Technical and Regulatory Strategies for Reducing the Carbon Footprint of Maritime Transport

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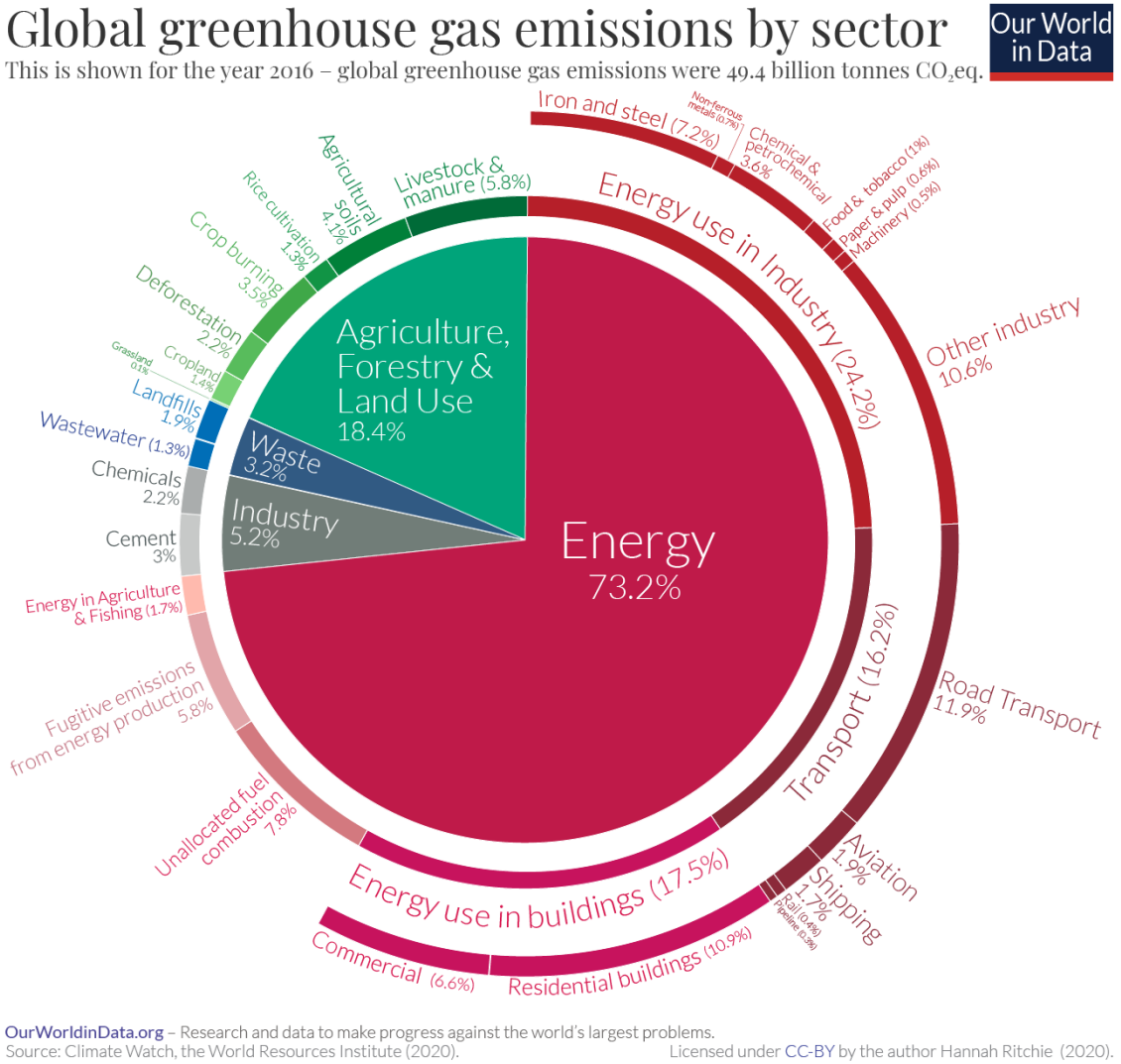
*Opinions are my own.

Background

- 1.7 % of global greenhouse gas emissions.
- Deep sea voyages are considered hard to abate.



Background

- Shipping's percentage and its decarbonisation challenges may be used to sustain evasive arguments, e.g.:
  - "Emissions originating from shipping are relatively small in relation to other industries, and therefore should not be the focus of regulations to reduce emissions".
  - "As shipping emissions are hard to abate, regulations should focus on reducing emissions from sectors whose emissions are easy to abate".
- Other examples of evasive arguments and their refutations are found on https://shippingpodcast.com/dr-tristan-smith-ucl-energy-institute/

Application Mechanisms

- Environmental, Social, and Governance (ESG).
  - Influence: restricted to the value chains in which shipping operates.
  - Intensity: small.

- International Maritime Organisation (IMO).
  - Influence: global.
  - Intensity: medium.
  - Source: Index of MEPC Resolutions and Guidelines related to MARPOL Annex VI (imo.org)

- European Union (EU).
  - Influence: regional.
  - Intensity: high.

Contents: April 5th

- IMO’s Strategy
- Technical Criteria
  - Energy Efficiency eXisting ship Index (EEXI)
  - Energy Efficiency Design Index (EEDI)
  - Carbon Intensity Indicator (CII)
- EEXI/EEDI
  - Implementation
  - Short-term conformity measures
  - Gaps and loopholes

Contents: April 10th

- CII
  - Implementation
  - Short-Term Conformity Measures
  - Gaps and Loopholes
  - Adoption Consequences
- EU Emissions Trading System (ETS)
- Mid and Long-Term Decarbonisation Strategies
  - Alternative Energy Sources
  - Adoption and Availability Uncertainties
- Conclusion

IMO's Strategy

.1 ***carbon intensity of the ship to decline through implementation of further phases of the energy efficiency design index (EEDI) for new ships***

to review with the aim to strengthen the energy efficiency design requirements for ships with the percentage improvement for each phase to be determined for each ship type, as appropriate;

.2 ***carbon intensity of international shipping to decline***

to reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008; and

.3 ***GHG emissions from international shipping to peak and decline***

to peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out as called for in the Vision as a point on a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals.

Source: Resolution MEPC.304(72) – Initial IMO Strategy on Reduction of GHG Emissions From Ships. Link: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Resolution%20MEPC.304%2872%29_E.pdf

IMO's Strategy

- Note the strategy is **not** aligned with the Paris Agreement (0 emissions in 2050), it is less ambitious.
- The IMO will revise the strategy this year. Discussions should include:
  - Financial penalties on GHGs emissions.
  - Tightening up of the carbon emission targets.
  - Emissions calculation methods ("well to wake" or "tank to wake").
  - Recommendations of and support to alternative energy sources.

Technical Criteria

- Follow the format:

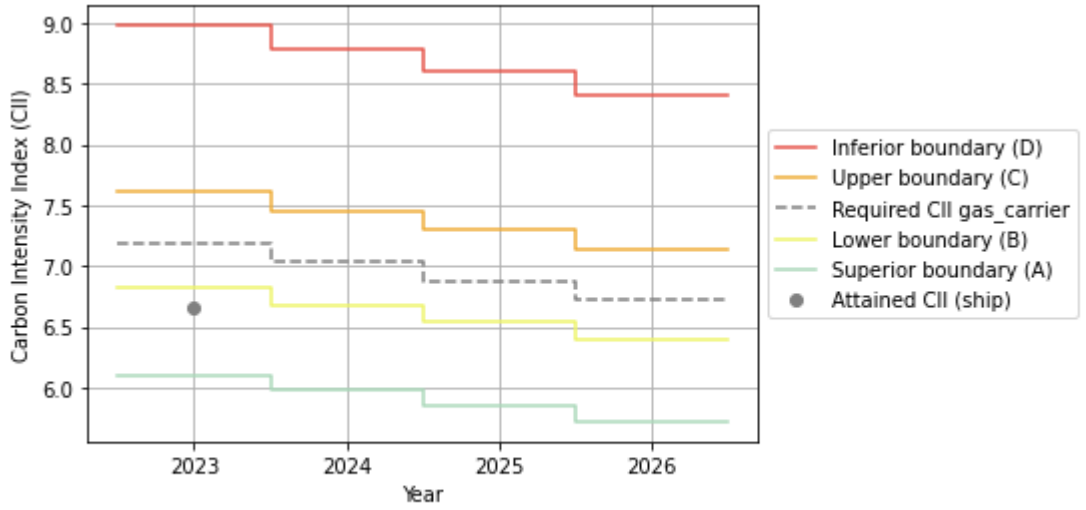
$$\frac{CO_2\ Emissions}{Performed\ Transport}$$

- The attained metric should be smaller than or equal to the required metric:

$$Attained\ EEDI\ \leq Required\ EEDI = \left(1 - \frac{X}{100}\right) \cdot Reference\ line\ value$$

Differences among EEXI, EEDI and CII

- Scope:
  - EEXI and EEDI are valid for vessels over 400 GT.
  - CII is valid for ships over 5000 GT.
- Calculation:
  - EEXI and EEDI are design / specification criteria.
  - CII is an operational criteria.
- Application over the years:
  - EEDI and CII become more restrictive over the roll out of different phases.
  - EEXI is applied as a stable criterion.



Assuming this vessel attains the same CII, it will end 2026 with a satisfactory rating.

An Anatomy of the Energy Efficiency Design Index (EEDI) Equation for Ships

MAIN ENGINES EMISSIONS | AUXILIARY ENGINES EMISSIONS | SHAFT GENERATORS/MOTORS EMISSIONS | EFFICIENCY TECHNOLOGIES

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

TRANSPORT WORK

ENGINE POWER (P)

Individual engine power at 75% of Maximum Continuous Rating

- $P_{eff(i)}$ Main engine power reduction due to individual technologies for mechanical energy efficiency
- $P_{AEff(i)}$ Auxilliary engine power reduction due to individual technologies for electrical energy efficiency
- $P_{PTI(i)}$ Power of individual shaft motors divided by the efficiency of shaft generators
- P_{AE} Combined installed power of auxilliary engines
- $P_{ME(i)}$ Individual power of main engines

CO_2 EMISSIONS (C)

CO_2 emission factor based on type of fuel used by given engine

- C_{FME} Main engine composite fuel factor
- C_{FAE} Auxilliary engine fuel factor
- $C_{FME(i)}$ Main engine individual fuel factors

SPECIFIC FUEL CONSUMPTION (SFC)

Fuel use per unit of engine power, as certified by manufacturer

- SFC_{ME} Main engine (composite)
- SFC_{AE} Auxilliary engine
- SFC_{AE}^{*} Auxilliary engine (adjusted for shaft generators)
- $SFC_{ME(i)}$ Main engine (individual)

CORRECTION AND ADJUSTMENT FACTORS (f)

Non-dimensional factors that were added to the EEDI equation to account for specific existing or anticipated conditions that would otherwise skew individual ships' rating

- $f_{eff(i)}$ Availability factor of individual energy efficiency technologies (=1.0 if readily available)
- f_j Correction factor for ship specific design elements. *E.g.* ice-classed ships which require extra weight for thicker hulls
- f_w Coefficient indicating the decrease in ship speed due to weather and environmental conditions
- f_i Capacity adjustment factor for any technical/regulatory limitation on capacity (=1.0 if none)

SHIP DESIGN PARAMETERS

- V_{ref}

Ship speed at maximum design load condition

- $Capacity$

Deadweight Tonnage (DWT) rating for bulk ships and tankers; a percentage of DWT for Containerships DWT indicates how much can be loaded onto a ship

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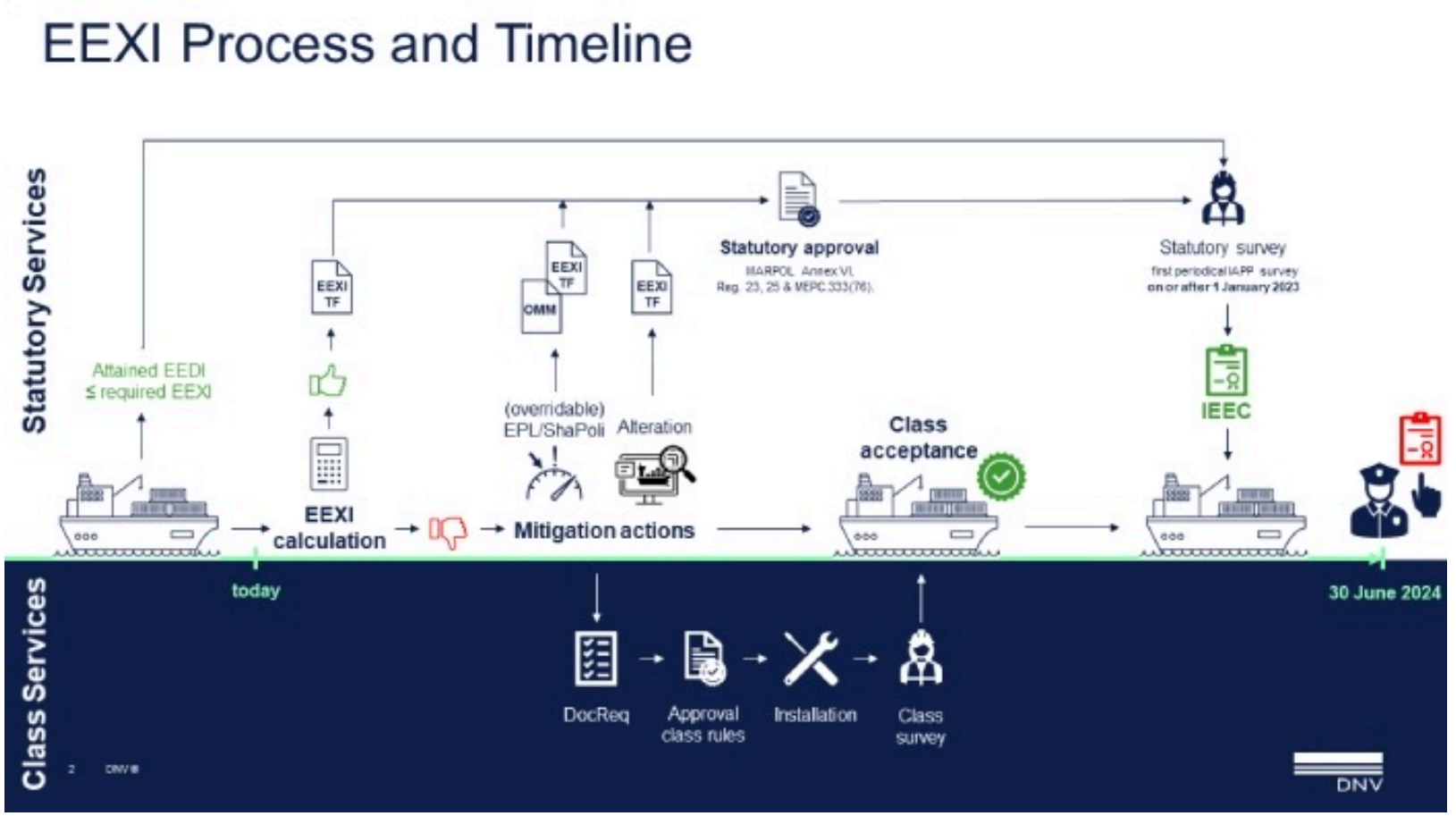
Implementation

- Application:
  - EEDI is in effect since 2015 (Phase 1) and becomes more restrictive as phases pass.
  - EEXI entered into force in January 2023.
  - Reference lines can be found in MEPC.328(76). Link: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/MEPC.328(76).pdf.

- Technical documents must be verified and approved by a competent authority (e.g., classification societies).

Implementation



Source: [EEXI | Energy Efficiency Existing Ship Index – DNV]().

Conformity Measures (EEXI)

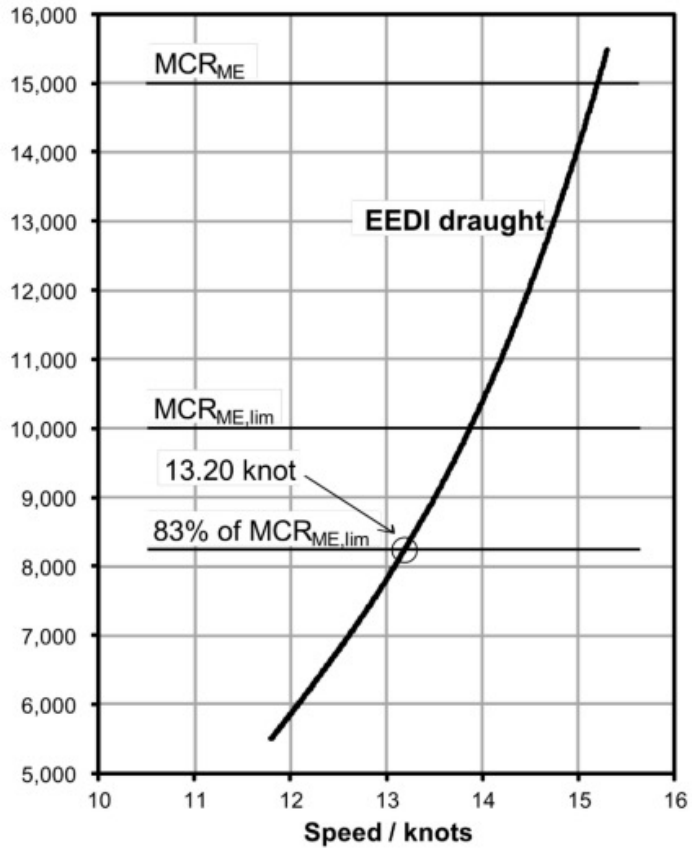


Figure 2.1: Power curve

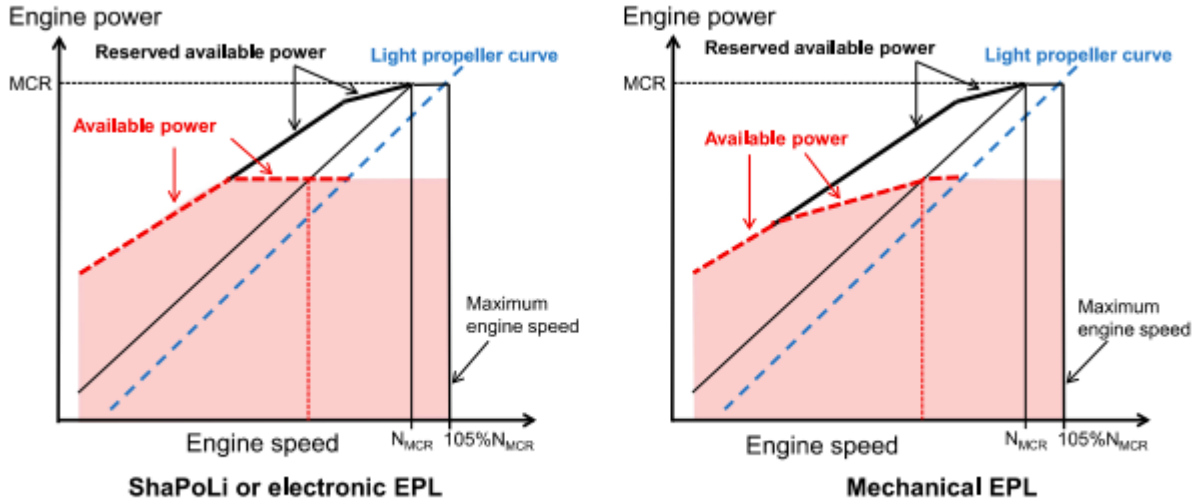


Figure 1: Engine load diagram on Shaft/Engine Power Limitation

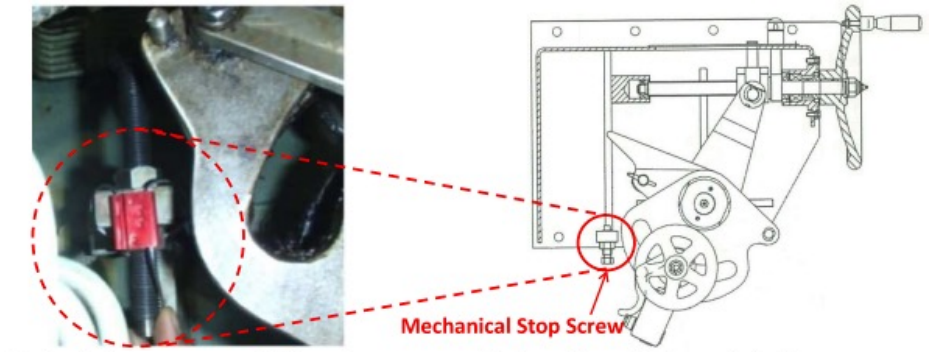


Figure 2: Sealing of mechanical stop screw

Source: 2021 Guidelines on the shaft / engine power limitation system to comply with the EEXI requirements and use of a power reserve. Link: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/MEPC.335(76).pdf

Conformity Measures (EEDI and EEXI)

Category (A): Technologies that shift the power curve, which results in the change of combination of P_P and V_{ref}: e.g. when V_{ref} is kept constant, P_P will be reduced and when P_P is kept constant, V_{ref} will be increased.

Category (B): Technologies that reduce the propulsion power, P_P, at V_{ref}, but do not generate electricity. The saved energy is counted as P_{eff}.

> ***Category (B-1)***: Technologies which can be used at any time during the operation and thus the availability factor (f_{eff}) should be treated as 1.00.
>
> ***Category (B-2)***: Technologies which can be used at their full output only under limited condition. The setting of availability factor (f_{eff}) should be less than 1.00.

Category (C): Technologies that generate electricity. The saved energy is counted as P_{AEeff}.

> ***Category (C-1)***: Technologies which can be used at any time during the operation and thus the availability factor (f_{eff}) should be treated as 1.00.
>
> ***Category (C-2)***: Technologies which can be used at their full output only under limited condition. The setting of availability factor (f_{eff}) should be less than 1.00.

(C) Emission reduction through the auxiliary power reduction by generating electricity for normal maximum sea load(P_{AEeff})

(B) Emission reduction through the propulsion power reduction (P_{eff})

$$\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}**\right)$$

$$f_i \cdot f_c \cdot Capacity \cdot f_w \cdot V_{ref}$$

(A) The combination of P_P and V_{ref} as reflected in the power curve (knot-kW curve)

Source: 2021 Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of the Attained EEDI and EEXI. Link: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/MEPC.1-Circ.896.pdf

Conformity Measures (EEDI and EEXI)

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 overall performance of the vessel	Can be treated separately from the overall performance of the vessel		Effective at all time	Depending on ambient environment
	$f_{eff} = 1$	$f_{eff} < 1$	$f_{eff} = 1$	$f_{eff} < 1$
– 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 (exhaust gas heat recovery and conversion to electric power)	– photovoltaic cells

Source: 2021 Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of the Attained EEDI and EEXI. Link: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/MEPC.1-Circ.896.pdf

Gaps and Loopholes

- EPL / Sha-Po-Li might have one of two undesirable effects:
  1. In case the vessel often travels at reference speed: The vessel will lose speed and will possibly make fewer voyages.
  2. In case the vessel often travels at speeds slower than reference speed: Conformity with the technical criterion may not have a practical effect on reducing emissions.

- Calculation of EEXI and EEDI does not take into account the vessel performance in different operational conditions, such as:
  1. Sea and weather states.
  2. Emissions in different draughts or buoyancy conditions.

Summary and Conclusions

- IMO makes use of several devices to try to reach the decarbonization targets stated in its strategy.
- The adequacy of decarbonization targets *vis-à-vis* strategies continues to undergo reviews according to IMO Members' objectives.
- EEDI and EEXI are criteria for limitation of emissions in previously specified (and non-operational) conditions.
- Among the means to achieve conformity with criteria are technologies for limitation of propulsive power and for energy saving.