INTERSESSIONAL MEETING OF THE WORKING GROUP ON REDUCTION OF GHG EMISSIONS FROM SHIPS
7th session
Agenda item 2

ISWG-GHG 7/2/15
7 February 2020
ENGLISH ONLY

FURTHER CONSIDERATION OF CONCRETE PROPOSALS TO IMPROVE THE OPERATIONAL ENERGY EFFICIENCY OF EXISTING SHIPS, WITH A VIEW TO DEVELOPING DRAFT AMENDMENTS TO CHAPTER 4 OF MARPOL ANNEX VI AND ASSOCIATED GUIDELINES, AS APPROPRIATE

Addressing concerns raised at ISWG-GHG 6 on the proposal to establish an Energy Efficiency Existing Ship Index (EEXI)

Submitted by Greece, Japan and Norway

SUMMARY

Executive summary:	This document aims to address questions and concerns raised at ISWG-GHG 6 on the proposal to establish an Energy Efficiency Existing Ship Index (EEXI): is a power limit effective as opposed to a speed limit, and will the proposed EEXI reduction levels lead to emission and carbon intensity reduction? What is the impact on SIDS and LDCs? And what is the impact on older ships?
Strategic direction, if applicable:	3
Output:	3.2
Action to be taken:	Paragraph 27
Related documents:	MEPC 75/7/2 and ISWG-GHG 6/2/3

Background and purpose

1 ISWG-GHG 6 undertook a constructive consideration of the proposal on establishing an Energy Efficiency Existing Ship Index (EEXI) by Japan and Norway provided in document ISWG-GHG 6/2/3, and the impact assessment provided in document ISWG-GHG 6/2. The purpose of this document is to provide further information and assessment of the proposal.

2 This document aims at responding to questions raised by Member States and observer organizations during ISWG-GHG 6. While expressing general support for the proposal, several questions and concerns were raised on the impact of the measure on

emissions and on States. First, a question was raised whether a power limit, which is a key option to comply with a required EEXI for many ships, will lead to an emission reduction compared to e.g. a speed limit. Second, several member States asked for further consideration of the impact on small island developing States (SIDS) and least developed countries (LDCs). And third, the impact on older ships should be further elaborated. This document aims to address these questions with more detailed explanations and analyses.

Impact on emissions: is a power limit ineffective as opposed to a speed limit?

3 During ISWG-GHG 6, some delegations raised the questions whether a power limit would not lead to emission reduction, as opposed to a speed limit. One of the main options to comply with a required EEXI for a ship is to limit the engine power, which is why it is important to address this question.

4 Speed and power requirements are closely related. Figure 1 below shows a typical speed/power curve and actual speed/power in operation. The power needed increases exponentially with higher speeds due to resistance (solid line). Actual performance will wary somewhat due to e.g. cargo load and draft, wind and currents, and hull condition (dots). A ship running at 85% Maximum Continuous Rating (MCR) can for example reach speeds of about 16 knots. The same ship would only reach around 14.5 knots with a power limit at a level of 65% MCR, depending on conditions.

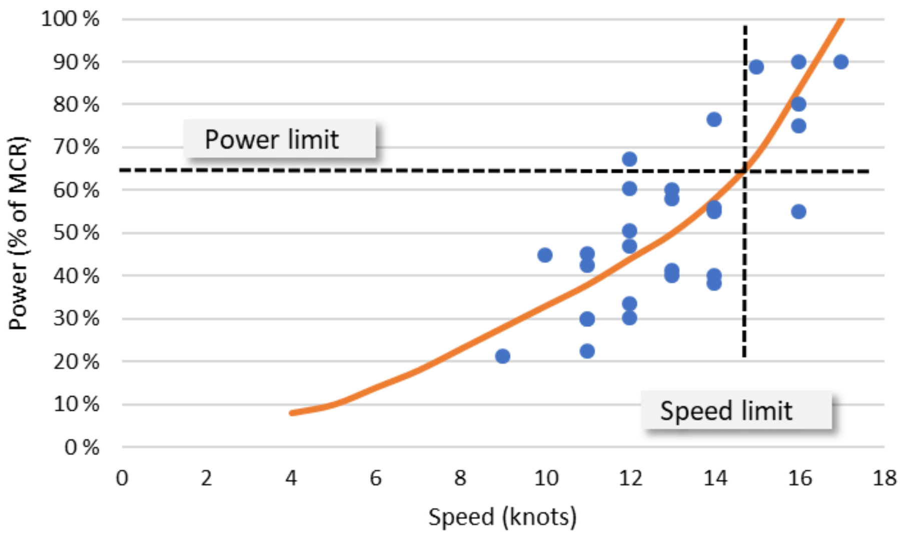

Figure 1: Typical speed-power curve (solid line) and actual speed-power achieved in operation (dots)

5 This relation between power and speed implies that a limit on one is a limit on the other. A limit on power is however directly limiting the fuel consumption and emissions, while emissions under a speed limit can show significant variation. The impact depends on the stringency of requirements and not the metric used. The impact of the EEXI with the stringency proposed in document ISWG-GHG 6/2/3 is analyzed in the next section.

6 Using a power limit has certain advantages over a speed limit, which has been thoroughly described in document ISWG-GHG 6/2/3. In particular:

.1 the EEXI and power limit can be pre-verified before commencing operation and any use of reserve power will be logged and controlled;

.2 by using the EEXI as metric, a wider range of compliance options for improving carbon intensity are available than is the case for a speed limit; and

.3 the wider range of compliance options ensures that already energy efficient ships are not penalized.

7 For these reasons, the EEXI, including the possibility to apply a power limitation, is preferred to a speed limit. Rather than debating if a speed limit is more effective, the discussion should focus on setting the right stringency of the EEXI requirements.

Impact on emissions: will the proposed EEXI reduction levels lead to emission and carbon intensity reduction?

8 The co-sponsors have analyzed the impact of the EEXI if all ships apply a power limit to reach the proposed requirements. We have based the analysis on AIS and ship data for 2019. The detailed method is described in annex to this document. Ro-ro cargo ships, ro-ro passenger ships and cruise ships are not included in the analysis of power limitation due to the complexity of calculating the EEXI based on values in available databases.

9 The ships within the size and type scope defined in regulation 21 of MARPOL Annex VI will be subject to the EEXI requirements, covering 85% of the 2019 fleet emissions, and providing 95% of the total transport work capacity. 18% of emissions in 2018 came from shipping within scope of the EEDI regulations (Phase 0 or Phase 1). Even though the share of ships with required EEDI will increase towards 2023 and 2030, existing ships not subject to the EEDI requirements will still have a significant share of total emissions and impact the overall world fleet carbon intensity. It is therefore important to address these ships by imposing both technical and operational requirements.

10 Table 1 below shows the number of ships per range of power reduction as % reduced from MCR, and average MCR reduction for each ship segment after applying the EEXI. This part uses the 2019 fleet without any scrapping or addition of new ships, even though the oldest ships will be scrapped before entry into force of the regulation. The average power reduction is 20% of MCR, with the largest limitations applied on containerships, general cargo ships and gas tankers. The most common limitation will be between 10% and 30% of MCR. About 6% of vessels would need to reduce MRC by more than 40%.

Table 1: Number of ships per range of power reduction

Ship segment	More than 40%	31-40%	21-30%	11-20%	1-10%	No change
Bulk carrier	82	616	3,805	3,986	1,955	323
Tanker and comb. carrier	283	892	2,906	3,063	1,280	829
Container ship	653	1,451	1,295	587	374	241
Gas/LNG carrier	92	281	433	256	58	30
General cargo ship	975	1,117	1,449	1,118	547	1,077
Refrigerated cargo carrier	3	6	61	84	110	205
Ro-ro cargo, vehicle	3	18	71	223	241	102
Total	**2,091**	**4,381**	**10,020**	**9,317**	**4,565**	**2,807**

11 Figure 2 below shows the average speed and engine load before and after a required EEXI is applied, which leads to an average in-transit (> 5 knots) speed reduction of 3% from 12.8 to 12.4 knots and a 11% reduction of average engine load from 56% to 50%.

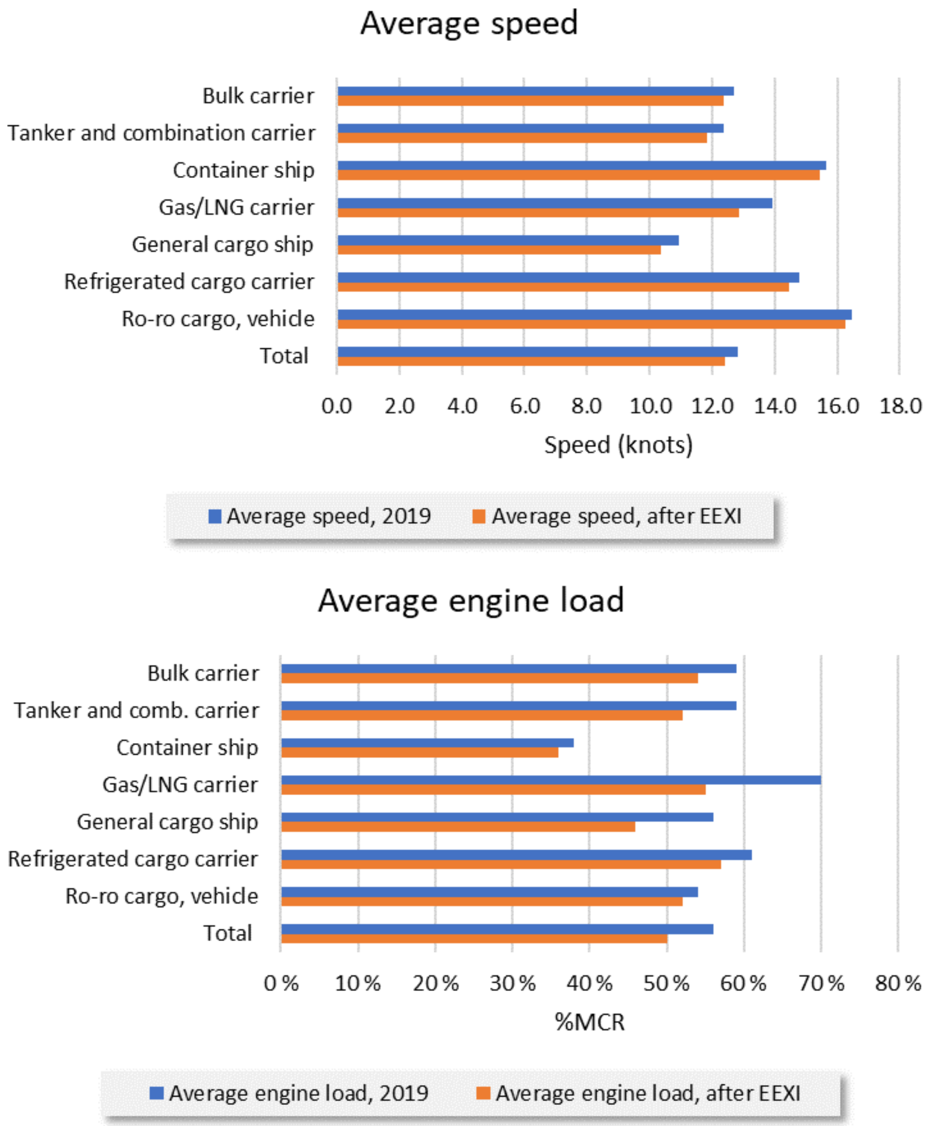

Figure 2: Changes in average in-transit (> 5 knots) speed and engine load, before and after applying the EEXI

12 Table 2 below shows the CO_2 emissions per deadweight-mile (Annual Efficiency Ratio – AER): for 2008, using numbers from the *Third IMO GHG Study 2014*; for 2018, before and after applying the EEXI requirements; and for 2030, removing ships expected to be scrapped by 2030.

13 The EEXI applied on the 2019 fleet will result in a 7% reduction in carbon intensity measured by the AER. The lower AER reduction compared to average engine load is due to more hours needed in-transit to do the same transport work. While the impact on average speed is limited, limiting power will reduce the hours spent at high engine load and fuel consumption.

14 When removing older ships expected to be scrapped before 2030, the reduction from 2008 to 2030 will be almost 50%. Further reduction can be expected due to even more efficient ships being built during the next decade. Note that this part of the analysis does not include ro-ro cargo ships, ro-ro passenger ships and cruise ships, and other vessels outside the scope of the EEDI and EEXI.

Table 2: Estimated AER (grams CO_2 emissions per deadweight-mile) per segment

Ship type	2008	2019 (Current)	2019 (with EEXI)	2030 (with EEXI)	Reduction 2008-2030
Bulk carrier	5.56	3.63	3.35	3.29	41%
Tanker and comb. carrier	5.04	4.63	4.26	4.04	20%
Containership	18.5	12.1	11.6	10.9	41%
Gas/LNG carrier	10.8	11.6	9.86	9.27	14%
General cargo ship	17.8	11.5	10.0	9.27	48%
Refrigerated cargo carrier	58.1	27.3	25.8	24.6	58%
Ro-ro cargo, vehicle	20.4	15.5	14.9	14.7	28%
Total	**9.93**	**5.82**	**5.41**	**5.03**	**49%**

15 Major reductions have already been achieved through both more efficient ships and speed reductions due to market conditions and fuel prices. While the impact on the 2019 fleet is only 7%, a key benefit of the EEXI is to prevent ships from speeding up in case future market conditions would make it a financially beneficial option. This will protect the energy efficiency gains already achieved. The co-sponsors also recommend that the EEXI be complemented with a strengthened SEEMP addressing operational measure and ships out of the scope of the EEXI.

16 In total, the proposed stringency on the EEXI should be sufficient to reach the carbon intensity ambitions by 2030. Further reduction can be achieved with more stringent requirements, but that will result in a larger impact on ships.

Impact on older ships

17 The next analysis compares the impact of EEXI and power limits on older ships. Figure 3 below shows the power limit per generation and ship type. The main difference between the generations is between ships built prior to the EEDI in 2013 and those that are built with a required EEDI. Figure 4 below shows the average speed before and after applying the EEXI on ships delivered before 2005.

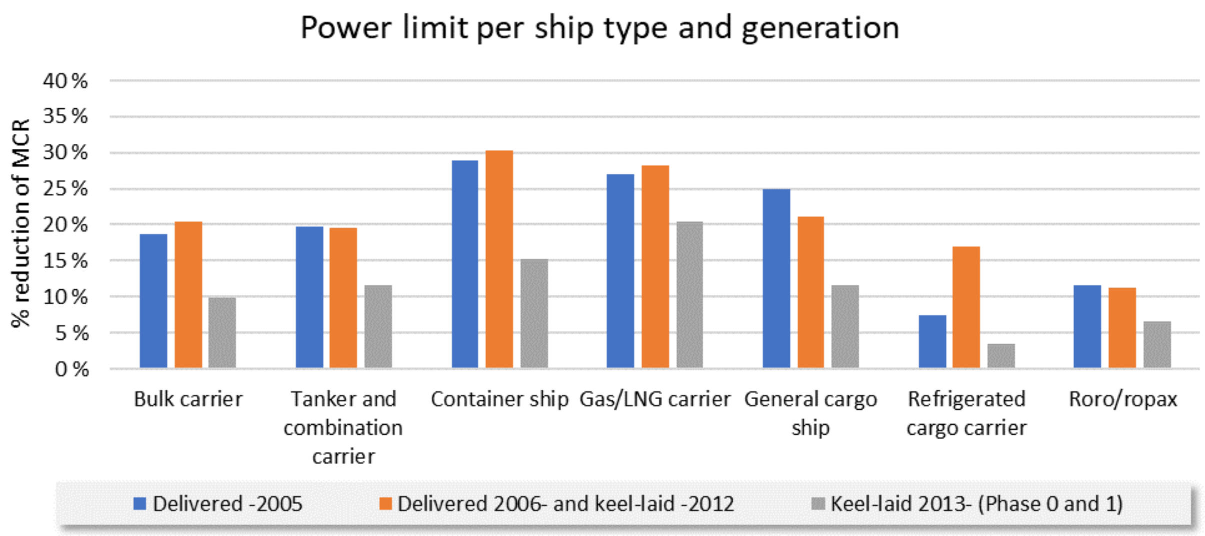

Figure 3: Power limit per ship type and generation

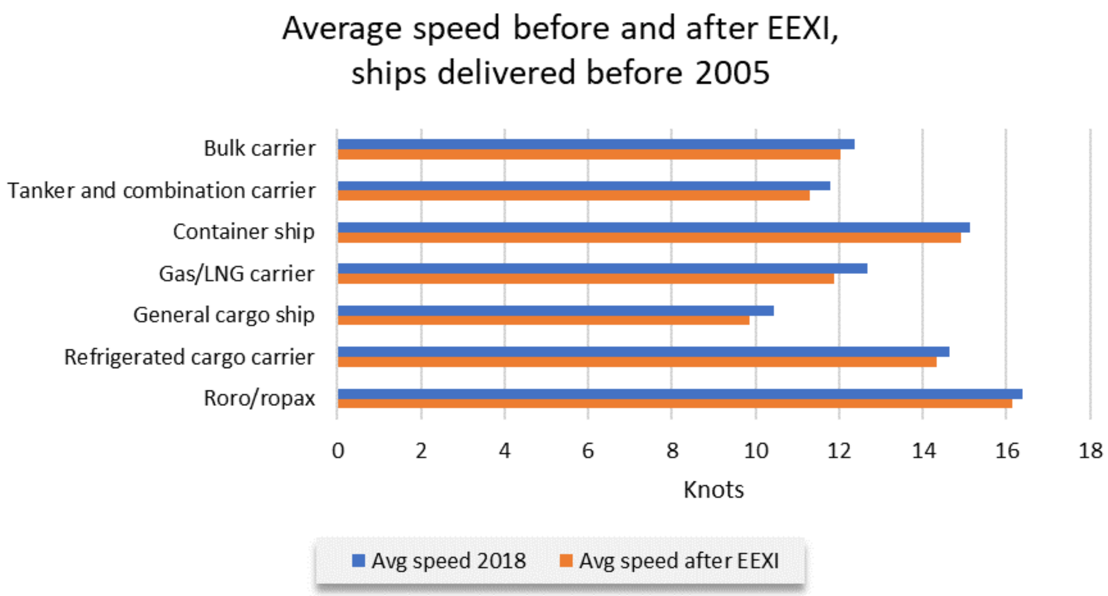

Figure 4: Average speed before and after applying the EEXI on ships built before 2005

18 The analysis shows that pre-EEDI ships will need a larger power reduction than newer ships. This is expected as these ships have not been subject to EEDI requirements. The largest impact will be on the general cargo segment with more than 3,200 vessels delivered prior to 2005 requiring an average 25% power limitation. Container and gas vessels will require the largest power limitation with up to 30% reduction on average. However, even for these ship types the average speed will not decrease significantly.

19 The level of reduction is not disproportionate for any of the segments, compared to the total fleet. The main impact will be to limit the maximum speed which may reduce operational flexibility, for example limiting the ability to catch up on delays. The analysis has not considered the technical challenges of installing a power limit on older vessels but focuses only on the impact on average speed, engine power and emissions.

Further assessment of Impacts on States: vessels servicing LDC and SIDS

20 To analyze the impact on LDCs and SIDS, the co-sponsors have looked at ships trading in two areas: the Caribbean and the South Pacific. Using AIS data for 2019, all ships that have stayed more than 24 hours without moving in the defined areas, which are assumed to have at least one port call and considered to be trading to the LDC and SIDS, have been identified. There may be some ships that have been waiting in the area on a transit included in the selection.

21 Table 3 below shows the number of ships with AIS transponder[1] per ship segment sailing in the two areas. There are approximately 2,200 ships trading in the South Pacific area, having CO_2 emissions of about 5.4 million tonnes. In the Caribbean there are approximately 1,800 ships with CO_2 emissions of about 5.1 million tonnes. Less than half the ships in the South Pacific fall under the scope of the EEXI. About 800 of the ships outside of the EEXI scope are fishing vessels. In the Caribbean almost 80% of the ships will be impacted by the proposed regulation. The CO_2 emission estimates for the identified ships in the two areas amounts to about 1.2% of the total CO_2 emissions from shipping.

Table 3: Number of ships within the scope of the EEXI and in total trading in the South Pacific and the Caribbean in 2019

Ship segment	**Caribbean**		**South Pacific**	
	EEXI scope	**Total**	**EEXI scope**	**Total**
Bulk carrier	375	380	275	279
Tanker and combination carrier	499	502	203	216
Container ship	153	159	88	98
Gas/LNG carrier	75	105	14	43
General cargo ship	131	151	128	155
Refrigerated cargo carrier	41	41	106	133
Ro-ro, vehicle and ro-pax	71	77	61	72
Cruise	59	72	44	64
Other	-	323	-	1168
Total	**1,404**	**1,810**	**919**	**2,228**

22 Some ships trade continuously in the area, while others can have a few port calls. There may be some ships that have been waiting in the area on a transit included in the selection. Figures 5 and 6 below show the ship traffic density, measured in CO_2 emissions, for the identified ships in the South Pacific and the Caribbean in 2019. The figures show annual CO_2 emissions per 0.1 x 0.1-degree grid, where the highest density is red representing approximately 8,000 tonnes CO_2 per year per grid cell. The grid areas are between 100 to 123 km^2.

[1] AIS transponders are required for all ships above 300 GT engaged on international voyages, cargo ships above 500 GT not engaged on international voyages and all passenger ships irrespective of size.

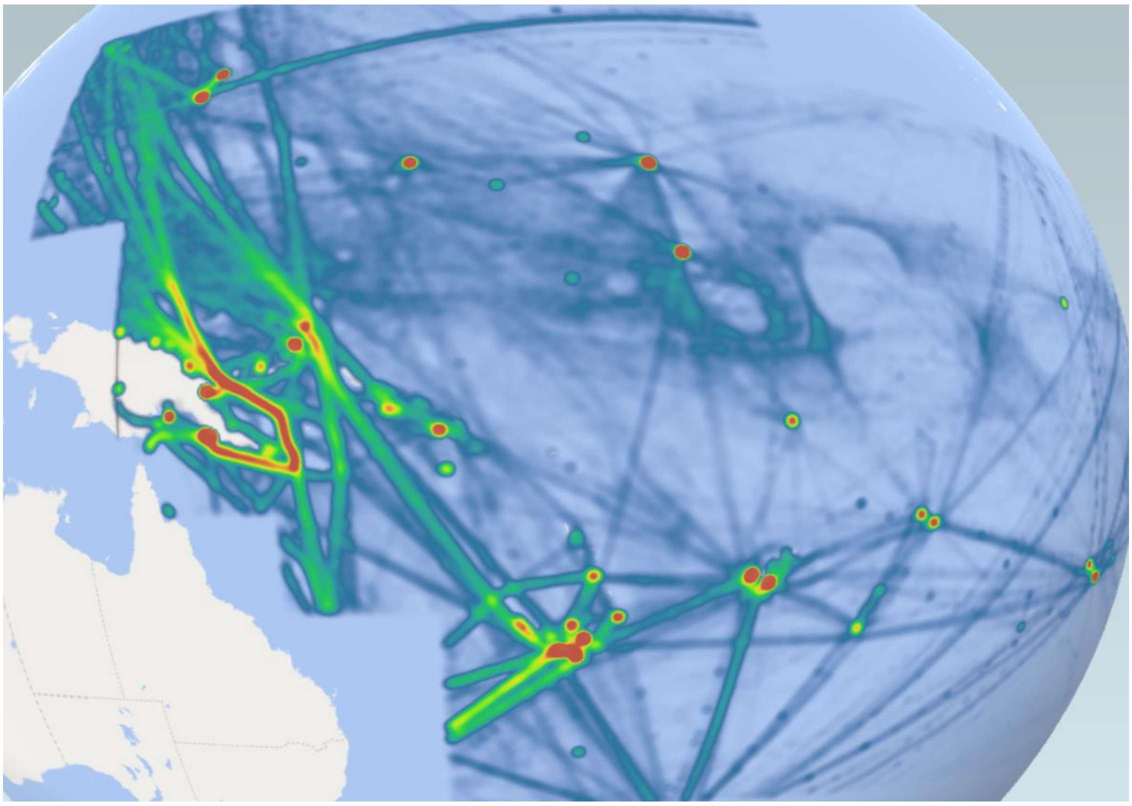

Figure 5: Ship traffic density in the South Pacific, by CO_2 emissions 2019. Red represents approximately 8,000 tonnes CO_2 per year per grid cell

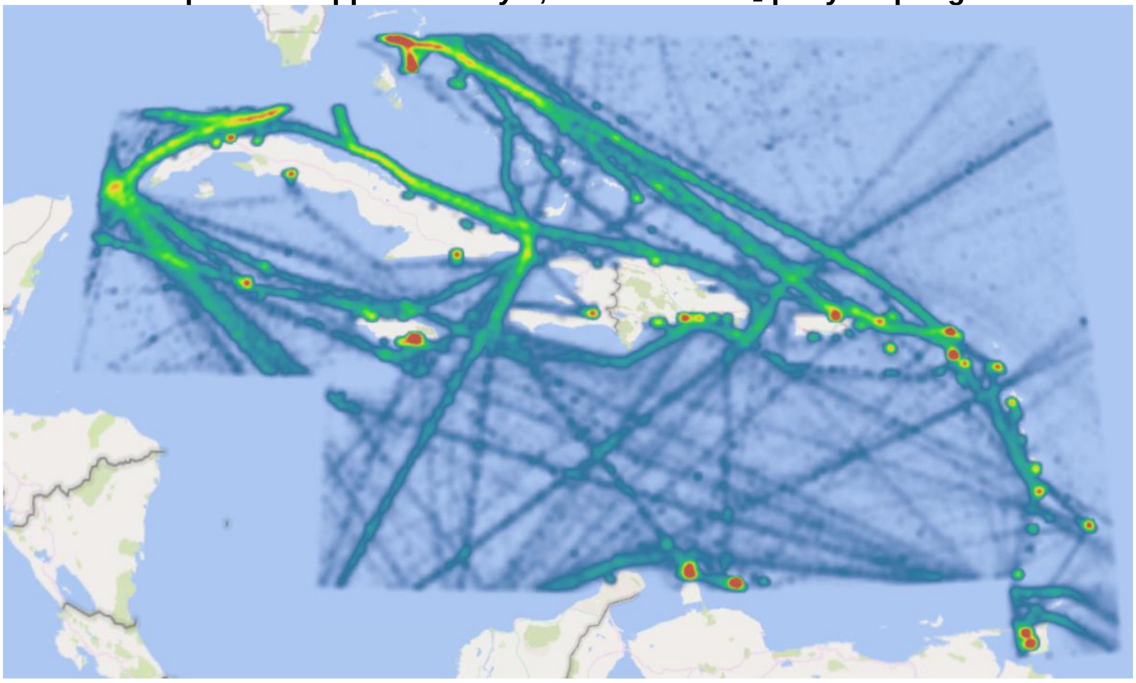

Figure 6: Caribbean ship traffic density, by CO_2 emissions 2019. Red represents approximately 8,000 tonnes CO_2 per year per grid cell.

23 Figure 7 shows the average age of the global fleet compared to the ships sailing in the two areas within the scope of the EEXI. In general, the fleet trading in the LDCs and SIDS are younger than the global average, in particular the tank and gas tankers, the general cargo ships and the ro-ro/vehicle/ro-pax ships.

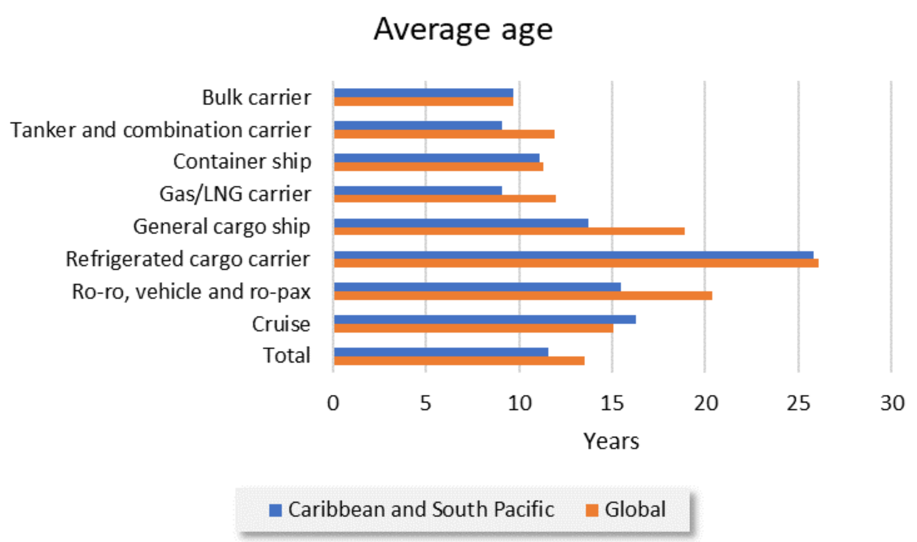

Figure 7: Average age of the global fleet and ship trading in the South Pacific and the Caribbean in 2019.The numbers only include ships within the scope of the EEXI

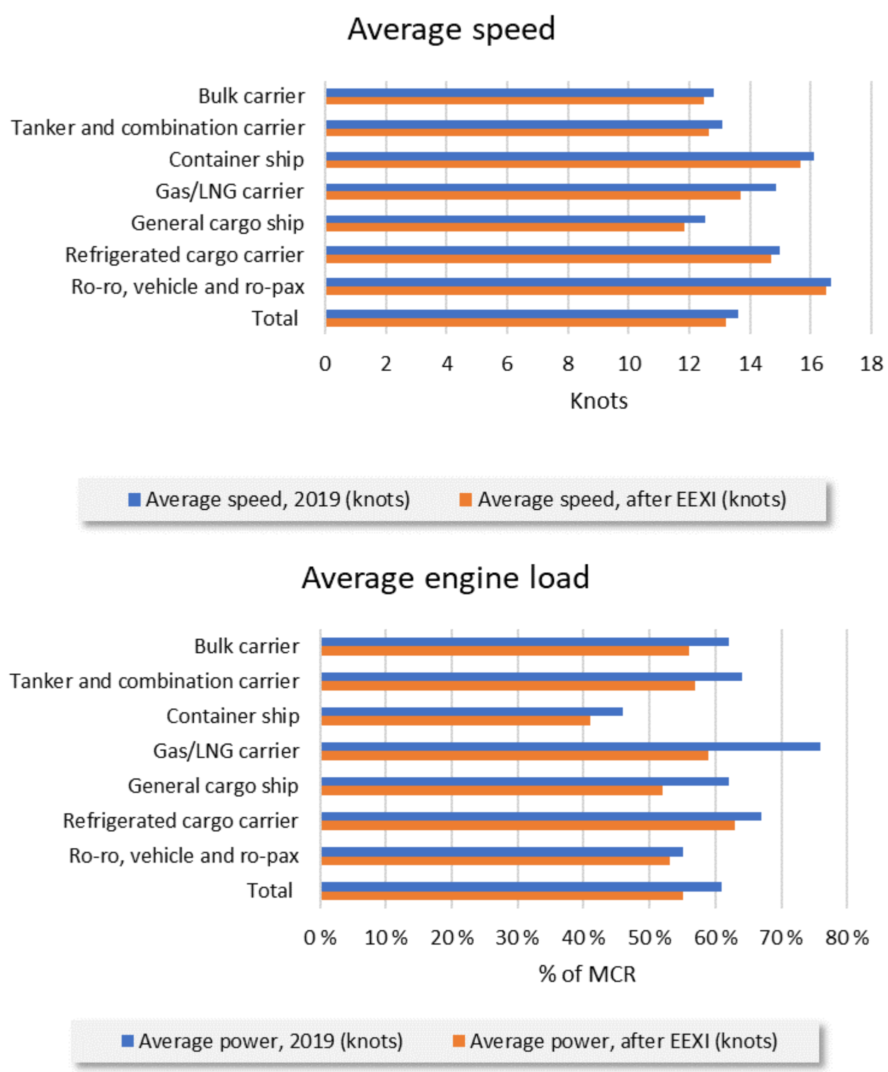

Figure 8: Changes in average in-transit (> 5 knots) speed and engine load of ships trading in the South Pacific and the Caribbean, before and after applying the EEXI

24 The speed and engine power reductions expected based on the analysis are shown in Figure 8 above. The largest reduction will be for gas carriers and general cargo ships. The impact on the average speed are expected to be limited and smaller than for the global fleet, likely due to the younger fleet.

25 The ships serving LDCs and SIDS are not very different than the global fleet and are in some cases younger than the global average, indicating that the impact of EEXI will not be disproportionate compared to the global fleet. The EEXI is expected to result in a reduction in fuel consumption and in reduced transport costs. Most ships will be able to operate according to schedules very similar to existing ones. Similar to the analysis of the global fleet, the reduced maximum speed will, however, limit the ability of a ship to catch up with any delays, e.g. due to bad weather conditions, and reduce the robustness of a schedule.

Conclusions

26 Based on the analysis presented, the following conclusions can be made:

.1 Impact on emissions: is a power limit ineffective as opposed to a speed limit?

No, as speed and power are closely related. The impact on emissions of a speed or power limitation depends on the stringency of the requirement and effectiveness of enforcement. The EEXI and a power limit is easier to enforce than a speed limit. Rather than debating if a speed limit is more effective, the discussion should focus on setting the right stringency for the EEXI requirements.

.2 Will the proposed EEXI reduction levels lead to emission and carbon intensity reduction?

Yes, if applying the stringency proposed at ISWG-GHG 6 to the 2019 fleet, the carbon intensity will reduce by 7% compared to same fleet in 2019, and almost 50% when comparing from 2008 to 2030. While the impact on the 2019 fleet is only 7%, a key benefit of the EEXI is to prevent ships from speeding up in case future market conditions would make it a financially beneficial option. This will protect the energy efficiency gains already achieved. In total, the proposed stringency of the EEXI should be sufficient to reach the carbon intensity ambitions by 2030. Note that the co-sponsors also recommend that the EEXI is complemented with a strengthened SEEMP addressing operational measure and ships out of the scope of the EEXI.

.3 What is the impact on older ships?

The major difference between generations is between ship built before and after the EEDI came into force in 2013. The level of reduction is not disproportionate for any of the segments, compared to the total fleet. The main impact will be to limit the maximum speed which may reduce operational flexibility, for example limiting the ability to catch up on delays. The analysis has not considered the technical challenges of installing a power limit on older ships but focuses only on the impact.

.4 What is the impact on SIDS and LDCs?

The ships serving LDCs and SIDS are not very different than the global fleet and are in some cases younger than the global average, indicating that the impact of EEXI will not be disproportionate compared to the global fleet. The EEXI is expected to result in a reduction in fuel consumption and in reduced transport costs. Most ships will be able to operate according to schedules very similar to existing ones. Similar to the analysis of the global fleet, the reduced maximum speed will, however, limit the ability of a ship to catch up with any delays, e.g. due to bad weather conditions, and reduce the robustness of a schedule.

Action requested of the Working Group

27 The Group is invited to consider the information and proposals put forward in this document and take action as appropriate.

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ANNEX

DESCRIPTION OF THE METHOD USED

1 The analysis in this paper is based on AIS and IHS data using DNV GL environmental accounting model: MASTER (Mapping of Ship Tracks, Emissions and Reduction potentials)[2]. AIS data provide a detailed and high-resolution overview of current sailing speeds, operating patterns, sailed distances (nautical miles) and time spent by each vessel. The information from AIS is compiled with technical databases (e.g. IHS) for detailed information on the individual ships, such as installed power on main and auxiliary engines, machine configuration (diesel-electric versus diesel-mechanical / direct-driven), ship design speed, tonnage, etc.

2 These data form the basis of the AIS based environmental accounting, which is used to calculate fuel consumption and emissions and operational characteristics for voyages and when in port. Separate calculations for main engines, auxiliary engines and boilers are made for each individual ship. The method has been established in cooperation with the Norwegian Coastal Administration (NCA). The output of the MASTER model has been validated against actual reported consumption from 5,000 vessels of all types.

3 The main engine load is calculated based on the ship's design speed and observed actual speed over ground based on AIS signals. The model assumes that the design speed is achieved at 85% of the engine load and the engine load at other speeds are calculated according to the "Cubic Rule" method where the engine power increases speed raised to the third power. This is an approximation as in reality, the speed over ground achieved at a certain engine load will vary according to cargo load, hull condition, weather and currents. Comparison of the AIS estimated with reported fuel consumption shows that the model is accurate for larger set of ships over time, typically up 5% for most cargo carrying ship types.

4 For port calls, the uncertainty in total fuel consumption will be linked to fuel consumption for auxiliary engines and boilers, where AIS cannot be used for other than indicating operating hours. However, consumption in port is not the main objective of this study as it does not affect estimated reduction potential due to power limitation.

5 We evaluate the impact of the EEXI on the fleet and observed operations in 2018. To estimate the impact on the 2030 fleet, vessels that are expected to be scrapped are removed. We assume that the oldest and least efficient vessels are scrapped. We can expect that any new vessels to be build the next decade will be at least as efficient as the best vessels in the 2018 fleet. This analysis does not include these vessels in the AER for 2030 and will likely underestimate of future carbon intensity improvements.

6 Each year about 1% to 3% of the fleet is scrapped and new builds enter the fleet replacing the capacity and accommodating for growth. This analysis does not consider any variation in the scrapping rate due to short-term market conditions but looks only at long-term developments, assuming a scrapping of 2% of the fleet transport capacity per year. The share of transport work in 2018 per generation of vessels are determined using AIS data and shown in Table 1. The scenario is based on the BAU Scenario 13 in the *Third IMO GHG Study 2014*.

2 For more information on the MASTER model, see: Mjelde et al, 2014: Environmental accounting for Arctic shipping – A framework building on ship tracking data from satellites. Marine Pollution Bulletin, 87(1–2), 22–28. https://doi.org/10.1016/j.marpolbul.2014.07.013.

Table 1: Estimated distribution of ships per generation (one decade), measured in transport work capacity

Generation	Current	BAU Scenario 13
	2018	2030
Ships built before 2000	7%	-
Ships built 2000-2010	35%	12%
Ships built 2010-2020	58%	36%
Ships built 2020-2030		52%

7 We assume that all vessels will apply a power limitation to achieve the required EEXI. We can expect that other solutions will be used as well but this paper focuses on the backstop method that should be applicable for most of the ships.

8 For each ship, we calculate an Estimated Index Value[3] (EIV) as a proxy for the attained EEDI and EEXI, and the required EEXI using the proposed requirements in document ISWG-GHG 6/2/3 (see Table 2). Ro-ro cargo, ro-pax and cruise vessels are not included in the analysis of power limitation due to the complexity of calculating the EIVI based on values in available databases.

9 Based on this we estimate the maximum power level to reach the required EEXI, considering that limited power also reduces the reference speed.

Table 2: Proposed level of the required EEXI per ship type relative to the EEDI reference line

Ship type	Required EEXI
Bulk carrier	∆20%
Tanker and combination carrier	∆20%
Container ship	∆30-50% by size
General cargo carrier	∆30%
Gas carrier	∆20-30% by size
LNG carrier	∆30%
Refrigerated cargo carrier	∆15%
Ro-ro cargo (vehicle)	∆20%
Cruise ship	∆30%

10 In the next step, we calculate an operational profile for each vessel with number of hours, distance and CO_2 emissions per hours at each speed and engine load. We assume that the distance sailed above the power limit will have to be sailed at the limited power level and reduced speed. This also means it will take longer time. The additional hours would have to be covered either by more efficient port operation or adding more ships to supply the same transport work. In this analysis we assume the additional hours will be performed by the same ship (i.e. a ship with the same efficiency) regardless if the number of hours exceed the total number of hours in a year.

3 See MEPC.231(65): 2013 Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI).

11 In the below figures and tables, we show an example of the method applied on a 17,000 DWT ship with a 6,000kW main engine and design speed of 14.5 knots. Under the new requirements the power will be limited to 73% of MCR. Figure 1 shows the 2,200 hours sailed above the power limit in yellow. After applying the power limit, the same distance will have to be sailed at the power limit using 2,900 hours, shown in the blue bar. The CO_2 emissions per hour at the power limit is much lower than at the higher speeds and the total emission is reduced.

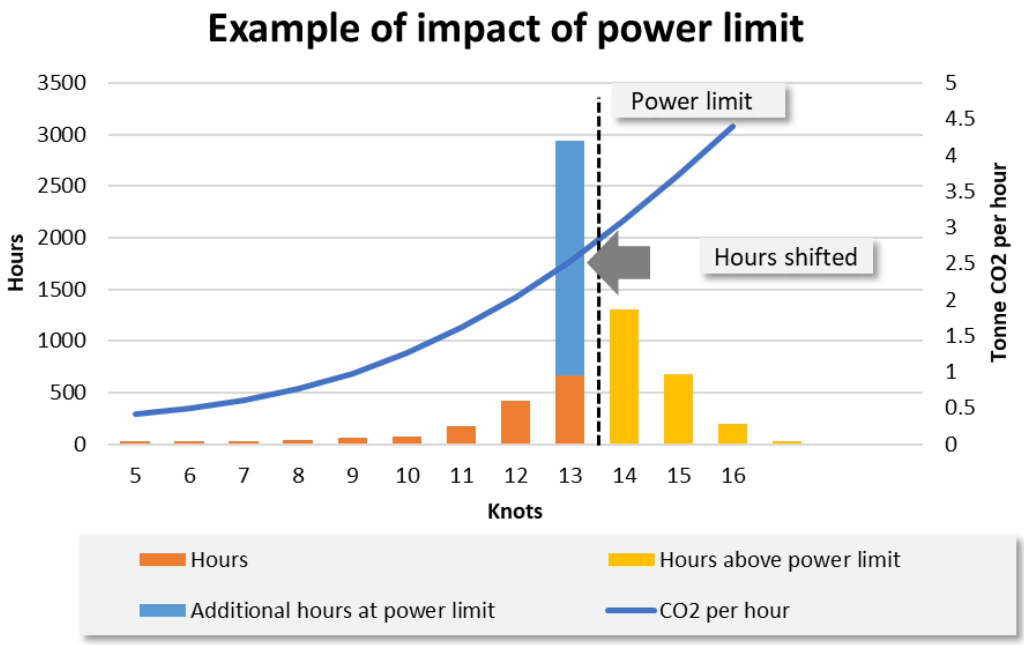

Figure 1: The hours above 13 knots (yellow bars) are shifted to 13 knots (blue bar) including additional hours to cover the same amount of transport work. The hours spent below the power limit are unchanged

12 For each segment we calculate the new emissions levels, average engine load and speed and carbon intensity after applying a power limitation to reach the required EEXI. Table 3 shows key design and operational parameters for the example ship before and after applying power limitation to comply with a required EEXI. The power limitation results in an EIV reduction of 17%. In operational this reduces CO_2 emissions and AER by 12%. The reduction in average speed is only 2% and the vessel would need about 80 hours extra to sail the same distance at lower speeds. However, there is a significate reduction as the power needed at high speed is exponentially higher than at lower speeds.

Table 3: Summary of key parameters before and after applying power limitation to comply with a required EEXI

	Current	After	Reduction
Main Engine power MCR (kW)	6000	4380	27%
Deadweight	17000	17000	-
Design speed (Vref)	14.5	13	10%
EIV (g/dwt-mile)	11.9	9.86	17%
Distance sailed (nm)	47000	47000	-
Avg actual speed (knots)	12.3	12.0	2%
Emissions (t CO_2)	17000	15000	12%
AER (g/dwt-mile)	21.3	18.8	12%

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