GREENER STRATEGY

HOW TO RESPOND TO IMO GHG REQUIREMENTS

OCT 2021

KOREAN REGISTER

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FOREWORD

The International Maritime Organization (IMO) amended MARPOL Annex VI at its MEPC 76 in June 2021. Consequently, ships engaged in international voyage will be obliged to comply with the Efficiency Existing Ship Index (EEXI) (MARPOL Annex VI, reg. 23 and 25). In addition, they must satisfy Regulation 28 of the same MARPOL Annex. Regulation 28 prescribes for the reduction of Operational Carbon Intensity through the Carbon Intensity Indicator (CII).

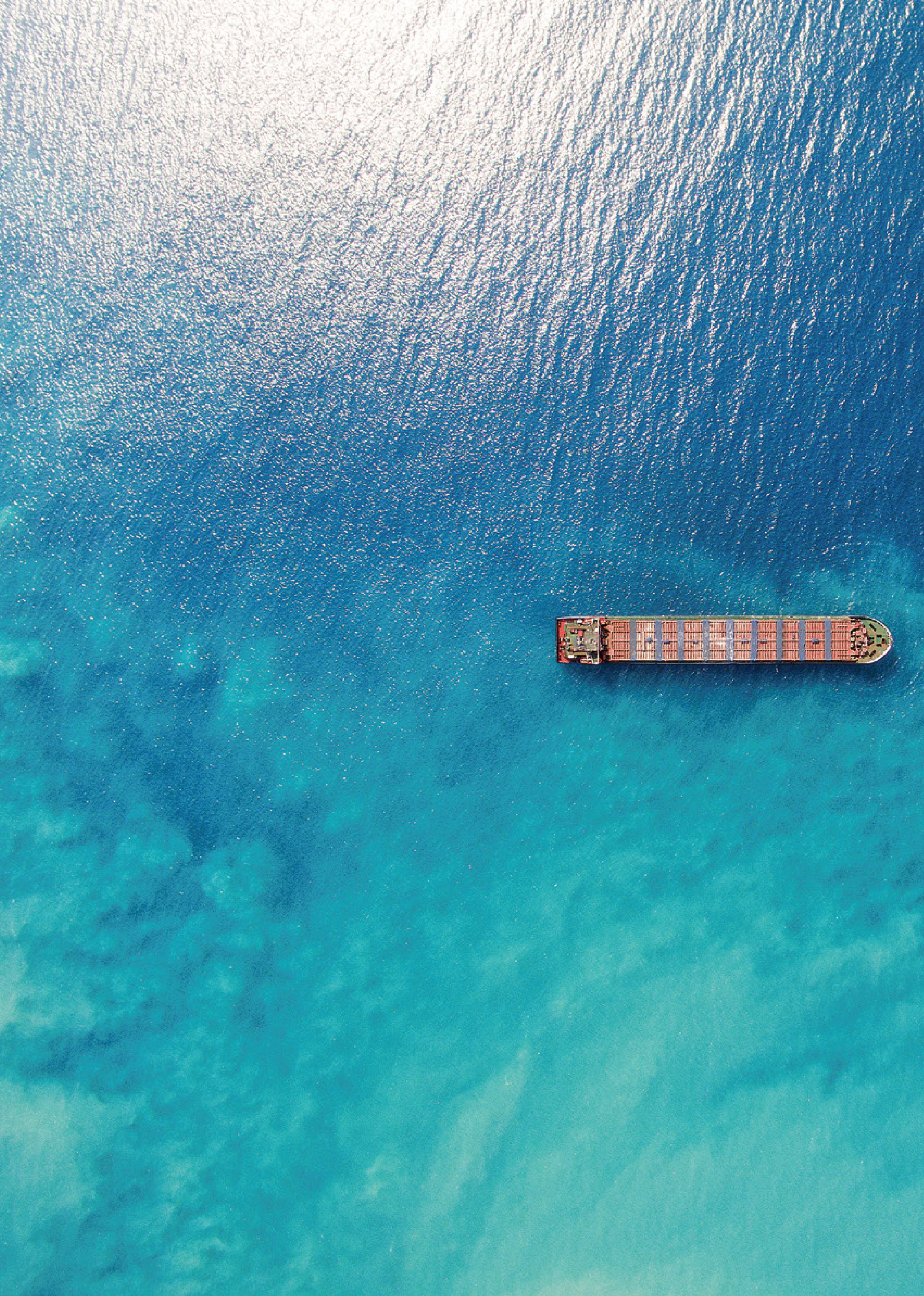
The effective date for these changes to become operational is 1 January 2023. Given this, the new regulatory movement of 2021 forces shipowners to demonstrate, by the initial or the next periodic survey, that their ships meet the requirements of EEXI and CII in order for them to receive the International Energy Efficiency Certificate (IEEC) and/or the International Air Pollution Prevention Certificate (IAPPC).

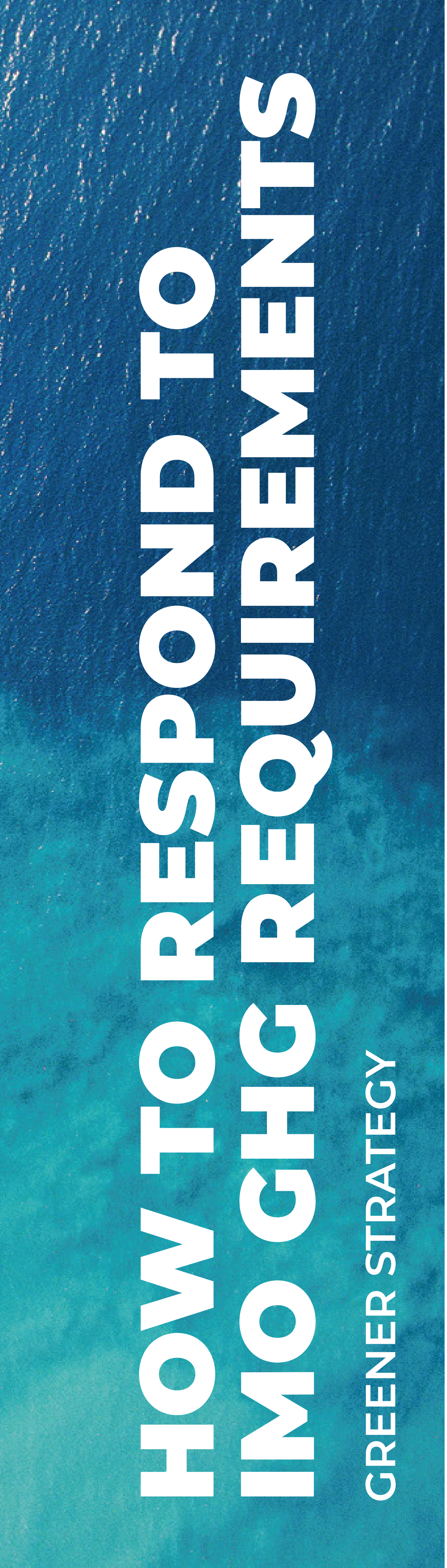
Accordingly, immediate attention must be given to the implications of EEXI and CII. This means that shipowners must begin to take steps to commence EEXI calculations of their fleet, and to improve energy efficiency by reducing carbon footprints to satisfy EEXI and CII requirements.

Your trusted partner, Korean Register (KR), is ready to help its clients by furnishing them with tailored EEXI calculations and suitable advice for a better CII rating so that they can maintain sustainable and green shipping statuses in today’s highly complicated and regulatory environment.

This **Transition 2050** report presents KR’s unique strategic approach to EEXI and CII solutions based on reliable simulation outcomes from more than 1,200 ships in operation.

CHAIRMAN & CEO OF KOREAN REGISTER
HYUNGCHUL LEE




HOW TO RESPOND TO
IMO GHG REQUIREMENTS
GREENER STRATEGY

LIST OF CONTRIBUTORS

SONG KANGHYUN

- Head / Senior Vice President
- Decarbonization·Ship R&D Center
- Ph.D. in Naval Architecture & Ocean Engineering

KIM SANGYEOB

- Deputy Senior Surveyor
- Ship & Offshore Technology Team
- Ph.D. in Naval Architecture & Ocean Engineering

CHOI BYONGCHOL

- Principal Surveyor
- Stability & Tonnage Team
- B.S. in Naval architecture & Ocean engineering

LEE JUNGYUP

- Senior Surveyor
- Green Ship Technology Team
- B.S. in Environment Science

KIM YEONGHO

- Senior Surveyor
- Machinery Team
- Ph.D. in Engineering

LIM JAEGYUN

- General Manager
- Decarbonization Solution Center
- M.Sc. in Mechanical Engineering

ABBREVIATION INDEX

AE	Auxiliary Engines
AIP	Approval in Principle
AMP	Alternative Maritime Power
BSR	Barred Speed Range
CAPEX	Capital Expenditures
CFD	Computational Fluid Dynamics
CII	Carbon Intensity Indicator
CRP	Contra-Rotating Propellers
DWT	Deadweight Tonnage Capacity
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EEXI	Efficiency Existing Ship Index
EPL	Engine Power Limitation
ESD	Energy Saving Devices
EU MRV	European Union (EU) Monitoring Reporting Verification
IAPPC	International Air Pollution Prevention Certificate
IEEC	International Energy Efficiency Certificate
IMO DCS	International Maritime Organization (IMO) Data Collection System
JDP	Joint Development Plan
MBM	Market Based Measure
MCR	Maximum Continuous Rating
MEPC	Marine Environment Protection Committee
MPP	Multipurpose Vessel
OICNW	Officer In Charge of Navigational Watch
OMM	Onboard Management Manual
OPEX	Operating Expenses
P/T	Power Turbin
P2G	Power to Gas
PBCF	Propeller Boss Cap Fins
PID	Propulsion Improving Devices
RO	Recognized Organizations
S/T	Steam Turbin
SEEMP	Ship Energy Efficiency Management Plan
SFC	Specific Fuel Consumption
ShaPoli	Shaft Power Limitation
SSS clutch	Synchro-Self-Shifting clutch

HOW TO TACKLE EEXI/CII

1 IMO GHG REQUIREMENTS

IMO GHG STRATEGY

VISION

DECARBONIZATION

Phase GHG emissions of ships **out in this century**

TARGET

REDUCE CARBON INTENSITY OF SHIPS	DECLINE CARBON INTENSITY OF INTERNATIONAL SHIPPING	GHG EMISSIONS TO PEAK AND DECLINE
· Through the implementation of further Phases of EEDI for New Ships	· By reducing CO2/ton-mile 40% by 2030 and 70% by 2050 compared to 2008	· Peak GHG emissions soon · Reduce total annual emissions 50% by 2050 compared to 2008

*source : IMO 2021

2018-2023
Short-term measures

- Improvement of **EEDI and SEEMP**
- Develop **Technical and Operational Energy Efficiency Measures** for both new ships and existing ships with a **Three-Step Approach**
- Existing **Fleet Improvement** Program
- **Speed Optimization** and reduction
- Measures for **methane and VOCs**
- National Action Plans, Technical cooperation, and capacity-building, Port Development (AMP, etc.), R&D activities, Incentives for first movers, Lifecycle guidelines for fuels, GHG study

2023-2030
Mid-term measures

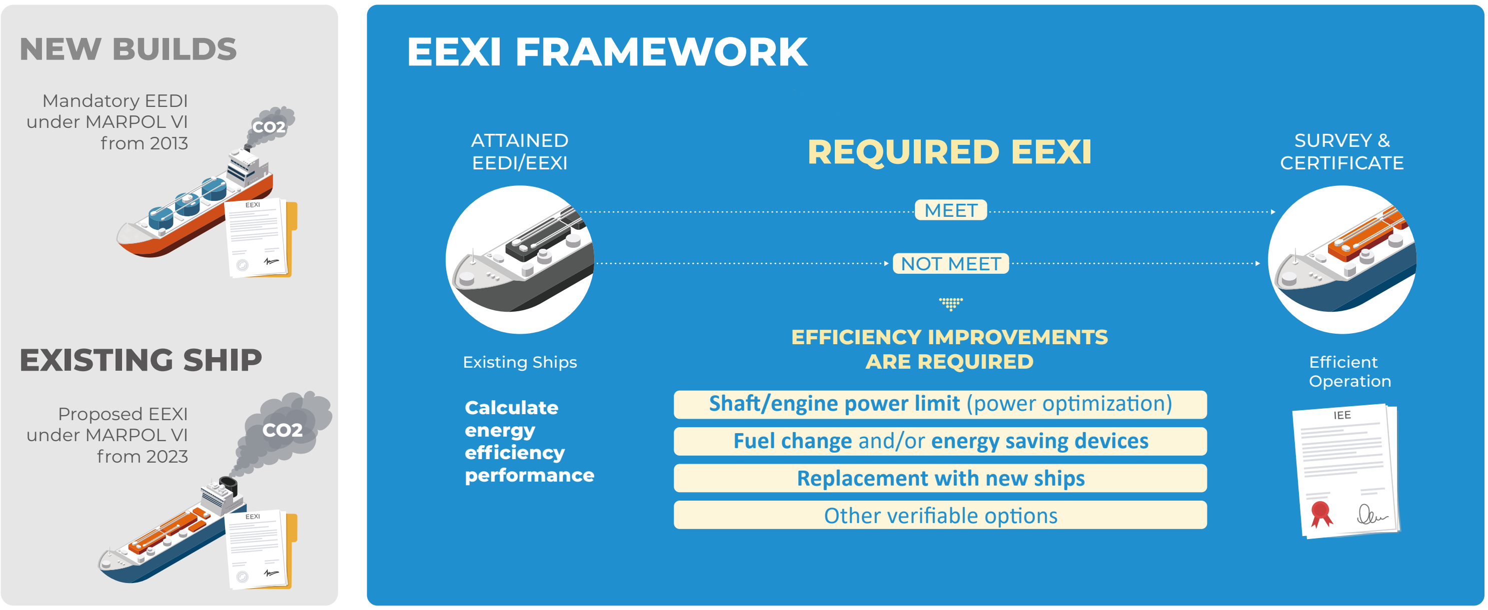
- Program for **Alternative Fuels**
- **Operational Energy Efficiency Measures** for both new and existing ships
- **Emission Reduction Mechanism (MBM)**
- Technical cooperation and capacity-building, Feedback mechanism

Beyond 2030
Long-term measures

- **Zero-carbon or fossil-free fuels**
- **Emission Reduction Mechanism**

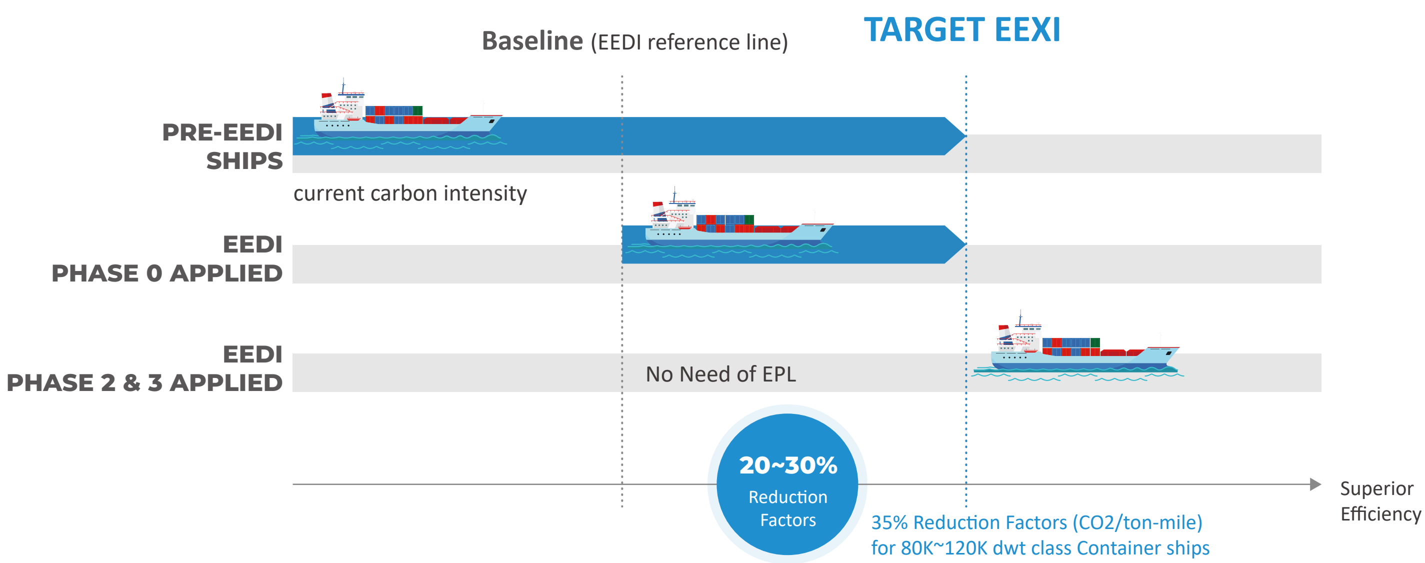
*source : IMO 2021 (MEPC 76)

EXISTING SHIP: EEXI



EEXI is a technical measure requiring the ship's energy performance to be rated technically. However, IMO is going a step further and requires the ship's actual GHG emissions to be evaluated as well as its CII (Carbon Intensity Indicator Rating).

EEDI REDUCTION RATES PER EEDI PHASE



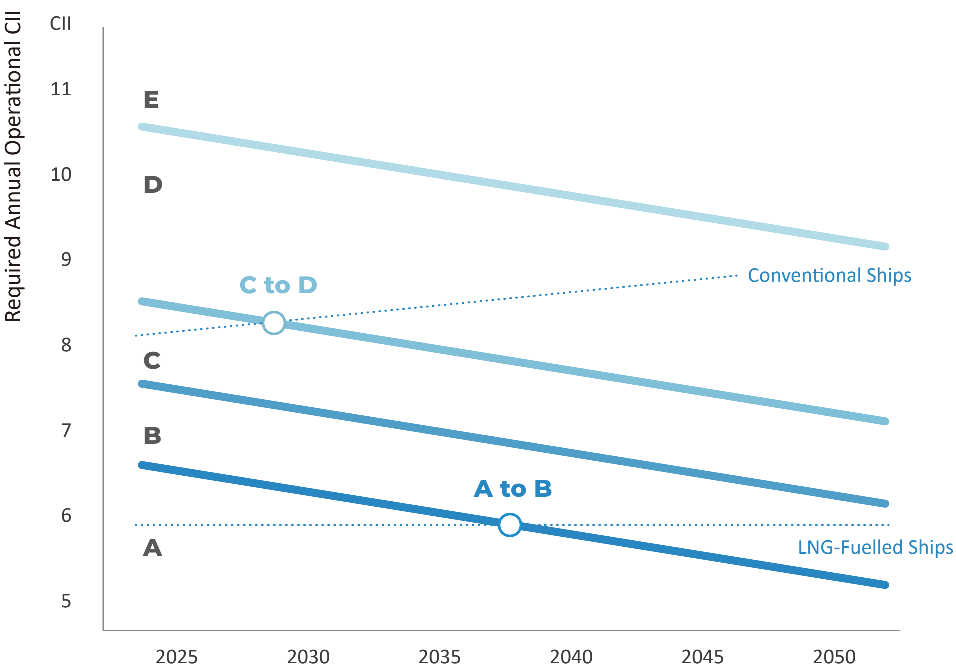
	PHASE 0	PHASE 1	PHASE 2	PHASE 3
YEAR	2013	2015	2020	2025
REDUCTION RATE	0%	10%	20%	30%

EEDI regulations for new build vessels were brought into force from phase 0 in 2013 with a reduction rate of 0%. Phase 3 starts in 2025 to reach a reduction rate of 30%. On the other hand, EEXI starts in 2023 with the goal to attain a reduction rate from 20% to 30% between phase 2 and phase 3.

Pre-EEDI ships should fill in the reduction rate gap from 20% to 30%, and more, in order to satisfy Target EEXI. As far as EEDI phase 0 ships are concerned, the reduction rate gap to fill is to be within 20~30%. Most of the phase 2 and 3 ships seem to be able to satisfy EEXI.

Technically speaking, **it is expected that most pre-EEDI ships may not satisfy EEXI, as doing so requires significant improvements in energy efficiency.** It must be noted too that some EEDI ships may also not be able to meet EEXI requirements, and therefore, would need various degrees of improvement.

CII: CORRECTIVE ACTIONS & SEEMP REVISION



CII is calculated based on IMO DCS data or actual fuel consumption over the previous year. Each vessel will then be rated from A to E.

Ships rated as E, as well as those rated D for three consecutive years, indicate that they are in serious adverse conditions, and require immediate corrective actions in order to improve energy efficiency.

If a conventional ship is found to fall within a C rating, this vessel is easy to fall down to a D in a few following years if no improvements are made to enhance energy efficiency. As part of corrective measures, shipowners can choose, to reduce ship speed as an effective means to improve ratings.

As shown in the graph, LNG fuelled ships with good energy efficiency can start out with an A rating, and these ships hardly set back to a Rating B or C within several years. They will not need to reduce ship speed to maintain their good rating. This benefits shipping business.

EEXI CALCULATION DATA FOR EXISTING SHIPS

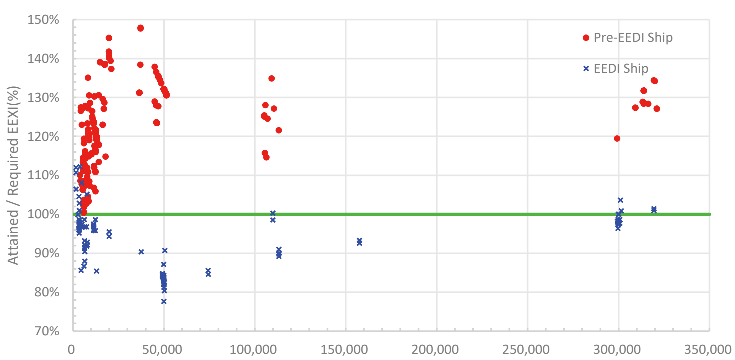
Of 1,650 ships reviewed,

1,363 ships are pre-EEDI.

TANKERS

In the charts below, we have applied EEXI calculations to tankers on the left and bulk carriers on the right. Note that most of the pre-EEDI tankers and bulk carriers do not satisfy EEXI. More attention should be paid to pre-EEDI tankers.

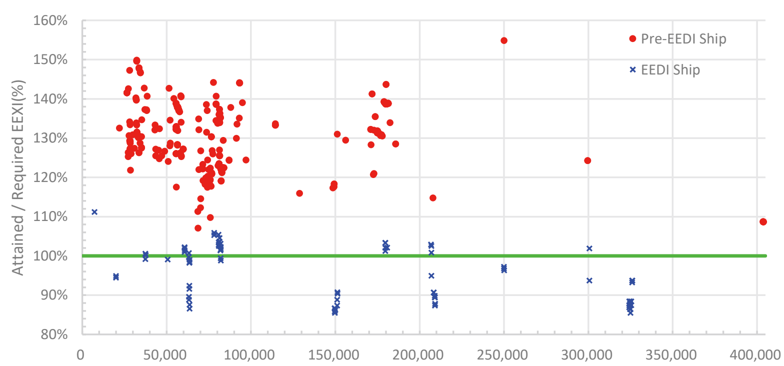
	TOTAL	SATISFIED	UNSATISFIED	FAILURE RATE
PRE-EEDI	406	14	306	75%
EEDI	105	76	7	7%
SUM	**511**	**90**	**313**	**61%**



BULK CARRIERS

Approximately, 84% of the bulk carriers are expected to need additional measures to improve their energy efficiency. As EEXI comes into force in 2023, shipowners should make improvements so that bottlenecks can be avoided.

	TOTAL	SATISFIED	UNSATISFIED	FAILURE RATE
PRE-EEDI	370	0	363	98%
EEDI	103	69	34	33%
SUM	**473**	**69**	**397**	**84%**

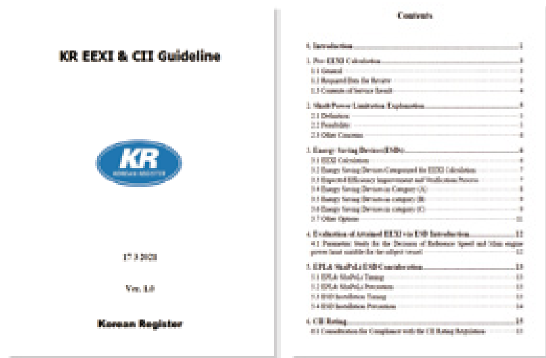


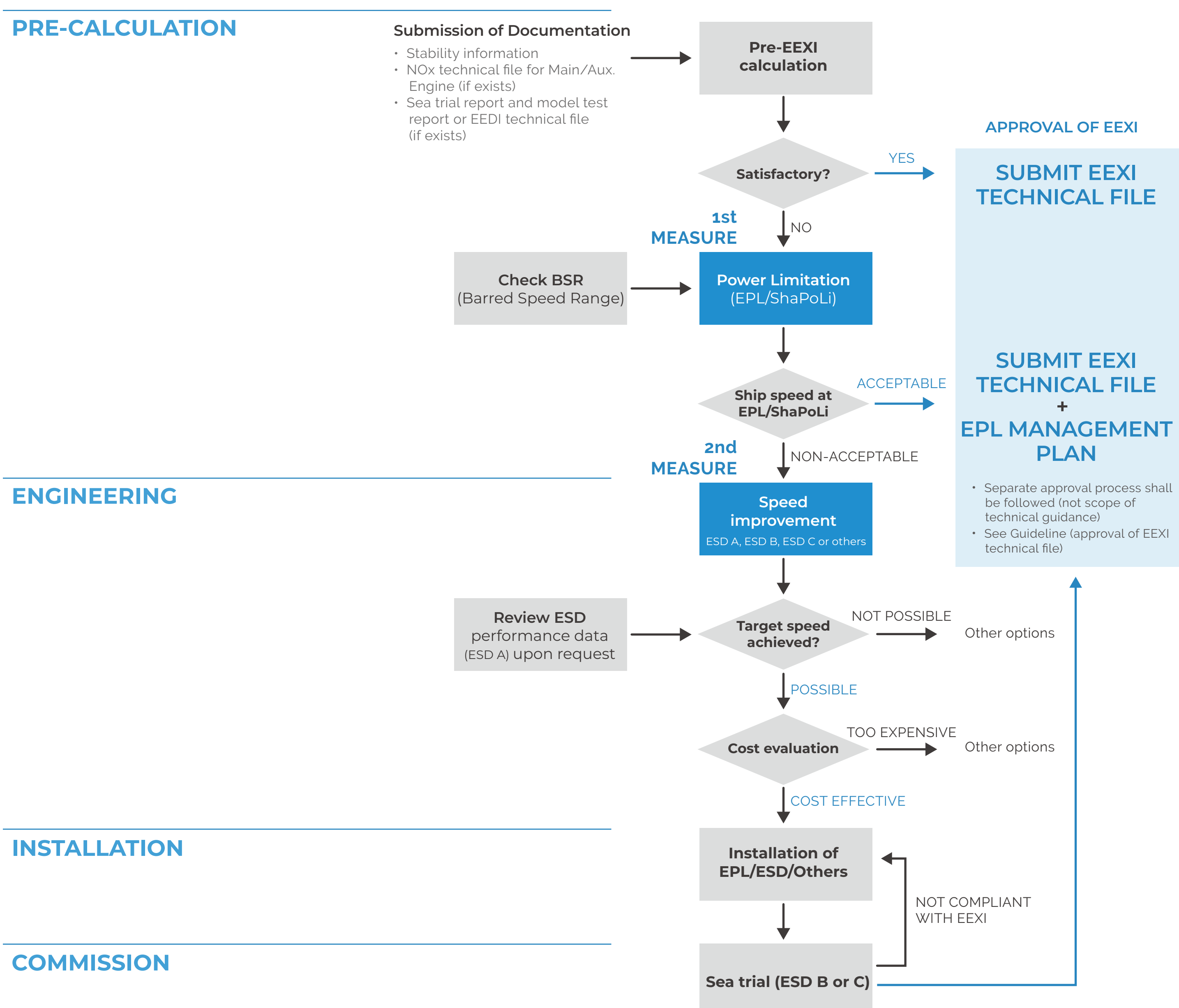
2 HOW TO COMPLY WITH EEXI

EEXI/CII GUIDELINE

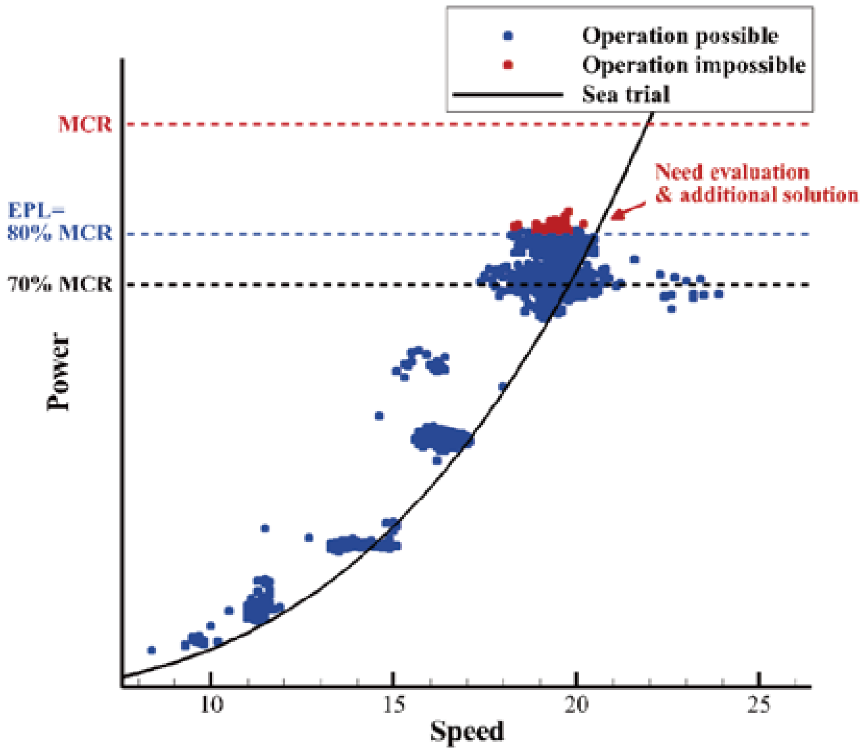
KR has developed EEXI and CII guidelines for customers. If vessels do not satisfy EEXI, the first step to take can be power limitation employing EPL (engine power limitation) or ShaPoli. This measure takes less time and costs to implement, and is also relatively undemanding to verify its results compared with other measures. If operating at a reduced speed does not interfere with commercial business, shipowners can apply for an International Energy Efficiency Certificate (IEEC).

However, if the reduced speed negatively impacts on business, then shipowners may need to resort to a range of Energy Saving Devices (ESDs). Other options can include, but not be limited to, new building, selling off older ships, and changing chartering arrangements. Even if reducing ship speed is acceptable, shipowners and operators should thoroughly evaluate its cost-effectiveness. For the furtherance of cost-effectiveness, it would be worth considering a combination of EPL and ESD.





EFFECT OF EPL ON SHIP OPERATION



Prior to adopting power limitation, shipowners should assess the impacts it might have on vessel operation, as well as on their business.

This graph shows a speed power curve based on ship operating profiles. The black line is the sea trial result. For example, if the power limitation is 20% of the maximum continuous rating (MCR) of engine, the impact would be as small as just 2 or 3 %.

However, if the power limitation is 30% or more, ship operation would be much more limited, and shipowners should re-evaluate and, perhaps, find alternative solutions, taking advantage of data with good quality which support better decisions.

POSSIBLE OPTIONS

OPTION 01	EPL	EPL (engine power limitation) can cost less and take less time.
OPTION 02	EPL with ESD	EPL can be combined with ESD.
OPTION 03	LNG DF RETROFIT	LNG DF Retrofit can be considered for ships with less age.
OPTION 04	NEW BUILDS	New builds can be an option to substitute for low energy efficiency ships.

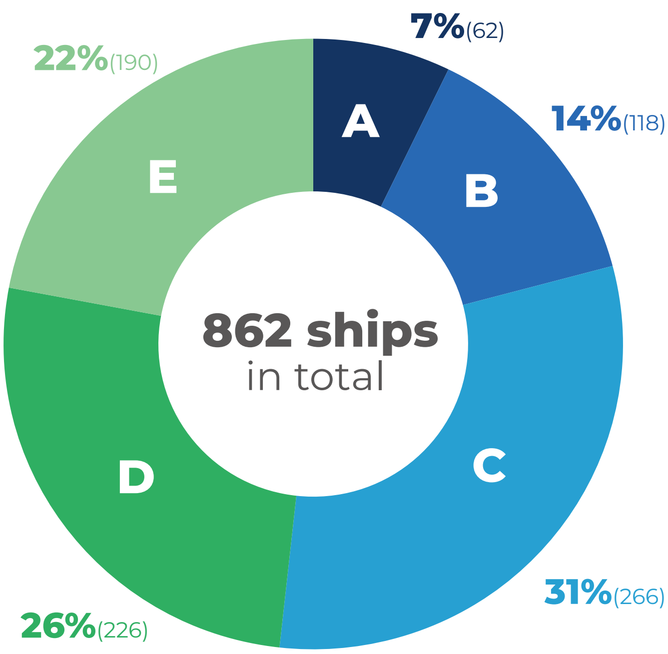
FACTORS TO BE CONSIDERED FOR COST EFFECTIVE SOLUTION

Specific solutions may vary per ship.

- CAPEX
- OPEX
- Remaining Service Life
- Time for Engineering, Installation & Verification
- Chartering Speed
- CII for Life Time
- Retrofit vs New builds

3 HOW TO KEEP A GOOD CII RATE

EXISTING VESSELS UNDER CII REQUIREMENT AND RATING STATUS FOR 862 SAMPLE SHIPS (2019)



*Note: A rating indicates the highest positive point.

We have carried out CII calculations for about 900 ships and the results have been quite remarkable. We found that around 50% of vessles were ranked as D or E where corrective action is necessary. If we also believe that vessels rated as C are vulnerable to be re-rated to D, then there are a total of 80% that might require additional measures.

We believe only 20% of vessels are ranked A or B and it is these ships that will be incentivized by the charterers and the banks.

To improve CII, the systematic maintenance of hull, propellers and engines is necessary. Shipowners should develop a life cycle management plan based on CII optimisation.

Systemic Maintenance

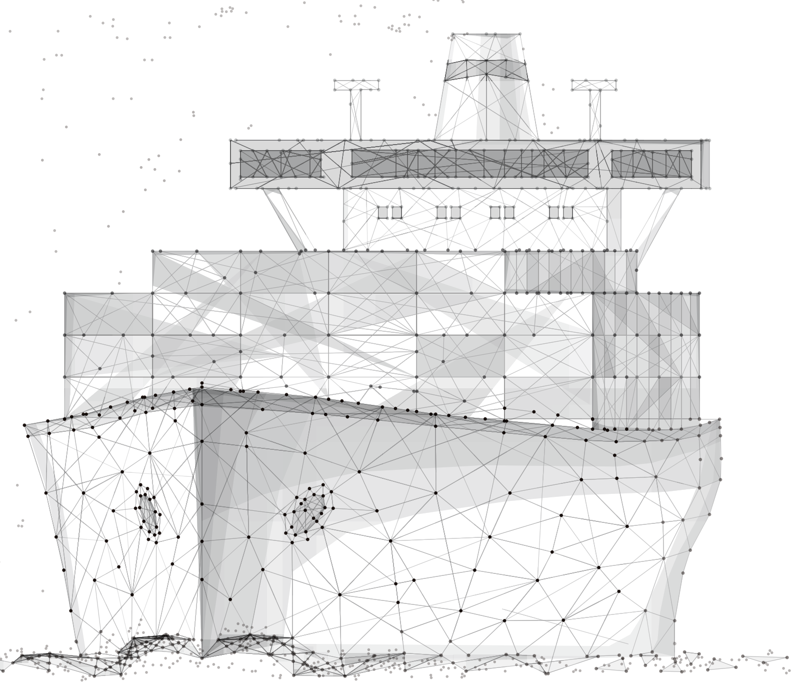
- Hull, Propellers, Engines

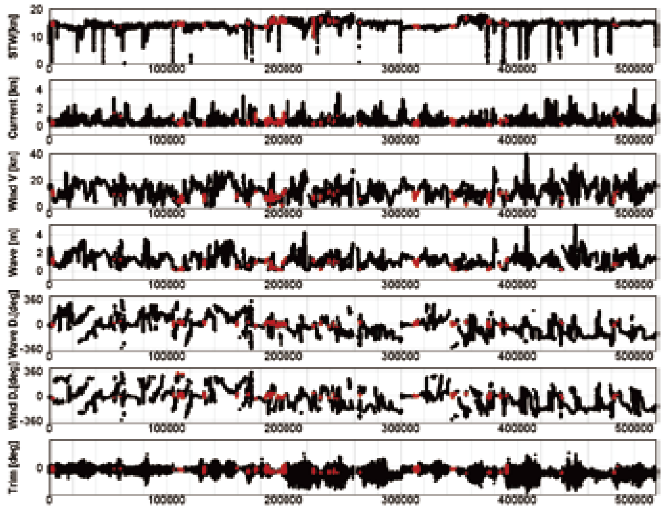
Optimum Operation

- Speed, Trim, Route optimization
- Minimize hotel loads
- Minimize idling or harbor operation
- AMP in harbor operation

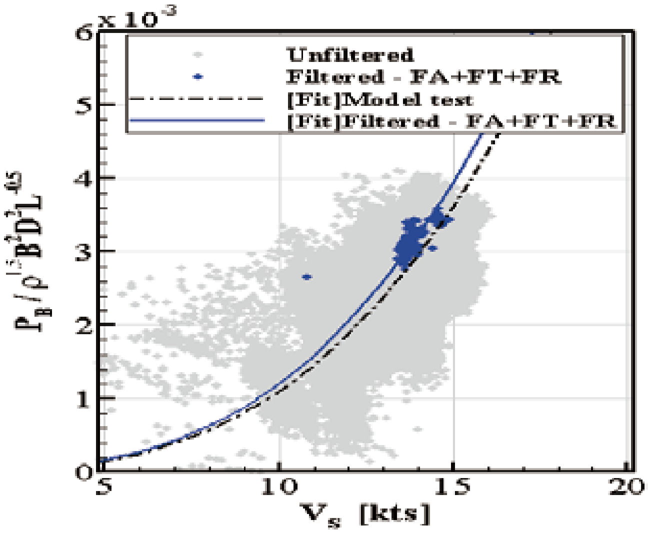
Life cycle management based on CII simulation

- Plan for Retrofit or ESD
- Bio fuel (Conventional ships)
- LNG retrofit
- Ammonia ready





<On-board measured data & weather data>



<Speed-power performance>

4 TRAILBLAZING TOWARD GREENER TECHNOLOGIES

CARBON NEUTRAL FUELS

Bio Fuel

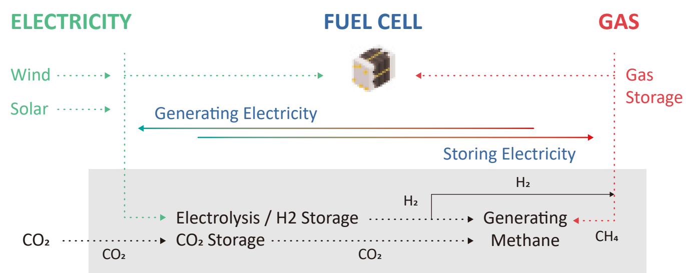
Effort to commercialize bio heavy fuel oil as marine fuel (HMM, HHI, KSOE, KR, and KBEA)

KR is working together with customers to procure technologies regarding carbon neutral fuels like **bio fuel and synthetic fuel**.

Synthetic Fuel

Power to Gas system

· Production and storage of H2 through water electrolysis utilizing wind and solar energy
· GHG Reduction through methanation of CO2 using produced H2

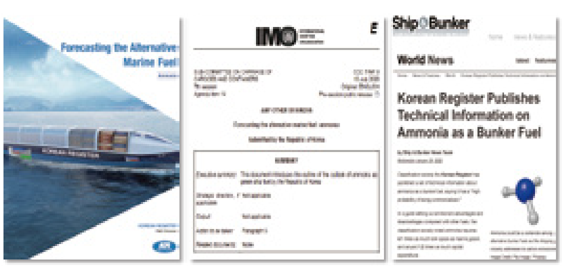


Green Hydrogen Production (P2G Electrolysis)

· Operating of 3MW class Electrolysis system(Alkaline & PEM electrolysis) using Wind power in Jeju island
· Demonstration of the hydrogen production system(600kg/day) as to hydrogen bus

AMMONIA AS MARINE FUEL

'Forecasting the alternative marine fuel ammonia', published in IMO CCC 7



To support the commercial adoption of ammonia as ship fuel, KR has submitted several technical documents to IMO, and published technical reports to provide essential information to industry stakeholders.

Recently, KR has been accelerating its efforts to ensure that KR Class rules for Ammonia-fuelled ships is released in 2021. KR has also implemented Approval in Principle (AIP) for Ammonia Bunkering vessels, and projects are underway to develop Ammonia engines with an engine maker.

JDP for Ammonia Bunkering Vessel

KR
EMEC
MAN Energy Solutions
Navig8

8K Ammonia DF Bunkering Vessel

· KR, EMEC, MAN Energy Solutions, and Navig8 signed an agreement to form a Joint Development Plan(JDP) to develop an ammonia bunkering vessel.

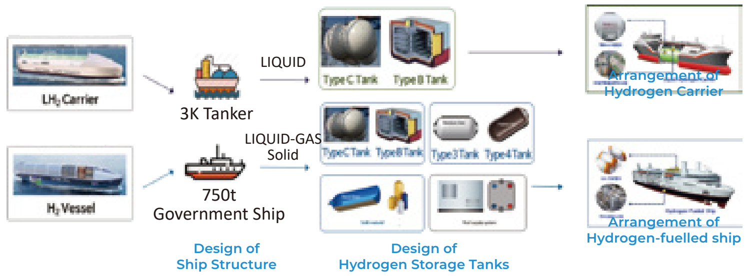
· The JDP includes:
  · AIP (Approval in Principle)
  · Risk Assessment for Ammonia bunkering vessel
  · Technical support and development draft regulations

H2 BUNKERING, LOADING AND STORAGING

Safety Standards Development for H2 bunkering and loading/unloading

- Generic Models for H2 bunkering and H2 loading/unloading system
- Risk Assessments for Generic Models
- Safety Standards Development

Development of safety standards for H2 storage vessels and fuel supply systems

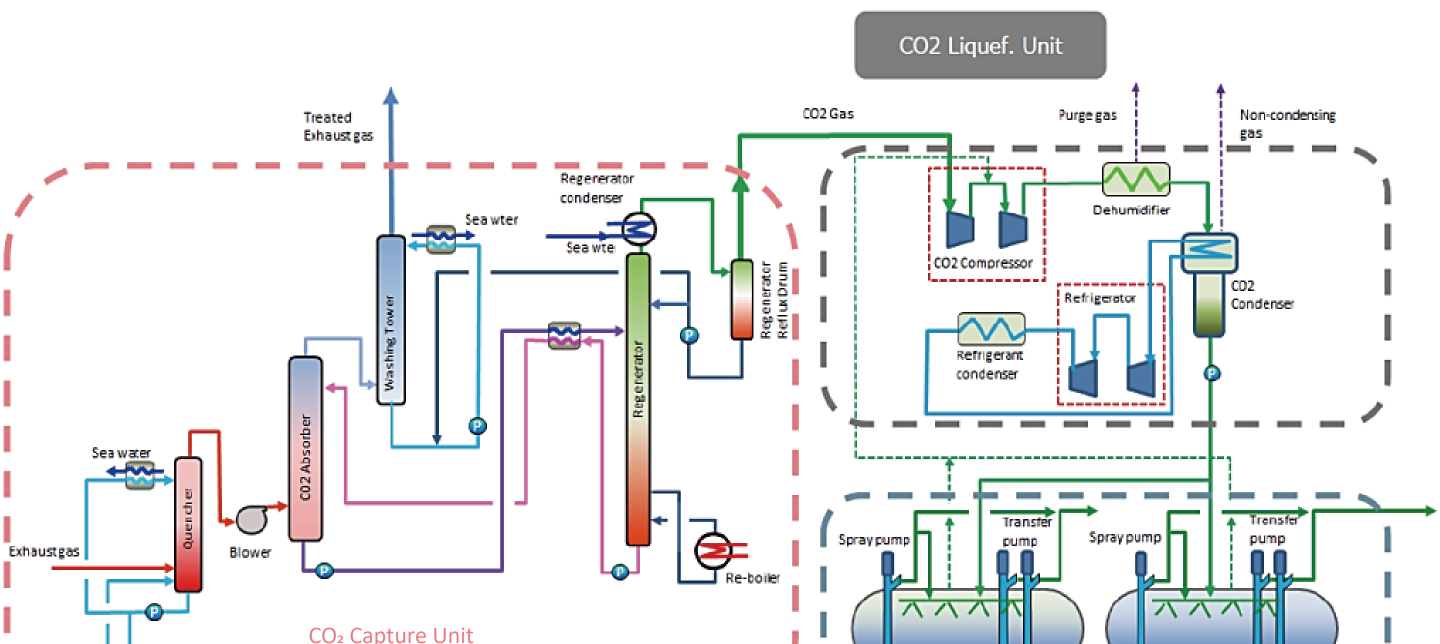


- Development of safety standards and verifications for Hydrogen supplies and storage systems
- Results: AIP, Safety and technical standards, IACS regulation(draft), domestic laws and regulations, etc.

POST-TREATMENT SYSTEM FOR CO_2 ABATEMENT

Low carbon fuelled engine (CO2 reduction rate ~20%) + alpha technology

Additional CO2 reduction technology will be necessary because GHG regulations are expected to be more and more stringent from year to year.

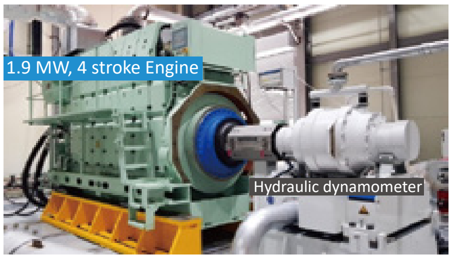


Source: MLIT, Roadmap to zero emission from international shipping, Dec.02, 2019.

KR R&D CENTERS FOR DECARBONIZATION

Greenship TCC: Internal Combustion Engine

Low speed engine test bench



Medium speed engine test bench

High speed engine test bench

MASTC: Electric propulsion

MASTC(Marine Application Substantiation Technology Center)

KR has established infrastructure for testing eco-friendly technologies. KR is operating three cutting-edge laboratories, including a specialized test basin for engines and post-treatments such as scrubber, SCR, carbon capture system, and one for electric propulsion tests, as well as a LNG bunkering simulation center. These R&D centers are fostering test technologies and helping to accelerate Decarbonization.

LSC:
LNG bunkering simulation

LNG-fuelled bunkering Simulation Center(LSC)

II

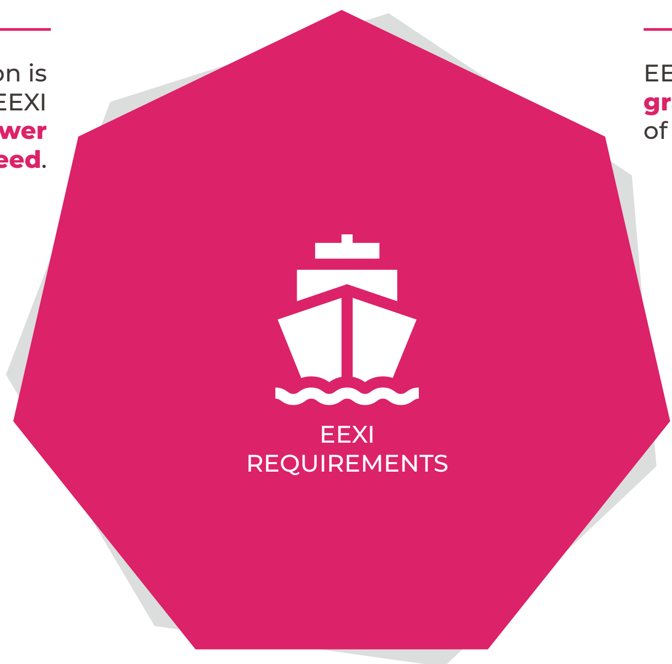
EEXI CALCULATION

1 INTRODUCTION OF EEXI REGULATION

EEXI is energy efficiency design index **for existing ships**.

The purpose of the calculation is **to find the impact** of EEXI requirements for **ship power and speed**.

EEXI shows how much **CO_2 (in gram) is released** to carry one ton of cargo for one nautical mile.



The calculation covers **tankers, bulk carriers and container ships**.

Each ship's **attained EEXI must be below the required EEXI** to comply with EEXI requirements.

Ship power and speed should be reduced to meet EEXI requirements.

EEXI calculation has been carried out for **1259 ships**.

- To comply with EEXI requirements each ship's actual EEXI must be below the required EEXI.
- KR has carried out EEXI calculations for 1259 ships including tankers, bulkers and container ships to fully understand the impacts of meeting the EEXI requirements on a ship's power and speed.

2 DATA INPUT FOR EEXI CALCULATION

This presents the main parameters used to calculate the EEXI in accordance with the relevant guidelines. Parameters include Power of auxiliary engines, Specific Fuel Consumption, capacity and ship speed.

P_{AE} | Power of Auxiliary Engines

Use the formula

If **$MCR_{M/E}$** ≥ 10,000 kw
P_{AE} = 0.025 x **$MCR_{M/E}$** + 250

If **$MCR_{M/E}$** < 10,000 kw
P_{AE} = 0.05 x **$MCR_{M/E}$**

However, P_{AE} should be calculated based on MCR not MCR_{LIM}(EPL)

SFC | Specific Fuel Consumption

Use a NOx technical file or Specified by a manufacturer

For those engines which do not have a technical file or manufacturer data confirmed by a verifier, SFC is defined as:
$SFC_{M/E}$: 190 [g/kwh]
$SFC_{A/E}$: 215 [g/kwh]

CF corresponding to SFC is defined as:
CF = 3.114 [t.CO2/t.fuel]

DWT Capacity | Deadweight Tonnage Capacity

Passenger ship & Cruise passenger
- Gross tonnage(GT)

Container ship
- 70% of the deadweight of full load draft

Other ship
- Deadweight of full load draft

Speed

For a ship that has a sea trial report
under the EEDI draft:

$$V_{ref} = V_{S,EEDI} \times \left[\frac{P_{ME}}{P_{S,EEDI}}\right]^{1/3} \text{[knot]}$$

For a ship that has a sea trial report
under the design load draft:

$$V_{ref} = k^{1/3} \times \left[\frac{DWT_{S,SERVICE}}{CAPACITY}\right]^{2/9} \times V_{S,SERVICE} \times \left[\frac{P_{ME}}{P_{S,SERVICE}}\right]^{1/3} \text{[knot]}$$

(Only apply to bulk, tanker and container)

For a ship that **has not speed-power curve**
under the EEDI or design load draft:

$$V_{ref,app} = (V_{ref,avg} - m_V) \times \left[\frac{\sum P_{ME}}{0.75 \times MVR_{avg}}\right]^{1/3} \text{[knot]}$$

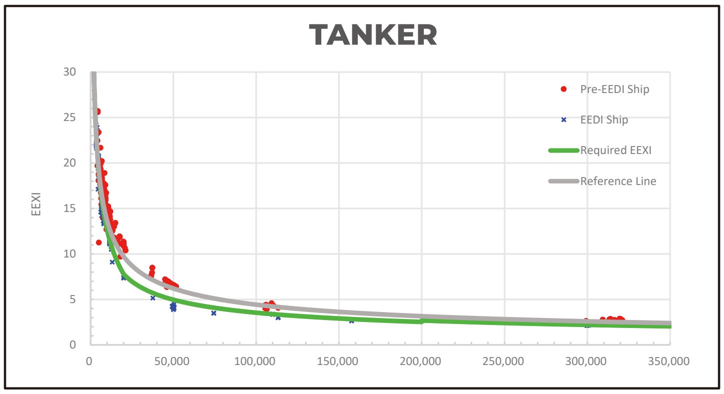
3 PRELIMINARY REVIEW: EEXI CALCULATION RESULTS

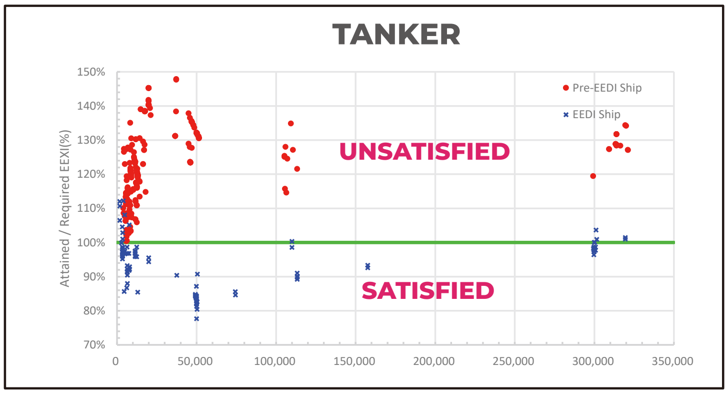
EEXI CALCULATION RESULTS OF 511 TANKERS

	Ships calculated	Satisfied	Unsatisfied	Inapplicable	Failure Rate
PRE-EEDI* SHIPS	406	14	306	86	75%
POST-EEDI SHIPS	105	76	7	22	7%
TOTAL	511	90	313	108	61%

*PRE-EEDI: Vessels to which EEDI requirements did not apply

(Unit: number of ships)

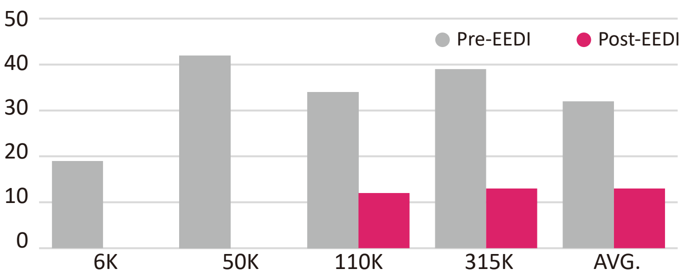




In this graph, red dots indicate Pre-EEDI ships while blue dots indicate Post-EEDI ships. The vessels above the green line satisfied EEXI requirements and those below did not. As seen above, most Pre-EEDI ships did not satisfy EEXI requirements.

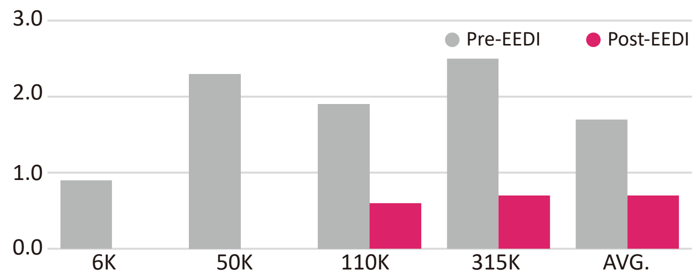
EEXI CALCULATION RESULTS FOR TANKERS: POWER & SPEED REDUCTION FOR EEXI SATISFACTION

POWER REDUCTION RATE (%)



The average power reduction rate necessary to satisfy EEXI requirements is **32%** of MCR. For Post-EEDI ships, an average power reduction rate for each ship size required to satisfy EEXI requirements is **13%** of MCR.

SPEED REDUCTION (KNOTS)



Average Speed Speed at MCR/MCRlim with SM(20%) (Unit: knots)

	Before EPL	After EPL	Speed Reduction
Pre-EED Ships	13.7	12.0	-1.7
Post-EEDI Ships	14.9	14.2	-0.7

This calculation is based on the EEXI calculation guidelines using an alternative method for speed and an approximated value for SFC. Regarding pre-EEDI ships, the average ship speed before EPL is applied remains **13.7** knots. This speed could be reduced to **12.0** knots after EPL, resulting in a difference of 1.7 knots. However, the 'before' and 'after' EPL speed reduction gap for Post-EEDI ships remains no more than **0.7** knots. As such, post-EEDI ships may satisfy EEXI with less speed reduction efforts than pre-EEDI vessels may be able to do.

EEXI CALCULATION RESULTS OF 473 BULK CARRIERS

	Ships calculated	Satisfied	Unsatisfied	Inapplicable	Failure Rate
PRE-EEDI* SHIP	370	0	363	7	98%
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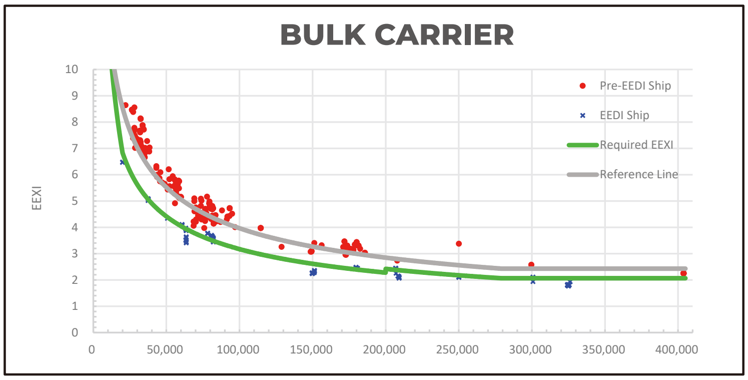
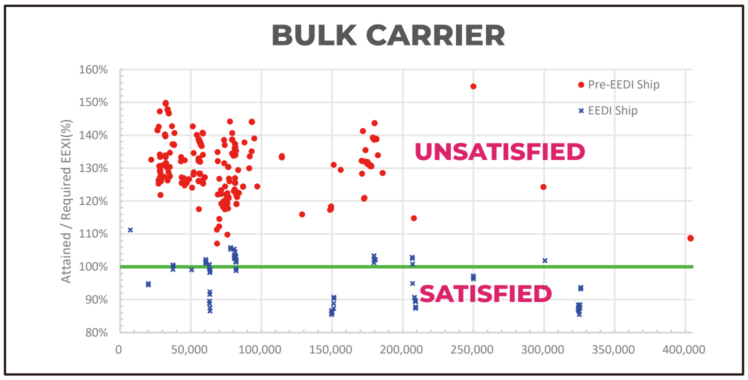
*PRE-EEDI: Vessels to which EEDI requirements did not apply

(Unit: number of ships)

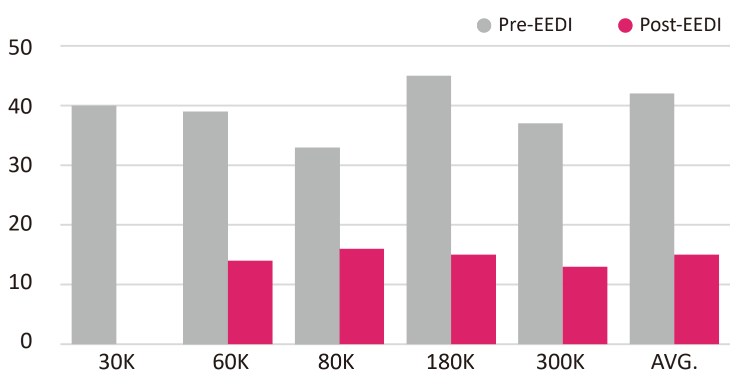




· The overall trend is similar to the results from tankers as explained in the relevant parts.
· Most of the 370 pre-EEDI ships did not satisfy EEXI requirements.
· The lower right graph suggests that an average of 30% of post-EEDI ships fall into the unsatisfactory category.

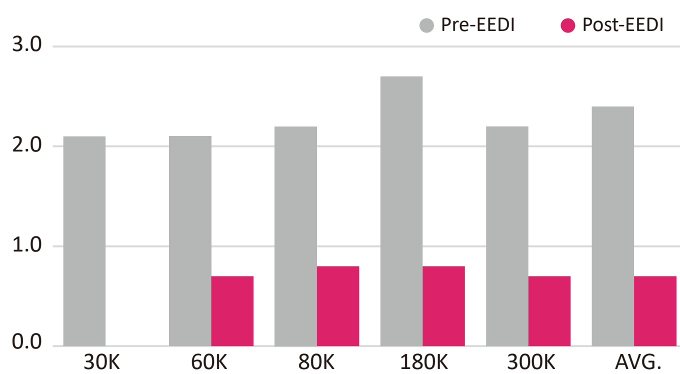
EEXI CALCULATION RESULTS FOR BULK CAFRIERS: POWER & SPEED REDUCTION FOR EEXI SATISFACTION

POWER REDUCTION RATE (%)



For Pre-EEDI bulk carriers, the average power reduction rate for each ship size needed to satisfy EEXI requirements remains **42%** of MCR. However, for Post-EEDI ships, at best, the average power reduction rate for each ship size to satisfy EEXI requirements remains at **15%** of MCR.

SPEED REDUCTION (KNOTS)



Average Speed Speed at MCR/MCRlim with SM(20%) (Unit: knots)

	Before EPL	After EPL	Speed Reduction
Pre-EEDI Ships	14.2	11.8	-2.4
Post-EEDI Ships	13.9	13.2	-0.7

To satisfy EEXI requirements, Pre-EEDI ships must achieve an average ship speed (before EPL) of **14.2** knots. This speed could be reduced to 11.8 knots after EPL. The pre- and post-EPL speed difference is **2.4** knots.

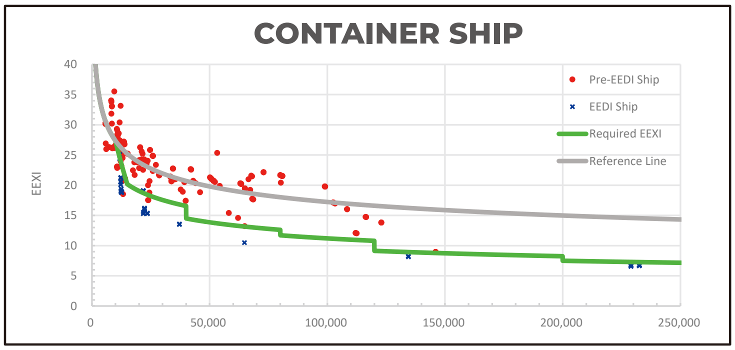
In the case of Post-EEDI ships, this difference is **0.7** knots. This result is similar to that for tankers.

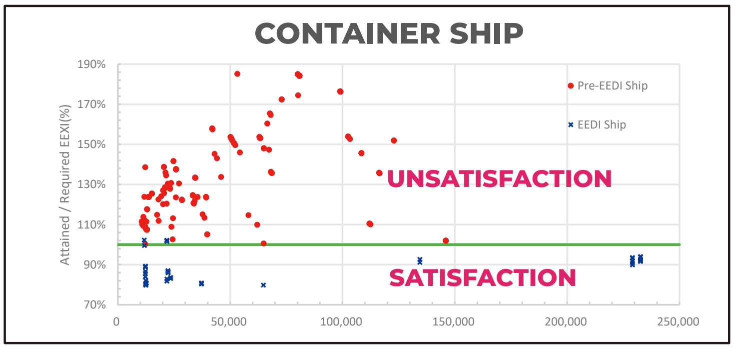
EEXI CALCULATION RESULTS OF CONTAINER SHIPS

	Ships calculated	Satisfied	Unsatisfied	In applicable	Failure Rate
PRE-EEDI* SHIPS	225	19	177	29	79%
POST-EEDI SHIPS	50	44	6	0	12%
TOTAL	275	63	183	29	67%

*PRE-EEDI: Vessels to which EEDI requirements did not apply

(Unit: number of ships)

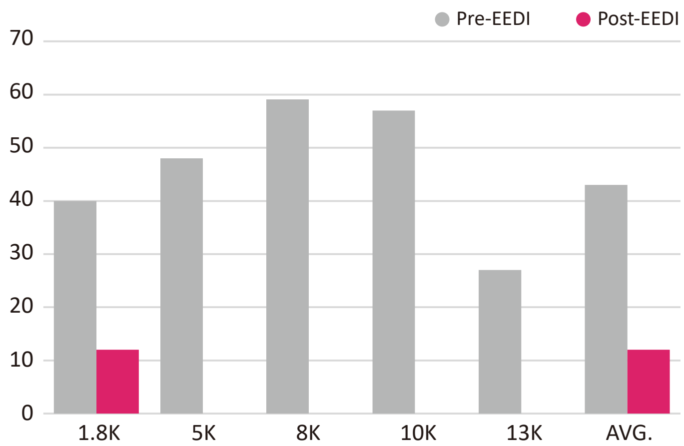




The overall result is similar to those of tankers and bulk carriers.
KR evaluated 225 pre-EEDI ships, and found that 79% did not satisfy EEXI requirements.

EEXI CALCULATION RESULTS FOR CONTAINER SHIPS: POWER & SPEED REDUCTION FOR EEXI SATISFACTION

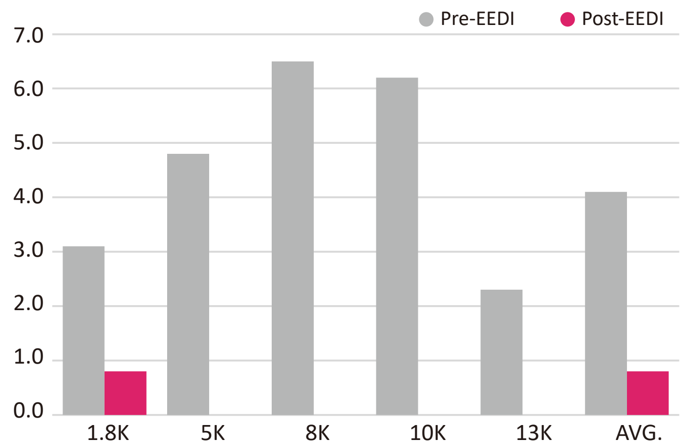
POWER REDUCTION RATE (%)



For Pre-EEDI ships, the average power reduction for each ship size is **43%** of MCR to satisfy EEXI requirements.

For Post-EEDI ships, the average power reduction rate for each ship size is **12%** of MCR.

SPEED REDUCTION (KNOTS)



Average Speed Speed at MCR/MCRlim with SM(20%) (Unit: knots)

knots	Before EPL	After EPL	Diff.
Pre-EEDI SHIPS	21.7	17.6	-4.1
Post-EEDI SHIPS	19.0	18.2	-0.8

To satisfy EEXI requirements for Pre-EEDI ships, the average speed before EPL remains **21.7** knots. This speed can be reduced to **17.6** knots after EPL, resulting in a difference of a whopping **4.1** knots.

For Post-EEDI ships, the difference in ship speed before and after EPL is no more than **0.8** knots.

PRE-EEDI VESSELS SUMMARY OF PRELIMINARY CALCULATION RESULTS

Most simulated Pre-EEDI ships failed to satisfy the EEXI requirements. This requires, on average, power reduction of between **19%** and **59%**. In addition, speed reductions of between **0.9** and **6.5** knots seemed to be required in order to meet EEXI requirements. It is projected that the average service speed of container ships may not be affected by speed reduction requirements, given that the current design speed of container ships has already been optimized at around the required values.

TANKER

- **19 ~ 42% power reduction may be required.**
- **0.9 ~ 2.5 knot speed reduction may be needed.**
- **Current service(market) speed may be affected.**

BULK CARRIER

- **37 ~ 45% power reduction may be required.**
- **2.1 ~ 2.7 knot speed reduction may be needed.**
- **Current service(market) speed may be affected.**

CONTAINER SHIP

- **27 ~ 59% power reduction may be required.**
- **2.3 ~ 6.5 knot speed reduction may be needed.**
- Current service(market) speed may **NOT** be affected since the present design speed is already high enough.

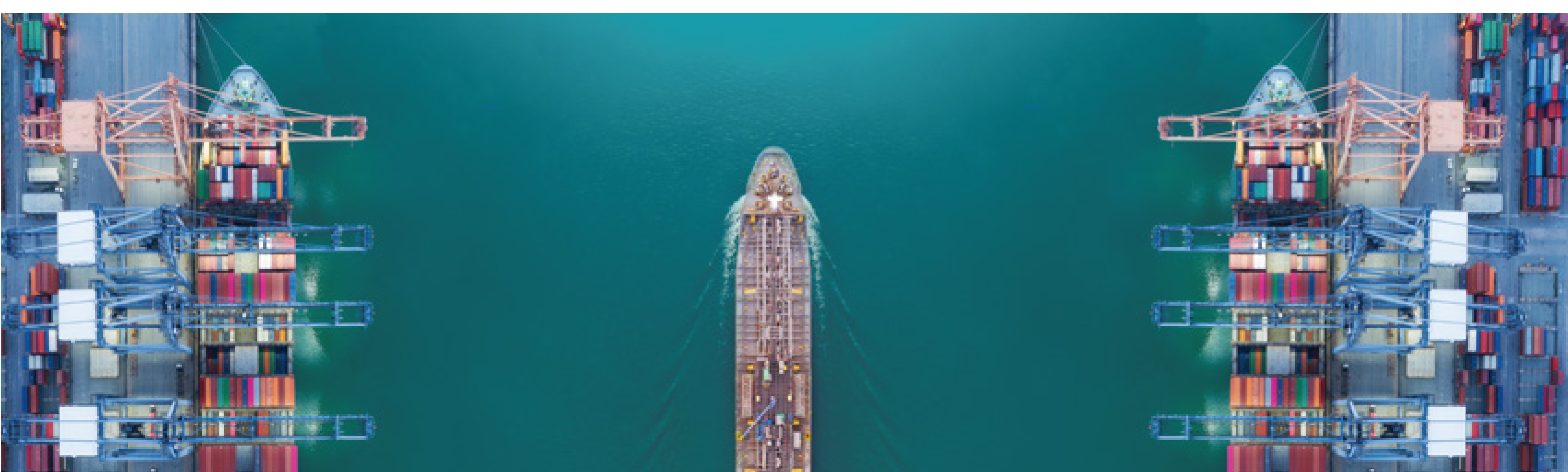
NOTE

- EEXI calculation simulation for sample ships was made **capitalizing on conservative** statistical methods.
- If EEXI calculation is made of the **actual data** of ships the required **speed and power reduction could be decreased.**

POST-EEDI VESSELS SUMMARY OF PRELIMINARY CALCULATION PRELIMINARY REVIEW

For Post-EEDI vessels, the power and speed reductions required to meet EEXI requirements appear to be much less than that for Pre-EEDI vessels.

- 0 ~ 16% power reduction and
- 0 ~ 0.8 knot speed reduction may be necessary in order to meet EEXI requirement.



4 DRAWING APPROVAL PROCEDURE

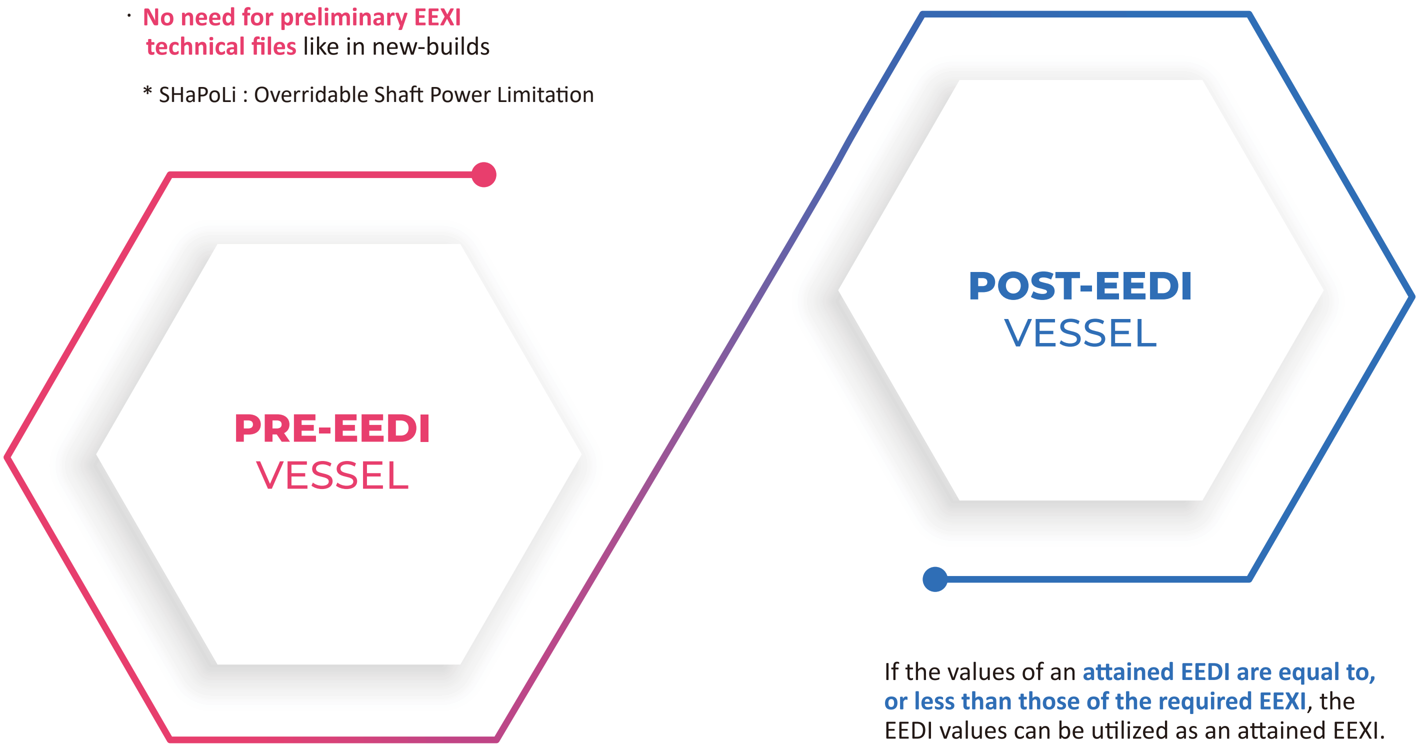
IEE CERTIFICATE

Owners of Pre-EEDI vessels will likely need to submit final EEXI technical files along with EPL management plans, because most existing vessels would not satisfy EEXI requirements, and would need to carry out EPL.

When new builds are planned, preliminary EEXI technical files will not be required. Post-EEDI vessels will already likely have EEDI technical files and IEE certificates. As such, Post-EEDI vessels will be analysed with the required EEXI by employing values on their IEE certificates. In these cases, it will be redundant to implement calculations on the attained EEXI. If the values of the attained EEDI are equal to, or less than the required EEXI, an EEXI technical file will not be required. Only ships that do not satisfy EEXI and need special measures, such as EPL, will be required to submit EEXI technical files for approval.

- **Final EEXI technical files + (EPL/SHaPoLi management plans)**
- **No need for preliminary EEXI technical files** like in new-builds

* SHaPoLi : Overridable Shaft Power Limitation



If the values of an **attained EEDI are equal to, or less than those of the required EEXI**, the EEDI values can be utilized as an attained EEXI.

In this case, there is no need for EEXI technical files to be submitted.

However, if the values of an **attained EEDI are above those of the required EEXI, EEXI technical files (and EPL management plan) should be prepared and submitted.**

III

POWER LIMITATION CONCEPT

1 INTRODUCTION OF EPL

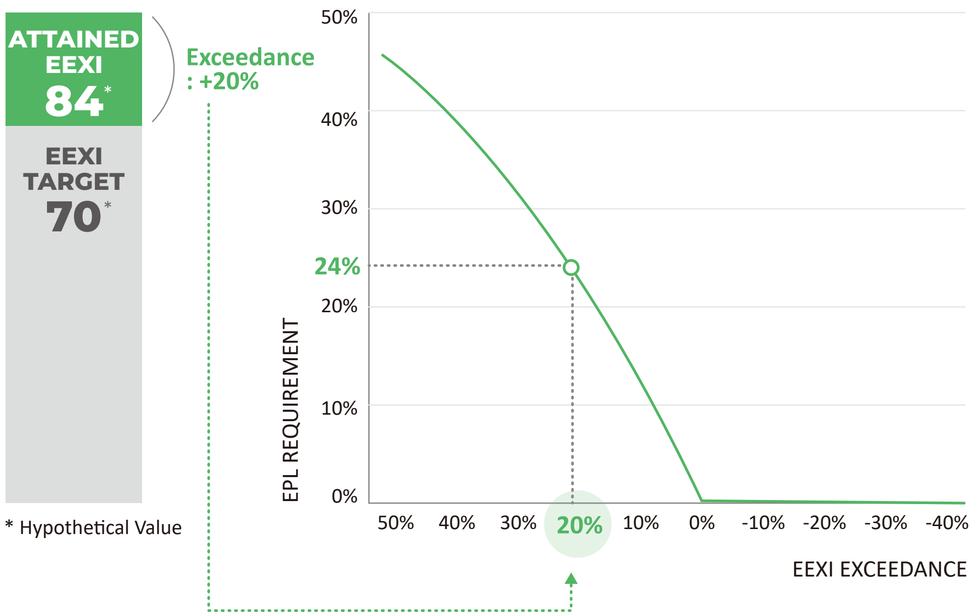
SELECTION OF AN EPL POINT

This graph presents the relationship between EEXI exceedance and EPL requirements. In particular, this suggests how much reduction of engine power is needed in order to meet the EEXI target.

Hypothetically assuming that the attained EEXI of a ship is 20% higher in a negative sense than its EEXI target, engine power of this ship would need to be reduced 24% from MCR.

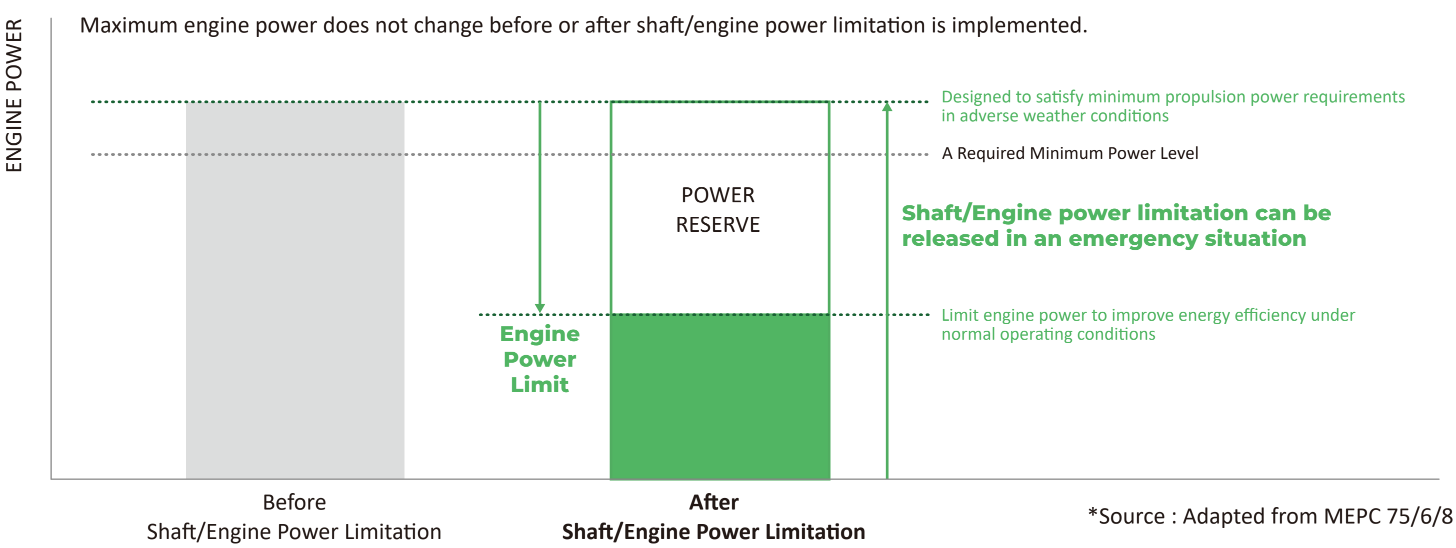
In this assumption where the sample vessel's attained EEXI is 84 but the EEXI target is 70, the attained EEXI exceeds the target by 20%. This indicates that the engine power should be reduced by 24%. However, this 24% is just a hypothetical value for the purpose of explanation, and specific relationships between EEXI and EPL may vary depending on a ship.

However – and importantly – when the attained EEXI is higher than the EEXI target, one simple and straightforward problem-solving approach and solution could be to limit the engine power.



*Source : Adapted from ICCT Working Paper

MINIMUM PROPULSION POWER



*Source : Adapted from MEPC 75/6/8

A ship's minimum propulsion power is the power that it should maintain for maneuverability even in adverse weather conditions. If a reserved power exceeds the required minimum propulsion power, the safety of the ship can be secured. There may be concerns that implementing minimum propulsion power to satisfy the EEXI target may compromise a vessel's seaworthiness. According to MEPC 75/6/8, EPL can be a solution only for efficient vessel operation, but this is not meant to affect minimum propulsion power. As such, it should be noted that when considered necessary, EPL settings can, and should be removed in order to maintain proper operation, and engine power can be returned to normal at any time. Therefore, minimum propulsion power should not be compromised with EPS.

2 POWER LIMITATION SYSTEM

ENGINE POWER LIMITATION (EPL)

Technical Methods of Engine Power Limitation for MECHANICALLY controlled engines

- Change governor parameters
- Adjust and Seal mechanical stoppers
- Add alarm points

Technical Means of Engine Power Limitation for ELECTRONICALLY controlled engines

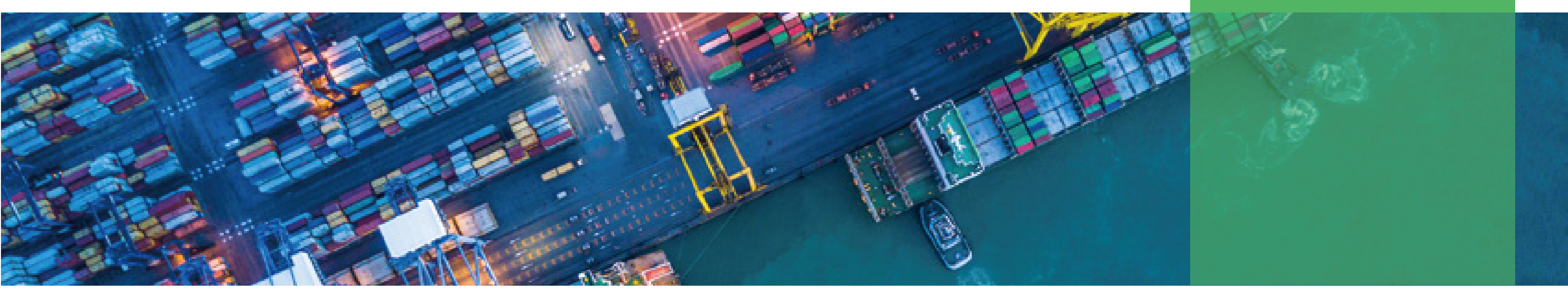
- Change the parameters of Engine Max Load or Chief Index Limit
- Add alarm points

For a mechanically controlled engine, shipowners can opt to : 1) change the BMS's governor parameters to meet the power limit target, 2) adjust the mechanical stopper setting on the local engine sides to meet the power limit and then seal it by wire, or finally, 3) add an alarm point when an action to remove the limit is applied in an emergency situation.

In contrast, for an electronically controlled engine, shipowners can choose to: 1) change the parameters in the ECU to meet the power limit target, or 2) add an alarm point in an emergency situation.

KR GEARs

A WEB-BASED EEXI · CII CALCULATION PROGRAM



SHAFT POWER LIMITATION (SHaPoLi)

Technical measures of Engine Power Limitation for non-conventional propulsion ships

- Change the setting of parameters in the control system
- Add alarm points

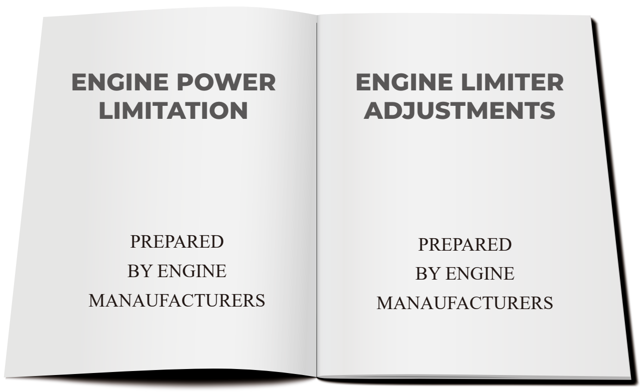
These power limitation methods can apply to electric propulsion systems but they are not appropriate for conventional propulsion systems.

These kinds of propulsion systems do not have a governor to regulate fuel. As such, power and RPM can be managed by a manufacturer's power control system. For this reason, specific limiting processes must be determined in consultation with individual propulsion system manufacturers.

Accordingly, for these non-conventional propulsion systems, changes to the parameters can be made in the specific power control system to meet power limit targets. It may also be necessary to add an alarm point when an action to remove EPL is taken in an emergency situation.

3 DOCUMENTATION & VERIFICATION

DOCUMENTATION



- Select engine power & RPM based on EEXI calculation
- Request EPL reports from engine licensors or manufacturers
- Make an Onboard Management Manual(OMM) including EPL reports
- Make an approval request of OMM to the Administrations or recognized organizations(RO)

MODIFICATION & VERIFICATION

First, shipping companies should calculate attained and target EEXI values to determine whether power limiting is required or not. If an attained EEXI value is higher than a target, they should find appropriate power and RPM using EEXI equations until the attained EEXI falls below the EEXI target.

Second, shipowners should request EPL reports from engine licensors or manufacturers based on power and RPM, as determined by EEXI calculations.

Third, they should create an Onboard Management Manual (OMM) by referring to EPL reports received from the engine licensors or manufacturers.

Lastly, the OMM should be submitted to recognized organizations(RO) for approval.

Once EEXI Technical Files and OMM are approved, shipowners should request engine manufacturers to carry out EPL work. Service engineers from engine manufacturers will conduct power limitation work specified in the OMM and EPL reports. The results of power limitation measures are to be inspected by RO surveyors.

USE OF A POWER RESERVE

- **Engine power can be overridden only by ship masters or the officer in charge of a navigational watch** (OICNW)
- **Engine power override can be allowed only for the purpose of securing the safety of a ship or saving life at sea**
  - Adverse weather
  - Ice-infested water
  - Rescue operation
  - Avoidance of pirate
  - Engine maintenance
- **The use of a power reserve in a record page of OMM should be kept recorded**
- **The use of a power reserve should be notified to the Administration or RO without delay**
- **Reactivating EPL should be confirmed by the Administration or RO at the earliest opportunity**

Use of reserve power is usually permitted only when necessary because of adverse weather, ice-infested water, rescue operations, pirate attacks, engine maintenance and the like.
When engine power limit gets released, the details must be recorded on the OMM record pages and reported to the Administration or RO. The list of required records is detailed in the MEPC documents. MEPC Res.335(76) should be referred to. As soon as the necessity for the temporary release is eliminated, the engine power should be lowered to below the power limit. EPL can then be reactivated at the nearest arrival port and be examined by an RO surveyor.

SUMMARY

- MEPC 75/6/8 concluded that **EPL or SHaPoLi does not affect the MPP.**
- EPL or SHaPoLi would be the first countermeasure in response to EEXI.
- Engine licensors or manufacturers could provide EPL reports.
- **Various methods of EPL could be taken** per engine control system.
- Only Shipmasters or OICNW have the authority to override engine power limit.
- Record and Notification shall be carried out with regard to every unlimiting measure.
- **Reactivation of EPL needs to be confirmed by RO** at the earliest opportunity.
- EPL will likely be a dominant approach to satisfying EEXI, as it requires the lowest cost and the least invasive means to comply with.

To summarize, EPL does not have to be constrained by Minimum Propulsion Power and it should be noted that without employing EPL, a lot of vessels may not be able to satisfy their EEXI targets.

IV

ENERGY SAVING DEVICES FOR EEXI IMPROVEMENTS

1. CATEGORIZATION OF ESDs IN MEPC
2. ESDs IN CATEGORY A
3. ESDs IN CATEGORY B
4. ESDs IN CATEGORY C
5. PERFORMANCE OF ESD (GENERAL)
6. COMBINATION OF EPL AND ESD

1 CATEGORIZATION OF ESDs IN MEPC

ENERGY SAVING DEVICES (ESD) CATEGORIZED IN MEPC.1/Cirs.815

ESDs are classified according to the terms that the device contributes to the EEXI.

$$\frac{\prod_{j=1}^{n} f_j \overbrace{\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right)}^{\text{Main engine emissions}} + \overbrace{\left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE} *\right)}^{\text{Aux. engine emissions}} + \overbrace{\left(\left(\prod_{j=1}^{n} f_j \sum_{i=1}^{nPTI} P_{PIT(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right)}^{\text{Aux. energy engine savings}} - \overbrace{\left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FEM} \cdot SFC_{ME} **\right)}^{\text{Main engine energy engine savings}}}{\underbrace{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref} \cdot f_m}_{\text{Transportation}}}$$

INNOVATIVE ENERGY EFFICIENCY TECHNOLOGIES

Reduction of Main Engine Power			Reduction of Auxiliary Power	
Category A	**Category B-1**	**Category B-2**	**Category C-1**	**Category C-2**
Cannot be separated from the overall performance of vessel	Can be treated separately from the overall performance of vessels feff=1	Can be treated separately from the overall performance of vessels feff<1	Effective at all time feff=1	Depending on ambient environment feff<1
· Low friction coating · Bare optimization · Rudder resistance · Propeller design	· Hull air lubrication system (air cavity via air injection to reduce ship resistance) can be switched off	· Wind assistance (Sails, Flettner Rotors, Kites)	· Waste heat recovery system (exhausts gas heat recovery and conversion to electric power)	· Photovoltaic cells

ESDs are classified as Category A, B, and C according to the area in which the ESDs contribute to the EEXI formula. For example, devices that can increase reference velocity are in category A, devices that can improve main engine energy efficiency fall within category B, and devices that can improve auxiliary engine energy savings belong to category C. These categories are further subdivided into Category B-1, B-2, Category C-1, and C-2 according to weather dependency of the ESDs.

2 ESDs IN CATEGORY A

Technology that improves the speed-power performance of ships Increase the reference speed(Vref) at the same Power(PME)	Inseparable from the overall performance of ships	Relatively inexpensive, simple to install, and a short engineering period compared with other categories of ESDs	Difficult to expect a dramatic improvement in the EEXI rating ($\because V_{ref} \propto \sqrt[3]{(P_{ME})}$)

Power Saving due to ESD	2%	4%	6%	8%	10%
EEXI (velocity) Improvement	0.7%	1.3%	2.1%	2.8%	3.5%

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

First, ESDs in category A are technologies that can improve the speed power performance of ships. This suggests that these ESDs can increase the reference speed for the fixed reference power. Here, the ESDs cannot be separated from the overall performance of ships. These devices have advantages in that they are relatively inexpensive, simple to install, and require a short engineering period compared to other ESDs. However, it is difficult to expect a dramatic improvement in the EEXI rating, because these effects are reflected as reference speed, but the speed is in proportion to the cube root of the power saving ratio. For example, if you install ESD A which can cut main engine power by 10%, you can expect about a 3.5% decrease in the EEXI rating.

ESD TO MAXIMIZE AVAILABLE SPEED

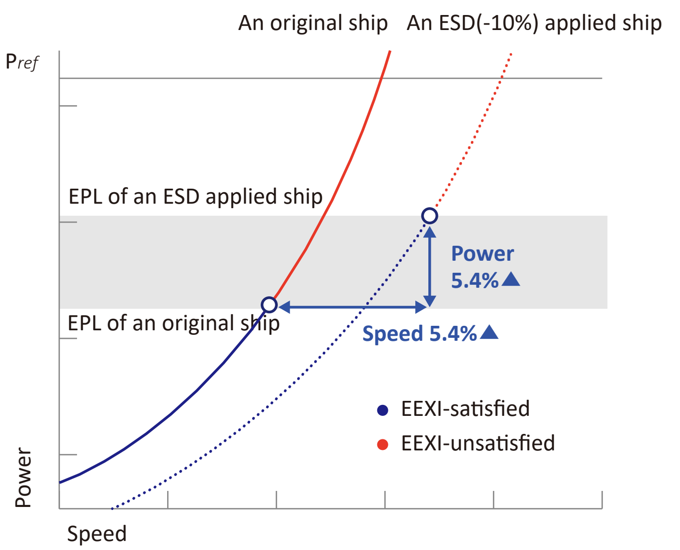
- Positive implications from the perspective of securing the available speed within the EEXI regulation
- EPL cutline for EEXI satisfaction changes due to ESD
- Expansion of the range of chartering speed that shipowners can consider

SIMPLE EXAMPLE

- ESD installation
- ESD within 10% power saving effects can increase **about 5% of available speed & power**

	EEXI	Speed	Power(=EPL)
Original Ship (A)	$EEXI_0$	V_0	P_0
ESD(-10%) installed Ship (B)	$EEXI_0$	$1.054 \cdot V_0$	$1.054 \cdot V_0$

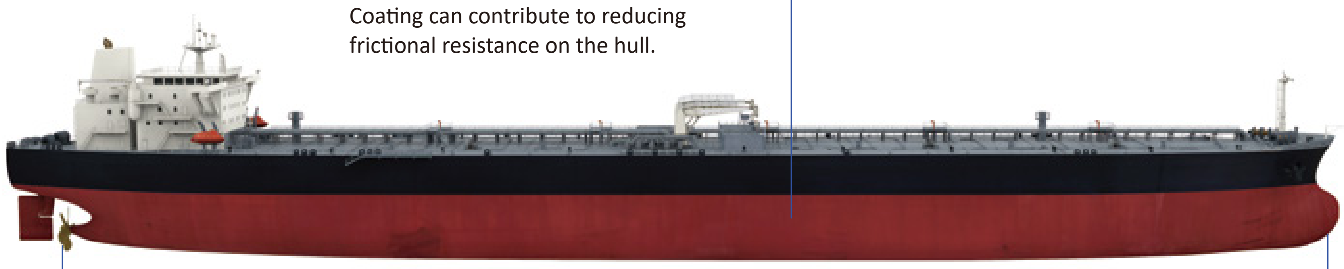
Although an ESD with 10% efficiency lowers the EEXI only by as much as 3.5%. This can be more positively interpreted from the perspective of securing the available speed within the EEXI regulation.



ESDs COMMERCIALIZED ON THE MARKET

Hull coating technique

Coating can contribute to reducing frictional resistance on the hull.

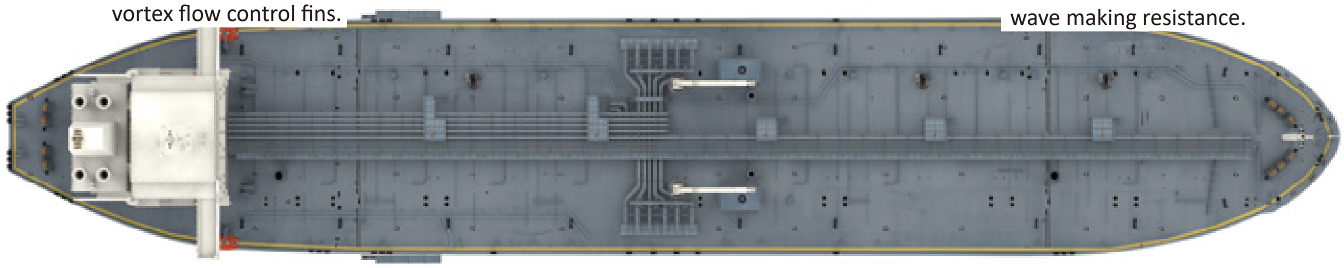


Vortex flow control fins

Hull friction resistance can be abated by vortex flow control fins.

Bulbous bow retrofit

A bulbous bow retrofit can reduce the wave making resistance.



ESDs COMMERCIALIZED ON THE MARKET: PROPULSION IMPROVING DEVICES (PID)

There are a number of PIDs on the market. These devices are designed to be installed near the propellers or the rudder in order to increase propulsion power. Some devices prevent propulsion loss arising out of rotation flow occurring behind the propeller. These devices include swirl recovery vanes, pre-swirl stator and contra-rotating propellers.

Rudder Bulbs and Propeller Boss Cap Fins(PBCF) can prevent the generation of a hub vortex behind the propeller, and they can reduce propellers energy loss. Rudder fins can also convert the lift force to thrust and increase power performance.

Rotational Flow

- Swirl Recovery Vanes
- Pre Swirl Stator (Duct, Fin)
- Contra-rotating Propellers (CRP)

Hub Vortex

- Rudder Bulb
- Propeller Boss Cap Fin (PBCF)

Additional Thrust

- Rudder Fin

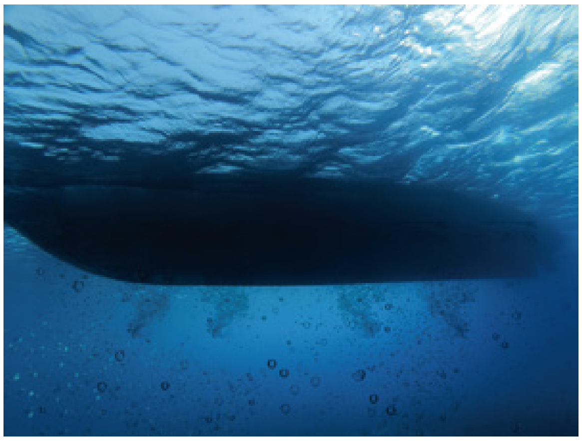
3 ESDs IN CATEGORY B

Technology that can reduce propulsion power Consideration of power reduction (Peff) and availability factor (Feff)	**Seperable from the overall performance of ships**	**Able to reduce the EEXI almost proportional to the power saving rate**	**Rather expensive and require prolonged engineering time**

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

EFFECTIVE AT ALL TIMES: AIR-LUBRICATION SYSTEM

- This involves spraying air bubbles at the bottom of ships which can change density in the boundary layer.
- It is able to reduce hull frictional resistance.
- It is applicable to ships with a flat bottom and small draught.



WEATHER DEPENDENT: WIND ASSISTANCE

Devices that can increase propulsion by using wind (weather dependent, feff)

Rotors, sails, kites

4 ESDs IN CATEGORY C

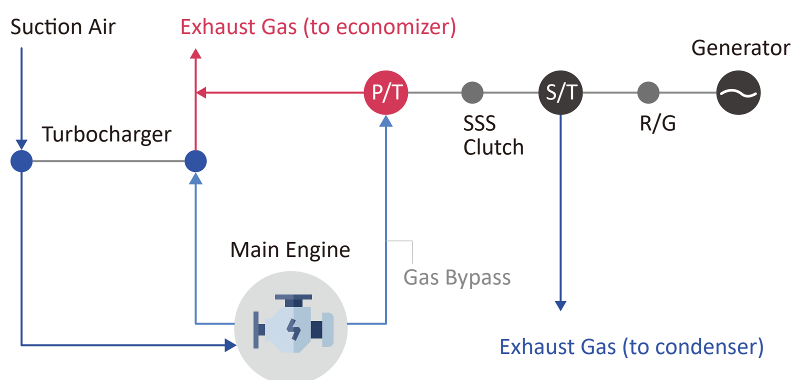
Technology that can generate additional electricity Saved energy is counted as effective auxiliary power (P_{AEeff})	**Possible to reduce the EEXI almost proportional to the power saving rate**	**Expensive and require a prolonged engineering time**	**Few track records**

The ESD C can also reduce an EEXI rating almost proportional to the power saving rate. But these devices are also very expensive and require long engineering time, and few have a proven track records.

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

EFFECTIVE AT ALL TIMES: WASTE HEAT RECOVERY SYSTEM

A waste heat recovery system can increase the efficiency of the utilization of the energy generated from fuel combustion in the engine through recovering the thermal energy of exhaust gas, cooling water, etc.



Waste Heat Recovery System (www.mhi-mme.com)

WEATHER DEPENDENT: SOLAR CELL

Solar cell can provide electric power from solar energy.

5 PERFORMANCE OF ESD (GENERAL)

The values presented in the table below may vary depending on ship specifications, operating/environmental conditions, manufacturers and verification methods.

ESD POSITION	PURPOSE	EXPECTED POWER SAVING							CATE-GORY	VERIFICATION
		BULK CARRIER	CONTAINER SHIP	TANKER	PRODUCT CARRIER	PCTC	LNG CARRIER	LPG CARRIER		
PRE-PROPELLER PLANE	Improvement of wake distribution by fins	0.5~ 1.5%	0.5~ 1.5%	0.5~ 1.5%	0.5~ 1.5%	0.5~ 1.5%	0.5~ 1.5%	0.5~ 1.5%	A	• CFD • Model Test
PRE-PROPELLER PLANE	Recovery of energy loss around stern bulb by duct or duct+fins or others	3.0~ 6.0%	2.0~ 4.0%	2.0~ 6.0%	3.0~ 6.0%	2.0~ 4.0%	2.0~ 4.0%	3.0~ 5.0%	A	• CFD • Model Test
POST-PROPELLER PLANE	Absorbing hub vortices by cap or rudder bulb or others	0.5~ 1.0%	1.0~ 2.0%	0.5~ 1.0%	0.5~ 1.0%	0.5~ 1.0%	1.0~ 2.0%	1.0~ 2.0%	A	• CFD • Model Test
POST-PROPELLER PLANE	Recovery of energy around propeller rear by rudder wing or twisted rudder or others	2.0~ 3.0%	2.0~ 3.0%	2.0~ 3.0%	2.0~ 3.0%	2.0~ 3.0%	2.0~ 3.0%	2.0~ 3.0%	A	• CFD • Model Test
BOTTOM	Reduction of frictional resistance by Air Lubrication System	no track record	under 5%	no track record	no track record	no track record	5.0~ 7.0%	under 5%	B-1	Submission of technical file and then sea trial
UPPER DECK	Wind adding propulsion by rotors or sails or kites	5~8% (based on 3ea)	no track record	5~8% (based on 3ea)	8~12% (based on 3ea)	2~3% (based on 3ea)	no track record	no track record	B-2	Submission of technical file and then sea trial
OTHERS	Recovery of wasted heat by Wasted Heat Recovery System	no track record	no track record	no track record	no track record	no track record	no track record	no track record	C-1	Submission of technical file and then, where possible, shop test at sea trial
OTHERS	Solar energy saving by photovoltaic cells	no track record	no track record	no track record	no track record	no track record	no track record	no track record	C-2	Submission of technical file and then, where possible, shop test at sea trial

*Source: Adapted from data provided by Hyudai Global Service Co., Ltd.

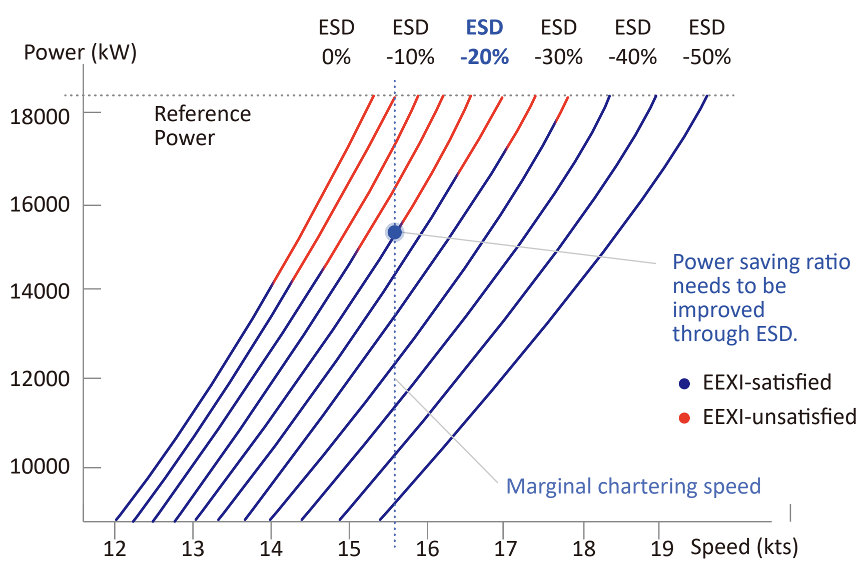
6 COMBINATION OF EPL AND ESD

OPTIMIZATION OF EPL & ESD

·Shipowners need to decide marginal chartering speed available, and identify **required power-saving ratios which ESD can achieve.**
·Shipowners have to find appropriate ESD considering CAPEX, verification costs and payback time.

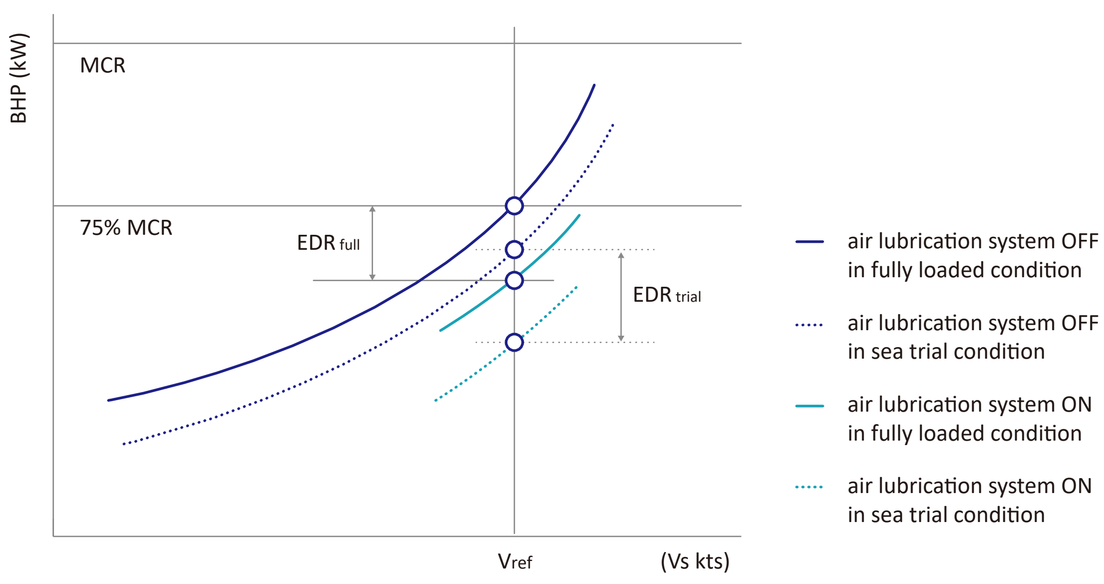
	CAPEX	EEXI Improvement	Verification
Category A	Low	Low	Model test / CFD / Sea trial
Category B	Medium	Medium	Sea trial
Category C	High	High	Shop test / Sea trial

Review of EEXI satisfaction in various ESD & EPL



In conclusion, if shipowners decide to install an ESD, they should first decide on their marginal chartering speed and identify the required power saving ratio through the ESD. This will require a number of EEXI calculations. After this, they will be able to opt for an appropriate ESD taking into account CAPEX, verification costs and payback time. In the worst case scenario, it might be necessary to replace current ship with new builds with higher energy efficiency.

ALS verification through sea trial



V

CONSIDERATIONS FOR **COMPLIANCE WITH CII RATING**

1. CII RATING REQUIREMENTS
2. EXPECTED CII RATING RESULTS
3. CONSIDERATIONS FOR IMPROVING CII

1 CII RATING REQUIREMENTS

ACTIONS TO COMPLY WITH CII RATING

SEEMP UPDATE

By the end of 2022, existing **SEEMP should be updated for approval.** This should include a CII calculation method, an implementation plan, a self-evaluation procedure, etc.

CII RATING

From 2024, attained CII should be reported to ROs by the end of March each year. CII performance affects a rating whose scale ranges from A, the highest, to E, the lowest.

CORRECTIVE ACTION PLAN

Ships rated D for 3 consecutive years, or rated E, should develop the **corrective action plans** and include them in the SEEMP within **1 month** after reporting CII.

In general, there are three actions that should be taken. Firstly, by the end of 2022, ships should update their existing SEEMP in order to be approved in accordance with SEEMP guidelines. The SEEMP guidelines are to be amended and will be completed at MEPC 78.
Once the SEEMP is updated, shipowners should implement plans to improve ship energy efficiency and should collect ship operating data for CII calculation during 2023.

Ships have to report their attained CII to the ROs within 3 months after the end of each calendar year from 2024. After reviewing the reports, ROs will issue the SoC indicating a ship's appropriate rating from A to E reflecting its CII achievements.

GUIDELINES FOR CII RATING

Four guidelines for a CII rating were adopted at MEPC 76.

- G1 · CII guidelines for calculation
- G2 · CII Reference lines guidelines
- G3 · CII Reduction factor guidelines
- G4 · CII Rating guidelines

MEPC 76 adopted all four guidelines under CII framework.

GUIDELINE 1

Correction factors and voyage exclusions are not included and will be further discussed in
New guidelines (G5) to be developed.

GUIDELINE 3

A phased approach is introduced:
Phase 1 (2020~2022), Phase 2 (2023~2026), and Phase 3 (2027~2030). The phase 3 will be further strengthened and developed to take into account the results of the review of the short-term measures.

These four guidelines of the CII rating regulations have been developed by the IMO correspondence group between January to March and further discussed at ISWG-GHG 8 with a view to their adoption at the MEPC 76 meeting.

G3 generated many different views among IMO member states. Several members insisted on an 11% reduction by 2030, compared to the base year of 2019. Others favored a reduction of 22% or more by 2030. Ultimately, the committee decided to introduce a phased approach.

Phase 1 from 2020 to 2022 requires an annual reduction of 1%, and Phase 2 from 2023 to 2026 requires 2%. The reduction factors for Phase 3 will be decided at a later stage.

2 EXPECTED CII RATING RESULTS

ANALYSIS BASED ON THE 2019 IMO DCS DATA WHICH KR VERIFIED

Ship Type	No. of Ships	Rating				
		A	B	C	D	E
Bulk Carrier	323	17 (5.3%)	37 (11.5%)	**90 (27.9%)**	**98 (30.3%)**	**81 (25.1%)**
Tanker	199	11 (5.5%)	35 (17.6%)	**84 (42.4%)**	**49 (24.6%)**	**20 (10.1%)**
Container Ship	92	15 (16.3%)	20 (21.7%)	33 (35.9%)	15 (16.3%)	9 (9.8%)
General Cargo Ship	97	6 (6.2%)	8 (8.2%)	**24 (24.7%)**	**21 (21.6%)**	**38 (39.2%)**
Refrigerated Cargo Ship	2	0 (0%)	2 (100%)	0 (0%)	0 (0%)	0 (0%)
Ro-Ro Cargo Ship (Vehicle Carrier)	82	0 (0%)	0 (0%)	**22 (26.8%)**	**38 (46.3%)**	**22 (26.8%)**
Ro-Ro Cargo Ship	7	1 (14.3%)	4 (57.1%)	0 (0%)	2 (28.6%)	0 (0%)
Ro-Ro Passenger Ship	4	0 (0%)	2 (50.0%)	0 (0%)	2 (50.0%)	0 (0%)
LNG Carrier	14	1 (7.1%)	4 (28.6%)	3 (21.4%)	3 (21.4%)	3 (21.4%)
Gas Carrier	34	6 (17.6%)	7 (20.6%)	9 (26.5%)	4 (11.8%)	8 (23.5%)
Total	**854**	**57 (6.7%)**	**119 (13.9%)**	**265 (31.0%)**	**232 (27.2%)**	**181 (21.2%)**
				TOTAL 80%		

KR calculated attained CII based on the 2019 IMO DCS data, which KR verified, and analyzed expected 2023 CII ratings. To ensure the reliability of the analysis, any data that did not cover the entire calendar year were excluded. The results of the simulated analysis suggest that the ships rated C, D or E represented about 80% of the entire analysed fleet. Bulk carriers, tankers, general cargo ships and vehicle carriers had particularly low ratings.

Detailed information regarding the standards employed for this analysis can be found on the KR GEARs website.

3 CONSIDERATIONS FOR IMPROVING CII

COMPARING TWO 1,800 TEU (23,000DWT) CONTAINERS SAILING THE SAME ROUTES IN 2019

SOUTH-EAST ASIA

Ship	A	B
Attained EEDI	**15.4**	**15.3**
Avg. Cargo Carried	10,400	9,500
Total Distance	87,650	97,800
Total Operation Hours	5,300	6,700
Avg. Speed	**16.5**	**14.6**
Attained CII	14.3	10.4
Expected CII Rating	**C**	**A**

On the same sailing route (South-East Asia), the ships showed similar attained EEDIs, but different attained CIIs.

Compared to Ship B, Ship A:
- carried a little more cargo
- navigated a shorter distance
- sailed faster than ship B

In general, ships with good EEDI values may have better operational efficiency, but this is not the case for all ships. For example, in our comparison of the two ships sailing the same route, though they attained similar EEDIs, they had different CII ratings. Ship A carried more cargo and sailed shorter and faster than ship B, which carried less cargo and sailed longer and slower than ship A. Given these operational characteristics, the attained CIIs of ship A and B turned out to be significantly different.

KOREA-VIETNAM-THAILAND-KOREA

Ship	A	B
Sailing Days	**19.5**	**18**
Hours Underway	293	376
Distance Sailed	4,815	5,405
Avg. Cargo Carried	11,300	9,600
Avg. Speed	**16.4**	**14.4**
Fuel Con. (HFO)	500	415
Fuel Con. (HFO) at berth	**75**	**16**
Attained CII	**14.0(C)**	**10.4**
Attained CII when reflecting fuel con. at berth of B	**12.3(B)**	**-**

Shipowners should consider Technical (e.g., installation of equipment) and Operational (e.g.,Operation optimization) aspects at the same time to establish CII improvement measures.

Ship A sailed a distance 12% shorter than ship B, at a speed that was 14% faster. In addition, ship A consumed about 7% more fuel in sailing, and its fuel consumption during berthing was about 5 times higher than that of ship B. In conclusion, ship A sailed faster than B, and berthed for a longer time. The parameters for AER or cgDIST reflect on total annual fuel consumption, operating distance and capacity (DWT is applied for AER and GT for cgDIST).

Ship A (reasons for low rating)

- About 12% less distance
- About 14% faster speed
- Consumed about 7% more fuel for sailing and about 5 times during berthing

$$'AER'\ or\ 'cgDIST' = \frac{Fuel\ cosumption \times Cf}{Capacity(DWT\ or\ GT) \times Distance}$$

OPERATIONAL ASPECTS DO MATTER

Identify two factors:
- **controllable ones (e.g. captain risk, energy management procedure)**
- **uncontrollable ones (e.g. port congestion)**

Capacity is a default value, but the other parameters are variables. In particular, it should be noted that total fuel consumption during berthing or anchoring is included in annual fuel consumption. This indicates that the longer anchoring or berthing takes, the worse the CII value will be, because distance does not apply. However, if ship A reduces its fuel consumption during berthing to the level of ship B, its CII rating could have changed from C to B.

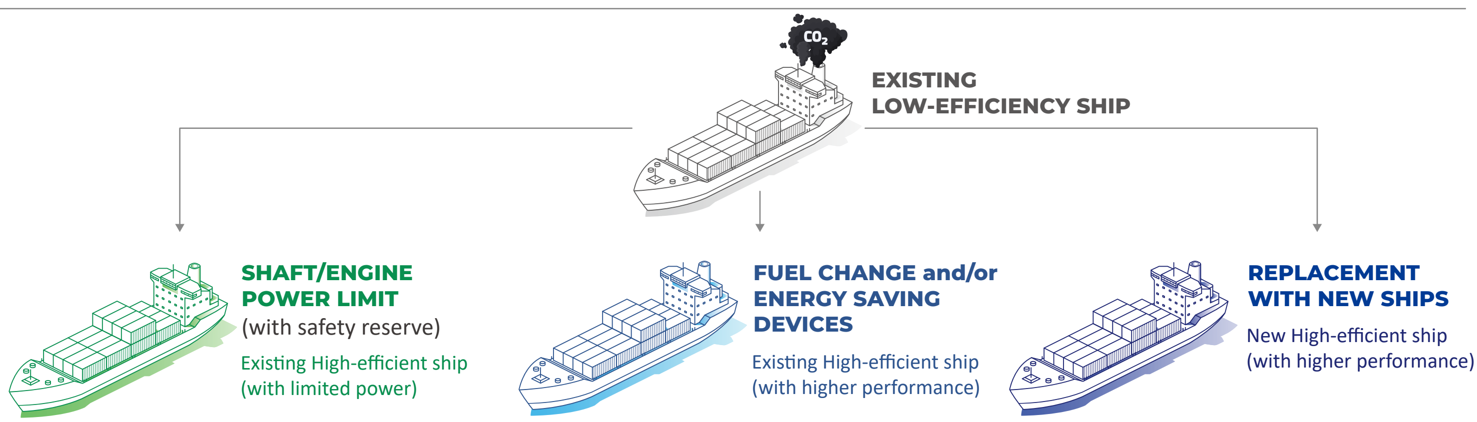
VI

TECHNICAL SERVICES

1 IMPACTS OF EEXI AND CII

CHALLENGES TO SHIPOWNERS, OPERATORS AND MANAGERS

SOLUTIONS TECHNICALLY FEASIBLE AND COST-EFFECTIVE



According to our preliminary review, the majority of pre-EEDI ships appeared to fail to meet the EEXI requirements. This suggests that ship owners must, as soon as possible, assess the current status of EEXI for their ships. In addition, they will need to explore alternative compliance measures to enable them to meet their target EEXI values.

The options available to them may include reduction in propulsive power, that is, engine power limitation. When this is not enough to get them to the required target, it may be necessary to consider retrofitting the ships with energy efficiency technologies. In some cases, scrapping might be the cost-effective option regarding older vessels, in order to simultaneously achieve regulatory compliance and commercial shipping profitability.

GHG SERVICE ORGANIZATION CHART

R&D CENTER FOR DECARBONIZATION
(70 experts)

DECARBONIZATION SOLUTION CENTER

GREEN SHIP TECHNOLOGY TEAM

- Strategy for GHG Issues
- Technology Road Map

SHIP & OFFSHORE TECHNOLOGY TEAM

- Naval Architecture
- Improvement of CII

MACHINERY EQUIPMENT RESEARCH TEAM

- Engine and Equipment
  - Biodiesel / Ammonia / LNG
- EU MRV, IMO DCS, CII

SYSTEM SAFETY RESEARCH TEAM

- Hydrogen
- Electric Propulsion
- Renewable Energy
- LNG Bunkering

KR recently launched its Decarbonization Solution Center to help its clients to comply with their EEXI and CII requirements. The Center will also support shipowners and operators as they brace for decarbonized shipping.

KR provides a variety of services in decarbonization.
KR R&D Center for Decarbonization comprises 4 teams and 70 researchers. Each team works on unique aspects of decarbonization, including strategies to deal with GHG challenges, technology road maps, CII advising, R&D regarding alternative fuels, biodiesel, Ammonia, LNG, verification for EU MRV and IMO DCS, hydrogen, electric propulsion, renewable energy, and LNG bunkering.

2 KR EEXI/CII SERVICES

KR EEXI/CII SERVICES

Release of Web-based EEXI/CII software (KR GEARs)

- Developed based on the results of MEPC 75
- Provides user manuals and demo videos
- Updated to reflect the results of MEPC 76

Preliminary EEXI technical services

- Calculate EEXI
- Assess power limitation and speed reduction

Consulting service for EPL/ESDs

- General advisory service
- Review of engineering report/CFD analysis
- Collaboration with engineering companies

Guidelines for air lubrication system installation and surveys

Guidelines for wind assisted propulsion systems

Detailed EEXI/CII guidelines

Technical seminars for customers

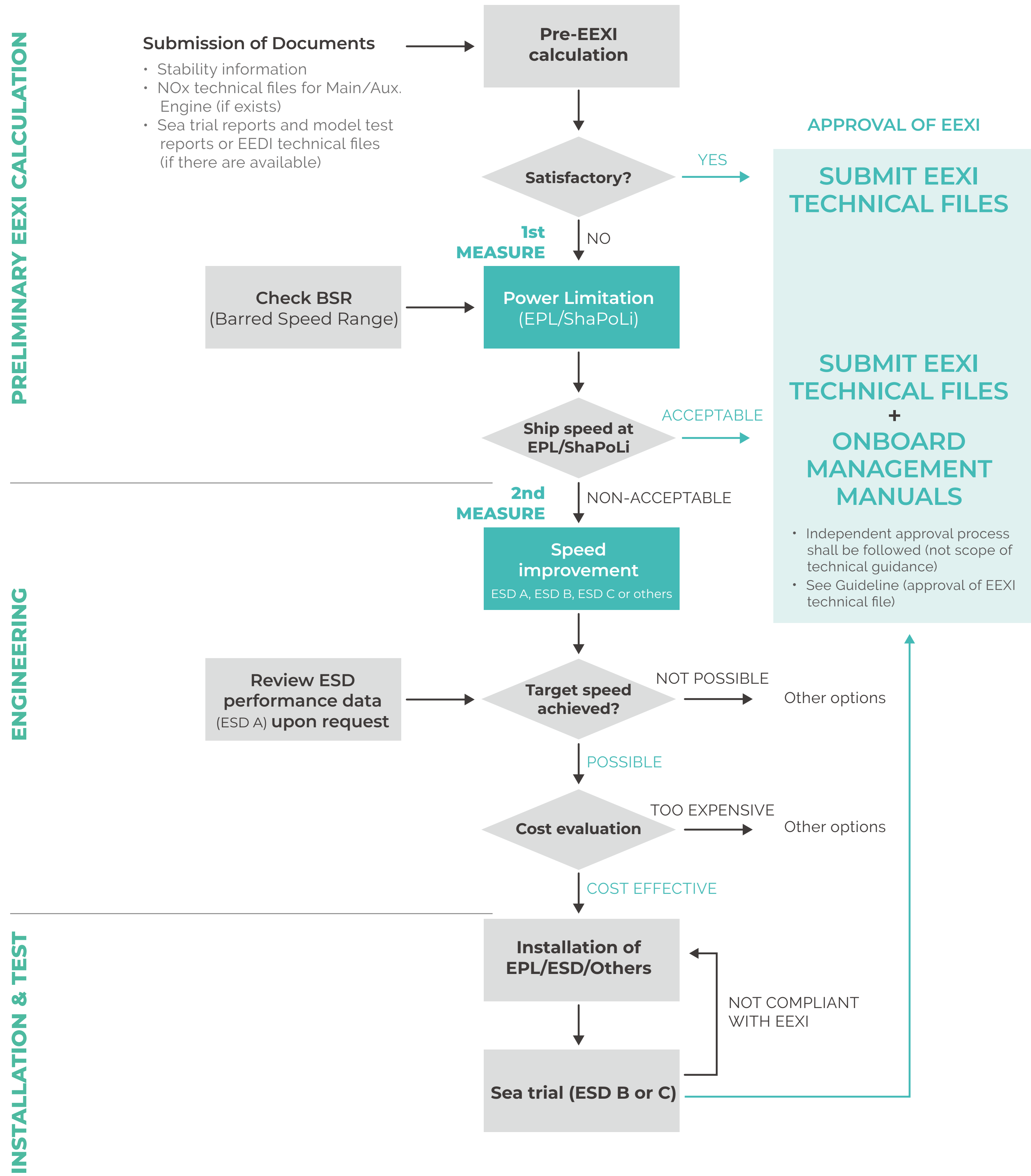
- Webinars
- Visits for seminars

KR has released a web-based EEXI and CII software for its customers. This program was developed and updated to reflect MEPC 75 and 76. Comprising user manuals and demonstration videos, it is available for no charge.

Where shipowners cannot respond to EEXI, and need technical support to develop a plan, KR is ready to provide services to calculate each vessel's power limitation and speed reduction requirements.

There will be cases where the adoption of EPL is not sufficient to achieve EEXI. This raises the following question: "What is the optimum combination of EPL and energy saving devices for a vessel to remain both commercially viable and operationally safe?" Working in collaboration with engineering companies, KR has assisted shipowners to determine appropriate performance improvements and to estimate costs. To support clients, guidelines for air lubrication systems and wind assisted propulsion systems have also been released. Most importantly, KR has developed detailed EEXI/CII Guidelines and is ready to provide technical seminars to customers for further informa-tion and more detailed guidance.

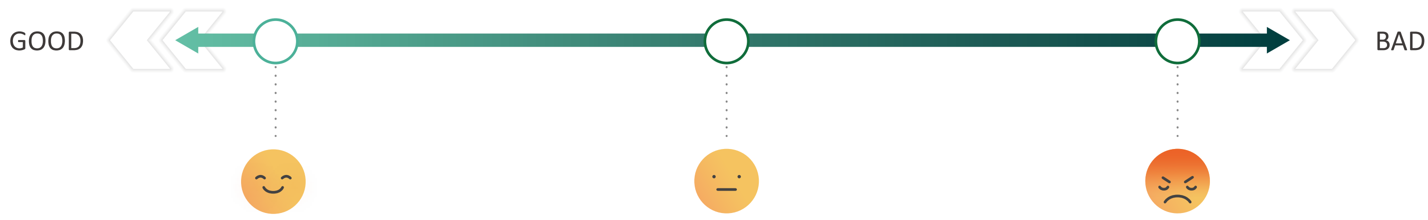
FLOW CHART OF EEXI REPONSES



EEXI challenges to some vessels might not be addressed with EPL or SHaPoLi alone. In these cases, Energy Saving Devices should be considered as the 2nd measure. Most importantly, it is worth noting that these devices should be verified by sea trial. In cases of type A ESD, numerical verification may be allowed in place of a model test or sea trial.

To sum up, shipowners must understand the implications of EPL, and investigate whether an investment in energy saving devices would pay off. The ability of a vessel to apply an EPL reduction to her commercial trade at charterparty is an important balancing act in both regulatory and business contexts.

GUIDANCE ON TIMELINE FOR SHIPOWNERS/OPERATORS



CASE 1

1	Calculate current EEXI	1D
2	Prepare EEXI Technical Files	1W
3	Approve EEXI Technical Files	2W
4	Issue new IEEC	1W
	Total	**4W**

CASE 2

1	Calculate current EEXI	1D
2	Assess improvement options by EPL considering conrtactual speed	1W
3	Design/manufacturing /installation of EPL (including onboard visit)	6W
4	Preparation of EPL management plan/ Preparation of EEXI Tehcnical File	1W
5	Approval of EPL management plan/ Approval of EEXI Technical File	2W
6	Class attendance for EPL verification and issue new IEEC	1W
	Total	**11W**

CASE 3

1	Calculate current EEXI	1D
2	Assess improvement options by EPL considering conrtactual speed	1W
3	Design/manufacturing /installation of EPL (including onboard visit)	6W
4	ESD Category A (Design/Manufacturing /Installation) * docking schedule may be harmonized	3~7M
5	ESD Category B (Design/Manufacturing /Installation) * docking schedule may be harmonized	8~12M
6	Preparation of EPL management plan/ Preparation of EEXI Tehcnical File including CFD anlaysis	1W
7	Approval of EPL management plan/Approval of EEXI Technical File including verification of CFD analysis	3W
8	Class attendance for EPL verification and issue new IEEC	1W
	Total (EPL+ESD **Category A**)	**6~10M**
	Total (EPL+ESD **Category B**)	**11~15M**

Hypothetically, there are 3 cases to consider:

Case 1 denotes that the attained EEXI meets the requirements. It takes about one month for a new international energy efficiency certificate to be issued. This includes the time it takes to calculate and prepare the EEXI issued.

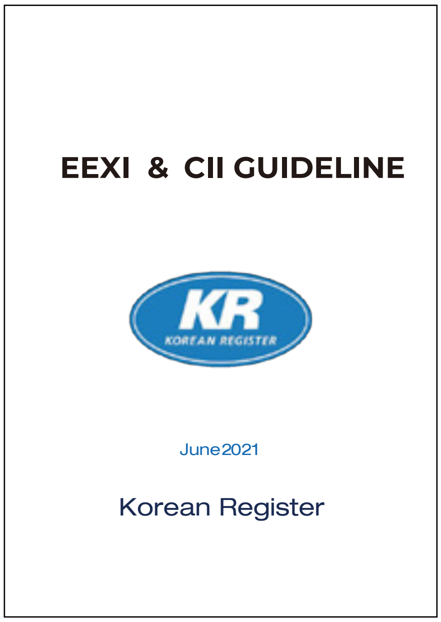
Case 2 indicates that the attained EEXI does not meet the requirements. The engineering work relating to engine power limitation, including design, manufacturing and installation, could take 6 weeks. The total process involved to meet EEXI requirements can take eleven weeks.

Case 3 is a worst-case scenario. In addition to engine power limitation and energy saving devices, shipowners must consider engineering work, and the installation period of ESD varies by category and type as presented in the tables above. Dry-docking schedule must also be looked into.

Category A vessels can take six to ten months. Category B ones may take eleven to fifteen months. Shipowners and operators can estimate costs by making use of this data. They can also get more detailed cost estimates from the engine makers and/or engineering companies.

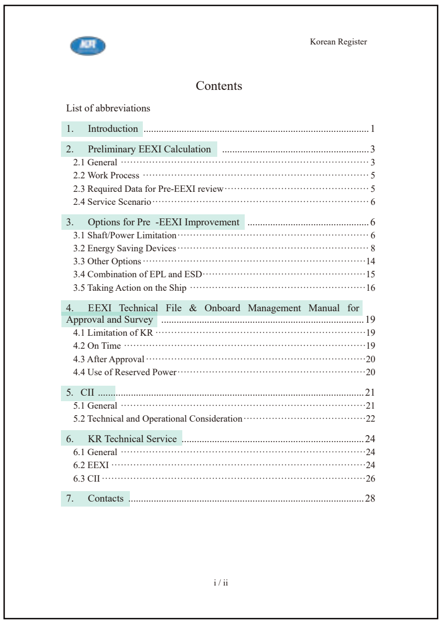
3 KR GEARs PROGRAM

KR EEXI & CII GUIDELINES


EEXI & CII GUIDELINE

June 2021

Korean Register


Korean Register

Contents

i / ii

KR has developed detailed EEXI and CII Guidelines. They consist of Preliminary EEXI calculations, an overall flow chart for EEXI, detailed options for pre-EEXI improvement, documents for approval and survey, CII consideration, technical services, and contact points.

KR GEARs

GEARs

GHG Emission
Authentic Reporting System

Monitoring Fuel Consumption & Operation Data

- Collection of fuel consumption (CO2 emission) and operation data
- Automatic generation of reports automatically for EU MRV & IMO DCS

Compliance with GHG & Air Pollution Regulations

EU MRV As an accredited verifier

- Assessment of monitoring plans
- Verification of emission reports

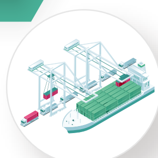
IMO DCS As a Recognized Organization (RO)

- Approval of SEEMP Part II
- Verification of ship's fuel oil consumption data for DCS

SIP As a technical expert

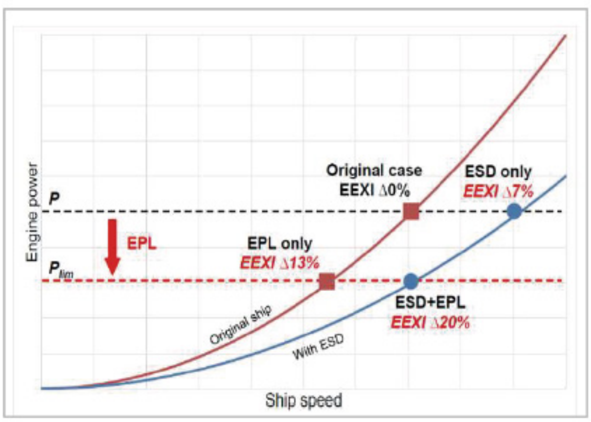
- Supporting voluntary action
- Visual checking of energy efficiency of ships
- Analysis of energy efficiency based on additional operation data

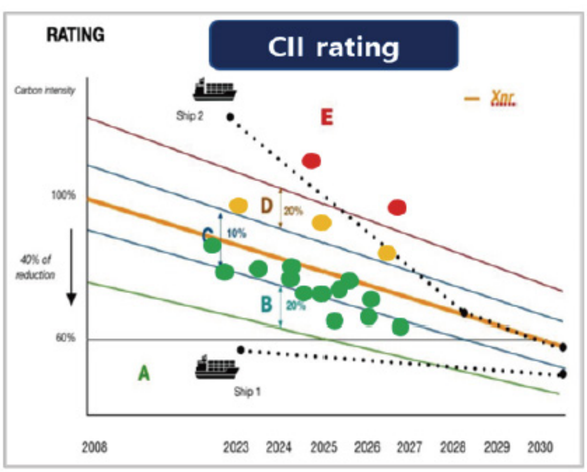
EEXI
CII



Management of Ship Energy Efficiency

- Supporting voluntary actions (e.g., EEOI)
- Visual checking of energy efficiency of ships
- Analysis of energy efficiency based on additional operation data





"

Provide one-stop services to Shipowners, Managers & Designers for the purpose of improving EEXI

Present in-depth guidance to Operators and Technical Superintendents to optimize vessel efficiency and to attain best results for CII

The KR GEARs program provides monitoring services regarding fuel consumption and operational data, generates automatic reports on EU MRV and IMO DCS, and supports ship energy efficiency management.

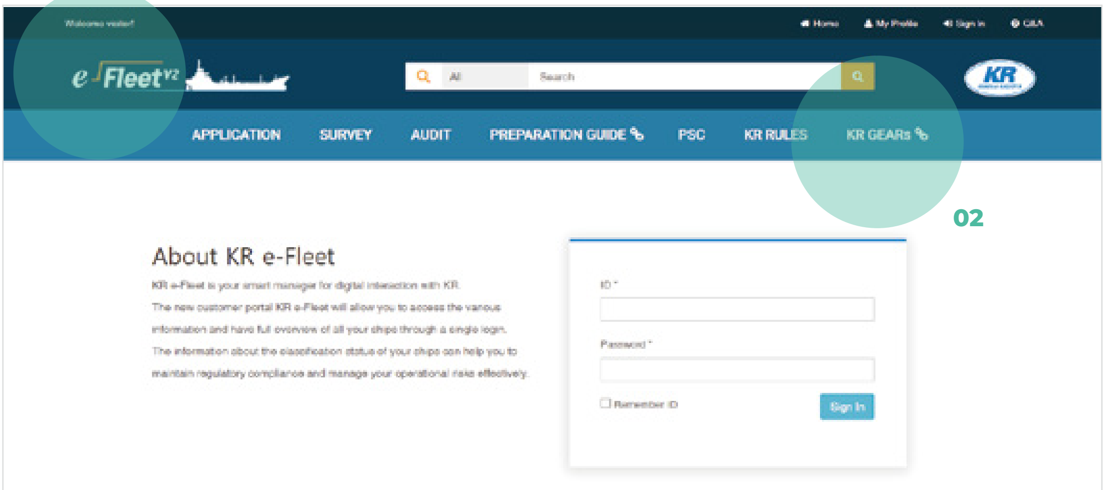
The EEXI and CII services functions have been added to provide a one-stop service facility to shipowners, managers and designers. The program also guides operators and technical superintendents to optimize vessel efficiency.

KR GEARs

You can use the KR GEARs program through KR E-fleet or KR EDAS ID. If you don't have an ID, please send an email to the following address.

CONTACT US BY
decarbonization@krs.co.kr

01



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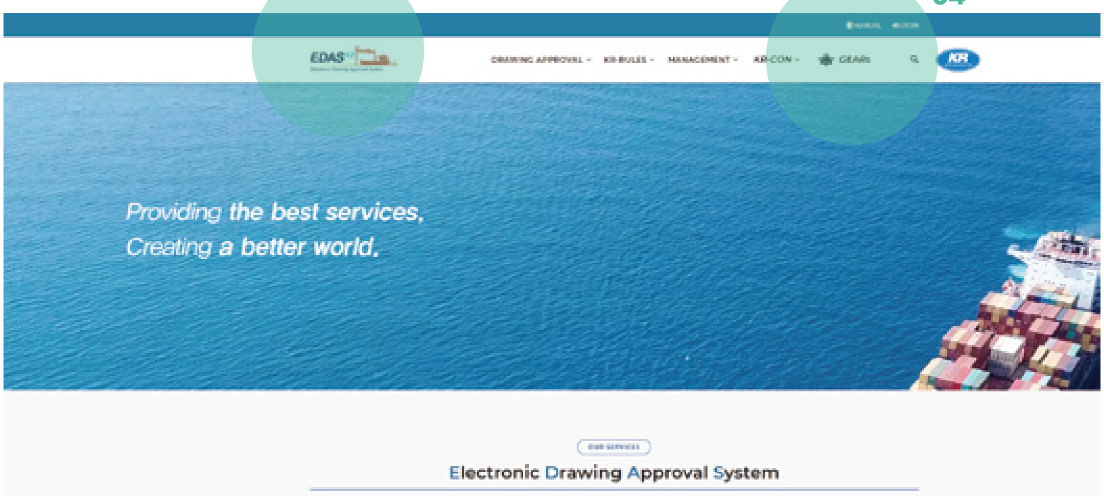

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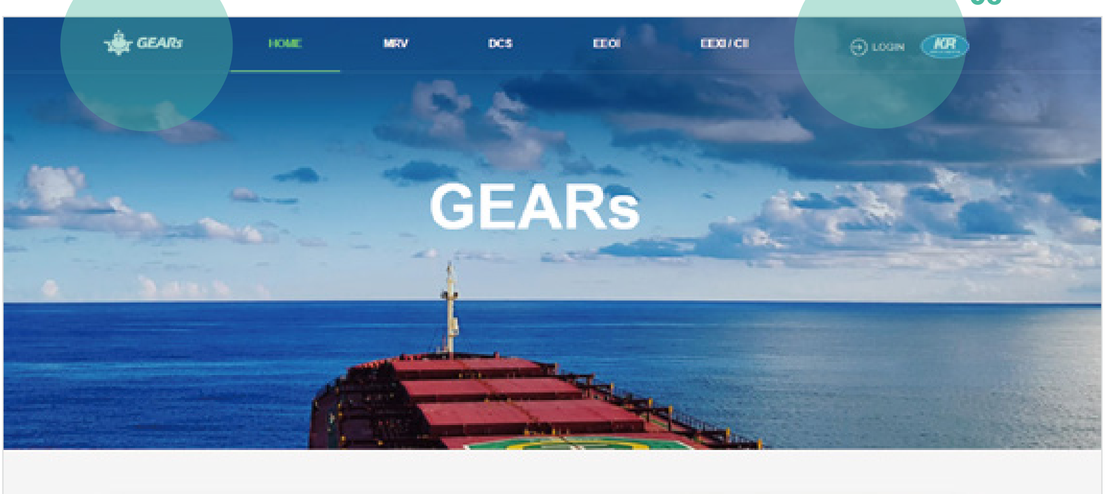

KR GEARs EEXI PROGRAM: CALCULATION FLOW

KR GEAR's EEXI program consists of three main functional processes, namely:

1. Ship specifications for basic information input
2. Ship speed input – if there is no speed-power table, speed calculation employs the alternative method provided by MEPC
3. Calculation takes other correction factors into account, and the graphically displayed results demonstrate attained and required EEXIs.

SHIP PARTICULARS

- Input basic information
- Page is configured to link necessary information when calculating the EEXI.

SHIP SPEED

- Input the speed-power table
- Provide alternative speed calculation in the absence of speed-power table
- Direct input of EEDI speed

CALCULATION

- Input correction factor variables
- Apply the dual-fuel calculation
- EEXI Calculation
- Display the attained EEXI & required EEXI


SME 대

KOREAN REGISTER

Established in 1960 as a not-for-profit ship classification society, Korean Register(KR) has been promoting safe ships and clean oceans by continually developing technology and human resources pertaining to shipping, shipbuilding and other industrial services.

KR became a member of the International Association of Classification Societies(IACS) in 1988, and in 1990, became listed in the Institute Classification Clause(ICC) of London Underwriters. The acquisition of these international standards of confidence is an indication of KR's solid underpinning and outstanding global recognition as a leading international ship classification society.

EDITORS

KIM KYUNGBOK

YOO JINHO

LEE OH

JI EUNBIT

JEON SUWON

TRANSITION **2050**

GREENER STRATEGY

HOW TO RESPOND TO IMO GHG REQUIREMENTS

KOREAN REGISTER (KR)
36, Myeongji Oceancity 9-Ro, Gangseo-Gu, Busan, Republic of Korea, 46762
Tel +82-70-8799-7114, 8114 **Fax** +82-70-8799-8999

www.krs.co.kr