RIGHTSHIP

The RightShip GHG Rating 2.0

Calculating and comparing CO_2 emissions from the global maritime fleet

Background

While international shipping is the most carbon efficient mode of commercial transport, total emissions are comparable to those of a major national economy, and as such provides the opportunity for significant emissions reduction. According to the International Maritime Organization's (IMO) Fourth Greenhouse Gas (GHG) Study[1] , shipping emitted 1,056 million tonnes of CO_2 in 2018, accounting for about 2.89% of the total global anthropogenic CO_2 emissions for that year.

In July 2011, the IMO Marine Environment Protection Committee (MEPC) adopted mandatory measures to reduce GHG emissions from international shipping through amendments to MARPOL Annex VI Regulations. These amendments included the application of the Energy Efficiency Design Index (EEDI) which required all ships built from 1 January 2013 to meet a minimum level of energy efficiency.

On 17 June 2021, the IMO adopted amendments to MARPOL Annex VI at MEPC 76, introducing regulations 23 and 25 - the Energy Efficiency Existing Ship Index (EEXI). The EEXI requires ships to attain approval once in a lifetime and must be completed by the first annual, intermediate or renewal survey due, whichever is the earliest from 1st January 2023.

RightShip's existing GHG Rating calculations is based on a vessel's CO_2 emissions at 75% of their Maximum Continuous Rating (MCR), and validated through their Energy Efficiency Design Index (EEDI) or Existing Vessel Design Index (EVDI™) certificates and calculations.

However, where EEXI compliance is achieved through Engine Power Limitation (EPL) or Shaft Power Limitation (ShaPoLi), this is calculated at 83% of the limited MCR (called MCR_lim). This creates a mathematical challenge to compare EEXI with EPL (83%) and EEDI (75%) vessels. In addition, power limitations can reduce the $gC0_2$/tnm figure rating and improve GHG despite a relatively small reduction in maximum operational speed with no real change to the speed-power-fuel relationship of the vessel.

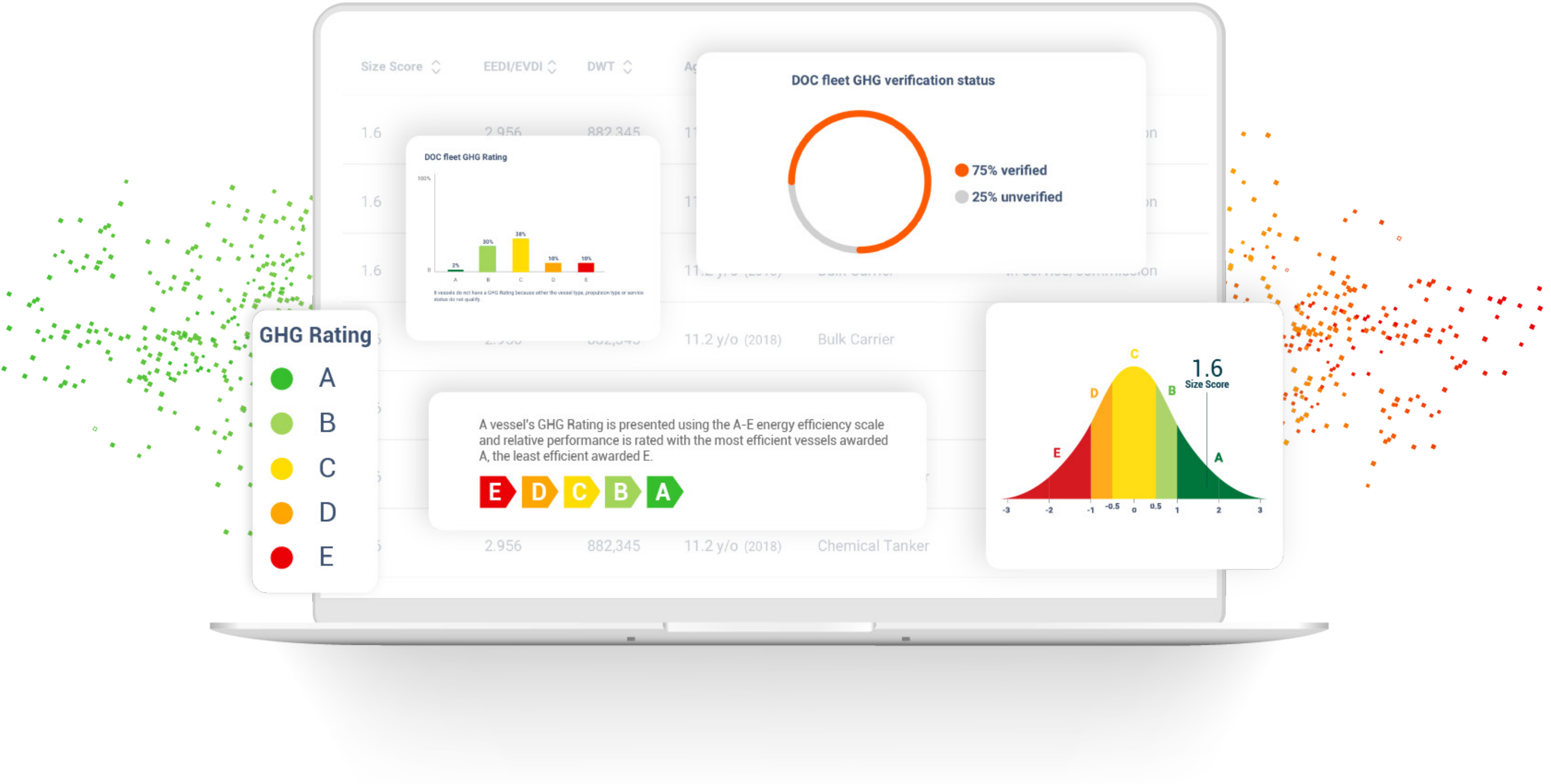
RightShip believes that power limitation should neither give undue advantage nor be discriminatory to such vessels, while promoting vessel efficiency to cut down CO_2 emissions. Therefore, the revised GHG Rating methodology addresses such barriers with a speed corrected approach and evaluates all vessel within a peer group (i.e., of similar size and type) at a common speed. The improved speed corrected approach to the GHG Rating is a necessary adjustment to an existing system.

This easy-to-use tool enables charterers, shipowners, ship managers, ports and terminals, and finance institutions to identify the most energy efficient vessel in the market. This ensures appropriate reward for shipowners who invest in technology and/or design to improve their vessels and aligns with ambitious industry decarbonisation targets.

[1] IMO, 2020, Fourth IMO GHG Study 2020, International Maritime Organization, London, UK.

Contents

Revision	Details	Date
1	Initial - Use of Admiralty formula	8th November 2022
2	Treatment of Auxiliary Engine emission	20th December 2022
3	Speed Cap boundary limitation, A-E new rating scale	11th August 2023



1. Summary

The IMO has defined energy efficiency as grams of CO_2 per tonne nautical mile and the IMO MEPC formulated both EEDI and EEXI as measures of a ship's CO_2 emissions. Both are calculated using characteristics of the ship at build, incorporating parameters that include ship capacity, engine power and fuel consumption.

In 2012, RightShip developed an Existing Vessel Design Index (EVDI™) to work alongside the EEDI as inputs into a Greenhouse Gas (GHG) Rating to enable comparisons of similar vessel types within peer groups. With the implementation of the GHG 2.0 Rating system, RightShip will start accepting the EEXI as a similar metric over-riding EVDI™ for existing ships. The speed corrected GHG 2.0 Rating uses EEDI, EVDI and EEXI and allows relative comparison of a ship's CO_2 emissions to vessels of a similar size and type. Ship types are largely consistent with those used by IMO MEPC.

This document details the calculations and methodology of the revised GHG 2.0 Rating and contains practical examples of their application to the shipping industry.

2. IMO EEDI/EEXI

The EEDI/EEXI were developed by IMO MEPC to measure the theoretical CO_2 emission performance of ships over 400 gross tonnes and are calculated from ship design and engine performance data. Designed to stimulate innovation and technical development of all elements influencing the energy efficiency of a ship from a design perspective, the metrics are calculated using the following formula:

[2]

$$\frac{\overbrace{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)}.C_{FME(i)}.SFC_{ME(i)}\right)}^{\text{Main engine(s)}} + \overbrace{\left(P_{AE}.C_{FAE}.SFC_{AE}*\right)}^{\text{Auxiliary engine(s)}} + \overbrace{\left(\left(\prod_{j=1}^{M} f_j.\sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)}.P_{AEeff(i)}\right) C_{FAE}.SFC_{AE}\right)}^{\text{Energy saving technologies (auxiliary power)}} - \overbrace{\left(\sum_{i=1}^{neff} f_{eff(i)}.P_{eff(i)}.C_{FME}.SFC_{ME}\right)}^{\text{Energy saving technologies (main power)}}}{\underbrace{f_i.Capacity.V_{ref}.f_w}_{\text{Transport work}}}$$

In which:

- ME and AE, represent Main Engine(s) and Auxiliary Engine(s)
- P, the power of the engines (kW)
- C_F, a conversion factor between fuel consumption and CO_2 based on fuel carbon content
- SFC, the certified specific fuel consumption of the engines (g/kWh)
- Capacity, the deadweight or gross tonnage (tonnes)
- V_{ref}, the ship speed (nm/h), and
- fj, a correction factor to account for ship specific design elements (eg. ice-class)

The calculated EEDI/EVDI/EEXI is a theoretical measure of the mass of CO_2 emitted per unit of transport work (grams CO_2 per tonne nautical mile) for a particular ship design.

$$\textbf{EEDI/EVDI/EEXI} = \frac{CO_2 \text{ emissions}}{\text{Transport work}}$$

[2] IMO, 2018, 2018 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS. Resolution MEPC 308 (73). International Maritime Organization, London, UK.

IMO, 2021, 2021 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY EXISTING SHIP INDEX (EEXI). Resolution MEPC 333 (76). International Maritime Organization, London, UK

3. RightShip's GHG 2.0 Rating

In 2012, RightShip developed a systematic and transparent means of comparing the relative theoretical efficiency of the existing fleet utilising EEDI and EVDI data leading to rating vessels on an A-G scale.

With the introduction of EEXI in 2023, RightShip will adjust the GHG Rating methodology to answer the mathematical challenges resulting from the introduction of engine power limitation (EPL) into the EEXI calculations through a speed corrected approach. This is intended to continue to provide a 'level playing field' for comparison of vessels within the same peer group, whilst driving the industry towards innovations and further decarbonisation efforts.

The GHG 2.0 Rating will continue to provide an innovative measure that allows comparison of a ship's theoretical CO_2 emissions relative to peer vessels of a similar size and type on a revised A-E scale. Ship types are largely consistent with those used by IMO MEPC.

The A-E rating enables charterers to identify the most energy efficient vessel, ship owners to be rewarded for investing in sustainability, banks to reduce their ESG risk by investing in efficient vessels, and ports and terminals to reward efficient vessels with reduced port fees and other incentives.

3.1 EVDI™

RightShip's Existing Vessel Design Index (EVDI™) is a data point used to calculate the GHG Rating, together with the corresponding reference speed (V_{ref}).

Similar to the IMO MEPC's EEDI, RightShip's EVDI™ measures a ship's theoretical CO_2 emissions per tonne/ nautical mile travelled. However, unlike the EEDI, which is applied only to new ships, the EVDI™ is designed for application to existing vessels where EEXI data is unavailable.

The 2007 Denmark paper that initially proposed the EEDI to the IMO at MEPC 57 (MEPC 57/INF.12) stated "it is not inconceivable that design indices or equivalent may be applied retroactively to existing ships." RightShip agreed with this approach and developed the EVDI calculation to account for over 48,000 existing vessels in the global fleet.

RightShip's EVDI™

> Over 48,000 pre-EEDI ships

IMO MEPC's EEDI

> New ships from 1 January 2013

IMO MEPC's EEXI

> Existing ships from 1 January 2023

[3] IMO, 2007. Prevention of Air Pollution from Ships, MEPC57/INF.12, p. 32, Danish Government

3.1.1 Data validity

EVDI™ values are calculated from vessel design information and associated data. The primary sources of this data are:

RightShip's Platform	Ship-sourced data	Classification societies	IHS Markit database

RightShip recognises that the reliability of its calculations directly correlates with the accuracy of source data used. As a digital solutions provider, RightShip has developed its cloud-based platform to contain the details of more than 200,000 vessels. Approximately one quarter of these represent the global trading fleet, with additional data on a range of other smaller vessels.

The data on the platform is collected from a variety of sources. Ship owners are able to upload approved Class certification and supporting documents on design information and associated data through a simple to use interactive process which is then processed by our internal specialists. This verification process is typically undertaken when owners are seeking to ensure the data we hold on file matches their technical document, and in particular when they are seeking to improve their ratings.

Otherwise, charterers may request a vetting of a particular vessel in which owners may be required to provide information about their vessel. Therefore, the platform is constantly being updated with new information.

Where data is not provided directly by ship owners we are able to utilise other databases such as IHS Markit where data is exchanged via API.

RightShip welcomes feedback pertaining to any missing or additional information including retrofits or upgrades through RightShip's Platform or by emailing *environment@rightship.com*

3.1.2 Assumptions

Where ship specific data is not available, such as specific fuel consumption, the values used in the EVDI™ calculation are based on the same assumptions used in the Second IMO GHG Study 2009 and/or detailed in IMO Circulars on calculation of the energy efficiency measure. RightShip's approach utilises the same data set recognised by IMO MEPC in their establishment of an EEDI reference line for new ships. Assumptions are shown below:

> Specific Fuel Consumption (Main Engine), SFC_{ME}:

Engine age	Above 15,000 kW	15,000 – 5,000 kW	Below 5,000 kW
Before 1983	205	215	225
1984 - 2000	185	195	205
2001 +	175	185	195

[4] IMO, 2009, Second IMO GHG Study 2009

> Specific Fuel Consumption (Auxiliary Engine), SFC_{AE}:

Engine age	MCR_{AE} > 800 kW	MCR_{AE} < 800 kW
Any	220 g/kWh	230 g/kWh

> Power (Main Engine), P_{ME}: = 0.75 MCR_{ME}

> Power (Auxiliary Engine), P_{AE}:

MCR_{ME}	> 10,000 kW	< 10,000 kW
P_{AE}	$=(0.025*MCR_{ME})+250$	$0.05*MCR_{ME}$

> Ship Speed, V_{ref}: Design Speed

> Capacity:

- 100% deadweight, for bulk carriers, tankers, gas tankers, ro-ro cargo and general cargo ships, tankers, gas carriers, LNG Carriers, Vehicle Carriers
- 70% deadweight, for container ships
- 100% gross tonnage for passenger and ro-ro passenger ships

> CO_2 Conversion Factors, C_F:

Fuel Type	Carbon Content	C_F (t-CO_2/t-Fuel)
Diesel/Gas Oil (DGO)	0.875	3.206
Light Fuel Oil (LFO)	0.86	3.151
Heavy Fuel Oil (HFO)	0.85	3.114
Liquified Petroleum Gas (LPG)		
> Propane	0.819	3.000
> Butane	0.827	3.030
Liquified Natural Gas (LNG)	0.75	2.750
Methanol	0.3750	1.375
Ethanol	0.5217	1.913

Table 1: EVDI assumptions

3.1.3 Ship types

The categories of ship used for the derivation of comparative GHG Ratings predominantly follow those in the MARPOL, Annex I (Revised 2021)[5] and regrouped for similar cargo type:

01	Bulker
02	Chemical tanker
03	Container
04	Crude & products tanker
05	Passenger/ Cruise ship
06	General cargo
07	LNG carrier
08	LPG Tanker
09	Refrigerated cargo
10	Ro-ro passenger
11	Ro-Ro Cargo
12	Vehicle Carrier

Table2: Ship types for peering

Non-Standard Propulsion: The EEDI, as presently constructed, is not designed or intended for application to vessels with a non-conventional propulsion system. It is anticipated that the IMO will develop refined parameters, formulas, and reference baselines for these ships in the near future. These vessels (including LNG and passenger vessels which have diesel-electric, turbine, and other non-conventional means of propulsion) do not have calculated EVDIs and GHG Emission Rating's in the system.

3.2 Speed corrected GHG Rating (GHG 2.0)

3.2.1 Definition of the new GHG Rating methodology:

A ship's CO_2 emission intensity (gCO_2/ton.NM) in its peer group at a reference speed which is the higher of the slowest vessel's V_{ref} in the peer and the speed cap identified from Table 3: Speed cap for various vessel types.

[5] IMO, International Convention for the Prevention of Pollution from Ships (MARPOL), Annex I .

3.2.2 Methodology

The sea trial and associated speed-power performance data is obtained within the IMO framework and guidelines to arrive at a no wind, no wave, no sea current, depth and water temperature correction. However, there is a gap, as widely known and discussed with the market, wherein sea trials are completed at ballast draft conditions, as single or few point speed trial runs, which are then extrapolated to form the whole Speed-Power curve.

Considering the above limitations, a theoretical approach based on known design principles of Naval Architecture, specifically around the 'Admiralty Coefficient' - sometimes referred to as propeller law - is taken to arrive at a speed corrected gCO_2/tnm. This coefficient is also referenced in the EEXI guidelines Section 2.2.3:

Admiralty Coefficient:

Propulsion Power (P) $\propto \frac{\Delta^{\frac{2}{3}} \cdot Speed^3}{Constant}$

Where Δ = Displacement

At a defined displacement and (EEDI/EVDI/EEXI) draught condition:

Propulsion Power (P) $\sim Speed^3$

At power P_{ME} and associated Speed V_{ref}, this becomes:

$$P_{ME} \propto V_{ref}^3 \quad \text{--- (1)}$$

3.2.3 Derivation

This section discusses various terms aspects of the EEDI/EVDI/EEXI formula and their relationship with the Admiralty Coefficient leading into the speed corrected approach.

EEDI/EVDI/EEXI (g CO_2/DWT-NM) =

Main engine emissions | *Aux. engine emissions* | *Aux. engine energy savings* | *Main engine energy savings*

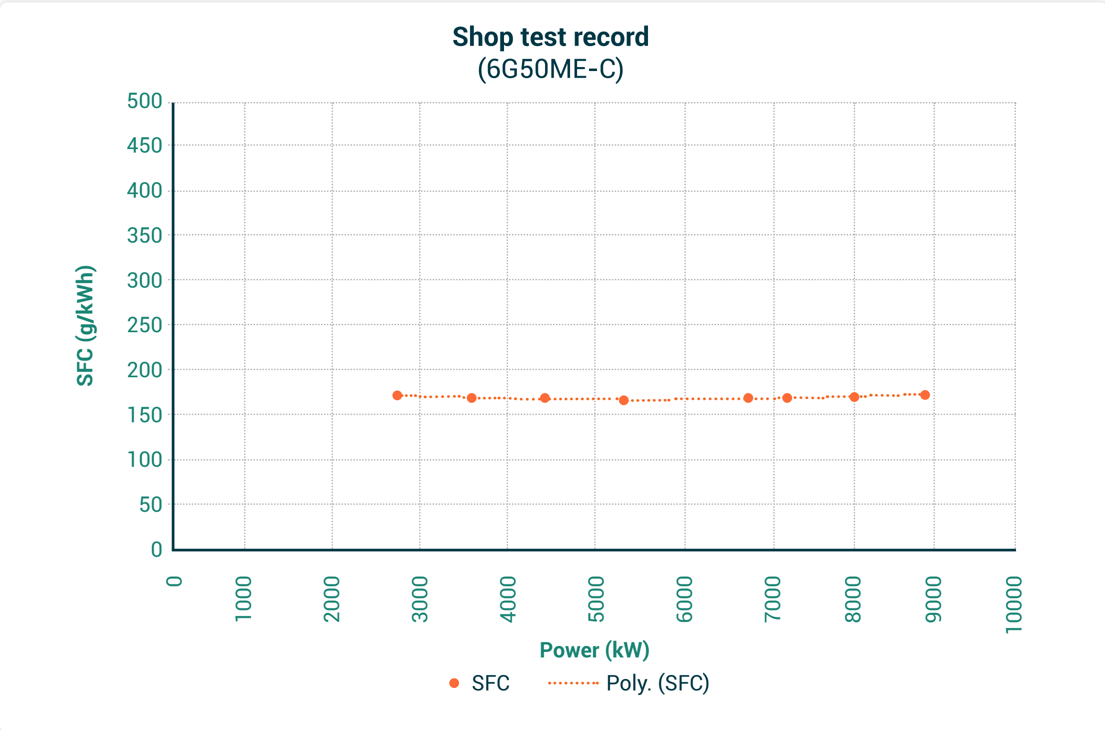
$$\frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}**\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref} \cdot f_m}$$

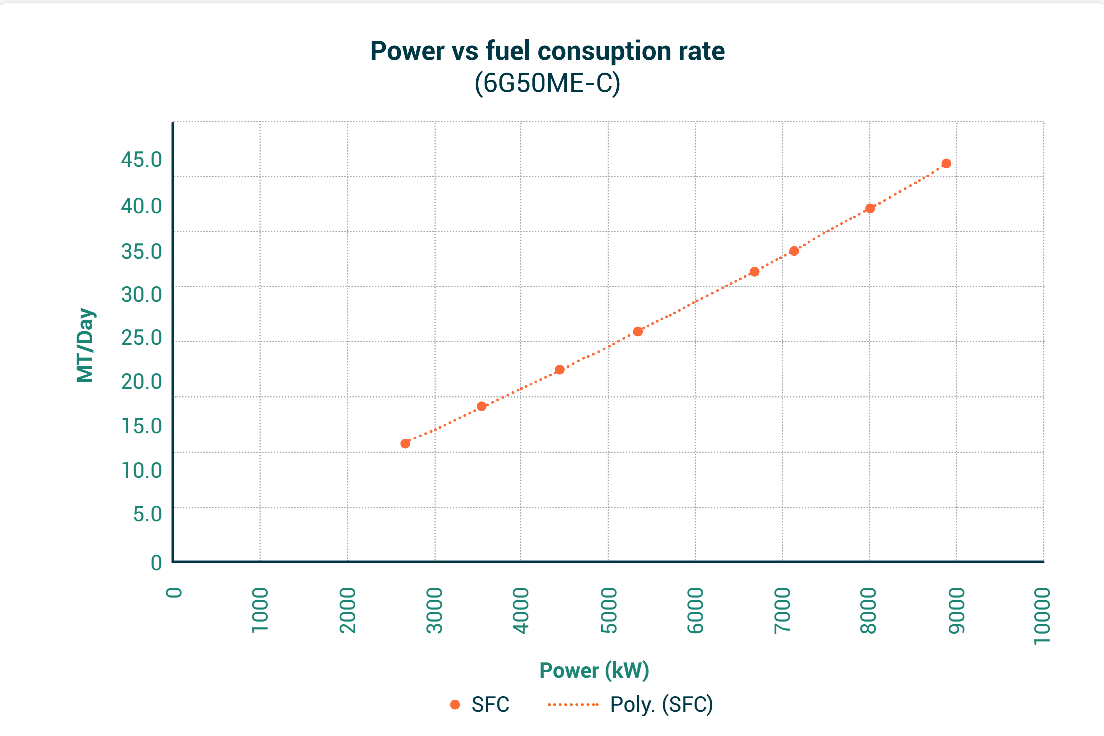
Transport works

[6] IMO, 2021, 2021 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY EXISTING SHIP INDEX (EEXI). Resolution MEPC 333 (76). International Maritime Organization, London, UK

a. Main engine emissions

Despite some variability in Specific Fuel consumption, SFC (g/kW-hr) across different loads, this variation is relatively insignificant from a statistical standpoint and hence SFC can be considered as a constant.





POWER (P_{ME}) α Fuel consumption rate (g/hour)
where Fuel consumption rate (g/hour) = P_{ME}*(SFC@P_{ME})

Correlating from (1) **Fuel consumption rate α V_{ref}^3** --- (2)

b. *Auxiliary engine emissions*

Reference EEDI guidelines[7] Section 2.2.5.6, the power of auxiliary engines (P_{AE}) is dependent on the maximum propulsion engine power (MCR). This contribution of Auxiliary Engine's emissions primarily stays constant and is independent of engine load at different vessel speeds hence will be treated as constant and will be excluded before the Speed correction is applied and then added back post the speed-correction.

$$P_{AE} * SFC_{AE} * \text{Carbon Emission factor} = \text{constant} \qquad \text{--- (3)}$$

c. *Auxiliary engine energy savings*

This factor has no dependency on P_{ME} and the contribution of this factor is minimal as compared to the emissions and energy savings referenced in assumption (a) above and (d) below and hence will be unaccounted for in the Speed corrected approach of GHG 2.0.

d. *Main engine energy saving devices*

a. Air lubrication

Reference innovative technology guidelines Section 1, this system operates by reducing the power demand from the propulsion engines to run at the same V_{ref}. With reference to the EEDI/EVDI/EEXI equation, the admiralty coefficient is still applicable with such technologies as they offset the curve while preserving its nature.

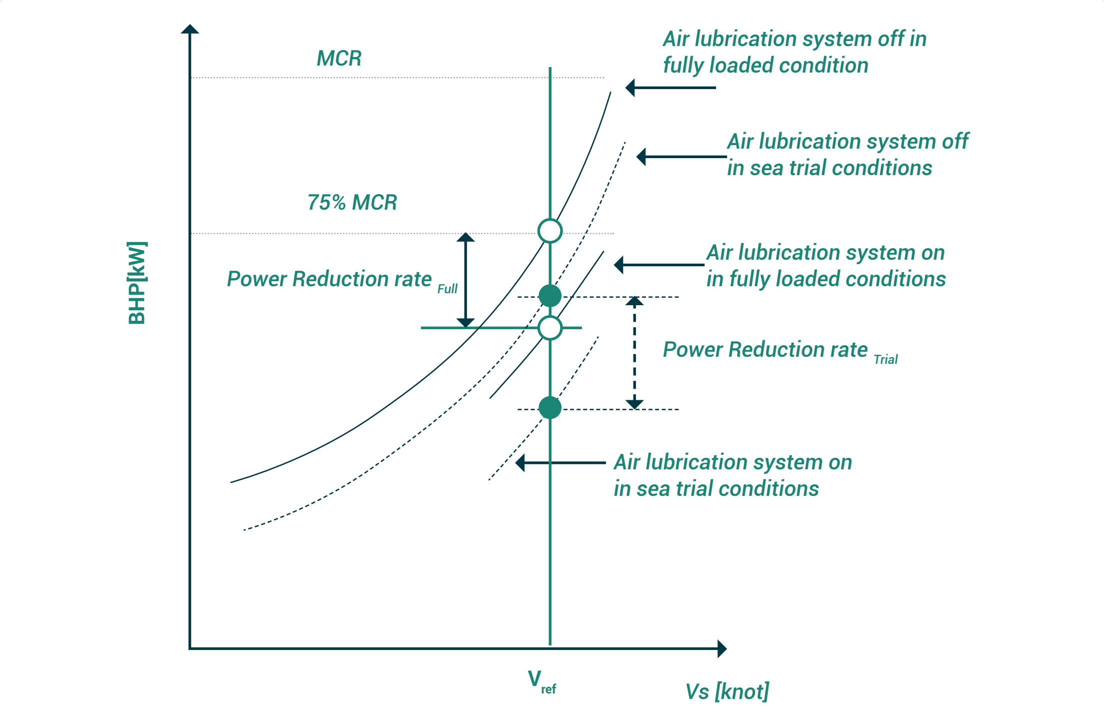


Figure 1: Offset of the speed-power curve power due to air lubrication

[7] IMO, 2018, 2018 GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS. Resolution MEPC 308 (73). International Maritime Organization, London, UK.

[8] IMO, 2021, 2021 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI AND EEXI. MEPC.1/Circ.896. International Maritime Organization, London, UK.

b. Wind Assisted Propulsion Systems (WAPS)
Reference innovative technology guidelines[9] Section 2.3:

The available effective power of wind assisted propulsion systems as innovative energy efficient technology is calculated by the following formula:

$$(f_{eff} \cdot P_{eff}) = \left(\frac{1}{\sum_{k=1}^{q} W_k}\right) \cdot \left(\left(\frac{0.5144 \cdot V_{ref}}{\eta_D} \sum_{k=1}^{q} F(V_{ref})_k \cdot W_k\right) - \left(\sum_{k=1}^{q} P(V_{ref})_k \cdot W_k\right)\right)$$

$$F(V_{ref})_k = (\Delta C_{Fx})_k * (0.5\ \rho\ V_k^2\ A)$$

$F(V_{ref})_k$ is the force matrix of the respective wind assisted propulsion system for a given V_{ref}. It represents the propulsion force in kilo Newton (kN) for the respective wind speed and angle.

Under no wind conditions in which a sea trial corrected curve is obtained, $V_k = V_{ref}$, therefore:

$f_{eff} \cdot P_{eff}\ \alpha\ V_{ref}^3$

Implementing (1) and (2) converts this relationship to:

Fuel consumption saving rate α V_{ref3} -- (4)

e. Speed corrected derivation

Broadly, the above findings can be bundled together to conclude that the numerator in the EEDI/EVDI/EEXI calculation is approximately related to the vessel speed (V_{ref}).

Fuel consumption rate α $V_{ref}3$ -- (5)

The fuel consumption multiplied with corresponding carbon factor of the fuel type results in:

CO_2 emission α $V_{ref}3$ -- (6)

It should also be noted that the contribution of propulsion machinery emissions in EEDI/EVDI/EEXI formula is much more than auxiliary emissions, yet the Auxiliary Engine emissions are constant and independent of propulsion loads and vessel speeds. Hence, this will be taken out from the speed corrected calculation at the beginning and then re-inserted towards the end to give better accuracy of the speed corrected intensity.

The EEDI/EVDI/ EEXI equation therefore converts to the below relationship:

$$\text{EEDI/EVDI/EEXI}\ \alpha\ \frac{\textit{Cost to society}}{\textit{Benefit to society}} = \frac{\textit{CO2 Emission}}{\textit{Transport work}} = \frac{\textit{CO2 emission}}{\textit{DWT x Speed}}\ \alpha\ \frac{\textit{Speed}^3}{\textit{DWT x Speed}}$$

At Speed = V_{ref}

$$\text{EEDI/EVDI/EEXI}\ \alpha\ \frac{V_{ref}^3}{V_{ref}} \quad \text{-- (7)}$$

$$\text{EEDI/EVDI/EEXI}\ \alpha\ V_{ref}^2 \quad \text{-- (8)}$$

Therefore, at any speed V_2, $\frac{E_2}{E_1} = \frac{V_2^2}{V_{ref}^2}$ where E_1 = EEDI/EVDI/EEXI

and E_2 = Speed Corrected Intensity (SCI) and V_2 = Slowest peer V_{ref}

[9] IMO, 2021, 2021 GUIDANCE ON TREATMENT OF INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES FOR CALCULATION AND VERIFICATION OF THE ATTAINED EEDI AND EEXI. MEPC.1/Circ.896. International Maritime Organization, London, UK.

f. *Speed cap Boundary conditions*

Vessels are designed for an optimum range of speed operation as per the operational need and changing market conditions.

Additionally, the Auxiliary Engine Emission contribution is static since it is independent of the vessel's speed. Therefore, at slower speeds this contribution becomes proportionally bigger as the main engine's emissions reduces.

The purpose of RightShip's GHG rating is to give insight into a vessel's design efficiency while in trade and therefore the necessity to focus on the Main Engine's emission contribution. Towards this and to focus on the emissions in the range of a vessels' market operating speeds a speed cap as noted below is applied to calculate the Speed Corrected Intensity in the previous section 3.2.3 (e).

Note:

The higher of the slowest vessel's V_{ref} in the peer and the speed cap identified from the below table for the vessel under evaluation, will be selected as the Peer V_{ref} (V_2) to calculate the Speed Corrected Intensity as per section 3.2.3 (e) for the vessel under evaluation.

The Speed cap selected was referenced from the Fourth IMO GHG Study 2020[10] . A reduction of 10% to the values in the referenced tables was applied to generate the below table to allow for slowdown of world fleet due to EEXI and Power Limitation coming into effect from 2023. These Average speed values mentioned in below table will be reviewed with release of IMO's next GHG study and adjustments done as needed if deviation is significant.

Ship Type	Size category	Unit	Average SOG at sea (knots)
Bulk Carrier	0-9999	DWT	8.4
	10000-34999	DWT	9.9
	35000-59999	DWT	10.3
	60000-99999	DWT	10.3
	100000-199999	DWT	10.1
	200000+	DWT	10.6
Chemical Tanker	0-4999	DWT	8.6
	5000-9999	DWT	9.3
	10000-19999	DWT	10.3
	20000-39999	DWT	10.9
	40000+	DWT	10.7
Container	0-999	TEU	10.6
	1000-1999	TEU	12.1
	2000-2999	TEU	12.8
	3000-4999	TEU	13.2
	5000-7999	TEU	14.1
	8000-11999	TEU	14.7
	12000-14499	TEU	14.7
	14500-19999	TEU	14.8
	200000+	TEU	14.7

[10] IMO, FOURTH IMO GREENHOUSE GAS STUDY 2020. Section 2 – Inventory of GHG Emissions from international shipping 2012-2018, Table 35 and Appendix O.7 – Detailed Bottom-up results, Table 81

Crude & Products Tanker (including OBO)	0-4999	DWT	7.8
	5000-9999	DWT	8.2
	10000-19999	DWT	8.8
	20000-59999	DWT	10.1
	60000-79999	DWT	10.4
	80000-119999	DWT	10.1
	120000-199999	DWT	10.3
	200000+	DWT	10.7
Passenger / Cruise	0-1999	GT	7.3
	2000-9999	GT	8.3
	10000-59999	GT	12.1
	60000-99999	GT	13.8
	100000-149999	GT	14.4
	150000+	GT	14.8
General Cargo	0-4999	DWT	7.9
	5000-9999	DWT	8.8
	10000-19999	DWT	10.3
	20000+	DWT	10.7
LNG Tanker	0-49999	CBM	10.5
	50000-99999	CBM	12.7
	100000-199000	CBM	13.4
	200000+	CBM	14.4
LPG Tanker	0-49999	CBM	10.5
	50000-99999	CBM	12.7
	100000-199000	CBM	13.4
	200000+	CBM	14.4
Refrigerated Cargo	0-1999	DWT	8.2
	2000-5999	DWT	10.0
	6000-9999	DWT	12.2
	10000+	DWT	14.7
Ro-Ro passenger	0-1999	GT	8.1
	2000-4999	GT	10.3
	5000-9999	GT	11.9
	10000-19999	GT	13.6
	20000+	GT	14.9
Ro-Ro Cargo	0-4999	DWT	7.3
	5000-9999	DWT	12.8
	10000-14999	DWT	14.0
	15000+	DWT	13.7
Vehicle carrier	0-29999	GT	12.2
	30000-49999	GT	13.2
	50000+	GT	14.0

Table 3: Speed Cap for different vessel types

SOG = Speed over Ground

g. Formulation

The complete formulation to account for the Auxiliary Engine emission will follow below steps:

	Calculation	Formula	Unit
Step			
A	Total emission per hour	= EEXI* Capacity *V_{ref}	gCO_2/hr
B	Auxiliary Engine Emission	= P_{AE}*SFC_{AE}*CF_{AE}	gCO_2/hr
C	Total emission per hour (A) - Aux Engine Emission per hour (B)	= A-B	gCO_2/hr
D	Remaining propulsion emission per hour (D)	= C/(Capacity*V_{ref})	gCO_2/ton mile
E	Speed corrected Remaining propulsion emission per ton-mile @ V2 knots (E)	= D*(($V_2/V_{ref})^2$)	gCO_2/ton mile
F	New remaining propulsion emission per hour (F) @ V_2	= E*(Capacity*V_2)	gCO_2/hr
G	Total new emission per hour (G)	= F + Aux. Engine emission (B)	gCO_2/hr
H	Speed corrected intensity (E_2)	= G/(Capacity*V_2)	gCO_2/ton mile

Table 4: Speed Corrected Intensity formulation

1. For bulk carriers, tankers, gas carriers, LNG carriers, ro-ro cargo ships (vehicle carriers), ro-ro cargo ships, ro-ro passenger ships, general cargo ships, refrigerated cargo carrier and combination carriers, deadweight should be used as capacity.

2. For passenger ships and cruise passenger ships, gross tonnage in accordance with the International Convention of Tonnage Measurement of Ships 1969, annex I, regulation 3, should be used as capacity.

3. For containerships, 70% of the deadweight (DWT) should be used as capacity.

3.2.4 Sample calculation

a. Speed cap compliant (Refer Section 3.2.3 (f))

DWT = 87,340	**Auxiliary Engine**
Attained EEXI = 3.38	P_{AE} = 513
V_{ref} = 13.18	SFC_{AE} = 216
Slowest peer V_{ref} = 12	CF_{AE} = 3.206
Speed cap (compliant) = 10.3	
Calculation speed (V_2) = 12	

Table 5: Sample Vessel's Details (Vessel Type = Bulk Carrier)

The slowest peer V_{ref} in this peer i.e. 12 knots is greater than the Speed cap of 10.3 knots for this vessel under evaluation reference Table 3. So, calculation will happen at V_2 12 knots.

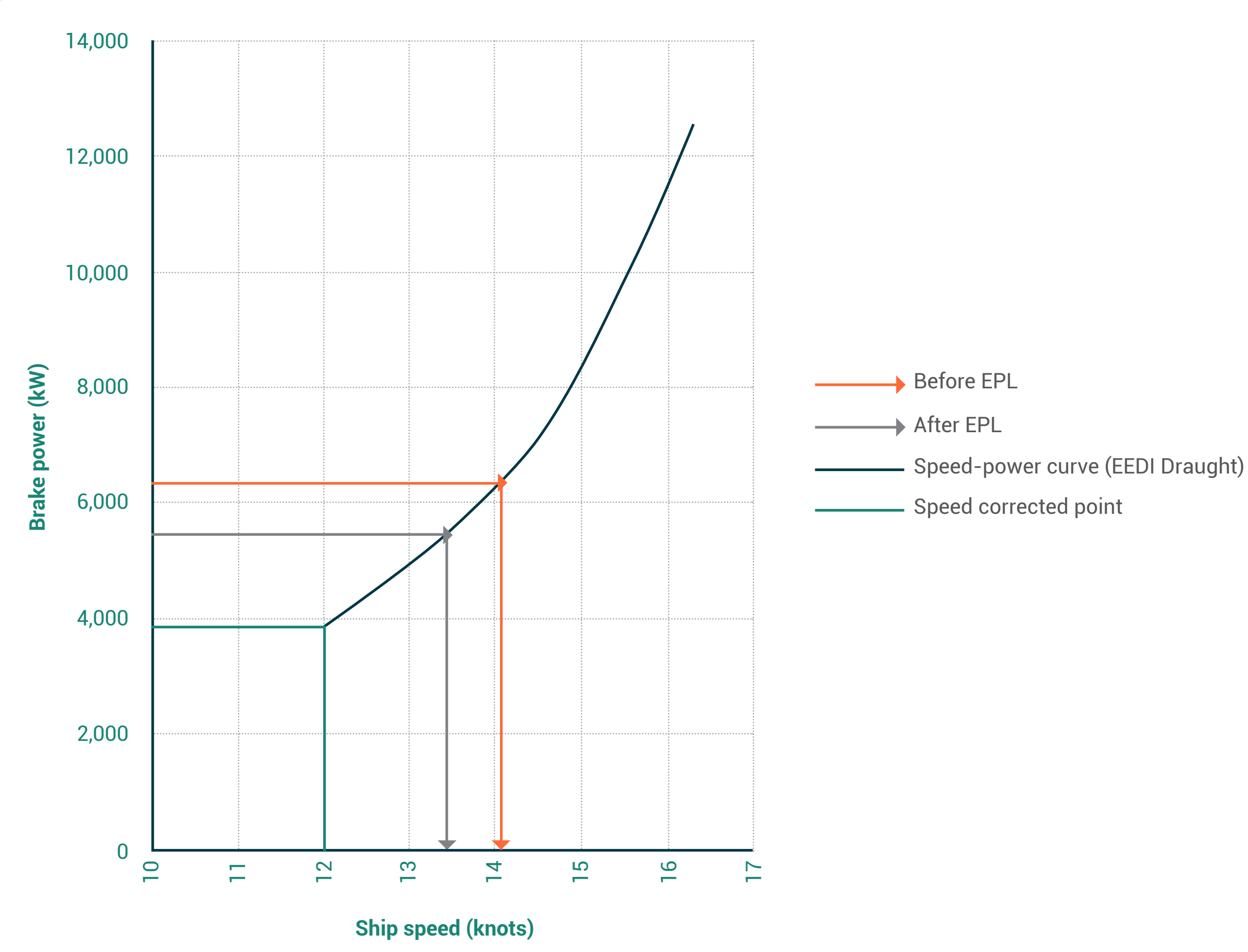


Figure 2: Speed power curve

Therefore, using Table 4: Speed Corrected Intensity Formulation, approximate emission intensity of this vessel at 12 knots on its EEDI draught can be calculated as:

	Calculation	Formula	Value
Step			
A	Total emission per hour	= EEXI* Capacity *V_{ref}	3,890,857.3
B	Auxiliary Engine Emission	= P_{AE}*SFC_{AE}*CF_{AE}	355,250.4
C	Total emission per hour (A) - Aux Engine Emission per hour (B)	= A-B	3,535,606.8
D	Remaining propulsion emission per hour (D)	= C/(Capacity*V_{ref})	3.1
E	Speed corrected Remaining propulsion emission per ton-mile @ V2 knots (E)	= D*((V_2/V_{ref})^2)	2.5
F	New remaining propulsion emission per hour (F) @ V_2	= E*(Capacity*V_2)	2,668,464.7
G	Total new emission per hour (G)	= F + Aux. Engine emission (B)	3,023,715.2
H	Speed corrected intensity (E_2)	= G/(Capacity*V_2)	2.88

Table 6: Sample Calculation

Therefore, **Speed corrected intensity (E_2) at 12 knots = 2.88 gCO_2/ ton-mile**

b. *Speed cap compliant (Refer Section 3.2.3 (f))*

DWT = 87,340	Auxiliary Engine
Attained EEXI = 3.38	P_{AE} = 513
V_{ref} = 13.18	SFC_{AE} = 216
Slowest peer V_{ref} = 9.7	CF_{AE} = 3.206
Speed cap (compliant) = 10.3	
Calculation speed (V_2) = 10.3	

Table 7: Sample Vessel's Details (Vessel Type = Bulk Carrier)

The slowest peer V_{ref} in this peer i.e. 9.7 knots is lesser than the Speed cap of 10.3 knots for this vessel under evaluation reference Table 3. So, calculation will happen at V_2 10.3 knots.

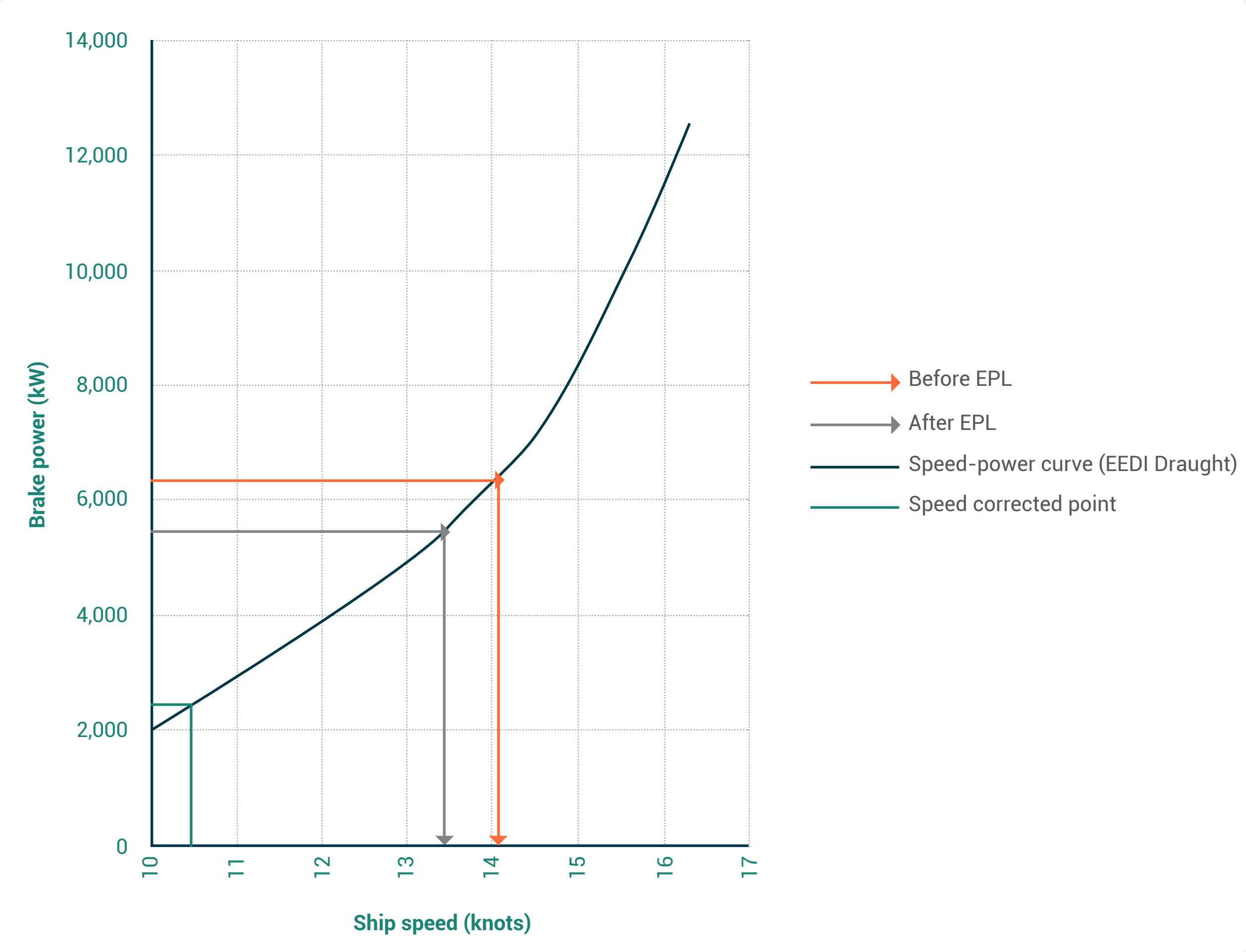


Figure 3: Speed power curve

Therefore, using Table 4: Speed Corrected Intensity Formulation:

Step	Calculation	Formula	Value
A	Total emission per hour	= EEXI* Capacity *V_{ref}	3890857.3
B	Auxiliary Engine Emission	= P_{AE}*SFC_{AE}*CF_{AE}	355250.4
C	Total emission per hour (A) - Aux Engine Emission per hour (B)	= A-B	3535606.8
D	Remaining propulsion emission per hour (D)	= C/(DWT*V_{ref})	3.1
E	Speed corrected Remaining propulsion emission per ton-mile @ V2 knots (E)	= D*((V_2/V_{ref})^2)	1.9
F	New remaining propulsion emission per hour (F) @ V_2	= E*(DWT*V_2)	1687444.1
G	Total new emission per hour (G)	= F + Aux. Engine emission (B)	2042694.6
H	Speed corrected intensity (E_2)	= G/(DWT*V_2)	2.27

Table 8: Sample Calculation

Therefore, **Speed corrected intensity (E_2) at 10.3 knots = 2.27 gCO_2/ ton-mile**

c. *Speed cap defaulting (Refer Section 3.2.3 (f))*

DWT = 79,801	Auxiliary Engine
Attained EEXI = 3.53	P_{AE} = 526.5
V_{ref} = 9.7	SFC_{AE} = 205.1
Slowest peer V_{ref} = 9.7	CF_{AE} = 3.206
Speed cap (defaulting) = 10.3	
Calculation speed (V_2) = 10.3	

Table 9: Sample Vessel's Details (Vessel Type = Bulk Carrier)

This is the slowest vessel in its peer. The slowest peer V_{ref} in this peer i.e. 9.7 knots is lesser than the Speed cap of 10.3 knots for this vessel under evaluation, reference Table 3. So, calculation will happen at V_2 10.3 knots.

Therefore, using Table 4: Speed Corrected Intensity Formulation:

Step	Calculation	Formula	Value
A	Total emission per hour	= EEXI*DWT*V_{ref}	2732466.0
B	Auxiliary Engine Emission	= P_{AE}*SFC_{AE}*CF_{AE}	346200.4
C	Total emission per hour (A) - Aux Engine Emission per hour (B)	= A-B	2386265.7
D	Remaining propulsion emission per hour (D)	= C/(DWT*V_{ref})	3.1
E	Speed corrected Remaining propulsion emission per ton-mile @ V_2 knots (E)	= D*((V_2/V_{ref})^2)	3.5
F	New remaining propulsion emission per hour (F) @ V_2	= E*(DWT*V_2)	2857033.0
G	Total new emission per hour (G)	= F + Aux. Engine emission (B)	3203233.4
H	Speed corrected intensity (E_2)	= G/(DWT*V_2)	3.9

Table 10: Sample Calculation

Therefore, **Speed corrected intensity (E_2) at 10.3 knots = 3.9 gCO_2/ ton-mile**

3.2.5 Speed corrected sample outlook

The calculation explained in section 3.2.4 above will be applied to all vessels in that peer group. The below image is an insight into the emission intensity distribution before and after the speed correction, where a reference speed of the slowest moving vessel in the peer is applied.

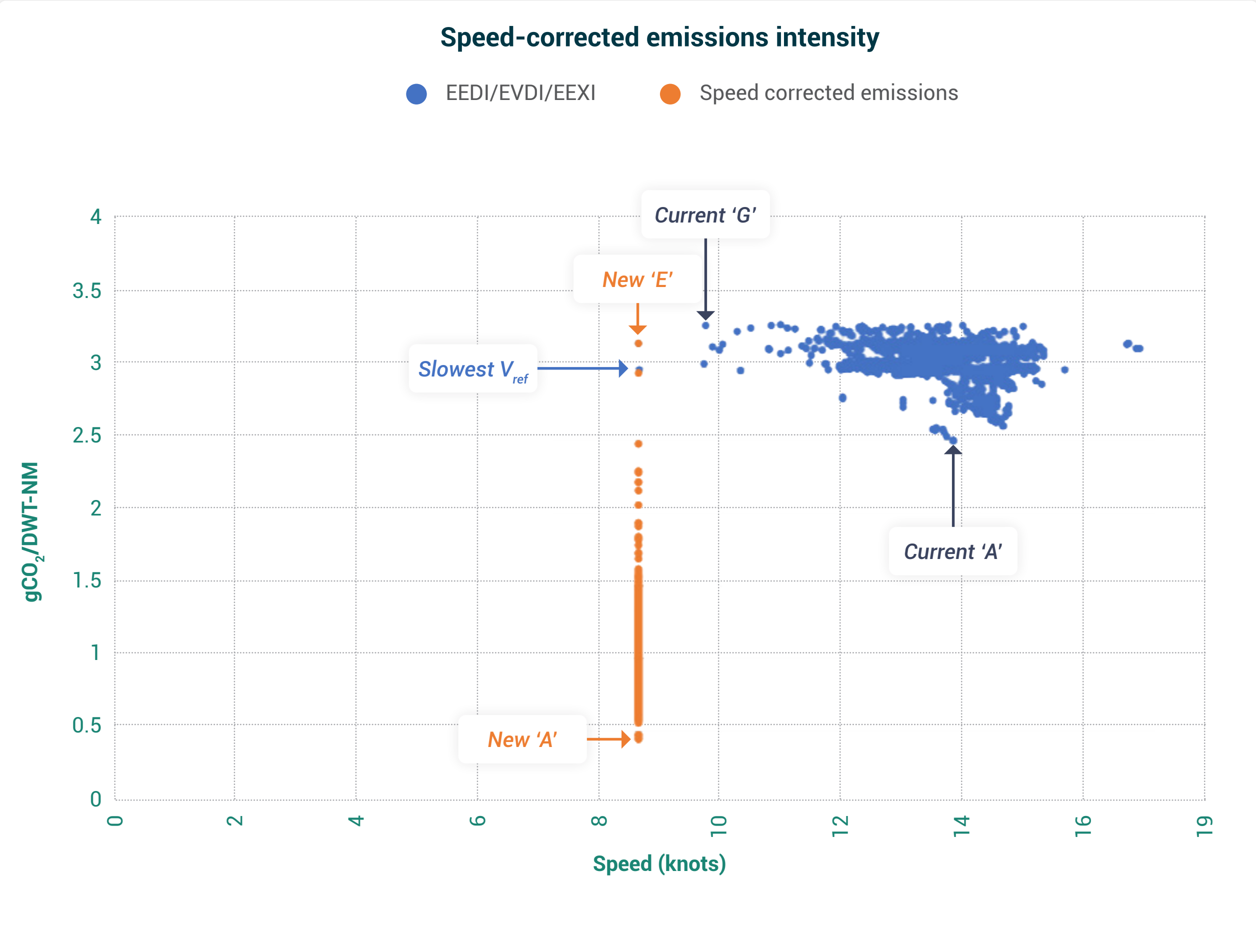


Figure 4: Speed corrected intensity (gCO_2/tnm)

3.3 GHG Rating A - E scale

A vessel's GHG Rating is presented using the A-E energy efficiency scale and relative performance is rated with the most efficient vessels awarded A, the least efficient awarded E.

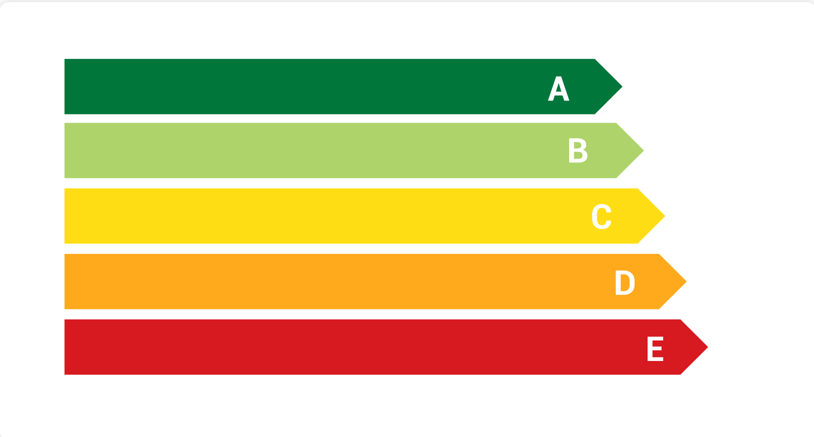


Figure 5: GHG Rating A - E scale

The GHG Rating size group is based on the size score, which indicates the number of standard deviations by which a vessel varies from the average for similar sized vessels of the same ship type.

If the distribution of the size scores exactly fit a normal distribution, the score ranges would match the fixed percentiles of the data set mentioned in Figure 6. The vessel's position on the A-E scale is determined by the size score and GHG Rating key as follows:

GHG Rating	E	D	C	B	A
Size score	<= -1.0	> -1.0	> -0.5	> 0.5	> 1.0
Area under curve	16%	16%	36%	16%	16%

Figure 6: GHG Rating key

The bell curve below in Figure 7 shows the percentage distribution with the corresponding letter displayed in the appropriately coloured area under the curve. The x-axis is expressed as a count of standard deviations which matches the size score in the key.

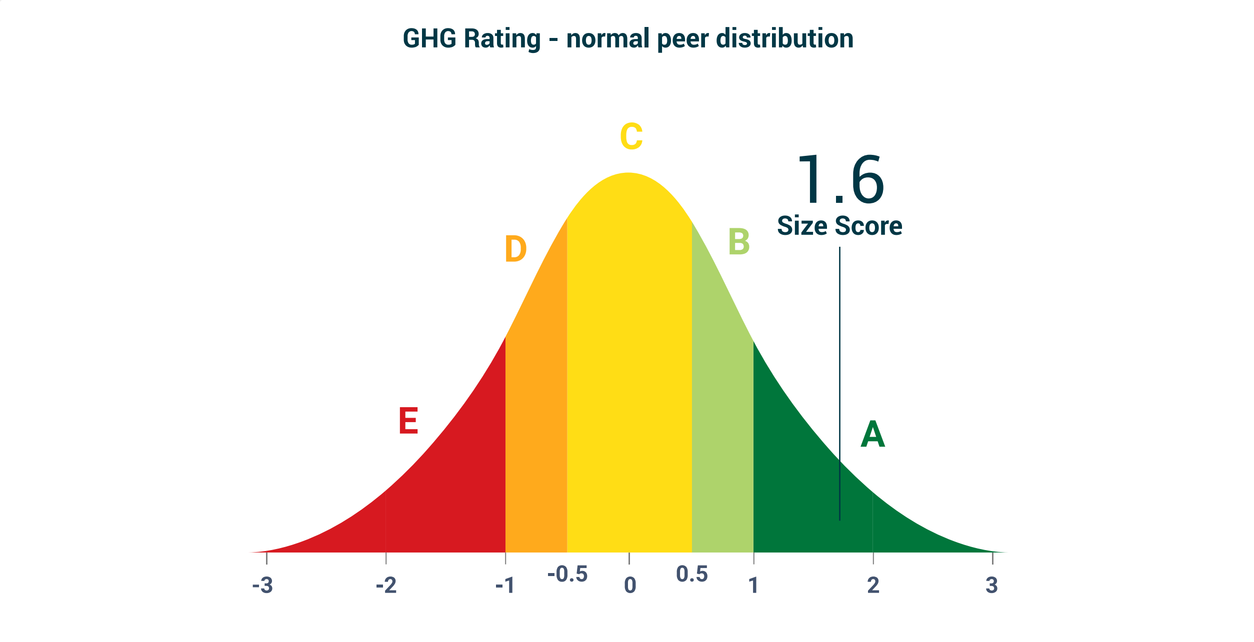


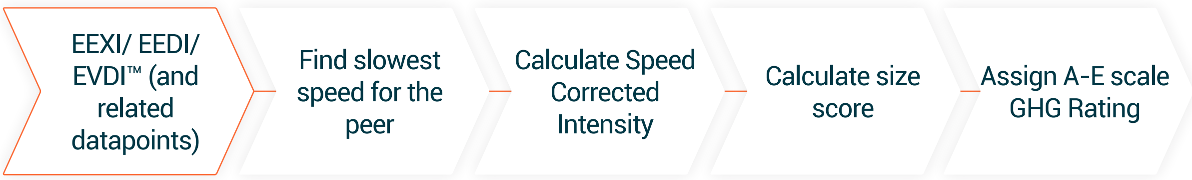
Figure 7: GHG Rating key – normal peer distribution

It is important to note that as each vessel size group is a subset of the entire ship type group, the percentages within each subset's size group will have some variability from these percentages.

3.3.1 GHG Rating calculation

Once a peer is selected, the latest RightShip verified data point amongst EVDI or EEXI is the preferred metric. If EEXI is not provided, then EVDI or EEDI and the associated V_{ref} is selected accordingly. Thereafter, the speed correction as explained in Section 3.2.4 is conducted.

Once the SCI is arrived at for all the vessels in a peer group, a size score is calculated indicating a vessel's position on the Bell distribution profile. The size score thus enables a GHG Rating to be allocated to all vessels.



3.3.1.1 The size score

A size score is a standard measure of the variation of an individual value from a normally distributed average, with a mean of zero and a standard deviation of one. It is calculated by the below formula:

$$\text{Size score} = \frac{(\hat{y} - Y_i)}{\sigma}$$

Where:

- > Y_i is the subject vessel's speed corrected intensity; and
- > $\hat{y}$ is the mean of speed corrected intensity of the peer vessels; and
- > σ is the standard deviation of the speed corrected values for the sampled peer vessels.

The size score is the value used in the allocation of A-E Ratings to vessels.

3.3.2 Natural adjustment

The GHG Rating is dynamic and will almost always use a different subsample group of vessels for each calculation. As older vessels are scrapped, new vessels are commissioned, or existing retrofits/upgrades are verified at sea trials, the relative performance of the peer group improves, and vessels will be rated against a new average.

3.3.3 Retrofits and upgrades

Vessels that invest in eco-efficiency technologies and/or measures such as waste heat recovery systems or propeller ducts are eligible for recognition from RightShip. Approved enhancement measures will have a plus (+) sign adjoined to their GHG Rating, as shown for the B+ rated vessel below:

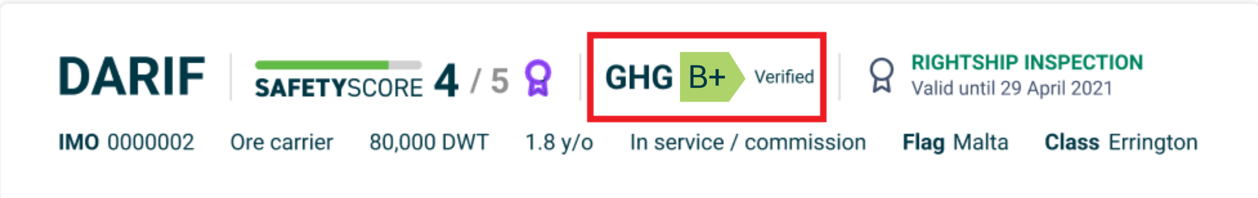


Figure 8: A plus (+) sign is adjoined to a vessel's GHG Rating for recognised retrofits and/or upgrades

RightShip believes it is important to acknowledge and reward owners who have invested capital in systems to operate their vessels above compliance and the plus (+) notation helps to increase the visibility of these endeavours. Aside from the plus (+) notation, the types of Energy Saving Devices deployed are featured for each respective vessel on the Platform.

3.3.4 Sister ships

Some sister ships can have a different GHG Rating. A vessel's EEDI/EVDI/EEXI value is based on many parameters and if any of these parameters - Deadweight, Fuel type, Energy Saving Devices upgrades for example - differ between sister ships it will lead to a different value and therefore a different speed corrected value. This therefore can move them into a different rating bracket.

3.3.5 Comparing existing ships' CO_2 emissions

RightShip's GHG Rating methodology segregates vessels by type and capacity. The major ship types and their calculation subsample criteria are shown below:

Ship type	Capacity (Subsample basis)	Peer range (+/- % of capacity)	Minimum vessels in peer
Bulk Carrier	DWT	10%	40
Chemical tanker	DWT	10%	40
Container	TEU	10%	40
Crude & products tanker (inc. OBO)	DWT	10%	40
Passenger / Cruise	GT	10%	40
General cargo	DWT	10%	40
LNG tanker	CBM	10%	40
LPG tanker (Gas carrier)	CBM	10%	40
Refrigerated cargo	DWT	10%	40
Ro-Ro Passenger	DWT	10%	40
Ro-Ro Cargo	DWT	10%	40
Vehicle Carrier	DWT	10%	40

Table 11: Peer selection criteria

The 'Peer range (% of capacity)' column indicates the subsample of vessels included in the size score calculation for each ship type. For example: for a bulker vessel "X" with a DWT 100,000, the subsample will contain bulker vessels in the range 90,000 to 110,000 DWT. If there are less than 40 vessels within the 10% DWT range, then the nearest 40 vessels in terms of capacity will be used to ensure sound statistical comparison. The number of peers in comparison and DWT range considered is shown by the peer group.

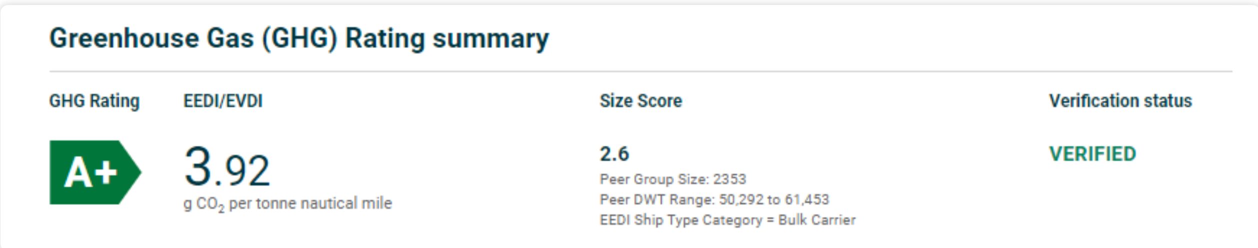


Figure 9: Peer group range

Detailed analysis of size scores across RightShip's database shows that the method used to develop a comparative rating of size scores as a component of the RightShip GHG Rating is applicable across the different ship types. The method therefore provides a statistically valid means of comparing the energy efficiency of existing ships.

Notwithstanding a vessel's individual size, speed, and year of build it is possible to demonstrate that certain vessels are simply designed more efficiently, and it is important that this is factored into the decision-making process.

Retrofits and upgrades such as changes to ship design, propulsion and machinery may help to improve a vessel's GHG Rating. The Class-verified certificates of any upgrade or retrofits can be submitted to RightShip, preferably with new EEXI certification. This will enable the vessel's GHG Rating to be recalculated. A vessel's GHG Rating does not consider operational measures such as slow steaming or eco speeds.

By focusing on design, a more meaningful outcome is achievable - enabling a like-for-like comparison and a score which demonstrates how efficiently the vessel can be operated. This benchmark can then be supplemented by operational measures when the ship is in use.

RIGHTSHIP

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