



# Propulsion of 200,000-210,000 dwt Large Capesize Bulk Carrier

Engineering the Future – since 1758.

**MAN Diesel & Turbo**





# Content

Introduction .....	5
EEDI and Major Ship and Main Engine Parameters.....	6
Energy Efficiency Design Index (EEDI).....	6
Major propeller and engine parameters.....	7
205,000 dwt large capesize bulk carrier .....	9
Main Engine Operating Costs – 14.7 knots .....	10
Fuel consumption and EEDI .....	10
Operating costs .....	12
Main Engine Operating Costs – 14.0 knots .....	14
Fuel consumption and EEDI .....	14
Operating costs .....	17
Summary .....	18



# Propulsion of 200,000-210,000 dwt Large Capesize Bulk Carrier

## Introduction

The main ship particulars of 205,000-210,000 dwt large capesize bulk carriers are normally approximately as follows: the overall ship length is 299.9 m, breadth 50 m and scantling draught 17.9-18.4 m, see Fig. 1.

Recent development steps have made it possible to offer solutions which will enable significantly lower transportation costs for large capesize bulk carriers as outlined in the following.

One of the goals in the marine industry today is to reduce the impact of CO<sub>2</sub> emissions from ships and, therefore, to reduce the fuel consumption for the

propulsion of ships to the widest possible extent at any load.

This also means that the inherent design CO<sub>2</sub> index of a new ship, the so-called Energy Efficiency Design Index (EEDI), will be reduced. Based on an average reference CO<sub>2</sub> emission from existing bulk carriers, the CO<sub>2</sub> emission from new bulk carriers in gram per dwt per nautical mile must be equal to or lower than the reference emission figures valid for the specific bulk carrier.

This drive may often result in operation at lower than normal service ship speeds compared to earlier, resulting in reduced propulsion power utilisation. The design

ship speed at Normal Continuous Rating (NCR), including 15% sea margin, used to be as high as 14.0-15.0 knots and with an average of about 14.7 knots. Today, the required ship speed should be expected to be lower, however it seems to be unchanged.

A more technically advanced development drive is to optimise the aftbody and hull lines of the ship – including bulbous bow, also considering operation in ballast condition. This makes it possible to install propellers with a larger propeller diameter and, thereby, obtaining higher propeller efficiency, but at a reduced optimum propeller speed, i.e. using less power for the same ship speed.



Fig. 1: Large capesize bulk carrier

As the two-stroke main engine is directly coupled with the propeller, the introduction of the ultra long stroke G70ME-C9.5 engine with even lower than usual shaft speed will meet this goal. The main dimensions for this engine type, and for the existing large capesize bulk carrier engine S70ME-C8.5 are shown in Fig. 2.

On the basis of a case study of a 205,000 dwt large capesize bulk carrier in compliance with IMO Tier II emission rules, this paper shows the influence on fuel consumption when choosing the new G70ME-C9.5 engine compared with the existing and normally used S70ME-C8.5 engine. The layout ranges of 5 and 6G70ME-C9.5 engines compared with 6S70ME-C8.5 are shown later in Fig. 4.

## EEDI and Major Ship and Main Engine Parameters

### Energy Efficiency Design Index (EEDI)

The IMO (International Maritime Organisation) based Energy Efficiency Design Index (EEDI) is a mandatory index required on all new ships contracted after 1 January 2013. The index is used as an instrument to fulfil international requirements regarding CO<sub>2</sub> emissions on ships. EEDI represents the amount of CO<sub>2</sub> emitted by a ship in relation to the transported cargo and is measured in gram CO<sub>2</sub> per dwt per nautical mile. The EEDI value is calculated on the basis of maximum cargo capacity (yet 70% for container ships), propulsion power, ship speed, SFOC (Specific Fuel Oil Consumption) and fuel type. De-

pending on the date of ship contract, the EEDI is required to be a certain percentage lower than an IMO defined reference value depending on the type and capacity of the ship.

The main engine's 75% SMCR (Specified Maximum Continuous Rating) figure is as standard applied in the calculation of the EEDI figure, in which also the CO<sub>2</sub> emission from the auxiliary engines of the ship is included. However, certain correction figures are applicable, e.g. for installed waste heat recovery systems.

According to the rules finally decided on 15 July 2011, the EEDI of a new ship is reduced to a certain factor compared to a reference value. Thus, a ship

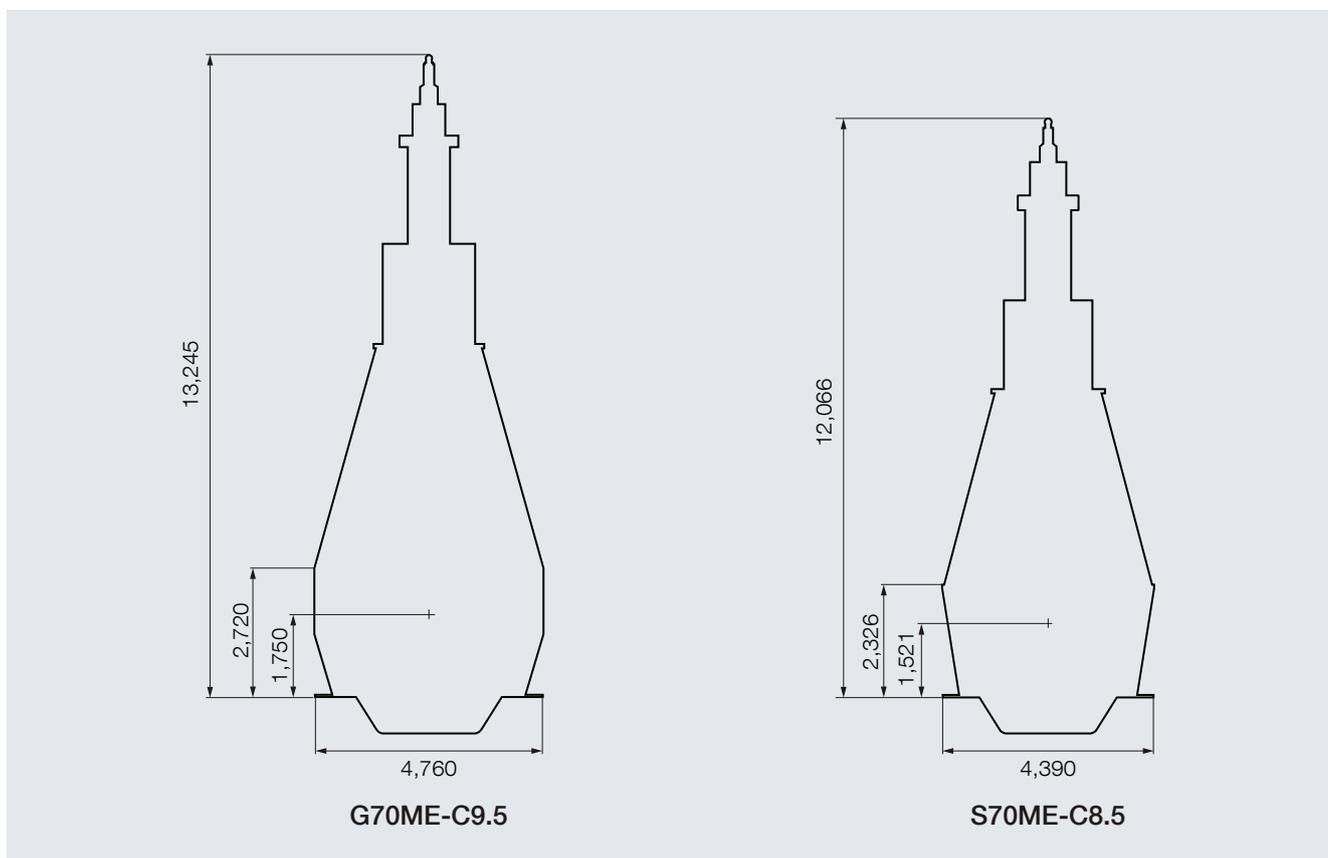


Fig. 2: Main dimensions for the new G70ME-C9.5 engine and the existing S70ME-C8.5 applied earlier

bigger than 20,000 dwt and built after 2025 is required to have a 30% lower EEDI than the 2013 reference figure, see also later in Figs. 8 and 14.

### Major propeller and engine parameters

In general, the highest possible propulsive efficiency required to provide a given ship speed is obtained with the largest possible propeller diameter  $d$ , in combination with the corresponding, optimum pitch/diameter ratio  $p/d$ .

As an example, this is illustrated for a 205,000 dwt large capesize bulk carrier with a service ship speed of 14.7 knots, see the black curve in Fig. 3. The need-

ed propulsion SMCR (Specified Maximum Continuous Rating) power and speed is shown for a given optimum propeller diameter  $d$  and  $p/d$  ratio.

According to the black curve, the existing propeller diameter of 8.3 m may have the optimum pitch/diameter ratio of 0.71, and the lowest possible SMCR shaft power of about 17,680 kW at about 88 r/min.

The black curve shows that if a bigger propeller diameter of 8.8 m is possible, the necessary SMCR shaft power will be reduced to about 17,120 kW at about 78 r/min, i.e. the bigger the propeller, the lower the optimum propeller speed.

If the pitch for this diameter is changed, the propulsive efficiency will be reduced, i.e. the necessary SMCR shaft power will increase, see the red curve. The red curve also shows that propulsion-wise it will always be an advantage to choose the largest possible propeller diameter, even though the optimum pitch/diameter ratio would involve a too low propeller speed (in relation to the required main engine speed). Thus, when using a somewhat lower pitch/diameter ratio, compared with the optimum ratio, the propeller/engine speed may be increased and will only cause a minor extra power increase.

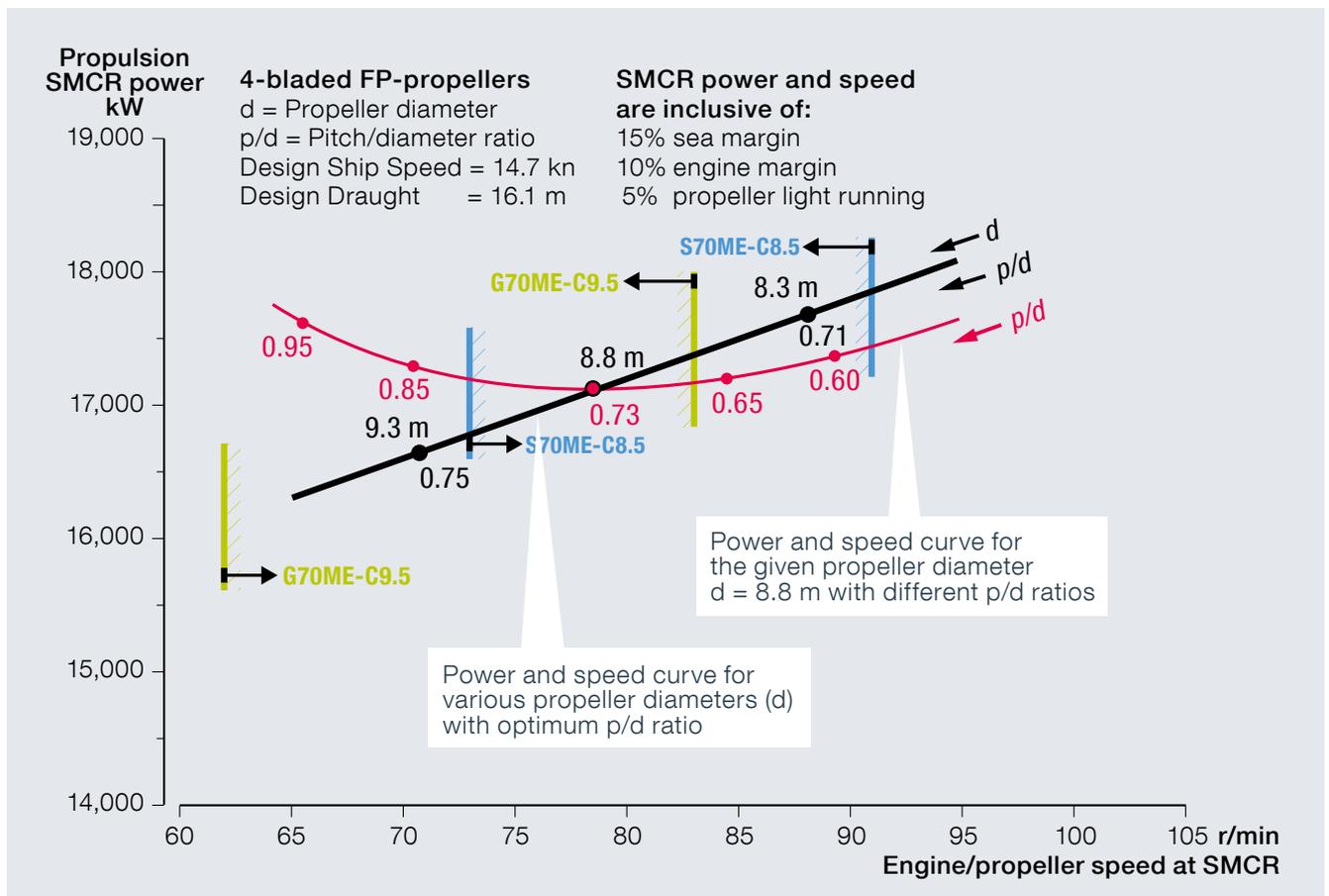


Fig. 3: Influence of propeller diameter and pitch on SMCR for a 205,000 dwt large capesize bulk carrier operating at 14.7 knots

The efficiency of a two-stroke main engine particularly depends on the ratio of the maximum (firing) pressure and the mean effective pressure. The higher the ratio, the higher the engine efficiency, i.e. the lower the Specific Fuel Oil Consumption (SFOC).

Furthermore, the higher the stroke/bore ratio of a two-stroke engine, the higher the engine efficiency. This means, for example, that an ultra long stroke engine type, as the G70ME-C9.5, may have a higher efficiency compared with

a shorter stroke engine type, like a super long stroke S70ME-C8.5.

The application of new propeller design technologies may also motivate use of main engines with lower rpm. Thus, for the same propeller diameter, these propeller types can demonstrate an up to 4% improved overall efficiency gain at the same or a slightly lower propeller speed. This is valid for propellers with Kappel technology available at MAN Diesel & Turbo, Frederikshavn, Denmark.

Furthermore, due to lower emitted pressure impulses, the kappel propeller requires less tip clearance that can be utilised for installing an even larger propeller diameter, resulting in a further increase of the propeller efficiency.

Hence, with such a propeller type, the advantage of the new low speed G70ME-C9.5 engine can be utilised also in case a correspondingly larger propeller cannot be accommodated.

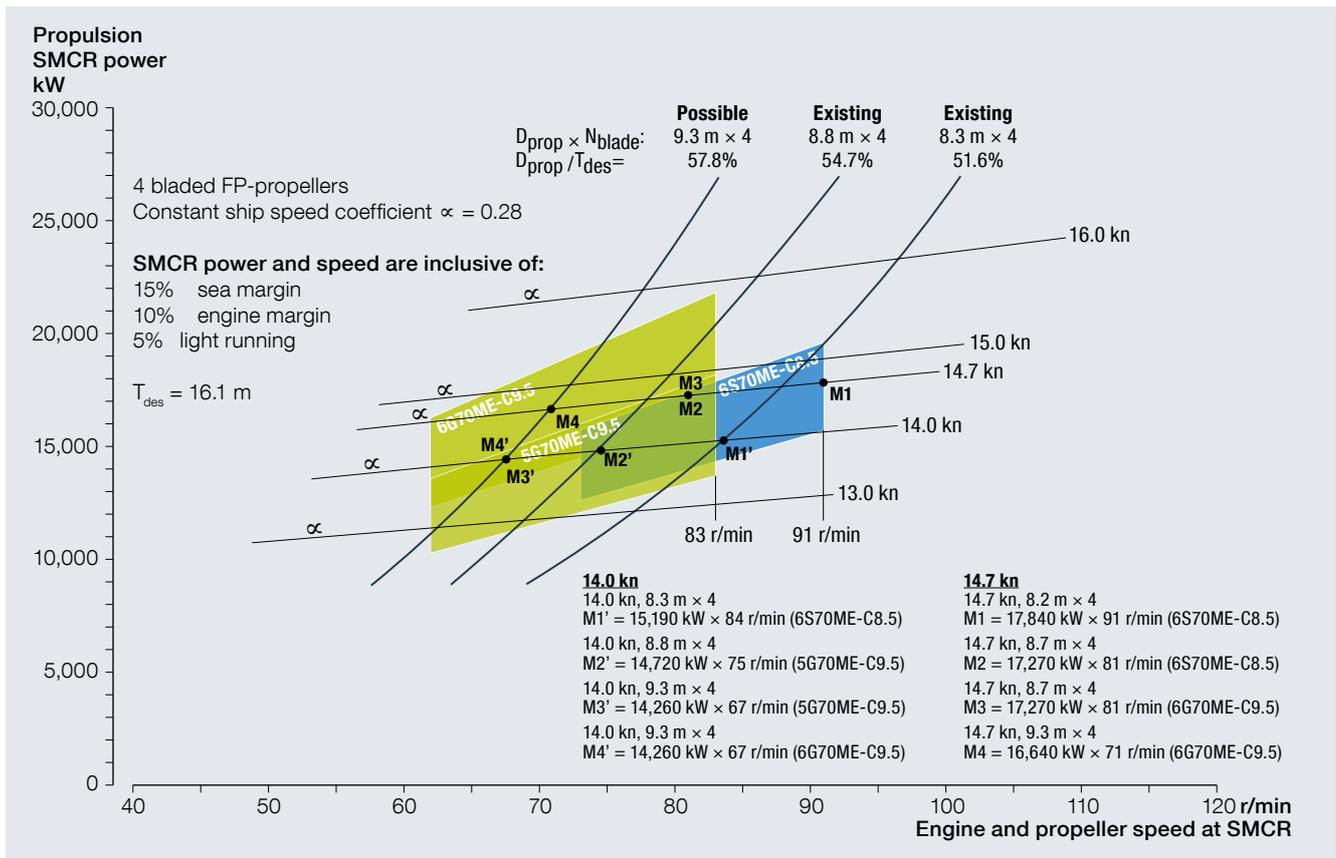


Fig. 4: Different main engine and propeller layouts and SMCR possibilities (M1, M2, M3, M4 for 14.7 knots and M1', M2', M3', M4' for 14.0 knots) for a 205,000 dwt large capesize bulk carrier operating at 14.7 knots and 14.0 knots, respectively

### 205,000 dwt large capesize bulk carrier

For a 205,000 dwt large capesize bulk carrier, the following case study illustrates the potential for reducing fuel consumption by increasing the propeller diameter and introducing the G70ME-C9.5 as main engine. The ship particulars assumed are as follows:

Scantling draught	m	18.2
Design draught	m	16.1
Length overall	m	299.9
Length between pp	m	291.0
Breadth	m	50.0
Sea margin	%	15
Engine margin	%	10
Design ship speed	kn	14.7 and 14.0
Type of propeller		FPP
No. of propeller blades		4
Propeller diameter	m	target

Based on the above-stated average ship particulars assumed, we have made a power prediction calculation (Holtrop & Mennen's Method) for different design ship speeds and propeller diameters, and the corresponding SMCR power and speed, point M, for propulsion of the large capesize bulk carrier is found, see Fig. 4. The propeller diameter change corresponds approximately to the constant ship speed factor  $\alpha = 0.28$  [ref.  $P_{M2} = P_{M1} \times (n2/n1)^\alpha$ ].

Referring to the two ship speeds of 14.7 knots and 14.0 knots, respectively, two potential main engine types, pertaining layout diagrams and SMCR points have been drawn-in in Fig. 4, and the main engine operating costs have been calculated and described.

The S70ME-C8.5 engine type (91 r/min) has often been used in the past as prime movers in projects for large capesize bulk carriers. Therefore, a comparison between the new G70ME-C9.5 and the existing S70ME-C8.5 is of major interest in this paper.

It should be noted that the ship speed stated refers to NCR = 90% SMCR including 15% sea margin. If based on calm weather, i.e. without sea margin, the obtainable ship speed at NCR = 90% SMCR will be about 0.6 knots higher.

If based on 75% SMCR, as applied for calculation of the EEDI, the ship speed will be about 0.2 knot lower, still based on calm weather conditions, i.e. without any sea margin.

**Main Engine Operating Costs –  
14.7 knots**

The calculated main engine examples are as follows:

**14.7 knots**

1.	6S70ME-C8.5 ( $D_{prop} = 8.2\text{ m}$ ) M1 = 17,840 kW × 91.0 r/min
2.	6S70ME-C8.5 ( $D_{prop} = 8.7\text{ m}$ ) M2 = 17,270 kW × 81.0 r/min.
3.	6G70ME-C9.5 ( $D_{prop} = 8.7\text{ m}$ ) M3 = 17,270 kW × 81.0 r/min.
4.	6G70ME-C9.5 ( $D_{prop} = 9.3\text{ m}$ ) M4 = 16,640 kW × 71.0 r/min.

The main engine fuel consumption and operating costs at  $N = NCR = 90\%$  SMCR have been calculated for the above four main engine/propeller cases operating on the average ship speed of 14.7 knots, as often used earlier, but also today, despite the EEDI demands. Furthermore, the corresponding EEDI has been calculated on the basis of the 75% SMCR-related figures (without sea margin).

**Fuel consumption and EEDI**

Fig. 5 shows the influence of the propeller diameter with four propeller blades when going from about 8.2 m to 9.3 m. Thus, N4 for the 6G70ME-C9.5 with a 9.3 m propeller diameter has a propulsion power demand that is about 6.7% lower compared with N1 valid for the 6S70ME-C8.5 with a propeller diameter of about 8.2 m.

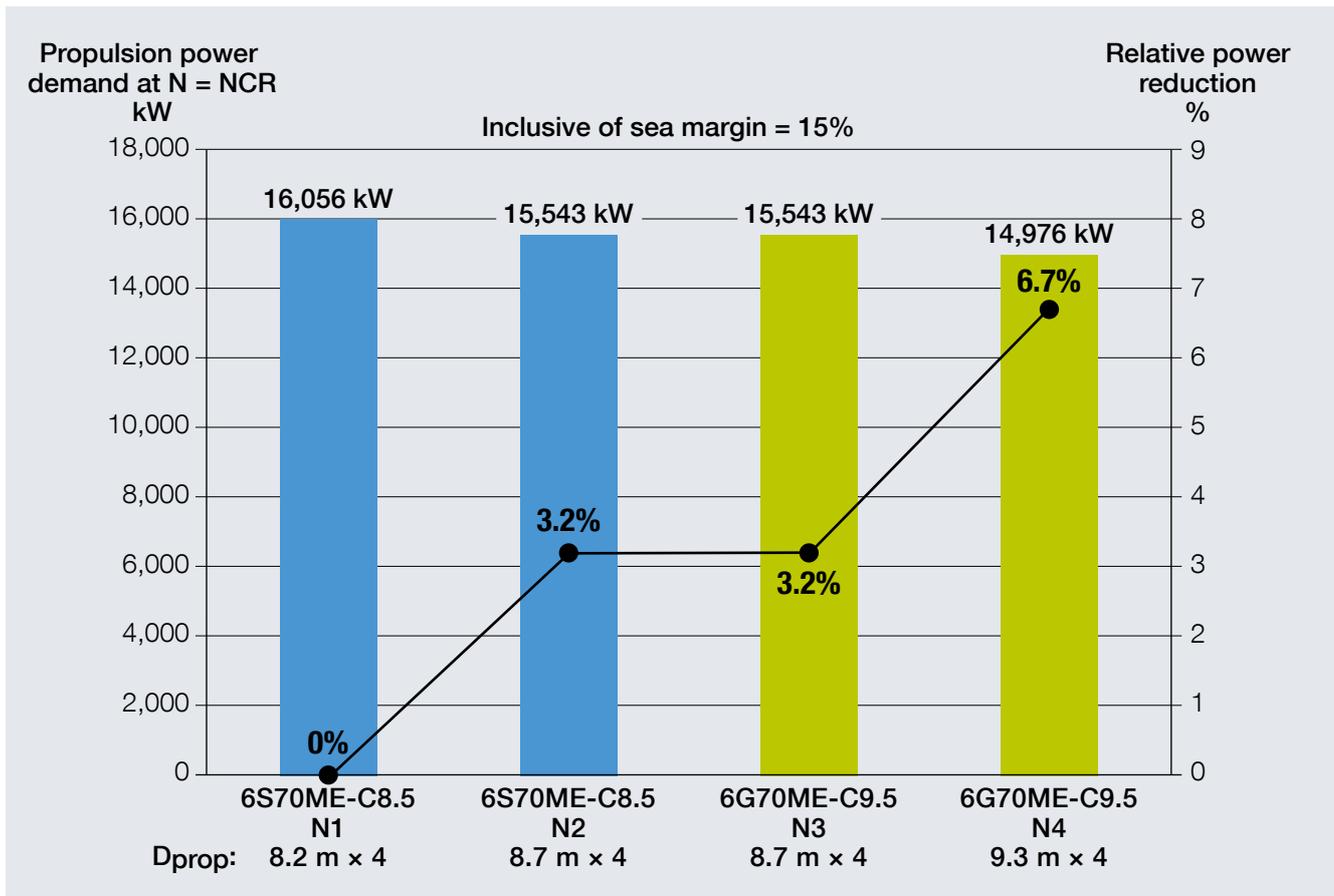


Fig. 5: Expected propulsion power demand at  $NCR = 90\%$  SMCR for 14.7 knots

Fig. 6 shows the influence on the main engine efficiency, indicated by the Specific Fuel Oil Consumption, SFOC, for the four cases. For N3 = 90% M3 with the 6G70ME-C8.5 SFOC is 159.1 g/kWh and for N1 = 90% M1 with 6S70ME-C8.5 SFOC is 164.1 g/kWh.

In N3, the SFOC is about 3.0% lower compared with N1.

When multiplying the propulsion power demand at N (Fig. 5) with the SFOC (Fig. 6), the daily fuel consumption is found and is shown in Fig. 7. Compared

with N1 for the existing 6S70ME-C8.5, the total reduction of fuel consumption of the new 6G70ME-C9.5 at N3 is about 6.1% and at N4 about 8.2% (see also the above-mentioned savings of 3.2%/6.7% (Fig. 5) and 3.0%/1.6% (Fig. 6)).

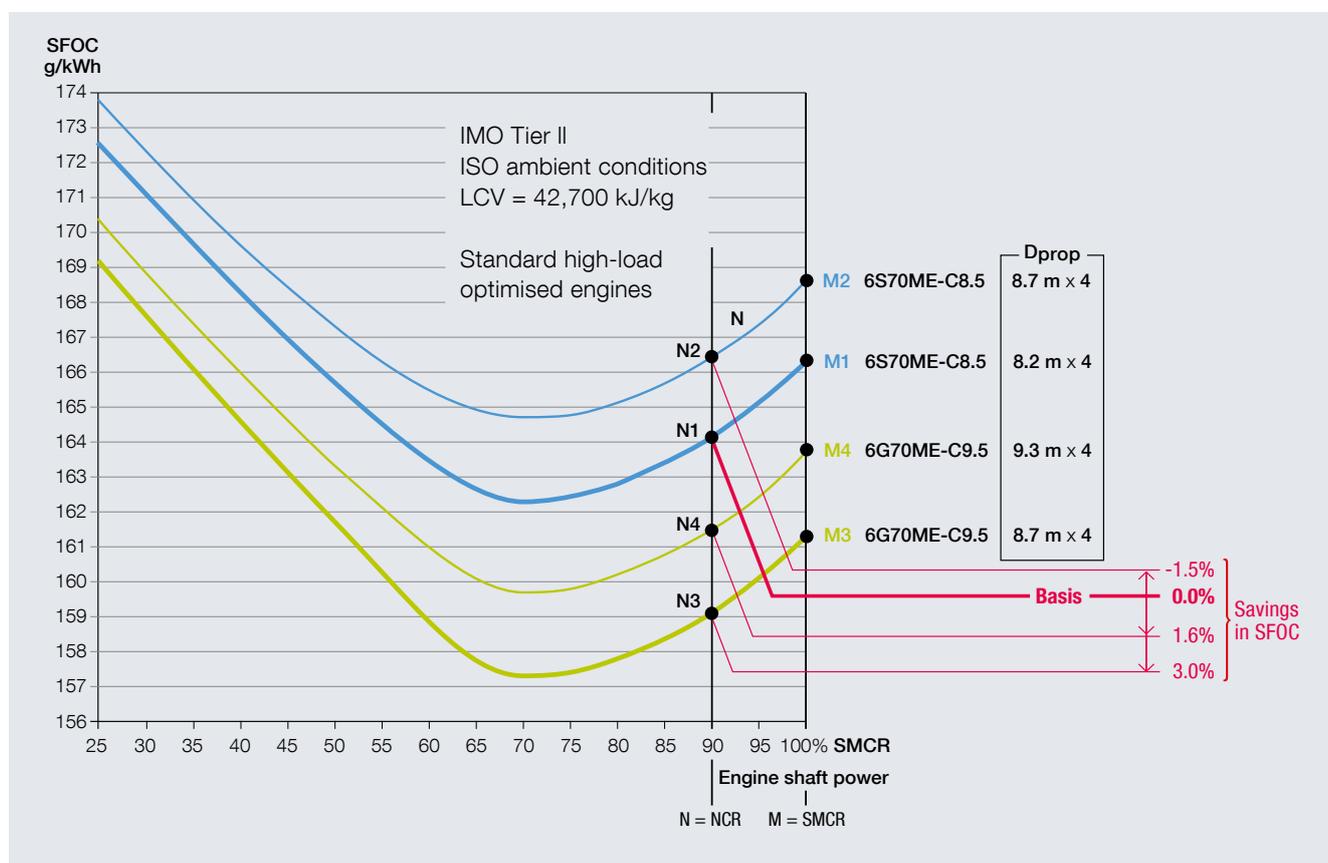


Fig. 6: Expected SFOC for 14.7 knots

The reference and the actual EEDI figures have been calculated and are shown in Fig. 8 ( $EEDI_{ref} = 961.8 \times dwt^{-0.477}$ , 15 July 2011). As can be seen for all four cases, the actual EEDI figures are relatively high with the lowest EEDI (86%) for case 4 with 6G70ME-C9.5. Cases 3 and 4 with 6G70ME-C9.5 are the only ones to meet the 2015 reference EEDI.

### Operating costs

The total main engine operating costs per year, 250 days/year, and fuel price of 700 USD/t, are shown in Fig. 9. The lube oil and maintenance costs are shown too. As can be seen, the major operating costs originate from the fuel costs – about 96%.

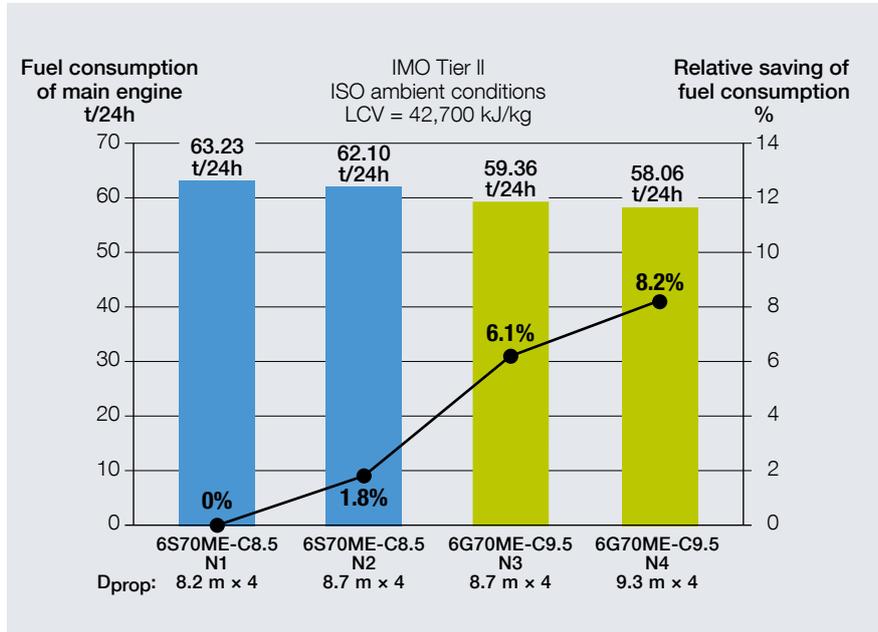


Fig. 7: Expected fuel consumption at NCR = 90% SMCR for 14.7 knots

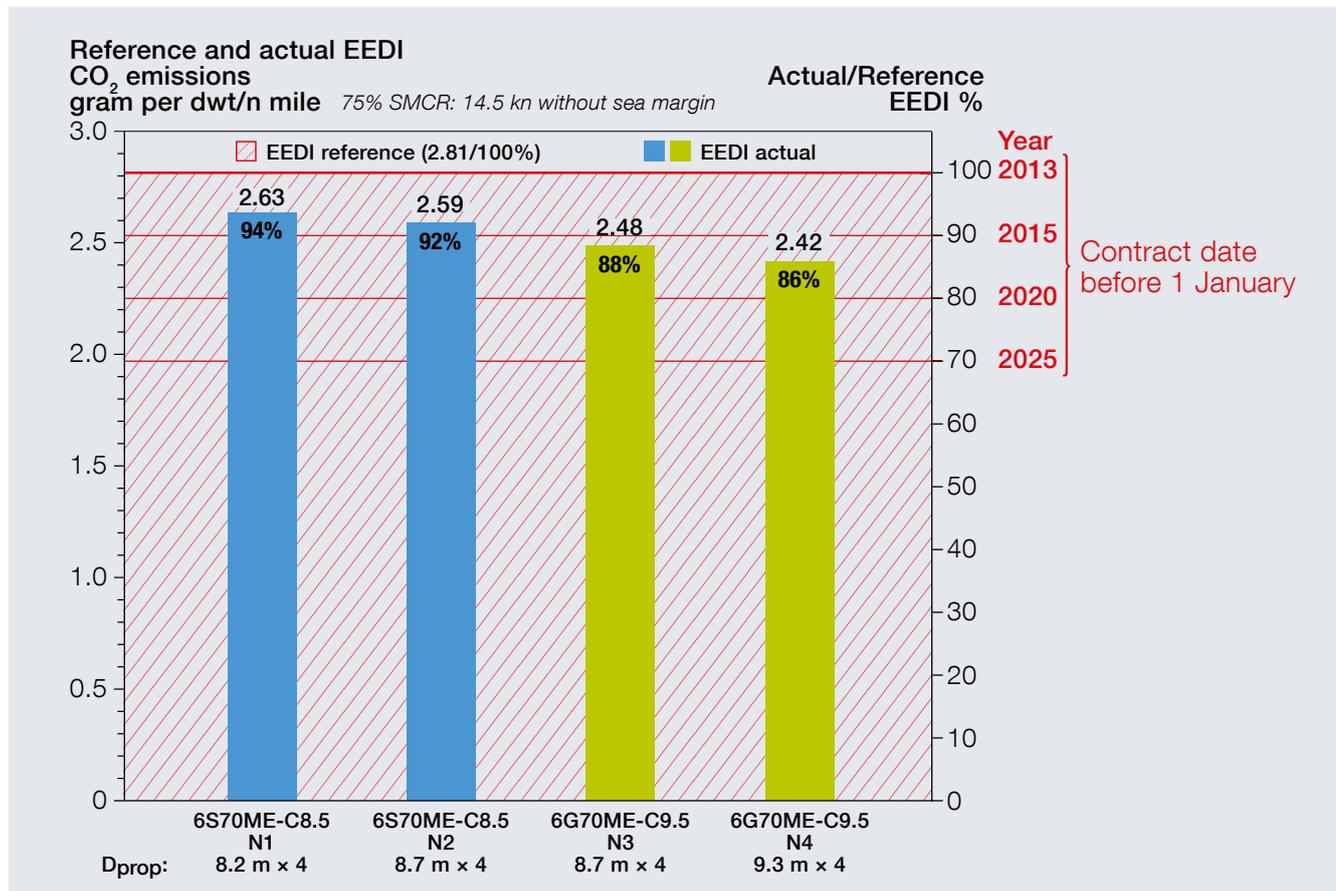


Fig. 8: Reference and actual Energy Efficiency Design Index (EEDI) for 14.7 knots

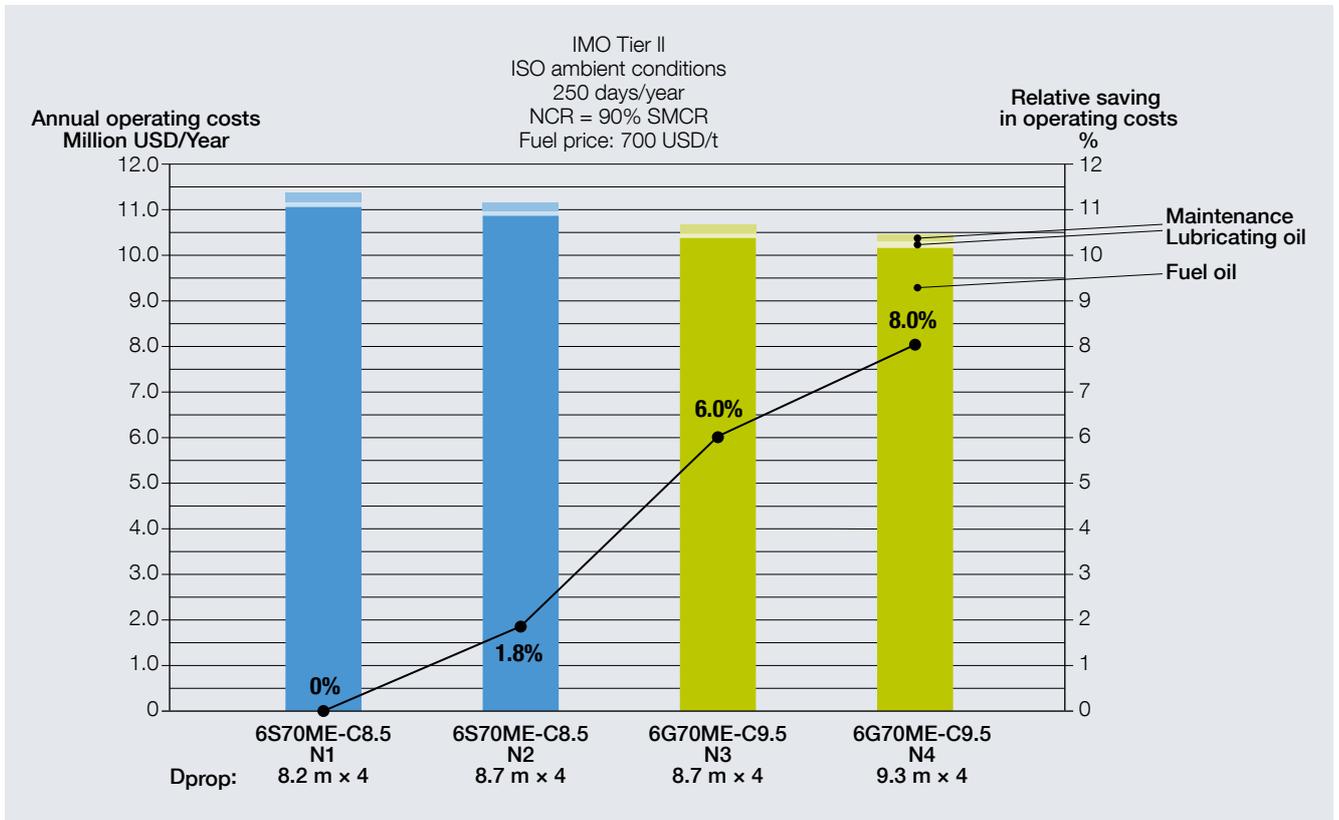


Fig. 9: Total annual main engine operating costs for 14.7 knots

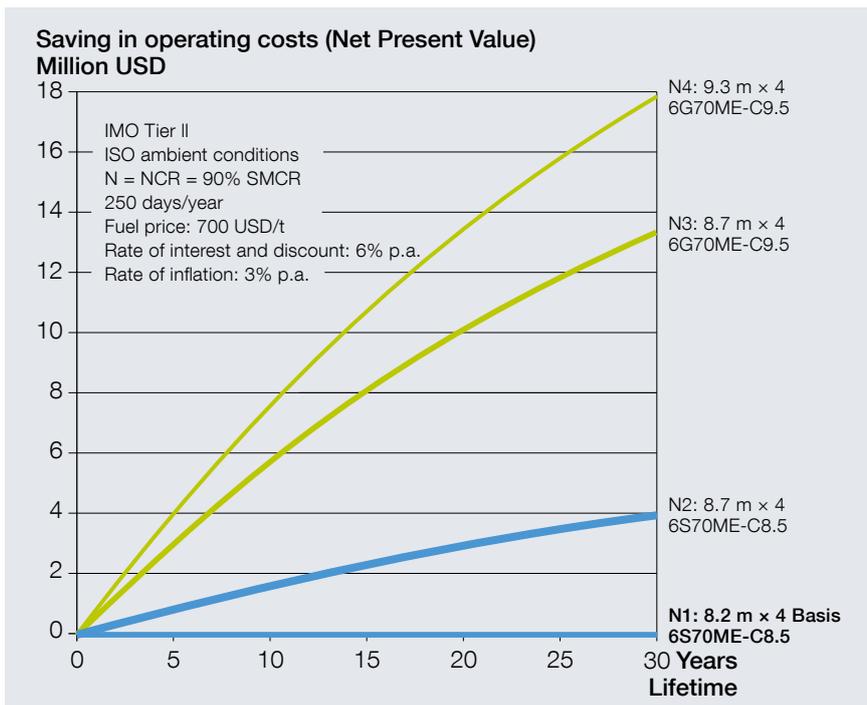


Fig. 10: Relative saving in main engine operating costs (NPV) for 14.7 knots

After some years in service, the relative savings in operating costs in Net Present Value (NPV), see Fig. 10, with the existing 6S70ME-C8.5 used as basis with the propeller diameter of about 8.2 m, indicates an NPV saving for the new 6G70ME-C9.5 engines. After 25 years in operation, the saving is about 15.9 million USD for N4 with 6G70ME-C9.5 with the SMCR speed of 71.0 r/min and propeller diameter of about 9.3 m.

**Main Engine Operating Costs –  
14.0 knots**

The calculated main engine examples are as follows:

**14.0 knots**

1'. 6S70ME-C8.5 ( $D_{prop} = 8.3$ m)	$M1' = 15,190$ kW $\times$ 84.0 r/min
2'. 5G70ME-C9.5 ( $D_{prop} = 8.8$ m)	$M2' = 14,720$ kW $\times$ 75.0 r/min.
3'. 5G70ME-C9.5 ( $D_{prop} = 9.3$ m)	$M3' = 14,260$ kW $\times$ 67.0 r/min.
4'. 6G70ME-C9.5 ( $D_{prop} = 9.3$ m)	$M4' = 14,260$ kW $\times$ 67.0 r/min.

The main engine fuel consumption and operating costs at  $N' = NCR = 90\%$  SMCR have been calculated for the above four main engine/propeller cases operating on the relatively lower ship speed of 14.0 knots, which is probably going to be a more normal choice in the future. Furthermore, the EEDI has been calculated on the basis of the 75% SMCR-related figures (without sea margin). Examples 3' and 4' indicate the influence of one extra engine cylinder.

**Fuel consumption and EEDI**

Fig. 11 shows the influence of the propeller diameter with four propeller blades when going from about 8.3 m to 9.3 m. Thus, N3' and N4' for the 5 and 6G70ME-C9.5 with an about 9.3 m propeller diameter has a propulsion power demand that is about 6.1% lower compared with the N1' for the 6S70ME-C8.5 with an about 8.3 m propeller diameter.

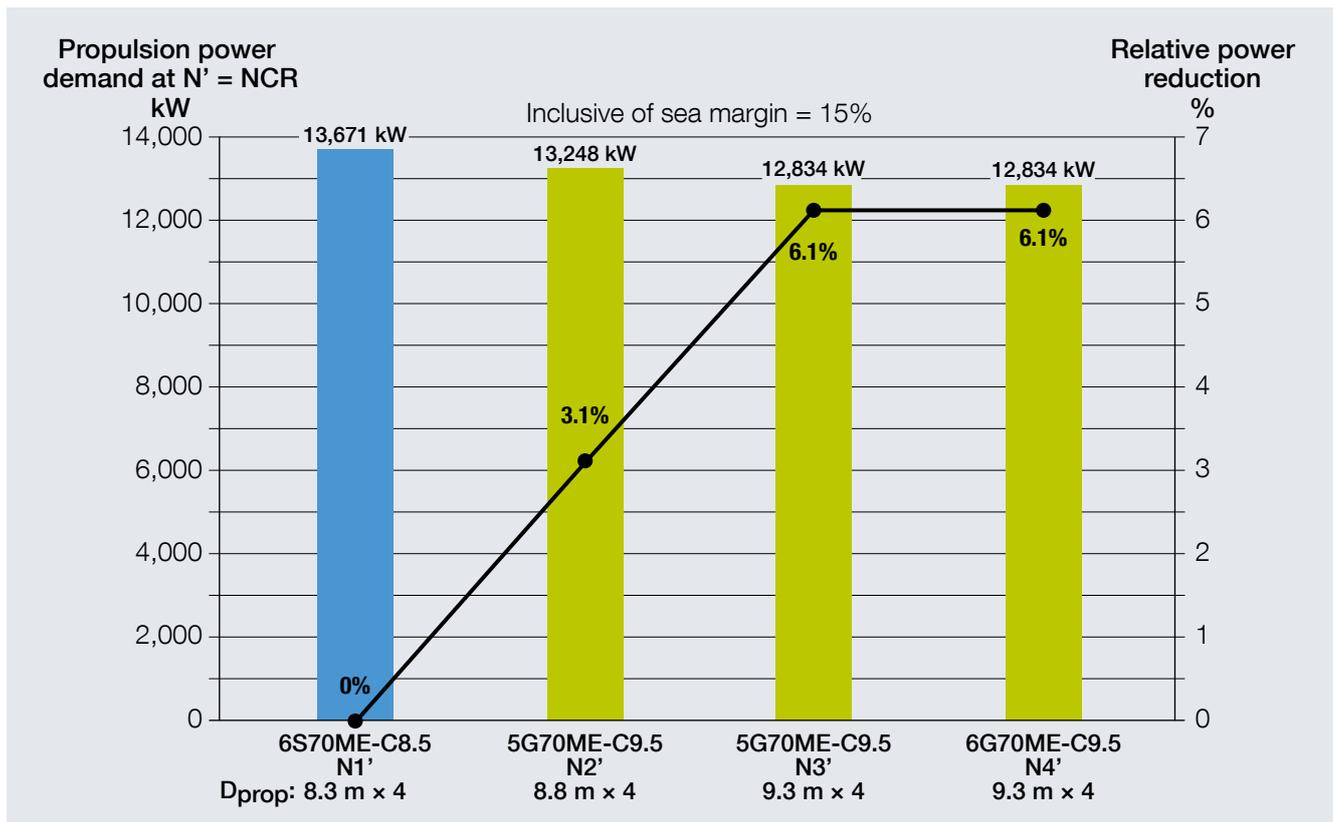


Fig. 11: Expected propulsion power demand at NCR = 90% SMCR for 14.0 knots

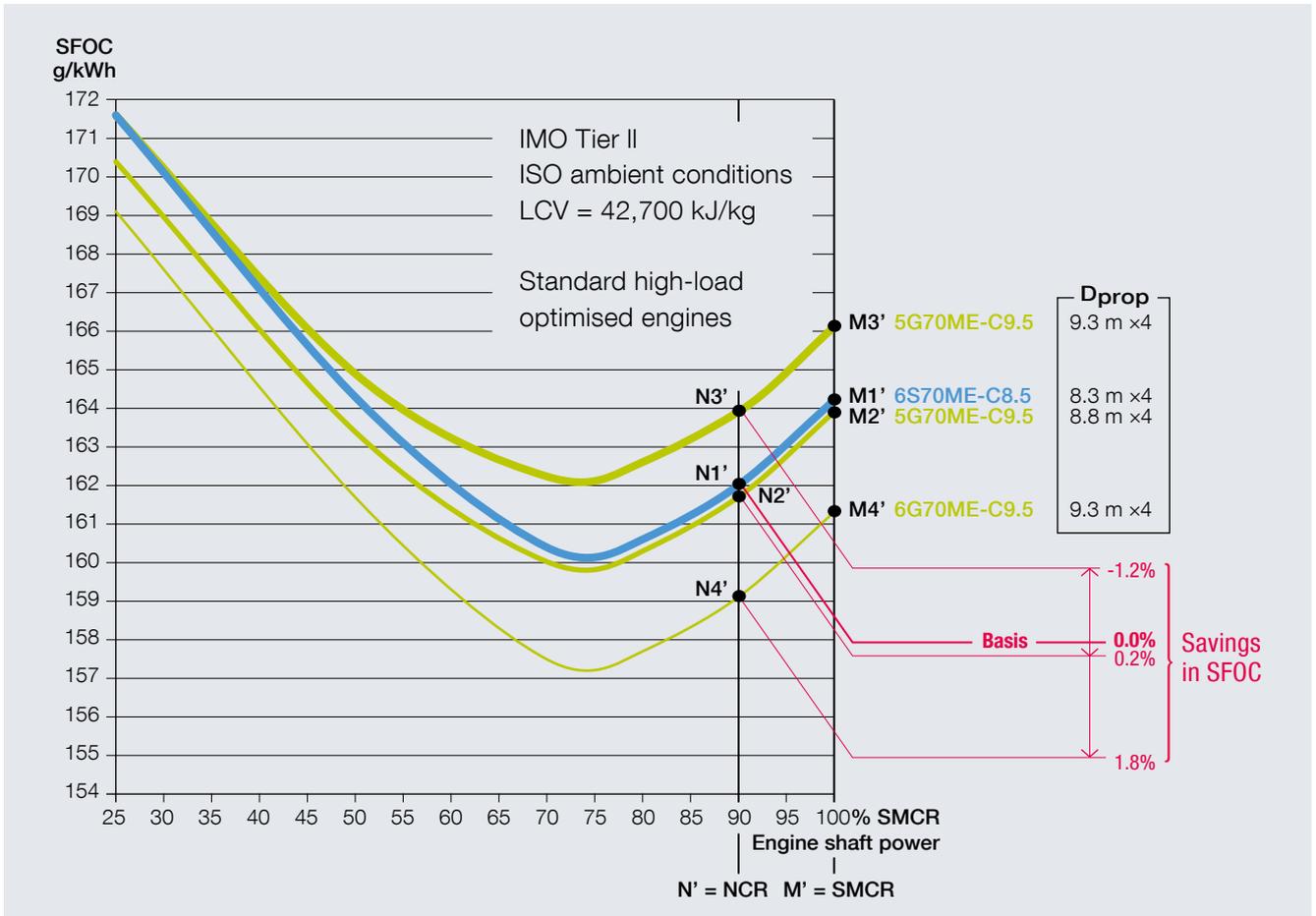


Fig. 12: Expected SFOC for 14.0 knots

Fig. 12 shows the influence on the main engine efficiency, indicated by the Specific Fuel Oil Consumption, SFOC, for the four cases. N3' = 90% M3' with the 5G70ME-C9.5 has a relatively high SFOC of 163.9 g/kWh compared with the 162.0 g/kWh for N1' = 90% M1' for the 6S70ME-C8.5, i.e. an SFOC increase of about 1.2%, mainly caused

by the greater speed derating potential giving higher mep of the 5G70ME-C9.5 engine type, but involving a higher potential propeller efficiency. However, for N4' = 90% M4' (in the same point as for N3') for the 6G70ME-C9.5, the mep derating involves a lower SFOC of 159.1 g/kWh corresponding to an SFOC reduction of 1.8%.

The daily fuel consumption is found by multiplying the propulsion power demand at N' (Fig. 11) with the SFOC (Fig. 12), see Fig. 13. The total reduction of fuel consumption of the new 6G70ME-C9.5, N4' with propeller diameter 9.3 m, is about 7.8% compared with the existing 6S70ME-C8.5 (see also the above-mentioned savings of 6.1% and 1.8%).

The reference and the actual EEDI figures have been calculated and are shown in Fig. 14 ( $EEDI_{ref} = 961.8 \times dwt^{-0.477}$ , 15 July 2011). As can be seen for all four cases, the actual EEDI figures are now somewhat lower than the reference figure because of the relatively low ship speed of 14.0 knots. Particularly, case 4' with 6G70ME-C9.5 has a low EEDI – about 77% of the 2013 reference figure. All G70ME-C9.5 engine cases will meet the stricter 2020 EEDI reference figure.

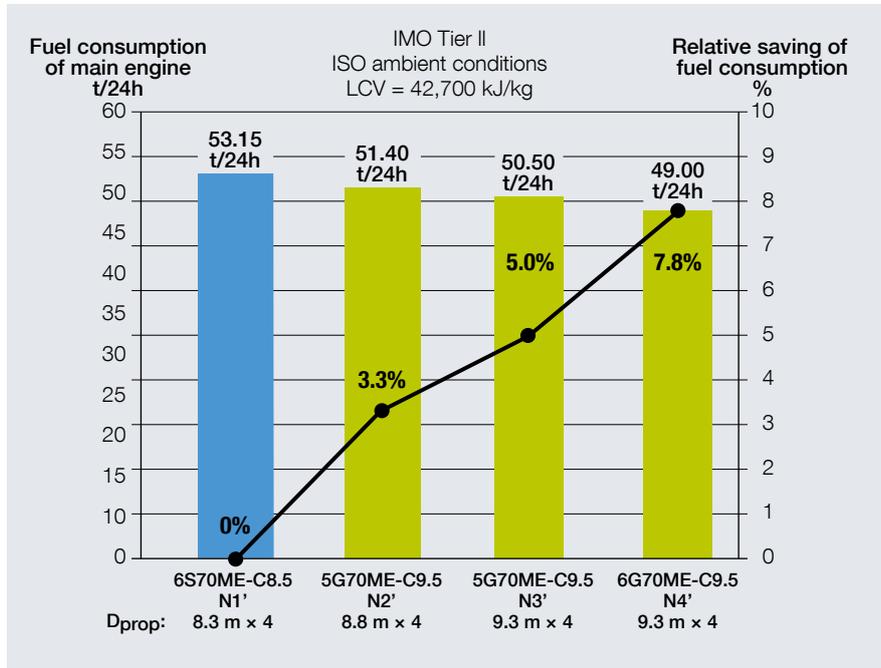


Fig. 13: Expected fuel consumption at NCR = 90% SMCR for 14.0 knots

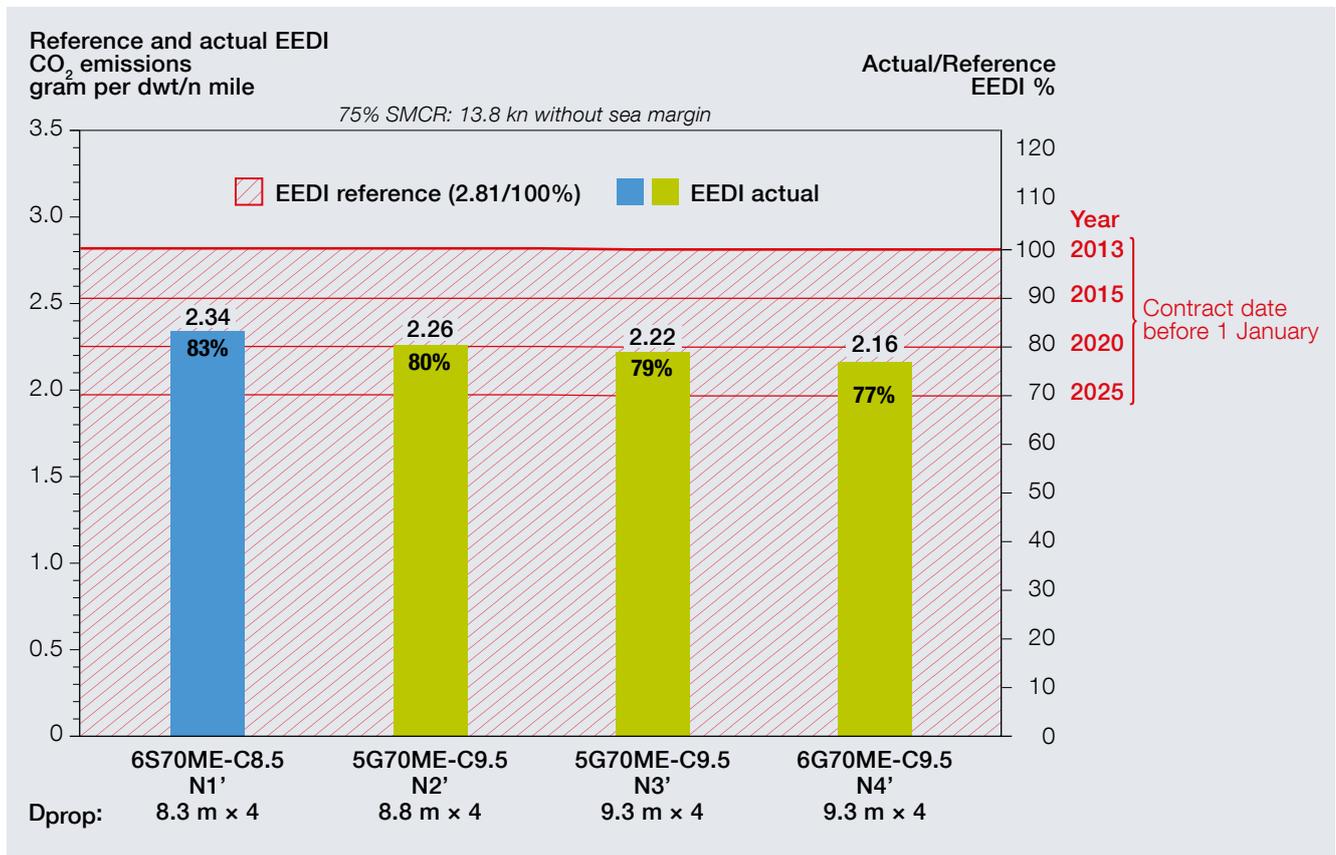


Fig. 14: Reference and actual Energy Efficiency Design Index (EEDI) for 14.0 knots

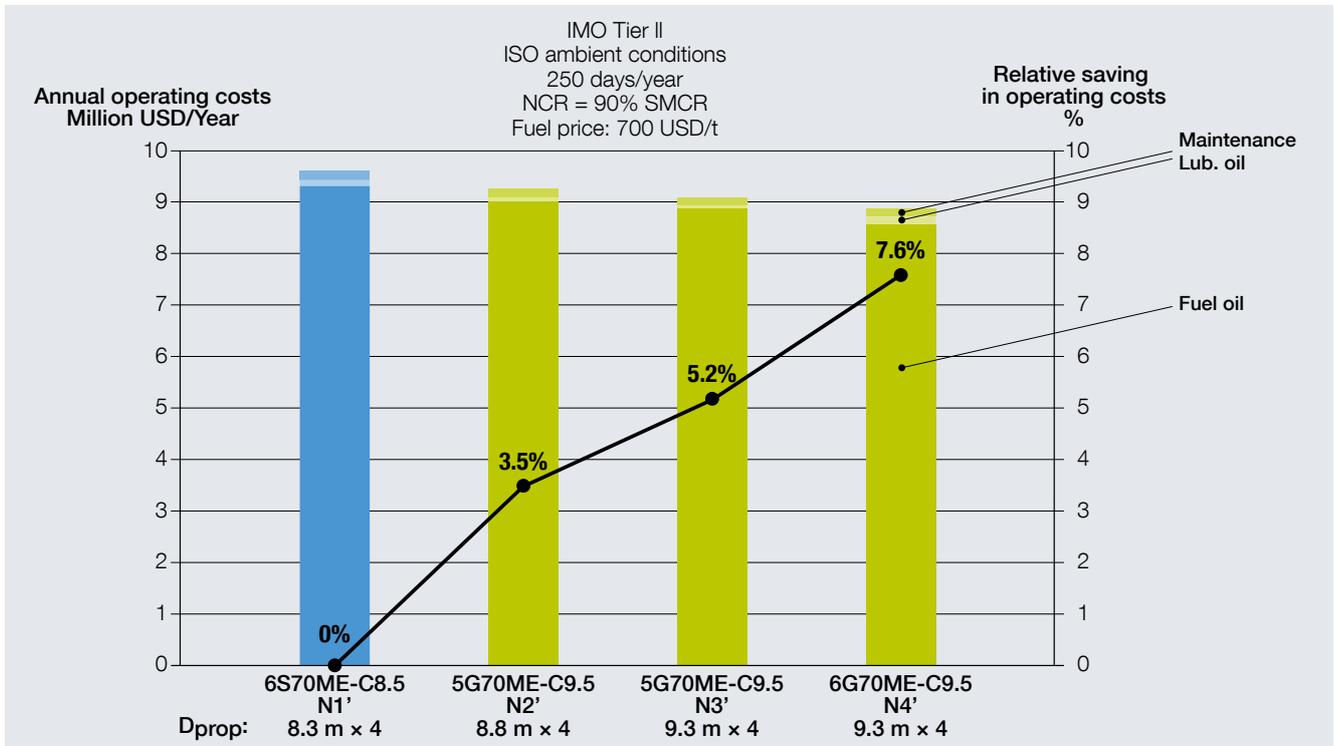


Fig. 15: Total annual main engine operating costs for 14.0 knots

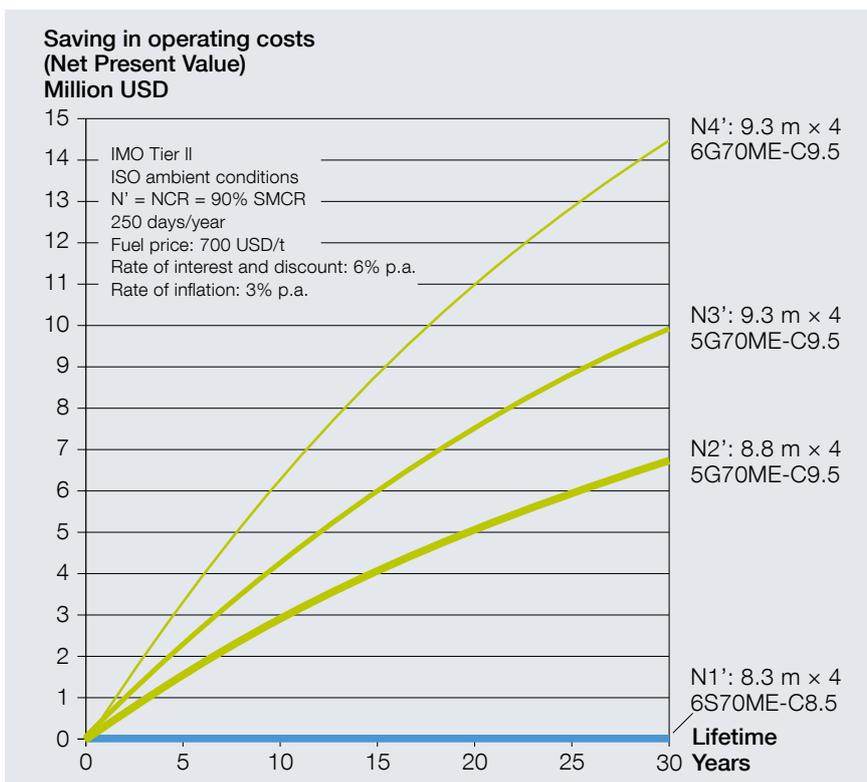


Fig. 16: Relative saving in main engine operating costs (NPV) for 14.0 knots

### Operating costs

The total main engine operating costs per year, 250 days/year, and fuel price of 700 USD/t, are shown in Fig. 15. Lube oil and maintenance costs are also shown at the top of each column. As can be seen, the major operating costs originate from the fuel costs – about 96%.

After some years in service, the relative savings in operating costs in Net Present Value, NPV, see Fig. 16, with the existing 6S70ME-C8.5 with the propeller diameter of about 8.3 m used as basis, indicates an NPV saving after some years in service for the new 5 and 6G70ME-C9.5 engines. After 25 years in operation, the saving is about 12.8 million USD for N4' with the 6G70ME-C9.5 with the SMCR speed of 67.0 r/min and propeller diameter of about 9.3 m.

## Summary

Traditionally, super long stroke S-type engines, with relatively low engine speeds, have been applied as prime movers in bulk carriers.

Following the efficiency optimisation trends in the market, the possibility of using even larger propellers has been thoroughly evaluated with a view to using engines with even lower speeds for propulsion of particularly bulk carriers and tankers.

Large bulk carriers and tankers may be compatible with propellers with larger

propeller diameters than the current designs, and thus high efficiencies following an adaptation of the aft hull design to accommodate the larger propeller, together with optimised hull lines and bulbous bow, considering operation in ballast conditions.

Even in cases where an increased size of the propeller is limited, the use of propellers based on the new propeller technology will be an advantage.

The new and ultra long stroke G70ME-C9.5 engine type meets this trend in the large bulk carrier and tanker market. This

paper indicates, depending on the propeller diameter used, an overall efficiency increase of 3-8% when using G70ME-C9.5, compared with the existing main engine type S70ME-C8.5 applied so far.

The Energy Efficiency Design Index (EEDI) will also be reduced when using G70ME-C9.5. In order to meet the stricter given reference figure in the future, the design of the ship itself and the design ship speed applied (reduced speed) has to be further evaluated by the shipyards to further reduce the EEDI.



All data provided in this document is non-binding. This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions. Copyright © MAN Diesel & Turbo. 5510-0146-00ppr Feb 2014 Printed in Denmark

**MAN Diesel & Turbo**

Teglholmegade 41  
2450 Copenhagen SV, Denmark  
Phone +45 33 85 11 00  
Fax +45 33 85 10 30  
info-cph@mandieselturbo.com  
www.mandieselturbo.com