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Project memo

Review of environmental indices in the maritime sector – with focus on heating and cooling systems onboard cruise ships

VERSION	DATE
1	23 December 2021

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CLIENT(S)	CLIENT'S REFERENCE
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PROJECT NO.	NO. OF PAGES:
502002540	12

Abstract

The objective of the CruiZE project is to develop innovative, integrated and environment-friendly concepts for supplying heating and cooling needs for the hotel facilities on board cruise ships. As in other sectors, there are non-technological barriers which must be addressed to pave the way for implementation of new technology. For example, increased knowledge is needed on the environmental indices that are applied by different stakeholders to assess a ship's environmental performance.

In this memo such indices are reviewed, with a focus on cruise ships, and how the heating and cooling systems are addressed. This will form a basis for further work in CruiZE, aiming at suggesting recommendations on how to modify such indices, to encourage the implementation of innovative heating and cooling technologies.

Included in the review are compulsory regulatory indices issued by IMO, voluntarily indices offered by classification societies, and indices applied to offer port fee reductions. The review shows that there is a need to adapt these indices to enable a more equitable assessment of new heating and cooling technologies.

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PROJECT MEMO NO.	CLASSIFICATION
AN 21.16.10	Unrestricted

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1 Introduction

The overall objective of the CruiZE project is to develop innovative, energy-efficient and environmental-friendly concepts for heating, cooling and freshwater production on board cruise ships. The aim is to suggest concepts, optimised for the ship's propulsion system and operating conditions, that enable zero emissions in ports, minimised emissions at sea and an average reduction in the ship's total energy usage by 10-20%.

As in other sectors, there are non-technological barriers (awareness, knowledge, political, social, and organisational) which must be addressed to pave the way for implementation of new technology. Lack of awareness and knowledge can be related both to the actual technology and its benefits, but also to up-coming regulations that imply the need for new technology. As technologies evolve towards more complex systems, more knowledge is required to fully understand the integration of subsystems and implication of specific choices on the ship's total energy consumption and emissions.

Increased awareness and knowledge are also needed in relation to incentives like quotas, fees and deductions, which are often based on different environmental indices, such as EPI (Environmental Port Index) applied in Norwegian ports, EEDI (Energy Efficiency Design Index) regulated by IMO, and environmental classification notations such as Clean Design applied by DNV-GL.

In this memo various environmental indices are described, with a focus on how the thermal energy systems (heating and cooling) are addressed. This will form a basis for further work in CruiZE, aiming at suggesting recommendations on how to modify such indices, to encourage the implementation of innovative heating and cooling technologies.

2 International Maritime Organisation (IMO)

As a measure to control CO_2 emissions, IMO introduced in 2013 the *Energy Efficiency Design Index (EEDI)* which is related to mandatory technical measures, and a voluntary *Energy Efficiency Operating Index EEOI*[1]. Following the IMO agreement in 2018 on CO_2 emissions targets, two new indices were adopted in 2021 and will enter into force in 2023 – the *Energy Efficiency Existing Ship Index (EEXI*) and the *Carbon Intensity Indicator (CII*)[2]. These four indices are briefly described below.

2.1 Energy Efficiency Design Index (EEDI)

Since 2013, new designs of most ship types need to meet a reference level of minimum energy efficiency expressed as gram CO_2 per "transport work". The transport work is defined as the ship's capacity (in tonnes) times the ships speed at maximum load conditions. For cargo ships the capacity is based on the ship's deadweight tonnage (DWT), which indicates how much cargo that can be loaded. For cruise and passenger ships, the capacity is instead given in gross tonnage (GT), a measure of the ship size[i].). The formula for calculating the EEDI is shown in Figure 1.

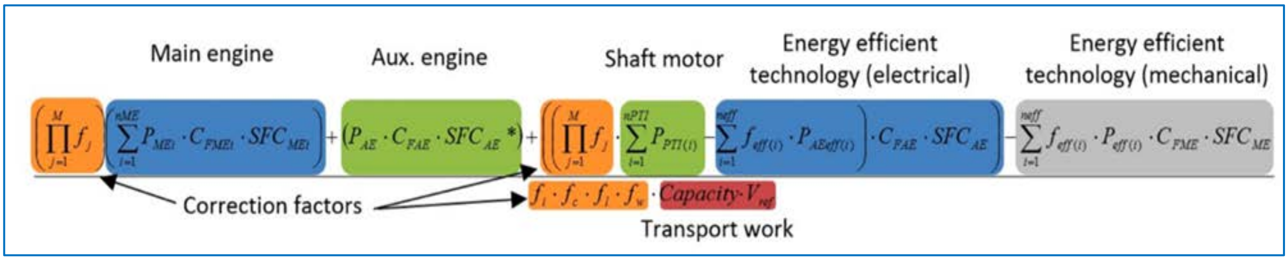

Figure 1: Formula for calculating the EEDI[3]

The ship's EEDI is calculated from design values and is noted in the ship's International Energy Efficiency Certificate (IEEC). In 2014, the scope of EEDI was extended to ro-ro passenger vessels (ships carrying both passengers and vehicles), and cruise ships having non-conventional propulsion (diesel-electric

There are guidelines for calculating the EEDI depending on the type of ship and equipment used onboard the ship[4]. For example, guidelines for the development of electric power tables, and treatment of innovative energy efficiency technologies.

The EEDI reference level is tightened every five years to stimulate continued innovation and technical development. Table 1 shows the EEDI reduction schedule for cruise ships.

Table 1: Required reduction in EEDI reference level for cruise ships.

Cruise ship	**EEDI reduction [%]**				
Capacity [GT]	*Phase 0* *2013-2014*	*Phase 1* *2015-2019*	*Phase 2* *2020 – 31 Mar 2022*	*Phase 3* *1 Apr 2022 and onwards*	*Phase 4* under discussion
≥ 85,000	n/a	5	20	30	
≥ 25,000	n/a	0-5	0-20	0-30	

[i] GT is a measurement of the ship's internal volume of its enclosed spaces, where 100 cubic feet of volume equals one ton

Some concerns for cruise ships are reported[5], for example:

- Consideration of design values only, i.e., the ship's various operational condition (speed, port stay, ambient conditions, etc.) is not considered.
- Consideration of the fuel consumption of the main and auxiliary engines only, i.e., the use of oil-fired boilers is not considered.
- Main engine and auxiliary power reduction measures are included in the EEDI formula, but limited to heat-to-power technologies (i.e., electric power generation). This implies that energy efficiency measures related to steam and hot water are ignored unless they reduce electricity generation.

There are also general concerns (for most ship types) on how well the EEDI reflects a ship's life-time CO_2 emissions. Recommendations to make the EEDI more efficient to serve the IMO targets include[6]:

- A realistic operating profile and more than one engine performance point is required to express the real ship operation and for more realistic estimates of emissions.
- All the ship energy systems (e.g., boilers) should be included to obtain realistic estimates of the ship performance and energy efficiency.
- IMO future targets consider not only CO_2 emissions but also the greenhouse warming impact of ships. Therefore, methane and other equivalent carbon emissions (such as F-gases used as refrigerants) should be considered.

IMO is currently working on EEDI Phase 4 which is suggested to include more than one loading condition and to include additional greenhouse gases such as methane and F-gases (DNV GL, 2020).

2.2 Energy Efficiency Operating Index (EEOI)

The voluntary use of EEOI enables operators to measure the fuel efficiency of a ship in operation and to gauge the effect of any operational changes or introduction of technical measures. The EEOI is calculated as the ratio of gram CO_2 emitted per unit of transport work (cargo mass times distance travelled). For cruise passenger ships the cargo mass can be taken as either the number of passengers or the gross tonnages.

2.3 Energy Efficiency Existing Ship Index (EEXI)

The **EEXI**, is equivalent to the EEDI phase 3 but applies to *existing* ships above 400 GT regardless of the year of build. Ships having diesel-electric propulsion are excluded, except for LNG carriers and cruise passenger ships. The EEDI can be considered as a retroactive EEDI phase 3 requirement. For large cruise ships this implies that the EEXI should be 30% lower than the EEDI reference value. The EEXI is to be verified by the Flag Administration and a new International Energy Efficiency Certificate (IEEC) issued no later than the first annual survey on or after 1 January 2023[7].

The EEXI is determined using the same method as for EEDI. The guidelines for calculation of the EEXI, adopted in June 2021, are based on the 2018 calculation guideline of the EEDI but with some adaptations for existing vessels, such as the handling of limited access to design data and with further options available for determining speed. As for the EEDI, the EEXI determines the standardized CO_2 emissions related to installed engine power, transport capacity, and ship speed. As it is a design index, and not an operational index, no measured values of past years are relevant, and no on-board measurements are required.

The EEXI calculation is goal-based, the operators decide how to achieve targets. There are several options for complying with the EEXI requirement, as illustrated in Figure 2. The "Engine Power Limit" (EPL) establishes a semi-permanent, overridable limit on a ship's maximum power and therefore speed. EPL is believed to be the easiest way for older ships to meet EEXI requirements because it requires minimal changes to the ship and does not change the underlying performance of the engine[8].

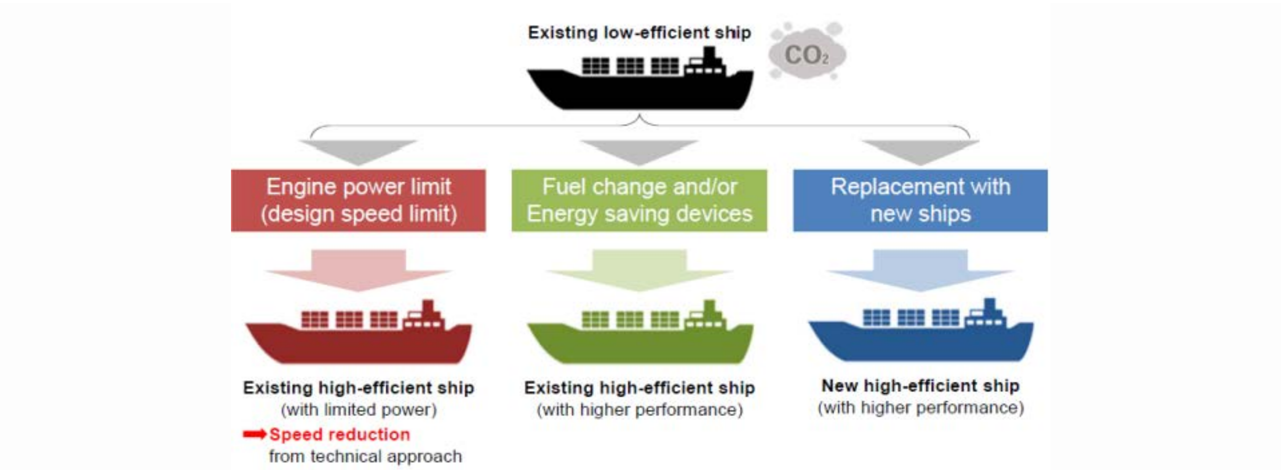

Figure 2: Options for improving EEXI[7]

Some concerns regarding the EEDI and EEXI is that the implementation of CO_2 saving technologies, such as battery solutions, shore power, use of biofuels or e-fuels, and wind-assisted propulsion, today has limited impact on EEDI or EEXI, although CO_2 savings can be significant. Thus, there is an urgent need to review the consideration of energy efficiency technologies. It is also argued that the EEXI will be particularly challenging for the ferry sector. The EEDI was designed to work best on ships where the weight of the cargo is the most important factor, such as tankers and dry bulk carriers. To make it better suited also for passenger ships, correction factors were added, limiting the influence of the ratio of main engine power and speed. However, this means that the most obvious solution, to limit power/speed, does not result in an improved EEXI[9]. Figure 3 below highlights how different measures are considered in the EEDI/EEXI calculation.

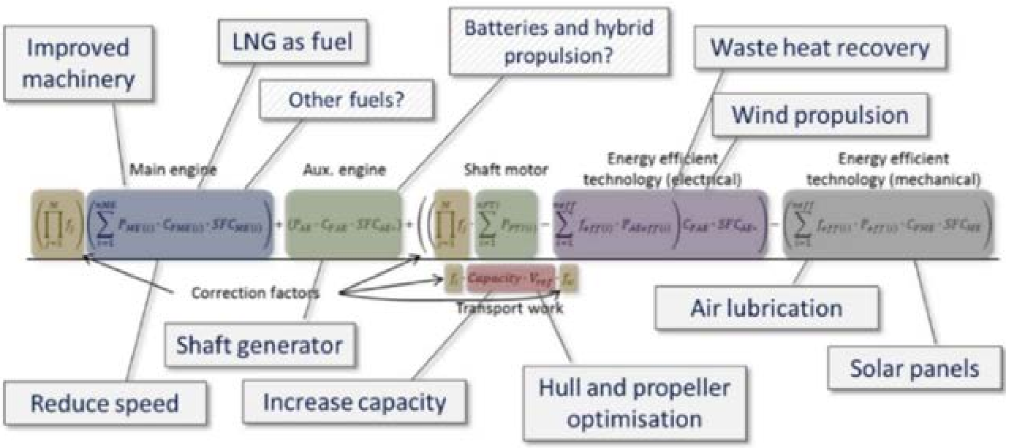

Figure 3: Example of different design measures to improve the EEDI/EEXI.

2.4 Carbon Intensity Indicator (CII)

The CII is an operational indicator, similar to the EEOI, and will be assessed annually from 2023 with year-by-year stricter emission limits. All ships above 5000 GT, regardless of propulsion type, must calculate its CII every year. Based on the CII, a ship will be given an annual rating (A-E), with increasingly stringent thresholds towards 2030. Each ship needs to achieve rating C or better. If rated with D for three consequent years or with E, the ship must develop and implement an approved corrective action plan[7] [10].

Figure 4: Calculation of annual CII[10]

The basic formula for calculating the CII is shown in Figure 4. Guidelines for CII calculations were adopted in June 2021. Additional guidelines are being developed for including correction factors for certain ship types, operational profiles and/or voyages[11]. In the current guideline it is encourraged to use different metrics for CII cacluations, for trial purpose. One of the suggested metrics is the EEOI. For cruise ships the it is recommended to, instead of applying GT as capcity, use ALB (Available Lower Berth). ALB is a measure of the standard capacity of a cruise ship, usually assuming two people per available cabin.

It is argued that the CII represents a particular challenge for cruise ships, due to the comparative size of such vessels' hotel load as a proportion of overall energy consumption. The formula upon which the index is based, where consumption per nautical mile is directly proportional to the CII, is better suited for assessing bulk vessels or container ships than passenger vessels. Due to the high portion of hotel load, cruise ships have a certain optimal speed, where consumption per nautical mile is considered; this is typically around 12 knots. The higher the propulsion power required, the lower is the optimum speed, and the higher the hotel load, the higher is the optimum speed. For example, reducing the speed below 12 knots would result in a lower CII rating, even if CO_2 emissions are reduced at the same time. This means that the ships can achieve the same CII rating whether cruising at 6 knots or at 21 knots, despite the huge difference in actual fuel consumption and CO_2 emissions per hour[12].

Another issue with CII is that it does not attribute fuel consumption to specific stages of a voyage or its operation. For example, consumption during anchoring or port-stay would simply be considered as consumption without distance travelled. However, certain exemptions or corrections are under discussion, for example "extended port stays".

The reference CII is calculated from the formula $a \cdot capacity^{-c}$, where the constants *a* and *c* differ between various ship types. The CII performance in 2019 is taken as reference, based on the IMO regulation on Data Collection System (DCS). For cruise ships, the reference CII is: $930 * GT^{-0,383}$.

3 Classification societies

The IMOs International Convention for the Prevention of Pollution from Ships (MARPOL) is the main environmental regulation for ships. Classification Societies are offering different environmental class notations (indices) as a proof of compliance with additional pollution prevention measures. In this chapter, such class notations are summarised, with focus on requirements related to heating and cooling systems. Of these the most commonly applied are related to refrigerants. The globally mandatory regulation (MARPOL) does not put any requirement on the Global Warming Potential (GWP) of the refrigerants.

3.1 DNV

As illustrated in Figure 5, DNV offers two environmental class notations: "Clean" and "Clean Design"[13]. These represents a proof of voluntary compliance with additional requirements, compared for ship design, operation and equipment reducing the environmental impact from emissions to air, discharges to sea, and deliveries to shore from vessels.

Figure 5: DNV class notations, with additional requirements to the IMO regulations (MARPOL)

The two class notations include additional requirements on refrigeration systems having more than 10 kg initial charge of refrigerant in centralised air conditioning systems and provision plants. Domestic type stand-alone air conditioning units and refrigerators do not fall into requirements[14].

- Class notation Clean: The use of ozone depleting substances is not permitted. The refrigerant may be an HFC or natural refrigerants such as NH_3 or CO_2. Annual refrigerant leakage shall be not more than 10% of the total refrigerant charge for each system.
- Class notation Clean Design: Refrigerants shall be either a natural refrigerant (e.g., NH_3 or CO_2) or alternatively an HFC with GWP ≤ 2000. This means that the commonly used refrigerant R404A is prohibited, but still allows the use of, e.g., R134a and R407C.

Worth mentioning is that in DNV's regulations dated 2015 the concept of "Total Equivalent Warming Impact (TEWI)" was introduced. The TEWI includes not only direct GHG emissions due to leakage of high-GWP refrigerants, but also emissions related to the generation of electric power for driving the plant. To assign the Clean Design notation it was stated that "As an alternative to GWP ≤ 2,000, a documented equivalent TEWI may be accepted". There were, however, doubts on whether the TEWI is a validated alternative to the GWP limit since input parameters are not clear. Therefore, the TEWI option was removed in 2017 edition.

Another class notation, indirectly related to thermal energy systems are "Shore Power", applicable for ships utilizing electrical connections while in port to supply the onboard distribution grid and/or charging electrical energy storage systems (batteries) onboard the vessel.

3.2 American Bureau of Shipping (ABS)

In 2020, the ABS class notation on Environmental Safety (ES) was replaced by the ENVIRO or ENVIRO+ notations[15]. The only requirements directly related to thermal systems are on refrigerants.

- The ENVIRO notation prohibits the use of ozone depleting substances (ODS) other than HCFCs, which are permitted on ships constructed prior to January 2020. This is in line with MARPOL, i.e. no additional requirements
- The ENVIRO+ prohibits the use of refrigerants with a GWP > 2000, other for ships with the notation EP2020+. The EP2020+ signifies the comitment to replace the existing refrigerant with one having a maximum GWP of 2000.

In 2021, some new notations were introduced, such as "Low Emission Vessel" (LEV), and "EEDI-Ph3".

3.3 Lloyd's Register

Lloyd's Register proposes the **ECO** class notation which is based on compliance with the voluntary ECO Rules setting standards for environmental ship design, construction and operation beyond statutory requirements. The rules are said to be updated regularly to reflect technological and legislative developments.

The ECO rules include requirements of the refrigerant used in all permanently installed refrigeration and air conditioning installations with more than 3 kg of refrigerant. The requirements do not apply to stand-alone refrigerators, freezers and ice makers used in galleys, pantries, bars and crew accommodation.

- The use of ODS (i.e., CFC and HFC) in existing and new installations is prohibited.
- It is also stated that "where possible", natural refrigerants, such as ammonia, carbon dioxide and Hydrofluoroolefins (HFOs), should be used". Note that the HFOs are not natural refrigerants since they are synthetically produced as low-GPW substitutes to HFC.
- For the use of HFCs, there is a maximum GPW limit of 1950.

There is also a supplementary “environmentally friendly character”; for refrigeration systems – "R".

- For assignment of the R character, natural refrigerants are to be used in all main refrigeration systems such as provision rooms and AC plants.
- Small factory-built system(s) that use refrigerants having a GWP < 1,950 are allowed.

Other relevant notations:

- EEDI-3: compliance with phase 3 of the EEDI.
- EnMS: Ship energy efficiency management. For the assignment of the EnMS character, certification under ISO 50001 is to be issued by an accredited organisation and is to be applicable to the management and operation of the ship.
- OPS notations (onshore power supply).

3.4 RINA

RINA (Registro Italiano Navale) offers several different class notations, of which the most relevant in this context are "Clean Air" and "GREEN PLUS", the latter based on both sea and air pollution prevention[16].

The CleanAir notation includes requirements on centralised refrigeration systems. The use of ODS is prohibited, the maximum allowable GWP is 2000, and the maximum annual leakage rate is 10%.

To be assigned with the GREEN PLUS notation the ships must have additional systems, component and procedural means (selected from a given item list) pertaining to at least nine different pollution sources. The assignment is also based on an environmental index, obtained by adding up the values of the contributions from each of the additional emission-preventing measures. Implementations for covering mandatory IMO requirement does not contribute to the index. Also, novel features can be considered to be included in the index calculation, such as measures to:

- maximise the recovery of waste heat,
- electrical propulsion designed to have maximum efficiency at different operational conditions, and
- any other fuel saving technique.

The GREEN PLUS include restrictions on the use of GWP refrigerants in central refrigerating facilities, such as provision refrigeration systems and air conditioning plants. They do not apply to domestic type stand-alone refrigerators and air conditioning systems. There are two alternatives for complying:

a) Avoid use of refrigerants with GWP > 150. If natural refrigerants are applied (i.e., CO_2) the energy efficiency must be ±20% to traditional refrigeration systems.
b) Design the system minimising piping systems carrying the refrigerant.

The contribution to the environmental index is based on the ratio between refrigeration capacity with refrigerants with GWP<150 and refrigeration capacities with other refrigerants (not complying with b)

Other relevant requirements / contributions to the environmental index include

- Use of non-fossil fuels: power onboard is partially or totally produced with non-fossil fuels (batteries, fuel cells, sails).
- Energy saving and energy conservation – the ship has an approved operational manual indicating procedures related to propulsion but also electric users for hotel/accommodation services (e.g., galleys, laundries, lighting) as well as steam production and users.
- Optimization of AC plant – measures are taken to reduce the power usage of the AC plants, including use of passive measures to reduce the demand (e.g., reflective glazing).
- Zero emissions in port: the ship is equipped with systems (e.g. batteries) designed to grant zero emissions in port (based on time in port and electrical load according to ship typical operating profile). Note that, the ship's thermal demand in port is not considered, which today is supplied with waste heat from onboard power generation and/or fossil fuel oil boiler[ii].

3.5 Bureau Veritas

The class notation CLEANSHIP prohibits the use of ODS (HCFCs) in the ship's centralized refrigerating and air conditioning plants, while the CLEANSUPER additionally requires that all refrigerants used onboard have a GWP not exceeding 2000[17].

[ii] Thermal storage and heat pumps: a step towards zero-emission cruise ships

4 Environmental indices for differentiated port fees

In this chapter, examples are given on environmental indices applied for rewarding low emission ships through, for example, environmental differentiation of port fees: the international "Environmental Shipping Index" (ESI), the Norwegian "Environmental Port Index" (EPI) and the Swedish "Clean Shipping Index" (CSI). These indices are based on the technical environmental-friendly level of the ship, and how it behaves during sailing and/or in port – e.g., related to type of fuel and consumption level. For a pollution prevention measure and/or equipment to be considered, the emissions must be reduced beyond requirements in national and international regulations[18 21].

4.1 Environmental Ship Index (ESI)

The ESI, initiated in 2010 by WPCI (World Port Climate Initiative) is used internationally for all ship types, and is primarily based on the ship's environmental performance in sailing mode. The size of the discount in port fee is determined by the actual port but is based on the following formula: *ESI points = ESI* NO_x *+ ESI* SO_x *+ ESI* CO_2 *+ shore power*. For example, the Port of Oslo has adapted the scheme so that the threshold for discount is low, but to achieve large discounts the ship has to reduce their emissions considerably.

4.2 Environmental Port Index (EPI)

A consortium of Norwegian cruise ports, in collaboration with DNV, has developed the Environmental Port Index (EPI) - a methodology for quantifying and reporting ship's environmental performance in ports.
Thus, where the ESI represents the overall emission level for all operations, focusing on sailing mode, the EPI indicates the ship's emission level when it is docked[19].

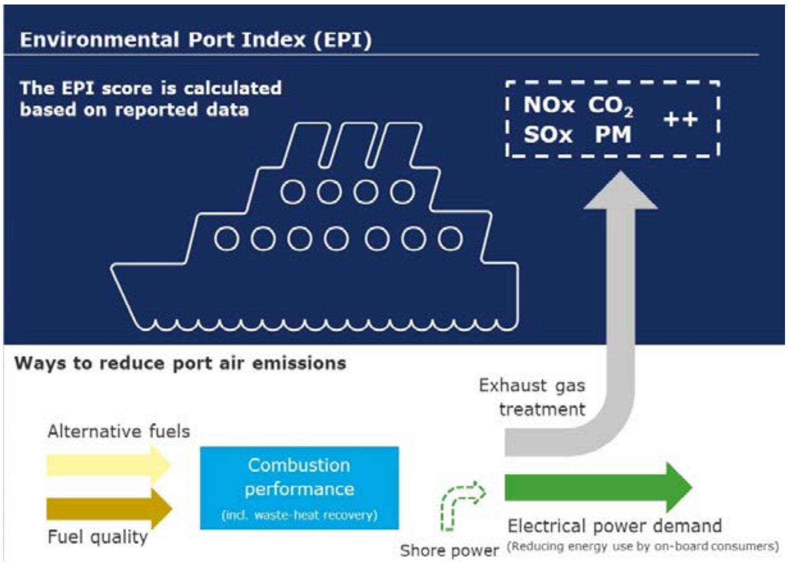

Figure 6: Environmental Port Index – a pilot project initiated within the Green Shipping Programme[20]

The ship is given an EPI score between 0 and 100 for each port call, mainly based on the ship's emissions of CO_2, SO_2, NO_x and PM while docked. As principally shown in Figure 6, the EPI score is calculated based on the ship's reported data on

- fuel consumption, including fuel type and quality,
- combustion performance, including waste heat recovery, exhaust gas treatment,
- use of shore power.

This score is subsequently converted into an adjustment factor applied to the port fees. Exactly how the EPI score is applied is up to each port to decide. For example, the Port of Bergen links the EPI with fees regarding quay dues, passenger fees, ISPS-fee and fairway dues.

4.3 Clean Shipping Index (CSI)

The Clean Shipping Index is an independent reporting and labelling system of the environmental performance of ships and shipping companies. The CSI tool consists of a questionnaire of 25 basic questions on the ship's environmental performance, going beyond existing rules and regulations and covering existing ships of different types. The self-assessment needs to be verified by an accredited third-party organization like DNV GL[21]. Table 2 gives an example of scoring for different requirements[22].

For refrigerants used in centralised AC and refrigeration systems onboard, a score is given when all refrigerants comply with the CSI standard. For scoring, the refrigerants should be natural (NH_3, CO_2) or an HFC with GWP < 3500. Additional points (3p) are achieved if the GWP is below 1850.

Regarding CO_2 emissions, the score is based on how the vessel's EEDI relates to the EEDI requirements, but the figure is reported as an EEOI. For cruise and passenger ships the EEOI is calculated as grams CO_2 per passenger-nautical mile.

Table 2: Example of scoring in the CSI reporting system

Emission	Requirement	Scored points
Refrigerants	GWP < 3500	1
	GWP < 1850	3
CO2	EEOI at reference EEOI	15
	EEOI 25% lower than reference EEOI	30
NOx	Shore power	9
	Plug-in-batteries	9
SOx	Shore power	5
	Plug-in-battery / fuel cell/ wind or similar	5
PM	Shore power	5
	Plug-in-battery / fuel cell/ wind or similar	5

Note that the ship will be given a good score when connected to shore power, but the need for thermal supply in port is not addressed. The tool does not specifically consider waste heat or boiler, except from chemical products used for treatment of boiler water or cooling water.

5 Concluding remarks

From the review of compulsory and voluntary environmental indies applied in the shipping sector, with a focus on cruise ships and the thermal energy systems, the following indicative conclusion are drawn.

The compulsory IMO indices related to energy efficiency and CO_2 emissions implies concerns for cruise and passenger ships, such as:

- The ship's various operational conditions, e.g., port stay and ambient conditions, are not considered.
- The use of oil-fired boilers is not specifically addressed.
- Waste heat recovery is not considered unless applied for electric power generation.
- The large proportion of hotel load can lead to mis-leading CO_2 emission ratings, specifically related to changes in ship speed.

Classification societies offer voluntary environmental class notations, rating the ship's compliance with stricter requirements. The heating and cooling systems onboard are seldom specifically addressed, with a few exceptions:

- Most class notations include requirements on the refrigerants GWP value.
- The RINA class notation GREENPLUS is based on an environmental index that also considers the hotel systems onboard.

Various environmental indices are applied for rewarding low emission ships through, for example, differentiation of port fees.

- Most indices are based on the ship's emissions of CO_2, SO_x and NO_x while sailing, but the Environmental Port Index (EPI) aims at assessing the emission level while docked.
- All indices reward the use of shore power, while thermal energy supply in port is not addressed.

To facilitate the uptake of energy-efficient and environmentally cooling and heating technologies, the suggestion for further work includes:

- Quantified evaluations of the influence of these technologies on the environmental indices, in relation the actual reduction in the ship's energy usage and emissions.
- Propose new and/or adapted indices for a more equitable assessment of these technologies.

6 References

1 Energy Efficiency Measures, imo.org (2019)
2 Further shipping GHG emission reduction measures adopted, imo.org (2021)
3 Energy Efficiency Technologies Information Porta,l IMO-Norway GreenVoyage2050 (2021)
4 2018 GUIDELINES ON THE METHOD OF CALCULATION OF THE EEDI FOR NEW SHIPS imo.org (2018)
5 Increasing energy efficiency in passenger ships by novel energy conservation measures El Geneidy R., et al., (2018)
6 A Comparative Analysis of EEDI Versus Lifetime CO2 Emissions Trivyza N., et. al. (2020)
7 Decarbonize shipping - DNV, dnv.com (2021)
8 EEXI – Energy Efficiency Existing Ship Index. dnv.com (2021)
9 EEXI for ro-ro / ro-pax Interferry (2020)
10 CII – Carbon Intensity Indicator - DNV, dnv.com (2021)
11 IMO working group agrees guidelines to support new GHG measures, imo.org (2021)
12 IMO REGULATIONS COULD INCREASE CRUISE SHIP CO2 EMISSIONS, Foreship (2021)
13 Environmental Class Notations dnv.com (2021)
14 Rules for Classification - Part 6 Additional class notations Chapter 7, Edition July, 2021 dnv.com (2021)
15 THE ENVIRONMENTAL PROTECTION NOTATIONS FOR VESSELS JANUARY 2021, American Bureau of Shipping (2021)
16 Rules for the Classification of Ships Effective from 1 July 2021 Part F Additional Class Notation, RINA (2021)
17 RULES FOR THE CLASSIFICATION OF SHIPS Part F Additional Class Notations, Bureau Veritas (2020)
18 PORT OF OSLO AS A ZERO-EMISSION PORT, City of Oslo (2018)
19 How the EPI Works | Environmental Port Index, epiport.org (2020)
20 Green Shipping Programme - DNV dnv.com (2019)
21 Clean Shipping Index (CSI) dnv.com (2018)
22 Methodology-Reporting-Guidelines.pdf Clean Shipping Index (2020)