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PREVENTION OF AIR POLLUTION FROM SHIPS

Comments on the EEDI Baseline Formula

Submitted by Greece

SUMMARY	
Executive summary:	This document provides some comments on the formula used to define the baseline for the Energy Efficiency Design Index (EEDI)
Strategic direction:	7.3
High-level action:	7.3.1
Planned output:	7.3.1.3
Action to be taken:	Paragraph 28
Related documents:	GHG-WG 2/2/7, GHG-WG 2/2/9, GHG-WG 2/2/22; MEPC 59/4/20, MEPC 59/WP.8, MEPC 59/24; MEPC 60/4/16, MEPC 60/4/17; MEPC.1/Circ.681 and MEPC.1/Circ.682

Introduction

1 MEPC 59 agreed to circulate the interim Guidelines on the method of calculation of the Energy Efficiency Design Index (EEDI) for new ships (MEPC.1/Circ.681) and the interim Guidelines for voluntary verification of the EEDI (MEPC.1/Circ.682). MEPC 59 also noted the progress made on the EEDI baseline issues and agreed to invite Member Governments and observers to submit proposals and comments on the summary of the Chairman of the GHG Working Group (MEPC 59/WP.8, paragraph 6.33) for further consideration at MEPC 60.

2 Greece would like to respond to this invitation by submitting this document, in accordance with MSC-MEPC.1/Circ.2, Guidelines on the organization and method of work.

3 Shipping enables world trade and prosperity and is the most cost and energy efficient form of transport. Greece shares the position of many delegations that cost effective measures to improve energy efficiency and to curb greenhouse gas (GHG) emissions should be implemented with a high sense of urgency. At the same time, any such measure, either technical, operational or market-based, should not lead to distortions of competition on international trade. Whatever the measure is, it should demonstrate compatibility with the goal to reduce GHG emissions and should not lend itself to misinterpretation or manipulation.

4 As a matter of principle, Greece has consistently supported the view that a holistic approach is needed to address GHG emissions reductions. To be successful, such an approach should take into consideration, *inter alia*, the availability of technology to reduce emissions, the need to encourage innovative designs and technologies, and the economics of world trade. With regard to the EEDI, a holistic approach would focus on designing the best possible ship hull forms, propulsion systems and other technologies to improve energy efficiency, and would avoid shifting the focus to practices that may achieve a lower EEDI on paper but may have negative side effects with regards CO_2 emissions. Last but not least, a holistic approach would avoid other pitfalls that may be encountered if deficiencies in the formulae for the EEDI and the EEDI baseline are not corrected.

5 To that effect, the fundamental objective of the present submission is to contribute to the goal of true GHG emissions reduction by identifying deficiencies in the formula for the EEDI baseline, and propose ways on how to alleviate these deficiencies and to improve on how this formula can be used. Other deficiencies, mostly connected to lifecycle considerations *vis-à-vis* the EEDI, and to possible misapplications of the EEDI formula if the ship is underpowered, are discussed in documents MEPC 60/4/16 and MEPC 60/4/17 (Greece).

6 Several delegations and independent researchers have already raised some concerns[1] on the formulae used to define the EEDI and the EEDI baseline and on how these formulae can be used. CESA document MEPC 59/4/38 (and specifically annex 2), shows that a ro-ro ship would have to operate below surface or have a negative wave resistance to achieve an EEDI below the baseline, thus claiming a fundamental error in the baseline EEDI concept.

7 Greece has noted many of the concerns expressed above and would like to add its own observations and analyses on the matter.

Regression caveats

8 The current baseline formula for EEDI is: $Baseline\ value = a \cdot Capacity^{-c}$. It may be expressed as **EEDI (baseline) = aDWT^{-c}**, where DWT is the deadweight and a and c are positive coefficients determined by regression from the world fleet database, per major ship category. The regression is carried out between EEDI values and ship size in DWT, and all outliers that differed more than two-standard deviations are removed.

9 Note that speed is not a regression variable. But speed very much enters the calculation of the EEDI that is used in the regression, according to the simplified formula:

$$EEDI = 3.13(190P_{ME}+210P_{AE})/(DWT \cdot V), \text{ where}$$

$P_{ME} = 0.75MCR$
$P_{AE} = 0.025MCR + 250$ if $MCR \geq 10{,}000$ kW
$P_{AE} = 0.05MCR$ if $MCR < 10{,}000$ kW
V = service speed corresponding to 75% of MCR.

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1 For instance, China (GHG-WG 2/2/9, MEPC 59/4/20), CESA (GHG-WG 2/2/22), and Germanischer Lloyd*, among others. China showed, among other things, that CSR bulk carriers and ships complying with NO_x Tier II have an EEDI above the EEDI baseline (i.e. not favourable).

* See Köpke, M., P. Sames, "Energy Efficiency Design Index for High Speed Crafts," 10th International Conference on Fast Sea Transportation (FAST 2009), Athens, Greece, October 2009. In that paper, a function of the square of the ship's Froude number was suggested to be included in the denominator of the EEDI formula.

10 An important caveat here concerns the speed data that is used in the regressions. The typical assumption by all who perform regressions is that that the service speed that is recorded in fleet databases is equal or close to the one corresponding to the 75% MCR level. Yet, this may not usually be the case, as in some databases service speed is at the 100% MCR level. Even if service speeds are accurately reported by shipowners to database developers (which is not usually the case), a 25% deviation in the value of speed used in the formula would result in a 33% deviation in the value of the EEDI, which can be significant. And even if such an error is not systematic, the entire the EEDI baseline regression results would be less reliable because of such inconsistencies. Thus, to the extent that ship speeds are drawn from such databases, caution is necessary on how they are obtained, how they are used and how the results of the regression curves are interpreted. The related documents studied in this connection, for instance: GHG-WG 2/2/7 (Denmark), GHG-WG 2/2/9 or MEPC 59/4/20 (China), are not explicitly clear on this issue.

11 For bulk carriers, tankers and containerships, Denmark computed the following regression coefficients in its submission GHG-WG 2/2/7:

Coefficient/Ship	Dry bulk carrier	Tanker	Containership
a	1,354	1,950.7	139.38
c	0.5117	0.5337	0.2166

12 Greece conducted its own regression analyses but was unable to replicate the Danish regression results. The Lloyds Register Fairplay Sea-web™ database was used, with ships built after 1999 for bulk carriers and tankers and ships built after 1996 for containerships. Speeds from that database were drawn as representing the 75% MCR level. Outliers above two standard deviations were removed. The results are shown in figures 1, 2 and 3 below. In each figure the results with and without outliers are shown.

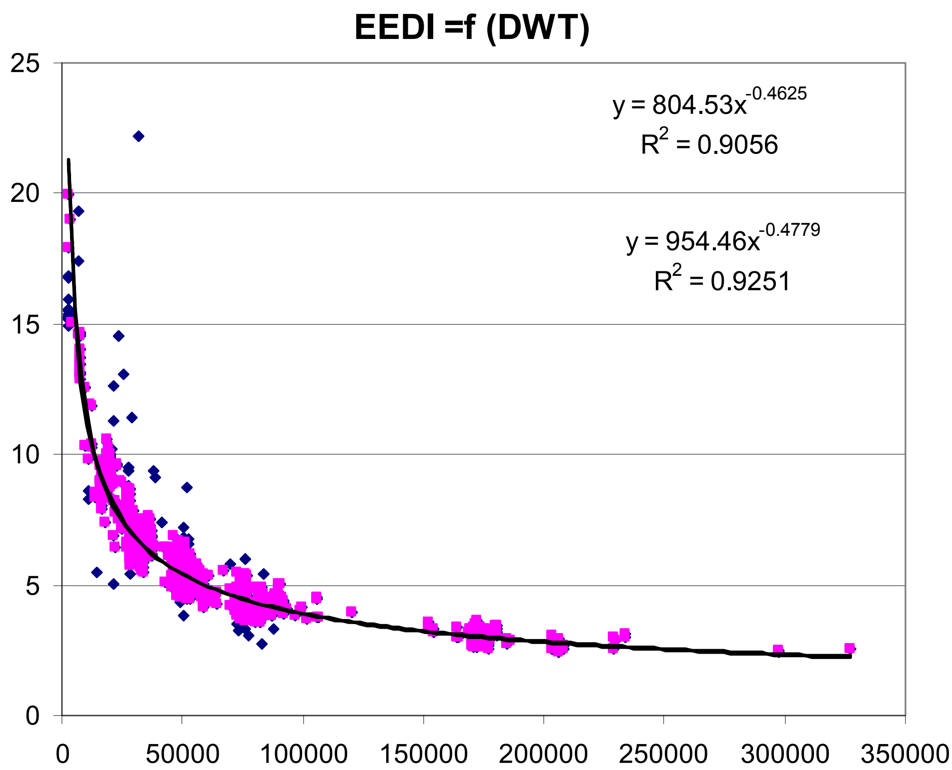

Figure 1: Dry bulk carriers
All data: 2,259 ships. Without outliers (shown in blue ◆): 2,218 ships

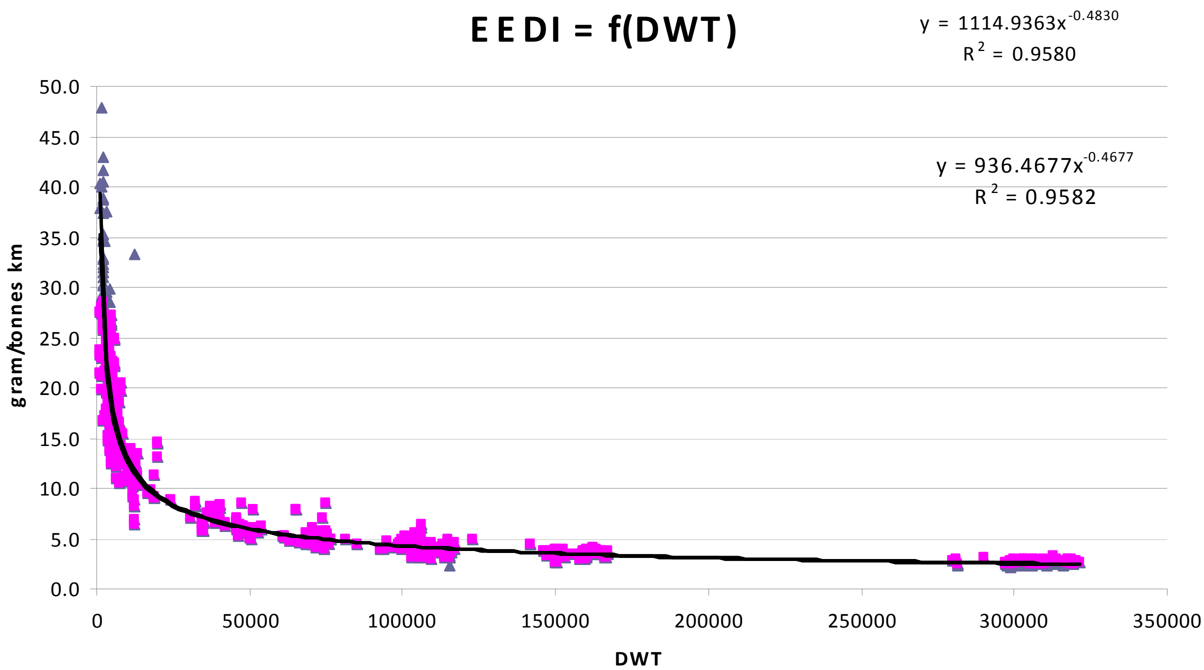

Figure 2: Tankers
All data: 1,463 ships. Without outliers (shown in blue ▲): 1,377 ships

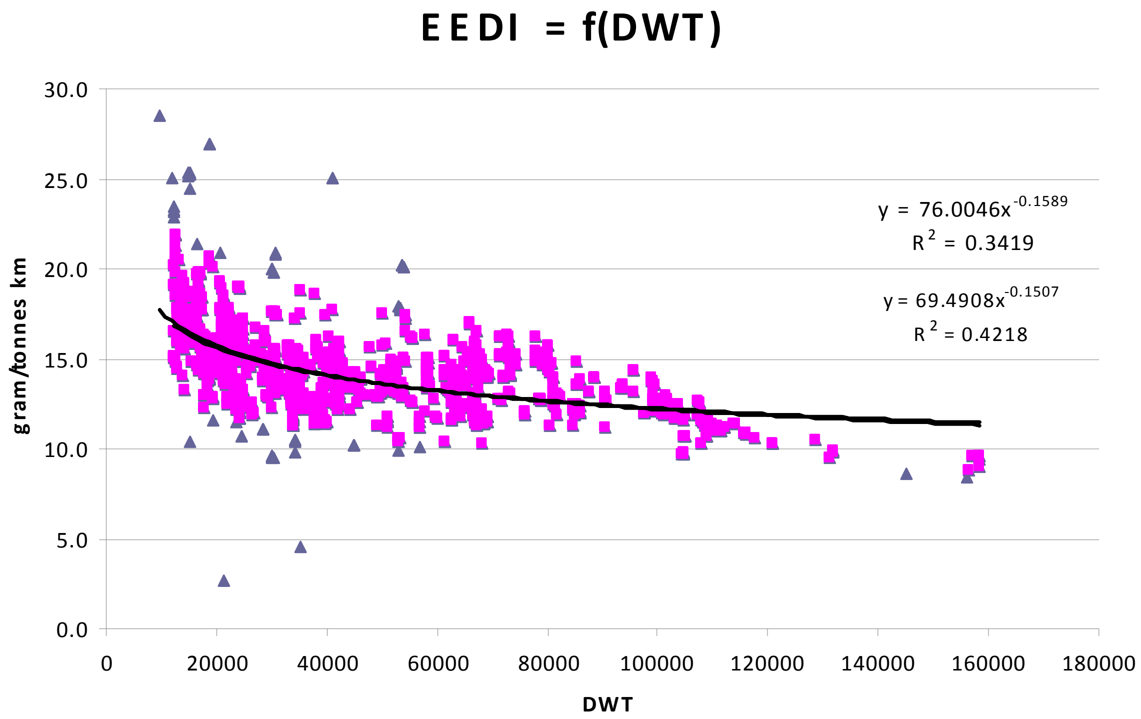

Figure 3: Containerships (>1,000 TEU)
All data: 2,447 ships. Without outliers (shown in blue ▲): 2,416 ships

13 These results are similar in form to those by Denmark, although the regression coefficients are different. Whatever the regression formula is, about half of the sample ships for which the regression is carried out, have an EEDI above the (EEDI) baseline, and about half are below it. This, in and of itself, is a problem. The EEDI criterion is not for current ships, but still, the fact that about half of the world fleet does not meet it, is serious.

14 Note that in the containership regression curve, the full DWT was used as the capacity variable. The same is true in the Danish and Chinese regression curves. However, the latest guidelines on the EEDI formula (MEPC.1/Circ.681) stipulate that, for containerships, 65% of the DWT should be used instead. Greece understands the rationale for such a provision, but is concerned about the lack of uniformity introduced by it. By the same token, tankers, bulk carriers and other vessels are not always 100% full when loaded, and they are also involved in substantial voyages in ballast. Greece therefore does not see why their DWT should be taken as 100% in the formula if this is not the case for containerships.

Effective imposition of speed limits

15 Greece believes that there is a serious physical inconsistency between (a) the EEDI formula and (b) the formula for the EEDI baseline. In (a), and assuming that ship engine MCR grows like the cube of speed, EEDI grows like speed squared. In (b), speed does not enter the formula at all. It is straightforward to check that this combination is tantamount to a speed limit, and that this speed limit can often be below the current operating speeds of several classes of ships.

16 In fact, and in order for the EEDI to be below the EEDI baseline, after some algebra (simplified formula for EEDI) it is straightforward to check that the following inequalities should be valid:

If MCR≥10,000 kW	$(462.46MCR+164,325)/(DWT \cdot V) < aDWT^{-c}$

If MCR<10,000 kW	$478.89MCR/(DWT \cdot V) < aDWT^{-c}$

17 It can be seen that the above inequalities are equivalent to an upper bound on the service speed 'V' corresponding to 75% MCR. In fact, if MCR<10,000 kW, the left-hand side of the inequality grows as the square of V, while the right-hand side is independent of V. Therefore in order for the EEDI to be no more than the EEDI baseline, V must be no more than a certain limit, which is a (weak) function of the DWT. The case MCR≥10,000 kW, yields essentially the same result. In both cases, for a given ship whose EEDI is above the baseline, calculating how much its service speed should be reduced to reach the baseline is straightforward. However, this would lead to service speeds which are unacceptable from a safety of navigation point of view for existing or foreseeable designs of propulsion and direction systems.

18 Assuming a cube law for the power-speed relationship causes no loss of generality it can be seen that speed limits are also essentially imposed even if the power-to-speed law is not the cube law, and in fact only if power is a linear function of speed this problem does not exist. However, a linear relationship is contrary to the laws of hydrodynamics.

19 In both cases above it can also easily be seen that the optimal ship speed is zero, as this would achieve the minimum possible EEDI (also zero). But this would not make sense, as no cargo would be carried. An arbitrarily small speed would achieve an arbitrarily small EEDI, but the side effects of that could be significant (of which more below).

20 As a further step in the analysis, Greece calculated the EEDI values in the sample that was analysed and compared them with the EEDI baseline values calculated for both Denmark's and Greece's regression constants, a and c. In all tables, values are for the average ship in each size bracket, again taken from the Lloyds Register Fairplay Sea-web™ database. The results are as follows (an asterisk * denotes cases where the EEDI is above the baseline, and therefore unacceptable).

DRY BULK CARRIERS							
SIZE		DWT	V (knots)	MCR (kW)	EEDI	DENMARK BASELINE	GREECE BASELINE
Handysize	15-35	28,052	14.00	6,209	7.571	7.171*	7.146*
Handymax	35-60	51,721	14.47	8,609	5.509	5.244*	5.335*
Panamax	60-85	76,120	14.44	9,982	4.349	4.303*	4.435
Post Panamax	85-120	91,310	14.38	11,684	4.240	3.920*	4.066*
Capesize	>120	182,469	14.70	17,234	3.033	2.751*	2.920*

TANKERS							
SIZE		DWT	V (knots)	MCR (kW)	EEDI	DENMARK BASELINE	GREECE BASELINE
Small tanker	(0-10)	4,474	11.99	2229	19.899	21.969	18.368*
Handysize	(10-60)	39,523	14.43	8050	6.760	6.868	6.630*
Panamax	(60-80)	72,101	15.02	11876	5.223	4.983*	5.005*
Aframax	(80-120)	108,224	14.95	13552	3.975	4.012	4.139
Suezmax	(120-200)	157,092	15.32	18001	3.527	3.289*	3.477*
VLCC/ULCC	(>200)	305,277	15.79	27217	2.645	2.307*	2.549*

CONTAINERSHIPS						
SIZE	DWT	V (knots)	MCR (kW)	EEDI	DENMARK BASELINE	GREECE BASELINE
Handysize (1000-2000 TEU)	19,266	19.15	12,914	16.633	16.448*	15.711*
Sub-Panamax (2000-3000 TEU)	34,685	21.67	22,056	13.789	14.481	14.379
Panamax (3000-4400 TEU)	50,709	23.60	36,163	14.112	13.338*	13.579*
Post Panamax (>4400 TEU)	74,453	24.93	57,100	14.315	12.273*	12.815*

An asterisk * denotes cases where the EEDI is above the baseline, and therefore unacceptable.

21 All cases with asterisks (in fact, most of the cases, which concern entire subsets of fleets) would have to impose a reduced service speed to achieve an EEDI below the baseline. Calculating the speed reduction is straightforward. For instance, the average service speed of 24.93 knots of the top tier containership size bracket would have to drop to 23.07 knots (a 7.5% reduction) if its EEDI were to drop to the Danish baseline. This may seem like a very small reduction, particularly given much more drastic practices today. But this may also shift the focus of action from designing the best possible hull forms, engines or propellers, to just reducing service speed at the design level.

22 There is nothing in the EEDI or the EEDI baseline formulas that would prevent a ship to sail at speeds higher than V, the speed corresponding to 75% MCR. But imposing an upper bound on V (and hence on MCR) would essentially mandate the construction of underpowered ships, which, in their attempt to go faster or just maintain speed in bad weather, would emit disproportionately more CO_2. Also, any attempted reduction of V will have to be implemented with utmost caution, as it will have other significant side effects.

23 Possible side effects of reduced speeds include (a) adding more ships to match demand throughput, (b) increasing cargo inventory costs due to delayed delivery, (c) increasing freight rates due to a reduction in tonnes mile capacity, (d) reduced manoeuvrability and navigational safety, and (e) inducing reverse modal shifts to land-based modes (mainly road), something that would increase overall GHG emissions.

24 None of these side effects is captured in the EEDI formula, let alone the EEDI baseline formula. Note that adding more ships would have a financial, environmental and safety cost because more ships would increase traffic in already crowded waterways and would require substantially more trained officers and crew already in short supply. Note also that society's demands for bulk cargo transport have developed larger ships with average all-weather, loaded/ballast average speeds of about 14.5-16.0 kn. Higher average speeds appear acceptable for passenger ships and more valuable, unitized cargoes. The trend in all forms of transport is for more energy-efficient, faster modes. This must not be overlooked by shipping when designing the formula if the side effects mentioned in this document are to be addressed.

25 The above analysis shows that, to the extent that the purpose of the EEDI is to help design and select the most environment friendly ship design and technologies, that it can easily lead to selecting service speed instead, or it can even be manipulated by manipulating speed.

Incorporating speed into the formula

26 If the current formula for the EEDI baseline does not include speed but it is ascertained that it should, the question is how. To that effect, various alternatives can be explored:

EEDI (baseline) = $a(DWT/V)^{-c}$, or $a(DWT/V^2)^{-c}$, or $aDWT^{-c}V^{-d}$.

27 At least one of the above alternatives has already been suggested by various delegations[2]. Greece has performed regression analyses on these alternatives and has reason to believe that these should be seriously explored as alternatives to the current formula. In the first two of these alternatives there is a single degree of freedom regarding the exponents of DWT and V, whereas in the third alternative each of these variables has its own independent exponent.

Action requested of the Committee

28 The Committee is invited to consider the information provided in this document: in particular, the alternatives for the EEDI baseline formula proposed above should be carefully considered, and decide as appropriate.

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[2] In document GHG-WG 2/2/22, CESA proposed the EEDI baseline formula = $a(V/DWT)^{-c}$, which is essentially the same as the first alternative. In document MEPC 59/4/20, China performed some calculations using this formulation.