eMARINA
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The Hong Kong Joint Branch of The Royal Institution of Naval Architects
and The Institute of Marine Engineering, Science and Technology,
and The Hong Kong Institute of Marine Technology
皇家造船師學會暨輪機工程及海事科技學會香港聯合分會
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Vol. 2 June 2021

HKJB & HKIMT Activities

New IMO Regulations on EEXI & CII to Cut Carbon Intensity from Existing Ships

The IMO Green House Gas (GHG) Strategy was revised in 2020. It aims to reduce carbon intensity of international shipping by at least 40% by 2030 and by 70% by 2050 compared to the carbon intensity as at 2008. To achieve the first goal, IMO MEPC 75 has amended the MARPOL Convention to cut the carbon intensity of existing ships. The amendments take a technical and an operational approach to achieve this goal. The Energy Efficiency Existing Ship Index (EEXI) (which addresses how a ship is retrofitted and equipped) and the Carbon Intensity Indicator (CII) (which addresses how a ship operates) were introduced in these amendments. They will enter into force on 1 January 2023.

In supporting the regulatory requirements in IMO, non-government organisations in the industry also take measures to speed up the successful implementation of the GHG Strategy. Notable ones are the Poseidon Principles established by the financial institutes, Sea Cargo Charter by a group of responsible bulk cargo owners and charterers and Rightship. The Poseidon Principles are consistent with the policies and ambitions of the IMO, its ambitions are to peak greenhouse gas emissions as soon as possible and to reduce shipping's total annual GHG emissions by at least 50% by 2050. These Principles will enable financial institutions to align their ship finance portfolios with responsible environmental behavior and incentivize international shipping's decarbonization i.e. to shape a better future for the shipping industry and society. Sea Cargo Charter provides a framework for aligning chartering activities with responsible environmental behavior to promote international shipping's decarbonization. Rightship GHG introduces the Existing Vessel Design Index (EVDI) to provide an industrial wide bench mark to rate ship emissions.

The urgency to comply with the EEXI and CII regulatory requirements on existing ships has imposed immense pressure on shipowners and ship managers. HKIMT and HKJB had invited Mr. Michael Qiao from StormGeo Ltd. to deliver a webinar on 11 June 2021 to highlight some of the solutions that are available commercially to help alleviating shipping companies burdens in coping with these requirements.

Mr. Michael Qiao is the Market Development Manager of StormGeo Ltd. for the Greater China Region. His company provides management solutions with a data bank that helps the shipping industry to calculate EEXI and CII for the GHG requirements. Prior to his managerial position in StormGeo Ltd., Michael was an experienced application engineer, project supervisor and sales manager of 4-stroke marine engine and propulsion products for many years.

Energy efficiency: Design Indices & Operational Indices

Mr. Qiao began his presentation by explaining the various design and operational indices that govern the performance of ships.

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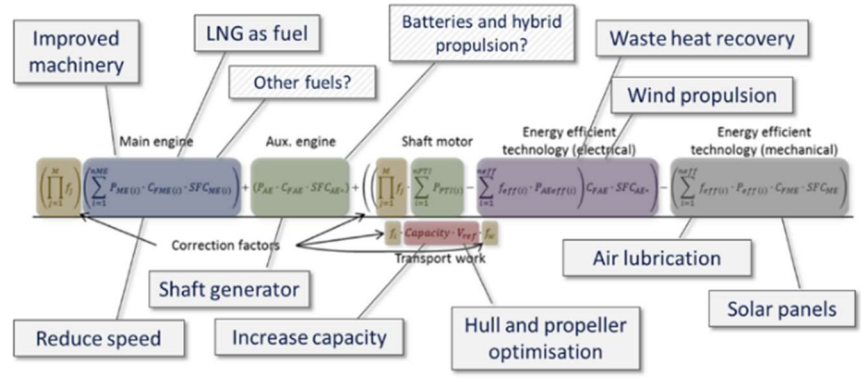


$$EEOI = \frac{\sum_i \sum_j FC_j \times C_{Fj}}{\sum_i M_{cargo} \times D}$$

$$AER = \frac{\sum_j FC_j \times C_{Fj}}{DWT \times D}$$

Design Indices
(EEDI / EEXI / EVDI)

Operational Indices
(CII / Poseidon Principles / Sea Cargo Charter)

a. Design indices like Energy Efficiency Design Index (EEDI), Energy Efficiency Existing Ship Index (EEXI) and Existing Vessel Design Index (EVDI) are difference ways to measure how efficiently a vessel is designed. It also refers to the theoretical carbon intensity of the vessel. The design indices are calculated based on the design specifications of a vessel, e.g., ME MCR, AE MCR in the nominator and design capacity, design speed in the denominator. In other words, EEDI/EEXI/EVDI are fixed when a vessel is designed and built, these values will not change during its lifespan unless the design specifications are modified.

b. Operational indices like Energy Efficiency Operational Indicator (EEOI) and Annual Efficiency Ratio (AER) are parameters that refer to the actual carbon intensity of a vessel which are the prime concern of the CII, Poseidon Principles and Sea Cargo Charter. The operational indices are indicators on how well a vessel is operated or managed and may not necessarily determined by its design indices.

   Both the nominator in the EEOI and AER equations are identical which represents the actual annual carbon emission. While the denominator in the EEOI equation utilizes actual transport work (actual cargo weight carried and distance travelled) and in the AER equation utilizes approximate transport work (deadweight and distance travelled).

   In the EEOI equation, the determination factor is the actual cargo weight carried. If a vessel is on a ballast voyage (i.e., no cargo carried), the denominator in the EEOI equation will always be equals to zero which makes the EEOI value infinite. This result is independent of EEDI/EEXI/EVDI which means that a good design index result does not necessarily guarantee a good EEOI result.

   In the real world, the carriage of cargo and its weight are not always under the owners' or managers' control. Therefore, the AER equation seems to be fairer for the owners or managers. Likewise, a good EEDI/EEXI/EVDI result does not necessarily guarantee a good AER result. Just imagine two sister vessels, one always fully loaded, sailing at full speed with more exposure to bad weather and heavy hull fouling, it would most likely get a worse AER than the other one that is always partly loaded with less exposure to

bad weather conditions and hull fouling and operates at a slower speed.

Energy Efficiency Existing Ship Index (EEXI)

EEXI is basically the same as EEDI which covers the same ship types and sizes but applicable to all the existing vessels regardless of their built date. The reduction factor of EEXI is made equal to the EEDI in January 2022 and with some adjustments to offset the challenges of existing vessels in meeting the requirements as compared to new buildings (which are shown in the table below).

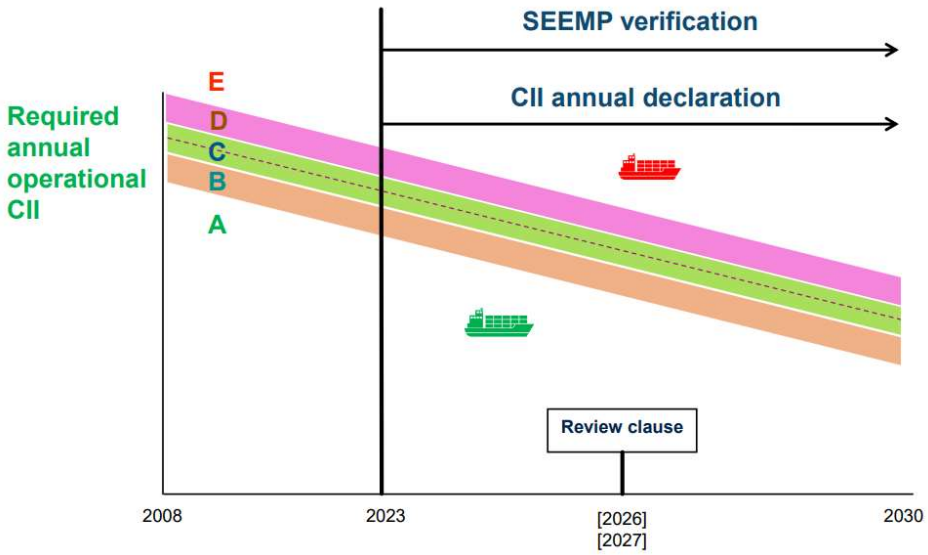
Ship type	Size	Reduction factor
Bulk carrier	200,000 DWT and Above	15
	20,000 to 200,000 DWT	20
	10,000 to 20,000 DWT	0-20*
Gas carrier	15,000 DWT and above	30
	10,000 to 15,000 DWT	20
	2,000 to 10,000 DWT	0-20*
Tanker	200,000 DWT and Above	15
	20,000 to 200,000 DWT	20
	4,000 to 20,000 DWT	0-20*
Container	200,000 DWT and above	50
	120,000 to 200,000 DWT	45
	80,000 to 120,000 DWT	35
	40,000 to 80,000 DWT	30
	15,000 to 40,000 DWT	20
	10,000 to 15,000 DWT	0-20*
General cargo	15,000 DWT and above	30
	3,000 to 15,000 DWT	0-30*
Reefer	5,000 DWT and above	15
	3,000 to 5,000 DWT	0-15*
Combination carrier	20,000 DWT and above	20
	4,000 to 20,000 DWT	0-20*
Ro-ro vehicle carrier	10,000 DWT and above	15
LNG carrier	10,000 DWT and above	30
Ro-ro cargo ship	2,000 DWT and above	5
	1,000 to 2,000 DWT	0-5*
Ro-ro passenger ship	1,000 DWT and	5
	250 to 1,000 DWT	0-5*
Cruise passenger ship having non-conventional propulsion	85,000 GT and above	30
	25,000 to 85,000 GT	0-30*

It is a regulatory requirement that EEXI must be available on the first annual, intermediate or renewal IAPP survey or the initial International Energy Efficiency (IEE) survey after 1 January 2023. The owners or ship managers need to calculate the EEXI of ships in their fleet and make sure that their EEXI values are lower than the required EEXI and submit these technical files for verification in anyone of the IAPP survey. Once verified, a new International Energy Efficiency Certificate (IEEC) will be issued. A flow diagram is attached below to explain the arrangements.

Carbon Intensity Indicator (CII)

CII is applicable to all existing cargo and cruise ships above 5,000 GT. While most people will focus their efforts in obtaining the EEXI, probably because of its imminent deadline by 2023 and clarity of the requirement. However, we should not underestimate the impact of CII. To certain extent, CII is even more challenging than EEXI. The challenges mainly come from 3 facts:

1. Unlike EEXI which is a one-time job, CII is an on-going task that requires to be calculated every year starting from 2023.
2. CII is a part of the IMO-DCS (Data Collection System) process, that starts from 2023. After the emission data is submitted and verified, a CII rating (from A to E) will be given to the vessel based on the annual carbon intensity result.
3. The value of the required CII is required to be reduced every year. This carbon intensity value is required to drop by at least 40% by 2030 and by 70% by 2050 as compared with the value in 2008 (a full picture of the requirement is depicted below for clarity).



If a vessel gets a rating of D for 3 consecutive years or a rating E in any year, it is required to develop and implement corrective actions to achieve rating C or better. The corrective actions is required to be submitted for verification otherwise the Statement of Compliance (SoC) will not be issued to the vessel.

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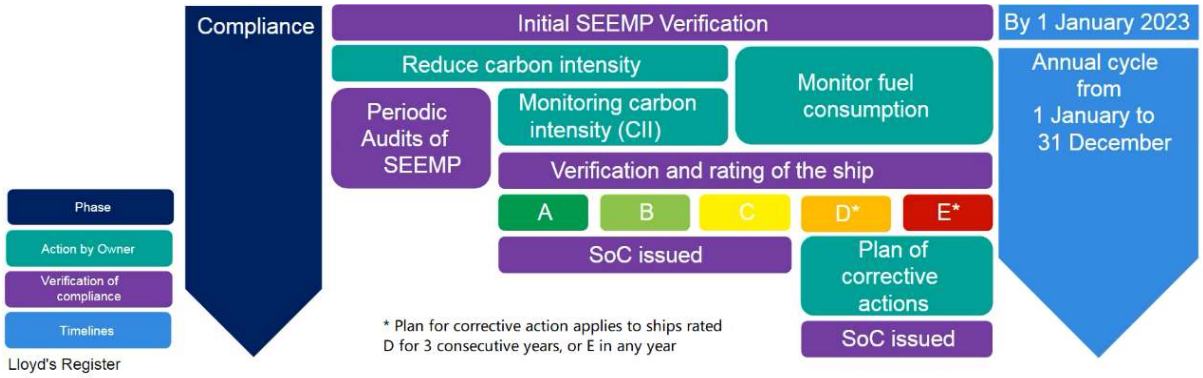


CII will not only bring extra workload to the technical managers, it will to a certain extent affect the commercial operations of a ship. Take a Time-Charter business as an example:

	In the past	After 2023

Owner	• Fuel cost on Charterer's account
	• Has no interest in fuel saving
		• Fuel cost still on Charterer's account
		// CII rating bonded with owner
		// Low rating -> Less competitive

Charterer	• Lack of transparency in actual performance	• Take CII rating into consideration when chartering vessels

IMO Guidelines

To help owners and ship managers to meet the CII requirements, IMO has developed four CII related guidelines for its calculation:

1. Guidelines on operational carbon intensity indicators and the calculation methods (CII guidelines, G1)
2. Guidelines on the reference lines for use with operational carbon intensity indicators (CII Reference line guidelines, G2)
3. Guidelines on the operational carbon intensity reduction factors relative to reference lines (CII Reduction factor guidelines, G3)
4. Guidelines on the operational carbon intensity rating of ships (CII Rating Guidelines, G4)

1. <u>Guidelines on operational carbon intensity indicators and the calculation methods (G1)</u>

Only one single metric should be taken as the mandatory CII for each and every ship type and the mandatory CII should be calculated on the basis of the Data Collection System (DCS). Since the data on board a cargo/passenger ship is not covered by the IMO DCS, the deadweight tonnage (DWT) or gross tonnage (GT) has to be taken as a proxy:

- AER = CO_2 emissions / (DWT × Distance travelled)

- cgDIST = CO_2 emissions / (GT × Distance travelled)

AER will be used for Bulk carriers, Gas carriers, Tankers, Container ships, General cargo ships, Refrigerated cargo carriers, Combination carriers, LNG carriers and ro-ro cargo ships (not vehicle carrier).

cgDIST will be used for Cruise passenger ships having non-conventional propulsion, ro-ro cargo ships (vehicle carrier) as well as ro-ro passenger ships.

To ensure that ships of various design and operational features can be compared, there is a need to introduce certain correction factors and to exclude certain voyages in the calculation of CII.

Correction factors:

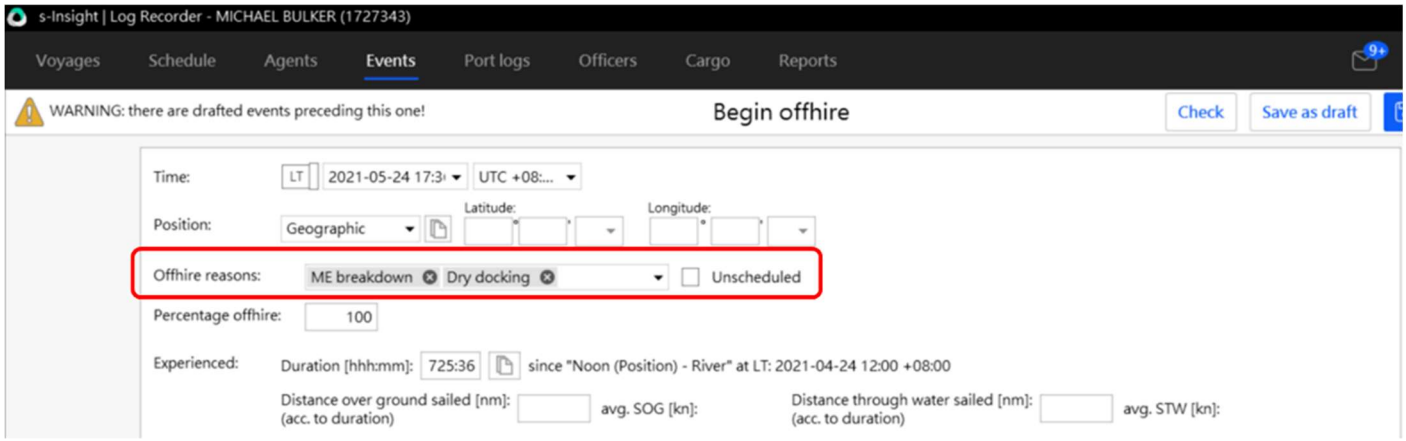
- ice-classed ships,
- for ships carrying refrigerated containers (reefers),
- for ships with cargo heating/cooling systems or other cargo handling gears.

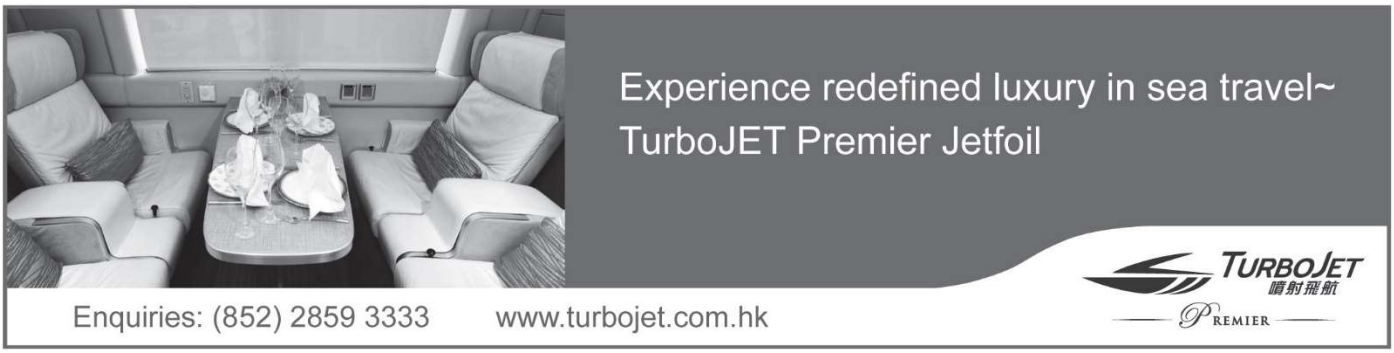
Voyage exclusion:

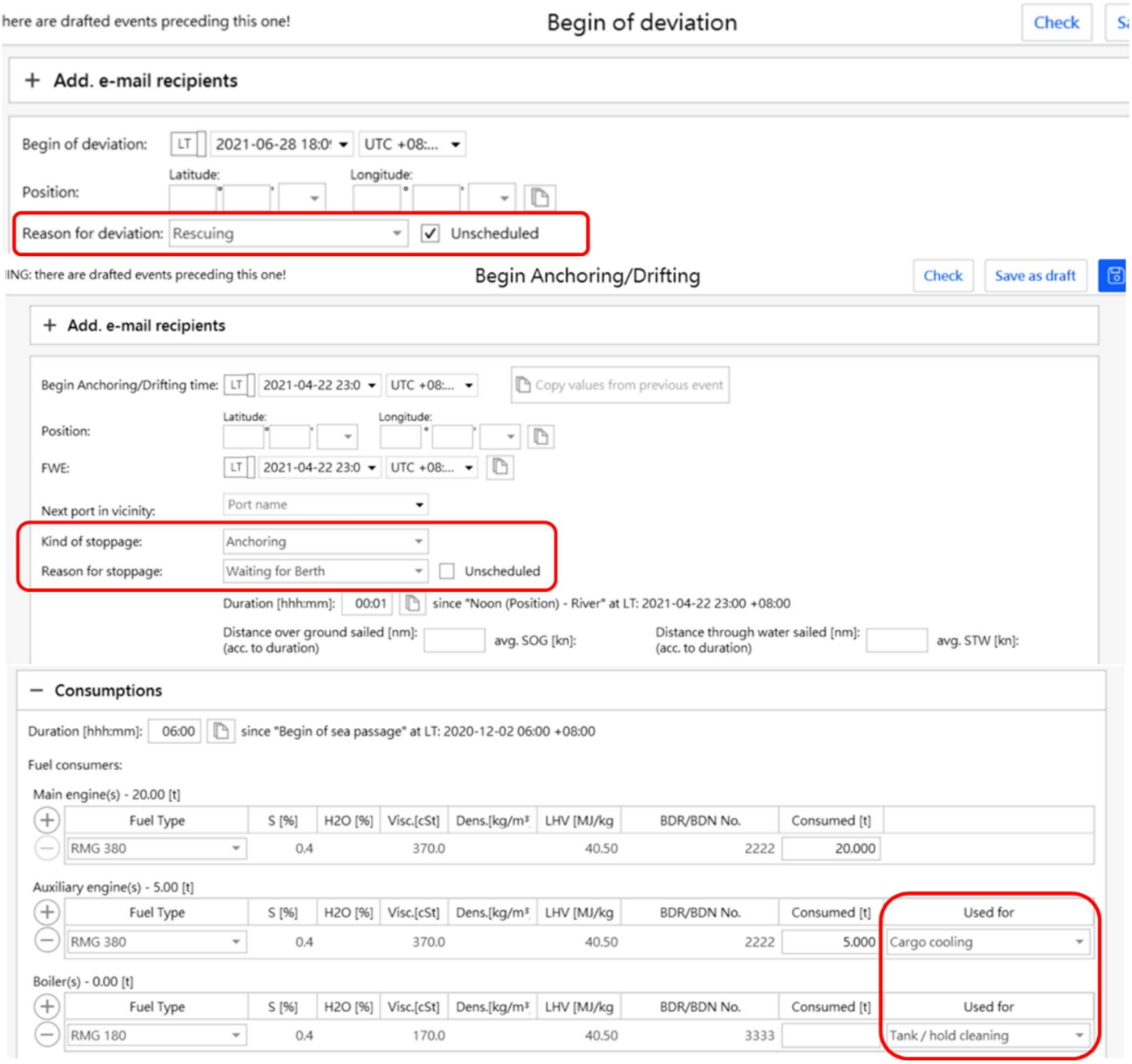
- those voyages specified in regulation 3.1 of MARPOL Annex VI,
- sailing in ice conditions,
- prolonged period without distance travelled,
- severe weather conditions,
- dynamic positioning (DP) operations,
- disproportionate fuel consumptions.

Note: Latest update of the list will be discussed in MEPC 76: A new correction factor guideline (G5) will have to be discussed in a Correspondence Group and agreed by MEPC 78 in 2022.

To help owners and managers in determining CII, StormGeo's s-Insight Log Recorder offers a helpful solution by collecting all the additional information of the corrections for the calculation.







2. *Guidelines on the reference lines for use with operational carbon intensity indicators (G2)*

Given the limited operational carbon intensity performance data of ship types for the year 2008, the operational carbon intensity performance of ship types in year 2019 is taken as the reference. For a defined group of ships, the reference line is formulated as follows:

$$CII_{ref} = a \times Capacity^{-c}$$

Ship type		Capacity	*a*	*c*
Bulk carrier	279,000 DWT and above	279,000	4977	0.626
	less than 279,000 DWT	DWT	4977	0.626
Gas carrier	65,000 and above	DWT	2384E7	1.910
	less than 65,000 DWT	DWT	8032	0.638
Tanker		DWT	5118	0.607
Container ship		DWT	1963	0.487
General cargo ship	20,000 DWT and above	DWT	61293	0.854
	less than 20,000 DWT	DWT	361	0.336
Refrigerated cargo carrier		DWT	6736	0.599
Combination carrier		DWT	151991	0.930
LNG carrier	100,000 DWT and above	DWT	9.860	0
	65,000 DWT and above, but less than 100,000 DWT	DWT	1966E10	2.498
	less than 65,000 DWT	65,000	1966E10	2.498
Ro-ro cargo ship (vehicle carrier)		GT	5831	0.633
Ro-ro cargo ship		[DWT]	[15958]	[0.677]
Ro-ro passenger ship		GT	7691	0.586
Cruise passenger ship having non-conventional propulsion		GT	904	0.380

Figure 1 Parameters for determining the 2019 ship type specific reference lines

3. *Guidelines on the operational carbon intensity reduction factors relative to reference lines (G3)*

The required annual operational CII for a ship is calculated as follows:

$$\text{Required annual operational CII} = (1\text{-}Z/100) \times CII_{ref}$$

** Latest update of MEPC 76: The CII reduction rates (a flat reduction factor at the global fleet level) were set to increase by 1 percentage point (pp) per year for 2020–2022, followed by 2 pp per year for 2023–2026. The rates for 2027–2030 will be decided as part of the review to be concluded by 1 January 2026. Proposals for allowing fleet averaging of the CII were not agreed but may, in principle, be considered in future as an option under mid- and long-term measures.*

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YEAR	Reduction factor to be increased per year	Reduction from 2019 reference	PHASE
2020	1.0%	1.0%	PHASE 1
2021	1.0%	2.0%	
2022	1.0%	3.0%	
2023	2.0%	5.0%	PHASE 2
2024	2.0%	7.0%	
2025	2.0%	9.0%	
2026	2.0%	11.0%	
2027	To be considered	To be considered	PHASE 3
2028			
2029			
2030			

4. <u>Guidelines on the operational carbon intensity rating of ships (G4)</u>

The rating boundaries can be determined by the required annual operational CII in conjunction with the vectors, indicating the direction and distance they deviate from the required CII value (denoted as dd vectors for easy reference).

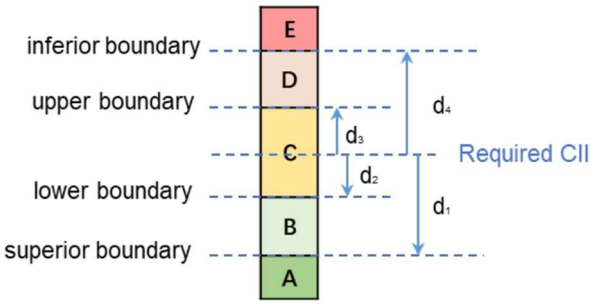


Figure 2 dd vectors and rating bands

The four boundaries fitted can be derived based on the required annual operational carbon intensity indictor (required CII), as follows:

$$\text{superior boundary} = \exp(d_1) \cdot required\ CII$$
$$\text{lower boundary} = \exp(d_2) \cdot required\ CII$$
$$\text{upper boundary} = \exp(d_3) \cdot required\ CII$$
$$\text{inferior boundary} = \exp(d_4) \cdot required\ CII$$

The estimated dd vectors after exponential transformation for determining the rating boundaries of ship types are as follow:

Ship type		Capacity in CII calculation	*dd* vectors (after exponential transformation)			
			exp(d1)	exp(d2)	exp(d3)	exp(d4)
Bulk carrier		DWT	0.86	0.94	1.06	1.18
Gas carrier	65,000 DWT and above	DWT	0.79	0.89	1.12	1.38
	less than 65,000 DWT	DWT	0.85	0.95	1.06	1.25
Tanker		DWT	0.82	0.93	1.08	1.27
Container ship		DWT	0.83	0.94	1.07	1.19
General cargo ship		DWT	0.84	0.95	1.07	1.19
Refrigerated cargo carrier		DWT	0.77	0.90	1.07	1.21
Combination carrier		DWT	0.88	0.95	1.06	1.26
LNG carrier	100,000 DWT and above	DWT	0.91	0.98	1.05	1.11
	less than 100,000 DWT		0.77	0.91	1.12	1.37
Ro-ro cargo ship (vehicle carrier)		GT	0.86	0.94	1.06	1.16
Ro-ro cargo ship		[DWT]	[0.67	0.90	1.09	1.37]
Ro-ro passenger ship		GT	0.73	0.87	1.10	1.37
Cruise passenger ship having non-conventional propulsion		GT	0.85	0.94	1.04	1.15

Figure 3 dd vectors for determining the rating boundaries of ship types

How to reduce the carbon intensity?

Mathematically, it is best to make the nominator as small as possible and the denominator as big as possible in the calculation of CII. However, due to the differences between design indices and operational indices, they can only be evaluated on a case-by-case basis.

There are currently four strategies available in the market to reduce carbon intensity and each of them will have their own pros and cons:

1. DWT Increase (DWI)
   Increasing the deadweight of the vessel which was reserved as the design margin, works well on AER and EEOI if the capacity can be fully utilized in laden voyages. However, this strategy would most likely make no significant change to EEXI, and could possibly make Rightship GHG rating worse because the vessel has to be compared and rated against other vessels of the same size and type (peer group) of +/- 10% of its deadweight. Increasing the DWT would return a new and uncertain rating because it may now fall into a different peer group.

2. Engine Performance Limitation (EPL)
   Applying power limit on engine or shaft is the most effective measure to reduce EVDI/EEXI, however it makes no contribution to reducing EEOI/AER because the propulsion efficiency could not be improved by EPL.

3. Hydrodynamics and Energy Saving Devices
   This strategy includes but is not limited to Propeller Boss Cap Fin, Duct, Wind Propulsion, shaft generator and etc., which improves propulsion efficiency and therefore contribute to EEOI, AER, EVDI and EEXI. However, this strategy normally requires heavy capital investment, e.g., dry-docking, new hardware/equipment, labor cost as well as considerable downtime comparing to other strategies.

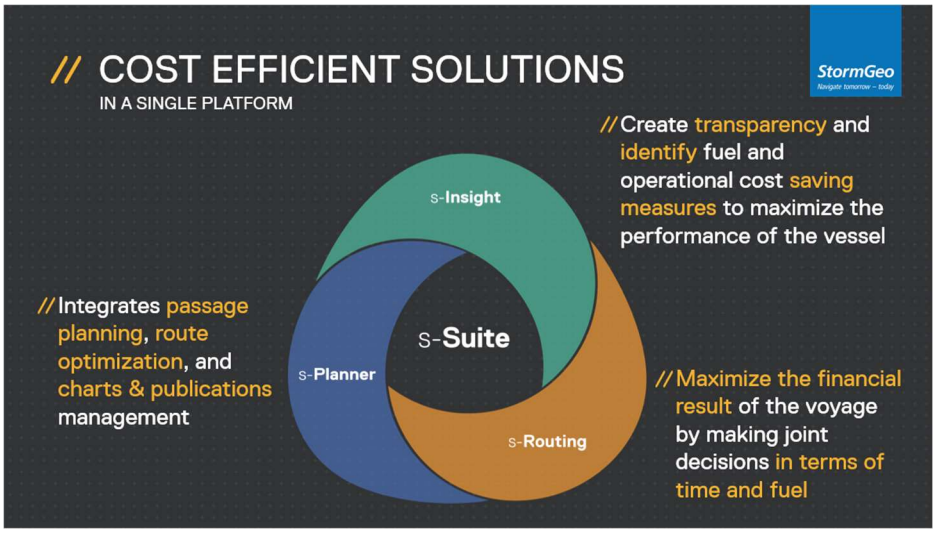
4. Energy Management
   This strategy refers to optimization of operation and management of the vessel without changes to the hardware. Therefore, it works well on the EEOI/AER, but not on EVDI/EEXI.

Description	Power limitation [% rel. to MCR]	Ship speed loss [% rel. to V_S]	EEXI Improvement [%]
Engine power limitation	up to 50	~21	~37
Description	**SFOC Improvement [%]**	**Different C_F [%]**	**EEXI Improvement [%]**
Fuel change from MDO to LNG	10	15	25
Description	**Power reduction [% rel. to P_{ME}]**	**Ship speed reduction [% rel. V_{ref}]**	**EEXI Improvement [%]**
Rotor sails (2 units) on Long Range 2 tanker	4		3.8
Installation of shaft generator	6	1.7	5.6
Combination of both installations	10	1.7	9.5
Description	**DWT increase [%]**	**att. EEXI gain [%]**	**EEXI Improvement [%]**
Deadweight increase	5	3.7	1.5
	10	7.1	3.0
Description	**Power reduction [% rel. to P_{ME}]**	**Ship speed increase [% rel. V_{ref}]**	**EEXI Improvement [%]**
Energy saving device (e.g. PBCF, duct)	1	0.3	0.3
	4	1.4	1.3
	7	2.4	2.3
	10	3.5	3.3

Figure 4 Potential of different improvement measures by DNV

StormGeo Solutions

StormGeo offers the s-Suite integrated solutions to help shipping companies to face the challenges. The s-Suite, mainly focusing on energy management. It helps to optimize the operation and management of voyage performance, hull performance as well as engine performance, which requires minimal capital investment comparing to Hydrodynamics and Energy Saving Devices.



s-Routing & s-Planner	s-Insight		
Voyage Performance	Ship Performance	Consumer Performance	Environment Performance
• Weather Routing • Voyage Planning • Speed Management • • •	• Hull degradation computation • Trim Optimization • Propeller slip • • •	• ME Fuel Efficiency • AE Fuel Efficiency • AE Utilization • Boiler Abuse • • •	• Data collection & quality checking • EU-MRV • IMO-DCS • NOx / SOx • Disposals
	Average 10%	Average 5%	

(Reported by Leslie Lee and validated by Michael Qiao)

HKJB & HKIMT Coming Activities

Date	Event
5 July 2021	Plastic waste on board merchant ships
28 July 2021	Webinar on Narrowboat Design for British Canal
14 September 2021	Committee Meeting
September 2021	Technical Seminar for Fire Fighting System on Yachts

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