Going Slow to Reduce Emissions

Can the current surplus of maritime transport capacity be turned into an opportunity to reduce GHG emissions?

Report
Delft, January 2010

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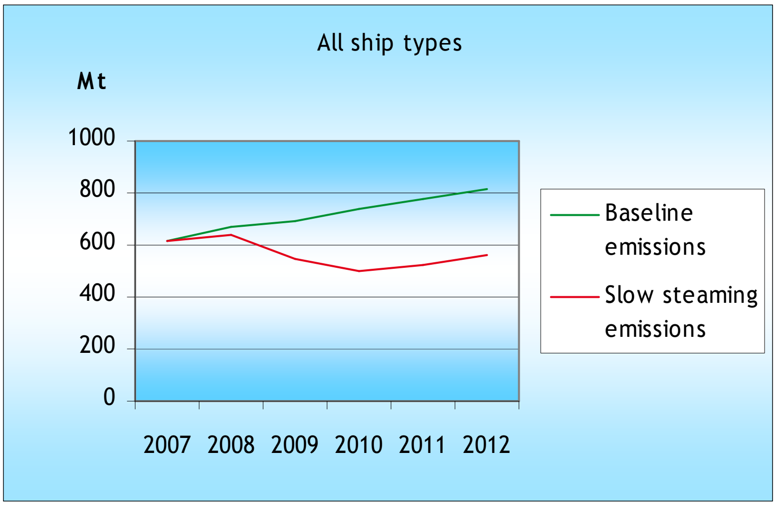
Summary

Global shipping emits over 3% of manmade greenhouse gases. In order to contribute to reducing emissions and keeping the temperature rise well below 2 °C, it needs to reduce its absolute emissions. A large number of measures may contribute to this, of which lowering the speed is an important one.

The global shipping industry currently faces an oversupply of ships. This creates an unique opportunity to reduce speed in order to match the supply with demand. This would also result in lower emissions.

This report estimates that emissions of bulkers, tankers and container vessels can be reduced maximally by about 30% in the coming years by using the current oversupply to reduce speed, relative to the situation in 2007. This estimate takes technical constraints into account. It is based on projected global trade growth rates and fleet developments. For container vessels, the reduction is somewhat lower, for bulkers it is higher.

Figure 1 Baseline emissions and maximum emission reductions with slow steaming



To some extent, speeds have been reduced in the past year, so some of the emission reductions have already been realised. Hence, the additional emission reduction potential is smaller than the maximum potential.

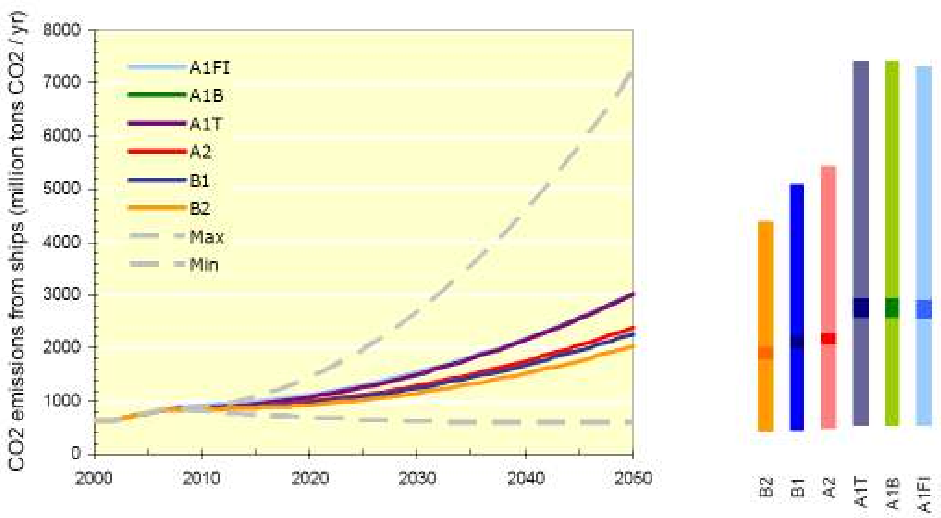
1 Introduction

1.1 Shipping and emissions of greenhouse gases

Shipping emitted approximately 1,000 Mt CO_2 in 2007 globally, and international shipping approximately 870 Mt CO_2 (IMO, 2009). These figures amount to 3.3 and 2.7% of global manmade greenhouse gas (GHG) emissions, respectively.

GHG emissions of maritime transport are projected to increase in the coming decades, driven by a growing demand for transport that outpaces fuel efficiency gains. In turn, demand growth is driven mainly by economic growth. IMO (2009) project emissions to increase to between approximately 2000 Mt and 3000 Mt CO_2 in most mid-range assumptions (see Figure 2).

Figure 2 Projections of maritime transport CO_2 emissions



Source: IMO, 2009.

Unconstrained growth of maritime GHG emissions would significantly increase the share of these emissions in total emissions, assuming that other anthropogenic emissions are reduced in order to keep the temperature increase below 2 °C, as agreed by major emitters in the Copenhagen Accord. In order to contribute to meeting the temperature target, shipping will have to reduce its absolute emissions considerably.

1.2 Measures to reduce shipping emissions

Reductions of absolute emissions probably require a large number of different measures to be taken. Increasing the operational efficiency of the fleet (in terms of emissions per tonne mile) is one category of measures. CE et al. (2009) estimate that the efficiency can be improved by 25-45% in 2030. IMO (2009) estimate that gains of 25-75% will be possible by 2050. While these efficiency improvements are unlikely to be sufficient to reduce absolute emissions, they would result in a much slower emission growth rates.

Improving the operational efficiency includes measures as diverse as new ship concepts, new hull and superstructure designs, improved power and propulsion systems, low carbon fuels, the use of renewable energy sources such as wind power, fleet management, voyage optimisation, et cetera.

Ships can improve their operational efficiency significantly by sailing at slower speeds. Generally, fuel use and speed are related by a third-power function, so a 10% reduction in speed corresponds to a drop in emissions of approximately 27% per unit of time or 19% per unit of distance. In reality, the reduction in emissions will be a little higher than 19% per unit of distance as ships sail only a part of their time at their optimal speed.

Reductions in operational speed stand out from other measures to reduce emissions as they do not require modifications to the ship. Thus, speed reduction can in theory be introduced overnight. However, speed reductions do require more ships for the same amount of transport work, and also affect the logistical chain by increasing the time at sea of cargo. Hence, contracts need to be changed and other changes in shipping practices may be needed.

1.3 Using the current oversupply of ships to reduce speed

There is currently a large oversupply of maritime transport capacity, caused partly by the recession and partly by the fact that ship orders were at record highs just before the recession struck (see e.g. Platou, 2010). Shipping companies have to some degree reacted by slowsteaming (Notteboom et al., 2008), thereby using the oversupply to lower their fuel costs and CO_2 emissions.

This report assesses what the potential benefits would be of using the current oversupply of ship capacity to increase the amount of slowsteaming. Of course, such a measure would be complicated by a number of technical, practical, logistical and legal issues. This report does not look into these complicating factors. It rather asks the question whether from an environmental point of view, it could be worthwhile to use the current oversupply of ships to increase slowsteaming.

To this end, this report analyses the relation between speed and GHG emissions in Chapter 2; our model to estimate the benefits of slow steaming is presented in Chapter 3 and the results of this model in Chapter 4.

2 Ship speed and emissions

2.1 The relationship between speed and fuel consumption

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.

However, this 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) strongly varies with the engine's load.

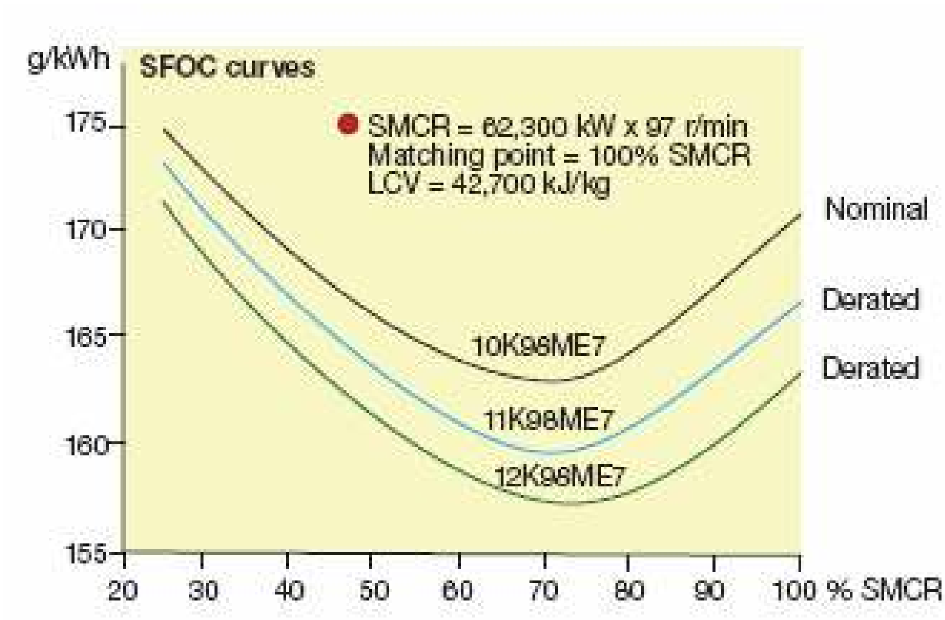
In examining this relation, 2-stroke and 4-stroke engines should be distinguished due to different operational principles of the engines. In general, 4-stroke engines are used in smaller ships and 2-stroke engines in larger ships. Typical engine applications are:
- 4-stroke: Container feeder, multipurpose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

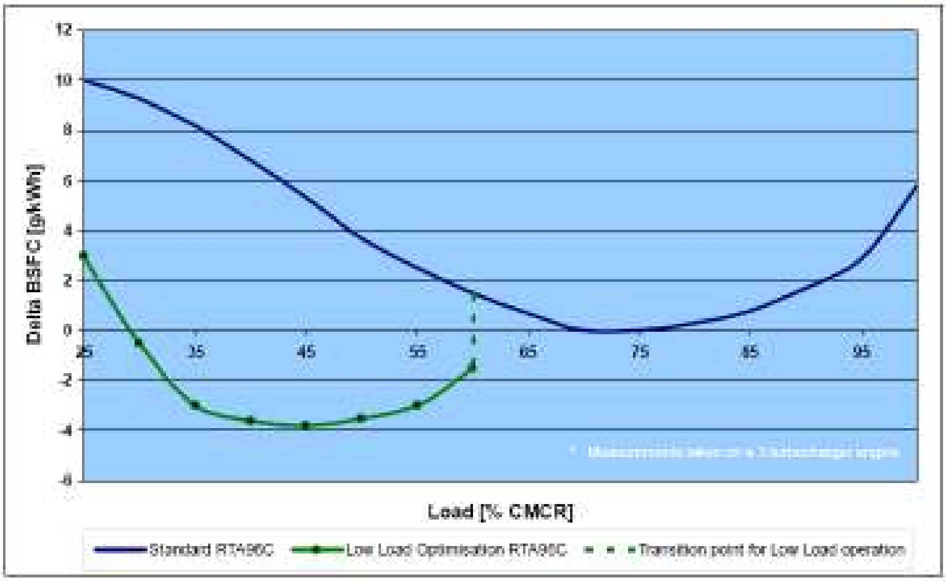
Figure 3 and Figure 4 are showing the variations of fuel consumption depending on engine load. The displayed values are for ideal engines taken from manufacturers' brochures, with effects of optional retrofits for slow steaming.

Figure 3 Example of the relation between engine load and specific fuel oil consumption for a 2-stroke engine



Source: MAN.

Figure 4 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 be not sufficient and therefore an oil boiler must be use to generate sufficient heat onboard.
- 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 compounds are more critical, for example auxiliary blowers which 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 compounds. If all auxiliary blowers would be 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.

2.2 Minimum engine loads

Engines cannot be operated at any load without adjustments to the engine. The minimum load depends on the technical specification of the manufacturer for each individual engine. Even engine of the same engine type might differ to each other, depending on engine configurations such as revolutions, stroke, etc.

Experience gained in recent years sailing with slow steaming have shown following damages:
– Increased pollution of the exhaust gas economiser through increased appearance of soot. Exhaust gas economiser fires due to built up of soot were occurred.
– 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.

The above mentioned damages, which have occurred in the past, occurred during ‘normal’ slow steaming not explicit running engines below their minimum load. It is to expect that the frequency of these damages will increase when running an engine below their minimum load. Engine manufactures advice against possible damages caused by slow steaming in their technical specifications.

Trials have shown that for 2-stroke engines the limit could be set to about 40% without permanent use of auxiliary blowers, for 4-stroke engines the limit is lower, perhaps as low as 10% of MCR. Electronically controlled engines are more flexible to operation in off-design and can generally be operated at lower loads than mechanically controlled engines. If ship operators want to reduce speed below these levels, they can derate their engines or install ‘slow steaming upgrade kits’.

3 The Model

In this chapter the model that has been used to determine the emission reduction potential of slow steaming is described in greater detail. Starting point of the analysis is the fleet/emission inventory for 2007 of the second IMO GHG study (IMO, 2009). In Annex A you can find a table with the data given in this report.

3.1 Basis model assumptions

The model matches supply of maritime transport with demand by adjusting the productivity of ships. In this study, productivity is only adjustable by slow steaming and varying the capacity utilization of the ships accordingly.

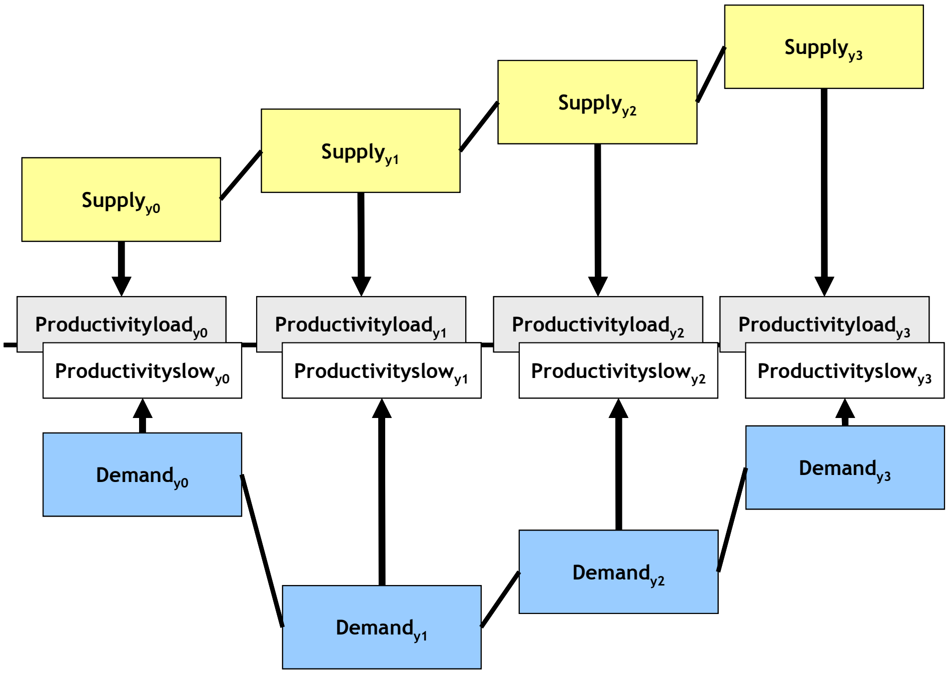
Both supply and demand are considered to be exogenous. Supply of ships, at least in the time period considered, is assumed to be a function of the current fleet size, the order book and the expected scrapping. Demand for transport services is assumed to be perfectly correlated with changes on volume of world trade. In other words, we assume that both, the share of maritime transport in total transport and trade routes are stable over the period considered.

A graphical presentation of the model is shown in Figure 5. The supply of ships in dwt develops in line with the order book and the expected scrapping. The demand for transport falls because of the recession and rises in subsequent years. The model adjusts the productivity each year so that supply matches demand. This is done in two ways (see Figure 5):

1. By adjusting the average amount of cargo that ships carry, but not the speed.
2. By adjusting the average service speed of the fleet, but not the average amount of cargo.

For each of these fleet productivities, emissions are calculated taking into account either lower cargo load factors or lower engine load factors.

Figure 5 Graphical presentation of the model



We assume that in 2007 supply and demand for maritime transport work were in equilibrium. We derive in the first instance the fleet supply and the demand for transport work for the period 2008-2013[1]. Then the emissions without slow steaming are determined. Deriving the potential for slow steaming we are then able to calculate emission reduction potential of slow steaming.

3.2 Supply of transport

3.2.1 Supply of transport in 2007

We approximate the supply of maritime transport in 2007, i.e. the fleet in dwt and TEU, by making use of the average cargo capacity and the number of ships per ship size categories as specified in the second IMO GHG study (IMO, 2009). This leads to the following supply per ship type in 2007:

Table 1 Supply of transport in 2007

Results:	2007
Bulker fleet, dwt	391,662,800
Tanker fleet, dwt	413,330,403
Container flleet, dwt	142,392,910
Container fleet, TEU*	10,466,036

*Average of begin 2007 and begin 2008: 13.52 dwt/TEU (UNCTAD, 2008).
Dwt is determined by average cargo capacity together with the weight of containers (7 ton/TEU).

To assess this approximation we compared this result with fleet data as given in UNCTAD (2008).

1 For 2013 the supply can only be determined for container ships.

Table 2 **UNCTAD (2008) fleet supply data**

	Begin 2007	Begin 2008	Mid 2007 (average)
Bulker fleet, dwt	367,542,000	391,127,000	**379,334,500**
Tanker fleet*, dwt	418,713,000	446,130,000	**432,421,500**
Container flleet, dwt	128,321,000	144,655,000	**136,488,000**
Container fleet, TEU	9,436,377	10,760,173	**10,098,275**

* Oil tanker, liquefied gas tanker and chemical tanker.

Taking the fleet supply data derived from the IMO data as mid-year-numbers[2] and comparing them with the average of the begin-2007 and begin-2008 data as given in UNCTAD (2008) the following can be stated:

- The bulker fleet supply derived from the IMO study is about 3.3% higher.
- The tanker fleet supply derived from the IMO study is about 4.4 % lower.
- The allocation of the tanker fleet supply over the types of tankers differs in the sense that the supply of oil tankers as derived from the IMO study is relatively low and the supply of chemical tankers as derived from the IMO study is relatively high.
- The container fleet supply as derived from the IMO study is about 3.5% higher.

From this comparison we concluded that the fleet supply data we derived from the IMO study does deviate from the fleet supply data provided by UNCTAD (2008) but that this difference lies within an acceptable range.
To guarantee consistency, the supply and demand data for 2008-2013 has been derived by applying relative and not absolute changes to the 2007 data derived from the IMO data.

3.2.2 Supply of transport 2007-2012

The development of the supply of transport is based on two data sources:

- GL Market Intelligence. And
- UNCTAD (2008, 2009).

From UNCTAD (2008, 2009) we know the fleet capacity for the period begin 2007-begin 2009.

Table 3 **Fleet capacity for the period begin 2007-begin 2009**

		Begin 2007	Begin 2008	Begin 2009
Bulkers	dwt	**367,542,000**	**391,127,000**	**418,356,000**
Oil tankers	dwt	382,975,000	407,881,000	418,266,000
Liquefied gas tankers	dwt	26,915,000	30,013,000	36,341,000
Chemical tankers	dwt	8,823,000	8,236,000	8,141,000
Tankers		**418,713,000**	**446,130,000**	**462,748,000**
Container ships	dwt	**128,321,000**	**144,655,000**	**161,919,000**

Source: UNCTAD, 2009.

From GL we know the fleet supply growth index for the different ship types from end 2008-end 2013.

[2] The time reference in the IMO GHG report, in terms of begin-/mid-/end-year figure is not clear.

Table 4 **Fleet supply growth index**

	Bulker	Tanker	Container ships		
			<3,000 TEU	3-8,000 TEU	>=8,000 TEU
End 2008	100	100	100	100	100
End 2009	107	110.5	98	108	125
End 2010	116	110	93	112	170
End 2011	122	118	91	114	220
End 2012	128	120	90	120	265
End 2013	n.s.	n.s.	98	121	270

Source: GL Market Intelligence.

Growth rates are derived from these data. Thereby we took the sum of the capacity of the different tankers to derive a growth rate from the UNCTAD data. We applied the growth rates of bulkers and tankers evenly to all the ship size classes. This results in the following fleet supply from 2007 until 2013.

Table 5 **Fleet supply from 2007 until 2013 (in dwt)**

	Mid 2007	Mid 2008	Mid 2009	Mid 2010	Mid 2011	Mid 2012	Mid 2013
Bulkers	391,662,800	428,143,752	468,082,548	504,262,841	538,181,866	565,317,087	-
Tankers	413,330,403	434,594,284	465,773,815	487,900,837	504,496,103	526,623,125	-
Container ships	142,392,910	161,176,312	175,964,571	186,587,926	198,465,696	210,884,644	219,637,419

The according number of ships in the fleet is derived, assuming that the average cargo capacity per ship size class does not change over time.

Table 6 **Fleet supply form 2007 until 2013 (number of ships)**

	Mid 2007	Mid 2008	Mid 2009	Mid 2010	Mid 2011	Mid 2012	Mid 2013
Bulkers	7,391	8,079	8,833	9,516	10,156	10,668	-
Tankers	12,524	13,168	14,113	14,784	15,286	15,957	-
Container ships	4,163	4,712	5,016	5,025	5,037	5,106	5,286

3.3 Demand for transport work

In the next step the demand for transport work (tonmiles) is determined for the years 2008-2013. Starting point is the transport work that has been done in 2007 as specified in the IMO study. The demand for the period 2008-2013 is derived, making use of growth data of the World Economic Outlook of the IMF (IMF, 2009). More specific, for 2008-2010 we used the annual percentage change of the world-wide trade volume (which we assumed to be the average of the import volume and the export volume that did not match) and for 2011-2013 the annual percentage change of the world-wide volume of the trade of goods and services. The according annual percentage changes are given in Table 7.

Table 7 **Annual percentage change of demand for transport work as used in study**

2007	2008	2009	2010	2011	2012	2013
6.6%	2.7%	-13.0%	2.7%	6.4%	6.4%	6.4%

3.3.1 Emissions

To be able to determine the emission reduction of slow steaming both has to be determined, the emissions when no slow steaming is applied and the emissions when slow steaming is applied. The former are called the baseline emissions.

The emissions under slow steaming are determined making the simplifying assumption that only the emissions from the main engines are affected by slow steaming. The emissions of the auxiliary engines and the boilers (of crude oil and product tankers) are taken to be constant per ship.

The emissions of the main engines of a ship type category are determined as follows:

$$Emissions = SFOC * Power * Engine\,Load * DaysAtSea * 24\ .$$

The emissions of the main engines of a ship type category are thus determined by the specific fuel consumption (SFOC), by the power of the main engines, by the engine load of the main engines, and by the annual hours a ship is at sea. Thereby, for each variable the average per ship type category is taken.

3.3.2 Baseline emissions

Given the demand for transport work and given the supply of ships as derived above, the baseline emissions are determined, assuming that the average speed of the ships in the period 2008-2013 is the same as the average speed in 2007.

In the model it can be accounted for a certain percentage of the ships of a category to be laid-up. For the container fleet we know from GL the share of the fleet that has been laid-up in the period October 2008 until January 2010 in terms of TEU. We estimated that in 2008 on average about 1% and in 2009 on average about 10% of the total container fleet capacity has not been used. For the period 2010-2013 it is difficult to predict the amount of lay-up. We therefore decided to take the two extreme cases into account that either no container ships or that 10% are laid-up in this period.

In case of the baseline emissions, the capacity utilisation of the ships is taken to be endogenous. It is being determined by assuming that the cargo is evenly spread over the ships per size category.

From GL we know that the degree of capacity utilization has an impact on the emissions of a vessel. We derived two different baseline emissions, one where this effect is not taken into account and another where it is taken into account. This shows that the effect should be accounted for, otherwise leading to a significant overestimation of the baseline emissions.

From GL we know that for bulkers the difference of fuel oil consumption between laden and empty voyages can be expected to be between 8 and 10 % (being 100% power demand loaded and 90-92% at ballast). For tankers the results can be expected to be similar. For containers the difference between least loaded voyages (rarely sail in ballast) and most loaded voyages differs with ship size, being 10-30% for feeders, 15-25% for PanMax vessels and 6-15% for Post-PanMax vessels.

The impact of the degree of capacity utilization on the emissions of a vessel have been incurred in the model as follows:
We assumed that, consistent throughout the study, the capacity utilization of the ships is at its maximum in 2007. We further assumed that the capacity utilization of container vessels when least loaded is 30 %. The overall emissions under ballast/least loaded are taken to be:
- 9% lower for bulkers and tankers.
- 20% lower for container vessels < 5,000 TEU.
- 10% lower for container vessels ≥ 5,000 TEU.

than under maximum capacity utilization.
We take a linear function to approximate the relationship between percentage overall emission reduction and capacity utilization.

In Table 8 and

Table 9 the baseline emissions are given for the case that the lower emissions due to a lower capacity utilization is taken into account.

Table 8 Baseline CO_2 emissions (Mt) with no lay-up of container ships in 2010-2013

	2007	2008	2009	2010	2011	2012	2013
Tankers	227	239	254	264	273	285	-
Bulkers	166	181	195	208	222	233	-
Container ships	223	247	242	268	281	298	301
Total	617	666	691	739	776	816	301

Table 9 Baseline CO_2 emissions (Mt) with 10% lay-up of container ships in 2010-2013

	2007	2008	2009	2010	2011	2012	2013
Tankers	227	239	254	264	273	285	-
Bulkers	166	181	195	208	222	233	-
Container ships	223	247	242	248	261	276	281
Total	617	666	691	720	755	794	281

3.3.3 Emissions under Slow Steaming

To be able to determine the emissions under slow steaming, the maximum possible speed reduction is determined in the first instance. The speed reduction is restricted:
- By the fact that the demand for transport work per year has to be met.
- By the supply of ships.
- By the maximum capacity utilization of the vessels.
- And by the fact that the engines can be harmed when the load of the engines is too low.

The relationship between the actual speed of a ship, the maximum speed of a ship, and its engine load is as follows:

$$Engine\ Load = \left(\frac{Actual\ Speed}{Maximum\ Speed}\right)^3$$

We derived the average maximum speed per ship size category from the average engine load of the main engines and the average speed as given in the IMO GHG report for 2007.

The maximum reduction potential through slow steaming without retrofit measures cannot be generalised. However, for the calculation model the following minimum engine loads are assumed (which have been observed by GL on long term measurement on certain ships):

– 10% for 4-stroke engines and
– 40% for 2-stroke engines.[3]

Then the following speed reductions turn out to be feasible in the period 2008-2013.

Table 10 Maximum possible speed reduction when no retrofit measures are taken

	Tanker	Bulkers	Container ships
2008	0-0.5%	4%	8%
2009	12%	17%	15-16%
2010	16-21%	17-27%	15-18%
2011	16-20%	17-29%	11-16%
2012	16-18%	17-28%	4-16%
2013 (for container only)	-	-	2-16%

In 2008 the potential for slow steaming is relatively low, especially for tankers. For some types of tankers there is even no scope for speed reduction. Here the small speed reduction the fleet size would allow for would, even lead to an increase in emissions: the higher SFOC would outweigh the negative effect of the speed reduction on emissions. From 2009-2012 the potential for slow steaming is significantly higher, ranging from 12-20% for tankers, 17-29% for bulkers and 4-16% for container ships.

Note that it has not been taken into account that there has been made use of slow speeding in 2008 and 2009. This can lead to an overestimation of the potential for slow steaming.

To determine the emissions under slow steaming, not only the potential speed reduction has to be determined but also the impact of the change of the speed on the specific fuel oil consumption (SFOC).

From GL we know that the SFOC varies with the engine load and that the SFOC can be, as a first approximation, be estimated as a function of the engine load. The minimum SFOC lies roughly speaking at 85% of the engine load.

In the IMO GHG study a range of typical values of specific fuel oil consumptions are given for different engine types and for different ranges of years of construction of the engine. Assuming that the lower value of a range is the minimum value (at 85% engine load) we used the arithmetic mean of the lower values of the engines stemming from 1984-2000 and 2001-2007, not knowing the age structure of the engines in the fleet.

[3] In Annex B you can find an overview of the engine type we assumed the ship size categories to have.

Table 11 **Minimum SFOC as assumed in this study (g/kWh)**

	2-stroke	4-stroke	4-stroke	4-stroke
		> 5,000	1,000-5,000 kW	< 1,000 kW
1984-2000	170	180	180	200
2001-2007	165	175	180	190
Average	**167.5**	**177.5**	**180**	**195**

We approximated the relationship between the engine load and the SFOC by estimating per ship size category a parabola that goes through the minimum as specified above and that, at the same time, goes through the engine load-SFOC combination as specified in the IMO inventory in 2007.
Since these parabola lead to unrealistic high SFOC values for very low engine loads we additionally defined an upper limit for the SFOC. This maximum value is taken to be 210 g/kWh for 2-stroke engines. For 4-stroke engines 375 g/kWh for ships with average ME power ≤ 4 MW and 305 g/kWh for ships with average ME power > 4 MW.

Given the maximum possible speed reduction as determined in the table above, the emissions of the fleet under consideration then turn out to be as follows.

Table 12 **CO_2 emissions under slow steaming (Mt)**

	2008	2009	2010	2011	2012	2013
Tankers	227	238	212	184	194	208
Bulkers	166	174	131	124	130	138
Container ships	223	227	201	190	200	215
Total	617	640	545	498	524	561

4 Using oversupply of ships to steam slowly

When tankers, bulkers and containers would reduce their speed up to an extent that the oversupply in the market is being used and that no retrofit measures would have to be taken, our model shows that the CO_2 emissions of this part of the world fleet could be reduced significantly in the period 2007-2013.

In Table 13 and Table 14 the absolute and the relative reduction potentials per year and ship type are given, related to the baseline emissions of these ship types. Some reduction potentials are given as a range. This reflects the fact that the number of container vessels laid-up in 2010-2013 is difficult to predict.

Table 13 Absolute CO_2 emissions reduction potential of slow steaming (Mt)

	2008	2009	2010	2011	2012	2013
Tankers	1	41	79	79	77	-
Bulkers	6	64	84	92	95	-
Container ships	19	41	58-77	60-81	61-83	52-72
Total	27	146	221-241	232-252	233-255	52-72

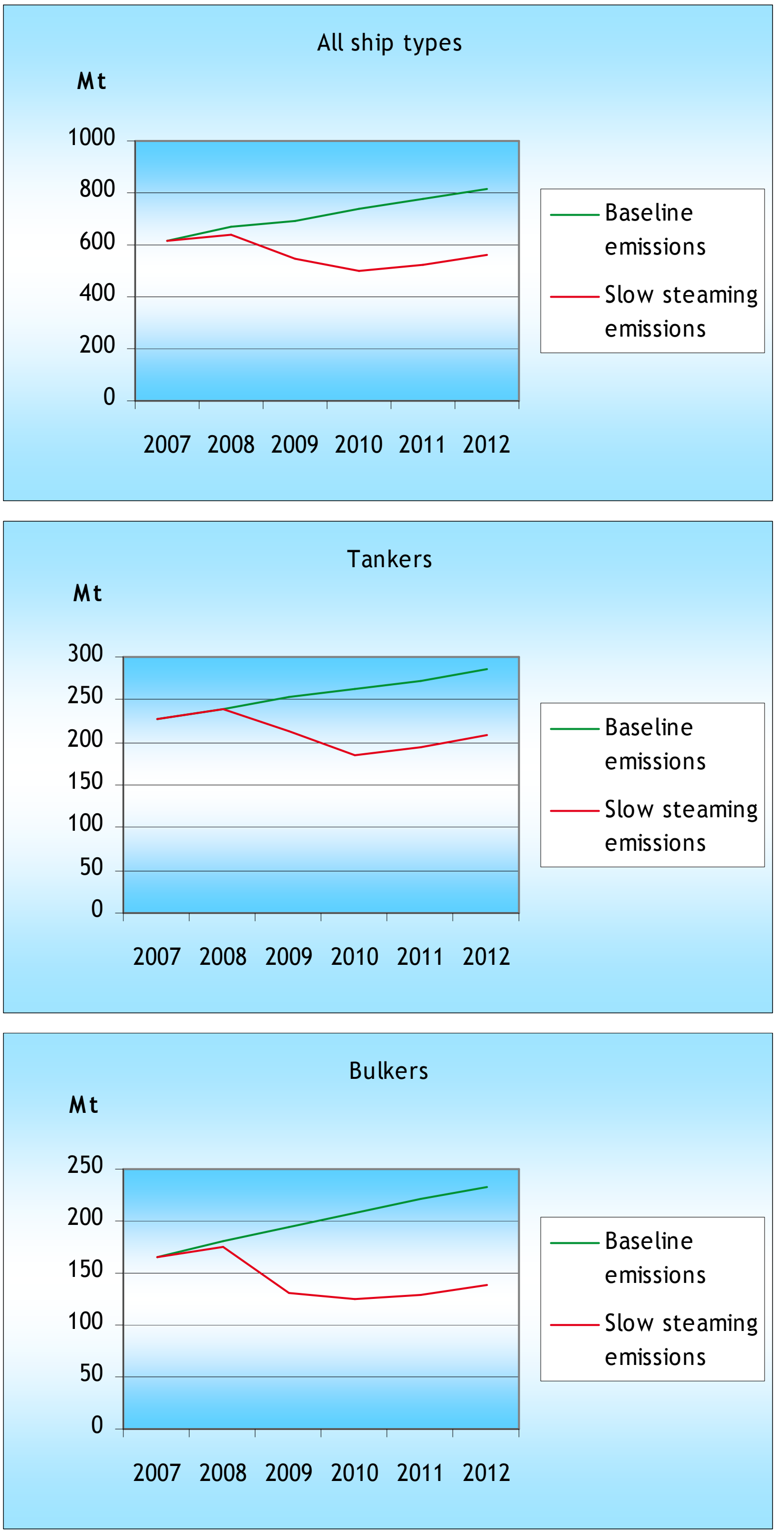
Table 14 Relative CO_2 emissions reduction potential of slow steaming

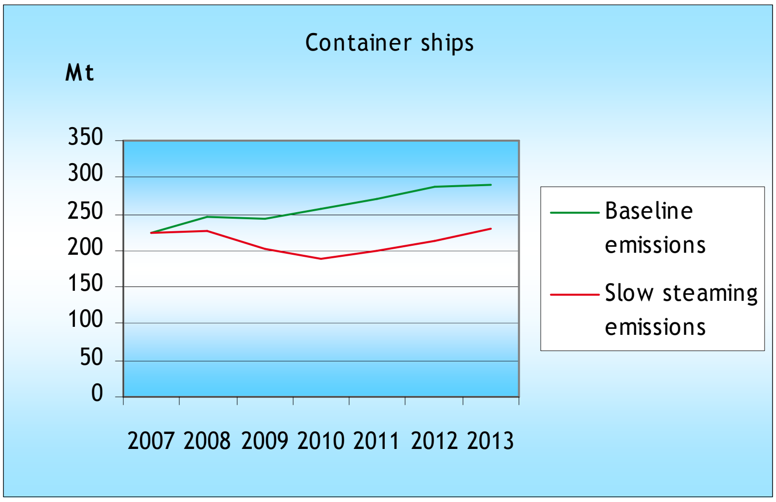
	2008	2009	2010	2011	2012	2013
Tankers	0.4%	16%	30%	29%	27%	-
Bulkers	4%	33%	40%	42%	41%	-
Container ships	8%	17%	23-29%	23-29%	22-28%	19-24%
Total	4%	21%	31-33%	31-33%	30-32%	

The relative reduction potential per year, tankers, bulkers, and container ships taken together, ranges from 4 to 33%, the absolute reduction potential from 27 to 255 Mt per year. The absolute reduction potential is the highest in 2012 with about 245 Mt. This is equal to a relative reduction of about 32%. When looking at the different ship types, the reduction potential is the highest for bulkers since oversupply allows bulkers to reduce the average service speed up to 30%.

Baseline emissions and absolute reduction potential are illustrated in the following graphs. The 2010-2013 baseline emissions of the container fleet are depicted on average.

Figure 6 Baseline emissions and maximum emission reductions with slow steaming





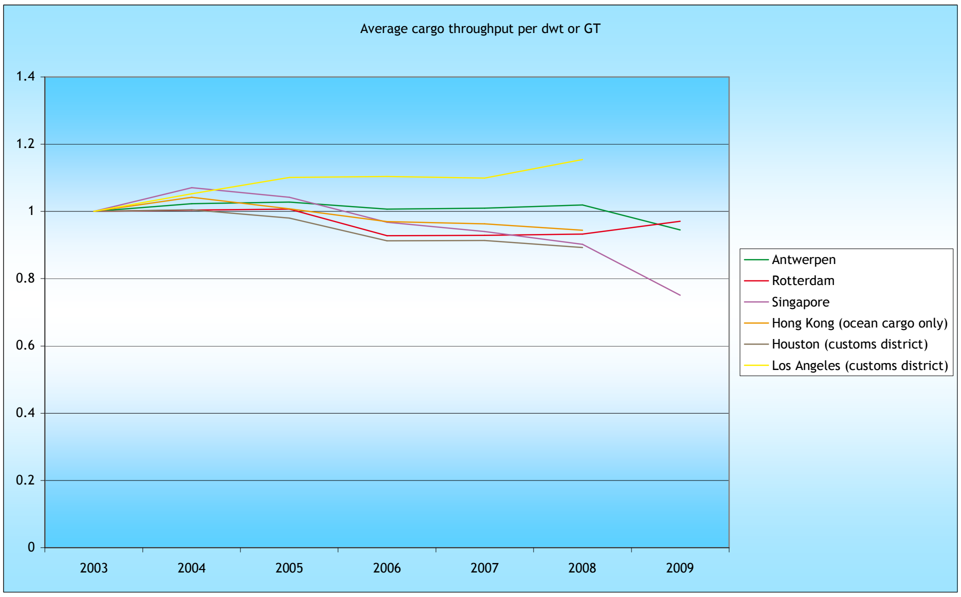
Source: This report.

5 Discussion of results

Chapter 4 shows that the potential fuel and emission savings of slow steaming are considerable. A share of these savings has already been achieved, as many shipping companies have announced slow steaming (see e.g. Maersk, 2009; ZIM, 2009; Cosco, 2009; Notteboon and Vernimmen, 2008). Most publicity has been generated by container shipping companies. We do not know whether this is because they are the main sector that has reduced speed or whether they are more likely to publicly announce it because of their diverse customer base.

In addition, shipping companies have idled ships. In 2009, over 10% of the container capacity was said to be laid up (Journal of Commerce, 2009). The extent to which load factors have been reduced is hard to estimate. On the one hand, companies like A.P. Møller Maersk have stated 'Capacity utilisation was generally lower in 2009 than in 2008' (A.P. Moller - Maersk Group, 2010). On the other hand, data from ports on tonnage of ships and throughput shows different trends for different ports (see Figure 7). If anything, there seems to be trend of decreasing capacity utilisation that stretches over years.

Figure 7 Cargo throughput per unit of capacity in selected ports



Source: Port Authorities; for US customs district: U.S. Department of Transportation Maritime Administration.

So some of the benefits calculated above are already present. We are not able to estimate with any accuracy how much emissions are currently reduced relative to the baseline, but we expect that in theory, more emission reductions are possible.

6 Conclusions

The economic recession has resulted in a significant decrease in the volume of cargo transported internationally. As the major share of cargo is transported over sea, maritime transport has been hard hit. Moreover, pervious to the recession, the shipping industry had ordered a record amount of transport capacity, much of which is being delivered this year and the following years. As a result, the shipping industry faces a significant oversupply of ships which is likely to last for several years.

There are several ways in which the industry can deal with the oversupply of ships. One is to decrease the amount of cargo carried per ship, another is to idle ships, and a third is to sail at lower speeds. The latter option has the advantage that fuel is saved and emissions are reduced.

This report estimates the potential emission reductions of slow steaming. It does so against a baseline in which ships continue to sail at their historic speeds, but decrease the average amount of cargo they carry. The report demonstrates that from 2010 through 2012, emission reductions in the order of 30% are maximally achievable without the need for retrofitting slow steaming equipment. For bulkers, the potential reductions are even higher.

A share of these emission reductions are currently realised as ships are slow steaming. However, there seems to be additional potential to sail even slower. Of course, realising all of these savings will require certain technical and operational barriers to slow steaming to be addressed.

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Annex A 2007 Fleet Data

Table 15 Fleet data as given for 2007 in the IMO GHG study

			Average cargo capacity (tonne)	Average yearly capacity utilization	Average service speed (knots)	Transport work per ship (tonne-nmiles)	# Ships	Average ME kW	Average ME load	AE average CO_2 emissions per ship (tonne)	Boiler average CO_2 emissions per ship (tonne)
Tankers	Crude oil	200,000+ dwt	295,237	47.56%	15.4	14,197,046,742	494	24,610	73%	3,711	3,775
	Crude oil	120 -199,999 dwt	151,734	47.38%	15	7,024,437,504	353	7,075	80%	4,420	2,718
	Crude oil	80 -119,999 dwt	103,403	47.59%	14.7	4,417,734,613	651	12,726	80%	2,885	9,060
	Crude oil	60 -79,999 dwt	66,261	47.51%	14.6	2,629,911,081	80	10,529	70%	2,438	9,060
	Crude oil	10 -59,999 dwt	38,631	47.39%	14.5	1,519,025,926	245	7,889	70%	2,431	4,530
	Crude oil	-9,999 dwt	3,668	47.51%	12.1	91,086,398	114	1,865	65%	757	1,545
	Products	60,000+ dwt	101,000	55.07%	15.3	3,491,449,962	198	12,644	80%	2,927	10,872
	Products	20 -59,999 dwt	40,000	54.93%	14.8	1,333,683,350	456	8,482	66%	2,762	9,060
	Products	10 -19,999 dwt	15,000	50.00%	14.1	464,013,471	193	4,640	70%	1,783	5,436
	Products	5 -9,999 dwt	7,000	44.92%	12.8	170,712,388	466	2,691	75%	991	2,781
	Products	-4,999 dwt	1,800	45.20%	11	37,598,072	3,959	1,032	65%	419	927
	Chemical	20,000+ dwt	32,200	64.17%	14.7	1,831,868,715	1,010	9,027	80%	3,004	0
	Chemical	10 -19,999 dwt	15,000	63.99%	14.5	820,375,271	584	5,161	80%	2,077	0
	Chemical	5 -9,999 dwt	7,000	63.99%	14.5	382,700,554	642	3,252	76%	1,418	0
	Chemical	-4,999 dwt	1,800	63.99%	14.5	72,147,958	1,659	1,257	65%	736	0
	LPG	50,000+ cbm	46,656	47.49%	16.6	2,411,297,106	138	13,494	70%	3,603	0
	LPG	-49,999 cbm	3,120	47.50%	14	89,631,360	943	3,225	65%	1,487	0
	LNG	200,000+ cbm	97,520	47.53%	19.6	5,672,338,333	4	37,322	70%	11,517	0
	LNG	-199,999 cbm	62,100	47.53%	19.6	3,797,321,655	239	24,592	70%	8,322	0
Bulker	Bulker	200,000+ dwt	227,000	49.42%	14.4	10,901,043,017	119	17,224	71%	3,573	0
	Bulker	100 -199,999 dwt	163,000	49.42%	14.4	7,763,260,284	686	15,108	70%	3,136	0
	Bulker	60 -99,999 dwt	74,000	55.12%	14.4	3,821,361,703	1,513	9,912	70%	2,471	0
	Bulker	35 -59,999 dwt	45,000	55.10%	14.4	2,243,075,236	1,864	8,209	70%	2,264	0
	Bulker	10 -34,999 dwt	26,000	55.18%	14.3	1,268,561,872	2,090	6,436	70%	2,138	0
	Bulker	-9,999 dwt	2400	59.82%	11	68,226,787	1,120	1,532	65%	968	0
Container	Container, unitzed	8,000+ teu	68,600	69.95%	25.1	6,968,284,047	118	68,477	67%	18,096	0
	Container, unitzed	5 -7,999 teu	40,355	69.99%	25.3	233,489,679	417	55,681	65%	14,293	0
	Container, unitzed	3 -4,999 teu	28,784	70.15%	23.3	2,820,323,533	711	34,934	65%	8,720	0
	Container, unitzed	2 -2,999 teu	16,800	69.86%	20.9	1,480,205,694	667	21,462	65%	6,654	0
	Container, unitzed	1 -1,999 teu	7,000	69.97%	19	578,339,367	1,115	12,364	65%	4,338	0
	Container, unitzed	-999 teu	3,500	69.95%	17	179,809,363	1,110	5,703	65%	2,455	0

Source: IMO, 2009.

Annex B Engine Type per Ship Category

Table 16 Assumed main engine type per ship category

			ME type
Tankers	Crude oil	200,000+ dwt	2-stroke
	Crude oil	120 -199,999 dwt	2-stroke
	Crude oil	80 -119,999 dwt	2-stroke
	Crude oil	60 -79,999 dwt	2-stroke
	Crude oil	10 -59,999 dwt	2-stroke
	Crude oil	-9,999 dwt	4-stroke
	Products	60,000+ dwt	2-stroke
	Products	20 -59,999 dwt	2-stroke
	Products	10 -19,999 dwt	2-stroke
	Products	5 -9,999 dwt	4-stroke
	Products	-4,999 dwt	4-stroke
	Chemical	20,000+ dwt	2-stroke
	Chemical	10 -19,999 dwt	2-stroke
	Chemical	5 -9,999 dwt	4-stroke
	Chemical	-4,999 dwt	4-stroke
	LPG	50,000+ cbm	2-stroke
	LPG	-49,999 cbm	4-stroke
	LNG	200,000+ cbm	2-stroke
	LNG	-199,999 cbm	2-stroke
Bulker	Bulker	200,000+ dwt	2-stroke
	Bulker	100 -199,999 dwt	2-stroke
	Bulker	60 -99,999 dwt	2-stroke
	Bulker	35 -59,999 dwt	2-stroke
	Bulker	10 -34,999 dwt	2-stroke
	Bulker	-9,999 dwt	4-stroke
Container	Container, unitzed	8,000+ teu	2-stroke
	Container, unitzed	5 -7,999 teu	2-stroke
	Container, unitzed	3 -4,999 teu	2-stroke
	Container, unitzed	2 -2,999 teu	4-stroke
	Container, unitzed	1 -1,999 teu	4-stroke
	Container, unitzed	-999 teu	4-stroke