



**Regulating speed:
a short-term
measure to reduce
maritime GHG
emissions**



Committed to the Environment

Regulating speed: a short-term measure to reduce maritime GHG emissions

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Summary

Shipping GHG emissions are projected to increase by 20-120% between 2012 and 2050. In fact, they have increased by 2.4% in the period 2013-2015.

The Paris Agreement aims to let global emissions peak as soon possible and decline towards zero in the second half of this century. If shipping is to contribute to achieving the Paris Agreement goals, it should reverse the upward trend soon.

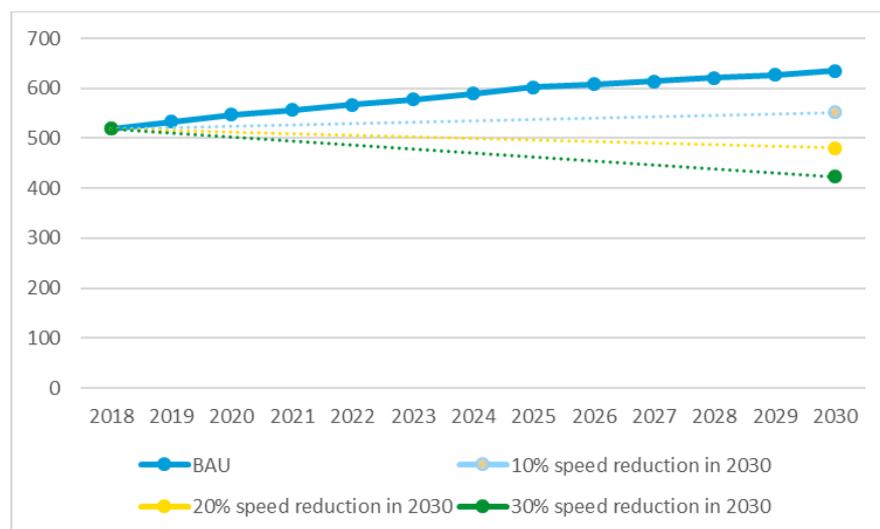
The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) is working on a Comprehensive Strategy on the Reduction of Greenhouse Gas Emissions from Ships, the initial version of which should be finalised in April 2018. Amongst others, the Strategy will contain a list of candidate short- medium- and long-term measures to reduce emissions.

One of the few measures that will deliver emission reductions in the short-term, is slower steaming.

This report shows that speed of ships can be regulated either globally, unilaterally as a condition of entry into a port or as a condition to navigate in coastal waters, or bilaterally between ports in two states. In order to effectively reduce emissions, speed regulations have to be mandatory and there has to be an enforcement system that deters ships from not complying. Speed regulations can best be differentiated to ship type and size so that ships do not have to operate at technically challenging low loads and in order not to disturb the competition between ship types. An issue that needs to be studied in more detail is whether it is more effective to regulate average or maximum speeds. Probably regulating maximum speeds is easier to implement, because it does not require regulation on how averages would be calculated.

Requiring ships to slow down to such an extent that the idle and laid-up ships would be drawn back into the fleet would reduce emissions immediately by 4%. Further speed reductions of 20-30% would put shipping emissions on a declining pathway, thus contributing to reaching the goals of the Paris Agreement.

Figure 1 - Impact of speed reductions on maritime emissions in 2030



Slow steaming may change the terms of trade and may have a larger impact on the competitiveness of countries which are far away from their main markets. This study has analysed two cases of exports from South America to the EU. Even with very conservative assumptions about the impacts, the economic impacts of slow steaming appear to be modest: export values will be reduced by a few tenths of a percent at most, and the overall economic impact would be well below a tenth of a percent for the whole of South America.



1 Introduction

The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) is working on a Comprehensive Strategy on the Reduction of Greenhouse Gas Emissions from Ships, the initial version of which should be finalised in April 2018. Amongst others, the Strategy will contain a list of candidate short- medium- and long-term measures to reduce emissions.

Almost all States have agreed that anthropogenic greenhouse gas emissions need to peak ‘as soon as possible’ and reduce ‘rapidly’ after the peak to zero ‘in the second half of the century’ in the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC). This implies that shipping emissions also need to peak and subsequently decline. Hence, it is important to develop policy measures that can achieve a rapid reversal of the current trend of rising emissions (ISWG-GHG, 2017a) .

A review of measures that are proposed to be included in the Strategy shows that very few, if any, are able to achieve emission reductions in the short-term (ISWG-GHG , 2017b). One of the few that may do so is speed reductions.

As a rule of thumb, there is a cubic relation between speed and power for ships. This means that a speed reduction of 10% reduces power demand by 27%. Since ships cover less distance when they slow down, the reduction in energy per unit of distance is 19%, a square relation. While there are technical constraints, they appear to be manageable.

CE Delft et al. (2012) has extensively studied legal, technical and economic aspects of speed reductions. The main conclusions of that report were:

- 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 greater for ships that spend a large number of days at sea.
- Mandatory slow steaming is legally feasible either under a global agreement or unilaterally as a condition of entry to a port.

In recent discussions on regulated speed reductions, two main issues have come to the fore. First, concerns have been raised about the impact on States, especially on States that are far removed from their main markets. Second, questions have been asked about which policy instruments could effectively result in speed reductions.

The aim of this report is to assess the potential for shipping to reduce emissions through speed reductions immediately, as well as in the short- to mid-term, taking into account the demand for maritime transport, technical and operational constraints as well as the IMO Guidelines for determining the Minimum Propulsion Power. To that end, the following scenarios will be analysed:

1. The emission reduction that can be achieved by bringing the idle and laid-up ships back into the fleet and absorbing this additional capacity by reducing speed.
2. The emission reductions that will result from a 10, 20 and 30% reduction in speed, while simultaneously assessing the associated need for new vessels.

The report also presents two case studies about the impact on states, taking long-distance trade routes as an example.

Finally, the report discusses how speed can be regulated.



2 Emission reductions through speed changes

2.1 Introduction

This chapter analyses the emission reductions that can be achieved through changes in ship speed. It starts with looking into the constraints to reduction of design speed that are set by minimum power requirements. Next, it discusses operational speed changes and the impacts on the specific fuel consumption of the engine. The final sections quantify the speed reductions that can be achieved by bringing back the laid-up ships in the active fleet and by reducing speeds across the board by 10, 20 and 30%, respectively.

2.2 Speed and minimum power requirements

Ships need to be able to escape from adverse weather conditions. Responding to concerns about whether the EEDI could result in underpowered ships, the MEPC has developed guidelines for determining the minimum propulsion power of ships (MEPC.1/Circ.850/Rev.1) (IMO, 2015a). All new ships need to comply with the minimum propulsion power standard.

The minimum propulsion power is based on a minimum navigational speed of 4 knots, and a minimum course-keeping speed for bulk carriers and tankers of 4-9 knots, depending on the shape of the ship. Other studies into the subject assume that the speed through the water under adverse weather conditions needs to be at least 6 knots (MEPC 70/INF.30) (MEPC, 2016).

The minimum propulsion power is based on the speed that ships need to be *able* to attain when they encounter adverse weather conditions. It is not directly related to the speed at which ships sail, because they may operate their engines below the maximum continuous rate. In fact, the average speed at sea is often well below the design speed of a ship, suggesting that ships often operate their engines at part-load (IMO, 2015b).

When considering the potential to reduce speeds, this report assumes that ships will meet the minimum power requirements and that, if the reduced speeds are below the design speed, ships will operate their engines at part-load to attain the reduced speeds.

2.3 Speed, MCR and specific fuel consumption

Engines operating at part-loads are often less energy-efficient: the amount of fuel they require to produce a unit of power output increases with lower loads. This can offset a share of the energy-efficiency gains brought about by slow steaming.

Yu, et al. (2012) provide an example of a slow-speed diesel engine where a 33% speed reduction, requiring the engine to run at 25% MCR instead of 85% MCR, results in a 12% deterioration of the energy-efficiency of the engine. In this case, the fuel savings per unit of time would be 67% instead of 71%.



There are several remedies to the deterioration of the fuel efficiency at low loads. Yu, et al. (2012) show how changes to the start of injection and the compression ratio can improve the fuel efficiency by several percent. Holtbecker (2014) shows that cutting off one or more turbochargers, possibly in combination with the installation of an auxiliary blower, can have a large impact, as can engine de-rating. Also, new engines have a larger range over which they are optimised. If ships continue to sail at lower speeds, one or more cylinders could be cut off.

In conclusion, while the fuel efficiency of engines deteriorates at lower loads, the reduction in power demand is generally much larger than the deterioration in efficiency. Moreover, there are several remedies to mitigate the impact on fuel efficiency.

2.4 Speed and emission reduction potential

The speed and emission reduction potential of international maritime shipping has been analysed from two perspectives. First, the immediate (2018) speed and emission reduction potential has been determined for the case that the currently laid-up and idle fleet were added to the 2018 fleet to enable slow steaming. Second, the short-to-mid-term (2018-2030) emission reduction potentials of specific speed regimes (10, 20, and 30% speed reduction) have been determined, considering the fleet requirements of these regimes. In Subsections 2.5 and 2.6 the results of these two analyses are presented. Before, the most important aspects of the underlying analyses are briefly sketched.

The emission reduction potential is determined by applying the rule of thumb that a ship's main engine energy consumption per unit of time has a cubic relationship with its speed and under the assumption that the efficiency of the auxiliary engines is not affected by speed reduction - it develops just as in the baseline. In order to retain the baseline transport work, additional ships have to be added to the fleet. The CO₂ emissions of these additional ships have been accounted for in the analysis. In contrast, the CO₂ emissions of shipbuilding have not been included in the analysis, since these have been found to be comparably small. CE Delft et al. (2012), using a comparatively high value for CO₂ emissions from steel production, found them to range from 4 to 6% of the emission reductions achieved by slow steaming.

The speed reduction potential has been determined assuming that the baseline transport work is retained under slow steaming and that the days in port on a (sub)fleet level do not change compared to the baseline, with the baseline being the *1.6°C Middle of the Road* baseline as presented in David S. Lee; CE Delft (2017) (see Table 1).

Table 1 - BAU emissions of the global fleet and the subfleet analysed

[Mt]	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Sum
Subfleet analysed	519	533	547	557	567	578	590	602	608	614	620	627	635	7,596
Global fleet	970	987	1,005	1,021	1,037	1,053	1,070	1,087	1,097	1,106	1,116	1,126	1,136	13,809

Source: (David S. Lee; CE Delft, 2017).

The analyses cover the three ship types that provide the majority of the transport work and that collectively accounted for 492 Mt CO₂ emissions out of a total of 938 Mt (52%) in 2012. The reduction potential has been determined for CO₂ emissions only.



2.5 Immediate potential

The analysis of the speed and emission reduction potential is carried out on a ship category level. This means that idle or laid-up ships of a certain size and type that could re-enter the fleet allow the ships of a similar size and type to slow down. Or put it the other way round, for a ship of a certain size and type to be able to slow down, ships of the same size and type category have to be added to the fleet.¹

In June/July of 2017, about 3.5% of the container fleet, about 1%, of the dry bulk fleet and about 2.5% of the oil (crude & product) tanker fleet had been laid-up or idle, with shares differing between the different ships sizes.

Table 2 - Laid-up and idle fleet in terms of number of ships in June/July 2017 (rounded numbers)

Number of ships	Laid-up & idle vessels*	Share laid-up & idle ships
Container vessels	180	3.5%
Dry bulk vessels	100	1%
Crude & product tanker	170	2.5%

Sources: Own calculation based on Clarkson's World Fleet Register Listing (2017) and Drewry Maritime Research.

*For container vessels: Idle ships only.

If these ships were brought into service again in 2018, this would allow container ships to reduce their speed by up to 8%, dry bulkers by up to 3%, and oil (crude & product) tankers by up to 22%, enabling an immediate CO₂ emission reduction of 4% which is about 20 Mt (see Table 3).

Table 3 - CO₂ reduction potential if laid-up & idle ships are brought into service to enable speed reduction

	2018 BAU CO ₂ emissions [Mt]	2018 CO ₂ emissions using laid-up & idle ships to reduce speed [Mt]	Speed reduction potential*	CO ₂ emission reduction potential	
Container fleet	227	215	0-8%	12 Mt	12%
Dry bulk fleet	190	186	0-3%	4 Mt	4%
Crude & product tanker fleet	112	108	1-22%	4 Mt	4%
Total	529	509		20 Mt	4%

*Depending on ship size category.

The overcapacity in terms of laid-up and idle ships differs between ship size categories. This is why the speed reduction potential differs between these categories too, explaining the ranges given in the fourth column of Table 3. Note thereby that the highest speed reduction potential is not necessarily associated with the highest emission reduction potential, with the latter also depending on, for example, the number of ships and their baseline emissions. As Table 3 shows, the CO₂ emission reduction potential in absolute terms is - at around 10 Mt - the highest for the container fleet.

¹ Since there is a lack of cargo load factor data, an increase of the cargo load factor to enable slow steaming could not be accounted for in the analysis.



According to The ICCT (2017), shipping CO₂ emissions increased by 2.4% in the period 2013-2015 (ISWG-GHG, 2017a). Hence, the emissions reductions that could be brought about by bringing the idle fleet back would more than offset this increase.

2.6 Additional potential and fleet requirements

In the short-to-mid-term, the scope for speed reduction is naturally higher since, next to the laid-up and idle ships, additional ships could be added to the fleet.

For three alternative speed regimes (10, 20, and 30% speed reduction) the CO₂ emission reduction potential has been determined for the period 2018-2030.

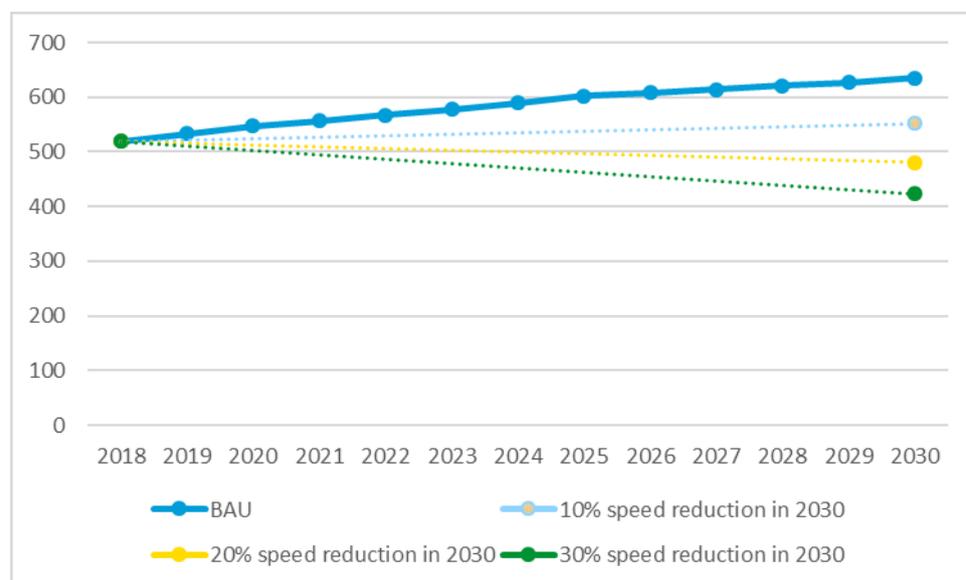
For the three ship types considered, the analysis shows that the baseline CO₂ emissions could be reduced by 13, 24, and 33% if the ships reduced their speed by 10, 20, and 30% (see Table 4).

Table 4 - Relative CO₂ emission reduction potential for alternative speed regimes

	10% speed reduction	20% speed reduction	30% speed reduction
Container fleet	13%	23%	32%
Dry bulk fleet	15%	28%	38%
Crude & product tanker fleet	10%	18%	24%
Total	13%	24%	33%

Figure 2 illustrates the CO₂ emission reduction potential of the three alternatives speed regimes in absolute terms, assuming a gradual implementation until 2030.

Figure 2 - CO₂ emissions of the three ship types in the BAU scenario and under three alternative speed regimes



For the entire period 2018-2030, a 10% speed reduction would, if not gradually implemented, enable a 990 Mt, a 20% speed reduction a 1,830 Mt, and a 30% speed reduction a 2,510 Mt CO₂ emission reduction, the three ship types taken together (see last column of Table 5).



Table 5 - Annual absolute CO₂ emission reduction potential for the three ship types under three alternative speed regimes

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Sum
10% speed reduction	67	68	70	72	73	75	76	78	79	80	81	82	83	985
20% speed reduction	123	127	130	133	136	139	142	145	146	148	150	152	154	1,825
30% speed reduction	169	174	179	183	187	191	195	199	201	204	206	209	212	2,508

The annual average savings in the period 2018-2030 thereby amount to around 75 Mt, 140 Mt, and 190 Mt, depending on the speed reduction (see Table 6).

Table 6 - Average annual CO₂ emission savings in the period 2018-2030

[Mt]	10% speed reduction	20% speed reduction	30% speed reduction
Container fleet	34	62	85
Dry bulk fleet	32	59	83
Crude & product tanker fleet	10	19	25
Total	76	140	193

On ship type level, the reduction potential in absolute terms is as follows:

- the container fleet has the highest reduction potential;
- the dry bulk fleet has, compared to the container fleet, a slightly lower emission reduction potential;
- the oil (crude & product) tanker fleet has the lowest emission reduction potential compared to the other two ship types; this can be explained by the combination of a relative high auxiliary/boiler consumption and a relative high number of days in port - after all slow steaming does not improve the efficiency of the auxiliary engines and boilers.

To enable these emission reduction potentials, the active 2018 fleet would have to grow by 6, 13, and 23%, depending on the speed reduction regime (see Table 7).

Table 7 - Growth of active fleet required in 2018 in terms of number of ships

	10% speed reduction	20% speed reduction	30% speed reduction
Container fleet	7% (6-8%)	15% (14-18%)	26% (23-30%)
Dry bulk fleet	6% (5-6%)	13% (12-14%)	22% (21-25%)
Crude & product tanker fleet	5% (5-8%)	12% (11-17%)	21% (18-29%)
Total	6%	13%	23%

(Percentage ranges in brackets give fleet growth range, depending on ship size categories.)

If the currently laid-up and idle ships were brought into service, the additional fleet required to enable the three speed regimes would naturally be lower and amount to 4, 11 and 21%, all three ship types taken together.



Per ship size category, the required growth in terms of the number of ships can differ highly. For some oil tanker size categories, laid-up and idle ships are sufficient to enable a 10% or even a 20% speed reduction (see also Table 3), whereas for most other categories the active fleet would have to grow beyond the laid-up and idle ships to be able to reduce the speed by 10%.

Ship deliveries (also accounting for the substitution of scrapped ships) in the period 2018-2030 would have to increase by 10, 22, and 37%, depending on the speed reduction regime (see Table 8).

Table 8 - Gross* ship delivery growth required for 2018-2030

	10% speed reduction	20% speed reduction	30% speed reduction
Container fleet	10%	23%	39%
Dry bulk fleet	9%	20%	34%
Crude & product tanker fleet	12%	28%	47%
Total	10%	22%	37%

* Laid-up and idle ships not subtracted.

The growth of the delivered ships required in the first year of speed reduction is naturally the highest - after all, enough ships have to be active to allow the entire (sub)fleet to slow down.

If per ship type and size category, the maximum number of ships delivered in a year over the past ten years (as documented by Clarksons World Fleet Register), was assumed to be delivered in 2018, then some ship types/sizes would be able to reduce their speed by up to 60%, while others would not be able to reduce their speed by 10%. Thus, depending on the flexibility of the shipyards, a gradual increase of a speed reduction requirement, for example 5% in the first, and 10% in the second year could therefore be considered. Bringing the currently laid-up and idle ships back into service would thereby be very helpful.

Apart from the first year of implementation, for tankers and bulkers the deliveries required for a 10% speed reduction are less than the maximum new deliveries in the past decade. And after some years of implementation, the maximum new deliveries in the past decade are enough to even accommodate a 20% speed reduction of tankers and bulkers and a 30% speed reduction for tankers. For container ships however there may be a shortage of yard capacity, mainly for small-sized container vessels under each of the speed regimes.



3 The impacts of speed reduction on trade

3.1 Introduction

In order to ascertain the impact of slower steaming on trade between distant countries, two export products transported via ships will be used in case studies in order to gauge how likely it is that the distant exporting country will lose out due to this regulation. The export products are oilcake and chilled beef, and the trade is between Argentina and The Netherlands.

Assessing the impacts of changes in transport duration or trade costs on the volume of trade and on economies is complex because of the many interactions involved. This chapter presents two case studies, which have the benefit of providing analytical clarity, but the disadvantage of not taking into account all possible interactions. Another option would be to use a trade model, which comprises more interactions (e.g. import substitution by domestic production and substituting imports from one country by imports from another), however, because of the different interactions, the results may not always be immediately understandable.

This chapter employs two case-study methods. In both cases, very conservative assumptions have been used to model the impacts, i.e. assumptions that result in assessment of the upper limit of the potential impact on the exporting countries. The first case assumes that all the costs associated with longer travel times will be borne by the exporter and result in a lower GDP. (In reality, a new market equilibrium is likely to emerge with slightly lower export values and slightly higher import values, as a result of which the exporter and importer will share the costs. Moreover, the case study does not take the cost savings resulting from lower fuel costs into account, again a very conservative assumption). The second case assumes that the costs will result in higher import values, in turn resulting in import substitution. As a result, the volume of imports will be smaller.

In theory, one could argue that slower steaming will affect the terms of trade of distant countries more than those of nearby countries, *ceteris paribus*. A recent study by (Krammer, 2016), who similar to this analysis used Eurostat's EXTRA EU Trade database, estimated the value of time for seaborne shipping for multiple types of manufactured goods: for instance for manufactured food products the estimated value of time was € 0.04 per tonne per hour, while for machinery and vehicles this was € 1.08/t/h. Using the definition of (Krammer, 2016) that *time costs* are equal to the *value of time* multiplied with the *transit time*, a longer transit time will increase time costs, and since according to (Krammer, 2016) time costs can be added to other costs, this also increases the total costs for the firm when keeping the value of time for the product constant. A longer travel time will therefore lead to relatively higher time costs for machinery and vehicles than for manufactured food products.

Importing from a distant exporter will take longer when ships sail at lower speeds. However, this does not necessarily lead to switching from distant exporters to nearby exporters, since this depends on the exporter substitutes available to the importing country. If there are no nearby alternatives for the importing country, then the export volume may not be adversely affected by the regulation.

In order to determine the impacts, the case of unilateral maritime trade from Argentina to the Netherlands will be taken since this is one channel of trade which may be impacted by the speed regulation. The Netherlands was chosen due to the importance of the Port of Rotterdam for European trade.



We will first provide a short market overview of two goods which are imported by ship, one as dry bulk, and the other in containers, since these are two different forms of maritime transport which may be affected by the regulation. The International Trade Database of Eurostat was used, which has separate databases for non-EU exporters (Eurostat, ongoing) and EU exporters (Eurostat, 2017a).

For the former database, the exports are differentiated according to the mode of transport. This is important since the first step in gauging the likely impact of slow steaming on import streams is a market analysis for the import good. Not only are importer substitutes by sea important for the analysis, but also the likelihood of substitution from one mode to another, e.g. from sea to air (although this effect is likely to be limited due to the large difference in freight rates). If a good is hardly exported by plane, it is unlikely that slower steaming will result in any significant substitution from maritime to aviation transport, especially in the case of large volume commodity exports.

The latter database however does not give an accurate representation of the main export substitutes for the Netherlands, since many EU countries import products from outside the EU and subsequently re-export them to another EU country. This is the case for oilcake (one of the products to be discussed), with Germany being one of the largest exporters to the Netherlands of oilcake produced from soya-beans, with for instance € 37.1 million worth of exports in 2015 (Eurostat, ongoing). However Germany also imported some € 633 million worth of oilcake from soya-beans in 2015 from non-EU exporters, as well as importing some € 435 million from the Netherlands. The fact that the Netherlands is an important exporter to Germany probably has to do with the Port of Rotterdam since some € 1.6 billion worth of oilcake was imported to the Netherlands in 2015 (Eurostat, ongoing). This clearly reveals the large magnitude of the intra-EU trade of products, which does not help in identifying the largest exporters to the Netherlands of the two products to be discussed. The analysis will therefore focus on non-EU exporters since it is clear that these are the countries where the export streams originate from. This will help in analysing which countries become exporter substitutes to the Netherlands if slow steaming makes South American countries less attractive to import from.

3.2 Oilcake using assumption 1 - cost borne by exporter

One of the largest export products from South America to the Netherlands is oilcake, which is a residue resulting from the extraction of oil from different kinds of agricultural products such as soya-beans, sunflower seeds, palm nuts or coconuts, and which is used as animal feed and in the fertiliser industry. This case-study method assumes that all the costs associated with longer travel times will be borne by the exporter and result in a lower GDP.

3.2.1 Current trade in oilcake

In 2015, € 1.6 billion worth of oilcake was imported to the Netherlands from outside the EU, with 89% originating from soya-beans. Of all the non-EU oilcake imports to the Netherlands, the largest exporters are Brazil and Argentina, with soya-bean oilcake imports worth respectively € 939 million and € 383 million in 2015 (Eurostat, ongoing). These imports were almost exclusively transported via ship.² Sea imports make up 58% (from Brazil) and 24% (from Argentina) of all the Dutch non-EU imports for oilcake in terms of value and all transport modes.

² Eurostat reports that air transport amounted to € 895 worth of imports from Argentina and € 380 from Brazil.



Sea imports also represent 97% of all the oilcake imports to the Netherlands³. Since the value of time for goods is relatively low when transported by sea (Krammer, 2016) the fact that oilcake is predominantly transported by ship seems to point to its low value of time.

From Table 9 it is clear that most of the oilcake imports originate from distant countries with respect to the Netherlands, with only the Ukraine exporting a relatively large amount while being relatively nearby. All these countries export their oilcake to the Netherlands by sea.

Table 9 - Top 5 countries exporting oilcake to the Netherlands in 2015 in value with corresponding tonnage imported.

Exporting country	Source of oilcake	Mode of transport	Value of imports (in millions)	% of total value	Imports (kilo tonnes)	% of total imported (tonnes)	Main container port	Nautical miles from main container port to Rotterdam
Brazil	Soya-bean	Sea	€ 939	58%	2,518	49%	Santos	5,529
Argentina	Soya-bean	Sea	€ 383	24%	1,046	20%	Buenos Aires	6,386
Indonesia	Palm nuts	Sea	€ 96	6%	887	17%	Tanjung Priok	8,705
Uruguay	Soya-bean	Sea	€ 53	3%	133	3%	Montevideo	6,304
Ukraine	Sunflower seeds	Sea	€ 29	2%	119	2%	Odessa	3,567
Total oilcake imports			€ 1,620					

Source: (Eurostat, ongoing); CIA World Factbook; Marine Traffic.

Travel time oilcake Buenos Aires to Rotterdam

Oilcake is transported as a dry bulk cargo. It is assumed the oilcake is transported on bulk carriers with a dry weight tonnage of around 100,000 which have average speeds at sea of 12.2 knots (23km/h) (IMO, 2015b). The distance between the ports of Rotterdam and Buenos Aires is 6,386 NM (11,827 km), hence a bulk carrier will take 21.8 days to deliver the oilcake from Buenos Aires to Rotterdam.

3.2.2 Import stream trends oilcake

The volatility of an import stream may mean that an analysis for a single year could give a distorted image of this flow. It is therefore useful to analyse the import streams from Argentina over the last five years for oilcake, but also to compare this with another South American country in order to make a comparison, hence Brazil was also included in this volatility analysis.

For Argentina and Brazil there is a downward trend since 2013 with regards to exports to the Netherlands, both in terms of the quantity exported (kilo tonnes) and in terms of value (€ million) (Eurostat, ongoing). To investigate the volatility of this import stream, Argentina and Brazil's exports to the EU will be focussed on in order to determine whether there are notable trends to the EU as a whole. Factors which may impact this volatility for oilcake are bad harvests in Argentina and Brazil or their exchange rates with respect to the euro.

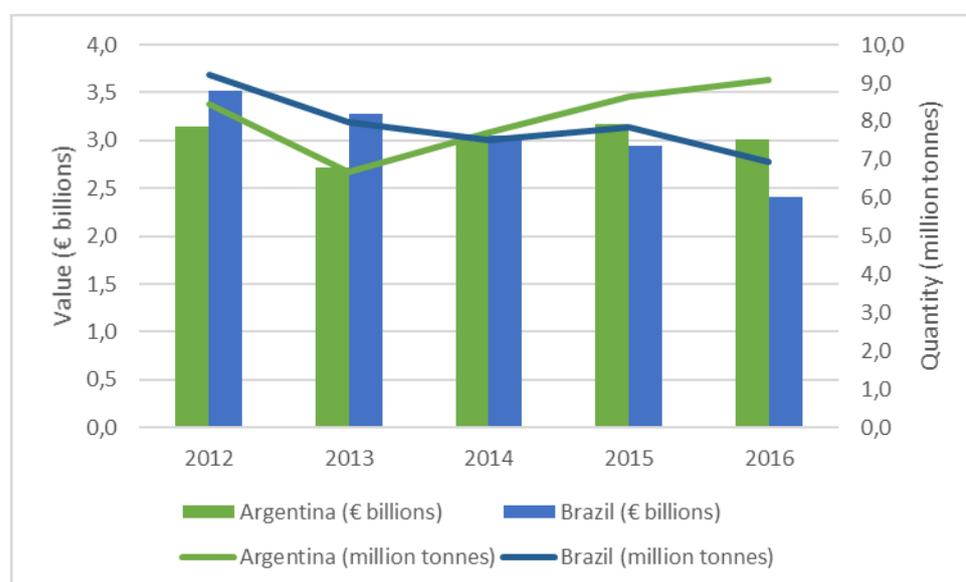
³ Road transport imports were also included in the Eurostat data for the countries in the table below, however this probably points to intermodal transport of some sort since these countries are separated by oceans with the Netherlands. Hence, the value of road imports to the Netherlands was assumed to also be transported by ship when calculating the modal split for all imports. This is also the case for beef exports in the next section.



Oilcake from soya-beans depends on the production of raw soya-beans. According to OECD data (OECD-FAO, 2017). The production of soya-beans in Argentina and Brazil has increased over the period 2012-2015. This means that bad harvests are unlikely to explain the decreasing trend in oilcake exports to the Netherlands. Another factor may be the exchange rate of the Argentine and Brazilian currencies respect to the euro, which may have changed the value of these imports for Dutch importers. The Brazilian real has indeed appreciated by approximately 42% over the period 2012-2016 with respect to the euro, however the Argentine peso has depreciated by nearly 200% over the period 2012-2016 with respect to the euro⁴.

In Figure 3 the EU imports for oilcake from both countries could shine some light on the factors contributing to the earlier mentioned trends. Argentine and Brazilian oilcake exports made from soya-beans to the EU-28 for the period 2012-2016 have experienced differing developments, as can be seen in Figure 3.

Figure 3 - Export trend to the EU-28 of soya-bean oilcake from Brazil and Argentina 2012-2016



Source: (Eurostat, ongoing).

The Argentine exports have remained steady in terms of value, but increased in terms of exported tonnes from 2013 onwards. The fact that the value remained relatively stable while the quantity exported increased could imply that the exchange rate depreciation may have played a role in increasing the Argentine exports in terms of quantity. On the other hand, Brazilian exports experienced a downward trend both in terms of value and exported tonnes, which may likewise be attributable to the exchange rate, which in the case of Brazil appreciated over the period.

3.2.3 Effect of slow steaming on oilcake exports

Slower steaming has the obvious effect of increasing the time to deliver imports. For oilcake exports this study assumes that import prices and freight rates are unaffected by the costs of slower steaming, the exporter will experience a smaller profit since the costs fall on them to finance the longer travel time as well as extra insurance costs. This is clearly a conservative assumption since transport costs

⁴ www.xe.com/currencycharts/?from=EUR&to=ARS&view=10Y



may decrease as a result of lower fuel costs. The additional costs are made up of an interest expense to finance the longer travel time, and insurance costs, since these may increase to ensure safe transport of the goods for a longer time.

For a bulk carrier transporting oilcake from Buenos Aires to Rotterdam, the usual time needed for the voyage is 21.8 days (assuming an average speed of 12.2 knots). With a 10% decrease in speed the time needed increases to 24.2 days (11% increase in time), with a 20% decrease in speed it increases to 27.3 days (25% increase in time), and for a 30% decrease in speed it increases to 31.2 days (43% increase in time).

In 2015, Argentine soya-bean oilcake exports to the Netherlands amounted to € 383 million. Assuming these exports were funded with a loan with a 10% annual interest rate, and the speed reduction varies between 10 and 30%, the additional interest expense for the longer travel time for all ships carrying Argentinian oilcake is determined using the following formula:

$$\text{Additional interest expense} = \text{value of exports in year } t * \text{annual interest rate} * \frac{\text{extra days travelled}}{365,25}$$

The value of the exports is multiplied by the annual interest rate and with the additional days of travel in terms of years (with the denominator being 365.25 to account for leap years). It is assumed that the interest is compounded once per year for all the exports and the value of the exports are funded by an annual loan for the extra time needed to transport the goods.

According to the (OECD, 2011) insurance fees are between 1.5 and 2% of the traded value per annum. On the one hand, according to (Meyer, et al., 2012) insurance costs are more or less fixed with respect to the vessel's speed. This implies that slowing the speed, which may intuitively lead to a decrease in the likelihood of damaging the ship and goods, does not lead to lower insurance fees. The speed however has an effect on the time needed to transport the goods. According to (Yin, et al., 2014) insurance costs are a fixed daily cost, hence increasing the number of travel days will lead to higher insurance costs. The upper bound of 2% of the total value will be used to quantify the additional insurance cost for slower steaming. This will be used to calculate the fixed daily insurance cost, which is simply multiplied by the extra travel days to calculate the additional insurance expense.

For the Argentine soya-bean oilcake exports to the Netherlands the following additional interest and insurance expenses are summarised in the table below depending on the degree of speed reduction. These additional expenses are the total expenses of all Argentine oilcake exports to the Netherlands for one year resulting from the extra travel time. For a speed reduction of 30%, the additional interest and insurance expense can amount to 0.31% of the total value of the exports. Assuming exports worth € 383 million in 2015 from Argentina to the Netherlands, a speed reduction of 30% will result in additional expenses of € 1.2 million.

Table 10 - Additional interest and insurance expenses due to varying speed reduction for oilcake exports

Speed reduction	Extra travel days	Additional interest expense (€ 1,000)	Additional insurance expense (€ 1,000)	Total additional expenses (€ 1,000)	Additional expenses % of total value
10%	2.42	254	51	305	0.08%
20%	5.45	572	114	686	0.18%
30%	9.35	980	196	1,176	0.31%

Source: CE Delft calculations based on Eurostat, EXTRA EU Trade Since 2000 By Mode of Transport (HS6).



Argentine GDP effect

If the costs were borne completely by the exporter, the GDP of Argentina would drop by € 1.2 million in the case of a speed reduction of 30%. In percentage terms the loss in export value of oilcake is 0.31%.

3.3 Chilled beef using assumption 2 - costs borne by importer

Another important export product to the Netherlands from South America is fresh or chilled bovine meat, i.e. beef. This case-study method assumes that the costs will result in higher import values, in turn resulting in import substitution. As a result, the volume of imports will be smaller.

3.3.1 Current trade in chilled beef

Exports to the Netherlands of chilled beef are dominated by distant countries as can be seen in the table below. In 2015, approximately € 580 million worth of chilled beef was imported to the Netherlands, with 99% of this being transported by ship. Similar to the case of oilcake exports, the value of time for goods is relatively low when transported by sea (Krammer, 2016), hence the fact that chilled beef is predominantly transported by ship seems to point to its low value of time. It is therefore unlikely that slow steaming will result in a switch from maritime transport of chilled beef to aviation transport since the latter mode usually transports goods with a high value of time. The top 5 beef exporters to the Netherlands accounted for 88% of the chilled beef imports (in terms of value) to the Netherlands in 2015.

Table 11 - Top 5 countries exporting chilled beef to the Netherlands in 2015 in value with corresponding tonnage imported

Exporting country	Mode of transport	Value of imports (in millions)	% of total value	Imports (kilo tonnes)	% of total imported (tonnes)	Main container port	Nautical miles from main container port to Rotterdam
United States	Sea	€ 128	22%	10	18%	New York	3,340
Argentina	Sea	€ 121	21%	10	18%	Buenos Aires	6,386
Brazil	Sea	€ 92	16%	9,8	18%	Santos	5,529
Uruguay	Sea	€ 90	15%	9,3	17%	Montevideo	6,304
Australia	Sea	€ 80	14%	8,7	16%	Melbourne	12,385
Total chilled beef imports		€ 580					

Source: Eurostat, EXTRA EU Trade Since 2000 By Mode of Transport (HS6); CIA World Factbook; Marine Traffic.

Travel time chilled beef Buenos Aires to Rotterdam

Chilled beef is transported in refrigerated containers. According to the Cargo Handbook⁵ the chilled meat should be transported at or around freezing point, however this range can be extended by using different types of storage techniques. Depending on the best practice techniques, the storage life can be extended from 6 to 20 weeks.

According to the Third IMO GHG Study (2014) refrigerated products are increasingly being transported by container ships equipped with reefer containers instead of dedicated refrigerated ships. Container

⁵ www.cargohandbook.com/index.php/Meat,_chilled



ships have an average speed at sea of 16.3 knots. A ship transporting chilled beef from Buenos Aires to Rotterdam will take 16.3 days to complete the journey.

3.3.2 Effect of slow steaming on beef exports

Slower steaming may make locally produced goods more attractive to produce due to the longer waiting time for these products to arrive, thereby increasing the costs of importing. These costs are the additional interest and insurance expenses, which were determined based on the same calculations as for oilcake exports. The expenses are summarised in Table 12.

Table 12 - Additional interest and insurance expenses due to varying speed reduction for beef exports

Speed reduction	Extra travel days	Additional interest expense (€ 1.000)	Additional insurance expense (€ 1.000)	Total additional expenses (€ 1.000)	Additional expenses % of total value	Fall in tonnes imported Argentina ($\sigma = 0.8$)	Fall in tonnes imported Argentina ($\sigma = 3.85$)
10%	1.8	€ 60	€ 12	€ 72	0.06%	4.8	23.0
20%	4.1	€ 135	€ 27	€ 162	0.13%	10.7	51.7
30%	7.0	€ 232	€ 46	€ 278	0.23%	18.4	88.6

Source: CE Delft calculations based on Eurostat, EXTRA EU Trade Since 2000 By Mode of Transport (HS6).

To gauge the impact of lower speeds on the attractiveness of locally produced beef, the elasticity of substitution between Dutch (home) and Argentine (foreign) beef will be used. The impact of slower steaming on beef imports is assumed to result in higher import values, leading to import substitution. This seems likely since the Netherlands is a large player in the beef market, with 382,52 kilo tonnes of slaughtered beef produced in 2015 (Eurostat, 2017b). This means that the Netherlands can switch from imports of beef to domestically produced beef in case the imports become more expensive.

The extent to which import substitution occurs is captured by the Armington elasticity. (Ramos, et al., 2010) used the Global Trade Analysis Project's elasticity of substitution for bovine meat products of 3.85 between EU domestic production and South American imports in order to model the impact of tariffs on trade flows. In other parts of the world, much lower elasticities are reported: Kawashima and Sari (2010) find elasticities for beef imports in Japan to range between 0.8 and 1.1. Differing Armington elasticities can have large impacts on the modelled flow of imports (Ramos, et al., 2010). We will therefore use these two sets of Armington elasticities as the lower (0.8 from Kawashima and Sari (2010)) and upper bound (3.85 from Ramos et al. (2010)) in order to determine the possible impact of slow steaming on Argentine beef imports to the Netherlands.

Argentina exported around 10 kilo tonnes of chilled boneless beef to the Netherlands in 2015, which is a relatively high quality export product (Ramos, et al., 2010). If it is assumed that the Armington elasticity between Dutch domestic beef production and Argentine beef imports ranges from 0.8 to 3.85, a 1% increase in the price ratio of beef prices in Argentina and the Netherlands would lead to the ratio of demand for Dutch domestic production to the demand for Argentine beef increasing by 0.8-3.85%, or conversely a 0.8-3.85% decrease in demand for beef imports from Argentina.

As can be seen in Table 12, 30% (resp. 10%) slower steaming leads to an increase in costs of 0,23% (resp. 0.06%) relative to the value of the exports (not taking into account the fuel savings because of the conservative assumptions). The drop in demand will be 0.89% (resp. 0.05%) in case an Armington elasticity of 3.85 (resp. 0.8) is used⁶. This percentage drop in imports can be multiplied with the imported tonnes to the Netherlands (10 kilo tonnes) to quantify the drop in imports in terms of

⁶ This is simply calculated by multiplying the Armington elasticity with the percentage increase in expenses.



tonnes. In the case of an Armington elasticity of 3.85 (resp. 0.8), the volume of imports will fall by 88.6 (resp. 4.8) tonnes.

Argentine GDP effect

For this case-study method it is assumed that the importer will foot the bill of the additional expenses, leading to a higher price for chilled beef imports from Argentina. The GDP of Argentina will fall as a result of import substitution in the Netherlands. In the case of 30% slower steaming and an Armington elasticity of 3.85, chilled beef imports will drop by 88.6 tonnes, meaning that 0.23% higher import prices will lead to a loss in Argentina's GDP equal to the value of the drop in imported tonnes. This can be calculated by determining the value of imported chilled beef per tonne, and multiplying this by the volume of lower imports.

Argentina exported 10 kilo tonnes of chilled beef to the Netherlands in 2015, which was worth € 121 million, meaning 1 tonne of chilled beef cost € 12,100, or a kilo cost € 12.1. If an increase of 0.23% higher import prices due to 30% slower steaming leads to 88,6 tonnes less chilled beef being imported from Argentina, then the value of these lower imports is € 1.1 million, a drop of approximately 0,89%. This means that Argentina's GDP would fall by € 1.1 million at most. The real impact is likely to be smaller since this study has taken conservative assumptions.

3.4 Impacts of slow steaming on GDP for South America

In order to provide a very rough estimate of the impact of slow steaming on the GDP of South America, the effects of slow steaming found in the two cases on Argentina's GDP will be extrapolated to the South American economy. Since the two case-study methods of oilcake and chilled beef differ with respect to the assumption of who foots the bill for the additional expenses, the GDP effects will differ. These differing GDP effects can be used as a lower and upped bound for extrapolating to the South American economy as a whole. Of course, this method is not very accurate but it can provide information on the order of magnitude of the economic impacts.

South American GDP effect

Based on World Bank data on GDP in current US\$ (The World Bank, 2017) and the magnitude of exports (WITS, 2017) in US\$ the weighted average of exports to South America's GDP could be calculated. In 2015 South America had a GDP (in current US\$) of \$ 3.7 trillion, while it exported approximately \$ 515 billion, hence the export share of GDP was 14%.

The GDP effects of oilcake and chilled beef will be extrapolated to all South American maritime exports by using the modal split of South American exports to the EU (we are not aware of data on the modal split for South American exports). The export share of GDP, and the share of maritime exports to the EU, can then be used to extrapolate the GDP share of all of South America's maritime exports to the rest of the world. In 2015, South America exported 72% of its products to the EU by sea, approximately € 47 billion worth of goods (Eurostat, 2017c). We therefore assume that South American maritime exports to the rest of the world contribute 10% to the GDP of South America based on the share of South American exports to GDP (14%) and the modal split of exports to the EU (72% maritime based exports)⁷. Again, this is a conservative estimate because exports to nearby countries and intra-continental trade are more likely to use land-based transport modes.

⁷ The 10% share of maritime exports to GDP is calculated by multiplying the export share of GDP and the percentage of maritime-based exports.



As was seen earlier, oilcake transport costs are expected to rise by € 1.2 million in case of 30% slower steaming, leading to a lower GDP in the Argentine economy. The additional expenses are 0.31% of the total value of Argentine oilcake exports to the Netherlands. It is assumed that in the case of 30% slower steaming, all maritime-based exports from South America to the rest of the world where no import substitution is possible can be assumed to lead to 0.31% higher expenses, depressing value and thereby lowering South America's GDP by 0.03%⁸. This amounts to a loss in GDP of \$ 1.2 billion in 2015 if 30% slow steaming would be enforced.

In the case of chilled beef the importer bears the additional expenses from slower steaming, leading to a drop in imports and a consequent drop in import value of 0.89% for 30% slower steaming and an Armington elasticity of 3.85. If all South American exports were susceptible to import substitution, GDP could drop by 0.09% in case of 30% slower steaming⁹. In 2015 this would mean a drop in GDP worth \$ 3.3 billion.

The above losses provide a range of possible GDP effects in case of slower steaming: 30% slower steaming could result in a loss in GDP in South America of less than a tenth of a percent, or in monetary terms, a few billion US dollars. This provides a conservative estimate since fuel savings were not accounted for in this study.

⁸ The GDP effect is determined by multiplying the share of maritime exports to South America's GDP (10%) with the drop in GDP for oilcake (0.31%) which equals 0.031%.

⁹ Since the value of beef imports drops by 0.89%, and exports make up 10% of the South American economy, the fall in GDP if all South American exports fell by 0.89% would be 0.089%.



4 Policies to reduce speed

4.1 Introduction

Ships can choose their speed within certain limits. The upper bound is set by the design speed of a vessel, the lower bound by the load at which the ship and the engine can still be safely operated. If ship speeds would be chosen purely on the basis of economic considerations, the main drivers would be fuel prices and freight rates (Ronen, 1982). When freight rates are high, ships would speed up in order to maximise profits by increasing revenues; when fuel prices are high and there is a sufficient supply of ships, they would slow down in order to save costs. In reality, institutional factors, such as charter contracts, constrain the ability of ships to choose their optimal speed (Assmann, et al., 2015). Another constraint is the availability of port infrastructure: a ship may adjust its speed to be at berth when a berth is available (Kim, et al., 2016).

Fuel prices do not reflect the damage caused by CO₂ emissions. If these external costs would be internalised, the costs of using fossil fuels would be significantly higher and the optimal speeds consequently lower. For example, it has been estimated that the carbon price required to reach a 2°C target would be 60 USD₂₀₀₅/tCO₂ in 2020 increasing to 80 USD₂₀₀₅/tCO₂ in 2030 and 160 USD₂₀₀₅/tCO₂ in 2050, (Vuuren, et al., 2010), although there is a considerable band of uncertainty around these estimates: (Guivarch & Rogelj, 2017)). This would translate approximately in a fuel price increase of approximately USD₂₀₁₇ 225 in 2020¹⁰ and USD₂₀₁₇ 300 in 2030.

Merely including these costs in the fuel price, e.g. by applying a carbon levy, would not necessarily reduce speeds to the optimal level because of the institutional constraints mentioned above. Moreover, a global levy may be hard to achieve politically. And without one, ships would reduce their profits (or become loss-making) when they reduce their speed. A solution to this conundrum could be a policy that requires all ships to slow down.

Speed reduction policies have several design choices, including:

1. The policies can be voluntary or mandatory:
 - a Voluntary policies include facilitating ships to sail at an optimal speed by providing information on the availability of berths well in advance.
 - b Mandatory policies can be enforced by flag states and by port states. They can be globally agreed or set unilaterally as a condition of entry into a port.
2. The policies can have a global scope or a regional scope:
 - a Global policies would apply to ships regardless of where they sail. They would need to be agreed at a global level and enforced by Flag States with inspection rights for Port States.
 - b Regional policies could regulate speeds in certain areas or on voyages between ports in participating states. They could also be implemented unilaterally by states as a condition of entry into a port. They could be based on globally agreed guidelines which could specify e.g. how speed is defined.
3. Speed regulation can be differentiated with regard to ship type and size.
4. The policy can regulate the average speed, the maximum speed, or both.
5. The policy could have provisions that allow for flexibility:
 - a Provisions could allow ships in special circumstances to exceed the speed limit, e.g. when executing search and rescue missions, circumnavigate areas with adverse weather, et cetera.

¹⁰ Calculated using the USD GDP price deflator from BEA, USD₂₀₀₅ 1 is worth USD 1.226 in 2017, and a CO₂ emission factor of 3.1 for marine fuels.



- b Provisions could allow specific ships to exceed the speed limit permanently, e.g. ships with an exceptionally good design efficiency or operational efficiency.

This chapter discusses each of these design choices in subsequent sections.

4.2 Voluntary or mandatory speed regulations

There are multiple examples of voluntary speed regulation. One of the more well-known ones is so-called 'virtual arrival', which adapts the freight contract while a ship is underway when there is a known delay in the port of discharge. Instead of sailing at the contracted speed, the ship can sail at a lower speed and arrive just in time, thereby reducing fuel consumption (Intertanko; OCIMF, 2010). Voluntary agreements work well when there is a mutual benefit to reduce speeds. However, when it is more profitable for one party not to comply, they will not work, either because the party has control over speed and can choose not to comply by itself, or when a party does not have control over a vessel's speed, it can pay the ship operator to speed up.

Hence, in order to effectively reduce emissions, speed regulations have to be mandatory and there has to be an enforcement system that deters ships from not complying.

4.3 Geographical scope

The speed regulation can be set globally, unilaterally as a condition of entry into a port, or bilaterally between ports in two states.

Global speed limits need to be agreed upon by the IMO. They can be enforced by Flag States and Port States.

Unilateral speed limits can be implemented as conditions of entry into a port. These conditions could be set unilaterally or follow globally agreed rules or guidelines. The former option could perhaps be implemented under the National Action Plans. The latter option would be similar to emissions control areas, which Coastal States can implement under certain conditions agreed by the Parties to MARPOL Annex VI.

Regardless of the scope, regulators need to be able to monitor compliance. The available information is discussed in Section 4.3.1.

4.3.1 Monitoring compliance

Both flag states and port states have the possibility to monitor speed and thus to monitor compliance with a certain type of regulation (CE Delft; The ICCT; Mikis Tsimplis, 2012):

- All passenger ships and all cargo ships with a volume of 300 GT or more are required to have a Long Range Identification Tracking (LRIT) system. They have to report their position at least four times per day. LRIT data can be accessed by SOLAS contracting states¹¹ for vessels that are included in the states registry, vessels that indicate they intend to enter a port of the state and for vessels operating within 1,000 nm off their coast. From the position, the average speed during the six preceding hours can be calculated. Because a ship may not always know its port of destination, and because the port may change, port states may not have access to all the LRIT data of ships entering their ports.

¹¹ The 1974 SOLAS Convention, which establishes LRIT in Regulation V/19-1, has been ratified by 163 IMO Members and 3 Associate members, out of 174 signatories to the 1948 IMO Convention.



- The same ships are also required to have an Automatic Identification System (AIS) which transmits information on a ship's position and speed at least every 10 seconds. Commercial operators have launched satellites that pick up AIS signals from space and can track ships everywhere on the globe. This data is available to every paying customer, including states. However, because AIS has not been designed for signal detection from space, interference problems can arise leading to signals from ships that sail close to each other not all being detected.
- IMO Assembly Resolution A.916(22) - 'guidelines for the recording of events related to navigation' requires that for each voyage, records must be kept so that 'a complete record of the voyage' can be restored. This is included in Annex 22 of SOLAS chapter V. SOLAS does not prescribe *how* speed should be recorded but it is clear that when a complete record of a voyage can be restored, at least the average speed can be calculated. Often, the Deck Log Book has daily entries of average speed.

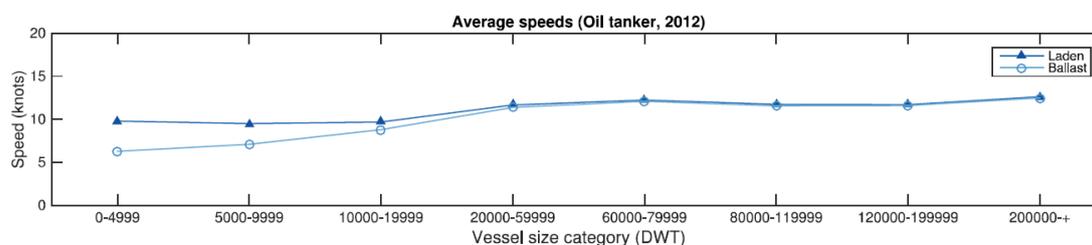
Hence, both flag states and port states have the possibility to monitor compliance with a speed regulation. In some cases, they may have to build up the organisational capacity to do so. For example, it is not known how many flag states regularly monitor the position of their ships via either LRIT or AIS, and it is not likely that any flag state currently monitors speed.

4.4 Uniform or differentiated speeds

Different ship types are designed to sail at different speeds. Whereas large bulk carriers and oil tankers typically have a design speed between 15 and 16 knots, container ships and large cruise ships are often designed to sail well over 20 knots. Requiring all ships to sail at the same speed would be problematic. If the speed target of a policy is set at a level which requires all ships to slow down, container ships and cruise ships could face technical difficulties because of extremely low engine loads. Moreover, in order to supply the same amount of transport work, the fleet of these ship types would have to grow fast. If, on the other hand, the speed is set so that container ships could meet it, it might be meaningless for tankers and bulk carriers.

A similar argument holds for ship sizes. For almost all ship types, small ships have lower design speeds than large ships. The difference can be quite large: the fleet of oil tankers with a deadweight up to 5,000 tonnes had an average design speed of 11.5 knots in 2012, whereas VLCCs had an average design speed of 16.0 knots (IMO, 2015b). Accordingly, the operational speed of smaller vessels is lower than the operational speed of larger vessels, as shown for oil tankers in Figure 4. This means that one speed target per ship type would either require large ships to slow down to speeds which may be challenging from a technical perspective, or let small ships continue to sail at their current speeds and not contribute to emission reductions. It is therefore advisable to set ship type and size dependent speed reduction targets.

Figure 4 - Average speeds of oil tankers (2012)

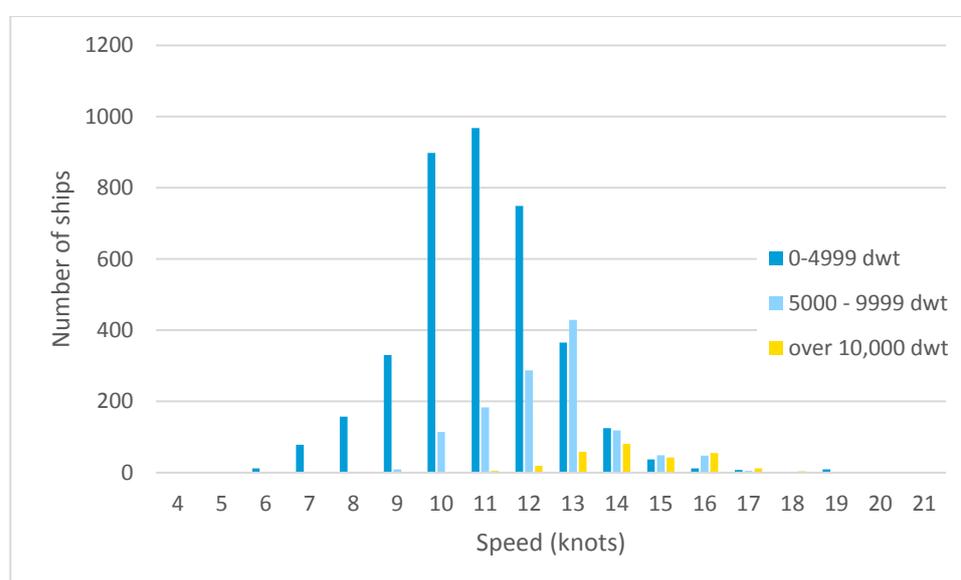


Source: (MEPC, 2015).



There is also a considerable variation in design speeds for ships of a similar size and type. This is shown in Figure 5 for general cargo ships: small ships have speeds between 4.5 and 19 knots; large ships between 9 and 20 knots. Typically, this variation is larger for small ships than for large ships. The reason is probably that large ships, e.g. VLCCs, compete on the same global market whereas small ships are often active in regional markets or even designed for specific trades. The question is whether this variation should also be taken into account when setting speed targets. Similar arguments in favour of such an approach could be made as for differentiating between ship types. However, a counter-argument would be that if ship-specific speed targets are set, depending e.g. on the design speed of a ship, each ship would need to have a certified design speed. Moreover, it would be much harder to monitor whether a ship complies with the policy or not, because the speed target cannot be inferred from observable characteristics like ship type and size. Hence, the enforceability of a target would improve if the variation within ship categories were not taken into account.

Figure 5 - Design speed distribution of general cargo ships



Source: Own calculations, Clarksons World Fleet register, September 2017.

In conclusion, a speed target that differentiates between ship types and sizes is more environmentally effective and has a smaller chance of distorting competitive markets than a uniform speed target.

4.5 Average or maximum speeds

An important issue to consider is whether the policy should strive to reduce average speeds or maximum speeds. If ships would sail at a constant speed, both types of policies would have the same effect, however it is well known that ship speeds vary over time.

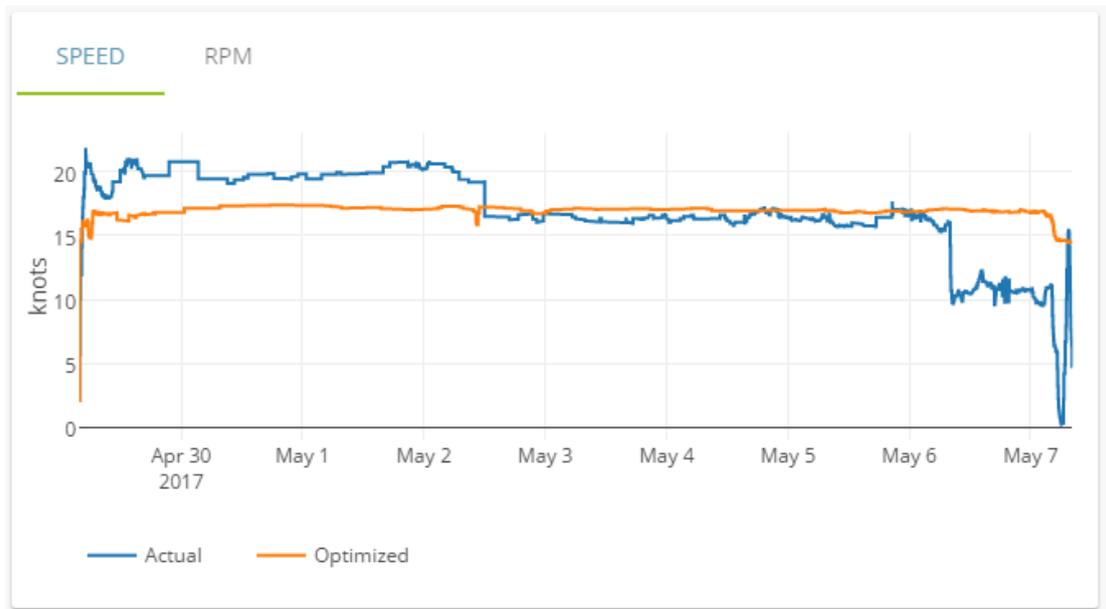
In order to understand the impact of each type of regulation on the operational speed profiles of ships, this section first analyses the reasons why ship speeds vary and the extent to which they do. Next, it discusses the impacts of regulations on average and maximum speeds.

Figure 6 shows the speed profile of a ship, probably a container ship, sailing from Port Klang (MAL) to Jebel Ali (UAE), covering a distance of approximately 3,300 nm in just over 8 days. The ship starts at a relatively high speed, slows down about halfway through the voyage to a lower, more or less constant



speed, and slows down considerably about one day prior to arrival. Assuming that this is indeed a container ship, this pattern can be explained by the fact that the ship has to arrive in Jebel Ali at a certain time in order to meet a schedule. The fast start may be chosen to generate a margin for unforeseen circumstances, or to avoid bad weather. When the margin was large enough, the ship slowed down to a more economical speed. On entering the Gulf, the speed was reduced even more and the ship probably had to wait for the pilot just prior to arrival. The relatively small variations in speed may have been the result of waves and currents.

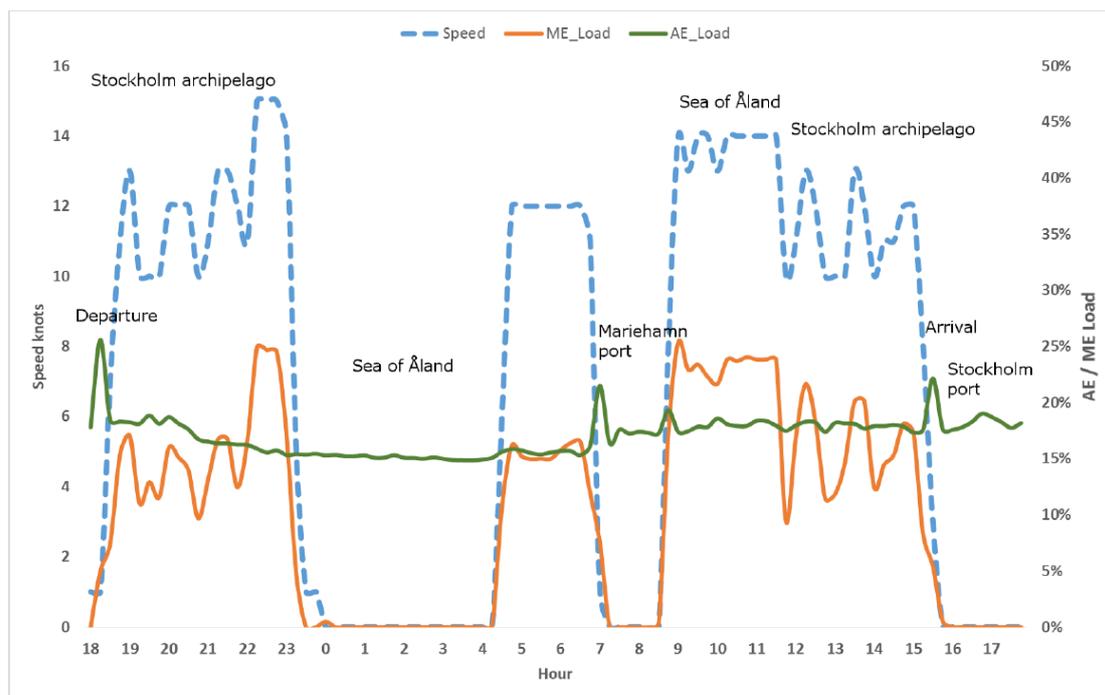
Figure 6 - Operational profile of a ship sailing from Port Klang (MAL) to Jebel Ali (UAE)



Source: (NAPA Fleet Intelligence, 2017).

A very different example is provided by a ferry sailing between Stockholm and Mariehamn (Figure 7), a distance of under 100 nm. This particular ferry leaves Stockholm in the evening and arrives in Mariehamn the next morning. In order to do so, it has to either sail very slowly or reduce its speed to zero. The latter also has the advantage that the main engine can be turned off and the noise is reduced. The speed variations in the Stockholm Archipelago are probably caused by requirements to manoeuvre in narrow sea-lanes.

Figure 7 - Operational profile of a ferry in the Baltic Sea

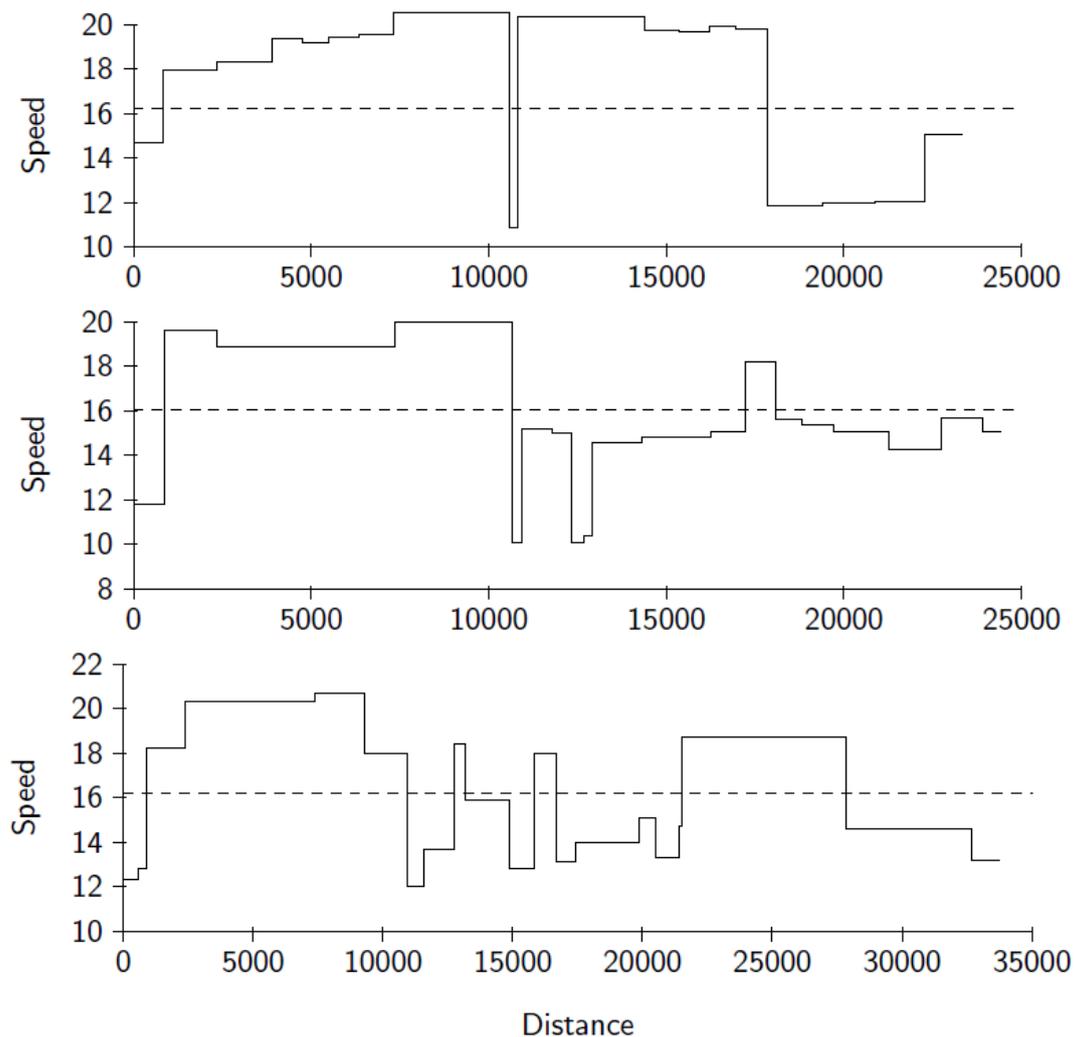


Source: (Baldi, et al., 2015).



Figure 8 shows the average speeds of container vessels on three different Asia - Europe loops. This figure does not show the actual speeds, like the previous two, but the average speeds between so-called waypoints (ports, canals, et cetera). These containerships are sailing on a schedule, and the speeds on each part of the voyage are set so that they arrive in time at the next port. It can also be seen that the return voyage to Asia (the right half of the graphs) is executed at a lower average speed than the voyage to Europe. This probably has to do with the amount of cargo carried, which is higher on westbound legs.

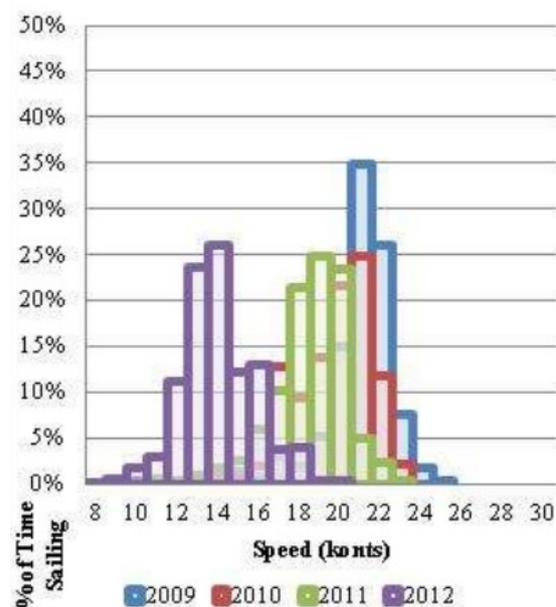
Figure 8 - Speed profiles for three different rotations operated by Maersk Line between Asia and Europe



Source: (Karsten, et al., 2015).

Figure 9 presents a histogram of the speed distribution of two container ships in four consecutive years. It shows that average and median speeds have reduced, but also that as ships have moved away from their design speed, the range of speeds has become larger.

Figure 9 - Speed distribution of two Post Panamax container vessels (2009-2012)



Source: (Banks, et al., 2013).

Ships are more efficient when they sail at a constant speed through the water than when they operate at variable speeds. Hence, shipping companies have an incentive to sail at constant speed. Still, the examples provided above demonstrate clearly that they do not. They also show a number of reasons why ships operate at varying speeds:

- schedules have to be met, and weather is unpredictable (Figure 6);
- schedules have to be met, and idling can only occur in certain areas (Figure 7);
- whether vessels are fully laden with time-sensitive cargo or not, and probably port arrival times (Figure 8);
- ships sail at different speeds when in ballast or laden (Figure 4).

Regardless of whether maximum or average speeds are regulated, the chances exist that schedules have to be changed. This need not be a major issue as schedules are adjusted frequently and both shipping companies and shippers can deal with it as long as the changes are announced well in advance.

Regardless of whether maximum or average speeds are regulated, ships will want to have a safety margin in meeting their schedules. A regulation of maximum speed would possibly result in a more lopsided speed distribution and thus to a more constant speed. A regulation of average speeds would possibly see the continuation of the current distribution of speeds, as shown in Figure 9. If this is indeed the case, a regulation of maximum speeds is likely to have a higher environmental effect.

There are other issues to be considered:

- ships emit LRIT data once every six hours. Hence, speed observations based on LRIT data are always averages over six hours;
- regulation of average speed would require decisions on how to treat time idling, at anchor, waiting for a pilot and in other circumstances where ships do not move.

4.6 Introducing flexibility in speed regulation

When the goal of speed regulation is to reduce greenhouse gas emissions, it is possible to introduce flexibility by allowing ships to reduce emissions by other means. For example, ships that use low-carbon fuels could be allowed to slow down to a lesser extent. Likewise, ships that can demonstrate that their operational greenhouse gas intensity is as least as good as the average comparable ship when sailing at a reduced speed, could also be allowed to sail faster than the speed target.

This section provides two examples of provisions that could be introduced in the regulation.

Consider a bulk carrier of 70,000 tonnes deadweight sailing at 12 knots on average and consuming 34 tonnes of fuel per day, thus emitting 105 tonnes of CO₂ per day at sea. If this ship would be subject to a speed limit that reduces its speed by 20%, its emissions would be reduced to 54 tonnes of CO₂ per day at sea. If this ship would use a fuel mix that has 49% lower lifecycle CO₂ emissions, it would achieve the same emission reduction, and it could continue to sail at 12 knots. Such a fuel could be a blend of 36% fossil fuels and 64% of low-carbon fuels that have 80% lower lifecycle CO₂ emissions than fossil fuels.

Another example is a 7,000 dwt general cargo carrier, sailing 10 knots on average and consuming 11 tonnes of fuel per day, thus emitting 35 tonnes of CO₂ per day at sea. If this ship would be subject to a speed limit that reduces its speed by 10%, its emissions would be reduced to 26 tonnes of CO₂ per day at sea. If the ship can demonstrate that its operational efficiency is better than 26 tonnes of CO₂ per day, or better than 0.12 tonnes of CO₂ per nautical mile, it could continue to sail at 10 knots.

4.7 Conclusions

One reason to regulate speeds of ships is that current speeds are higher than socially optimal because the external costs of greenhouse gas emissions of ships are not internalised. If they were, fuel costs would be significantly higher and the optimal speeds significantly lower.

In order to effectively reduce emissions, speed regulations have to be mandatory and there has to be an enforcement system that deters ships from not complying. Speed regulation can either be set globally, unilaterally as a condition of entry into a port or as a condition to navigate in coastal waters, or bilaterally between ports in two states.

Speed regulations can best be differentiated to ship type and size so that ships do not have to operate at technically challenging low loads and in order not to disturb the competition between ship types. An issue that needs to be studied in more detail is whether it is more effective to regulate average or maximum speeds. Probably regulating maximum speeds is easier to implement, because it doesn't require regulation on how averages would be calculated.

A speed regulation could have alternative means of compliance, such as the use of low-carbon fuels or equivalent improvements of operational efficiency by other means than speed reduction.



5 Conclusions

The aim of this report is to assess the potential for shipping to reduce emissions through speed reductions in the immediate and short- to mid-term. We find that a an emission reduction of up to 4% or 20 Mt CO₂, can be achieved by bringing the ships that are currently idle or laid-up back into the active fleet. This would more than reverse the 2.4% increase in emissions that have occurred between 2013 and 2015 and bring the shipping industry back on the downward trend in emissions that started in 2008. The associated speed reduction would vary between 0 and 12%, depending on the ship type and size, because the laid-up ships are unevenly distributed over the fleet.

In the period up to 2030, baseline CO₂ emissions could be reduced by 13, 24 and 33% if the ships reduced their speed by 10, 20 and 30%. A 10% speed reduction would still see a slight increase of emissions between 2018 and 2030, while the other two scenarios would put shipping emissions on a downward path even in the absence of other measures.

In order to achieve these emission reductions, the fleet would need to grow and the demand for new ships would have to increase by 10, 22 and 37% for a 10, 20 or 30% speed reduction respectively. Speed reductions of 10 and 20% can be achieved if new deliveries grow back to the highest levels seen in the past decades. Larger speed reductions would require exceeding those levels for bulkers and small container ships.

The impacts of slow steaming on economies of exporting countries that are far removed from their main markets are modest. Even when making very conservative assumptions about the impacts, this report shows that in two cases they are unlikely to have an economic effect amounting to more than a tenth of a percent of the GDP of South American countries. It is unlikely that other countries would experience higher impacts.

There are no legal impediments to speed regulation. Speed regulation can either be set globally, unilaterally as a condition of entry into a port or as a condition to navigate in coastal waters, or bilaterally between ports in two states. In order to effectively reduce emissions, speed regulations have to be mandatory and there has to be an enforcement system that deters ships from not complying.

One reason to regulate speeds of ships is that current speeds are higher than socially optimal because the external costs of greenhouse gas emissions of ships are not internalised. If they were, fuel costs would be significantly higher and the optimal speeds significantly lower.

Speed regulations can best be differentiated to ship type and size so that ships do not have to operate at technically challenging low loads and in order not to disturb the competition between ship types. A speed regulation can have alternative means of compliance, such as the use of low-carbon fuels or equivalent improvements of operational efficiency by other means than speed reduction.



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