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Analysis of the effect of the new EEDI requirements on Dutch build and flagged ships

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Commisioned by the Ministry of Infrastructure and the Environment

July 2011

Projectnumber 3134

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1 Introduction

Within IMO the Energy Efficiency Design Index (EEDI) is subject to approval during the MEPC 62 meeting. The guidelines for calculation and verification of the index will be included in MARPOL Annex VI. The aim of this index and corresponding criteria is to reduce the CO_2 emissions of new build vessels. The index is supposed to enable a fair comparison of energy efficiency of various ships.

The Ministry of Infrastructure and the Environment has concerns about the effects of the EEDI mandatory regime on ships built and flagged in The Netherlands. The Netherlands fleet mainly consists of small ships with a variety of tasks and operational requirements. The formulation may lead to unwanted effects on the design, which may not really contribute to the end goal of a significant reduction of CO_2.

To determine the effects of the index and to collect information in support of the development of the EEDI, The Ministry of Infrastructure and the Environment tasked CMTI with an impact study. As starting point the most recently adopted EEDI formulation and criteria had to be used. Also the CO_2 reduction potential for future ships had to be investigated. The results of this study are included in this report.

The study builds on two previous studies, conducted by CMTI on the effects of the EEDI. In the first study[1] the effects of application and the robustness of the EEDI was investigated and suggestions for improvement were developed. In the second study[2] (ref 2) the effects of the EEDI were calculated for a selection of the database and the application on diesel electric propulsion was investigated.

Great care has been given to collect reliable data on the Netherlands fleet. The study was actively supported by an number of shipyards, design offices and ship owners.

Ing. D.W. Anink

Ir. M. Krikke

[1] 2009 CMTI study: The IMO Energy Efficiency Design Index a Netherlands Trend Study

[2] 2010 CMTI study: Energy efficiency of small ships and non-conventional propelled ships

2 Status EEDI at IMO

The Energy Efficiency Design Index (EEDI) was adopted during MEPC 62. Via an amendment to MARPOL annex VI, the EEDI is planned to become mandatory as from 1st of January 2013. Although the formula is accepted in its present formulation, there are still a large number of items to be resolved. Discussions during a number of MEPC meetings showed that the indexing system is rather complex, despite the straightforward formulation of the index. The main reason for this complexity is the huge variety of ship designs.

In the period between now and the getting into force of the new requirement, the working group on greenhouse gases will continue its work on the items which are still unresolved. A work program was proposed to MEPC 62 which is dealing with the ship types which are not yet included in the current amendments. Also a revision point was initiated to give parties the opportunity to come forward with alternative proposals for indexing small ships and in particular the general cargo ships.

During the writing of this report, work on the guideline for calculation method for the attained EEDI was in progress. The last version of this guideline[3], as prepared by the chairman of the correspondence group, was used for the calculations.

[3] MEPC 62/5/4

3 Calculations of the EEDI

In the first part of the study, the index values for a number of ships built and flagged in The Netherlands were calculated and compared to criteria, according to the latest guidelines[4]. The first step was to gather ship data from reliable sources, like ship owners, design offices and shipyards in The Netherlands. In total 120 ships were analysed. Great effort has been given to determine the correct speed - power data, calculate the most realistic attained EEDI values of the specific ships. To get insight in the effects of state of the art technology, currently applied to new ships, mostly ships from recent years are selected for the calculations.
The results of the calculations were used to perform a statistical analysis on the effect of the EEDI on ships build and/or flagged in The Netherlands. The following characteristics were essential in this analysis:

- Specific ship type
- Real operational profile of the specific ship
- Ship size
- Age of the ship

The database used for this study contained the following four dominant ship types: General Cargo Ships, Gas Tankers, Tankers and Reefer Ships. Results of EEDI calculations are presented for each of these ship types, and compared with their respective criteria lines. The criteria lines are based on the amendments of MARPOL Annex VI as stated in the report of MEPC 62[5]. Annex 1 contains the data necessary to establish the criteria lines.

3.1 General Cargo Ships[6]

The first set of results are on the General Cargo Ships built and/or flagged in The Netherlands. Of this type 59 ships were analysed. The results are plotted in the usual way as EEDI versus Deadweight. In figure 1 four criteria lines[7] are included; representing the phase zero to phase three criteria. The uppermost line is the phase

[4] MEPC 62/5/4 guideline including the changes made during MEPC 62 as stated in MEPC 62/24
[5] MEPC 62/24 and MEPC 62/24.add.1
[6] In The Netherlands often called ‘multi-purpose’ ships, fitted to carry a wide range of cargo types, such as dry bulk cargoes, containers, project-cargo/heavy lift, break-bulk, etc., see also paragraph 3.1.3
[7] Red line – Phase 0, Yellow line – Phase 1, Light Green line – Phase 2 & Dark Green line – Phase 3

zero criterion line. In the subsequent phases the criteria will be more strict, corresponding to lower positions of the criteria lines.

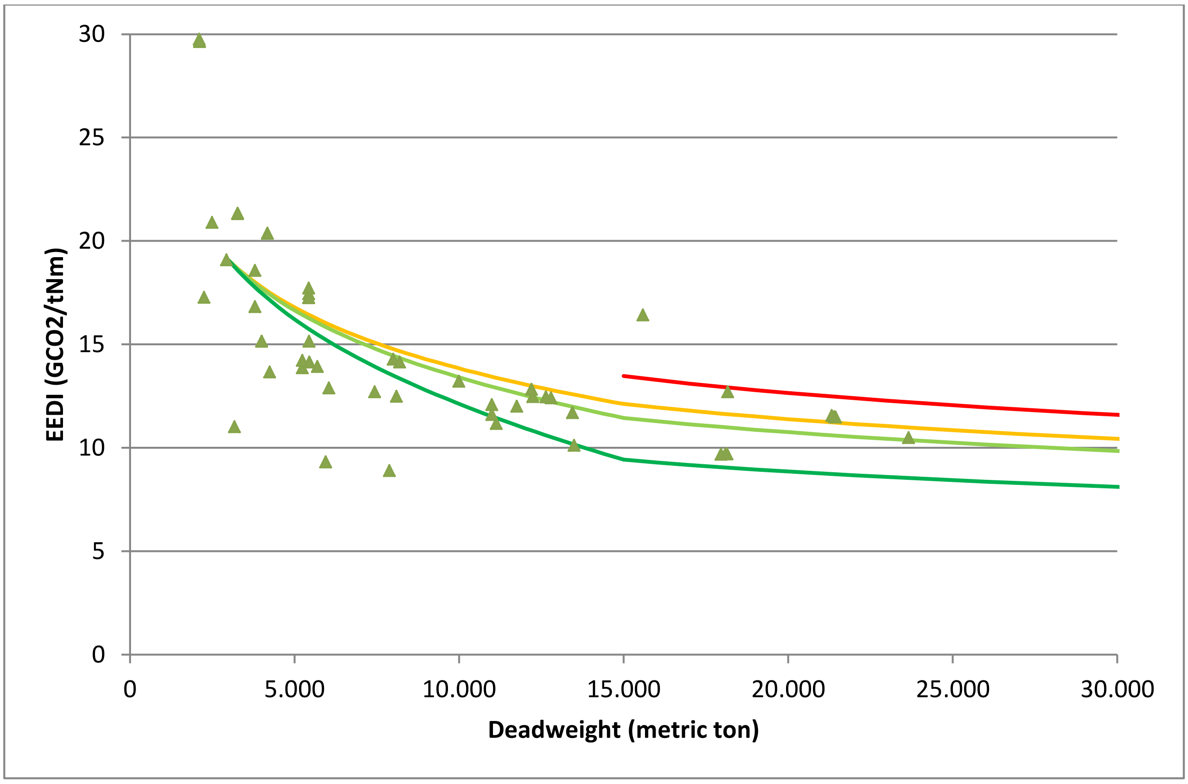

Figure 1: General cargo ships vs their required index lines (phase 0 to phase 3)

Most general cargo ships will pass the phase zero criteria, which is valid for ships larger than 15.000 ton DWT. The few ships that do not pass the criteria show high EEDI values and will be considered later.

The phase one and two criteria lines are very close. In these phases a small group of ships will not fulfil the requirements. From phase two to three the number of ships not passing the criteria increases significantly.

A striking observation is that at least up to phase two a large group of existing ships will fulfil the requirements. This is due to the high scatter and the relative high position of the criteria lines. Assuming that new designs will also have a wide scatter in EEDI values, due to the differences in operational profiles, many of those designs do not have to be adjusted to decrease the EEDI value. Therefore the burden of CO_2 reduction is laid on the shoulders of a small group of ship designs with high EEDI values. The high EEDI values of these designs are in most cases not caused by a very low inherent energy efficiency. For most designs the high EEDI value is caused by special operational requirements, leading to high installed power, small deadweight – lightweight relations and restricted drafts. This effect will be discussed later in the detailed consideration of some specific ship designs.

3.1.1 Spread of the fleet in relation with the EEDI reference line

Based on previous studies, it was expected to see the attained indexes spread around the phase 0 line, which is the same as the reference line for a specific fleet. As can be seen, the main part of the fleet is below the phase 0 line. This can be explained by the effect of some factors in the attained index calculation. The scatter in data remains high, with increasing scatter at decreasing DWT values.

Example of a factor which has a great effect on the index value is the f_i factor and the f_j factor. These factors are used to compensate ships for extra installed power and less deadweight which are the result of Ice class notations.
These Ice class notations were not taken into account when establishing the reference lines. Example of the effect of these factors:

General cargo ship
MCR: 2700 kW
DW: 5700 mt
V_{ref}: 12.4 kn
P_{PTO}: 450 kW
Iceclass: 1A
Attained EEDI: 13,93 gCO_2/tNm **including ice class corrections**

Required EEDI:
Phase 0: none
Phase 1: 16,22 gCO_2/tNm
Phase 2: 16,04 gCO_2/tNM
Phase 3: 15,48 gCO_2/tNm

Calculation of this ship, with the ice class factors f_j and f_i set to 1:

In this case the attained EEDI will be:

16,09 gCO_2/tNm

This EEDI is close to the reference line value of this ship and in line with the guideline on calculation of the reference line.

Figure 2 shows the reference line for general cargo ships calculated with ships with ice class and figure 3 shows the ships with the ice class factors set on 1.

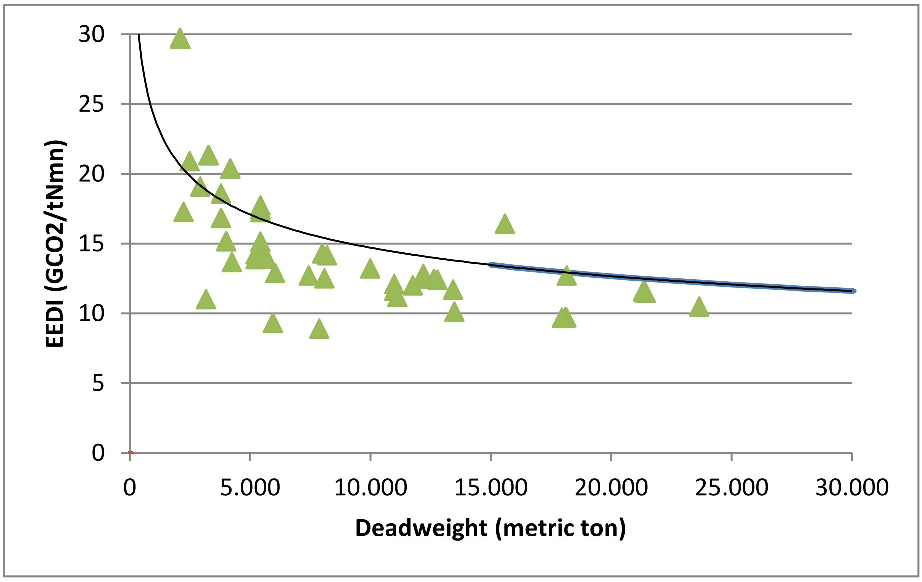

Figure 2: EEDI with ice class corrections

The largest number of the ships is below the reference line

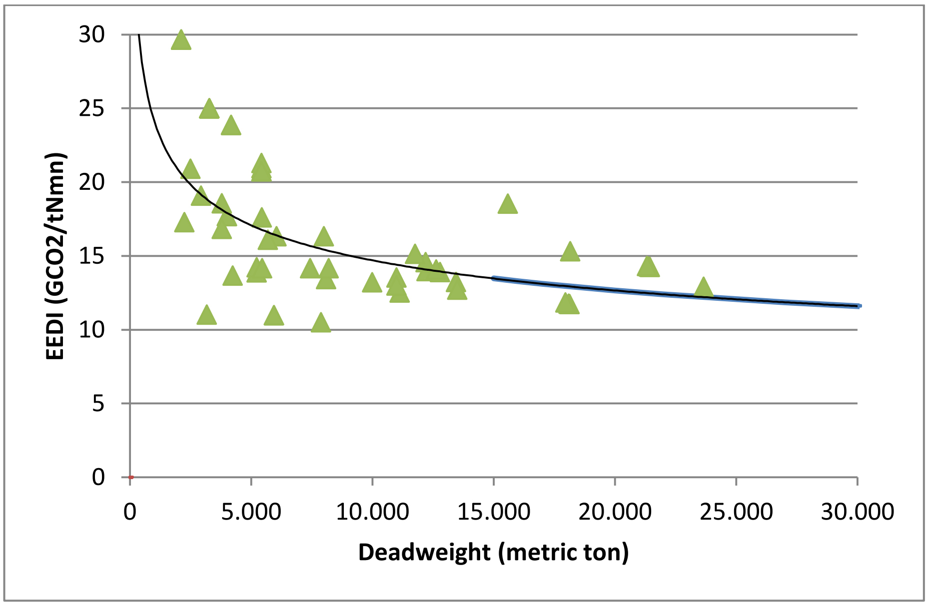

Figure 3: EEDI without ice class corrections

In figure 3 the spread of the ships is more around the reference line. This is only one of the reasons why it appears that attained index calculations of ships are lower than the reference calculations.

3.1.2 General cargo ships versus bulk carrier and containership requirements

In order to demonstrate the effect of the specific factors in the formula, the general cargo ships were recalculated using the formulation for bulk carriers. This resulted in an increase in values of the attained EEDI, up to 5 index points, see figure 2. The main reason for this difference is the effect of the Ice class factors fi and fj. Each ship type has its own formula for calculating f_j and f_i. In figure 2 criteria lines for bulk carriers are plotted as well.

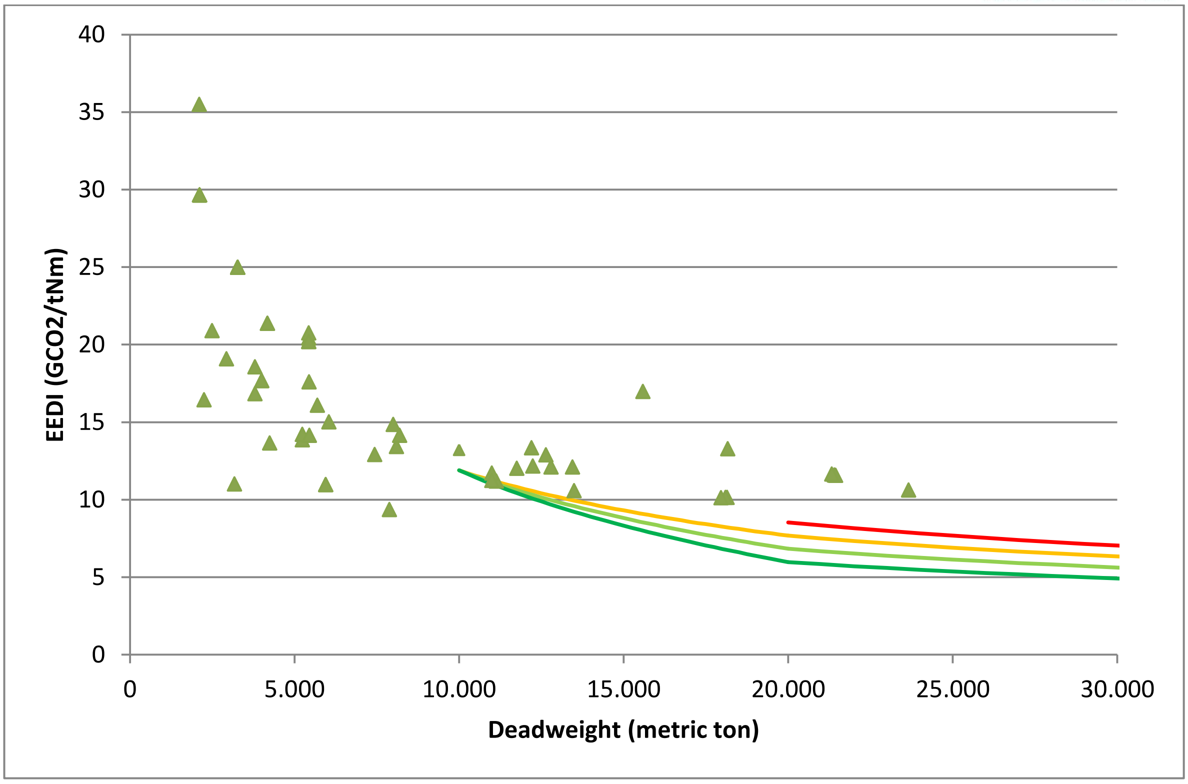

Figure 4: Index values of general cargo vessels calculated according to bulk carrier requirements and compared with the phase lines of bulk carriers.

A similar exercise was done using the formula for container ships, see figure 5. The calculated index values are far higher, mainly due to the fact that calculations are done with 65%[8] of the total deadweight.

[8] As amended during MEPC 62. Capacity for container vessels is changed from 75% of DWT to 65% of DWT

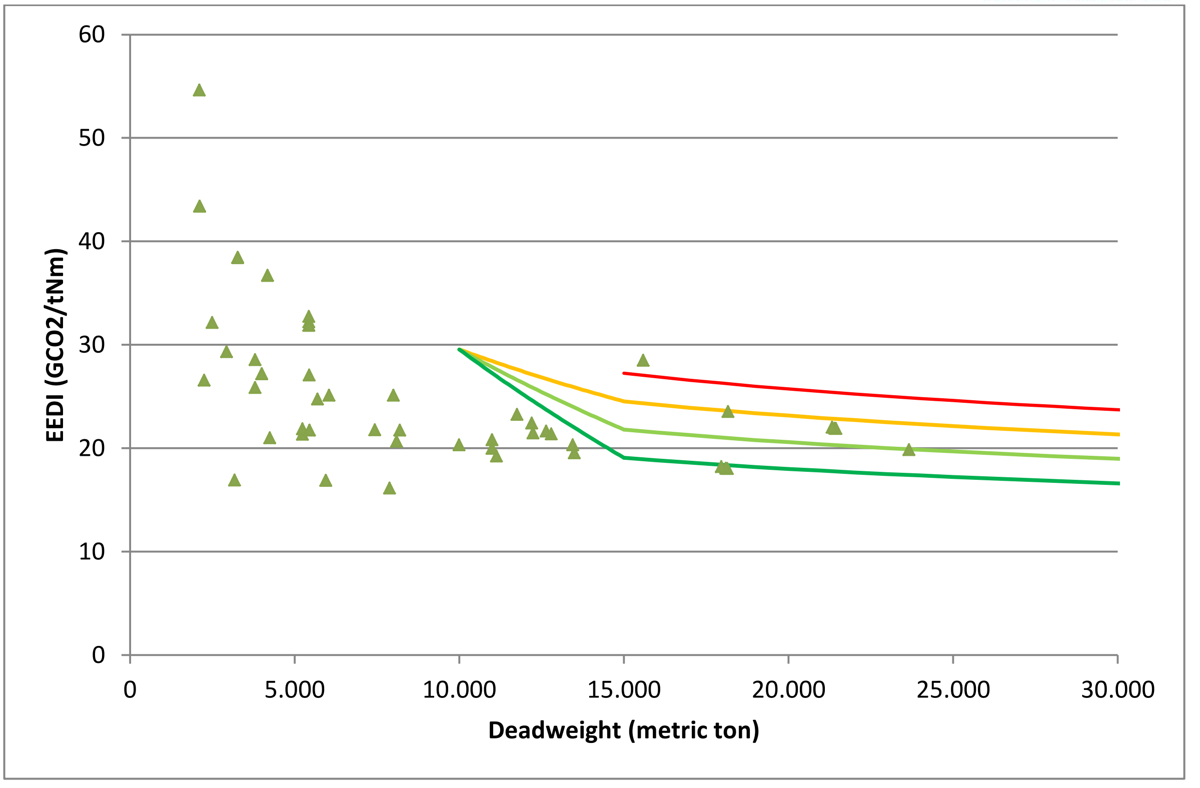

Figure 5: Index values of general cargo vessels calculated according to the container ship requirements and compared to their phase reduction required index lines.

3.1.3 Boundaries between the different ship types

General cargo ships are designed to carry all sorts of cargo types. Some ships are designed to carry cargo in bulk, break bulk, project cargo/heavy lift as well as containers. The following pictures shows a variety of general cargo ships. Each ship is optimized for a different cargo type. These ships all have a certificate by class stating that te ship is categorized as general cargo ship.

Pictures of general cargo ships

In the draft MARPOL Annex VI part two, general cargo ships are defined as a ship with a multi-deck or single deck hull designed primarily for the carriage of general cargo. In practice all cargo ships which do not fall under any other definition are classified as general cargo ships. As illustrated in the pictures, these ships have very different hull design and different operational profile for which they have been optimized.

The IMO guideline on calculation method for the reference lines contains a list of ships which should be included in the calculation method and a list which ship types should be excluded. Heavy lift ships are excluded from the reference line calculations. During MEPC 62 it was decided that these shiptype should be excluded for the time being from the EEDI requirements as adopted during that session. This study goes into the rational why these groups should be adressed seperatly.

In this respect a clear guideline should be established to avoid misunderstanding and inappropriate application of the new EEDI requirements. For ships designed for special purposes such as transport of heavy lift cargo, the following should be considered:

- special compensation factors should be developed to compensate for special design features wich influence their efficiency or,
- reference lines that reflect the realistic energy efficiency of these ship types should be developed.

Chapter 4 will elaborate into a detailed analysis in the effect of difference in optimisation of ships to the attained EEDI of these ships.

3.2 Gas tankers

In this section the calculation of the gas tanker fleet is analysed. The calculation consists of 7 gas tankers. The results are plotted in the usual way as EEDI versus Deadweight. In figure 6 four criteria lines are included, representing the phase zero to phase three criteria for gas tankers.

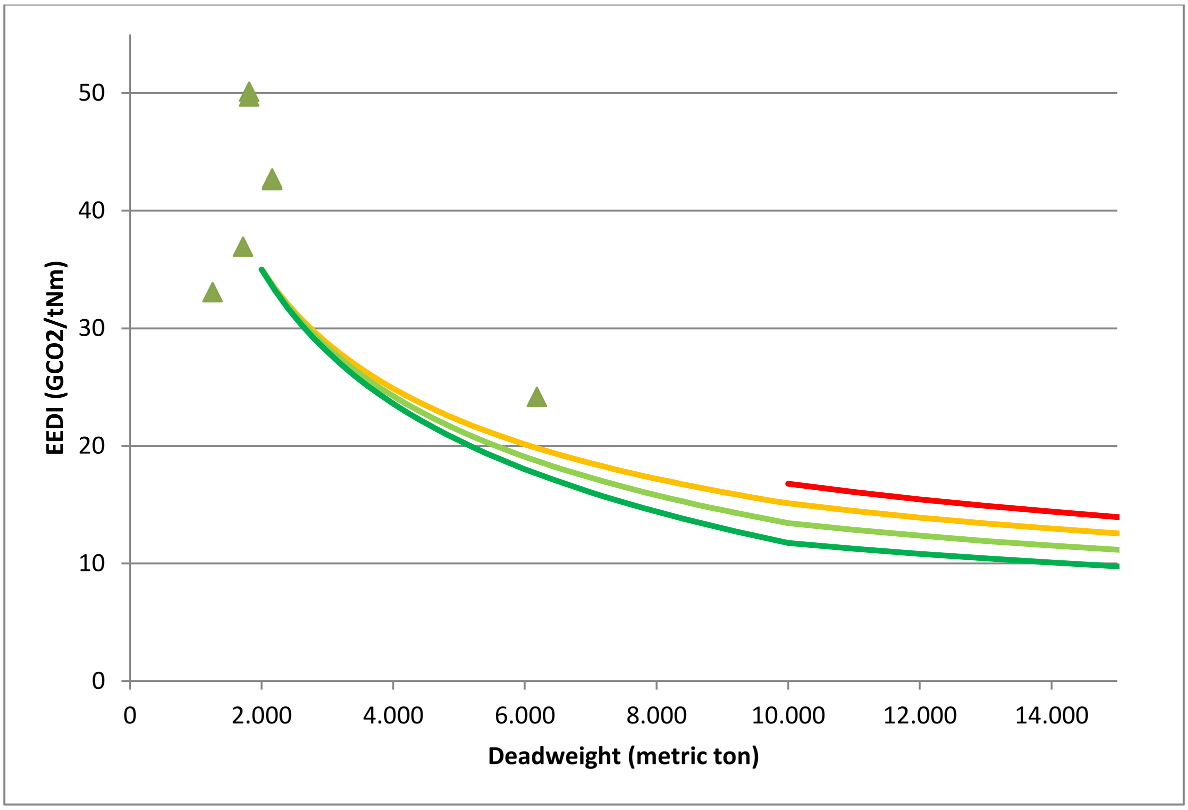

Figure 6: EEDI calculations of Dutch gas tankers versus reduction lines phase 0 to phase 3

The limited Dutch gas tanker fleet exists mostly of small highly specialized ships, often built for special trading areas, which are equipped to carry a wide variety of gasses. To treat this variety of gasses, these ships are equipped with cargo treatment systems which influences the design of the ship and its auxiliary equipment. The weight and space required for these treatment systems is substantial, thus leading to a relative high lightweight of the ship. For example, a ship with a cooling plant for the gaseous cargo will have a higher lightweight - deadweight ratio than a ship with the same deadweight but without the cooling plant.

Especially for small ships the effect of the relation between deadweight and lightweight on the index value is significant. De penalty on EEDI has no relation with the energy efficiency of the ship.

A typical Dutch gas tanker

The effect of this can be seen in figure 6. Most Dutch, high sophisticated gas tankers, do not meet the EEDI requirements. It is unclear at this moment how new designs for these types of ships will be able to achieve the requirements.

3.3 Tankers

In this section the calculations of the tankers are analysed. The calculation was done for 13 tankers. The results are plotted in figure 7, in the usual representation as EEDI versus deadweight. In this graph four criteria lines are included, representing the phase zero to phase three criteria for tankers.

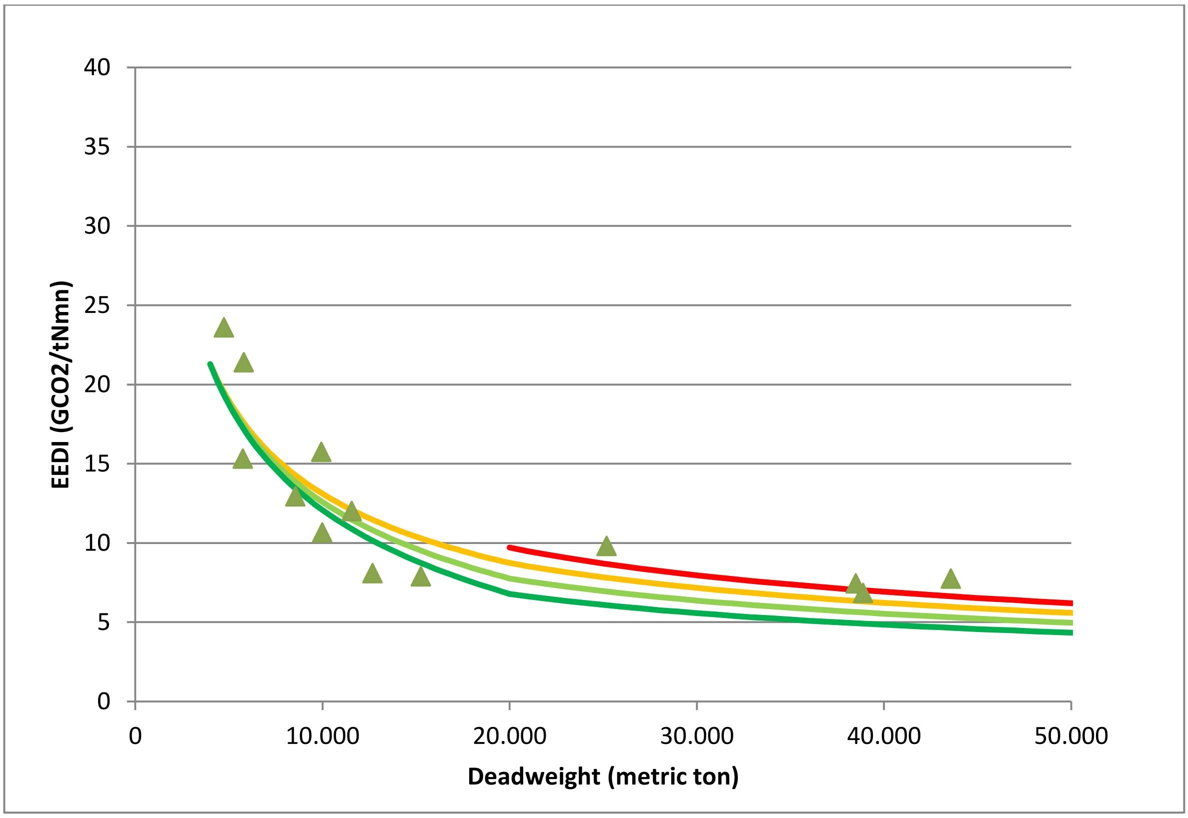

Figure 7: EEDI calculations of tankers versus reduction lines phase 0 to phase 3

The spread of the group is distributed equally around the phase 0 line. In this graph, especially the values for bigger ships seems to be more in the upper region of all phase lines. The smaller ships are more spread equally around the lines.
The group consists mostly of chemical tankers. At MEPC 62 it was stated by some delegates that chemical tankers will have difficulties to meet the requirements. Based on these calculations it is difficult to conclude whether or not the chemical tankers will have difficulties in reaching the EEDI requirements.

3.4 Reefer ships

In this section the calculation of the gas refrigerated cargo carrier fleet is analysed. The calculation were done for 38 reefer ships. The results are plotted in figure 8 in the usual way as EEDI versus Deadweight. In this graph four criteria lines are included, representing the phase zero to phase three criteria for refrigerated cargo carriers.

The reefer market is a very specialized market which is currently under great pressure. This pressure on containerised reefer transport is not favourable for conventional reefer ships. Result of this is that the replacement of the old ships is going very slow. For calculation of the attained index it was not possible to use only recently build ships. In figure 8 therefore ships build in the last 20 years are shown.

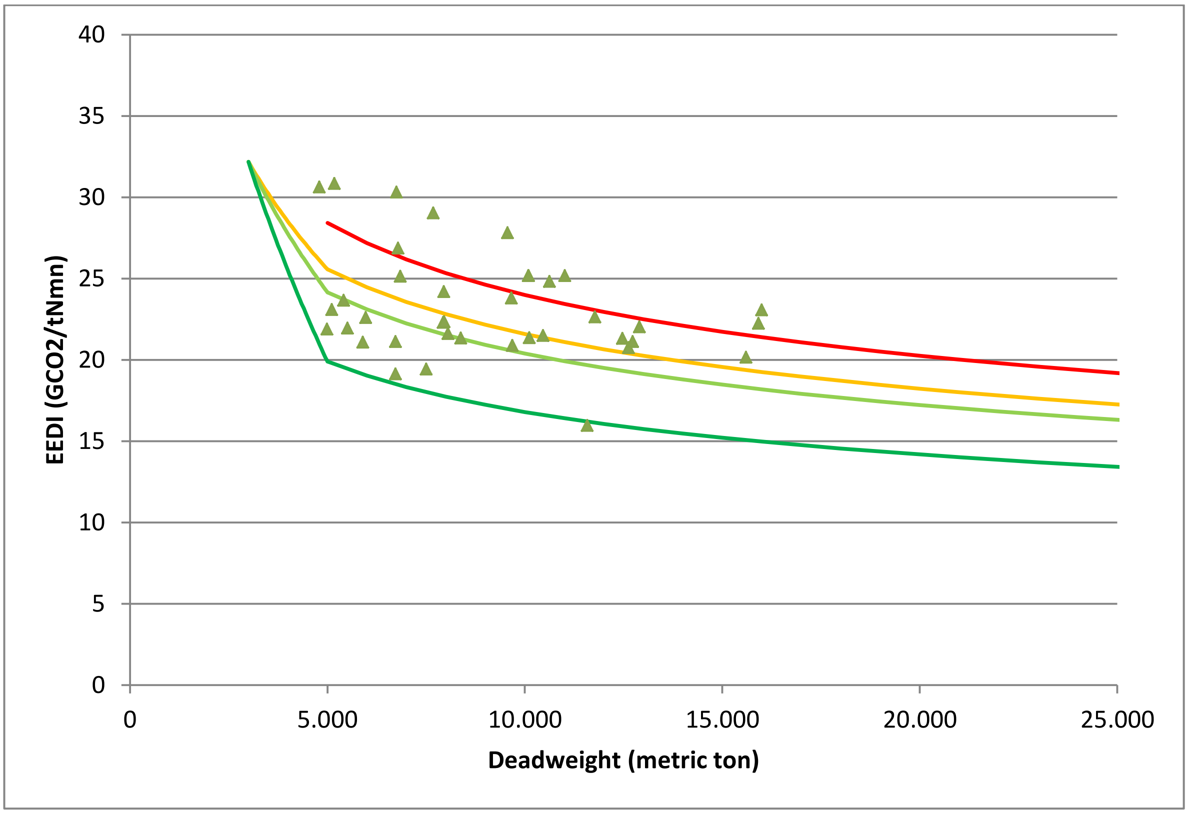

Figure 8: EEDI calculations of the current Dutch reefer fleet plotted against the EEDI requirements for reefer ships

The effect of the EEDI system on CO_2 emission of this fleet will in the coming years almost be zero. This is due to the fact that currently no new reefer ships are on order and that ship owners expect to delay new building of ships until after 2015-2017.

This means that phase 0 and phase 1 will not have effect on this fleet and no reductions will be achieved in this time frame.

Two ships in this reefer fleet are recently build vessels (2010 and 2011). Both ships have a high speed (21,5 knots). They fulfil the phase 0 requirements. If the same ships would be built after phase 1, they need to be optimized or have to sail at lower speeds. Reefer ships however are speed depending trade ships. Reducing speed is in most cases not an option. Depending on the type of cargo, ships need to keep up their schedule, to avoid that off spec cargo arrives in the ports. Due to this fact containerising of reefer cargo will be encouraged. The efficiency difference between carrying refrigerated cargo by reefer ship or in containers on board container liners is not within the scope of this study, but might be an interesting comparison to be made. The EEDI does not give the possibility to compare ships outside their ship type scope.

A typical modern refrigerated cargo carrier (reefer ship)

4 Analysis of individual ships

In the previous chapters it is suggested that there are good reasons for ships to have high EEDI values, far above the criteria lines, not to be attributed to a bad design in terms of low energy efficiency. To get more insight in the reasons for the high EEDI values two individual ship designs were analysed. Both designs had the same main dimensions and installed power. One of these designs is adapted with heavy lift cranes, which forced the designers to add sponsons to the general cargo design.

The particulars of both designs are depicted in table 1.

Table 1: Particulars of two specific designs

		General cargo ship	Heavy lift ship
Deadweight	Tonnes	18143	18163
Reference Speed Vref	Kn	17	13
MCR	kW	8400	8400
P_{PTO}	kW	900	900
Ice class		1A	1A
Attained EEDI	CO2/Tonmile	9,71	12,71
Year of built		2009	2010

Both selected ship types are defined in the guidelines.

- General Cargo Ship: Multipurpose ship with own cargo handling equipment specialized in general cargo
- Heavy lift Ship: Heavy lift cargo vessel with special lift equipment for heavy lift

Both ships are calculated and evaluated according to the general cargo ship requirements for EEDI calculation.

Both ships were based on the same design. The main difference between both ships is the additional beam of the hull in the form of sponsons. Compared to the general cargo ship, the heavy lift ship has an increased beam around the summer load line of the ship. This extra beam was constructed to give the ship additional stability during hoisting operations. It also gives additional stability during transit in full loaded condition.

The disadvantage is that the increase in beam will create additional resistance and therefore reduces the speed. This heavy lift ship had two different design speeds: 17 knots in ballast conditions, in which the beam is equal to the beam of original design, and 13 knots in fully loaded conditions, in which the beam is much wider. The EEDI has to be calculated on fully loaded condition. Therefore the ship receives a great penalty for their optimized design.

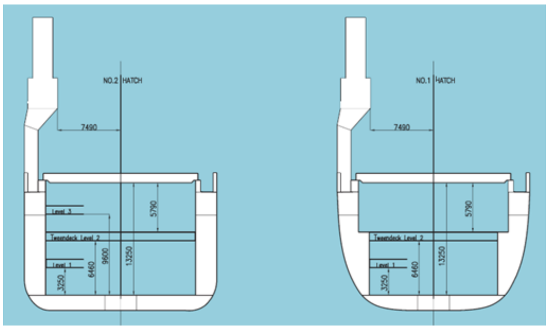

Figure 8: General cargo ship mid ship section

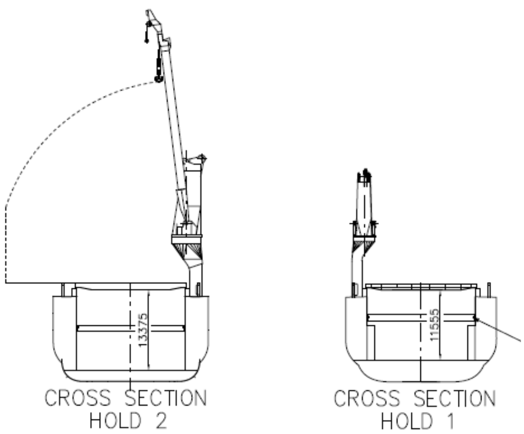

Figure 9: Heavy lift ship mid ship section

Although the ship is optimized for its operational profile, it will never meet the Minimum EEDI requirements.

5 Comments on current calculation method

For the calculation of the attained EEDI for the ships in this study, the latest version of the guideline for calculation method of the attained EEDI, as prepared by the correspondence group, was used (MEPC 62/5/4). This chapter deals with interpretation problems which were observed during the calculations of the attained EEDI.

5.1 Calculation of P_{PTO}

The guideline on the calculation of the EEDI is not clear on the amount of deduction of the installed main engine power in case a shaft generator is installed (P_{PTO}). The power of this generator should be limited to hotel services and for supplying the engine room of the minimum necessary auxiliary systems for the main engines.

The guideline states as follows:

$P_{ME}(i) = 0.75x(MCR_{MEi} - P_{PTOi})$

Irrespective of the maximum output of an installed shaft generator, the maximum allowable deduction of 75% of P_{PTOi} within the calculation of $P_{ME(i)}$ is to be no more than P_{AE} as defined in paragraph 2.5.6

It is not clear whether the deduction of P_{PTO} should be no more than P_{AE} or 75% of P_{AE}? ($P_{PTO} \leq P_{AE}$ or $P_{PTO} \leq 0.75\ P_{AE}$) This will create a small difference in attained EEDI. For ships just on or above the required EEDI line, it is essential to clear this matter up.

5.2 Shaft generator for cargo treatment systems

Some ships have an significant amount of power usage for cargo treatment systems. To generate this power as efficient as possible, some ship owners have equipped their vessels with larger main engines together with relatively large shaft generators. There is an option to deduct this power from the MCR for calculating the attained EEDI. The guideline is not clear how to establish the amount of power which can be deducted from the MCR.

The guideline states as follows:

Where power from the shaft generator is being used for cargo loads under normal seagoing conditions, (e.g. reefer containers) then these should not be included in the calculation.

For specialized designs, where an engine is installed with a higher power output than the shaft(s) and propeller(s) are capable of delivering, then the value of PME(i) used for EEDI purposes is 75% of the power that the propulsion system is capable of delivering through the propulsor.

(Alternative proposal from BIMCO)
Where power from the shaft generator is being used for cargo loads under normal seagoing conditions , (e,g. reefer containers) then these should not be included in the calculation.

$P_{ME(i)}$ is in all circumstances to be no less than 75% of the power that the propulsion system is capable of delivering through the propulsor.

Both definitions do not give guidance on how to calculate which part is used for the cargo load and which part has to be taken for the calculation of MCR.

Further guidance should be developed by IMO on how to establish the P_{PTO} value for deduction from MCR.

5.3 P_{PTO} – MCR – P_{ME} and P_{AE} relation

The relation between P_{PTO} – MCR – P_{ME} and P_{AE} is not very consistent. Especially for ship types where a fully integrated system exists of auxiliary systems coupled with the main engines, it is unclear how to calculate the value of MCR, P_{AE} and the effect of P_{PTO}

Currently it is stated in the guideline that for calculation P_{AE}, the nominal MCR should be used without the deduction of P_{PTO} for the part which is used for cargo loads. This

is not in line with the general approach in the guideline. The guideline should only be focused on the power which is necessary for propelling the vessel.
In case of calculating the MCR to establish the value of P_{AE}, the P_{PTO} part which is used for cargo treatment systems during the voyage, should be deducted from MCR before calculating P_{AE}. After that P_{PTO} can finally be established.

The current procedure as defined in the guideline for calculation method:

In the guideline it is stated that P_{PTO} should not be higher than P_{AE}. In relation with the possibility to compensate P_{PTO} for the part which is used for cargo treatment equipment, the following can be stated:

$P_{PTO} = P_{AE} + P_{PTOCARGO}$

$P_{PTOCARGO}$ = is part of the shaft generator power which is used for cargo treatment systems during normal sea operations.

For ships with MCR is less than 10.000 kW:

$P_{AE} = 0.05 \times \Sigma MCR_{MEi}$

$P_{PTO} = (0.05 \times \Sigma MCR_{MEi}) + P_{PTOCARGO}$

$= 0.05\ MCR_{MEi} + P_{PTOCARGO}$

$P_{ME} = 0.75\ (MCR_{MEi} - P_{PTOi})$

$= 0.75\ (MCR_{MEi} - (0.05\ MCR_{MEi} + P_{PTOCARGO}))$

$= 0.75\ (0.95\ MCR_{MEi} - P_{PTOCARGO})$

$\mathbf{P_{ME} = 0.7125\ MCR_{MEi} - 0.75\ P_{PTOCARGO}}$

Situation in formula in case that P_{AE} is established with MCR which is compensated for the power used for cargo treatment systems.

For calculating P_{AE} the following is stated:

$MCR' = \Sigma MCR_{MEi} - P_{PTOCARGO}$

$P_{PTOCARGO}$ = is part of the shaft generator power which is used for cargo treatment systems during normal sea operations.

For ships with MCR is less than 10.000 kW:

$P_{AE} = 0.05 \times (\Sigma MCR_{MEi} - P_{PTOCARGO})$

$= 0.05\ MCR_{MEi} - 0.05\ P_{PTOCARGO}$

$P_{PTO} = P_{AE} + P_{PTOCARGO}$

$= (0.05\ MCR_{MEi} - 0.05\ P_{PTOCARGO}) + P_{PTOCARGO}$

$= 0.05\ MCR_{ME} + 0.95\ P_{PTOCARGO}$

$P_{ME} = 0.75\ (MCR' - P_{PTO})$

$= 0.75\ ((MCR_{MEi} - P_{PTOCARGO}) - (0.05\ MCR_{ME} + 0.95\ P_{PTOCARGO}))$

$= 0.75\ (0.95\ MCR_{MEi} - 0.05\ P_{PTOCARGO})$

$\mathbf{P_{ME} = 0.7125\ MCR_{MEi} - 0.0375\ P_{PTOCARGO}}$

This second approach will result in a higher, but more realistic P_{ME} and in line with this a higher, but more realistic attained index value. Depending on the $P_{PTOCARGO}$, the outcome can vary up to several percentage points (4-7%) in EEDI value.
Guidelines should be developed how to determine $P_{PTOCARGO}$ for a certain vessel.

5.4 Fc factor

5.4.1 IPTA proposal MEPC 62/6/13

During MEPC 62 IPTA submitted a submission in which their concerns were stated about the effect of the required index requirements on chemical tankers. According to their calculations chemical/parcel tankers have a higher index value compared to other tankers. In the current EEDI requirements the chemical/parcel tankers will have to fulfil the tanker reference line requirements. According to IPTA this will pose problems for the high efficient chemical/parcel tankers. The optimization for the parcel tanker trade causes, according to IPTA, these tankers to have relatively higher index value. However due to their design, it is possible to operate them more efficiently than their tanker sisters due to the fact that they can take a very wide range of cargos which results in less ballast voyages.

In their submission IPTA shows via calculations that the performance of chemical tankers according to the EEDI is less than those of other tanker types. Secondly they propose a factor to compensate for the relatively higher index value for chemical/parcel tanker. By doing so IPTA hopes that the burden on the fleet to become more efficient will be the same as on other tanker types. In short, they want a fair comparison and avoid that the chemical/parcel tankers will come in a situation that it is impossible to perform them in a efficient manner.

In this chapter we will review the IPTA submission in one step:

- A short investigation in their statement about the average higher index value of chemical/parcel tankers.

Furthermore we have looked in more detail into the proposal and especially into the definition of a chemical/parcel tanker. Secondly a tentative proposal is made for a different approach on how different groups of tankers can be compensated for optimization for their operational profile.

5.4.2 Chemical tankers and reference line calculation

In their submission IPTA states that 49% of the current fleet does not comply with the reference line value, many with a wide margin. This means that these ships will not fulfil the phase 0 requires. In this section we will do a short investigation to see if this trend of low compliance of chemical/ parcel tankers can be confirmed.

In the figure 10, the reference line as calculated by IMO secretariat and submitted to IMO in document MEPC 62/6/4 is shown:

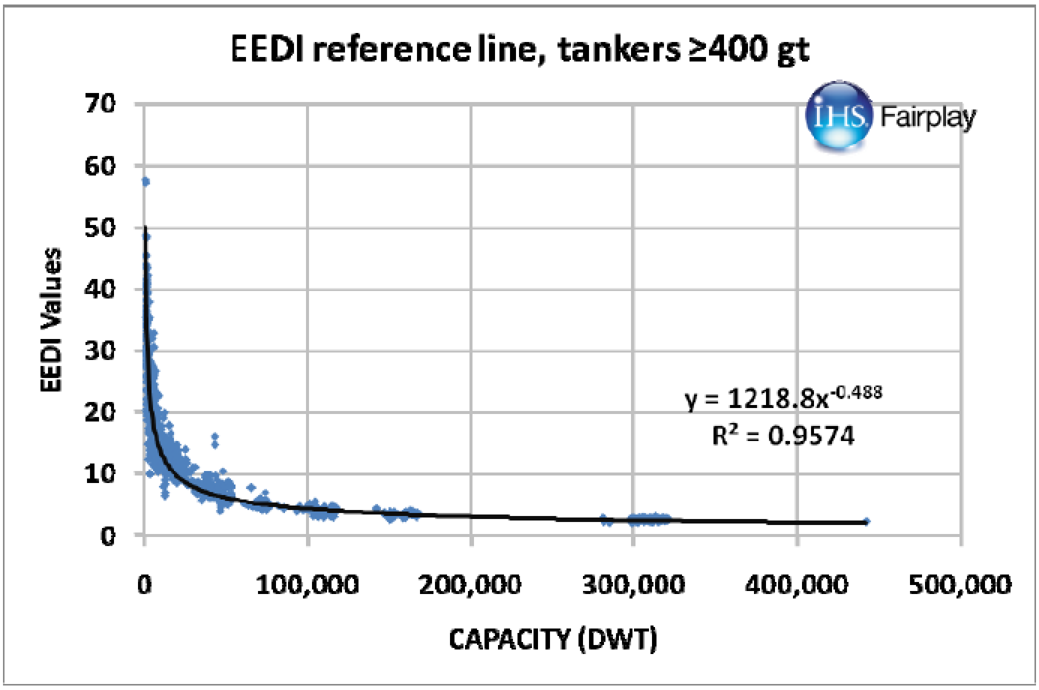

Figure 10: reference line for tankers according to IMO secretariate

This graph shows us a few things:

- The R^2 is high compared to the reference line calculation of other ship types
- The spread around the reference line increases in the lower deadweight range
- The scatter around the reference lines seems to be equally spread around this reference line
- In this calculation it is impossible to distinguish the different groups of tankers
- The dataset of IMO secretariat was not available for this study to do a further analysis of the reference line

For this study some Dutch based chemical tankers were examined on their EEDI merits. The following graph shows the calculation of Dutch flagged and or build ships in relation with the reference line as calculated by the IMO secretariat.
The lower line in the graph shows the trend line as calculated for this specific group of ships.

At first sight it looks like that the chemical/ parcel tankers are performing well in relation to the reference line. The amount of ship samples however is too small to actually define a trend in relation to the reference line. Therefore no firm conclusions can be drawn up from this calculations.

Based on experienced with the chemical/ parcel tankers, it can be expected that the EEDI of this fleet will be located on the upper side of the group spread around the reference line as calculated by the IMO secretariat and therefore will have more difficulties to fulfil the EEDI requirements in coming years.

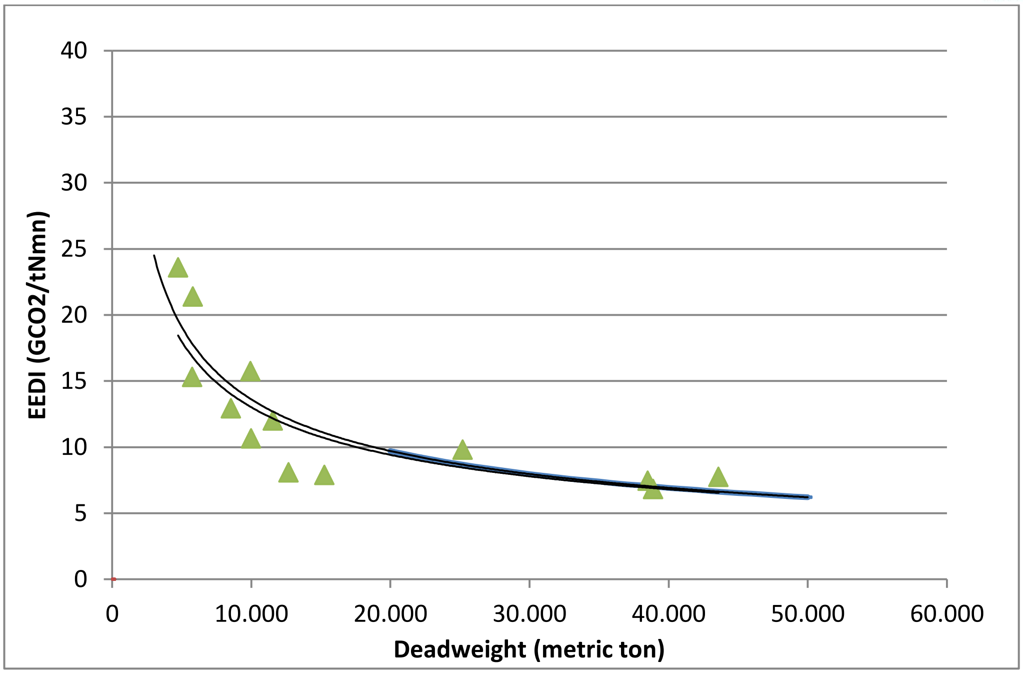

Figure 11: EEDI calculations of 13 Dutch build and or flagged chemical/ parcel tankers

The Upper line represents the IMO reference line. The lower line represents the trend line based on the 13 EEDI calculations plotted in the graph

5.4.3 Fc factor and Ratio R

To compensate for the average higher EEDI value, IPTA proposes to introduce a f_c factor in the nominator of the EEDI formula as shown in the formula below:

Factor fc

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

The basis for the f_c factor is the ratio R. Ratio R is defined as the deadweight volume ratio: deadweight/total liquid capacity. R = mt/m3

Ratio R and f_c are defined as follows. In the lowest row of the table, the compensation in percentage of de attained EEDI calculation are shown.

Table 2: Ratio R

R	< =0.70 – 0.80	0.81 – 0.90	0.91 - 0.99	> 0.99
f_c	1/R	(1/R)-0.05	(1/R)-0.005	1
compensation of EEDI	30% - 20%	16% - 6%	9% - 1%	

In this section we look into the effect of ratio R. To be able to use ratio R as a basis for the compensation factor f_c, this factor should fulfil one of the important requirements of a compensation factor: it should have a clear capacity to distinguish between the group for which the factor is intended to be used. In this case, the factor should distinguish between the chemical tanker and the other tanker types used for reference line calculation. Secondly there should be a clear relation between the ratio R and the effect of it on the efficiency of the ship.

For these calculations a large dataset is used in which different tanker types were available together with the data for deadweight and the liquid capacity.
To find out if the factor is able to distinguish between the different tanker types, the ratio is calculated for three different tanker types:

- Chemical tankers
- Crude oil tankers
- VLCC

In the following graph the outcome of the different calculations is plotted against the deadweight:

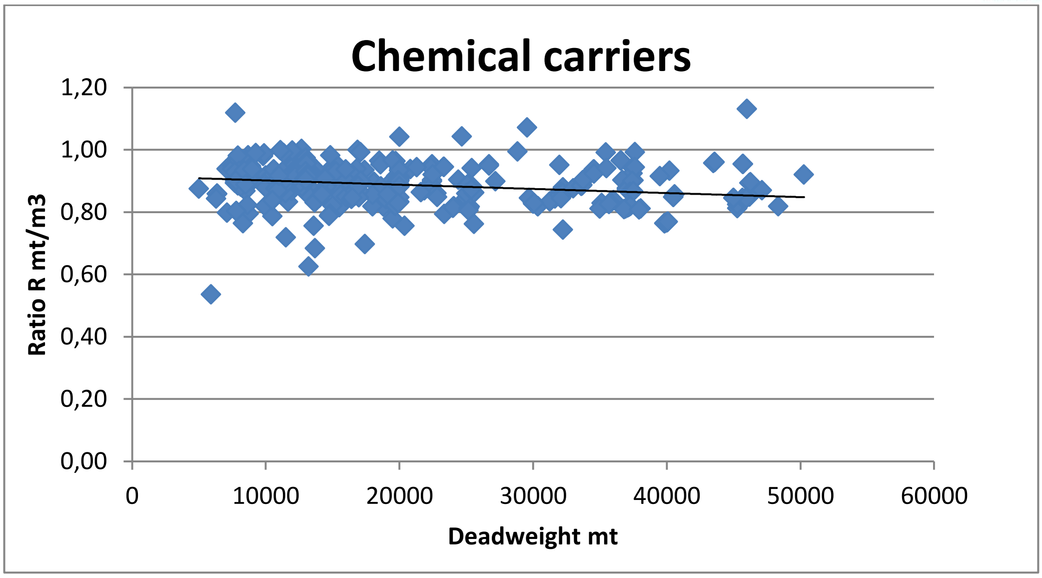

Figure 12: Chemical tankers and parcel tankers

Number of samples: 693

Average value: 0.89 mt/m³

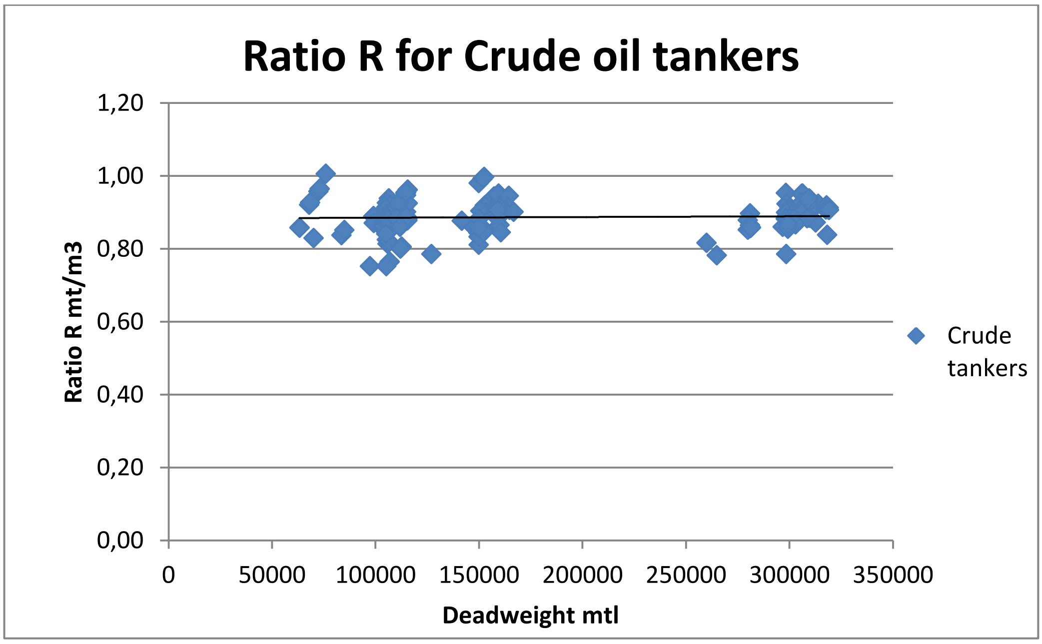

Figure 13: Crude Tankers

Number of samples: 474

Average value: 0.88 mt/m³

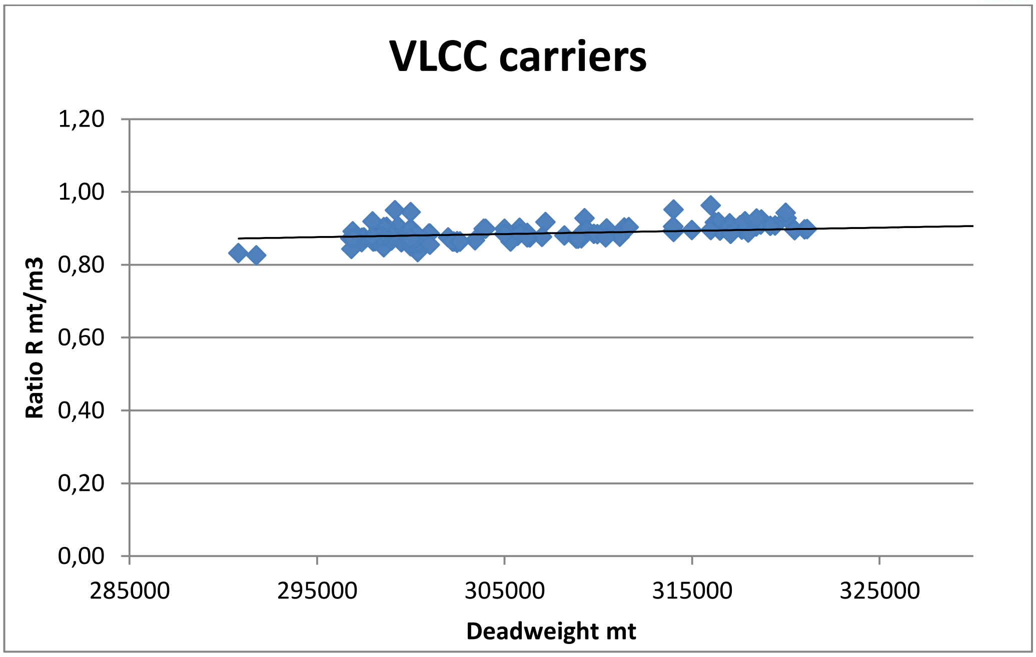

Figure 14: VLCC's

Number of samples: 161

Average value: 0.89 mt/m³

In the following graph, the three groups are combined in one graph.

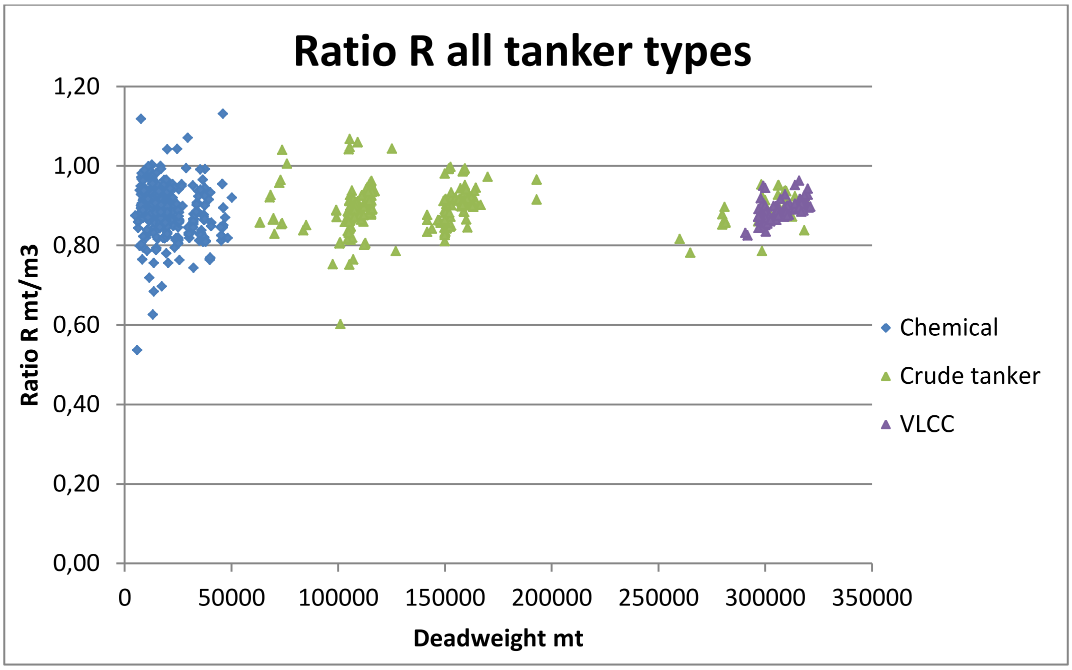

Figure 15: ratio R for all tanker types

Based on the graphs, the following conclusions can be drawn up:

- All tanker group have the same average ratio value: 0.89 mton/m^3
- The spread around this average value is larger for the chemical tankers.
- No clear distinction between the different tanker types can be made. Therefore this factor does not fulfil the requirements of being able to distinguish between the different types.
- Because a distinction between the different tanker types based on the deadweight liquid capacity rate cannot be observed, the suggested relation between the average higher EEDI values for chemical tankers and the ratio R cannot be confirmed.

5.4.4 Effect of proposed f_c on dimension of EEDI formula

The EEDI regime is based on the comparison of the EEDI reference line, its reduction factor and a calculated attained index. The comparison is realistic because both values have the same dimension and almost the same method of calculation. Therefore a ship with an EEDI below the reference line, is a more efficient ship than ships used for calculation of the reference line. This approach is only valid when the calculation of the attained EEDI does not vary to much from the calculations done for the EEDI reference line. Compensation factors in this respect can be a treat to this fair comparison.

In this paragraph an analysis is made of the changes made by adding factor f_c to the attained EEDI calculation of a tanker.

Factor R is calculated to divide the deadweight by the liquid capacity of a ship. This results in a R with a dimension of mton/m^3.
Adding the factor f_c as 1/R in the formula, the dimension of the attained EEDI changes from **gCO_2/tNm to gCO_2/ m^3Nm**

The dimension of the factor is changed. The attained index is calculated as a relation of the carriage of liquid capacity instead of deadweight tons.

This change in dimension makes the comparison with the reference line less realistic. A comparison is made between tankers calculated in the reference line with mtons as capacity to new ships with liquid capacity m^3 as capacity. It is like changing the speed dimension from nm/hr to km/hr. It is clear that a comparison between these values does not make sense.

A ratio like R as proposed by IPTA can be used in the factor, but then a thorough investigation should be done in the loss of efficiency related to this ratio. Based on this a dimensionless factor which expresses this relation can be added to the attained EEDI formula.

The change of dimension and the lack of prove of the loss of efficiency of chemical tankers makes the factor R unreliable to be used as a compensation factor.

5.4.5 Conclusion

- Fc factor as proposed by IPTA does not work. The relation between R and efficiency cannot be seen.
- The distinctive capacity of the factor to distinct between the different tanker types is not proved.
- The factor creates an index value with a different dimension than the reference line.

5.4.6 Alternative approach

In the previous part of this chapter, the approach proposed by IPTA for a compensation factor for chemical parcel tankers was criticized. However the necessity to establish a factor to compensate for the extra burden on chemical/parcel tankers to fulfil the required EEDI requirements seems necessary. Therefore a short investigation in possible other solutions to compensate the chemical/parcel tanker is made.

To do so the definitions for different tanker types were reviewed:

- What are according to IMO the definitions of the different tanker types
- What are according to the market the definitions of the different chemical tankers.

- Based on these definition, can these groups of ship be distinguished on several design issues?
- What is a reasonable factor to distinguish between the different tanker types in relation with their efficiency.

5.4.7 A chemical tanker according to IMO

Chemical tankers are difficult to define. According to MARPOL annex II, there are two types of tankers: The chemical tanker and the NLS tanker, the Noxious Liquid Substances tankers. The chemical tankers are divided in three types of tankers: IMO type 1,2 and 3. The type 1 tankers will have the highest requirements on cargo handling and damage stability and type 3 the lowest requirements.

This categorisation by IMO has created a large group of different tankers. Some of them have large tanks with little cargo treatment equipment, where others have a high segregation and small tanks with substantial amount of cargo treatment equipment. It is difficult to distinguish these tankers on specific requirements as you sometimes see mixes of both.

The only distinction which is possible on current legislation is on tanker type: Type 1 to 3

5.4.8 A Chemical Tanker according to the market

Commercially chemical tankers are divided into two groups: the chemical parcel tanker and the chemical product tankers. The first group is in most cases the more specialized ship. It can be recognized by its large amount of tanks compared to its size. A 40.000 ton parcel tankers has typically between 30 and 40 cargo tanks. These ships are specialized to carry different parcels in one time and are able to segregate numerous amounts of cargo. Most of them are type 2 tankers. Some of them have also type 1 notification.

The chemical product tanker is specialized in the larger parcels. For example they are specialized in carrying of methanol or ethanol in larger parcels. These ships have typically less tanks compared to their parcel sister vessels. Typically a 50.000 tons product tanker has 12 tanks. Less segregation is possible. These ships are mostly classified as type 2 or 3 tankers.

Generally all these chemical tankers have an IOPP (International Oil Pollution Prevention) certificate and are allowed to carry oil products. Therefore these ships are classified as chemical and oil tankers.

5.4.9 Differences between the groups

The operation profile of a parcel tanker is different from that of a chemical product tanker. This profile is not taking into account in the EEDI calculation.
Difference in profiling lies in:

- More tank segregation
- Different hull form for optimization for shallow draft restrictions
- Speed differences
- Extra cargo treatment equipment
- Different construction materials such as stainless steel

These differences have influence on the general operational profile characterises. The parcel tanker will be heavier and will have more auxiliary equipment to enable the ship of cargo heating, tank washing and other cargo treatment systems. This profile will also give the ships a different efficiency profile. Per ton/mile these ships will be less efficient than the product chemical tankers. But due to the high flexibility as a result of the high amount of tanks and flexibility to take all different kinds of cargos these ships will have less down time or less ballast voyages and therefore make them more efficient in a specific trade.
This factor of operational profile and its effect on the ships efficiency according to the EEDI calculations was already recognized in previous CMTI studies.

5.4.10 Alternative factor (deadweight lightweight Ratio)

We suggest a factor which is able to distinguish different tanker types we looked into the difference in deadweight lightweight ratio. The following table shows the deadweight lightweight ratio of a small group of tankers.

Table 3: DW/LW ratio of tankers

	Lightweight	Deadweight	Liquid cap	lw/DW ratio	Dw/Lqcap ratio	
Parcel Tanker 1	11250	36800	37921	0,31	0,97	
Parcel Tanker 2	8300	29709	35136	0,28	0,85	
Parcel Tanker 3	6500	19689	19408	0,33	1,01	
Parcel Tanker 4	6600	19087	19425	0,35	0,98	
Parcel Tanker 5	6200	19508	21798	0,32	0,89	
Parcel Tanker 6	7400	25776	30825	0,29	0,84	
Parcel Tanker 7	7700	25148	30511	0,31	0,82	
Parcel Tanker 8	11400	36634	37921	0,31	0,97	
Parcel tanker 9	11000	37622	37928	0,29	0,99	
				0,31	**0,93**	Average value
Chem product 1	9560	46719	53800	0,20	0,87	
Chem product 2	9340	46923	51909	0,20	0,90	
chem, product 3	11110	50921	51566	0,22	0,99	
Afra max	25868	163417	173721	0,16	0,94	
VLCC	42749	321300	341527	0,13	0,94	
				0,18	**0,93**	Average value

In this table the difference in Deadweight lightweight ratio between the different tankers can be seen. For a parcel tanker, the average ratio is around 0,31 whereas the average ratio for chemical product tankers is around 0.20.

This Ratio might be a way forward in setting the basis for a compensation factor f_c for chemical/parcel tankers.

Further investigation is necessary to see if there is a relation between the deadweight/lightweight ratio of tankers and its efficiency as calculated via the EEDI.

5.4.11 Conclusion

- Classification of tankers is difficult. IMO classification does not give a clear possibility in dividing the tankers in different efficiency groups.
- Classification in parcel and product chemical tankers gives us a clue in the difference of design and operational profiles existing in current world fleet
- Difference in tanker operational profile and design might have a relation with the deadweight/lightweight ratio
- A short investigation shows differences between the deadweight lightweight ration between different tanker types
- Relation between this ratio and the differences between EEDI efficiency is not yet investigated

- EEDI is not sufficient enough to estimate the real efficiency potential of a ship. The EEDI should be a better reflection of the real purpose of the ship in relation with its operational profile.

6 Calculation of the reduction potential

In the previous chapter it is shown that a limited number of recently built ships do not pass the criteria. Assuming that ship designs of future ships will have an equal spread of EEDI values, the CO_2 reduction potential of the EEDI can be estimated. The calculations are made as if the EEDI is the only CO_2 reduction measure taken for shipping. The calculations are limited to Dutch built and flagged ships.

Figure 16 shows the calculation method of reduction potential. Ships above the line have to become more efficient to fulfil future requirements. If these types of ship are built under future requirements they will at least be on the reduction target line. Ships below the target line don't need further improvements.

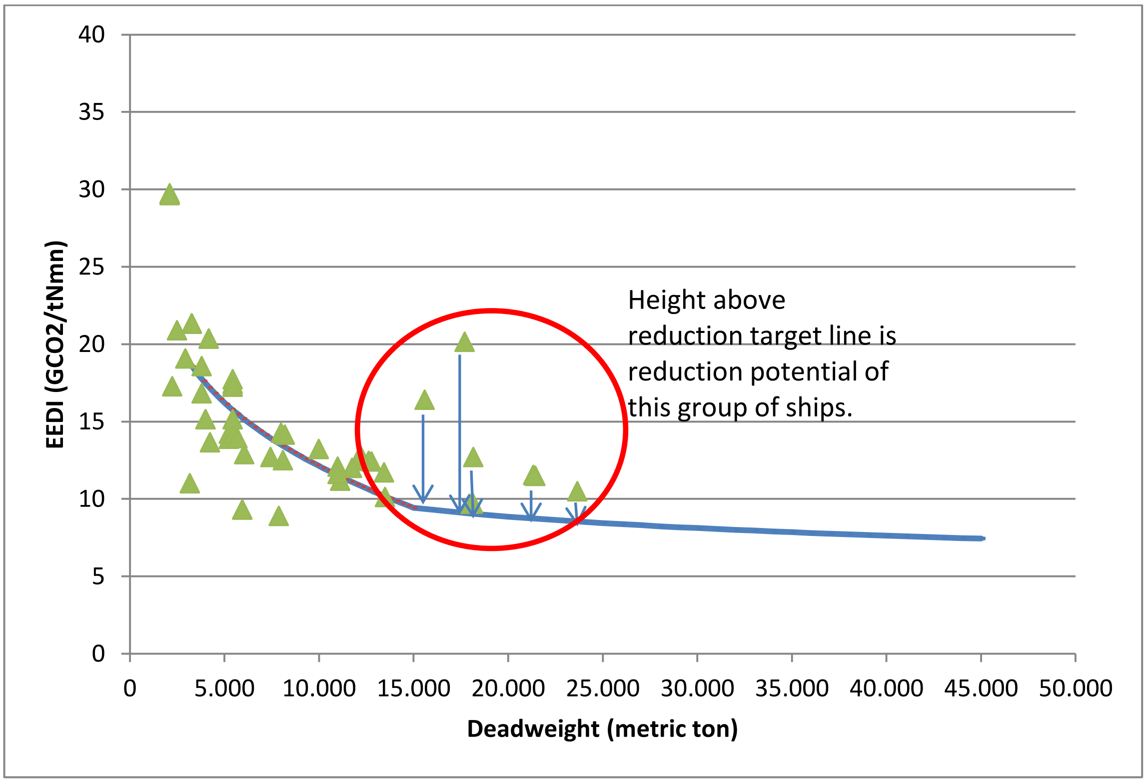

Figure 16: Calculation method for reduction potential

New requirements only apply to ships build after the applicable phase date.

6.1 Reduction potential

The reduction potential by the current legislation is calculated based on the existing fleet. Results are shown in the table below:

	attained	phase 0	phase 1	phase 2	phase 3
General cargo	933,98	10,22	38,31	44,03	74,78
Gas tankers	279,22	0,00	22,20	23,43	24,66
Ref car	883,76	23,97	64,83	94,34	218,28
Tanker	31,77	0,00	0,64	1,42	2,20
Bulkers	12,45	0,09	0,45	0,82	1,57
Container	35,35	0,00	0,00	0,00	0,00
	2176,53	34,28	126,44	164,04	321,50
		1,6%	**5,8%**	**7,5%**	**14,8%**

Table 4: Reduction potential per phase

In the first column the combined attained index values of the current fleet is given. The column's 2 to 5 show the amount of index value the fleet is above the specific index reduction target line. The percentage shown below the table is the percentage of the amount of index value above the index reduction target line of the specific phase against the total attained index values. These percentages gives an indication of the reduction potential solely by the EEDI legislation

6.2 Fleet development

To calculate the real reduction potential, it is necessary to know the amount of new buildings which are to be expected in combination with the coherence of the current fleet. Only then it is possible to predict a realistic reduction potential in CO_2 emissions based on the EEDI regulation.

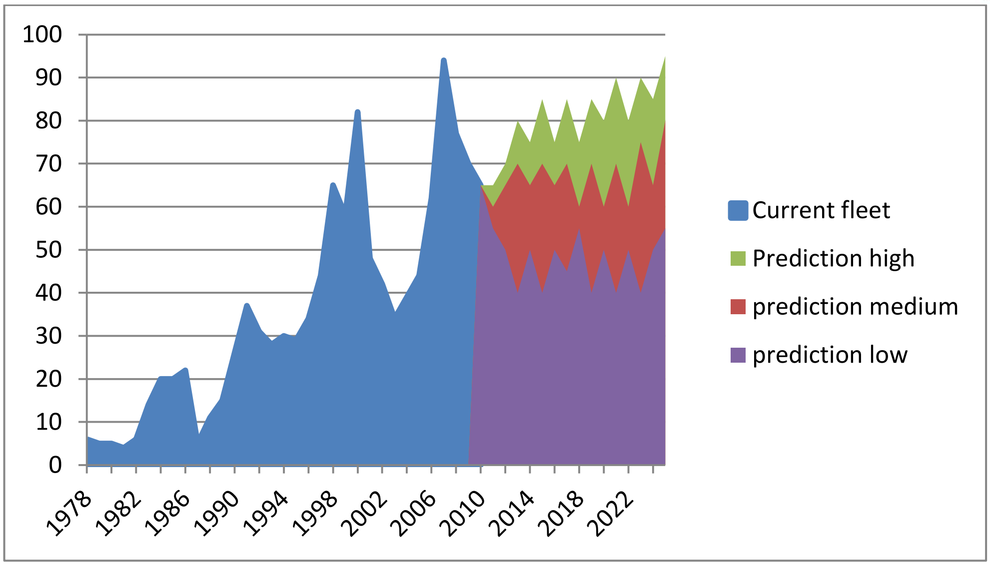

Figure 17: Estimations of Dutch fleet development

Figure 17 shows of the Dutch fleet by year of build and still in operation. The blue part all together is the current Dutch fleet. For the prediction of the CO_2 reduction potential, three scenarios are made:

- Prediction high: the Dutch ship-owners remain under Dutch flag and extend their fleet
- Prediction medium: Business as usual, Ship-owners will stay under Dutch flag. The replacement of ships will be less than expected
- Prediction low: The Dutch flag will be less favourable for Dutch ship-owners and less ships will be replaced.

6.3 Actual reduction calculation

Taking into account a lifetime span of a average ship of 30 years, It is possible to estimate the amount of ships of a specific age per year.

The following table shows the amount of ships per year up to 2026 based on the medium prediction model, to which phase requirements of the EEDI regulation will apply. These amounts make it possible to calculate the cumulative actual CO_2 reduction due to the effects of the EEDI regulations.

Pre EEDI	Phase 0	Phase 1	Phase 2	Phase 3	Total	Reduction	Phase	Year
1271					1271	0%		2012
1257	70				1327	0,08%	Phase 0	2013
1237	135				1372	0,16%		2014
1217	135	70			1422	0,44%	Phase 1	2015
1195	135	135			1465	0,68%		2016
1190	135	205			1530	0,92%		2017
1179	135	265			1579	1,11%		2018
1164	135	335			1634	1,32%		2019
1138	135	335	60		1668	1,56%	Phase 2	2020
1101	135	335	130		1701	1,84%		2021
1070	135	335	190		1730	2,07%		2022
1042	135	335	265		1777	2,33%		2023
1012	135	335	330		1812	2,56%		2024
983	135	335	330	80	1863	3,12%	Phase 3	2025
949	135	335	330	160	1909	3,67%		2026

Table 5: Reduction estimation for medium scenario,, expressed in total EEDI values

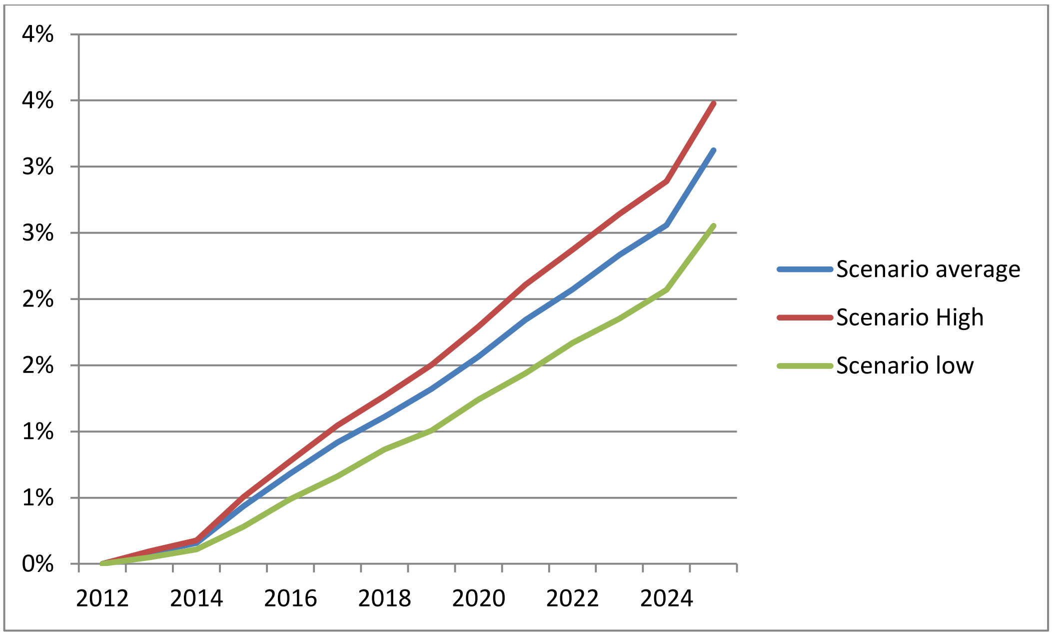

Figure 18: Cumulative CO2 reduction potential per year in the three scenario's

This calculation has been repeated for the low and high fleet development scenario's Results are shown in figure 8. It is concluded that the cumulative reduction potential is only 3-4 % up to 2025

7 Concluding remarks

EEDI calculations

1. For general cargo ships the wide scatter in EEDI values as observed in previous studies is confirmed in the small ship range.
2. In general the first phase reduction criteria will not give significant problems. Some ships are above the baseline. Most of them are specialized general cargo ships such as heavy lift vessels. For the specialized general cargo vessels, specific reference lines or compensation factors should be developed.
3. It is not clear if feasible designs of specialized gas tankers, which are operated by Dutch ship-owners, can be produced, that fulfil the required EEDI values. Specialized gas tankers have additional equipment on board for cargo treatment, which will influence their deadweight - lightweight ratio in a negative way. Most of these ships have a large P_{PTO} which will result in larger main engines. It is not clear how compensation for these larger P_{PTO} should be achieved.
4. It is not foreseen that the current reefer ship fleet will be replaced in the next few years. The first two reduction phases of the EEDI will therefore have no effect of the reefer fleet. An important element of the operational profile of a reefer ship is its speed. In future, new ships be designed for lower speed to fulfil the EEDI requirements. This will have great effect on the existing fleet as a lot of trade will/can not accept reduction of the speed. It may be important to compare the efficiency of containerised reefer cargo with a container liner with the efficiency of the same cargo on a reefer ship.

Comments on calculation method

5. The guideline for calculation method of the EEDI was finalized by a correspondence group of IMO. During this study it became clear that still some issues are not resolved or unclear. Especially around the use of P_{PTO}, the guideline is vague which will create a potential source of misuse.

6. During last MEPC 62 session IPTA proposed the introduction of a compensation factor f_c for tankers. It is concluded that the ratio R deadweight/ liquid capacity was not useable for this factor. An alternative ratio lightweight/deadweight ratio is proposed. Further investigation is necessary into the relation between this ratio and the noncompliance of chemical parcel tankers with the required EEDI regime.

CO_2 reduction potential EEDI

7. Based on calculations of the Dutch fleet and the reduction potential effect of the EEDI, it is established that the EEDI will result in approximately 3% efficiency increase of the fleet in 2025.

References

MEPC 61.WP10	Working group report on Greenhouse Gases
MEPC 62/6/3	Amendments to MARPOL Annex VI – Inclusion of regulations on energy efficiency for ships
MEPC 62/6/4	Calculation of parameters for determination of EEDI reference values
MEPC 62/5/4	Report on the correspondence group: Draft guidelines on the Method of calculation of the attained energy efficiency design index for new ships
MEPC 62/6/13	Introduction of a cubic capacity correction factor into the EEDI formula.
MEPC 62/24	Report of MEPC 62
MEPC 62/24.add.1	Annex to report of MEPC 62

CMTI Study 2009: Energy Efficiency van kleine schepen

CMTI Study 2010: Energy efficiency of small ships and non-conventional propelled ships

Supporting organisations

KVNR and its members
Scheepsbouw Nederland and its members

Annex 1

Table 1. reduction factors (in percentage) for the EEDI relative to the EEDI reference line

Ship Type	Size	Phase 0 [1 Jan 2013 – 31 Dec 2014]	Phase 1 [1 Jan 2015– 31 Dec 2019]	Phase 2 [1 Jan 2020– 31 Dec 2024]	Phase 3 [1 Jan 2025 onwards]
Bulk Carrier	20.000 DWT and Above	0	10	20	30
	10.000 – 20.000 DWT	n/a	0-10*	0-20*	0-30*
Gas Tanker	10.000 DWT and above	0	10	20	30
	2.000 – 10.000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20.000 DWT and above	0	10	20	30
	4.000 – 20.000 DWT	n/a	0-10*	0-20*	0-30*
Container Ship	15.000 DWT and above	0	10	20	30
	10.000 – 15.000 DWT	n/a	0-10*	0-20*	0-30*
General cargo Ship	15.000 DWT and above	0	10	15	30
	3.000 – 15.000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5.000 DWT and above	0	10	15	30
	3.000 – 5.000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20.000 DWT and above	0	10	20	30
	4.000 – 20.000 DWT	n/a	0-10*	0-20*	0-30*

*. Reduction factor to be linearly interpolated between the two values dependent upon vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

n/a means that no reguired EEDI applies.

The reference line values shall be calculated as follows:

Reference line value $= a \times b^{-c}$

Where a, b and c are the parameters given in table 2.

Table 2. Parameters for determination of reference value for the different ship types

Ship type	a	B	c
1.4 Bulk carrier	961.79	DWT of the ship	0.477
1.5 Gas Tanker	1120.00	DWT of the ship	0.456
1.6 Tanker	1218.80	DWT of the ship	0.488
1.7 Container ship	174.22	DWT of the ship	0.201
1.8 Geeral Cargo Ship	107.48	DWT of the ship	0.216
1.9 Refrigerated cargo carrier	227.01	DWT of the ship	0.244
1.10 Combination carrier	1219.00	DWT of the ship	0.488