



IMO

E

INTERSESSIONAL MEETING OF THE
GREENHOUSE GAS WORKING GROUP
2nd session
Agenda item 2

GHG-WG 2/2/22
6 February 2009
ENGLISH ONLY

CONSIDERATION OF THE ENERGY EFFICIENCY DESIGN INDEX FOR NEW SHIPS

CO₂ reduction requires efficient instruments based on sound technical solutions

Submitted by the Community of European Shipyards' Associations (CESA)

SUMMARY

<i>Executive summary:</i>	This document provides conclusions from the trial application of the draft Energy Efficiency Design Indexing (EEDI) to complex, highly optimized ships. The results show that fundamental elements of the EEDI concept have not been developed to a level of technical maturity that would allow mandatory application. CESA describes problems that still have to be resolved and proposes improvements of the baseline. CESA strongly recommends fully developing and verifying all aspects of CO ₂ indexing before approval and reiterates that complementing market-based instruments are indispensable.
<i>Strategic direction:</i>	7.3
<i>High-level action:</i>	7.3.1
<i>Planned output:</i>	7.3.1.1 and 7.3.1.3
<i>Action to be taken:</i>	Paragraph 33
<i>Related documents:</i>	MEPC 58/4/8, MEPC 58/4/12 and MEPC 58/WP.8

Background and introduction

1 CESA would like to reiterate that an efficient approach towards reduction of GHG emissions from international maritime transport is urgently needed. The European shipbuilders and ship-repairers will contribute significantly to the global combat against climate change through technical innovation implemented in new ships and in major conversions of existing ships. The necessary innovation in ship design and marine equipment can most efficiently be promoted by market-based instruments (MBI) that provide incentives to develop state of the art energy efficient designs. In particular, MBI can be applied to both new and existing ships resulting in immediate reduction of maritime GHG emissions.

For reasons of economy, this document is printed in a limited number. Delegates are kindly asked to bring their copies to meetings and not to request additional copies.

2 CESA is deeply concerned about the limited progress made at MEPC 58 with regard to MBI and the excessive focus that is placed on EED indexing as the sole mandatory measure to limit maritime CO₂ emissions before this instrument has reached a level of technical maturity that is necessary to ensure consistent, verifiable and fraud-resistant implementation.

Trial application and discussion of the draft Energy Efficiency Design Index and baseline

3 Since MEPC 58, CESA member shipyards in close co-operation with leading European technical universities have conducted trial applications of the draft EEDI and the related baseline concept in order to verify the applicability to complex ship types that require special technical attention and form the biggest portion of the order book of European shipyards.

4 The main body of this submission summarizes the main findings of several contributions, which are annexed to this submission:

- .1 annex 1 on the *Draft EEDI Regime Versus Typical Design Scenario for RoRo Cargo Vessels in Short Sea Shipping* by R. Nagel (Flensburger Schiffbau-Gesellschaft) discusses the implications of the draft EEDI on the design process of a typical RoRo cargo ship;
- .2 annex 2 on *Concerns about the Energy Efficiency Design Index (EEDI) for RoRo Vessels* by S. Krüger and L. Pundt (TU Hamburg-Harburg) explores the mathematical background for the severe application problems and limitations for the design options;
- .3 annex 3 on an *Alternative Baseline Concept for the Energy Efficiency Design Index (EEDI) for RoRo Vessels* by S. Krüger and L. Pundt (TU Hamburg-Harburg) provides the proposal for an improved version of the baseline using speed and capacity as parameters; and
- .4 annex 4 contains the proposal of the Euroyards Technical Committee highlighting the need for further development and modifications to the EEDI in order to accommodate the concept of diesel electric power generation.

Observations and conclusions

5 The trial application of the draft EEDI with complex ship types shows a higher level of scatter than standard ship types, such as bulk carriers, tankers and container vessels. The bandwidth of the data increases towards smaller ships.

6 The significant scattering of data is induced by several sources. With ship types that carry a lot of (safety related) equipment, the draft EEDI is not capable of modelling the design peculiarities in an appropriate manner. The foremost factor influencing the EEDI, however, is the speed resulting in a bad baseline regression with ship types where larger deviations from average operating speed can be expected.

7 The baseline formulation based on capacity as the only parameter makes it impossible to distinguish between the different parameter influencing the attained EEDI. Therefore, the reasons for differences between the required and attained EEDI cannot be assessed and the result does not contain any information about the quality of energy efficiency optimization of the design.

8 The current EEDI formula could produce misleading results: highly optimized ship, designed by means of state of the art tools for hydrodynamic and structural optimization and the best available energy efficient equipment, could appear to be less efficient than an outdated and badly-designed ship for the sole reason that the former is capable of operating at a slightly higher speed or features additional redundancy power.

9 Although the draft EEDI formula contains a large number of variables and factors, the options for optimization available to the ship designer are quite limited (ref. to Annex 1). Simplified to the significant parameters, the draft EEDI takes the following form that allows for easy exploration of available design options for optimization of the energy efficiency of a ship:

$$EEDI \approx \frac{C_F \text{ SFC } P}{\text{Capacity } V_{ref}}$$

- .1 Fuel factor C_F : the non-dimensional conversion factor between fuel consumption and CO₂ production is based on the carbon content of the fuel used. Gas fuels have slightly lower values than oil fuels. But since the fuels do also differ in calorific value the use of cleaner fuels (in terms of C_F) does not translate into similar CO₂ reductions. Although gas-fuelled engines could in future reduce the GHG emissions, this potential cannot be exploited yet since no international regulations exist for the use of gas as ship's fuel. Therefore for the time being C_F is not considered to be a viable design option for the optimization of the energy efficiency;
- .2 Specific Fuel Consumption SFC : also the SFC does not offer much room for improvement since modern diesel engines have been significantly improved through decades of innovation resulting in a mature power generation device that nowadays operates as close as possible to the theoretical thermodynamically achievable efficiency. The SCF values do not differ greatly between engine makers and the residual improvement potential is limited. In contrast, it can be anticipated that other emission reduction requirements, e.g., NO_x and SO_x, could result in detrimental side effects on the CO₂ production. The overall meagre SFC reduction potential does therefore not constitute an encouraging option for optimization;
- .3 Capacity: depending on the ship type, different possibilities exist to increase the capacity of a vessel. The reduction of the light ship weight through structural optimization, or the advanced concepts in internal design, could increase the capacity, e.g., the deadweight or lane meters of a ship. Since the capacity appears both in the EEDI and in the related baseline, which form the left and right hand side of an (in)equation, the significance of the capacity as an option for optimization depends on the value of the baseline regression parameter c . If c is relatively high, which is the case with RoRo vessels, this option does only contribute marginally to the optimization opportunities to meet the required EEDI. In addition an increase in capacity does not correspond to the transport task requested by the owner; and

- .4 Power P: the power demand for a given design speed can be reduced through hydrodynamic optimization in order to reduce the frictional and wave resistance. Whereas the frictional resistance can only be marginally improved, the optimization of the hull form can be achieved by means of model test and CFD analyses, etc. This significant reduction potential is, however, overshadowed by the influence of a reference speed reduction.

10 This assessment of the theoretical options available to lower the EEDI values shows that for the time being the foremost option to adapt to the requirements set by the baseline is to modify the design speed. The simplistic nature of the draft EEDI, however, does not ensure that the modified ship design will result in lower CO₂ emission.

11 In many cases, the EEDI will only act as a speed limit for newbuildings, which could be achieved in a more efficient, reliable, implementable and fraud-resistant manner through straightforward incentives to reduce or limit the dimensionless speed of a vessel, namely the “Froude Number” (F_n):

$$F_n = \frac{V_{ref}}{\sqrt{g L_{PP}}}$$

12 In addition, it has to be acknowledged that the ship design has to respect the transport task defined by the shipowner, which is influenced not only by the transport work (capacity multiplied by the speed) but also by several factors such as sailing schedules, fleet structure, etc.

13 In order to encourage improvements of the fuel efficiency for all ship types and speed classes the design index must take into account operational aspects, which cannot be assessed through a single ship approach based on design parameters only. Also the speed at which transport work is performed is crucial for the access of maritime transport to certain cargoes and therefore beneficial for the society and the environment.

14 In order better to understand those drawbacks from the ship designer’s point of view, the draft EEDI has been thoroughly investigated from a mathematical perspective. Annex 2 explains the relation between hydrodynamic optimization and speed reduction in detail, while keeping all abovementioned parameters constant that do not offer a reasonable CO₂ limiting potential.

15 The main findings, which are derived from an assessment of several modern, highly optimized RoRo vessels, can be summarized as follows (refer to figure 1 of annex 2):

- .1 the hydrodynamic optimization to achieve the required EEDI, namely the reduction of the Residual Resistance Coefficient C_R , is possible in a narrow range of F_n only, e.g., between $F_n = 0.2$ and 0.23 for the sample RoRo ships under consideration;
- .2 if F_n is higher a permissible EEDI can only be achieved by speed reduction or design of fully submerged RoRo submarines; and
- .3 on the other hand, for vessels operating at low F_n the required index can be achieved far too easily. Therefore, the index does not set any incentives for the

improvement of the energy efficiency and does not contribute to the goal of an overall reduction of CO₂ emissions for all ships regardless of size, speed or type.

16 The scientific evidence produced for RoRo ships is conceptually straightforward and convincing. Equivalent results can in principle be expected for other complex ship types.

Proposal for an improved baseline formulation

17 Since the draft EEDI does not take into account the speed power relation, which derives from the unavoidable wave resistance of surface vessels, it is not appropriate to use capacity as the only baseline regression parameter.

18 This fundamental error in the baseline concept, as proposed in document MEPC 58/4/8, can be avoided if both speed and capacity are used as input variables for the baseline *B*:

$$B = a \cdot \left(\frac{V_{ref}}{Capacity} \right)^{-c}$$

19 The Technical University of Hamburg-Harburg has investigated this new baseline concept for RoRo vessels. The results of this study are summarized in annex 3.

Proposal for further modification of the draft EEDI

20 Even with an improved baseline definition the technical development of the EEDI itself has to continue. It is recalled that the GHG Working Group at MEPC 58 was not in the position fully to consider the various problems arising from specific ship design configurations and identified the remaining tasks to be carried out concerning the new EEDI, including the correct development of a definition of propulsion power for diesel-electric propulsion systems and auxiliary power. Passenger ships and RoRo passenger ships have a significant power demand for non-propulsion purposes. These ships require clear provisions for the calculation of the CO₂ production for all configurations of main and auxiliary power generation and propulsion systems.

21 It is also noted that the benchmarking undertaken so far does not include electrically propelled ships. The database does not provide adequate distinction of the installed machinery and therefore all modern cruise ships have been excluded from the evaluation.

22 Cruise ships have to comply with specific safety requirements, such as the new SOLAS Safe Return to Port regulations for passenger ships, entering into force in July 2010, which are additionally driving the need for more redundancy in power networks. Power redundancy is an important safety factor and this aspect is to be addressed to avoid penalizing ship safety.

23 Annex 4 provides further development of a meaningful formulation for the EEDI that takes into account the design principles of such complex ships, electrically propelled, with the purpose of allowing designers, builders and operators the opportunity to develop commercial designs that meet market needs while still delivering the desired environmental benefit.

24 In particular, modification demands arise from diesel-electric propulsion. The diesel-electric power generation and propulsion concept widely used on board cruise ships

and other passenger vessels does not allow a distinction between main and auxiliary engines as required by the draft EEDI, since the total electrical power generated by several generator sets is distributed via switchboard to several consumers.

25 Also, RoRo passenger vessels form a very complex ship type comprising a variety of arrangements and transport concepts operating in a short sea shipping environment. Vessels in this category range from cargo (trailer) oriented high deadweight ships to cruise ferries focusing on passengers with only limited car deck capacity. Therefore, the capacity definition requires special consideration in order to reflect the specific benefit for the society related to both cargo and passenger transport.

Summary and recommendations

26 The trial application of the draft EEDI under consideration still reveals severe conceptual problems that prevent the index from providing the necessary incentives to facilitate the overall reduction of CO₂ emissions from ships.

27 Without adequate modelling of the fundamental physical relation of the speed power relation of surface vessels, it cannot be expected that energy efficient ships can be distinguished from badly designed polluters with the necessary exactness. The introduction of several new factors intended to improve the adaptability of the concept to the variety of ship designs does hamper the efficient, homogenous and fraud-resistant application to all ship types and speed classes that are needed to fulfil the various task of maritime transport.

28 Therefore, it is recommended to keep the EEDI for the time being as simple as possible and to gain experience through further trial applications to existing ships and new designs.

29 Further improvements of the EEDI concept could be anticipated by modifications of the baseline formulation as proposed in paragraphs 18 to 20 and annex 3 of this submission.

30 It is also recommended to consider further development of the EEDI formulation for ships with diesel-electric power generation, with specific reference to the design principles of modern cruise ships.

31 The European shipbuilders and ship-repairers will continue contributing to the development of any CO₂ reduction initiatives including energy efficiency indexing. CESA, however, would like to reiterate that MBI or other measures aiming at existing ships are considered to be more efficient regarding ease of application and reduction potential on both the CO₂ and the time-scale.

32 Finally, CESA would like to voice concern that any mandatory application of the EEDI in conjunction with the baseline concept proposed in document MEPC 58/4/8 (Denmark) would be extremely premature, could impose significant damages to maritime transport as well as ship safety and induce significant market distortion in the shipbuilding industry.

Action requested of the Intersessional Meeting

33 The Intersessional Meeting is invited to consider the views and proposals presented and take action as appropriate.

ANNEX 1

DRAFT EEDI REGIME VERSUS A TYPICAL DESIGN SCENARIO OF A RORO CARGO VESSEL IN SHORT SEA SHIPPING*

General

1 The following trials have been performed by Flensburger Schiffbau-Gesellschaft in order to investigate the consequences of the draft EEDI regime on the design of RoRo cargo vessels, if such an instrument will become mandatory. A modern state of the art design has been chosen as example. The focus is the mechanism, how the EEDI works and influences the future design on vessels in principle.

2 A RoRo cargo vessel is typically designed based on the main capacities prescribed by the owner(s) in order to deliver a certain transport task as follows:

Cargo capacity

3 First of all, the cargo or transport capacity will be decided based on the needs of the owner in terms of lane meters or trailer capacity. Instead of trailer capacity, the required capacity of Mafis or cassettes may be given in order to provide transportation of more specialized RoRo cargo.

4 This main capacity will generally determine the size of the vessel, together with possible restriction of the main dimensions such as harbour restrictions for length, draught or in some cases even in breadth due to the limited size of locks.

5 RoRo vessels are in general rather truck or lane meter carriers than deadweight carriers. Therefore it is suggested to use lane meters as capacity (or Gross Tonnage) unit when calculating the EEDI of RoRo ships.

Deadweight

6 Payload: The kind of RoRo cargo is important in order to define the required deadweight for the vessel. Trailer weights including cargo are typically in the range of 20 to 30 t per unit on average, whereas the average unit weight for cassettes (e.g., paper rolls on cassettes) or Mafis (double stacked 40' containers on Mafi) might be in the range of 45 to 60 t. Single weights end up at 90 t per unit. Depending on the type of cargo, the payload requirement thus varies easily by the factor of two, although all these vessels are categorized as RoRo vessels.

7 Bunker & Stores: As RoRo cargo vessels are mainly used in short sea shipping, the amount of bunker and stores is generally in the range of approximately 1500 to 2000 t (heavy fuel oil, diesel oil, lubricating oil, freshwater, stores).

* Prepared by Rolf Nagel, Flensburger Schiffbau-Gesellschaft mbH.

8 **Ballast Water:** In order to provide good seakeeping behaviour and to protect the cargo against damages, roll stabilization tanks or fin stabilizers are installed. Those systems need extra water in the range of 500 t, whereas in some cases, even ballast water is needed to maintain the stability of RoRo cargo vessels and thus are part of the deadweight. This extra ballast water might reach up to 3000 t. Fin stabilizers are part of the lightweight and thus lead to a decrease of deadweight. Roll stabilization tanks need an amount of water in the range of 200 to 800 t and this amount of water is included in the deadweight.

9 The overall required deadweight thus includes the components payload (which shall be transported in a certain time as benefit for the society), bunker and stores, anti-heeling water, roll stabilising water and ballast water.

Speed

10 The speed is generally chosen to meet various requirements like regular departure times, rest times for drivers and other time dependent traffic constraints in ports.

11 A total amount of cargo needs to be transported from port A to port B in a certain time (as a benefit for the society) and this has to be performed at lowest costs for ship owners and thus for the customers.

12 With this scenario in mind, the number and size of ships and corresponding speed will be decided in an economical evaluation.

Sample scenario

13 For a transportation of trailers and Mafis between port A and port B, the economical evaluation resulted in two twin screw RoRo vessels to be projected, having 4200 lane meter each, a maximum deadweight of 12500 t at 7.05 m maximal draught and a service speed of 21.5 knots equivalent to a Froude Number of 0.255. The installed main engine power is 20.790 kW.

14 The deadweight composition as described above for this projected vessel was:

Bunker and stores	2000	t
Anti heeling water	500	t
Roll stabilization water	250	t
Payload	9750	t
Total deadweight	12500	t

15 The chosen service speed resulted also from optimization of loading and unloading procedures by simulation, excellent manoeuvring capabilities in port in order to reduce the time in port and thus cut down the required service speed. This was found to be the economic optimum.

16 There have been no restrictions of main dimensions; this is in favour in order to design a hull form, which can be optimized in the best possible way. The hull form was model tested with excellent results.

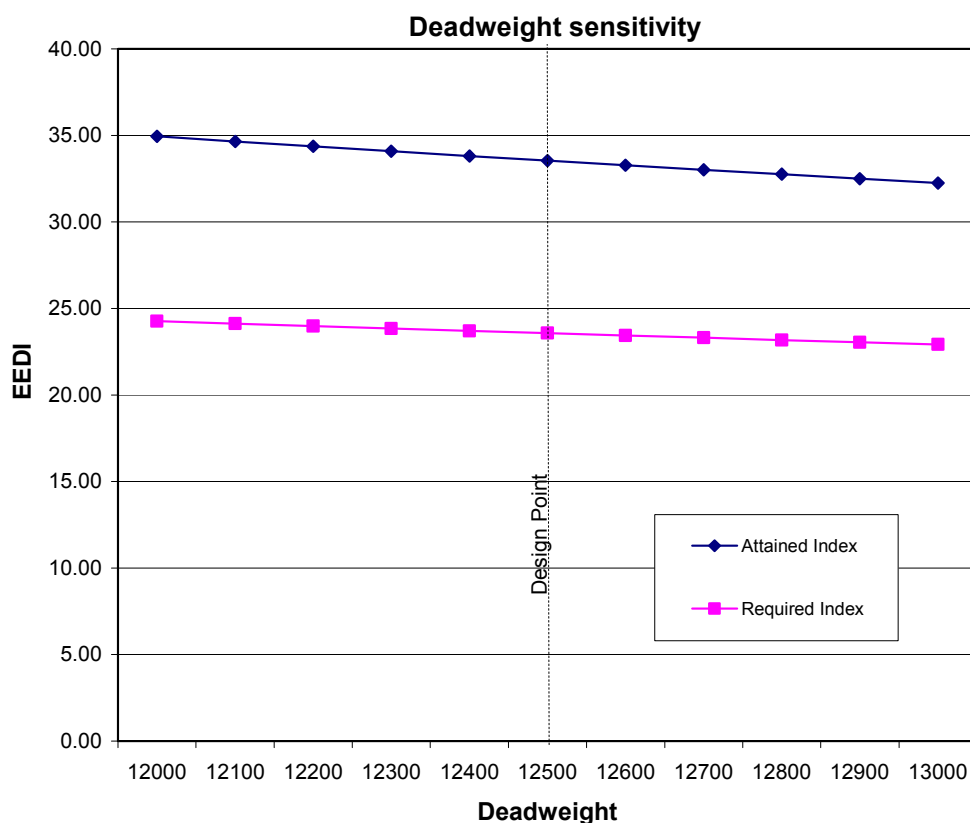
17 In order to achieve 21.5 knots service speed at the maximum draught of 7.05 m, two main engines with a total installed power of 20790 kW at maximum continuous rating (MCR) are projected. The following margins have been included: 15% engine margin, 2% gear box losses and 10% sea margin, generally corresponding to the 75% MCR to be taken into consideration with the EEDI calculation procedure. Shaft generators in sea condition can also be used at a reduced engine margin.

18 The EEDI of this projected vessel then is calculated to be 33.54 g·CO₂/t·nm, using the projected dwt as capacity acc. to the formula as agreed for trial applications of MEPC 58/WP.8.

19 The projected vessel has an EEDI significantly higher than that permitted by the baseline, which is 23.57 g·CO₂/t·nm using the regression line $y = 19788 x^{-0,7137}$. This is quite surprising, as the vessel is hydrodynamically optimized with numerous CFD studies and the model test results have been extremely good with respect to the wave pattern and wave resistance coefficient (approximately $0.58 \cdot 10^{-3}$).

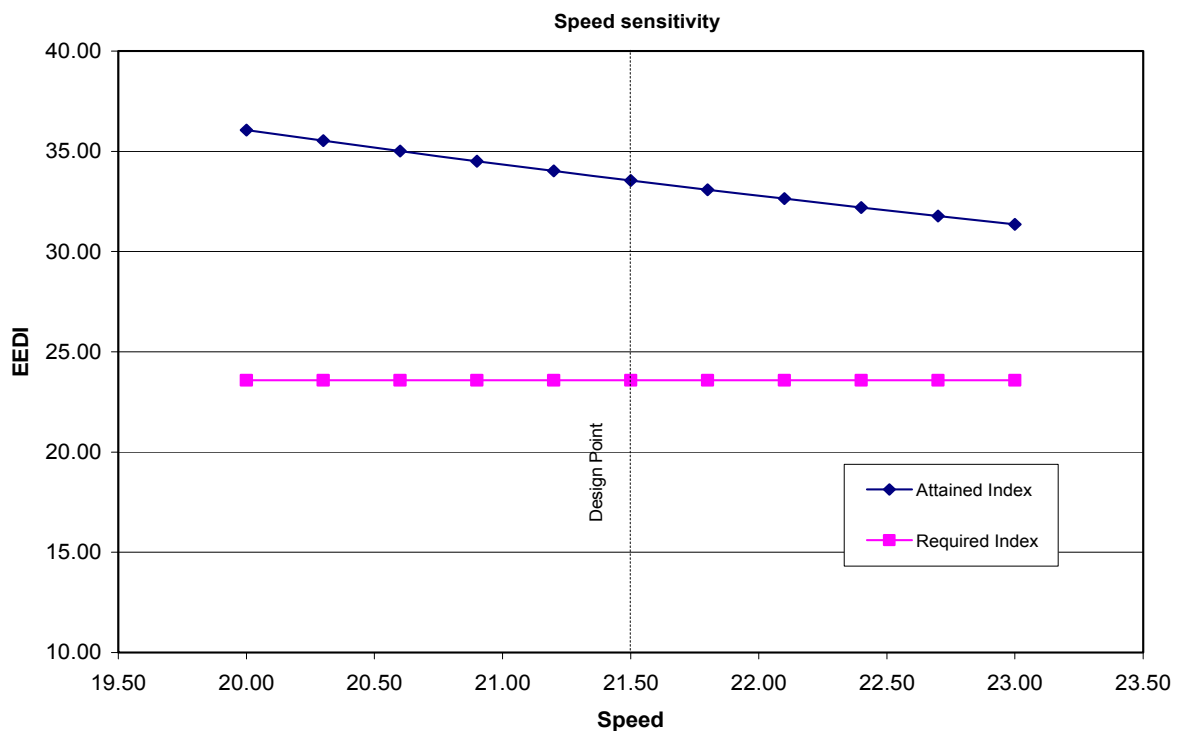
20 The following options have been investigated in order to meet the draft EEDI baseline:

- .1 Option 1 – Deadweight optimization: the use of light weight construction would result in an increase of deadweight above 12,500 tons (although not required by the owner) but a variation of the deadweight while keeping all other parameters constant in the EEDI formula was not promising. With increased deadweight, the required and attained EEDI have nearly similar slope and a point interception will not be reached in a reasonable deviation from the design point:



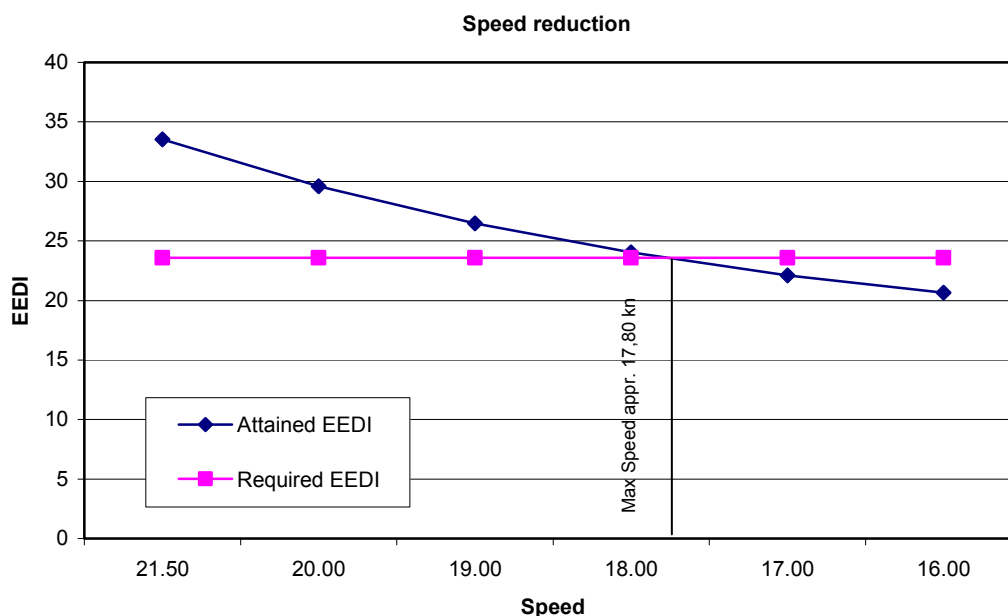
Instead of increasing the deadweight, the hull form could also be modified, resulting in a slightly lower block coefficient and thus less installed power, which of course is, in principle, beneficial for the attained EEDI. Light weight construction is not always the preferred solution by owners due to wear and tear especially on the RoRo cargo decks, but yards will be encouraged to use this option in order to gain a better attained EEDI.

- .2 Option 2 – Hydrodynamic optimization: By means of improved lines, propulsion, etc., the designer tries to achieve a higher speed out with the same installed power. The speed sensitivity is limited: the required index stays the same, whereas more speed only gives very little benefit.



In order to maintain the design point it is preferred to reduce the installed engine power while keeping the design speed constant. This option is investigated and the installed power was reduced in order to press the attained index just below the required index. At a value of 14,500 kW, the attained index became equal to the required index. Comparing 14,500 to 20,790 kW is a reduction of 30% in engine power, which is definitely unrealistic and physically impossible. The frictional resistance of the vessel is given by the surface of the wetted hull and is calculated according to the well known law of nature, thus only the wave resistance can be improved. If the wave resistance is already extremely small as for this projected design, it must be close to zero or even negative in order to allow for the power reduction. This solution has been declined. At project stage also a certain margin needs to be considered and will definitely become part of the contract between yards and owners in a mandatory EEDI regulatory regime. Therefore, the required power reduction will be even higher than 30% in real life.

- 3 Option 4 – Speed reduction: The only practical way to comply with the required EEDI is the option to reduce the speed along the predicted speed/power curve from the model tests as long as there is an interception point between the required and the attained EEDI. This point was found at a speed of 17.8 knots.



Consequences for the future design process

21 The EEDI also acts as a limitation of the total installed main engine power. In this example 12150 kW can be installed as a maximum, any higher power would directly violate the required EEDI. A typical set of main engines for the projected vessel has $2 \cdot 6000 = 12000$ kW, thus the installed power is too low. As a consequence, the maximal speed will be further reduced. The next step of available engines is $2 \cdot 7000 = 14000$ kW, but then, the main engines have to be derated to 12150 kW to exploit the maximal benefit from the design.

22 Any additional sea margin, engine margin, etc., is prohibited by the mechanism of the EEDI. Again, the only possible way to care for extra margins beside those incorporated in the EEDI is to further reduce the speed and while keeping the attained below the required EEDI. As the sea margin is more or less independent from the speed, the typical range of sea margin in percentage must be increased in the future, as the absolute value is the relevant figure (e.g., 10% of the installed power = 2079 kW, thus 17.1% sea margin is required). Otherwise the vessels will be underpowered to keep the time schedule or to manoeuvre in bad weather.

23 As a consequence of this mechanism, it is evident that paragraph ships will be designed in the future. From an operators point of view generally a maximum speed at the design draught (not at maximum draught where the EEDI refers to) is required. Any speed from 18.5 to 20.5 knots can be adjusted for the sample design. From this point of view, as much power as possible under the EEDI regime might be used and any further safety aspects like additional sea margin, redundancy, shaft generator operation, etc., will be neglected in order to achieve a high speed. Any required flexibility by the owner or ship designer is thus obstructed.

24 In order to adapt the vessels to a fixed transport schedule two options are in general possible:

- .1 Option 1: Three slightly smaller vessels with reduced speed are necessary to ensure the same transport task. Although they will have a lower installed engine power, the absolute CO₂ emission is difficult to predict, as these vessels are obviously much longer at sea in the same time period and auxiliaries of three vessels instead of two are running all the time. Depending on the actual duty cycle, the possible amount of CO₂ reduction can be calculated for each individual transport task only but not in general.
- .2 Option 2: If no restriction of main dimensions apply, two vessels with approximately 5,300 lane metres each are needed which indeed are very big ships for short sea shipping. As a rough idea, an increase in lane metres by 1,100 m corresponds to a ship which is more than 30 m longer. Alternatively, the breadth may be increased (to reduce the lengthening) with massive impact on steel structure and layout of RoRo cargo holds due to even longer span of deck stiffening structures. Typically, extremely wide RoRo vessels suffer from a non-proportional increase of steel weight and very bad stability characteristics due to high breadth/draught ratio. In many cases, traffic flow will be hampered by pillars or extra supporting walls.

We would guess that such a RoRo vessel operating at approximately 17 knots might need an installed main engine power of 13,500 kW. This vessel could by chance fit into the EEDI regime but tremendous costs for new harbour infrastructures are necessary and must be added to the holistic approach for an economical comparison and have to be weighted against the gained CO₂ reduction.

Conclusions

25 Assuming that the proposed baseline could be used in a mandatory EEDI regime, many new vessels especially in short sea shipping simply will have to reduce their speed in the future. The example provided clearly demonstrates that on the long run a speed limitation is the natural consequence, as the required size of the vessel in terms of deadweight or GT is well prescribed by the owner in most of the scenarios and an unlimited growth in size is not adequate due to many restrictions for main dimensions in the short sea shipping business.

26 The consequences as shown are of various nature and cannot be answered by big and slow steaming ships only. The severe risk of evading an existing industry and change of volume to other, less CO₂ efficient transport modes is quite obvious and needs to be taken into consideration in the further discussion in the GHG working group. Most probably, older vessels will remain for a long time in the fleet as they do not suffer from the speed limitation.

27 The effect of implementing a CO₂ reduction regime by a mandatory EEDI on the RoRo short sea shipping industry cannot be predicted at all at the moment and needs careful further investigations. A total figure for CO₂ reduction cannot be delivered by this proposed regulatory regime, because the nature of the EEDI inherently does not produce such information, which is of vital importance for a discussion of future effectiveness of an EEDI regulatory regime.

28 The question will be which increase of the costs for transportation might be acceptable to the community to reduce a certain amount of CO₂. This is not part of the technical discussion here, but needs to be considered when implementing a new regulatory instrument at IMO in order to be compared to other possible instruments like, e.g., CO₂ emission trading scheme.

ANNEX 2

SOME CONCERNS ABOUT THE ENERGY EFFICIENCY DESIGN INDEX (EEDI)
FOR RORO VESSELS*

Summary: *Several RoRo ships, which were known to be very fuel efficient, were analysed according to the proposed EEDI- concept. It was found that this EEDI actually results in a severe speed limit for those ships. It was further found that this type of ship can fulfil the EEDI only at physically impossible negative wave resistances for their desired design speed. This is due to the fact that the present EEDI violates commonly accepted physical principles of the powering of ships. It is strongly recommended to review the EEDI concept or to introduce a better speed dependency into the future baseline definition.*

At the Institute of Ship Design and Ships Safety of Hamburg Technical University, the Energy Efficiency Design Index (EEDI) has been implemented into the existing ship design software. This allowed the use of our design data database of about 60 recently build RoRo and Ro-Pax vessels, which included reliable model test data with respect to the hydrodynamic performance of the investigated ships. The proposed baseline of DNV has been used to simulate a required EEDI and its impact on ship design. At first, all ships were investigated with respect to the EEDI obtained and they were found to be roughly in line with the DNV investigations, see Figure 2. **It has to be remarked that the general scatter of the data is significant.** It was further found that this large scatter does not represent the fuel efficiency of different ships; instead it represents only the deficit of the proposed EEDI concept. Therefore, some ships were investigated in more detail.

The calculation procedure was the following: for a given ship with a certain deadweight and speed, the required EEDI results in a maximum installable main engine power for propulsion purposes. This calculation is valid for the full scantling draft of the ship. On design draft, including sea and engine margin, this maximum allowed installable power by the EEDI results in a maximum speed the ship can achieve at design draft under design conditions.

For all investigated RoRo ships it was found that this maximum allowable speed is drastically smaller compared to the speed the ship was designed for, so the present EEDI concept clearly results in a significant speed limit for RoRo ships.

It may be argued that these ship designs may be inefficient ones with respect to their fuel consumption, as their attained speed loss is that high. Therefore, we further investigated the possibility of improving the ships designs with respect to hydrodynamic performance. In a second step, we have postulated that a ship shall be operated at its **desired design speed** and must be optimized to meet the EEDI requirements. This results in a theoretical reduction of the ships resistance which is to be achieved by the optimization. As the frictional resistance can hardly be influenced by the ship designer, especially for fuel efficient ships with small block coefficients, the only possibility for optimization is the **reduction of the wave resistance**. Therefore, we have computed the necessary wave resistance which is to be obtained for the ship to fulfil the required EEDI. If that permissible wave resistance becomes zero, the ship must be operated as a submarine.

* Prepared by S. Krüger, L. Pundt, TU Hamburg- Harburg.

As an example, we have selected the ship which has the **best hydrodynamic performance** of our data base, which is represented by the smallest residual resistance coefficient C_R . The results are shown in Figure 1. The ship gets an attained index of 48.6, whereas the required index would amount to 29.0. On the other hand, the ship has an extremely low power demand at its design speed of 22.5 knots, indicated by an extremely low C_R value of 0.8E-3 at design speed. The graphs in Figure 2 show that the permissible speed occurs where both curves intersect, which is the case for $F_n = 0.21$, corresponding to a ship speed of 18.3 knots. The ship was actually designed for a speed of 22.5 knots ($F_n = 0.255$), and the graph shows that the required wave resistance to meet the EEDI requirements must actually be negative:

If this (already very efficient) ship shall be operated at its design speed of 22.5 knots, the wave resistance to fulfil the EEDI requirements must actually be negative, which means that the ship has to gain energy from the waves. This is clearly not possible due to fundamental physical laws of ship hydrodynamics.

The same trend was also found for all other ships of our database.

On the other hand, the graphs in Figure 1 show the fact that if the speed of the ship is low enough (e.g., below $F_n = 0.2$), the ship will fulfil the EEDI requirements even with a significantly increased wave resistance. Regardless of the actual limiting value of a possible baseline, this will definitively lead to the fact that slower ships will, according to the present EEDI concept, become significantly more inefficient compared to existing ships. This will lead to waste of fuel and increased emissions.

The graphs in Figure 1 clearly show that there is a fundamental different slope of the actual C_R value of the ship and the required C_R according to the EEDI concept. **This is due to the fact that the actual proposal of the EEDI clearly disregards fundamental physical principles of the powering of ships.** The well known principle that the required power of a ship approximately depends on the speed to the power of three is not reflected by EEDI or by the baseline definition. The latter must at least appropriately take the speed of a ship correctly into account.

This results in the following situation for **RoRo vessels**:

- .1 all the very fuel efficient hull forms we investigated fail to pass the EEDI close to their design speed;
- .2 beyond a Froude number $F_n = 0.25$ (about 22 knots for a 200 m vessel), the required wave resistance to meet the EEDI requirements must become negative;
- .3 the design of RoRo ships beyond a Froude number of 0.22 (e.g., 18.9 knots for a ship of 200 m in length) will be impossible, as their wave resistance must be close to zero;
- .4 if the selected speed of the ship is slow enough, the EEDI allows for totally inefficient ship designs;

- .5 the EEDI is therefore clearly a speed limit, which favours inefficient ships at slow speeds; and
- .6 the above mentioned problems occur due to the fact that the draft EEDI as well as the general baseline concept clearly violates well known fundamental physical principles of the powering of ships.

It is therefore the main conclusion to **replace** the present EEDI concept by an alternative proposal which does take into account the influence of the ship speed on the fuel consumption according to the well known physical principles. This may be done by either modifying the principal formula of the EEDI or by introducing the relevant variables into a future baseline definition.

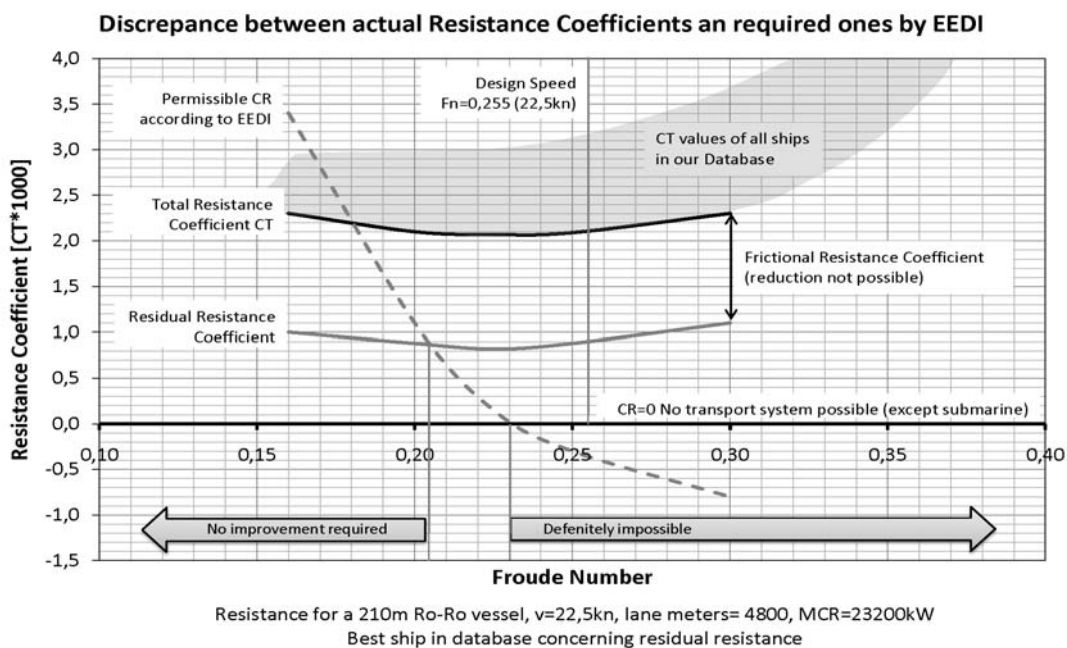


Figure 1: Impact of the EEDI on the most fuel efficient ship of our database. If the ship shall operate at its design speed, the wave resistance must be negative to fulfil the EEDI requirement.

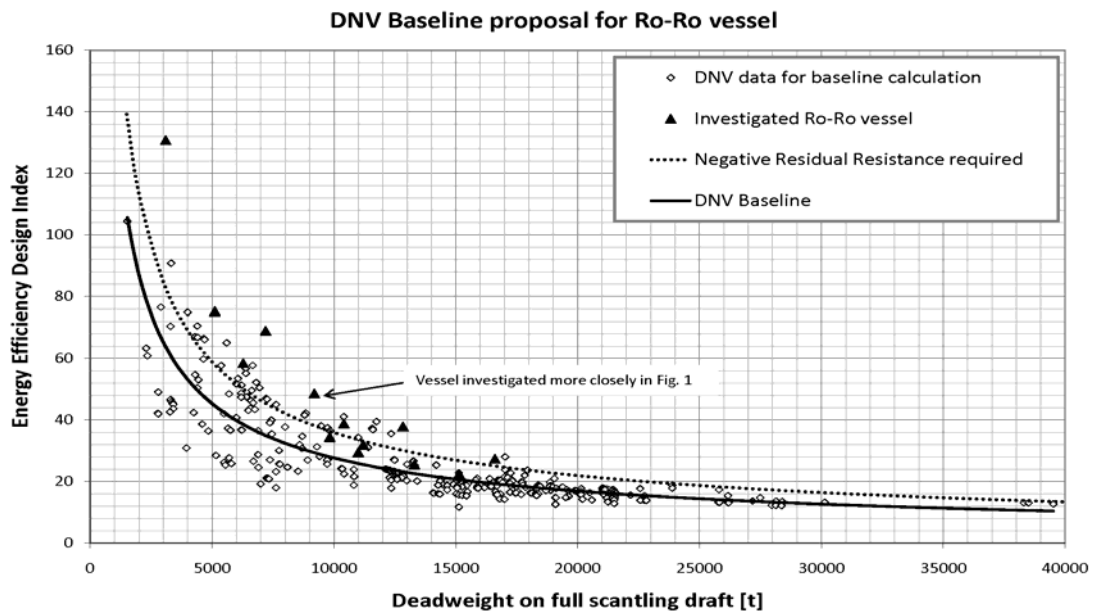


Figure 2: EEDI for all RoRo ships investigated by TUHH compared to the DNV results and the baseline definition. The dotted line indicates an allowable wave resistance of zero, which means that these ships must operate below the surface to fulfil the EEDI.

ANNEX 3

AN ALTERNATIVE BASELINE CONCEPT FOR THE ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR RORO VESSELS*

Summary: *Detailed investigations on the energy efficiency design index for RoRo vessels have shown that there are severe mathematical as well as physical inconsistencies in the actual EEDI proposal as well as for the principal development of the baseline. The latter solely depends on the ships deadweight, but it can be demonstrated from a straightforward mathematical approach that the selection of deadweight as input variable for the baseline definition leads to a clear inconsistency, which makes the EEDI not applicable. In the following, a more feasible alternative is developed which would make the EEDI concept practically applicable.*

At the Institute of Ship Design and Ships Safety of Hamburg Technical University, the Energy Efficiency Design Index (EEDI) has been implemented into the existing ship design software. This allowed to use our design data database of about 60 recently build RoRo and RoPax vessels which included reliable model test data with respect to the hydrodynamic performance of the investigated ships. The proposed baseline of DNV has been used to simulate a required EEDI and its impact on ship design. As one major result, it turned out that the **scatter of the data with respect to the baseline was significant** and it was hardly possible to influence the EEDI by other design measures except by simply reducing the ship speed. This leads us to a more detailed mathematical investigation of the proposed EEDI- and baseline concept, which is presented in the following.

The present EEDI is actually defined as the ratio of an estimated power demand of the ship multiplied by the CO₂-generation of that power demand, divided by the corresponding ship speed and deadweight. The baseline was made solely dependent on the ships deadweight, and a regression formula was developed for that baseline on the basis of several ships investigated (see Figure 1).

This means that the following simplified equation can be put forward for the EEDI and the baseline:

$$EEDI = \frac{\text{Power} \cdot \text{const}}{\text{Deadweight} \cdot \text{Speed}} = \text{BASELINE}(\text{Deadweight})$$

The regression formula found for the baseline is of the following type:

$$\text{BASELINE}(\text{Deadweight}) = c_1 \cdot \text{Deadweight}^{-c_2}$$

This can be written as:

$$\text{BASELINE}(\text{Deadweight}) = \frac{c_1}{\text{Deadweight}^{c_2}}$$

If this baseline definition is compared to the definition of the EEDI, one can immediately see that the deadweight cancels out of the total formula if the constant c_2 would equal to 1. **This clearly means that the EEDI does not depend on the deadweight at all.** However, as c_2

* Prepared by S. Krüger, L. Pundt, TU Hamburg-Harburg.

was not exactly determined as 1, there remains a very weak dependency on the deadweight, which is only a theoretical one as the results of the regression strongly depend on the analysed ships.

Further, if c_2 would equal 1, the deadweight cancels out of the formulae and it remains:

$$\frac{\text{Power} \cdot \text{const}}{\text{Speed}} = c_1$$

It is quite clear that this formula violates any known principle of naval hydrodynamics, as the power of a ship depends at least on the speed to the third power.

This simple investigation clearly shows that the EEDI concept in its actual form is definitively not applicable to RoRo ships, as it does depend on the wrong variables. But the problem can be solved without generally modifying the EEDI definition by an alternative proposal for the baseline definition. If the EEDI is left unchanged, then for RoRo ships, the baseline should depend on the v/dw ratio. This introduces the most important variable speed (v) into the baseline and leaves the unimportant variable deadweight (dw) out.

Therefore, the present proposal suggests developing a baseline proposal for RoRo ships in such a way that now, the ratio v/dw is used as an input variable for the baseline definition of RoRo ships.

CESA has analysed all RoRo ships of our database with respect to that alternative proposal (see Figure 2), and the results do clearly show a significantly reduced scatter of the data, which is a clear proof for the fact the alternative baseline proposal represents the physical laws much better.

If the final regression for that baseline is adjusted correctly, it should also turn out that for some inefficient ships, the best way to reduce the CO₂ emissions is actually a speed reduction. But other than the present EEDI proposal, this alternative baseline concept allows also to reduce emissions by making the ship more efficient.

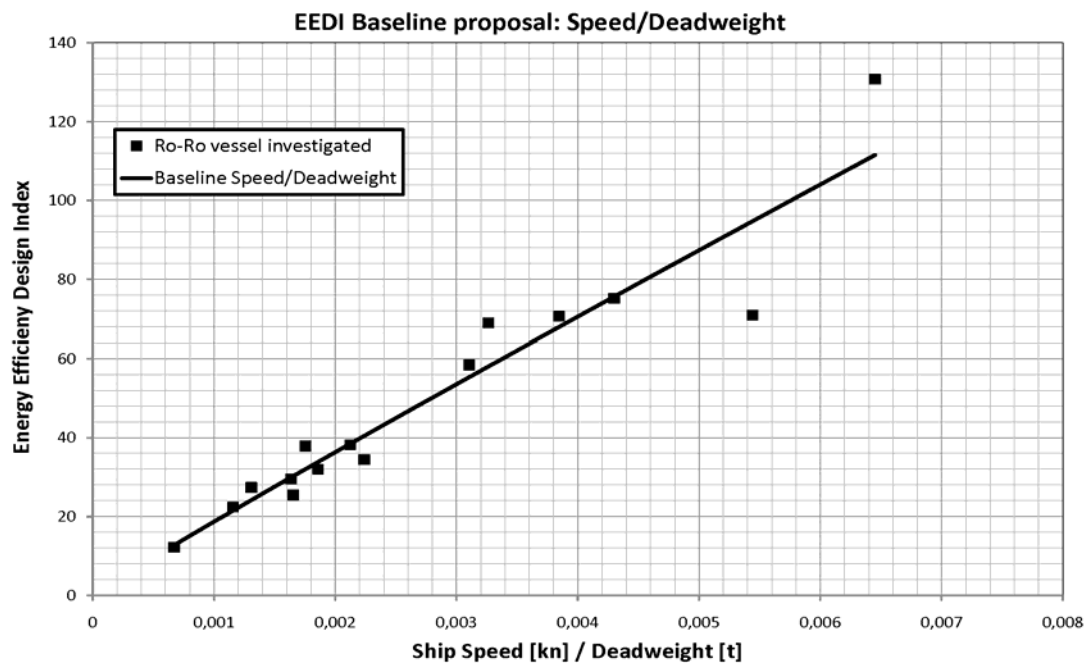


Figure 1: The draft EEDI definition shows good correlation when used with the alternative baseline.

ANNEX 4

PROPOSAL FOR EEDI MODIFICATIONS CONCERNING DIESEL ELECTRIC PROPULSION*

The current EEDI formula as proposed by MEPC 58 has been specifically developed to cover the majority of ship types that have conventional propulsion systems where a prime mover is coupled directly (or via a gear box) to a propulsion shaft, and have auxiliary diesel generators that provide the electrical power. The installed power required for the auxiliary load is very small when compared to the required main propulsion power.

Propulsion systems and auxiliary power distribution networks for passenger ships do not fall into the typical model that has been used to develop the EEDI to date. For example, nearly all modern cruise ships utilize propulsion electric motors, and have no main engines as such. The total electrical load required to supply hotel services typically accounts for about 30% to 40% of the total installed power.

The design of the modern cruise ships is based on using power plants creating energy for both the propulsion and the auxiliary load. For the creation of power nowadays diesel engines, and gas turbines or a combination of both will be used.

The size of the power plant is not only based on the design figures like maximal speed and is furthermore required to consider the demands of the ship operator regarding redundancy, safety requirements and maintenance considerations.

The high redundancy and maintenance requirements of the ship operator are based on the design of the vessel for continuous operation (high penalties for cancellation of cruises).

Another criterion for the power plant design is the operation flexibility of the ship operator to design the vessel to fulfil different operation profiles.

This special configuration for passenger ships requires a dedicated EEDI formula, based on the existing principles, but considering the special situation of the power plant design.

In addition, the ever increasing environmental regulatory regime – both international and local – requires the fitting of more and more equipment, all of which consume more power. While these requirements sometimes apply to all ship types, many are directly linked to numbers of persons on board and therefore the effect is significantly larger on passenger ships. The current EEDI proposal takes no account of these aspects.

The introduction of new safety requirements – for example, those associated with the new Safe Return to Port regulations entering into force July 2010, and ship owners commercial considerations, are quite rightly driving the need for more redundancy in power networks. If the total installed power is used as the benchmark for the EEDI then these designs will be penalized or ship designers will be forced to reduce the safety level.

* Prepared by Euroyards Technical Committee.

An investigation of the auxiliaries' loads for passenger ships has been carried out by cruise ship builders shows that vessel with the similar size and operation profile are comparable regarding auxiliaries load but there is a difference in the installed power based on the different design concepts of the ship operators.

To overcome this discrepancy between the operation load and the installed power it could be by a first idea to relate the terms of the EEDI formula to the load and not to the installed power as shown in the sketch below.

The innovative technologies can be different measures which relate to the propulsion load and or to the auxiliary/hotel load.

Generic and simplified diesel electric propulsion plant

