jurisdictional zones as well as with respect to marine environmental protection. The extension of the coastal States' rights under UNCLOS is balanced by a liberal regime for navigation. This consists of an express right granted to States[4] for freedom of navigation in the high seas,[5] in the EEZ,[6] the right of innocent passage in the territorial sea and the regime of transit passage for straits and archipelagic lanes.

Thus an important legal question is whether the protection of freedom of navigation under UNCLOS can coexist with mandatory slow steaming. UNCLOS does not specify what exactly is included within this freedom of navigation concept.

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1 The legal character of mandatory slow steaming in today's world is based on adopted State practice and agreed powers between flag States and coastal States developed well before the effects of shipping on local and global atmospheric pollution have become important. Thus the analysis is based on existing legal norms. However States can modify existing norms in relation to emissions from ships.

2 Convention on the International Regulations for Preventing Collisions at Sea, 1972 (London, 20 October 1972).

3 Rule 5.

4 UNCLOS does not provide for rights and obligations of private parties. A right of navigation in the high seas is granted to all States. Art. 90.

5 Freedom of navigation is part of the freedom of the high seas granted to all States under Art. 87.

6 UNCLOS Art. 58. However the exercise of the freedom of navigation in the EEZ is subject to rules and regulations imposed by the coastal State "in accordance with the provisions of this Convention and other rules of international law in so far as they are not incompatible with this Part."

There is no judicial authority or international convention that decides that speed restrictions imposed on ships restricts the freedom of navigation at the high seas. It can be argued that the term navigation only includes the path followed by the ship and freedom of navigation means the right to move between any two points of the high seas following any available path.[7] If this is correct, requirements for mandatory slow steaming do not affect the freedom of navigation of ships at the high seas while, for example, mandatory shipping lanes would provide such restrictions.

If it is accepted that the term 'navigation' includes the speed of the ship, it does not necessarily follow that ships can proceed under whatever speed the master sets. It only means it is an exclusive right for the flag State to regulate the ship's speed in the high seas.[8] Thus flag States can impose compulsory slow steaming on ships flying their flags at the high seas.

Note also that the adoption of measures affecting the ship's speed by various States indicate that in at least some cases such measures are acceptable.

Note also that if mandatory slow steaming were to be imposed through a global agreement this would be in essence a new norm in international law. To the extent that such a norm does not presently exist what matters is the extent by which a coastal State or a group of coastal States can unilaterally impose such a slow steaming regime for the purpose of reducing atmospheric pollution.

It should not be forgotten that:

a The effects of atmospheric emissions from ships have only recently started becoming apparent.

b The ship's speed has only been considered in the past as an aspect of safety and with respect to shipping accidents but not as a factor contributing to increased emissions.

Thus development of laws in order to deal with these issues is expected. It is within this context that compulsory slow steaming should be considered as an appropriate regulatory development. The answer to this largely turns upon the effectiveness of compulsory slow steaming as a measure to reduce GHG

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7 Some support for this argument can be found in Art. 18 where the term "passage" is defined as "navigation through the territorial sea…". It is then stated "Passage shall be continuous and expeditious. However, passage includes stopping and anchoring, but only in so far as the same are incidental to ordinary navigation or are rendered necessary by *force majeure* or distress or for the purpose of rendering assistance to persons, ships or aircraft in danger or distress." Thus it can be argued that the word expeditious qualifies the passage as being performed without delay. Thus it can be argued that it adds a qualification to passage in relation to speed because passage and navigation by themselves do not include any requirement or reference to speed. In some context it is clear that there is a distinction between navigation and speed. For example the NY Code § 45 states: "Reckless operation of a vessel; speed. 1. (a) Every master or operator of a vessel shall at all times navigate the same in a careful and prudent manner in such a way as not to unreasonably interfere with the free and proper use of the navigable waters of the State and all tidewaters bordering on or lying within the boundaries of Nassau and Suffolk counties or unreasonably endanger any vessel or person. Reckless operation is prohibited. Any person operating a vessel in violation of this subdivision shall be guilty of a misdemeanour punishable as set forth in section seventy-three-b of this article.
(b) No person shall operate a vessel at a speed greater than is reasonable and prudent under the conditions and having regard to the actual and potential hazards then existing.
Surely if navigation includes speed then the establishment of penalties for reckless navigation would § 45(2) be unnecessary."

8 In addition freedom of navigation must be exercised with "due regard for the interests of other States in their exercise of the freedom of the high seas", Art. 87(2). However this does not provide rights for another State to regulate the speed of foreign ships in the high seas.

emissions and atmospheric pollution and the ways it can implemented rather than its legal feasibility.
The right to prescribe mandatory slow steaming on ships by a State or a group of States must be distinguished from the right to enforce such measures against foreign ships. Severe restrictions on enforcement exist in the high seas where only the flag State has the right to board a ship except where a) there are such rights granted under a treaty or b) there are reasonable grounds for suspecting that the ship in question is involved in one or more of the prohibited activities described under Art. 110. In the EEZ UNCLOS grants some enforcement rights to the coastal State in terms of requiring information[9] and undertaking physical inspection.[10] Such rights refer respectively to violations of "applicable international rules and standards for the prevention, reduction and control of pollution from vessels"[11] and can lead to physical inspection or detention of the vessel.[12] Even within the territorial sea the rights of enforcement by the coastal State are restricted against a ship on innocent passage.[13]

3.1.1 Compulsory slow steaming: legal feasibility

Ships flying the flag of a Member State
States can impose speed restrictions on ships flying their flag. Such restrictions will have to be observed by ships registered in these States wherever they sail. Such restrictions may only be subject to laws applicable at the territorial seas and internal waters of other States.

Ships destined for or sailing from a State's ports and facilities.
Under customary international law the coastal State has sovereign rights over its ports and internal waters. It is on the basis of this sovereignty that it regulates access to its ports. A coastal State is not under any obligation to permit access to its ports, save where there is human life at stake. Thus the coastal State may deny entry to the port or its internal waters to a foreign ship. It follows that the coastal State may set any conditions whatsoever for the entry of foreign ships into its ports or internal waters.

It is strongly arguable that this right is very wide under customary international law but in practice it has been restricted through the adoption of international treaties.[14]

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9 Art. 220(3).

10 Art. 220(5).

11 Art. 220(3).

12 Art. 220(5) and 220(6).

13 UNCLOS Art. 17.

14 Thus there is an obligation not to discriminate under UNCLOS (see Arts 24(1)(b), 25(3), 119(3), and 227) and under International Trade law (see Art. XX General Agreement on Tariffs and Trade 1994; 1867 UNTS 190; GATT 1994). See also the discussion in Molenaar, E. J. (2007), Port State Jurisdiction: Toward Comprehensive, Mandatory and Global Coverage, Ocean Development and International Law, Volume 38, Numbers 1-2, January 2007 , pp. 225-257(33).

States also generally avoid exercising jurisdiction on matters internal to the ship if these do not affect the interests of the State.[15]
There are several examples where States do exercise such jurisdiction against foreign ships for the enforcement of international treaties even where the flag State is not a signatory to the treaty. This suggests that there is a right to exercise jurisdiction on ships voluntarily entering the ports of a State.[16]

However States prefer to act under international arrangements rather than rely on such inherent powers unilaterally probably because of the loss of competitiveness and the commercial disadvantages to the ports of the State imposing such conditions where other nearby States are not imposing such restrictions.[17]

The conclusion that the port State has powers to set conditions for entry and to enforce them does not necessarily mean that such conditions can be arbitrary and without a jurisdictional basis. Thus it may be necessary to differentiate between conditions for entry referring to the ship's conduct when these operate in internal territorial or archipelagic water and conditions referring to the EEZ of the coastal State or the high seas.[18]

This position is preserved to a large extent under UNCLOS. Note also that under Art. 25(2) "the coastal State also has the right to take the necessary steps to prevent any breach of the conditions to which admission of those ships to internal waters or such a call is subject" with respect to ships proceeding under innocent passage to a port of facility.

There are several examples where States have imposed conditions for entry to ships. These include national laws enforcing IMO or ILO adopted measures as well as regulation of fisheries. Examples or State practice reflecting national requirements also exist.

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15 There is a dictum by a Judge of the International Court of Justice which suggests that State are required to "exercise moderation and restraint as to the extent of jurisdiction assumed by its courts in cases having a foreign element, and to avoid encroachment on a jurisdiction more properly appertaining to, or more appropriately exercisable by another State". (Barcelona Traction Case (1970) ICJ Rep 3, 105 (Judge Fitzmaurice)). The reference to jurisdiction in this statement is about jurisdiction on the merits with respect to a default by a foreign company that should have been dealt by the courts of the State where the company was established. The statement has limited value as it was in a separate judgement and the court did not discuss or decide such issues. If correct it could probably be taken to mean in the shipping context that where an issue can be regulated by another State the port State would better restrict is actions. For shipping matters the jurisdiction of the flag State or issues concerning the ship's conduct in the ports or internal waters of another State are examples which would probably be covered by this suggested principle. However the practice of port State control suggests that in the field of environmental protection (whether this is pollution or fisheries), the safety of navigation, employment or seamen, human rights, and health considerations indicates that exercise of the inherent powers of the coastal State are generally welcomed and considered as safeguard against deficient flag State controls to fishing.

16 Of course what each State has to provide to all foreign personalities, companies, and arguably ships, is the protection of the national law (see Barcelona Traction Case (1970) ICJ Rep 3, Judgment para. 33).

17 Molenaar E.J., in Port-State Jurisdiction: Towards Mandatory and Comprehensive Use, suggests a more restrictive position by accounting five grounds under which such jurisdiction could be justified and by distinguishing between the right to restrict access from that of exercising jurisdiction. He also suggests that the type of enforcement action is also relevant.

18 For an analysis of the jurisdictional bases that are exercised see the Report of the Task Force on Extraterritorial Jurisdiction (International Bar Association, s.a.).

1. State practice in fisheries

The rights of States to impose conditions for port entry with respect to fisheries under the 1982 LOSC are notably enhanced by virtue of the UN Fish Stock Agreement[19] which in Art. 23(1) states : "A port State has the right and the duty to take measures, in accordance with international law, to promote the effectiveness of subregional, regional and global conservation and management measures. When taking such measures a port State shall not discriminate in form or in fact against the vessels of any State." Thus arguably a duty to exercise port State control against all ships whether flying the flag of a contracting State or not is imposed. Art. 23(2) and 23(3) provide the option to the port State to inspect and adopt regulations prohibiting the landings and transhipments. Art. 23(4) states: "Nothing in this article affects the exercise by States of their sovereignty over ports in their territory in accordance with international law" thus clarifying that the coastal State retains any jurisdiction in excess to what is described in Article 23. In essence the innovation of Art. 23(1) is the imposition of an obligation to exercise the inherent powers available. Examples of such conditions follow:

- Canada denies port access to vessels that undermine conservation measures adopted by Regional Fishery Management Organisations to which Canada is a member.
- Iceland does the same for foreign vessels that act contrary to international agreements to which Iceland is signatory. Japan, Norway also impose similar regulations.
- The US (which are not a party to UNCLOS) have similar legislation and prosecute foreign ships in its ports which have violated fishing laws of other States while fishing in the other State's waters.

The EU control Regulation 2847/93 as amended provides conditions that have to be complied with for non-EU vessels to offload fish in EU ports.

Ireland's Sea-fisheries (Control of Catches) (Deep-Sea Stocks) Regulations 2009, S.I. No. 38 of 2009, regulation 3 which Implements Council Regulation (EC) No. 1359/2008 of 28 November 2008, requires under Art 7(2) that

> *"(…)Vessels holding a deep-sea fishing permit that have entered the areas defined in paragraph 1 shall not retain on board or tranship any quantity of orange roughy, nor land any quantity of orange roughy at the end of that fishing trip unless:*
> *(a) all gears carried on board are lashed and stowed during the transit in accordance with the conditions laid down in Article 20(1) of Regulation (EEC) No 2847/93; or*
> *(b) the average speed during transit is equal to, or greater than, 8 knots.(...)"*

Thus a minimum average speed is set as a condition for entry.

Australia's Fisheries Management Act 1991 s. 105H and 105I impose liability to foreign vessels fishing in the High Seas which violate international fisheries agreements and are not authorised (generally or by granting a licence) by the flag State.

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[19] United Agreement For The Implementation Of The Provisions Of The United Nations Convention On The Law Of The Sea Of 10 December 1982 Relating To The Conservation And Management Of Straddling Fish Stocks And Highly Migratory Fish Stocks, Un A/Conf.164/37, 8 September 1995.

Thus within fisheries port State jurisdiction is well established as practice for the purpose of enforcing internationally agreed standards.

The European Court of Justice in the *Poulsen* Case[20] permitted the confiscation of 22 tons of salmon caught outside the waters of Member States on the basis of EC Regulation (EEC) No 3094/86.[21] According to the judgement the regulation became enforceable because of the presence of the ship in a Danish port. This was considered to be consistent with international law.
It can be concluded that in relation to fishing State practice supports the exercise of port jurisdiction even where this concerns fishing activities in the high seas.

Chile requires that the flag State exercises effective jurisdiction over its vessels and cooperates in the conservation of straddling and highly migratory stocks. [22]

2. State practice in CDEM standards

CDEM standards are primarily determined through IMO instruments. However there is residual prescriptive jurisdiction under UNCLOS and States have exercised this.

Following the Prestige incident the Spanish government excluded all single hull tankers from Spanish ports.[23]

Following the same incident and in response to Spanish and French pressure the EC accelerated the phasing out of single hull tankers for the carriage of heavy oils by unilaterally developing legislation.[24] This led to accelerated phasing out by the IMO. Note that the EC phasing out was in force a year and a half (1/10/2003) before the IMO Resolution MEPC.111(50) (5/4/2005).

Section 4115 of OPA 90 US 1990 Oil Pollution Act[25] also had the effect of excluding double hull tankers larger than 5,000 grt before any IMO agreement was reached.[26]

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20 Case C-286/90, Anklagemyndigheden (Public Prosecutor) and Peter Michael Poulsen, Diva Navigation Corp.

21 Of 7 October 1986, laying down certain technical measures for the conservation of fishery resources (OJ 1986 L 288, p. 1).

22 Decree No. 123 May 3,2004.

23 24343 Royal Decree-Law 9/2002 of 13th December.

24 REGULATION (EC) No 417/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 February 2002 on the accelerated phasing-in of double hull or equivalent design requirements for single hull oil tankers and repealing Council Regulation (EC) No 2978/94. This was amended by Regulation (EC) No 1726/2003 of the European Parliament and of the Council of 22 July 2003 amending Regulation (EC) No 417/2002 on the accelerated phasing-in of double-hull or equivalent design requirements for single-hull oil tankers.

See also REGULATION (EC) No 457/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 April 2007 amending Regulation (EC) No 417/2002 on the accelerated phasing-in of double hull or equivalent design requirements for single hull oil tankers.

25 33 US Code §§2701-2761 and 46 US Code §§ 3701-3718.

26 The US opted out of the amendments in MARPOL introducing the double hull standards.

The 1996 Stockholm agreement[27] provides another example where a group of States exercised their jurisdictional right to impose conditions for entry in relation to CDEM.
Council Directive 2005/33/EC[28] (July 2005) imposes maximum limits of sulphur content to passenger vessels operating between EU ports and when they are within EU ports irrespective of flag.

Molenaar (2007) reports a ruling of the Environmental Court of Appeal in Sweden which decides, amongst other issues, that nothing in the 1982 LOSC or MARPOL 73/78 prevents a port from establishing more strict, than MARPOL, non-discriminatory measures in relation to nitrogen oxide emissions.[29]

The demand for compliance with specific CDEM requirements can of course be justified by the presence of the ship in the port and does not concern the non-compliance at high seas although these necessarily follow.[30]

In *Sellers v Maritime Safety Inspector* Mr Sellers, the master of a foreign pleasure craft was fined for leaving New Zealand without the required by local law radio tranceiver and an emergency location beacon on board. The CA reversed the conviction. In their view[31] New Zealand:

> *"…has no general power to unilaterally impose its own requirements on foreign ships relating to their construction, their safety and other equipment and their crewing if the requirements are to have effect on the high seas. Any requirements cannot go beyond those generally accepted, especially in the maritime conventions and regulations; we were referred to no generally accepted requirements relating to the equipment particularly in issue in this case so far as pleasure craft were concerned. In addition, any such port State powers relate only to those foreign ships which are in a hazardous state."*

However the judgement concedes that internationally agreed measures are enforceable.

3. State practice in ship source pollution

Express enforcement rights are granted to port States under UNCLOS Article 218 to deal with breaches of internationally agreed rules in areas outside the jurisdiction of the port State[32] but not in areas within the jurisdiction of another State[33] unless that other State has required action by the port State or

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27 Agreement concerning Specific Stability Requirements for Ro-Ro Passenger Ships undertaking Regular Scheduled International Voyages between or to or from Designated Ports in North West Europe and the Baltic Sea Concluded at Stockholm, 27-28 February 1996 and Opened for Signature at the Headquarters of the International Maritime Organization, London, from 1 July until 30 September 1996. This was originally signed by Denmark, Finland, Germany, Ireland, Netherlands, Norway, Sweden, UK which undertook to impose the new stability measures, which were more strict than the then applicable under SOLAS, to the ships of non-contracting States.

28 DIRECTIVE 2005/33/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 July 2005 amending Directive 1999/32/EC as regards the sulphur content of marine fuels.

29 Page 231. It is also stated there that the Netherlands under the Foreign Ship Act can require compliance with EU regulations on safety as a condition for entry in the port even where these are more strict that the IMO standards.

30 However see Sellers v Maritime Safety Inspector (The 'Nimbus')- Court of Appeal 5 November 1998 reported in Lloyd's Maritime Law Newsletter, 13 may 1999.

31 Supported by some commentators and considered as flawed by others. See Molenaar above.

32 218(1).

33 218(2).

the port State has also suffered pollution. Such enforcement rights are granted in relation of international rules and standards. These would certainly include the IMO agreed standards but also standards in regional and bilateral agreements.

There is no State practice, to our knowledge, to suggest that enforcement for discharges in the high seas is in use.

MARPOL, SOLAS, contain the 'no more favourable' treatment of ships of non-contracting States which in essence obliges foreign ships of non-contracting States to follow the rules of the port State or face the same consequences as if they were non-compliant ships of a contracting State.

4. Other conventions

The Maritime Labour Convention 2006 also contains the 'no more favourable' treatment provision under Art. 5(7). Art. 15 of 2001 Underwater Cultural Heritage Convention provides "States Parties shall take measures to prohibit the use of their territory, including their maritime ports …. in support of any activity directed at underwater cultural heritage which is not in conformity with this Convention."

5. US measures for the protection of right whales

The U.S has introduced both compulsory and voluntary speed limits in several areas and for various purposes.

a Under the Endangered Species Act and the National Marine Sanctuaries Act, the Maritime Administration (MARAD) now requires, as a condition of a Federal Deepwater Port license, that carriers of liquefied natural gas (LNG) travelling to deepwater ports off Boston proceed at speeds of 10 knots or less when right whales are detected in the area (NMFS, 2007a; NMFS, 2007b).

b The US Coast Guard has established speed limits in some river and port entrances ranging from 5–10 knots for the purpose of enhancing national security (e.g., 66 FR 53712; 67 FR 41337; 68 FR 2201).

The imposition of such measures are justified on grounds of marine environmental protection but are based on the powers of a State to impose conditions for entry. Admittedly these do not relate to risks in the high seas.

6. State practice in the provision of vessel monitoring system data as conditions for entry.

The provision of such a system would be essential to the imposition of regulated slow steaming for ships. Significant State practice exists in this respect in relation to fisheries and in relation to Particularly Sensitive Sea Areas.[34]

Support can also be found under LOSC Art. 211(3) which says:

> "States which establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their ports or internal waters or for a call at their off-shore terminals shall give due publicity to such requirements and shall communicate them to the competent international organisation. Whenever such requirements are established in identical form by two or more coastal States in an endeavour to harmonise policy, the communication shall indicate which States are participating in such cooperative arrangements. Every State shall

[34] See the section on PSSAs.

require the master of a vessel flying its flag or of its registry, when navigating within the territorial sea of a State participating in such cooperative arrangements, to furnish, upon the request of that State, information as to whether it is proceeding to a State of the same region participating in such cooperative arrangements and, if so, to indicate whether it complies with the port entry requirements of that State. This article is without prejudice to the continued exercise by a vessel of its right of innocent passage or to the application of article 25, paragraph 2."

3.1.2 Compulsory slow steaming and the right of innocent passage

Within the territorial sea the coastal State has wide jurisdiction in prescribing and enforcing navigational and environmental rules but this jurisdiction is co-existent with the right of innocent passage which is granted to all ships of all States.

The term passage includes two ways of travelling. First it covers going through the territorial sea without going to a port, internal waters or other facility of the coastal States. The second situation concerns ships going to or coming from a port or other facility of the coastal State.

Passage must be continuous and expeditious. The term expeditious must mean that a vessel under innocent passage should not delay its progress through the territorial sea. This by itself cannot be considered as excluding the possibility of compulsory slow steaming.

Innocent passage is defined as passage which is not "prejudicial to the peace, good order or security of the Coastal State". When a ship is under innocent passage the coastal State cannot intervene with the passage. Where however the passage ceases to be innocent then the coastal State can intervene. This arrangement in our view suggests that during innocent passage a restriction on the enforcement powers of the coastal State is imposed. However it does not follow that the ship is permanently immune from the enforcement jurisdiction of the coastal State for violations of the laws of the coastal State committed when the ship was on innocent passage. It is arguable that enforcement can take place if the vessel comes under the enforcement jurisdiction of the coastal State either because it enters a port of the coastal State or because its passage can not be characterised as innocent.

Article 19 contains an exhaustive list of activities which may make the passage non-innocent. The most relevant activity to the present study is any 'wilful and serious pollution contrary to this convention'. The term used is 'pollution' rather than 'marine pollution' which prevails in other parts of UNCLOS. This indicates that the term arguably covers all types of pollution including atmospheric pollution. However emissions from the propulsion of a ship cannot, in the general case, be argued to be 'serious pollution' contrary to UNCLOS. Such an interpretation would be contrary to the intention of UNCLOS and customary international law. Thus non-compliance with a speed restriction with the consequence of increasing the amount of atmospheric emissions cannot be considered, in our view, as making the passage non-innocent.

The coastal State has, under Art. 21, the right to adopt laws and regulations applicable to ships on innocent passage through the territorial sea in respect of a number of issues including "the preservation of the environment of the coastal State and the prevention, reduction and control of pollution thereof". Thus, laws and regulations in the form of speed restrictions may be prescribed in relation to vessels undertaking innocent passage provided they can be justified as pollution reduction measures. Foreign ships under innocent

passage must comply with such laws. However it is unclear whether any violation of such laws and regulations would automatically render the passage non-innocent or whether the passage must become "prejudicial to the peace, good order or security of the coastal State" for the passage to be considered as not innocent. The better view is that the prevailing obligation is that the coastal State is under a duty not to hamper the innocent passage of foreign ships and therefore only where the passage is not innocent is enforcement of coastal State's laws permissible. This enforcement can not hamper innocent passage but can be delayed to the time when the vessel is at a port where enforcement jurisdiction exists.

A coastal State cannot hamper innocent passage by "imposing requirements on foreign ships which have the practical effect of denying or impairing the right of innocent passage" or "discriminate in form or fact against the ships of any State or against ships carrying cargoes, to or on behalf of any State". Thus speed restrictions which may make the navigation of a ship impossible or which will solely apply to ships destined to a particular State are not permitted.

The continuing practice of many States to challenge and oppose measures affecting navigation when these are adopted unilaterally by a coastal State[35] indicate that speed restrictions imposed for the purpose of reducing emissions may be argued as hampering innocent passage and therefore as actions in excess of the rights granted to the coastal States under international customary law as well as under UNCLOS.

However, speed restrictions in the territorial sea do not in general hamper the innocent passage of the ship. They only specify the way the right of innocent passage is to be conducted. Violation of such a speed restriction surely will not entitle the coastal State to intervene, save, possibly, in situations where the speed restrictions are imposed for safety of navigation purposes. Moreover if a ship does not later call at a port of the coastal State (or States) that have imposed such speed restrictions there is arguably no consequence on the ship or the master.

However, enforcement of speed restrictions does not have to take place at the moment the offence is committed but can take place later on when the ship is at an appropriate port or against an owner or operator if personal jurisdiction against them exists. In such a case non-compliance with the restriction imposed by the coastal State will put the master and the ship at risk of facing proceedings and fines. However this risk is created by the decision of the master/shipowner to enter the port of the coastal State and not by the requirement to observe the speed restriction while sailing in the territorial seas of that State.

3.1.3 Compulsory slow steaming and transit passage

Straits which act as choke points for international navigation pose additional problems because if a coastal State can impose any type of restrictions then the strait may be effectively closed for some ships. From the point of view of the coastal State the existence of the strait imposes obligations to ensure safety of navigation and minimise the risk of pollution. UNCLOS attempts to resolve these problems by recognising a right to transit passage for straits used in international navigation which is more liberal than innocent passage but which does not affect otherwise the character of the waters. The following points are important in this discussion:

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[35] Including reporting systems, compulsory pilotage and traffic separation schemes.

- Ships in transit passage have to proceed without delay and the transit must be 'continuous and expeditious'.
- Furthermore ships in transit must comply with international generally accepted regulations and procedures for navigation and pollution from ships.
- Coastal States can introduce laws applicable to ships in transit passage in relation to safety of navigation and laws which implement 'applicable international regulations regarding the discharge of oil, oily wastes and other noxious substances'.
- Speed restrictions for the purpose of reduction of atmospheric emissions from ships could not cover ships in transit passage even if approved internationally unless the emitted substances are noxious.
- Transit passage should not be hampered nor can be suspended. This means that the enforcement jurisdiction of a coastal State is at its minimum.

Thus the enforcement powers of the coastal State are severely restricted against ships on innocent passage. However, there is nothing within UNCLOS that stops a coastal State from enforcing laws violated during transit passage at any subsequent port of call of the ship or through contacting the flag State.

3.1.4 Restrictions based on extraterritoriality

A major restriction in the exercise of State's jurisdiction can be argued on the basis of extraterritorial effects that nationally applicable legislation may have. Thus, for example it is questionable whether it is appropriate for a State to enforce environmental regulations against a ship for actions undertaken in the territorial seas of another State. In United States v Mitchell,[36] criminal proceedings were brought against a US citizen under the 1072 US Marine Mammal Protection Act. The accusation was that Mr Mitchell was in violation of the Act as he was catching dolphins under a licence granted from the Bahamian government and in Bahamian waters. The US Court held that the criminal liability regime to enforce a moratorium in taking dolphins could not be applied against Mr. Mitchell. The decision was based on an interpretation of the intent of the Congress but it does recognise the difference between having jurisdiction and not exercising such jurisdiction as a matter of comity against foreign courts or as a consequence of accepted practice.[37] This decision appears in sharp contrast with the decision of the EJC in the *Poulsen* case[38] discussed above.

In both cases the jurisdiction of the court was well established, in one by the nationality of the defendant and in the other by the presence of the ship in the port. The difference is on the attitude each court took on whether such jurisdiction should or should not be exercised. This in turn depends indeed on the intentions of the legislator and need to be made clear in any regulations on slow steaming.

A recent ECJ Case C-366/10[39] provides some indication of the views that may be advanced in front of the ECJ in relation to regulations concerning emission

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36 644 F2d 1324 (9th Cir. 1981), as amended Oct. 22, 1981, cert. denied, 50 U.S.L.W. 3465 (1981).

37 Note though that many laws due have extraterritorial effects, for example taxation of income. Thus it can be argued that it is a matter for public policy and the courts to decide to what extent the existence of such effects should not apply to particular actions.

38 Case C-286/90, Anklagemyndigheden (Public Prosecutor) and Peter Michael Poulsen, Diva Navigation Corp.

39 The Air Transport Association of America and Others, opinion delivered on 6 October 2011 and the decision of the court on December 21, 2011.

controls. The background of this must be explained before the extent to which this decision relates to shipping is discussed.

In this case the air industry challenged, before the English High Court, the measures taken by the UK through its implementation of Directive 2008/101/EC which extends the EU emissions trading scheme to aviation.

The air industry challenged, amongst other things, the jurisdiction of the EU to apply the scheme to flights over air-space which is not EU Member State's space or high seas or involve airports outside the EU.

Also the air industry based an argument on the Kyoto Protocol arrangements and claimed that because the reduction of GHG emissions should be made within the context of the ICAO and not introduced unilaterally the Directive in question was inconsistent with this international agreement.

Thirdly the air-industry consider the emissions trading scheme as a tax or charge prohibited by other international agreements.

The first two of the issues are of direct relevance to the shipping industry and can be deployed to argue against any unilateral effort by the EU or a Member State to regulate GHG emissions from ships for example by imposing compulsory slow steaming.

The ECJ found,[40] to the extent relevant to this discussion, that the following principles of international law can be relied upon in assessing the validity of the Directive:

a The principle that each State has complete and exclusive sovereignty over its airspace.
b The principle that no State may validly purport to subject any part of the high seas to its sovereignty.
c The principle which guarantees freedom to fly over the high seas.

Thus the obligations under the Kyoto Protocol were not found as precise enough to be relied upon for assessing the validity of the Directive because the wording of Art. 2(2) was not considered to be unconditional and sufficiently precise.[41]

The standard applicable to assess the validity of the Directive against these principles is whether the EU in adopting the Directive made "a manifest error of assessment concerning the conditions for applying these principles".

The court stated that:

> *"The European Union must respect international law in the exercise of its powers, and therefore Directive 2008/101 must be interpreted, and its scope delimited, in the light of the relevant rules of the international law of the sea and international law of the air…."*[42]
>
> *"On the other hand, European Union Legislation may be applied to an aircraft operator when its aircraft is in the territory of one of the Member States and, more specifically, on an aerodrome situated in such*

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40 ECJ Case C-366/10 judgement of 21/21/2011.

41 Paragraphs 77 and 78 of the judgement.

42 Paragraph 123.

territory, since, in such a case, that aircraft is subject to the unlimited jurisdiction of that Member State and the European Union…" [43]

The air industry sought to rely on a principle in international law under which aircraft over the high seas are under the exclusive jurisdiction of the State of registration. The ECJ stated that insufficient evidence exists that the relevant principle applied to ships also applies to aircraft.[44]

The ECJ further stated in Paragraph 129 that the fact that pollution originates "in an event which occurs partly outside" the territory of the Member States can not call "into question, in the light of the principles of customary international law capable of being relied upon in the main proceeding, the full applicability of European law" outside EU Member State territory.

In essence the ECJ accepted the extraterritorial effects EU environmental law may have if jurisdiction is established through the voluntary presence of the foreign aircraft at an airport of an EU Member State.

It is clear that the same conclusions will be reached in the case of ships within an EC port with the only difference that in relation to ships a further argument which relates to the exclusive jurisdiction of the flag State at the high seas can be made.

Thus an argument on whether an EU imposed speed restriction that has to be complied with by foreign ships at the high seas is clearly violating the exclusive jurisdiction of the flag State at the high seas is likely to be put forward.

Extraterritorial enforcement, in the port, may be restricted where a State has agreed to do so.[45] The question then is the exclusive jurisdiction of the flag State in respect of its vessels' activities in the high seas,[46] is such a restriction of the coastal State's enforcement jurisdiction even when the ship has voluntarily entered the port of the Coastal state. It is submitted there is no express legal instrument of judicial decision restricting the powers of a coastal State against a ship present in its port and that the restriction in respect of the criminal liability of the master and crew for collisions and other incidents of navigation can not be taken to cover liability for breach of environmental regulations at large. Thus it is argued that speed restrictions imposed on the high seas are not a violation of the exclusive rights of the flag State because they are not enforceable unless the ship chooses to enter the port of the State imposing such restrictions. This is exactly equivalent with the surrender of emission allowances under Directive 2008/11 for parts of the flight at the air-space of non-Member States which was not considered a violation of the exclusive jurisdiction of each State over its airspace in the ECJ decision in Case-366/10.

Thus it is submitted that speed restrictions on ships imposed as conditions for entry in the EU Member State ports are legally feasible. They are easier to justify when compliance is demanded for voyages to and from Member States.

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43 Paragraph 124.

44 Paragraph 106.

45 For example criminal liability of the master or other persons employed by the ship for collisions or other incidents of navigation in the high seas has been agreed under UNCLOS Art. 97 to be for the exclusive jurisdiction of the flag State.

46 Leaving aside cases of piracy, slavery, drug trafficking and unauthorised broadcasting which enable all States to act against such ships in the high seas.

The port State has, in our view, jurisdiction to enforce such measures. Thus it is a matter for the national legislator whether the enforcement jurisdiction of the port State should be exercised against foreign ships violating such speed restrictions.

3.1.5 To what extent coastal States have jurisdiction with respect to atmospheric pollution from ships?

The availability of compulsory slow steaming for ships to States as a measure concerning protection of the environment under UNCLOS depends on:

a The extent of permission given to the coastal States under UNCLOS to dictate navigational matters for the purpose of the protection of the environment.

b Whether atmospheric pollution is covered by UNCLOS and how.

In relation to atmospheric pollution a coastal State has the right to:

1. Take appropriate measures of enforcement on ships destined to or coming from a port when the ship is in its territorial seas.
2. Take appropriate measures of enforcement in relation to violations of national laws on ships in ports and internal waters.

However it is strongly arguable that a coastal State is not entitled to interfere with a ship exercising its right of innocent passage through the territorial waters of the coastal State because of a breach of a national law relating to atmospheric emissions. Similarly it is strongly arguable that no such enforcement jurisdiction exists in relation to the EEZ of coastal States.

3.1.6 Conclusions

Compulsory slow steaming can be imposed by a State on the ships flying its flag. For such ships the flag State has prescriptive and enforcement jurisdiction.

A coastal State can impose speed restrictions on all ships in its territorial waters. Such speed restrictions cannot be enforced while a foreign flagged ship is on transit or on innocent passage. In such a case enforcement is possible but only when the ship's passage stops being innocent or where the ship voluntarily enters the port of the coastal State.

A coastal State can further prescribe speed restrictions on foreign flagged vessels travelling through the EEZ or at the High Seas. Such restrictions can not be enforced at the high seas as they will interfere with the exclusive jurisdiction the flag State enjoys under customary international law and the LOSC. Nor can such speed restrictions be enforced in the EEZ unless the enforcement is consistent with the relevant provisions of UNCLOS.

However such measures on the high seas or the EEZ can be imposed as conditions for entry into a port of a coastal State and can be enforced on the basis of the presence of the ship in that port. Issues relating to the extraterritorial character of speed restrictions at the high seas or the EEZ are likely to arise but, it is our view, because they are imposed as conditions for entry to a port the fact that they dictate behaviour in areas outside the enforcement area of the coastal State is not a restriction in exercising enforcement rights because they are of no effect unless where a ship voluntarily visits the port of the coastal State.

3.2 Speed definition

Regulated slow steaming can be applied to different speed definitions: either speed over ground or speed through the water can be restricted. Moreover, the top speed or the average speed can be restricted. Hence, there are at least four speeds that can be restricted (see Table 9).

Table 9 Conceivable restricted speeds

	Speed through the water	Speed over ground
Top speed	Maximum speed through water during a voyage or a time period	Maximum speed over ground during a voyage or a time period
Average speed	The sum of the sailing distance and the current between two ports divided by the sailing time	The sailing distance between two ports divided by the sailing time

The definition of speed has a relation with the environmental impact and with the feasibility of monitoring. Both will be discussed below.

3.2.1 The environmental relevance of the speed definition

The definition of speed determines to an extent the relation with emissions.

The CO_2 emissions of a ship per unit of time depend on different factors:

$$CO_2\ emissions = Emission\,factor * \left(Engine\,power * \int_0^T \left(SFOC_t * Engine\,load_t \right) dt \right)$$

The CO_2 emissions of a ship are thus determined by the CO_2 emission factor of the fuel (a constant) and the fuel consumption per unit of time. The latter is a function of the engines' power (a constant) as well as the specific fuel oil consumption (SFOC) and the engine load. At higher speeds through the water, a ship requires a higher engine load, mainly to overcome the sharp increase in wave making resistance (Buhaug et al., 2009). The SFOC will increase the further away an engine is from its optimal design point, which is often between 65 and 80% of the maximum engine power (CE Delft and GL, 2010). Because the changes in engine power are typically larger than the changes in SFOC, speed through the water determines to a large extent a ship's fuel consumption and thus its CO_2 emissions. The same holds for emissions of SO_x, NO_x and probably BC.

As a rule of thumb, a ship's engine load is related to the third power of its speed. Numerically, a 10% speed reduction results in a 27% engine load reduction.

Speed over ground is not directly related to engine load. If a ship is sailing with the current, the speed through the water is lower than the speed over ground and thus the engine load is lower. While on average one can assume that a ships sails as often with the current as against it (although routing systems are available that make optimal use of sea currents), a constant speed over ground requires more fuel than the same constant speed through the water because of the convex relation between speed and fuel consumption.

Speed through the water is therefore environmentally more relevant than speed over ground.

3.2.2 Top speed or average speed

There are two relevant aspects of the choice to limit average or top speeds. The first is the feasibility of monitoring speed. The second is the flexibility provided to ship operators.

Average speed can be monitored effectively through inspection of log books, which contain information on time of port entry and exit and often also on position of the ship at certain times, and (S-)AIS data. Top speed can only be monitored using (S-)AIS data. Average speed can therefore be determined more easily than top speed.

Since a restriction on the average speed does not set a limit on the maximum speed, it allows ships flexibility to overcome unexpected delays by speeding up.

For existing vessels, Maersk introduced Super Slow Steaming (De Kat, 2011) and found that is was better to occasionally sail at high speeds in order to clean the turbocharger. A limit on top speed would not allow for this, and could potentially lead to either the necessity to redesign the engine and turbocharger, or result in engine or turbocharger failure.

A restriction either on top speed or on average speed would have similar environmental effects, as both would result in lower speeds. Only if a speed restriction resulted in a less constant speed, would there be an environmental disadvantage because of the concave relation between speed and engine load.

3.2.3 Monitoring speed

Monitoring speed through the water

Speed through the water could in principle be monitored by the ship itself (e.g. in a log or a tachograph). Ships over 300 GT and passenger ships are required to have a device measuring speed through water on board according to SOLAS Chapter V. Disadvantages of this approach are, first, that one has to rely on data gathered onboard and, second, that, to our knowledge, vessels are currently not obliged to document their speed through the water in their log books.

Alternatively, speed through the water could be monitored by making use of data on the vessels' speed over ground (e.g. GPS data) and combining this with independent data of surface currents. This could be done in two different ways. First, a vessel's speed over ground on a certain (randomly chosen) route could be monitored and could be corrected for the respective wind- and wave regime. Since wind- and wave regimes highly differ between seasons and between years, it is not possible to work with average correction values to this end. This makes this approach rather complex. Second, the average speed over ground sailed over a longer period, e.g. a year, could be monitored and not corrected for wind- and wave regimes, assuming that the impact of wind and wave average out in this period. The main disadvantage of this approach is that much more speed data would have to be processed.

Monitoring speed over ground

By contrast, different systems that aim at enhancing safety are already in place that permit the monitoring of a vessels' speed over ground. In the following the key features, as well as the advantages and disadvantages of two systems when used for a world wide monitoring of the speed over ground are listed.

Long Range Identification Tracking (LRIT)

- Technique: a satellite-based system.
- Mandatory for the following ships engaged on international voyages:
  - All passenger ships.
  - Cargo ships >300 GT.
  - Mobile offshore drilling units.
- Ships exempted: ships operating exclusively in the Sea Area A1 and fitted with AIS.
- Information transmitted:
  - Identity of ship.
  - Position of the ship.
  - Date and time of position provided.
- Advantages:
  - Coverage in terms of technical potential: global.
  - Coverage in terms of committed participants: Use of LRIT has been agreed upon at IMO level.
- Disadvantages:
  - Speed over ground is not reported directly.
  - Data is not gathered at one central point.
  - LRIT data is confidential in the sense that SOLAS contracting governments are only entitled to receive LRIT information from:
    - Vessels operating under their flag.
    - Vessels that indicate intentions to enter a port under their jurisdiction.
    - Vessels operating within 1,000 nautical miles of their coast.
  - Frequency at which information is transmitted: ships have to report at least four times a day. Speed data as such are not transmitted. But according to EMSA (2010) reporting rate can be changed from every six hours to potentially a maximum of every fifteen minutes.

(Satellite-based) Automatic Identification System ((S-)AIS)

- Technique:
  - (S-)AIS: a satellite-based system.
  - AIS: a VHS-based system.
- Mandatory for the ship types (AMSA, 2008):
  - IMO has made class A responder mandatory for:
    - Vessels engaged in international voyages and >= 300 GT.
    - Cargo ships not engaged in international voyages >=500 GT.
    - Passenger ships (more than 12 passengers), irrespective of size.
  - Non-SOLAS vessels can use class B responders but this is not mandatory. Note: signals from class B responders cannot be used for (S-)AIS.
- Advantages:
  - Coverage in terms of committed participants: Use of AIS has been agreed upon at IMO level.
  - Speed over ground is reported directly.
  - High reporting frequency:
    - For speed >= 3 knots: 2-10 sec.
    - For speed < 3 knots: 3 min.
  - Archiving of (S-)AIS data is allowed.
  - AIS: No confidentiality of information since AIS is a broadcast system.
  - (S-)AIS: Coverage in terms of satellites is not worldwide yet, however, many launches of AIS-enabled satellites are planned so that worldwide coverage is likely on the medium term.
- Disadvantages:
  - The AIS responder has to be calibrated correctly to get reliable data.

- Under certain circumstances ships fitted with AIS are allowed to switch off their AIS responder: Ships fitted with AIS shall maintain AIS in operation at all times except where international agreements, rules or standards provide for the protection of navigational information.
- AIS has a maximum guaranteed range of approximately 40 nautical miles from the coastline; AIS data can thus not be gathered centrally and also not on a global scale.
- (S-)AIS:
  - Access to (S-)AIS data may be via private parties.
  - Since AIS system has not been designed for signal detection from space, interference problems can arise leading to signals from ships that sail close-by not all being detected (Høye et al., 2004).

In principle, measurements of speed over ground can be converted into estimates of speed through the water. In ship routing consideration is given to wind, seas, ocean currents, fog and ice (Bowditch, 2002), whereas fog and ice are, for the vast majority of the world fleet, more a factor for rerouting than that they are decisive for the difference between speed through the water and speed over ground.
According to Bowditch (2002) it holds that:

- For light winds (less than 20 knots) ships lose speed in headwinds and gain speed slightly in following winds.
- For higher wind speeds the ships' speed is reduced in both head and following winds (this is due to the increased wave action, which in following seas results in drag from steering corrections).
- Head seas reduce ship speed, while following seas increase ship speed slightly to a certain point, beyond which they retard it. And
- Ocean currents can be a determining factor in route selection, which is especially true when the points of departure and destination are at low latitudes.

It is thus feasible that the ships' speed over ground is monitored over a relatively short, randomly chosen period of time, that it is corrected for wind and wave regime, and that, for the case that the speed restriction is violated, ships have the possibility to report the ocean current regime.

Or, it is feasible that ships' speed over ground is monitored over a longer period of time. In this case, correction for wind and wave regimes is a too high effort, whereas an average correction factor could be applied for ocean currents[47]. Disadvantage of this method is that a one-sided correction is applied and that the speed restriction could turn out to be non-binding. This approach can therefore be discarded.

However, considering this last aspect (of one-sided correction) suggests that not speed through the water but alternatively speed over ground could be used as the unit to be monitored: since it is better to monitor speed over ground in the first instance anyway, one could decide to monitor ships over a longer period of time and at the same time not correct for wind-, wave- and current regimes, assuming that these opposite effects cancel out. Speed over ground could therefore be used as a proxy for speed through the water, at least when a longer period of time is considered.

[47] Most currents have speeds less than or equal to 5 knots (NCERT, 2006).

3.2.4 One speed for all ship types or different restrictions

Currently, ships of different types have different design speeds. A typical large bulker or tanker is designed to sail 14 to 15 knots, whereas a large container ship is often designed to sail 25 knots (Buhaug et al., 2009).

Large ships (or more accurately: long ships) have a lower wave making resistance and often a higher design speed. Moreover, small ships are often feeders or coasters, which spend less time at sea and more time in ports and for whom, consequently, the optimal speed is lower. As a result, smaller ships are designed for lower speeds than larger ships. For example, a typical 5,000-8,000 TEU container ship has a design speed of 25 knots, whereas a 1,000-2,000 container ship has a design speed of 19 knots (Buhaug et al., 2009).

Average speeds are lower than design speeds, but still vary considerably between ship types. Table 10 shows the design speed and average speeds while at sea of a selected number of ships. The average speed of these ships varies from 10.5 knots to 22.7 knots, which is 90 to 96% of the design speed.

The data relate to the fleet in 2007. Other data relating to engine load of container ships in 2007 (e.g. De Kat 2011) indicate that container engine loads and speeds may have been lower, with loads between 55 and 58% and speeds of 20.0-21.6 knots. It is likely that current average speeds are lower than the ones reported here (see also Chapter 5).

Table 10 Design speeds and average speeds of selected ship types

Ship type	Ship size	Design speed	Average engine load	Average speed while at sea (2007)
Crude oil tanker	200,000+ dwt	15.4	73%	14.4
Crude oil tanker	60-79,999 dwt	14.6	70%	13.4
Bulk carrier	200,000+ dwt	14.4	71%	13.3
Bulk carrier	60-99,999 dwt	14.4	70%	13.2
General cargo	10,000+ dwt	15.4	80%	14.8
General cargo	-4,999 dwt	11.7	65%	10.5
Container	8,000+ TEU	25.1	67%	22.7
Container	3-4,999 TEU	23.3	65%	20.9

Source: Buhaug et al. (2009).

Note: Average speeds are calculated from the data on average main engine loads in Buhaug et al. (2009), assuming in line with Buhaug et al. that the design speed is at 90% MCR.

A single speed for all ships would be relatively easy to monitor and enforce. It would also be simple to communicate. However, a single speed for all ships, regardless of type, would either only affect fast ships (if it would be set at 16 knots, for example) or have a relatively small impact on slow ships but a huge impact on large ships (if it would be set at 10 knots, for example). One single speed would also change the competitive market between ship types. For example, shippers of cargo that can either be containerised or transported in bulk currently have the choice between a fast container ship and a much slower bulk carrier or tanker. Depending on the specific requirements of the transport, they can choose. The current fleet reflects the demand for both types of transport. Changing the relative performance of different ship types would render the current fleet composition less efficient.

If implemented over a short period of time, a low speed could result in a high demand for new ships, thus increasing new building prices, and a high demand

for engine and propulsion retrofits, leading to high prices for retrofit yards. If the markets would have sufficient time to adjust, price increases need not occur as there would not be such scarcity of yard capacity.

A differentiated speed restriction would not share many of these problems. However, a speed restriction that differentiates between ship types and ship sizes could be harder to monitor and enforce than one speed for all ships. Monitoring could perhaps be based on self reporting of ships entering ports where they report the speed they have been assigned with, the time when leaving the last port of call and the average speed. Another objection may be that some ships may be hard to categorise: e.g. so-called OBO (Oil/Bulk/Ore carrier) are a combination of oil tankers and dry bulk carriers; general cargo ships may or may not have capacity for containers; passenger ships may or may not have RoRo capacity, et cetera. However, the number of these ships is not so large and special solutions can be developed.

In sum, we think that a differentiated speed restriction is better than a single speed for all ships, mainly because it would not distort the competitive market. Moreover, a differentiated speed restriction would be in line with the outcomes of the discussion at MEPC 61 (see Chapter 1).

3.2.5 Conclusions

When a regulated slow steaming regime for ships would be introduced, speed through the water (and not speed over ground) should be restricted from an environmental point of view.

However, monitoring speed through the water requires that monitoring data is to be gathered on-board. Since speed through the water data is not gathered by default on-board, monitoring would require either the purchase of extra equipment (e.g. tachograph) or extra manpower to document data manually. Reliability of data has to be ensured under this approach.

Monitoring speed over ground and not speed through the water has the advantage that there are systems already in place that (at least technically) allow for gathering monitoring data by a third party. LRIT and (S-)AIS are the monitoring systems that should be thought of when it comes to a global slow steaming regime. Both systems (AIS and LRIT) are mandatory IMO systems, slightly differing with respect to the ship types having to make use of the system. Both systems have their advantages and disadvantages.

- AIS has the advantage that, in contrast to LRIT, speed over ground is reported directly.
- LRIT has the disadvantage that SOLAS contracting governments are only entitled to receive information from vessels operating under their flag, from vessels that indicate intentions to enter a port under their jurisdiction, and from vessels operating within 1,000 nautical miles of their coast. Transparency would be restricted. On the contrary, access to AIS data is not restricted. However, AIS transponders are allowed to be switched off when international agreements, rules or standards provide for the protection of navigational information. Monitoring data retrieved from AIS may thus be incomplete.
- Both systems have the disadvantage that monitoring data will be spread over different parties.
- The frequency at which the data is transmitted is important, in particular, when the average speed over ground per year is used as monitoring unit. In this concern AIS has the advantage that data is more frequently transmitted than LRIT data.
- As to their technical coverage, the systems are comparable, since both are satellite-based. However, LRIT has the advantage that global coverage is

reached yet, whereas global coverage of (S-)AIS can only be expected in the medium-run; more AIS enabled satellites have to be launched first.

Overall it can be conclude that (S-)AIS seems in principal to be the system better suited for monitoring speed over ground, however global coverage of the system is not reached yet.

A ship speed restriction that is dependent on ship size and type is preferable to a single speed for all ships, mainly because the latter would distort the competitive market between ship types. Ship-specific speeds could be monitored based on self-reporting of verifiable data.

3.3 Technical constraints

3.3.1 Technical constraints for new ships

Ships can in principle be designed to sail at lower speeds. In our interviews, some stakeholders have raised the issue of safety of slow ships. A related argument has been raised in the debate on EEDI requirements for ships, where some have expressed the fear that an ambitious reduction in the EEDI limit value would lead to the design of underpowered ships. The International Association of Classification Societies (IACS) has addressed this issue in a submission to the MEPC (MEPC 62/INF.21).

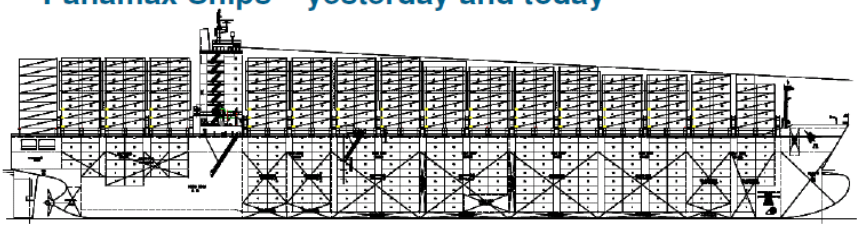
The IACS submission shows that the crucial issue in safety is not design speed but rather power. The submission provides an example of a VLCC that has a design speed of 15.5 knots and an engine that is able to deliver 17.7 MW at design speed. Under the adverse conditions defined in the report, the minimum power requirement is 9.7 MW. Hence, assuming a third power relation between speed and engine power, the design speed could be reduced to 12.7 knots without making the ship inherently unsafe. It is likely that in practice, the ship can be designed for lower speeds (and lower engine power) when hull, propeller and rudder are optimised to lower speeds.

Moreover, a ship can be designed to have an optimal full form, rudder and propeller to sail at a certain speed, while it may have redundant power in order to manoeuvre safely in adverse conditions. Of course, it should be noted that overpowered ships have higher costs.

When ships are designed to sail at lower speeds, their design may change. GL has presented a comparison of the designs of an typical existing post panama container ship with a design speed of 26 knots and a ship with a design speed of 22.5 knots. The latter has a higher block coefficient, meaning it is shorter and broader. As a result, its water resistance increases and its engine power does not decrease by 35%, as would be expected using a third power relationship between speed and engine power, but by 21.5%, less than square (see Figure 7).

Figure 7 **Slower ships may have a higher block coefficient which may counteract some of the engine power savings of slow steaming**

Comparison of main dimensions of 6500 TEU Post-Panamax Ships – yesterday and today



Item	6500 high speed	6500 „low" speed	delta
Lpp (m)	292,0	260,0	-32,0 / -11,0%
B (m)	40,0	42,8	+2,8 / +6,5%
v (kn)	26,0	22,5	-3,5 / -13,5%
main engine (kW)	42.800	33.650	-9.150 / -21,5%
14t TEU case	4790	4980	+190 / +4,0%

Source: Köpke, 2011.

In sum, we have not identified constraints to the design speed of new ships. There are constraints to the power of ships, related to the ships ability to manoeuver safely in adverse conditions, but ships can be equipped with redundant power, albeit at a cost. The decision becomes an economic consideration rather than a technical constraint. Ships designed for slower speeds may have a higher block coefficient. As a result, the third power relation between speed and engine power cannot be taken for granted for new ships.

3.3.2 Technical constraints for existing ships

In the past, it has been claimed that slow steaming on existing ships would lead to a higher risk of engine damage, such as (CE Delft and GL, 2009):

- Increased pollution of the exhaust gas economiser through increased appearance of soot. Exhaust gas economiser fires due to build up of soot.
- Piston rings sticking in top landings due to over-lubrication.
- Fuel pump and injector nozzle damage due to operating in off-design conditions.
- Increase of turbo charger fouling.
- Increase of cleaning and maintenance demand for complete engine.

However, Maersk has several years of experience with super slow steaming – operating containerships at 14 knots or 10% engine loads. Maersk concludes that it is technically and operationally feasible and that there are no negative impacts on ship safety, if implemented properly (De Kat, 2011). A number of specific problems require ad-hoc solutions, such as:

- Turbochargers may not be used in a specific load range where exhaust gas temperatures are above a limit.
- Cold corrosion can be avoided by managing cooling water and exhaust gas temperatures.

In other cases, Maersk Line has not experienced problems that had been anticipated, such as vibration damage or exhaust receiver soot build up (De Kat, 2011).

In recent years, several engine manufacturers have issued guidelines on low load operation of engines.

3.4 The impact of EEDI on design speed

In 2011, MEPC 62 adopted the Energy Efficiency Design Index (EEDI) for new ships. The EEDI is a measure of a ship's CO_2 emissions per tonne mile under standardised circumstances. As of 2013, new building bulkers, tankers, container ships, general cargo ships and reefers will have to meet or exceed an efficiency target.

There are many technology options available to meet the efficiency target. Since the EEDI is not technology prescriptive, ship builders are free to choose which technologies they will use to meet the EEDI. Reducing the engine power and thus a ship's design speed is one of them.

An analysis by DNV and LR (2011) shows that the EEDI could lead to small reductions in the design speed. For a number of ships, they have calculated reductions in design speed (Table 11).

Table 11 Impact of EEDI on design speed of selected ships (2025)

Ship type	Design speed 2010 (knot)	Design speed 2025 (knot)	Difference
VLCC	15.74	15.51	1.5%
Panamax tanker	15.09	14.65	2.9%
New Panamax Containership	24.46	23.98	2.0%
Panamax Containership	24.1	23.39	2.9%
Capesize bulker	14.6	14.33	1.8%
Handy size bulker	14.1	13.49	4.3%

Source: DNV and LR, 2011.

Table 11 shows that the speed reductions brought about by the EEDI requirements are likely to be small. Most of the ship's efficiency improvement will be achieved through hull optimisation and other technologies, according to DNV and LR (2011).

Other studies, such as IMarEST (2010) have indicated that a reduction of the design speed of a few knots would suffice to meet EEDI reductions of 25 to 40%.

In sum, while the EEDI will probably in many cases reduce the design speed of new ships, the extent to which it will do so is not clear. Speed reductions are likely to be modest for most ships.

3.5 Responsible entity

The choice of the responsible entity determines to a large extent the enforceability of the scheme and thus its environmental effectiveness. In order for a system to be effective, it is essential that a responsible entity is clearly identifiable. Moreover, the entity has to be a legal entity, otherwise a system cannot be enforced. Ideally, the responsible entity has full control over the speed of a ship. Other aspects may also be important in determining who is best suited as a responsible entity.

In practice, there are often several parties involved in the daily operation of a ship, including its speed, e.g.:
- the registered owner;

- the commercial operator;
- the technical operator, i.e. the DOC holder;
- the charterer;
- the master.

In addition, the ship itself can be designated to comply with certain features, as is the case e.g. in engine standards.

This section analyses the control of each entity over the speed of the vessel, the link of the entity to the vessel and the link that each entity has to possible enforcing authorities such as port States and flag States.

3.5.1 Registered owner

The registered owner need not have much control over a ship's speed. One of the commonly used ownership constructions in the shipping industry entails that the owner is an investment vehicle without control over operational measures that affect emissions. If the owner is not involved in operations, it would create an additional administrative burden if he would be responsible for compliance with a speed restriction. However, it is possible to set a speed restriction as a condition in a charter party agreement and thus transfer the obligation contractually to the operator.

The ship owner is either a company or a natural person and as such a legal entity. The ship owner is identifiable and linked to a ship by SOLAS regulation XI-1/3-1. Making the ship owner the responsible entity is in line with other regulations since operational procedures, management systems, and liability rules often hold the ship owner responsible.

The ship owner can have his domicile in any country. So-called open registries do not require the owner to be based in the flag State. Hence, a flag State may have limited means of ensuring compliance. Similarly, port States may have difficulties of enforcement against owners.

3.5.2 Commercial operator

The commercial operator is responsible for the commercial operation of a ship, e.g. which cargo it transports from where to where. If he is not the owner, he will have chartered the ship.

In general, a commercial operator has control over speeds and routes which to a large extent determine emissions.

While the commercial operator is a legal entity, he or she need not register with the flag State or otherwise. The ship operator is not named directly as an entity responsible for complying with conventions such as SOLAS, MARPOL or CLC. This means that additional efforts have to be made to identify the ship operator, for example through charter contracts.

The commercial operator is not required to have his or her domicile in either the flag State or a port State of the ship he or she operates.

3.5.3 Technical operator/DOC holder

The technical operator of a ship is the company holding the so-called Document of Compliance as per SOLAS IX/I. This implies that he is responsible for maintenance of the ship and equipment, safety management, instruction of the crew relating to safety and pollution, et cetera.

The technical operator does not have direct control over a ship's speed, unless where the speed interferes with the safety of a ship. He may assume a responsibility over speed if instructed to do so by the owner.

A technical operator has a clear link to a vessel. Each vessel has one technical operator, whose identity is registered in the so-called document of compliance (DOC), issued by the State in which the technical operator has domicile.
A copy of the DOC is held on board of each ship.

Since the technical operator has a document of compliance issued by the State in which it operates, and because these States are usually flag States, the DOC holder has a link to the flag State but not necessarily to the port State.

3.5.4 Ship charterer

The ship charterer charters a ship from the owner. Depending on the type of charter contract, the charterer may or may not have control over speed. If the charterer charters a ship for a specific voyage, he will indicate when and where the ship has to load cargo and when and where it has to deliver. Implicitly it sets the average speed on the voyage. However, if a ship is chartered for a certain period of time, the charterer need not have a control over its speed. In fact, the time charterer may sublet the ship under a voyage charter agreement, in which case the voyage charterer has control over speed. Hence, the only way in which a time charterer can influence speed is to agree on a given speed as a condition of the charter agreement. This resembles the way in which a ship owner has control over speed.

A ship charterer is not required to register. Charter parties are contracts under private law and need not be made public. Hence, it is not always possible to identify the charterer of a specific ship. In addition, as indicated above, one ship may be operated under multiple charter contracts.

The charterer is not required to have his or her domicile in either the flag State or a port State of the ship he or she operates.

3.5.5 Master

The ship master is responsible for the safe navigation of the ship, safe handling of cargo, management of personnel, maintaining the ship's certificates and documentation, et cetera. He sets the speed of the ship taking into account the instructions from the operator and the safety conditions.

While each ship can only have one master at a given point in time, over a time period she may have different masters. Similarly, a master may be the captain of several ships consecutively during a certain time period.

A ship master is licensed by the flag State of the ship.

3.5.6 The ship

In many cases, ships are regulated directly without designating a responsible entity. This is the case, for example, when technical standards are set for the emissions of engines (under MARPOL Annex VI).

A ship has a certain design speed and a maximum speed which depends to a large extent on the ship characteristics (but also on sea conditions, wind, load, et cetera). Hence, if a limit would be imposed on ship design speed, the ship would be an appropriate responsible entity. However, a ship has no control over its actual speed, which is set by the master, acting upon instructions from the commercial operator.

A ship is registered in a flag State. Moreover, when in port, it is under the jurisdiction of the port State.

3.5.7 Conclusion

The choice for the responsible entity requires a compromise between control over speed (which the commercial operator and the charterer exercise) and enforceability in terms of a directly identifiable link with the ship (ship, owner and DOC holder) and a link with the possible enforcing authority (ship, master, DOC holder).

If the enforcement mechanism is either port State control or refusal of entry into a port by the port State, the owner can be liable for transgressing a speed restriction and action can be taken against the ship. However, since the owner often cannot control the speed, care has to be taken that the regulation allows the owner to pass on the liability to the commercial operator or the charterer, who has a greater control over the speed of a ship.

3.6 Possible exemptions and flexible arrangements

In some situations, it could be desirable to offer flexible arrangements or exemptions to a speed limit. This section explores the possibilities for doing so. It first assesses whether it would be possible to exempt ships with a superior environmental performance, so that the emissions of these ships would equal those of conventional ships sailing at lower speeds. Second, it analyses whether exemptions could be created for ships that carry valuable or time-critical cargo.

3.6.1 Exemptions on the basis of technical performance of ships

Air pollution and black carbon

Exemptions could be granted on the basis of the environmental performance of ships. For example, if the purpose of the speed restriction is to lower air pollutant emissions or black carbon, a ship which has 19% lower emissions per kWh could sail approximately 10% faster while emitting the same amount of air pollutants or black carbon per mile as other ships. We explore for which pollutants such an exemption would be possible.

The emissions of NO_x per kWh of a ship's engines are documented in their Engine International Air Pollution Prevention (EIAPP) Certificates. Based on the known engine population, the average performance of engines can be calculated and for each engine, the distance to the average baseline can be determined. Alternatively, the distance of each engine to a certain target can be calculated, as is done in the Environmental Ship Index (ESI).[48] Ships that are cleaner than a certain standard could be given relaxed speed restrictions or, alternatively, be exempt from them altogether.

The emissions of SO_x are determined either by the sulphur content of the fuel or by the efficacy of a scrubber. The sulphur content of the fuel is indicated on the bunker delivery note. Ships that can demonstrate that they consistently use low sulphur fuel could be given relaxed speed restrictions or, alternatively, be exempt from them altogether.

Black carbon (BC) is currently not regulated, hence engine- or fuel-specific emission factors are not available, in contrast to NO_x and SO_x. BC emissions can be reduced by 10-90% using technologies such as slide valves, water-in-fuel

[48] http://esi.wpci.nl/Public/Home.

emulsions, particulate filters or sea water scrubbing (Corbett et al., 2010).[49] Provided that these results are verified, ships can demonstrate their environmental impact and could be given relaxed speed restrictions or, alternatively, be exempt from them altogether.

Fuel and carbon dioxide

As from 2013, each new ship will have an EEDI value (unless it will be built in a country that uses the five year waiver to this requirement). Some ships already have an EEDI (GL, 2010; DNV 2011)[50]. As discussed in Section 3.4, the EEDI reflects a ship's technical efficiency. Ships with an EEDI that is significantly below the baseline could be given relaxed speed restrictions or, alternatively, be exempt from them altogether. (Whether ships with a low EEDI would be capable of sailing at higher speeds depends on the technologies which are used to reach the EEDI. If a ship is equipped with a relatively small engine in order to attain a certain EEDI and is then exempted from a speed restriction, the impact on emissions should be studied because the specific fuel oil consumption when sailing at higher speeds may increase).

3.6.2 Exemptions on the basis of economic considerations

For some ships, slow steaming may be profitable while for others it may be costly, depending on the ship type, cargo and route.

While in principle a command-and-control instrument like regulated slow steaming is ill-suited to take economic considerations into account, certain modifications can be made that allow some flexibility for economic considerations. Perhaps some ships can be granted waivers, or regulators can sell or auction waivers for shipping companies, ships or voyages. It is beyond the scope of this report to study this type of exemption in detail.

3.6.3 Regional or route-based exemptions

Some countries and territories, such as remote islands, are highly dependent on sea transport. They may be served with ships whose capacity is tailored to the need of the country or territory. If these ships have to reduce their speed, the trade links of these regions with other economies would be diminished. Moreover, trade could become more expensive. Insofar as this is considered undesirable, route-based exemptions could be introduced.

Route-based exemptions can introduce market distortions and avoidance. For example, it could be possible that ships can reach their destination faster by making a detour via exempted routes. The possibilities for doing so would be constrained if only routes to and from very remote territories would be exempted and if the ports in these territories are so small that large ships cannot enter.

Route-based exemptions can either be introduced tacitly, e.g. through non-enforcement of speed restrictions on these routes, or officially by agreeing on the exemption of certain routes.

Exemptions may be introduced to reduce the risk of piracy. According to the *Best Management Practices for Protection against Somalia Based Piracy*, 'One of the most effective ways to defeat a pirate attack is by using speed to try to

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[49] JJ Corbett, JJ Winebrake, EH Green, An assessment of technologies for reducing regionalshort-lived climate forcers emitted by ships withimplications for Arctic shipping,***Carbon Management*** (2010) 1(2), 207–225.

[50] http://www.gl-group.com/en/press/news_18943.php; http://www.dnv.ae/press_area/press_releases/2011/dnvissuedeediverificationforasuper-largetankerownedbykotcinkuwait.asp.

outrun the attackers' (ICS et al., 2011). To date, ships sailing faster than 18 knots have not suffered pirate attacks. Hence, in order to reduce the piracy risk, speed restrictions could be relaxed in areas prone to piracy. If the speed restriction is on average speed, speeding up in a relatively small area could be compensated by slowing down for the rest of the voyage. If the area is relatively large, the speed restriction for ships sailing through that area could be relaxed.

3.6.4 Conclusions

Ships which have an outstanding environmental performance could be exempted from a regulated slow steaming regime. For most emissions except for black carbon sufficient data and measuring methodologies are available to base the exemptions on. Exemptions on the basis of economic consideration could be organised as pay-to-speed-up schedules. It could be argued, however, that if speed flexibility is required, market based instruments are better suited than speed limits. Regional exemptions for remote territories or to limit the risk of piracy could be included in a regulated slow steaming regime.

4 Detailed policy design

4.1 Design of regulated slow steaming policies

The design of regulated slow steaming policies comprises choices on eight issues, viz:

1. Legal basis and legal instrument.
2. Speed definition.
3. Responsible entity.
4. Ship type and size scope.
5. Monitoring and reporting requirements.
6. Enforcement.
7. Possible exemptions and/or flexible arrangements.
8. Time to introduction.

Considerations on the legal basis, the definition of speed, enforcement and possible exemptions have been presented in Chapter 3. This chapter applies these considerations to the regulated slow steaming regime that is analysed.

The chapter analyses three main regimes, two of which have variants. The regimes are:

1. Global
   a Global treaty for all ships. This would require a new convention, probably under IMO. This means that it would be enforced through flag and port States. The main benefit: reduction of CO_2 emissions.
   b Global treaty for existing ships where the speed of existing ships will be restricted to the average speed of new ships that have a lower speed because of the EEDI regulation. Main benefit: CO_2 and less distortion of competition.
2. Arctic. Again, this would have to be enforced as a condition of entry in a port. Main environmental benefits: reduction of air pollution and especially black carbon deposition in the Arctic.
3. EU. This would be imposed on ships sailing to EU ports
   a Regulated slow steaming for all ships in EU territorial waters as a condition of entry in EU ports. Could be speed for all ships or variable speeds for different ship types. Main benefit: reduction of air pollution. Since the emissions in EU territorial waters are a small share of total emissions, the climate benefits of this option would be limited.
   b Regulated slow steaming for all ships sailing between EU ports as a condition of entry in EU ports. Main benefit: air pollution. Since a little over half of the emissions on voyages to EU ports are from intra-EU voyages (i.e. from one port in the EU directly to a second port in the EU), there will be significant benefit in CO_2 emissions as well.
   c Regulated slow steaming for all ships sailing to EU ports as a condition of entry in EU ports. Main benefits: climate change and air pollution.

4.2 Treaty on global regulated slow steaming

4.2.1 Legal basis and legal instrument

The development of a global regime for compulsory slow steaming provides the most difficult to achieve but least difficult to implement legal option.
A general agreement on maximum average speeds for each type of vessel approved by the IMO's navigation committee and the MEPC would give global consent to such measures. This will reduce claims that speed restrictions violate the freedom of navigation in the high seas. Building consensus within the IMO would be a necessary prerequisite.

The legal justification for such a global regime requires reference to:

a The duty of all States to protect the marine environment under UNCLOS.
b The duty of States to ensure reduction of GHG emissions under the UN Framework Convention on Climate Change.
c The rights of coastal States to protect their population from the effects of atmospheric pollution.
d The obligation of all States to ensure that activities within their jurisdiction will not cause damage to other States or to areas beyond the national jurisdiction of all States.

The legal justification of such measures will also need financial justification and demonstrate the comparative advantages in efficiency of the measure proposed by comparison and in conjunction with other measures that can be applied. Adopting such measures as part of a global effort to reduce GHG emissions is legally more arguable because regulated slow steaming is, as demonstrated in this study, easy to design and implement, is presently voluntarily used by parts of the shipping industry and the coastal States and can be effected without a need for significant modification of the ship thus making them cost effective.

The implementation arrangements, practical and legal must also be outlined from the start and their feasibility would need to be demonstrated.

The major advantage of an IMO based agreement is that regulated slow steaming will become part of the internationally acceptable standard which will be supported by flag States as well as coastal States. Thus the enforcement in the areas where freedom of navigation applies will be based on the fact that the flag State has authorised the coastal State to ensure compliance, in other words through port State control.

4.2.2 Speed definition

In line with the considerations presented in Section 3.2, the regulated speed should be:

- average speed over ground so that it can be monitored and verified;
- dependent on the ship type and possibly size in order to limit distortions of competition.

4.2.3 Responsible entity

In a global system, enforcement would be both through flag State and port State control. As discussed in Section 3.5, the responsible entity can in that case be the ship owner. In case the owner is not the operator of a ship, he can contractually pass on the obligation to respect the slow steaming regime to the operator.

4.2.4 Ship type and size scope

With a ship type specific speed limit, there is no need to exempt ship types from regulated slow steaming as the speed limit can be adapted to the characteristics of a certain ship type.

In maritime regulations, two universal thresholds are used. IMO conventions such as MARPOL and the International Convention on the Control of Harmful Anti-fouling Systems on Ships have thresholds of 400 GT; SOLAS uses a threshold of 500 GT.

As discussed in Section 3.2.3, speed can be monitored with (S-)AIS. All ships over 500 GT and all passenger ships have to be equipped with AIS transponders. Hence, a threshold of 500 GT seems appropriate. According to CE et al. (2010), 1.92% of global ship CO_2 emissions in 2006 were from ships smaller than 500 GT.

4.2.5 Monitoring and reporting requirements

Ships can monitor their own speed over ground continuously using common instruments. Moreover, their logbook entries on time of departure from a port and time of arrival can be used to calculate average speeds. Regulators can monitor speed using (S-)AIS.

In a global system, all ships would need to comply with the slow steaming regime wherever they sail (except when making use of exemptions and flexible arrangements as described in Section 4.2.7). This means that the reporting requirements can be kept to a minimum, e.g. annual reporting to the flag State. The report would have to contain evidence that on each voyage, the ship has sailed at or below the mandated speed on average. The report can be verified using recorded (S-)AIS data and logbook entries.

Ships that are registered with States which are not party to the convention would need to keep a verified report on board.

4.2.6 Enforcement

Enforcement of a global regulated slow steaming regime would be organised using flag State obligations and port State rights. Flag States that would be a party to a convention would take on the obligation to enforce the regime on ships flying their flag. In addition, port States which are party to a convention would have the right to inspect any ship in their port for compliance. Compliance can either be demonstrated by a certificate from the flag State or a compliance report on board of the ship in case she is registered in a non-party State.

The legal basis for the enforcement through port State control could be similar to the one introduced in MARPOL: MARPOL imposes on contracting states the following obligation: “With respect to the ships of non-Parties to the Convention, Parties shall apply the requirements of the present Convention as may be necessary to ensure that no more favourable treatment is given to such ships.”[51] Thus contracting States to MARPOL use their prescriptive and enforcement power to require compliance with the MARPOL requirements as conditions for entry to its ports against ships registered in non-contracting as well as contracting States. This significantly expands the application of such measures.

4.2.7 Possible exemptions and/or flexible arrangements

Exemptions could be introduced as discussed in Section 3.6.

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[51] MARPOL Art. 5(4).

4.2.8 Time to introduction

The time to introduction depends on whether a new convention is needed or whether a regulated slow steaming regime can be introduced as a revision to an existing convention.

If a new treaty is required, its contents have to be negotiated, it has to be adopted and ratified (accepted, approved) by a sufficient number of countries (as specified in the adopted treaty) representing a sufficient share of the world fleet. None of these steps have a clear term, but experience with recent treaties suggests it may take 18 to 24 years between the time an issue is raised for the first time in IMO and entry into force of a convention. It should be noted that this time estimate is based on treaties recently adopted or entered into force. This assumes that a sufficient number of countries support the adoption of a treaty. Many proposals never reach that stage. On the other hand, amendments to existing treaties can enter into force much faster under the tacit amendment procedure, assuming that there is no strong opposition (IMO, 2011).[52]

Two of the most recently adopted conventions, on Ballast Water Management and on Anti Fouling, were adopted respectively 12 and 16 years after the issue was raised first at IMO's MEPC (IMO, 2011).[53]

Most IMO treaties and conventions take six to eight years between adoption and entry into force (IMO, 2011).[54]

With a lead time of 18 to 24 years, it may be assumed that the shipping sector has sufficient time to adjust and to increase the size of the fleet if necessary.

A revision of an existing treaty requires less time. We provide two examples.

- The revision of the MARPOL Annex VI sulphur standards and NO_x technical code started in 2005 with a 'Proposal to initiate a revision process' submitted by a number of countries (MEPC 53/4/4). In 2008, the amendments were adopted and they came into force in the period from 2010-2020 according to a timetable agreed in the revised Annex VI (MEPC 57/21, RESOLUTION MEPC.176(58)). Hence, there were 5-15 years between the first proposal and implementation.
- The introduction of a mandatory EEDI started with a proposal by Denmark and others at MEPC 57 (2005) to develop a 'mandatory CO_2 design index for new ships' (MEPC 57/4/4). A working group was tasked with developing the index. In 2011, following a vote, MEPC agreed on introduction of a mandatory index to be applied to new ships from 2013 onwards. In this case, the time from first proposal to implementation was 8 years.

Hence, the lead time for the amendment of an existing convention is between 5 and 15 years. A shorter lead time could give rise to a shortage of ships, since yards are constrained in the number of ships they can build. Currently, the maritime transport sector reacts to a shortage of ships by speeding up and extending the lifetime of ships; the first option would not be possible if a regulated slow steaming regime was in force.

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52 http://www.imo.org/About/Conventions/Pages/Home.aspx, accessed 30 November 2011.

53 http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx; http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-on-the-Control-of-Harmful-Anti-fouling-Systems-on-Ships-(AFS).aspx, accessed 30 November 2011.

54 http://www.imo.org/About/Conventions/ListOfConventions/Pages/Default.aspx, accessed 30 November 2011.

4.3 Treaty on regulated slow steaming to avoid distortion of competition by EEDI

In the discussions on the introduction of the EEDI, much attention has been paid to the impact of a mandatory EEDI on engine power and design speed. Some have argued that the EEDI would lead to underpowered ships and/or a significant decrease of the design speed.

Since the EEDI applies to new ships only, it could result in a competitive disadvantage for new, slower ships where they compete with older, faster ships. One way to avoid this distortion of competition would be to restrict the speed of existing ships.

The current analysis of the impact of the EEDI on ship speeds shows that the impact will be very limited (see Section 3.4). Hence, there seems to be little justification at present to subject existing ships to a regulated slow steaming regime upon introduction of the EEDI.

However, the present analyses of the impact of the EEDI on speed are all ex-ante evaluations. It may turn out that in practice ship owners and yards make different trade-offs. It could be contemplated to monitor design speed of new ships built in accordance with EEDI regulations. If it turns out that new ships are designed to be significantly slower than ships in the current fleet, a regulated slow steaming regime for existing ships could be a way to limit a distortion of competition between old and new ships. Such a regime would then apply to existing ships engaged in international transport. The design of the instrument would resemble the design of a global regime for all ships, as presented in Section 4.2. The speed limit could be set at the average speed of new built ships.

4.4 Regulated slow steaming in the Arctic

Black carbon is a short lived climate forcer that absorbs sunlight and thus contributes to global warming. If deposited on snow and ice, BC reduces the reflectivity and adds to regional warming in the Arctic. Ship black carbon emissions in the Arctic may increase in the future when the Northern Sea Route and/or the Northwest Passage become navigable for a longer period in summer, resulting in shipping in the Arctic on routes between two places outside the Arctic.

Regulated slow steaming in the Arctic would result in lower BC emissions and thus reduce the warming, relative to a baseline without slow steaming or BC policies. The primary aim of regulated slow steaming would be to reduce seaborne black carbon emissions and/or deposition of seaborne black carbon in the Arctic.

Note that currently, ships are sailing slower in the Arctic then they do elsewhere for safety reasons. Apart from the environmental impacts, a speed restriction would affect safety, the risk of mammal strikes, and emissions of greenhouse gases and other pollutants than BC.

4.4.1 Legal basis and legal instrument

Imposing regulated slow steaming in the Arctic can be done unilaterally by one or more States, as conditions for entry into their ports; by including a slow steaming regime in the Arctic as part of the, under development, Polar Code; or finally by imposing speed restrictions as an Associated Protective Measure within the designation of an Arctic PSSA.

Three aspects need to be considered for the successful submission of compulsory slow steaming in the Arctic under the Arctic PSSA option:

1. The justification of an Arctic PSSA.
2. The vulnerability of the Arctic environment to Black carbon.
3. The justification of the measure of slow steaming as an Associated Protective Measure.

This section will outline the way these can be achieved and identify potential difficulties in achieving them.

Justifying an Artic PSSA

The Arctic environment is unique, relatively unexplored and relatively unaffected by human activities.[55] The Arctic environment and its biodiversity are becoming increasingly more fragile due to the increases of atmospheric temperature. The reduction of polar ice is expected to make profitable shipping routes through the Arctic.

The Arctic has a human population of about four million, including over thirty different indigenous peoples who have special life styles and culture linked with the Arctic environment.

The opening of the Arctic ocean to shipping and sea bed exploration has been hailed as an opportunity for exploitation and development by the shipping and offshore industry. However, this will have important impacts on the Arctic environment and the indigenous population.

The impact of shipping activities for the Arctic environment has generally been recognised repeatedly and is a documented concern. For example the IMO guidelines[56] recognise the increased risks ships face when navigating in the Arctic environment and provide for special measures to increase the safety of navigation in the area. These guidelines do not deal with all the effects shipping has on the Arctic environment but only with the prevention of shipping incidents that can lead to pollution and the ship's preparation to deal with such incidents.

Notably the opportunity to exploit the Arctic shipping lanes has been created by the introduction of energy trapped by increased GHG in the atmosphere in the upper waters of the Arctic ocean which squarely falls within the LOSC definition of pollution of the marine environment.[57] Thus the opportunity to exploit the Arctic routes and resources has, under this view, occurred because all States, and primarily developed States including those surrounding the Arctic ocean contributed to the temperature increases in the Arctic. There is an express duty imposed on all States to protect the marine environment.[58] It can be argued that the increasing temperatures in the oceans leading to changes in the Arctic conditions constitute a failure by States to observe this duty.

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55 It is beyond the scope of this study to prepare a comprehensive report justifying the ecological, social and scientific importance of the Arctic. This can be done rather easily on the basis of numerous scientific and socio-economic assessments and research papers of the area when the documents for submission will be developed.

56 GUIDELINES FOR SHIPS OPERATING IN ARCTIC ICE-COVERED WATERS, MSC/Circ.1056, MEPC/Circ.399, 23 December 2002.

57 Art. 1(4): "Pollution of the marine environment" means the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities.

58 Under 1982 LOSC Art.192.

Whether the link between the benefits that can be obtained and the failure to observe the duty imposed under Art. 192, in turn, requires restriction in the express rights States have under the LOSC in relation to the exploitation of their resources[59] and the use of the shipping routes[60] is not resolved by the wording of LOSC. However it would be surprising if the resolution of this issue results in the conclusion that the LOSC permits gains to accumulate and rights to be exercised irrespective of the breach of its provisions. Surely such a result would be against any notion of sustainable development and any notion of fairness. Thus it is submitted that there is a duty on States to exercise their rights in ways which will mitigate the damages caused in the Arctic environment.

In respect of shipping routes one way of reducing the effects of increased shipping activities in the Arctic would be the establishment of an Arctic-wide PSSA and the adoption of appropriate Associated Protective Measures targeted into minimising or reversing the specific impacts of shipping activities.

In this report we are particularly concerned with the impacts that black carbon emissions from ships have. We propose the adoption of regulated slow steaming as an appropriate APM. This position is justified below.

The contribution of shipping activities to black carbon impacts in the Arctic[61]

A recent report published by the Arctic Council provides[62] the scientific consensus regarding the effects of BC in the Arctic. In outline the following points are important for this discussion:

- BC emitted both within and outside of the Arctic region contributes to Arctic warming.
- Per unit of emissions, BC emission sources within Arctic Council nations generally have a greater impact on climate change.[63]
- Sources of BC emit a complex mixture of substances, some of which may cool the climate, such as organic carbon or sulphates. However, in the Arctic, the potential for such offsetting effects from non-BC aerosols is weaker. When BC physically deposits on snow and ice (i.e. highly reflective surfaces), its warming impact is magnified; therefore, the same substances that might cool the climate in other regions may cause warming in the Arctic.
- Measures aimed at decreasing these emissions will have positive health effects for communities exposed to PM emissions containing BC.
- Although CO_2 emissions are the dominant factor contributing to observed and projected rates of Arctic climate change, addressing SLCFs such as BC, methane and ozone offers unique opportunities to slow Arctic warming in the near term.

Because the report is clear that proximity of BC emissions results to increased effects we consider it evident that emissions from ships within the Arctic will

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59 Art. 193.

60 Art. 87 providing for freedom of navigation.

61 There is already a lot of published material demonstrating the potential effects of shipping activities in the Arctic both in relation to operational discharges and on the basis of pollution arising from shipping incidents. Here we will only develop the arguments relating to Black Carbon.

62 An Assessment of Emissions and Mitigation Options for Black Carbon for the Arctic Council is a report of the Arctic Council Task Force on Short-Lived Climate Forcers. © Arctic Council 2011.

This report and its supplemental material contained in appendices are available at: http://arctic-council.org.

63 I.e. Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, the Russian Federation, Sweden, and the United States of America.

contribute more than the shipping emissions outside the Arctic. For this reason we argue for special measure regarding BC emissions within the Arctic Ocean. The Arctic Council report concludes in relation to shipping activities[64]:

> ***Marine Shipping***. *The Arctic Council countries comprise 90% of current shipping activities in the region; therefore, they have a unique ability to influence the development of future BC emissions from this sector by enacting early voluntary measures and engaging in international regulatory regimes, such as the International Maritime Organization (IMO), including*
> - *Voluntary measures by all eight Arctic Council countries to decrease BC emissions, and encouragement of vessels (especially cruise ships) flagged in non-Arctic Council countries and operating in the Arctic to adopt these measures;*
> - *Support by all eight Arctic countries of the current IMO submission on BC by Norway, Sweden, and the United States, which raised the importance of BC emissions from shipping on the Arctic climate and identified a range of technical and operational measures (e.g., speed reduction, improved engine tuning, energy efficiency enhancements, better fuel injection, use of diesel particulate filters);*
> - *Adoption by all eight Arctic Council countries of the proposed amendment of MARPOL Annex VI to establish an Energy Efficiency Design Index for new ships; and*
> - *Ongoing provision of new scientific and technical developments to the IMO by AMAP and other Arctic Council working groups, and vice versa.*

Thus the report recommends the consideration of speed reduction amongst other measures as an effective measure for reducing the BC emissions in the Arctic.
The report also notes in relation to road transport that Oslo County has introduced, amongst other measures, speed limits for the purpose of reducing BC and PM emissions. If such measures are being adopted for the cleaner and more developed car engines surely they, at least, must be considered for ship engines too.
The Arctic Council synthesis report demonstrates that:

1. The vulnerability of the Arrtic region to BC is well established.
2. The importance of BC to accelerated climate change in the Arctic is also well established.
3. The contribution of marine shipping is presently an important contributor.
4. This contribution will increase with the increased usage of Arctic shipping routes.
5. The shipping contribution is one that should be dealt with by appropriate IMO measures.
6. One of the measures that needs to be considered is speed reduction.

The legal basis for the establishment of a PSSA

Regulated slow steaming can be imposed by the Arctic States as a condition for entry to ports in the Arctic as suggested by the Arctic Council report. This may be legally possible.[65] This would be a quick and efficient way of immediately reducing BC emissions in the region. However such an arrangement would not

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[64] Of course the Arctic Council's Report concerns present shipping activity. With rerouting of shipping through the Arctic the contribution of ships of non-Arctic States will increase.

[65] See Section 2 for the general powers coastal States have to impose conditions for entry and objections in relation to extraterritoriality that may be raised.

cover ships transiting the Arctic. Thus, either EU States would have to also impose such measures as conditions for entry in their ports or as we argue the imposition of regulated slow steaming must also be included as an APM within a designated Arctic PSSA.

The Arctic Ocean is an area of the oceanic environment that possesses recognised ecological, socio-economic, or scientific attributes vulnerable to damage by international shipping activities. It could be protected through action by the International Maritime Organization (IMO) by becoming designated as a Particularly Sensitive Sea Area (PSSA). [66]

The 1982 LOSC places an obligation on parties to

a Protect and preserve the marine environment.[67]
b Take all necessary measures needed to prevent reduce and control pollution from any source.[68]
c Take measures necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life.[69]

Within the EEZ coastal States are in general entitled to apply and enforce internationally agreed measures[70] However where the international measures are inadequate for the protection of the marine environment Art. 211(6)(a) of the 1982 LOSC provides the opportunity for coastal States to propose to the IMO[71] (described as the "competent international organisation") the adoption of special mandatory measures applicable within their EEZ. Such measures should be justifiable on scientific and technical grounds.

The IMO Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas[72] describe the necessary requirements as have in practice developed.

Thus a submission for an Arctic PSSA must provide:

- Evidence and arguments that the area's ecological, social, cultural, economic, scientific or educational characteristics are unique and exceptional.

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66 This is clearly documented by the aforementioned Arctic Council report and in particular by the extract reproduced from the report.

67 Art. 192.

68 Art 194. (1) which continues by demanding that this is to be done "… using for this purpose the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavour to harmonise their policies in this connection."

69 Art. 194(5). The measures taken in accordance with this Part shall include those necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life.

70 1982 LOSC Art. 211(5).

71 The IMO should decide with 12 months whether the supporting information justifies the proposed measures and the measures come into force 15 months after the submission of the proposal to the IMO.

72 IMO Assembly Resolution A.982(24).

We consider that the Arctic has the required unique and exceptional character in almost all respects and this can be easily justified.

- Evidence and arguments that the area's characteristics are at risk from international shipping activities.

This is clear with respect to BC effects. It is also evident that increased shipping activities will increase the risk of shipping accidents and pollution incidents.

- There are measures that can be adopted by the IMO to protect such characteristics by easing the pressure from shipping activities. These measures must be described and individually justified.

As already noted speed reduction is one such measure suggested by the Arctic Council report and its effects are further justified in this document.

The proposal for the designation of an Arctic PSSA must take place with associated protective measures targeted on the specific impacts shipping has in the region. This report supports the development of speed reduction policies for the purpose of reducing the impact of BC emissions in the Arctic.[73]

Procedure

The proposal for designating an Arctic PSSA[74] must be submitted by an IMO Member State to the MEPC.[75] Before the submission all bordering States need to be consulted by the State intending to submit the proposal. [76] In addition user States also need to be consulted.
Each of the associated protective measures will be assessed and approved by the corresponding sub-committee before the MEPC is in a position to declare the area as a PSSA. This necessarily means that the imposition of regulated slow steaming in the Arctic would be bundled together with the proposal for the designation of an Arctic PSSA and will be assessed by probably both the Marine Safety Committee and the Marine Environment Protection Committee.

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73 The development of an Arctic PSSA will give the opportunity to consider making the IMO guidelines for the Arctic a compulsory APM. Ballast water exchanges will also need to be assessed. Arguably an examination of the suitability of the limits of liability for oil and hazardous and noxious substances pollution under the various international conventions in the Arctic are also needed as salvage and clean up operations will be more difficult and expensive. These are beyond of the scope of this study.

74 See the Appendix for the detailed requirements.

75 Arguably if the legal basis is indeed UNCLOS such a State could only be a coastal State which has an EEZ within the proposed PSSA.

76 This is dictated by the requirement of collaboration under the 1982 LOSC.

Additional legal basis

Further powers to establish measures with respect to marine environmental protection are granted to Arctic coastal States under LOSC Art. 234.[77] This grants coastal States the right to adopt appropriate provisions for the "prevention, reduction and control of marine pollution from vessels" in such areas. Such measures should be non-discriminatory, based on the best available scientific measure and apply only within the EEZ of the coastal State. As a result it is arguable that Arctic coastal States can adopt protective measures without the need to refer the matter to the IMO's MEPC.[78]
A justification linking the measures with the problem posed is reasonable to be provided. Whether reduction and control of BC is "… marine pollution from vessel" as defined under UNCLOS Art. 1 is debatable. The way BCs operate to increase the atmospheric and consequently the oceanic temperature of the Arctic thus enhancing the impacts of GHG and threatening the existence of the Arctic ecosystem can, in our view, be considered to be "… the introduction by man, … indirectly, of … energy into the marine environment, …. which results or is likely to result in such deleterious effects as harm to living resources and marine life … ;" and thus within the definition of marine pollution under 1982 LOSC.

The Associated Protective Measure of compulsory slow steaming

Within a submission for an Arctic PSSA compulsory slow steaming needs to be justified as an associated protective measure and its implementation and enforcement must be detailed. Thus a submission of regulated slow steaming as an APM must:

1. Establish that such a measure is permitted under international law.
2. Declare and justify an appropriate speed to be adopted[79].
3. Demonstrate the effectiveness of the proposed measure in reducing the impacts of BC arising from shipping in the Arctic.
4. Describe how such a measure will be technically implemented.
5. Describe how such measures will be enforced.
6. Demonstrate that there are no other equally or more efficient and easy to implement APMs to adopt which can achieve the same result.

In relation to the first issue note the legal basis discussed at part 1 of this section and also the general discussion on availability of speed restrictions as a measure under the international law of the sea in the previous report.
The following issues (2-3) require technical information to justify the proposed associated protective measure on technical and scientific grounds. These are demonstrated in other parts of this report.

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[77] Article 234: Coastal States have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone, where particularly severe climatic conditions and the presence of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance. Such laws and regulations shall have due regard to navigation and the protection and preservation of the marine environment based on the best available scientific evidence.

[78] The interpretation of this article is controversial. The problem is the word "where" which can signify either that a potential application of Art. 234 is restricted to ice-covered areas in general or when severe climatic conditions prevail. Arguably the first interpretation is the correct one on the basis of literal interpretation. However, McRae, D. M. and Goundrey, D. J. (1982)(Environmental Jurisdiction in Arctic Waters: The Extent of Article 234; 16 U. Brit. Colum. L. Rev. 197) argue for the latter as the one supported by the history of the provision. The absence of conclusive interpretation in the scope of the provision permits cautious reliance.

[79] There should be exceptions for governmental and military ships as well as situations where there is a need of faster transect due to changing weather circumstances.

The technical implementation (4) also is a matter beyond the scope of the legal part of the report. However, it must be noted that mandatory ship reporting systems have been established within the context of other PSSAs[80] and the demand for Vessel Monitoring Systems by port States is also a practice widely exercised.[81]
The shore based facilities that will support the system must be detailed and contingency planning if the system is out of operation will also be needed.
The enforcement component is one that can be dealt with simply by a clear statement on the intended enforcement measures. For example it can be stated that:

> *All means will be used to encourage and promote the full participation of the ships recommended to submit speed reports. Where a ship that can be identified does not comply with the requirements either by not reporting or by not slow steaming the appropriate action will be taken, including reporting to the flag State in accordance with customary international law as reflected in the 1982 LOSC.*

Of course the enforcement provisions can also be of a more stringent or lenient character.

4.4.2 Geographical scope

The geographical scope of regulated slow steaming in the Arctic ensures that the aim of the measure is met, i.e. to reduce seaborne black carbon emissions and/or deposition of seaborne black carbon in the Arctic.

In case of the narrow aim, i.e. reduce seaborne black carbon emissions in the Arctic, the geographical scope would be confined to the Arctic, e.g. the 'Arctic Ice Covered Waters' as defined by IMO's Maritime Safety Committee in 2002 (MSC/Circ.1056 - MEPC/Circ.399).[82] Figure 8 shows a map of this area, in which ships have to comply with specific safety requirements.

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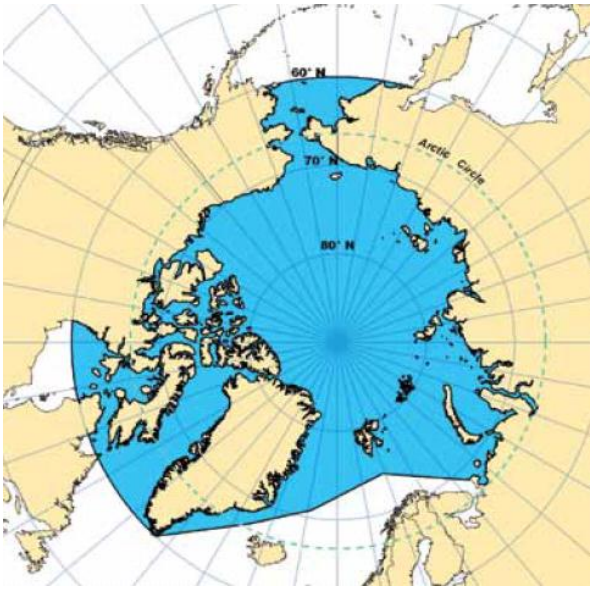
80 Six out of the nine approved PSSAs have mandatory reporting systems as part of their implementation.

81 See for example Conservation Measure 10-05 (2004) and CCAMLR Resolution 17/XX and the FAO Port State Model Scheme. Chile requires such information from fishing vessels Art. 1(d), Decree DS No 123, reported by Molenaar. See also the EC who has established such a system for EC fishing vessels.

82 "Located north of a line from the southern tip of Greenland and thence by the southern shore of Greenland to Kape Hoppe and thence by a rhumb line to latitude 67°03.9 N,longitude 026°33.4 W and thence by a rhumb line to Sørkapp, Jan Mayen and by the southern shore of Jan Mayen to the Island of Bjørnøya, and thence by a great circleline from the Island of Bjørnøya to Cap Kanin Nos and thence by the northern shore of the Asian Continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60° North as far as Il.pyrskiy and following the 60th North parallel eastward as far as and including Etolin Strait and thence by the northern shore of the North American continent as far south as latitude 60° North and thence eastward to the southern tip of Greenland", MSC/Circ.1056 - MEPC/Circ.399.

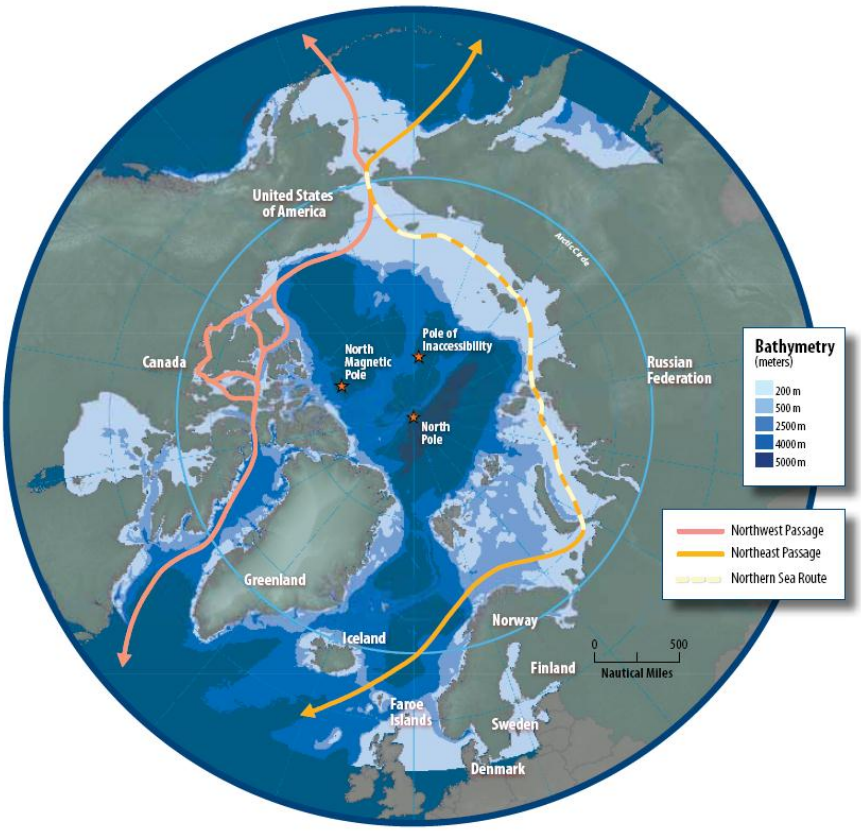
Figure 8 **Arctic ice-covered waters as defined by IMO's Maritime Safety Committee in 2002**



Source: MSMSC/Circ.1056 - MEPC/Circ.399.

An alternative demarcation would be the area north of Arctic circle, 66°33"N. This scope would include the Northwest passage, the Northeast passage and the Northern Sea Route (see Figure 9). This geographical scope would affect very few ships which do not use any of these Arctic sea routes. The only other routes affected would be domestic routes in Iceland, Canada, Norway and Russia (Arctic Council, 2009).

Figure 9 **Map of the Arctic and the main sea routes**



Source: Arctic Council, 2009: Arctic Marine Shipping Assessment 2009 Report.

If the aim of regulated slow steaming in the Arctic is broader, i.e. to reduce deposition of seaborne black carbon in the Arctic, the geographical scope needs to be larger than the Arctic itself. The relation between latitude of emissions and deposition is still the subject of debate in the academic literature (Frossard et al., 2011; Hirdman et al., 2010; Hegg et al., 2009; De Angelo, 2011)[83]. Most authors agree that emissions below 40°N have little impact on deposition in the Arctic. Hence, the boundaries of the region with reduced speed would lie between 40°N and the Arctic circle.

A wider geographical scope could also affect ships on voyages not involving the Arctic sea routes or even ports of Arctic countries. If these ships would sail through a regulated slow steaming area which is short relative to the total voyage, there is a risk that these ships would compensate for time lost within the area by speeding up outside the area. This would result in an increase in fuel use and emissions over the entire voyage. So, while the Arctic environment would be better off, this could be at the expense of the non-Arctic environment. The risk of speeding up depends on the limits of the geographical scope, the speed restriction, and the availability of alternative routes.
Regulated slow steaming in the Arctic could incentivise ship operators to avoid sailing through the Arctic. While this would not increase emissions relative to the current situation, in which the Arctic sea routes are infrequently used, it could result in higher emissions compared to a baseline in which the Arctic sea routes are open and reduce the distance between Asia on the one hand and East coast North America and Europe on the other (Eide et al., 2007)[84].

4.4.3 Speed definition

The regulated speed would be an average speed within the geographical scope.

Currently, sailing speed in the Arctic is limited by safety considerations. It depends on the ice thickness. For the Northern Sea Route, safe speeds vary from a little over 6 knots in spring to almost 13 knots in September (Liu and Kronback, 2010). It may be expected that ships will be able to sail faster if there is less ice, and that potentially different ship types will sail at different speeds in the future, as they do on the oceans.

The same speed could apply to all ships or speeds could be differentiated by ship types. The Arctic regulated slow steaming speed would have a geographical scope that results in many voyages being partly outside and partly within the area covered by regulated slow steaming. Hence, monitoring average speed during a voyage would not show compliance with the regime. Instead, ship speed within the Arctic would need to be monitored separately. This would add a level of complexity to monitoring compliance. Monitoring would be less complex if a single speed would apply to all ships.

A single regulated slow steaming speed would have the disadvantage of potentially distorting the market in the future. One speed for all ships would mean that container ships sailing from East Asia to the East coast of North America or to Europe would have a smaller time benefit from using any of the

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83 De Angelo, Benjamin Ed. (2011) An Assessment of Emissions and Mitigation Options for Black Carbon for the Arctic Council; Technical Report of the Arctic Council Task Force on Short´Lived Climate Forcers.Technical Report. Arctic Council.

84 Magnus S. Eide, Øyvind Endresen, Alvar Mjelde, Lars Erik Mangset, Gjermund Gravir, 2007, Global emission inventories for scenarios of future maritime shippingfor 2025, 2050 and 2100, Quantify deliverable 1.2.3.2.

Arctic sea routes than other, slower ships. Insofar as these ship types compete, a single regulated slow steaming speed would distort the market.

A single speed would need to be set rather low in order to reduce emissions of all ship types. If speeds would need to be reduced from the current situation, a speed of 10 knots or less would need to be imposed. This could result in very low engine loads for fast going ships. While in the past safety concerns have been raised in relation to very low engine loads, recent experience with super slow steaming, e.g. with Maersk, has indicated that many engines can safely operate at 10% load (De Kat, 2011).

Hence, a single regulated slow steaming speed would be easier to monitor and enforce, but could have negative impacts on the competitive market between different ship types in the future.

4.4.4 Responsible entity

Regulated slow steaming in the Arctic would be enforced through flag State and port State control, the latter by refusing entry to ships that have transgressed the regulated speed while sailing in the Arctic. As discussed in Section 3.5, the responsible entity can in that case be the ship owner; in case the owner is not the operator of the ship, he can contractually pass on the obligation to keep the regulated speed to the operator.

4.4.5 Ship type and size scope

With a ship type specific regulated slow steaming speed, there is no need to exempt ship types from the regime. After all, the speed can be accommodated to the characteristics of a certain ship type.

In maritime regulation, two universal thresholds are used. IMO conventions such as MARPOL and the International Convention on the Control of Harmful Anti-fouling Systems on Ships have thresholds of 400 GT; SOLAS uses a threshold of 500 GT.

As discussed in Section 3.2.3, speed can be monitored with (S-)AIS. All ships over 500 GT have to be equipped with AIS transponders. Hence, a threshold of 500 GT seems appropriate. According to CE et al. (2010), 1.92% of global ship CO_2 emissions in 2006 were from ships smaller than 500 GT.

4.4.6 Monitoring and reporting requirements

Ships can monitor their own speed over ground continuously using common instruments. Moreover, their logbook entries on time of departure from a port and time of arrival can be used to calculate average speeds. Regulators can monitor speed using (S-)AIS.

Under an Arctic regulated slow steaming regime, ships would need to comply with the speed restriction when sailing in the geographical scope of the regime (see Section 4.4.2). This means that they would be required to report:

a Time of entrance in the geographical scope.
b Time of exit of the geographical scope.
c Route and distance sailed within the geographical scope.
d Average speed in the geographical scope.

Reporting requirements would need to depend on the parties to a convention. If the number is large, flag State enforcement would cover most ships and reporting could be done on an annual basis. If, however, a small number of States ratify a treaty on Arctic regulated slow steaming, the risk that the speed restriction is not enforced on non-compliant ships increases because

there are more ships from non-participating States. Hence, enforcement through port State control becomes more important and this requires per voyage reporting of compliance before entry into a port.

4.4.7 Enforcement

The enforcement of Arctic regulated slow steaming could be organised by refusing entry to ports of contracting States of ships that cannot demonstrate compliance with the regime. Such measures could be similar to the enforcement mechanism under MARPOL: MARPOL imposes on contracting States the following obligation: "With respect to the ships of non-Parties to the Convention, Parties shall apply the requirements of the present Convention as may be necessary to ensure that no more favourable treatment is given to such ships."[85] Thus contracting States to MARPOL use their prescriptive and enforcement power to require compliance with the MARPOL requirements as conditions for entry to its ports against ships registered in non-contracting as well as contracting States.

4.4.8 Time to introduction

As of November 2011, thirteen areas have been designated PSSAs. Although little information could be found on the time between the proposal and designation of the area, it appears that usually this process takes a few years. Since a PSSA in the Arctic would affect comparatively few ships, the industry would not need to increase the number of ships. And since monitoring and reporting can be done with equipment currently on board ships, no adjustments would need to be made to ships. Hence, we do not expect that the relatively short leadtime will create problems.

4.5 Regulated slow steaming imposed on ships sailing to EU ports

Regulated slow steaming for ships sailing to EU ports could be introduced for two reasons. First, in order to reduce the climate impact of ships sailing to EU ports; and second, in order to reduce the air pollution around ports. The two aims have an impact on the geographical scope of the measure (Section 4.5.2).

4.5.1 Legal basis and legal instrument

The third option dealt with in this report is that based on unilateral measures imposed by the EU.[86] Two issues will be considered:

- the competence of the EU to prescribe such measures;
- the constraints on EU legal competence imposed by international law.

The competence of the EU to prescribe environmental measures

The EU has shared competence with Member States in relation to the environment (Art.4). The objectives that should be pursued by EU policies include environmental preservation and effects on human health. The EU competency in relation to climate change is prescribed as : "promoting measures at international level to deal with regional or worldwide environmental problems, and in particular combating climate change."

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85 MARPOL Art. 5(4).

86 Note that for the other two proposals the role of the EU will be necessarily reduced. The EU has only the status of observer in the IMO while it has not signed MARPOL (see case C-308/06).

(Art. 191). [87] Member States can impose more stringent measures than those imposed by the EU.[88]

The decision for action in a specific matter is taken by the European Parliament and the European Council following consultation with the Economic and Social Committee and the Committee of the Regions.[89]
A choice of legal instruments exists. A Regulation is directly applicable and binding in its entirety.[90] A Directive is binding while the result achieved by the forms and methods is left to the Member State.[91] The selection of the appropriate instrument is done on a case by case basis and in accordance with the principle of proportionality.[92]

Mandatory slow steaming measures for the purpose of reducing atmospheric pollution and GHG emissions are within the competence of the EU.
In relation to GHG emissions Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community provides in the preamble that where no international agreement for reduction of GHG emissions from ships is agreed through the IMO or the UN Framework Convention on Climate Change by 31/12/2011 then the EC will make "a proposal to include international maritime emissions according to harmonised modalities in the Community reduction commitment, with the aim of the proposed act entering into force by 2013".

The constraints on EU legal competence imposed by international law

The EU must respect international law in the exercise of its powers.[93] Acts of the EU institutions may be considered as inoperative by the ECJ if they are contrary to a rule of international law.[94] In relation to treaties to which the EU is a contracting member the obligation not to act against the convention is evident.
However, international treaties to which the EU is not a member do not have binding effect on the EU. In relation to these the EU institutions have a duty not to impede the performance of Member States' obligations arising from such treaties.[95]

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87 The EU policy must take into account (1) the available scientific and technical data; (2) the environmental conditions in the various regions of the Union; (3) the potential benefits and costs of action or lack of action; (4) the economic and social development of the Union as a whole and the balanced development of its regions. Art. 191(3).

88 Art. 193.

89 Art. 192.

90 The procedure to be followed for a Regulation or a Directive is described under Art. 284.

91 Art. 288.

92 Art. 296.

93 See Art. 3(5) and various ECJ decisions: Case C-286/90 Poulsen and Diva Navigation (1992) ECR I-6019, Paragraph 9; Case C-162/96 Racke (1998) ECR I-3655, Paragraph 45; Case C-308/06 Intertanko and Others ('Intertanko') (2008) ECR I-4057, Paragraph 51; and Joined Cases C-402/05 P and C-415/05 P Kadi and Al Barakaat International Foundation v Council and Commission ('Kadi') (2008) ECR I-6351, Paragraph 291.

94 Joined Cases 21/72 to 24/72 International Fruit Company and Others ('International Fruit Company') (1972) ECR 1219, Paragraph 6, and Racke (cited in footnote 29, Paragraph 27).

95 Intertanko and The Air Transport Association of America and Others.

The EU is a party to UNCLOS and therefore it is bound by its provisions.[96] It is also bound by relevant customary international law. The test applicable for using an obligation under an international convention as a benchmark for testing compliance of an EU instruments consists of two parts[97]:

- The European Union must be bound by the agreement concerned.
- The nature and the broad logic of the agreement concerned must not preclude such a review of validity and, in addition, its provisions must appear, as regards their content, to be unconditional and sufficiently precise. However in relation to principles of customary international law the test applied is one of whether the EU in adopting the Directive made "a manifest error of assessment concerning the conditions for applying these principles".[98]

The following principles of customary international law and included in UNCLOS can be used as a benchmark against any EU legal instrument prescribing mandatory slow steaming:

a The principle that each State has complete and exclusive sovereignty in its territorial and internal waters.
b The principle that no State may validly purport to subject any part of the high seas to its sovereignty.
c The principle which guarantees freedom of navigation in the high seas.
d The exclusive jurisdiction of the flag State in respect of its vessels' activities in the high seas.[99]

However, the ECJ recently made clear that the EU Directive 2008/101/EC which extends the EU emissions trading scheme to aviation and which applies over airspace that is not under the jurisdiction of the Member States is not inconsistent with the first three principles referred to above, as these apply to aircraft. It is our view that the answer would be the same for a properly drafted Directive imposing mandatory slow steaming, providing it is only enforced when a ship is voluntarily in a port of a Member State and that the enforcement methods are consistent with international law.

Thus, in our view, it is only the fourth principle that is still open to argue before ECJ as one that can possibly be violated by an EU Directive imposing mandatory slow steaming.[100] However, as discussed above[101] it is our view that there is no interference with the exclusive jurisdiction of the flag State by the imposition of mandatory slow steaming as a condition for entry for two reasons. First, because such requirements are unenforceable unless the foreign ship voluntarily calls at the port of a contracting States, in which case it submits to the jurisdiction of the coastal State and must comply with the laws of the coastal State and second because the exclusive jurisdiction of the flag

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96 UNCLOS is signed by the Community and approved by Decision 98/392. The provisions of that Convention form an integral part of the Community legal order (Case C-459/03 Commission v Ireland (2006) ECR I-4635, Paragraph 82).

97 Case 247/86 Alsatel (1988) ECR 5987, Paragraphs 7 and 8, and Case C-408/95, Eurotunnel and Others (1997) ECR I-6315, Paragraph 34 in conjunction with Paragraph 33.

98 ECJ Case C-366/10 judgement of 21/21/2011.

99 Leaving aside cases of piracy, slavery, drug trafficking and unauthorised broadcasting which enable all States to act against such ships in the high seas.

100 The ECJ did not find enough evidence to support the existence of a similar principle for aircraft.

101 See Section 3.1.

State in the high seas refers to, in our view, exclusively to enforcement jurisdiction in this oceanic area and not to prescriptive jurisdiction.

In our view the EU Member States have the right to prescribe mandatory slow steaming as a condition for entry not only in respect of voyages ending or starting from an EU Member State's port but for all voyages that a ship that enters their port performs. However, there are arguments against exercising such rights where there is no connection between the voyage the foreign ship performs and the EU.[102] These, in essence are a) that the State of departure, the State of destination and the flag State are better placed to regulate the behaviour of the foreign ship during such voyages; b) the enforcement would be more problematic.

4.5.2 Geographical scope

The geographical scope could either include all ships sailing to EU ports, ships sailing between EU ports or ships sailing in the territorial waters heading for EU ports.

Table 12 Emissions under different geographical scopes, 2006

Route groups	CO_2 emissions (Mt CO_2)
Voyages arriving at or departing from EU ports	310
Voyages arriving at EU ports	208
Voyages between EU ports	112
Voyages arriving at EU ports, territorial waters	38

Source: CE Delft et al., 2009.

Emissions of NO_x, $PM_{2.5}$ and other air pollutants from shipping within the 12-mile zone account for about 20% of the emissions within the EMEP region (IIASA, 2007). Shipping emissions, and especially emissions within the 12-mile zone, have a significant and growing impact on air quality, although long-range and hemispheric pollutant transport also have an important impact (IIASA 2007, Corbett et al., 2007).

4.5.3 Speed definition

In line with the considerations presented in Section 3.2, the regulated slow steaming speed should be:

- average speed over ground so that it can be monitored and verified;
- dependent on the ship type and possibly size in order to limit distortions of competition.

4.5.4 Responsible entity

In a regional system, enforcement would be mainly through port State control since many ships in EU ports are registered in non-EU Member States. If the enforcement mechanism is refusal of entry into a port by the port State, the owner can be liable for transgressing the regulation and action can be taken against the ship. However, since the owner often cannot control the speed, care has to be taken that the regulation allows the owner to pass on the liability to the commercial operator or the charterer, who has a greater control over the speed of a ship.

4.5.5 Ship type and size scope

With a ship type specific speed, there is no need to exempt ship types from the regulated slow steaming regime. After all, the speed can be accommodated to the characteristics of a certain ship type.

[102] These are partly discussed in Section 3.1.1 above.

In maritime regulation, two universal thresholds are used. IMO conventions such as MARPOL and the International Convention on the Control of Harmful Anti-fouling Systems on Ships have thresholds of 400 GT; SOLAS uses a threshold of 500 GT.

As discussed in Section 3.2.3, speed can be monitored with (S-)AIS. All ships over 500 GT have to be equipped with AIS transponders. Hence, a threshold of 500 GT seems appropriate. According to CE et al. (2010), 3.2% of CO_2 emissions on voyages to EU ports in 2006 were from ships smaller than 500 GT. Less than 4.4% of emissions on intra-EU voyages are from ships smaller than 500 GT.

4.5.6 Monitoring and reporting requirements

While some ships such as liners and ferries operate on specific routes for a considerable amount of time, many others operate wherever there is a demand for their services. This may result in a ship sailing to an EU port once and then being engaged outside the scope of the EU for a long time. Therefore, in order for regulated slow steaming to be enforced, ships should report their average speed within the geographical scope to the regulator upon entering a port. If a ship can ascertain that it will continue to sail in Europe, e.g. if it is a ferry on a regular service, the per voyage reporting requirement could be relaxed in order to reduce the administrative burden.

4.5.7 Enforcement

The ultimate instrument of enforcement of regional regulated slow steaming would be refusing ships that have sailed too fast entry to EU ports. Other instruments commonly used in port state control (e.g. warnings, fines) would also be available.

4.5.8 Time to introduction

An European Directive would take several years to be prepared and at least two years to be agreed upon by the Council and Parliament.

5 Cost benefit analysis

5.1 Introduction

We have carried out a cost benefit analysis for two different kinds of regulated slow steaming scheme:

1. For a global scheme. And
2. For a scheme for all ships arriving in an EU port, with the ships having to stick to the speed on their inbound voyage only.

For both schemes three alternative speeds have thereby been considered: namely speeds that lead to a 25%, to a 20% and to a 15% reduction of the average 2007 speed per ship type (see Table 23 in Section 5.6).

Since the fuel price turns out to be a crucial parameter in the cost benefit analysis, we further differentiate three different fuel price scenarios.

In the analysis we took the year 2015 as the year in which the regulated slow steaming becomes operative. Since the effects induced by regulated slow steaming are determined for a relatively long period (2015-2050),the results will not change significantly when the scheme would enter into force a few years later.

Due to data limitations we were not able to analyse a regulated slow steaming speed that holds for all ship types. The ship types we could take into account are the major ship types:

- Tankers (>100 GT);
- bulkers (>100 GT);
- general cargo vessels (conventional and specialised; >100 GT)) ;
- container vessels (>100 GT).

These account for about 72% of the total CO_2 emissions in 2007 (Buhaug et al., 2009).

In the following we will first describe the potential effects of a regulated slow steaming, then describe the baseline scenario that has been used in the analysis, illustrate the quantification of the effects, and finally present the results of the cost benefit analysis.

5.2 Cost and benefit items

Regulated slow steaming would have several potential effects on society. In Table 13 an overview of the conceivable cost and benefit items that are induced by regulated slow steaming are given. In Section 0 and 5.2.2 these items are further illustrated.

Table 13 Potential effects of regulated slow steaming

	Benefit Items	Cost Items
Direct effects	Fuel expenditure savings	– Costs of additional ships – Costs of ship and engine modifications – Higher inventory costs – Monitoring costs – Potential safety considerations
Indirect effects		– Adjustment of logistical chains – Less innovation energy saving technologies
External effects	– Lower emissions – Fewer whale strikes	– GHG emissions associated with additional ships

5.2.1 Cost items

Direct effects

Costs of additional ships
As ships sail slower, more ships are needed to deliver the same amount of transport work in a given time. Compensation of the reduction of the productivity of the active fleet can either be accomplished by making use of overcapacity (increasing the days at sea of the baseline fleet/using idle ships) or by purchasing new builds, resulting in additional capital and operational costs.

Costs of ship and engine modifications
Mandatory speed restrictions may require adjustments of the engine to be able to operate at lower speeds and/or a change of the form of the bulbous bow, the propeller and other elements of the ship in order to re-optimise it for operating at lower speeds. In some cases, antifouling does not work at lower speeds and systems may need to be changed. In the quantitative analysis we take engine modification costs into account.

Higher inventory costs
As cargo spends more time at sea, it will need to be financed and insured for a longer period of time.

Monitoring costs
When ships have to abide by a regulated slow steaming regime, their compliance would have to be monitored. We were not able to quantify these direct costs, but since it can be expected that monitoring can be done with existing technologies (e.g. AIS) we do not expect the monitoring costs to be very high.

Potential safety considerations
Within the debate on the EEDI, some stakeholders have claimed that ships with less power would be less safe to operate. This claim is not uncontroversial. Currently guidelines for determining the minimum propulsion power and speed to enable safe maneuvering in adverse weather conditions are being developed by the IMO. Given this uncertainty we did not quantify these external costs.

Indirect effects

Adjustment of logistical chains
When ships spend more time at sea logistical chains may have to be adjusted. These costs would probably be borne once. We were not able to quantify these indirect costs.

Less innovation in energy saving technologies
Regulated slow steaming can lead to less demand for energy saving technologies. New build ships that install an engine with less power to comply with the speed restriction might thereby comply with the EEDI as well and will not make use of additional energy saving technologies. Existing ships may be disinclined to apply energy saving technologies under regulated slow steaming since the fuel saving that is induced by slow steaming will make energy saving technologies less cost-effective. To the extent that these technologies are more cost-effective than slow steaming, regulated slow steaming may crowd out these technologies. Less demand for these technologies will disincentive innovation accordingly.

External effects

Emissions associated with additional ships
As ships sail slower, overcapacity has to be used and/or more ships are needed to deliver the same amount of transport work in a given time. This gives rise to more operational emissions. When the reduction of the productivity of the fleet has to be compensated by the use of additional new builds, emissions will increase due to the additional shipbuilding too. In the analysis we took the additional operational CO_2 and air pollution emissions as well as the extra CO_2 emissions from steel production and of shipbuilding into account.

5.2.2 Benefit items

Direct effects

Fuel expenditure savings
Lower operating speeds result, ceteris paribus, in fuel savings of the baseline fleet. However, the reduction of the productivity of the fleet that is induced by slow steaming has to be compensated by the use of overcapacity and/or additional new ships. These extra ships of course have to steam slowly too, but inherently are associated with extra fuel consumption. As can be seen in the analysis, the net effect on fuel consumption is nevertheless negative, i.e. even though more ships are active, fuel consumption declines. This only holds when ships do not speed up on parts of any voyages where slow steaming is not required.

External effects

Lower emissions
Slow steaming would reduce emissions of CO_2 and SO_x in areas where the speed is reduced. Unless ships speed up on parts of the voyage where slow steaming is not required, total emissions would also be lower. In most cases, emissions of NO_x and PM would also be reduced. We have quantified the change of the external costs of CO_2, NO_x, BC and of SO_x in the model.

Fewer whale strikes
In areas where whale strikes are common, they could be reduced by lower ship speeds.

5.3 Baseline scenarios

Two different baseline scenarios have to be determined, in order to analyse the global scheme and the scheme for all ships arriving in an EU port.

Global baseline

Starting point for the global baseline is the 2007 fleet and emission inventory, as well as the 2020 and 2050 fleet and emission projection of the IMO (Buhaug et al., 2009). More specifically, we have used the projection scenario A1B for the years 2020 and 2050. In this scenario, a medium level for future demand and future transport efficiency are assumed.

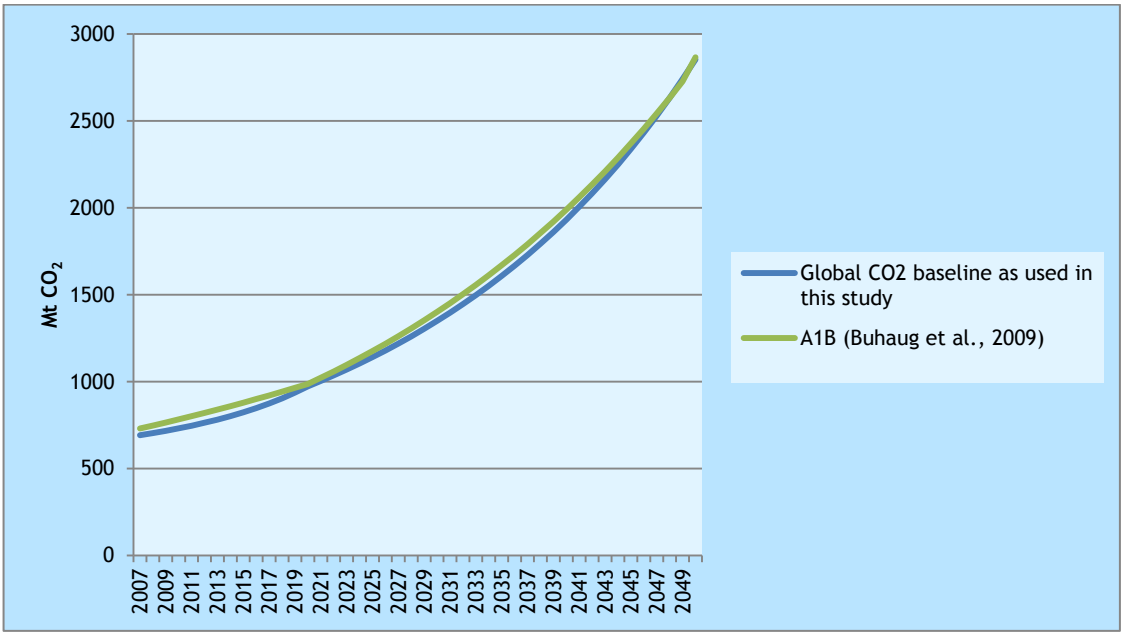
Since container vessels are known to have made use of slow steaming in the past, we assume, and therefore adjust the A1B scenario, that container vessels would make use of slow steaming even if no regulated slow steaming was implemented. From UNCTAD (2011) we know that currently in container shipping the majority Asia-Europe services run at 17 to 19 knots. We therefore adjust the baseline (2015-2050) such that we assume that container vessels will sail maximally 18 knots in the baseline. This corresponds to a range of 0-20% speed reduction of the container vessels, depending on the vessel size.

Speed reduction is assumed to have an impact on the main engine (ME) fuel consumption only and ships are assumed to be added to the fleet to compensate for the loss of the fleet productivity that is induced by the speed reduction.

In accordance with the IMO A1B projection, the efficiency of the ships is assumed to improve over time in the baseline. The efficiency improvement amounts to around 7-12% in 2020 compared to 2007 and to around 25-27% in 2050 compared to 2020.

In Figure 10 a comparison of the global CO_2 emission baseline (of the ship types taken into account in this study) as used in this study and the A1B baseline as presented in the Second IMO GHG Study (Buhaug et al., 2009) is given are given. Figure 10 thus shows the impact of market driven slow steaming of the container fleet on total emissions. For the ships analysed in this study, slow steaming by container ships will reduce emissions by 62 Mt CO_2 in 2020 and 225 Mt CO_2 in 2050.

Figure 10 Comparison of global baseline used in this study and the A1B baseline as presented in the Second IMO GHG Study (for the ship types considered in this study)



All ships arriving in EU ports baseline

Due to a lack of specific data on all ships that arrive in EU ports, this baseline is derived from the global baseline.

From CE et al. (2009) we know that in 2006 around 21% of global fuel consumption is related to ships arriving in EU ports and we know the contribution of the various ship type categories to intra-Europe fuel consumption in 2006 (see Table 14).

Table 14 Contribution of ship type categories to intra-Europe fuel consumption

	Contribution in %
Container	24.8%
Tanker	15.6%
General Cargo	10.6%
Bulker	10%
Reefer	2.7%
RoRo	7.1%
Passenger	22.3%
Fishing	1.4%
Rest	5.3%

Source: CE Delft et al., 2009.

The baseline for all ships arriving in an EU port is then derived under the assumptions that the distribution of fuel consumption within these ship type categories is the same as on global level and that the growth of the fuel consumption of the different ship types is in line with the global baseline.

5.4 Quantification of costs and benefits

5.4.1 Costs of additional ships

Purchase of additional new builds

We have determined the number of additional new builds that have to be purchased, taking two different factors into account: the speed reduction and overcapacity.

When overcapacity is not taken into account, It is reasonable to assume that a x% reduction in speed will result in a (1/(1-x%)-1) share of additional active ships, e.g. a 25% reduction in speed then results into a 33% increase in the number of active ships. Here a theoretical example:
Say the baseline fleet consists of 3 ships of the same ship type, which make 12 voyages à 1,000 km per year, transporting each 1,000 tons per voyage and each sailing on average at 40 km/hour in the baseline scenario. The baseline productivity of this fleet would then be 36 million ton kilometres per year and each ship would sail 300 hours a year. When under a 25% speed reduction ships would sail 30 km/hour on average, then a ship would need 33% more time for one voyage. In the 300 hours, a ship could only make 9 voyages and the productivity of the fleet would only amount to 27 million ton kilometres per year. In total 4 ships instead of 3 ships would be necessary to provide the same fleet productivity. The share of extra ships needed under the speed reduction thus amounts to (1/(1-% speed reduction)-1).

When overcapacity is considered, less additional new builds have to be purchased. We take overcapacity in two ways into account. On the one hand,

we allow the ships to increase their annual days at sea, on the other hand, idle ships are expected to be used to compensate for slow steaming.

When taking the extra days at sea into account, the growth of the fleet can be determined adjusting the formula above:

$$F_1 = F_0 \frac{\frac{DAS_0}{1 - \%SR} + 365 - DAS_0}{365}$$

with

0: baseline case
1: speed reduction case
F: fleet
DAS: days at sea
SR: speed reduction

As to idle ships we assume that only during the period 2015-2020 overcapacity can be used to compensate for slow steaming. We think that it is reasonable to assume that, at least for the case of the global regulated slow steaming, no overcapacity is left after 2020 for two reasons; due to the speed reduction there will be a large demand for transport supply and until 2020 the market is able to adjust to the speed reduction in terms of new orders that are placed. A new economic crisis could of course again lead to new overcapacity in the market. Quantifying this effect would however be mere speculation. To quantify transport overcapacity for the period 2015-2020 we make the simplifying assumption that overcapacity of tankers, bulkers and general cargo ships in 2015 equals overcapacity in 2010 (see Table 15), and that overcapacity gradually declines until 2020.

Table 15 Tonnage surplus by vessel type 2010

Vessel type	Idle fleet (million dwt or m^3)
Tanker	10.48
Dry bulk	2.86
Conventional general cargo	0.78
LNG carrier	1.53
LPG carrier	0.13

Source: UNCTAD, 2011.

As to the container vessels we assume that there is no overcapacity left in 2015. Data from Alphaliner on the idle container fleet shows that the share of the fleet that has been laid-up is significantly lower at the beginning of 2011 compared to 2009 and early 2010 (IMDO, 2011). We assume that this trend will continue.

The costs of additional ships are based on UNCTAD (2009). Since prices for new builds have been very volatile, with 2007 being a year with above average prices, we applied a correction factor of 0.7 to the 2007 data, in line with IMarEST (2010).

Operational costs of additionally active ships

The costs of non-fuel operational costs (crew, maintenance, etc.) was based on CE et al. (2010).

5.4.2 Costs of ship and engine modifications

In the analysis we assume that for every ship engine modification costs accrue. These costs are taken to be USD 200,000 per ship (according to the Hapag-Lloyd AG (Hapag Lloyd, 2011), Dynamar estimates engine modification costs in its Slow Steaming Report 2010 to be USD 200,000 per ship).

5.4.3 Higher inventory costs

To quantify the increase of the inventory costs we first estimate the value of seaborne trade per ship type per year. From the UNCTAD Handbook of Statistics we know the total value of all global exports in 2009, which is around USD 12,335 billion. Lloyds MIU (2009) has estimated that around 60% of the value of the overall trade is seaborne trade and that the distribution of the value of seaborne trade over the different ship types is as follows: 52% container, 22% tanker, 20% general cargo, 6% dry bulk.

The total value that is transported per year in the period 2015-2020 is derived by assuming that the value that is transported per year per ship category does not change when there is no speed reduction and thus rises with the number of ships that is added to the fleet in the baseline (without speed reduction) reflecting the rise of the future demand.

Assuming that the average baseline transit time is 38 days we can then calculate the increase in transit time per ship type per year due to regulated slow steaming and then determine the costs of financing this extra transit time given the value of the goods transported. An example: when regulated slow steaming requires the ships to reduce their average speed by 25% then transit time increases by 33%. The average transit time would thus increase by around 12 days. The value of the goods that are transported by general cargo carriers in 2015 can be expected to amount to around 1,565 billion USD. Given a 10% interest rate per annum, financing the extra inventory costs of the goods transported by general cargo carriers in 2015 amounts to around 5,430 million USD.

5.4.4 Emissions associated with additional ships

In the analysis we have taken the extra CO_2 emissions related to the construction of the additional new builds into account. More specifically, we took the CO_2 emissions of the steel fabrication and CO_2 emissions of the building process at the yard into account. To this end we estimated the average lightship weights of the different ship types, making use of typical deadweight coefficients from the literature (Barrass 2004). We then applied an emission factor of 1.75 ton CO_2/ton steel for the steel fabrication and an emission factor of 0.216 ton CO_2/ton steel for the building process (Gratsos, 2009). Note that the emission factor for steel fabrication is relatively high compared to the one that is given in the SimaPro LCA software which is 1.45 ton CO_2/ton steel.

5.4.5 Fuel expenditure savings

Speed reduction leads to a reduction of the fuel consumption of the ships' main engine. As a rule of thumb a cubic relation between ship speed and main engine fuel consumption can be used, which means that a speed reduction of 25% leads to a reduction of main engine fuel consumption of approximately 58% on a ship basis per year. Total fuel consumption saving on the fleet level however will be less per year for three reasons:

1. The fuel consumption of the auxiliary engines will not be reduced (we assume that it stays constant).
2. Additional ships are/overcapacity is used due to slow steaming.
3. Slow steaming allows for a change of the design of new container vessels and other fast ships. Germanischer Lloyd expects the new build container

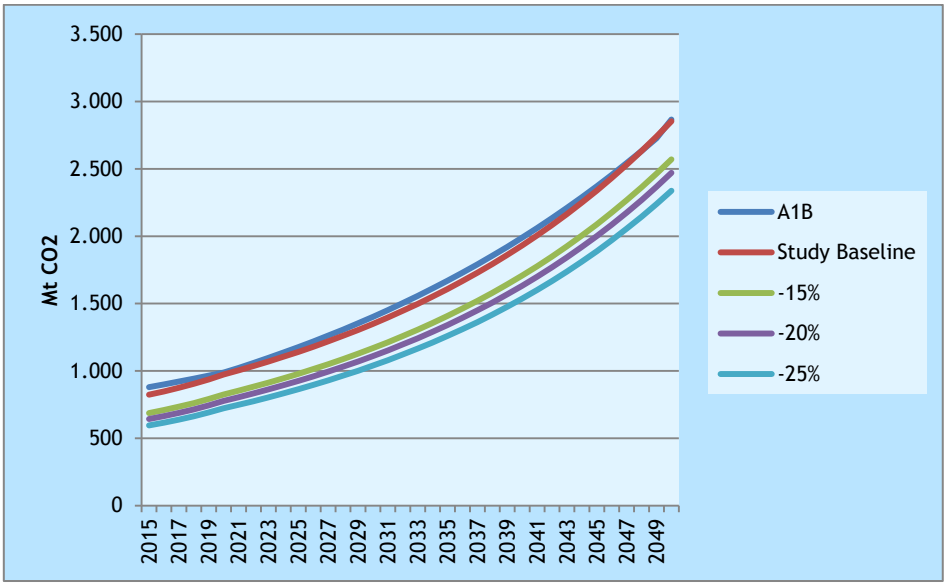
vessels subject to regulated slow steaming to be characterised by a higher block coefficient, leading to lower speed reduction related fuel savings (Köpke, 2011). In the model we therefore assumed that the main engine fuel saving of the container ships that are added to the fleet due to regulated slow steaming is less. We assume a quadratic relationship between speed and main engine fuel consumption instead which is equal to a 43% reduction of main engine fuel consumption on a ship basis per year.

5.4.6 Lower emissions

As can be seen in the analysis, the net effect of regulated slow steaming on the total fuel consumption is negative, i.e. even though more ships are deployed, fuel consumption declines per year. This only holds when ships do not speed up on any parts of the voyage where regulated slow steaming in not required.

The CO_2 emissions as a result of global regulated slow steaming are presented in Figure 11. Note that the effect on CO_2 emissions is thereby only illustrated for those ship types and sizes that have been considered in the study. See Table 22 for the corresponding relative and absolute emission reduction values.

Figure 11 CO_2 emissions as a result of global regulated slow steaming



Source: This report.

When overall fuel consumption is reduced, the emissions of CO_2, NO_x, black carbon (BC), and SO_x decline as well.

In the analysis we took the impact on the related external effects into account. We quantified the external effects using the following data:

1. CO_2 emissions
   a Emission factors: carbon content of fuel as specified in Buhaug et al. (2009).
   b External costs: Global regime: as specified in EPA (2010) for 2.5% discount rate; EU regime: as specified in the IMPACT handbook (CE et al., 2008).

2. NO_x emissions
   a Emission factors
      – 2007: 2-stroke 84.9 kg/ton fuel equivalent and 4-stroke 56.3 kg/ton FE (Buhaug et al., 2009);
      – 2020: 61 kg/ton FE (Buhaug et al., 2009);
      – 2050: 49.1 kg/ton FE (Buhaug et al.,2009).
   b External costs: 7150 USD/ton NO_x based on Holland and Watkiss (2002).
3. BC emissions
   a Emission factors: 220 g/ton fuel (Lack et al. 2011).
   b External costs: 14,300 USD/ton BC (here the external costs for $PM_{2.5}$ are used, based on Holland and Watkiss (2002)).
4. SO_x emissions
   a Emission factors:

	2015-2019	2020-20149	2050
Global speed limit	40.6 kg/ton fuel	9.2 kg/ton fuel	8.6 kg/ton fuel
All ships arriving in EU ports	15.4 kg/ton fuel	4.5 kg/ton fuel	4.3 kg/ton fuel

Source: based on Buhaug et al.,, 2009.

   b External costs: 6,950 USD/ton SO_x (based on Holland and Watkiss (2002)).

Please see Section 2.4 for a discussion of the emission factors.

5.4.7 Other main assumptions

Fuel price

The fuel price between 2015 and 2030 is one of the key elements in the cost benefit calculations. We have projected the fuel price through 2050. The projection was based on:
– the crude oil price projections from the European Commission;
– the correlation of historical heavy fuel oil (HFO) prices and crude oil prices;
– the projected impact of the MARPOL Annex VI regulation on the maritime fuel prices.

Oil prices projections over the long run are highly uncertain, just like prices in the past have been very volatile (Figure 12).

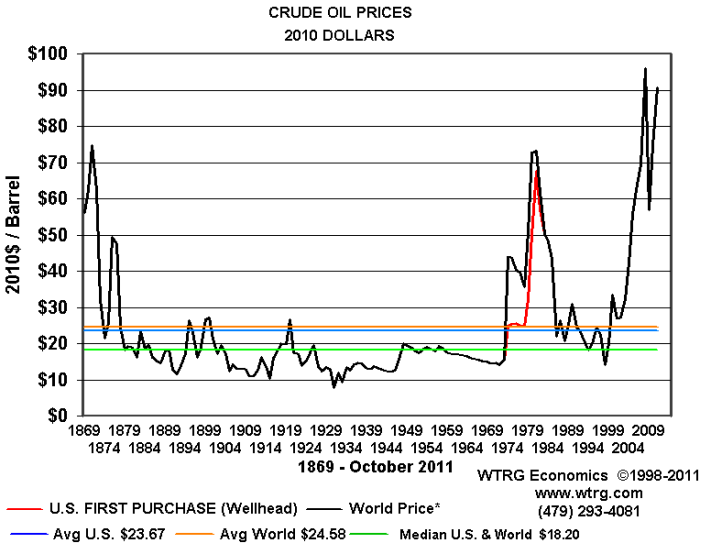
For this study, we have used the oil price scenarios that the European Commission has used in the Low Carbon Economy Roadmap and the Transport White Paper, both from 2011 (Table 16).

Table 16 EC crude oil price projections (USD_{2005}/bbl)

Oil Price Scenario	2005	2010	2020	2030	2040	2050
Global baseline	55	70	78	96	115	138
Global action	55	70	74	77	76	69
Fragmented action	55	70	75	88	102	117

Source: EC (2011)288 final.

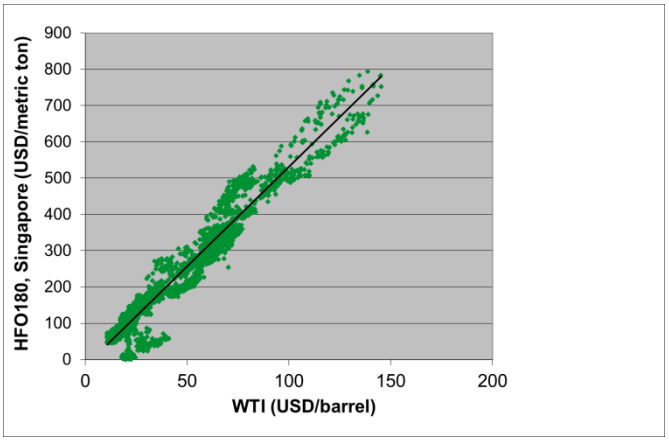
Figure 12 Oil prices have been volatile



Source: WTRG.

Heavy fuel oil (HFO) is primarily the residue of the distillation process of crude oil. HFO is the fuel grade that is used the most by the world shipping fleet. When looking at historical prices for HFO and crude oil, a well-defined relationship can be established. Using EIA data on prices of HFO in Singapore and West Texas Intermediate (WTI) crude oil prices, we found that the price of HFO in USD per metric tonne is on average five (5) times the price of WTI in USD per barrel shows de correlation of both prices in the period 1986-2010. An analysis of the prices for different time periods, for example using Brent instead of WTI as the benchmark for the crude oil price; or using Rotterdam LSO instead of Singapore HFO, did not significantly alter this result.

Figure 13 Historic relationship between crude oil price (USD/barrel) and HFO 180 spot price (Singapore, USD/mt), 1986-2010



Source: EIA.

Future requirements on the sulphur content of maritime fuels are likely to affect prices. The sulphur content is regulated by Annex VI of the MARPOL convention. In October 2008, the IMO's Marine Environment Protection Committee (MEPC) adopted a revision of this Annex which, among other things, sets stricter standards for the sulphur content of maritime fuels. The maximum sulphur content limit will decrease from 4.5% m/m today to

3.5% m/m in 2012 and on to 0.5% m/m in 2020 or 2024 (depending on the availability of low sulphur fuels as determined in 2018) and to 0.1% m/m in emission control areas (ECAs) in 2015.

Recently, a number of studies on the costs of low sulphur fuels have been published. An IMO expert group estimated in 2007 that low sulphur fuels have a historical price premium of 50 to 72% (BLG 12/6/1). For 2020, the expert group report of model runs, suggested a price increase of 25%. Since then, additional studies have been published. In the Purvin and Gertz Inc. (2009) study, it is estimated that bunker fuel with 0.5% maximum sulphur content will cost USD 120 to USD 170 more per tonne than the current high sulphur quality, leading to an increase of the costs of bunker fuel in the range of 30-50%, depending on the process option (Purvin and Gertz Inc., 2009). In a study by the Ministry of Transport and Communications Finland (2009), it is estimated that HFO with a maximum sulphur content of 0.5% will be about 13-29% more expensive than the HFO with a maximum sulphur content of 1.5%. Based on these findings, we assumed a cost increase range of 10-50%, with a middle estimate of 30%.

For this report, we have used the fuel price projections of the global baseline with a 30% increase due to the switch to low sulphur fuels, which we have assumed to take place in 2020. For a sensitivity analysis, we have used the global action scenario with a 10% uplift and a late (2024) shift to low sulphur fuels, and a global baseline scenario with a 50% uplift and an early shift.

Table 17 Maritime fuel price scenarios (USD_{2005}/tonne of maritime fuel)

		2020	2030	2040	2050
Base	Global baseline, shift in 2018, 30% price increase for low sulphur fuel	507	624	748	879
Low	Global action, shift in 2024, 10% price increase for low sulphur fuel	370	424	418	380
High	Global baseline, shift in 2018, 50% price increase for low sulphur fuel	585	720	863	1,035

Source: This report.

We are aware that the current bunker fuel prices are well over USD 600 in current prices. Even when adjusting for inflation, the projections may imply a decrease in prices in the coming decade. While many may consider this to be implausible, we have chosen to stick with the transparent methodology for projecting prices.

Discount rate

Overall results of the cost benefit analysis will be presented as the net present value of the overall costs of the regulated slow steaming. In the first instance we have thereby worked with a uniform discount rate of 4% but have also carried out a sensitivity analysis with respect to the discount factor. In two extra scenarios we work with two discount factors respectively, applying a lower discount factor to the change of the external costs of CO_2. The discount factors used in the sensitivity analysis are 4% and 10% as well as 2% and 6%.

5.5 Results of cost benefit analysis

In Table 18 and Table 19 the net present value (NPV) of the effects of two different kinds of regulated slow steaming are given:

1. A global scheme and
2. a scheme for all ships arriving in EU ports.

The NPV is given for the base year 2015 as related to the period 2015-2050 and for a uniform discount factor of 4%.

Three different regulated slow steaming speeds are differentiated respectively: a speed limit that leads to a 25%, 20% or 15% speed reduction related to the ships' 2007 average speed.

The scenarios low, base and high differ with respect to the fuel price projections (see 5.4.7 for more details). Note that the scenarios thus differ only with respect to the fuel price related items, i.e. the change of the fuel expenditure of the baseline fleet and the fuel expenditure of the additional ships used.

Table 18 Costs and benefits of regulated slow steaming (4% discount factor)

Net present value (billion USD)									
Speed reduction	-25%			-20%			-15%		
Fuel price scenario	Low	Base	High	Low	Base	High	Low	Base	High
Costs for purchase extra ships	668	668	668	476	476	476	327	327	327
Fuel expenditure extra fleet	350	575	663	261	425	490	197	320	369
Other annual expend. extra fleet	431	431	431	310	310	310	214	214	214
Change of fuel expend. baseline fleet	-1262	-2069	-2387	-938	-1529	-1764	-697	-1133	-1307
Engine modification costs	26	26	26	25	25	25	24	24	24
Extra inventory costs	759	759	759	516	516	516	343	343	343
Change of external costs									
– Costs operational CO_2	-298	-298	-298	-229	-229	-229	-172	-172	-172
– Shipbuilding CO_2	19	19	19	12	12	12	7	7	7
– No_x	-608	-608	-608	-453	-453	-453	-335	-335	-335
– BC	-5	-5	-5	-4	-4	-4	-3	-3	-3
– SO_x	-150	-150	-150	-114	-114	-114	-84	-84	-84
Net costs	**-70**	**-653**	**-883**	**-137**	**-564**	**-734**	**-178**	**-491**	**-617**

Table 19 Costs and benefits of regulated slow steaming for all ships arriving in EU ports (4% discount factor)

Net present value (billion USD)									
Speed reduction	-25%			-20%			-15%		
Fuel price scenario	Low	Base	High	Low	Base	High	Low	Base	High
Costs for purchase extra ships	131	131	131	92	92	92	63	63	63
Fuel expenditure extra fleet	64	105	121	45	74	85	33	54	63
Other annual expend. extra fleet	83	83	83	59	59	59	41	41	41
Change of fuel expend. baseline fleet	-229	-377	-435	-163	-267	-308	-119	-194	-224
Engine modification costs	6	6	6	5	5	5	5	5	5
Extra inventory costs	172	172	172	116	116	116	77	77	77
Change of external costs									
– Costs operational CO_2	-52	-52	-52	-39	-39	-39	-28	-28	-28
– Shipbuilding CO_2	3	3	3	2	2	2	1	1	1
– No_x	-109	-109	-109	-79	-79	-79	-57	-57	-57
– BC	-1	-1	-1	-1	-1	-1	0	0	0
– SO_x	-27	-27	-27	-20	-20	-20	-14	-14	-14
Net costs	**41**	**-66**	**-108**	**20**	**-55**	**-85**	**1**	**-53**	**-74**

Global regulated slow steaming is cost efficient, i.e. is associated with negative net costs, for all three speed reduction scenarios, independent of the fuel price scenario. In the low price scenario a speed reduction of -15% is more advantageous than a speed reduction of -20% or -25%, whereas in both the base and the high price scenario a speed reduction of -25% is more advantageous than a speed reduction of -20% or -15%.

Regulated slow steaming for all ships that arrive in EU ports is cost efficient for all three speed reduction scenarios in the base and the high fuel price scenario, but not cost efficient in the low fuel price scenario. Just as for the global scheme it holds that in the low price scenario a speed reduction of -15% is more advantageous than a speed reduction of -20% or -25%, whereas in both the base and the high price scenario a speed reduction of -25% is more advantageous than a speed reduction of -20% or -15%.

Fuel expenditure savings of the baseline fleet is the dominating benefit factor in all scenarios. The cost efficiency of the speed reduction naturally declines with the expected fuel price and is thus the lowest in the low fuel price scenario.

Independent of the speed reduction and the speed reduction/fuel price scenario, the fuel consumption of the total fleet decreases. Relative fuel reduction thereby differs by ship type and size category but is independent of the scope to which regulated slow steaming is applied (global or all ships arriving in EU ports). The resulting averages are given in Table 20.

Table 20 Relative fuel reduction on fleet basis

Ship type			-25%	-20%	-15%
01 Crude	Tanker	A 200,000+ dwt	36.4%	30.2%	23.4%
01 Crude	Tanker	B 120 -199,999 dwt	34.8%	28.9%	22.5%
01 Crude	Tanker	C 80 -119,999 dwt	25.3%	21.4%	16.9%
01 Crude	Tanker	D 60 -79,999 dwt	19.9%	17.1%	13.7%
01 Crude	Tanker	E 10 -59,999 dwt	23.2%	19.8%	15.7%
01 Crude	Tanker	F -9,999 dwt	12.2%	11.0%	9.2%
02 Products	Tanker	A 60,000+ dwt	17.0%	14.9%	12.0%
02 Products	Tanker	B 20 -59,999 dwt	8.7%	8.3%	7.1%
02 Products	Tanker	C 10 -19,999 dwt	8.2%	7.9%	6.8%
02 Products	Tanker	D 5 -9,999 dwt	12.2%	11.1%	9.2%
02 Products	Tanker	E -4,999 dwt	10.6%	9.8%	8.2%
03 Chemical	Tanker	A 20,000+ dwt	35.9%	29.8%	23.1%
03 Chemical	Tanker	B 10 -19,999 dwt	34.3%	28.5%	22.2%
03 Chemical	Tanker	C 5 -9,999 dwt	33.5%	27.9%	21.7%
03 Chemical	Tanker	D -4,999 dwt	24.7%	20.9%	16.5%
04 LPG	Tanker	A 50,000+ cbm	37.0%	30.7%	23.8%
04 LPG	Tanker	B -49,999 cbm	27.9%	23.4%	18.4%
05 LNG	Tanker	A 200,000+ cbm	34.9%	29.0%	22.5%
05 LNG	Tanker	B -199,999 cbm	34.2%	28.5%	22.2%
06 Other tanker	Tanker	B Other	27.7%	23.3%	18.3%
07 Bulker	Bulker	A 200,000+ dwt	38.6%	32.0%	24.7%
07 Bulker	Bulker	B 100 -199,999 dwt	38.5%	31.9%	24.7%
07 Bulker	Bulker	C 60 -99,999 dwt	37.4%	31.0%	24.0%
07 Bulker	Bulker	D 35 -59,999 dwt	36.6%	30.3%	23.5%
07 Bulker	Bulker	E 10 -34,999 dwt	35.2%	29.2%	22.7%
07 Bulker	Bulker	F -9,999 dwt	23.5%	20.0%	15.8%
08 General cargo	General Cargo	A 10,000+ dwt	37.1%	30.8%	23.8%
08 General cargo	General Cargo	B 5,000-9,999 dwt	36.7%	30.4%	23.6%
08 General cargo	General Cargo	C -4,999 dwt	31.4%	26.2%	20.5%
08 General cargo	General Cargo	D 10,000+ dwt, 100+ TEU	35.6%	29.5%	22.9%
08 General cargo	General Cargo	E 5,000-9,999 dwt, 100+ TEU	31.1%	26.0%	20.3%
08 General cargo	General Cargo	F -4,999 dwt, 100+ TEU	24.1%	20.5%	16.2%
09 Other dry	General Cargo	A Reefer	33.6%	28.0%	21.8%
09 Other dry	General Cargo	C Special	34.3%	28.5%	22.2%
10 Container	Unitised	A 8,000+ TEU	8.9%	0.0%	0.0%
10 Container	Unitised	B 5 -7,999 TEU	8.9%	0.0%	0.0%
10 Container	Unitised	C 3 -4,999 TEU	17.1%	8.9%	0.0%
10 Container	Unitised	D 2 -2,999 TEU	29.5%	23.0%	15.9%
10 Container	Unitised	E 1 -1,999 TEU	34.4%	28.6%	22.2%
10 Container	Unitised	F -999 TEU	28.7%	24.1%	18.9%

Resulting average relative fuel consumption reduction on fleet basis in the period 2015-2050 is given in the Table 21.

Table 21 Relative fuel reduction on fleet basis in the period 2015-2050

	Global	All ships arriving in EU ports
-25%	25%	23%
-20%	18%	17%
-15%	13%	12%

The average relative fuel consumption reduction differs per scope of the regulated slow steaming regime, since the share of the different ship type/size categories differs respectively.

The relative average fuel expenditure saving is higher. For the base fuel price scenario and a speed reduction of -25% it is for instance 35% for the global scheme and 33% for the scheme for all the ships arriving in EU ports. To give a reference, the NPV of the fuel expenditure in the baseline thereby amounts to around 5,900 billion USD on the global scale and to 1,150 billion USD for all ships arriving in EU ports.

The induced relative emission reduction in the period 2015-2050 corresponds to the relative fuel reduction as given in Table 21. As can be seen in Table 22, the relative emission reduction is, just as the fuel reduction, not constant over time. This is due to a change of the fleet composition over time.

Table 22 Changes in total CO_2 emissions (transport and shipbuilding) relative to the baseline resulting from regulated slow steaming

	Global speed limit			All ships arriving in EU ports-speed limit		
	2020	**2030**	**2050**	**2020**	**2030**	**2050**
-25%	-25% (245 Mt)	-22% (300 Mt)	-17% (484 Mt)	-23% (42 Mt)	-20% (52 Mt)	-15% (85 Mt)
-20%	-20% (193 Mt)	-17% (233 Mt)	-13% (366 Mt)	-18% (33 Mt)	-15% (39 Mt)	-11% (62 Mt)
-15%	-15% (146 Mt)	-13% (176 Mt)	-10% (272Mt)	-13% (24 Mt)	-11% (29 Mt)	-8% (45 Mt)

Source: This report.

The results presented so far have been calculated, using a uniform discount rate of 4%. We also carried out a sensitivity analysis with respect to the discount rate. In two extra scenarios we work with two discount factors respectively, applying a lower discount factor to the change of the external costs of CO_2. The discount factors used in the sensitivity analysis are 4% and 10% as well as 2% and 6%.

For the alternative discount rates, the global regulated slow steamingis still cost effective in all the speed reduction and fuel price scenarios taken into account. The net benefit however is lower in the base and high price scenarios. In the low fuel price scenario, the net benefit increases with the exception of the 15% speed reduction and 4%/10% discount rate case.

For the 4%/10% discount rates, the speed reduction for all the ships arriving in EU ports is only in one scenario not cost efficient, i.e. the 25% speed reduction together with a low fuel price. Compared to the case with the uniform 4% discount rate, cost efficiency improves in all low fuel price scenarios but deteriorates in all base/high fuel price scenarios considered. For the 2%/6% discount rates, regulated slow steaming is cost efficient in all the speed reduction and fuel price scenarios taken into account. Compared to the case with the uniform 4% discount rate, cost efficiency is higher with exception of the 15% speed reduction together with either the base or the high price scenario.

Note that the underlying effects are not evenly distributed over time. In the year that the speed reduction enters into force, expenditures for engine modifications and external costs of the CO_2 emissions for shipbuilding are relatively high. Note also that the costs and benefits of the speed reduction are also not evenly distributed over the different ship types. A speed reduction that is overall cost efficient may not be cost efficient for every ship owner. Note, finally, that not all effects of a regulated speed reduction could be

quantified. We did not quantify the following effects: the costs for monitoring the speed reduction, the costs for adjusting logistical chains, a reduction of the R&D incentive, possible safety effects, and the benefit of less whale strikes.

5.6 2007 reference speeds

Table 23 Average 2007 speed without speed reduction

Ship type			Average speed (knots)
01 Crude	Tanker	A 200,000+ dwt	14.35
01 Crude	Tanker	B 120 -199,999 dwt	14.42
01 Crude	Tanker	C 80 -119,999 dwt	14.15
01 Crude	Tanker	D 60 -79,999 dwt	13.43
01 Crude	Tanker	E 10 -59,999 dwt	13.33
01 Crude	Tanker	F -9,999 dwt	10.86
02 Products	Tanker	A 60,000+ dwt	14.71
02 Products	Tanker	B 20 -59,999 dwt	13.37
02 Products	Tanker	C 10 -19,999 dwt	12.97
02 Products	Tanker	D 5 -9,999 dwt	12.07
02 Products	Tanker	E -4,999 dwt	9.87
03 Chemical	Tanker	A 20,000+ dwt	14.13
03 Chemical	Tanker	B 10 -19,999 dwt	13.94
03 Chemical	Tanker	C 5 -9,999 dwt	13.72
03 Chemical	Tanker	D -4,999 dwt	13.01
04 LPG	Tanker	A 50,000+ cbm	15.27
04 LPG	Tanker	B -49,999 cbm	12.56
05 LNG	Tanker	A 200,000+ cbm	18.02
05 LNG	Tanker	B -199,999 cbm	18.02
06 Other tanker	Tanker	B Other	11.98
07 Bulker	Bulker	A 200,000+ dwt	13.29
07 Bulker	Bulker	B 100 -199,999 dwt	13.24
07 Bulker	Bulker	C 60 -99,999 dwt	13.24
07 Bulker	Bulker	D 35 -59,999 dwt	13.24
07 Bulker	Bulker	E 10 -34,999 dwt	13.15
07 Bulker	Bulker	F -9,999 dwt	9.87
08 General cargo	General Cargo	A 10,000+ dwt	14.81
08 General cargo	General Cargo	B 5,000-9,999 dwt	12.88
08 General cargo	General Cargo	C -4,999 dwt	10.50
08 General cargo	General Cargo	D 10,000+ dwt, 100+ TEU	13.82
08 General cargo	General Cargo	E 5,000-9,999 dwt, 100+ TEU	12.02
08 General cargo	General Cargo	F -4,999 dwt, 100+ TEU	10.50
09 Other dry	General Cargo	A Reefer	18.34
09 Other dry	General Cargo	C Special	17.94
10 Container	Unitised	A 8,000+ TEU	22.75
10 Container	Unitised	B 5 -7,999 TEU	22.70
10 Container	Unitised	C 3 -4,999 TEU	20.90
10 Container	Unitised	D 2 -2,999 TEU	18.75
10 Container	Unitised	E 1 -1,999 TEU	17.05
10 Container	Unitised	F -999 TEU	15.25

6 Conclusion

Slow steaming has significant environmental benefits. The most certain benefits are related to emissions of CO_2. A 10% reduction in fleet average speed results in a 19% reduction of emissions, after accounting for the emissions of additional ships needed to deliver the same amount of transport work and accounting for the emissions associated with building the additional ships. Emissions of SO_x, NO_x and probably black carbon will decrease in line with fuel use and CO_2 emissions.

Slow steaming has significant economic benefits. Taking into account both the direct costs (fuel use, crew, capital costs of ships), indirect costs (additional inventory costs, adjustment of logistical chains) and the external costs (impacts of emissions on human health and ecosystems, climate impacts), the benefits of slow steaming outweigh the costs. This result is robust for a number of fuel price assumptions and discount rates, although in some low fuel price scenarios the costs are larger than the benefits.

Slow steaming is already widely practiced. Many shipping companies have implemented slow steaming. Container lines were the first to do so, but the practice has permeated to tankers and bulkers as well. Estimates vary widely, and there is no reliable data set on the extent to which the fleet has slowed down. If the fleet has slowed down on average, some of the economic and environmental benefits of regulated slow steaming would already have been captured. If the circumstances incentivise ships to speed up again, some or all of these benefits may be lost.

Experiences with slow steaming vary across stakeholders. While most shipping lines appear to have positive experiences with slow steaming, as it has increased their profitability, many shippers have had to adjust their inventory levels and supply chains, resulting in higher costs. Other stakeholders such as ports and third party logistic suppliers have experiences ranging from neutral to positive.

Regulated slow steaming is legally feasible. Compulsory slow steaming can be imposed by a State on the ships flying its flag; on all ships in territorial waters, but cannot be enforced while the ship is on transit or innocent passage; and in the EEZ and the high seas as a condition of entry in a port of the imposing States. This view was recently supported by the ECJ judgement on the inclusion of aviation in the EU ETS. However, outside the EU, issues on extraterritoriality could be brought up in relation to mandating slow steaming in the high seas and the EEZ.

Regulated slow steaming is feasible to implement. Speed can be monitored, both by ships and by regulators, and reported to regulators with little additional effort. Enforcement can be based on existing port State control instruments. The time required to introduce a system of regulated slow steaming depends on the level at which it will be implemented. Experience with global treaties suggests it may take over a decade to reach agreement. Regulated slow steaming in a PSSA such as the Arctic may be implemented in a few years. Regulated slow steaming at an EU level could be implemented in up to ten years.

Regulated slow steaming has a number of advantages: Regulated speed reduction is the most cost effective way to reduce ship emissions, and implemented correctly, it is cost free to the shipping industry as a whole and entails marginal incremental logistic and supply chain costs to consumers; regulated slow steaming ensures that emissions in the shipping sector will be reduced, regardless of the fuel price and demand for shipping; a cap on speed would reduce the possibility to avert the otherwise likely spike in emissions if ships speed up in response to a recovery in demand, and a cap set today around current average ship speeds will have little impact on industry in the short term; regulated slow steaming is relatively easy to monitor and enforce, and may have a lower administrative burden than some of the recently proposed MBMs.

There are also disadvantages to regulated slow steaming: A restriction on speed reduces market flexibility; because of the perceived loss of market flexibility, regulated slow steaming appear to be widely opposed by shipping companies and shippers; it may not be cost-effective for all ships, on all routes or for all ship types; it reduces the cost-effectiveness of other means of fuel efficiency improvements and may result in less innovation; since it prescribes a specific measure it would run contrary to the goal-based approach to shipping environmental policy favoured in recent years; and while regulated slow steaming, if implemented carefully, need not impose additional costs on the shipping sector as a whole, neither would it raise revenues for use in fighting climate change in developing countries.

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