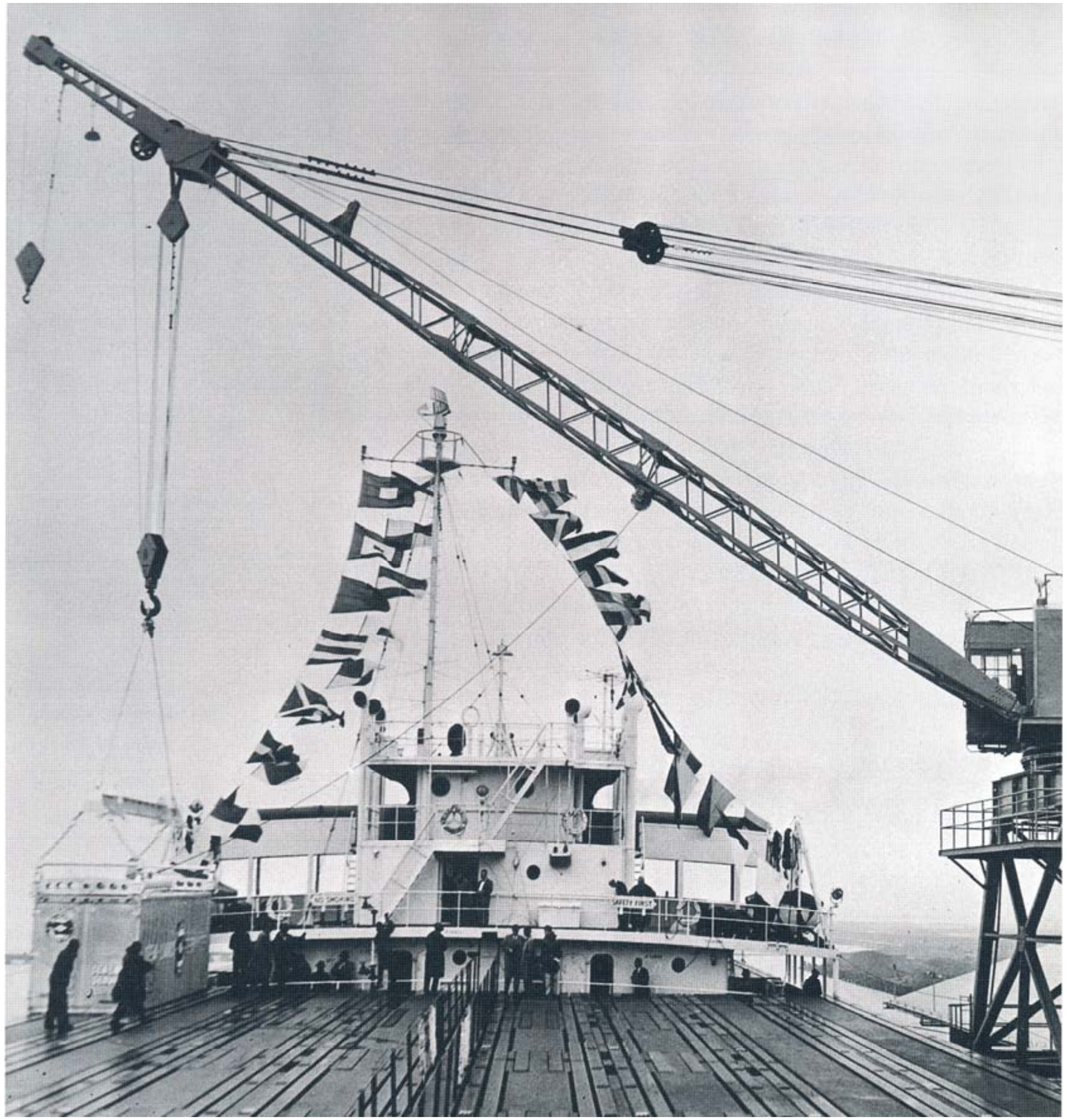
Model for Environmental Assessment of Container Ship Transport

By
Hans Otto Holmegaard Kristensen
Senior researcher
Technical University of Denmark

DTU Mechanical Engineering
Department of Mechanical Engineering

1956 – Ideal X (Malcom McLean)



2006 – EMMA MAERSK (14770 TEU)

Overview of presentation

1. Basic principles of model

2. Identification of critical parameters which influence EEDI

3. Basic principles of calculation model

4. The most important parameter: SPEED OF THE SHIP

5. Result of parameter analysis

6. Possible EEDI improvements

7. Summary/conclusion

EEDI definition

The Energy Efficiency Design Index (EEDI) is a measure of the CO_2 efficiency of a ship. It is calculated according to the following formula in its most simple formulation:

$$EEDI = \frac{P_{ME} \times SFC_{ME} \times C_{FME} + P_{AE} \times SFC_{AE} \times C_{FAE}}{\text{Deadweight} \times \text{Speed}}$$

P_{ME} and P_{AE} is main engine and auxiliary engine power

The basic principle of EEDI is that it expresses the CO_2 emissions per unit of the transport work of the ship.

SFC is the certified specific fuel consumption [g/kW/hour] of the engines.

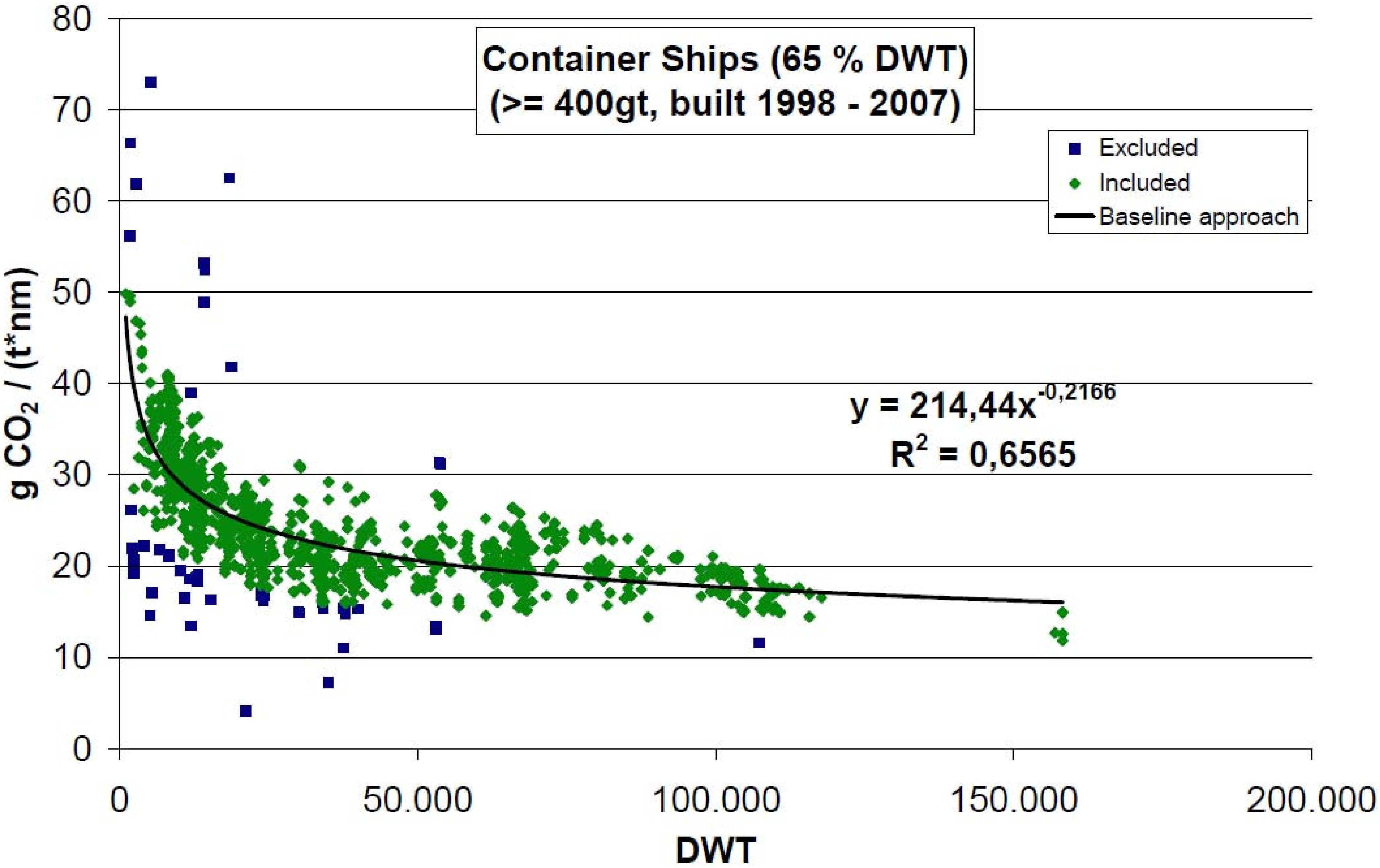
C_F is a non-dimensional conversion factor between fuel consumption and CO_2 emission

Main objective: Minimise EEDI

$$EEDI = \frac{P_{ME} \times SFC_{ME} \times CF_{ME} + P_{AE} \times SFC_{AE} \times CF_{AE}}{Capacity \times Speed}$$

$$EEDI = \frac{Constant \times P_{ME}}{Capacity \times Speed}$$

EEDI base line (MEPC 60/4/14)



Specific oil consumption and emissions

$$\frac{\text{Oil consumption}}{\text{Transport unit}} = \frac{\text{Engine power} \times \text{specific oil cons.}}{\text{Transport capacity} \times \text{speed}}$$

Calculation methods:

1. 'Bottom up' (pure statistical method)

2. 'Top down method' (model calculation – naval architechtual method)

Principles of calculation model

First calculate ship length, L, as function of cargo capacity, C

$$L = f_0(C)$$

⇓

On basis of statistical data calculate the ship's dimensions as functions of ship length, L

Beam = B = $f_1(L)$
Draft = T = $f_2(L)$
Depth = D = $f_3(L)$
Light ship weight = M = $f_4(L)$
Service speed = V = $f_5(L)$
Auxiliary machinery power = Pa = $f_6(L)$

⇓

Propulsion power, Pf, is calculated on the basis of main dimensions, cargo capacity, C, and utilization fraction, U (actual cargo/maximum cargo capacity)

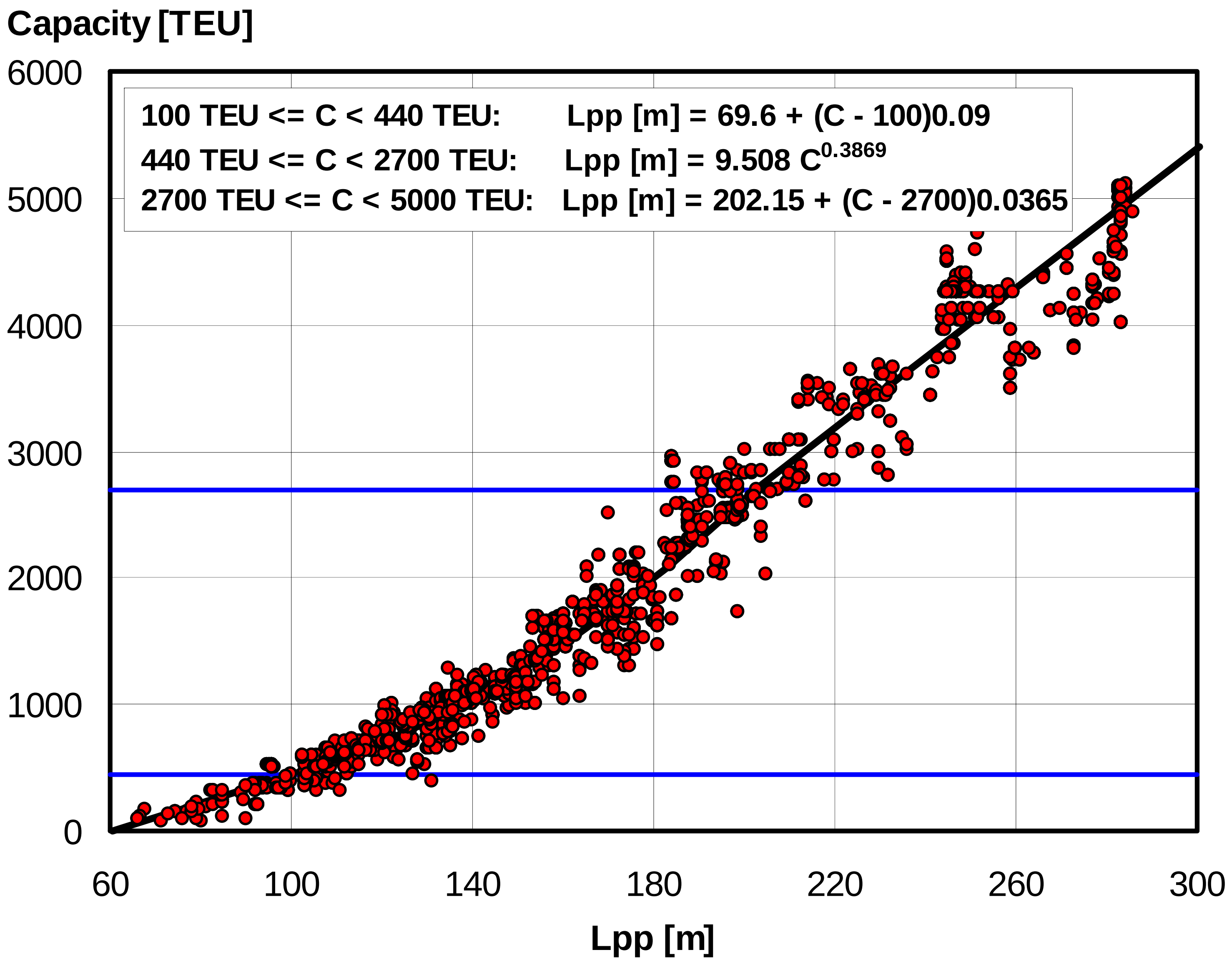
$$Pf = f_7(L, B, T, D, M, V, C, U)$$

⇓

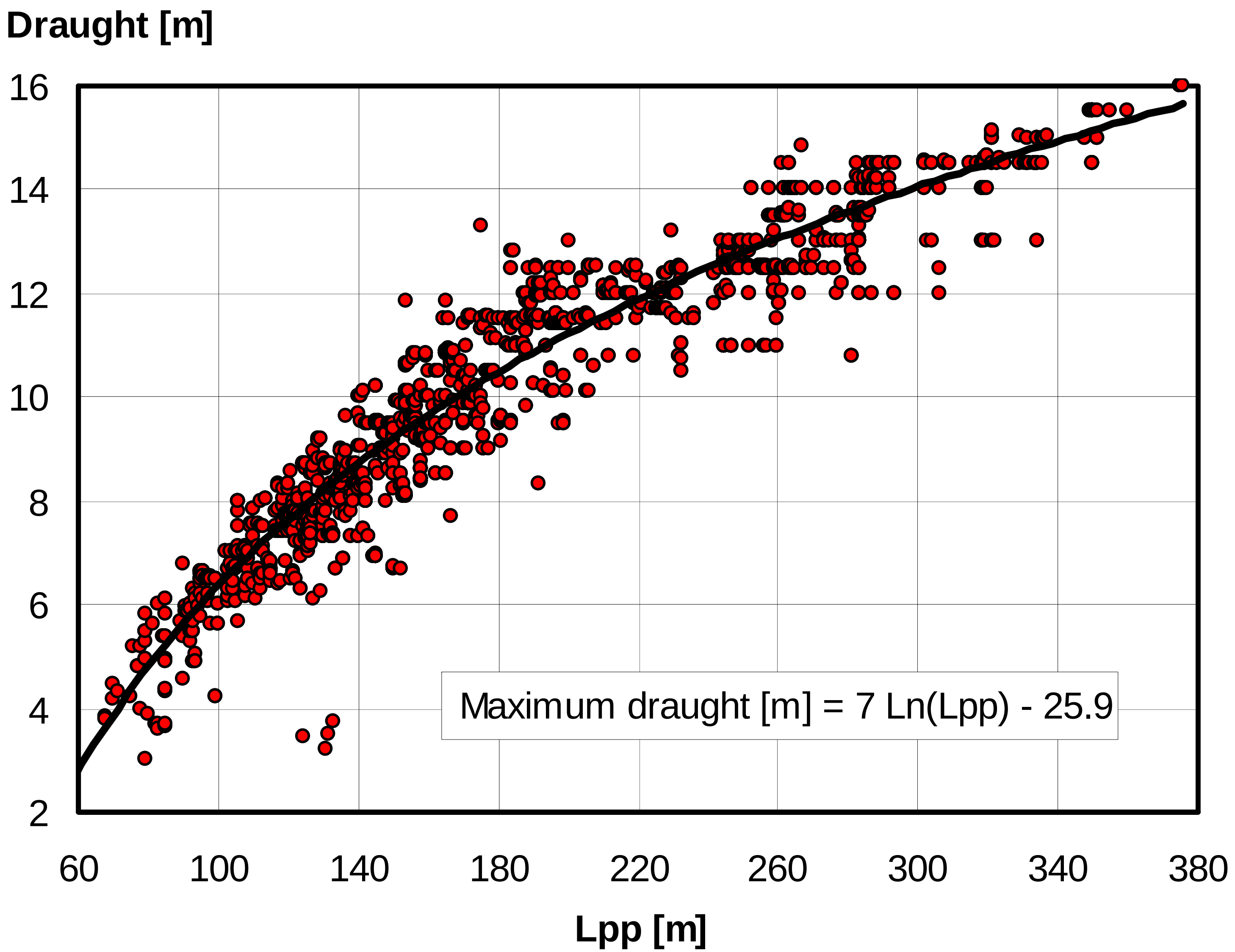
Energy consumption and emissions are calculated on the basis of the propulsion and auxiliary power Pf and Pa

Finally, main dimensions can be modified and their influence on propulsion power and energy consumption can be determined

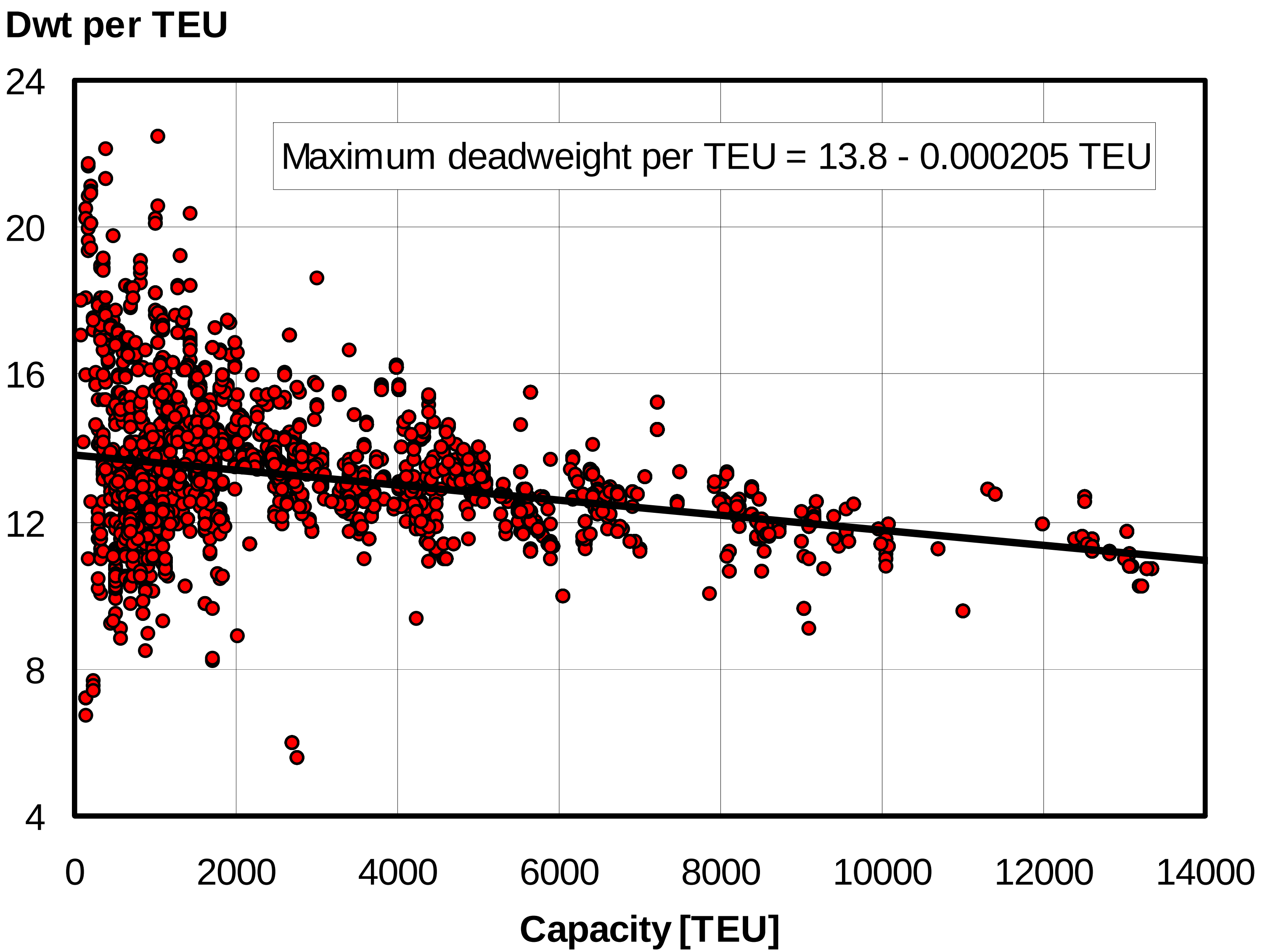
Panamax ships – Lpp versus TEU capacity



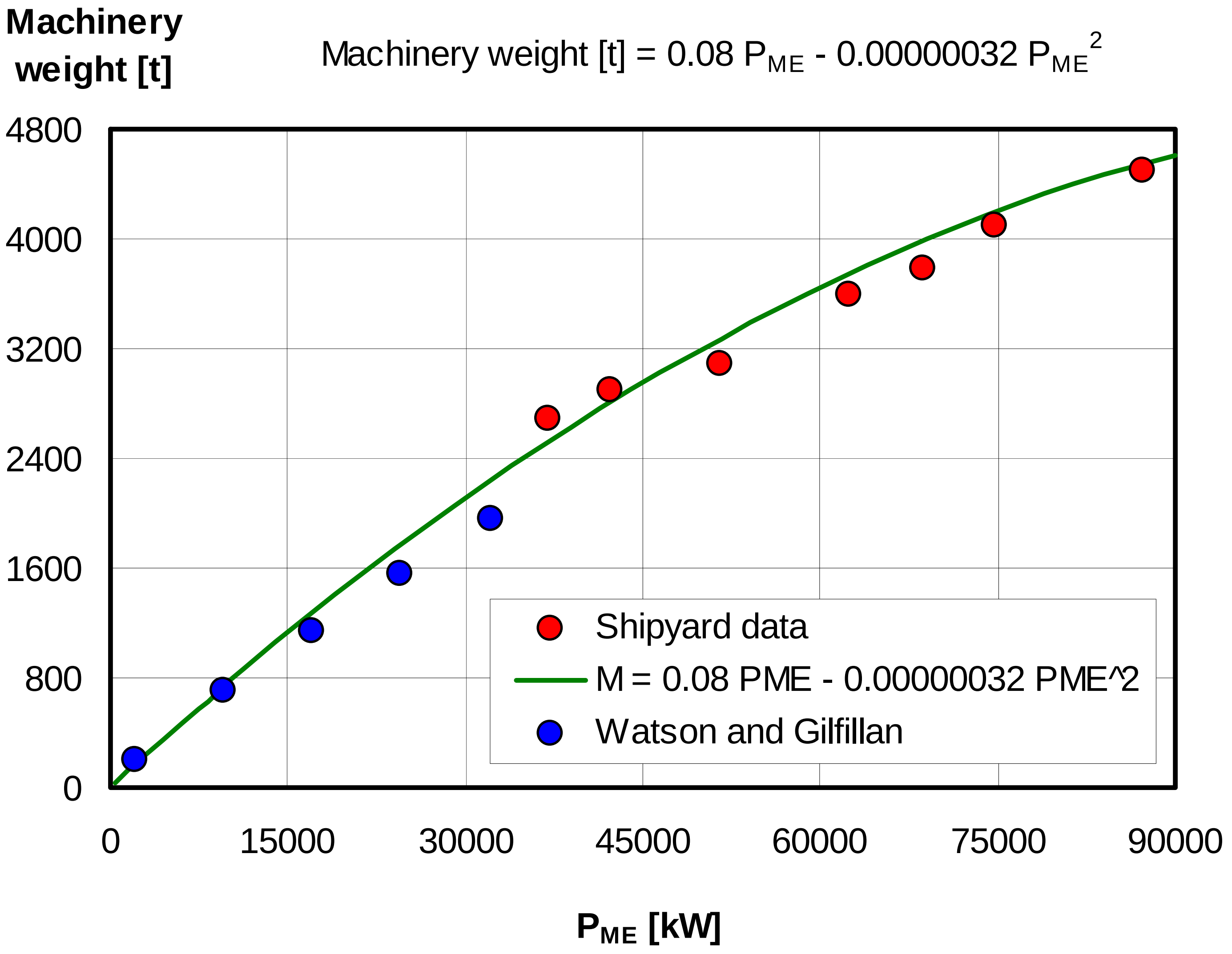
Maximum draught versus Lpp



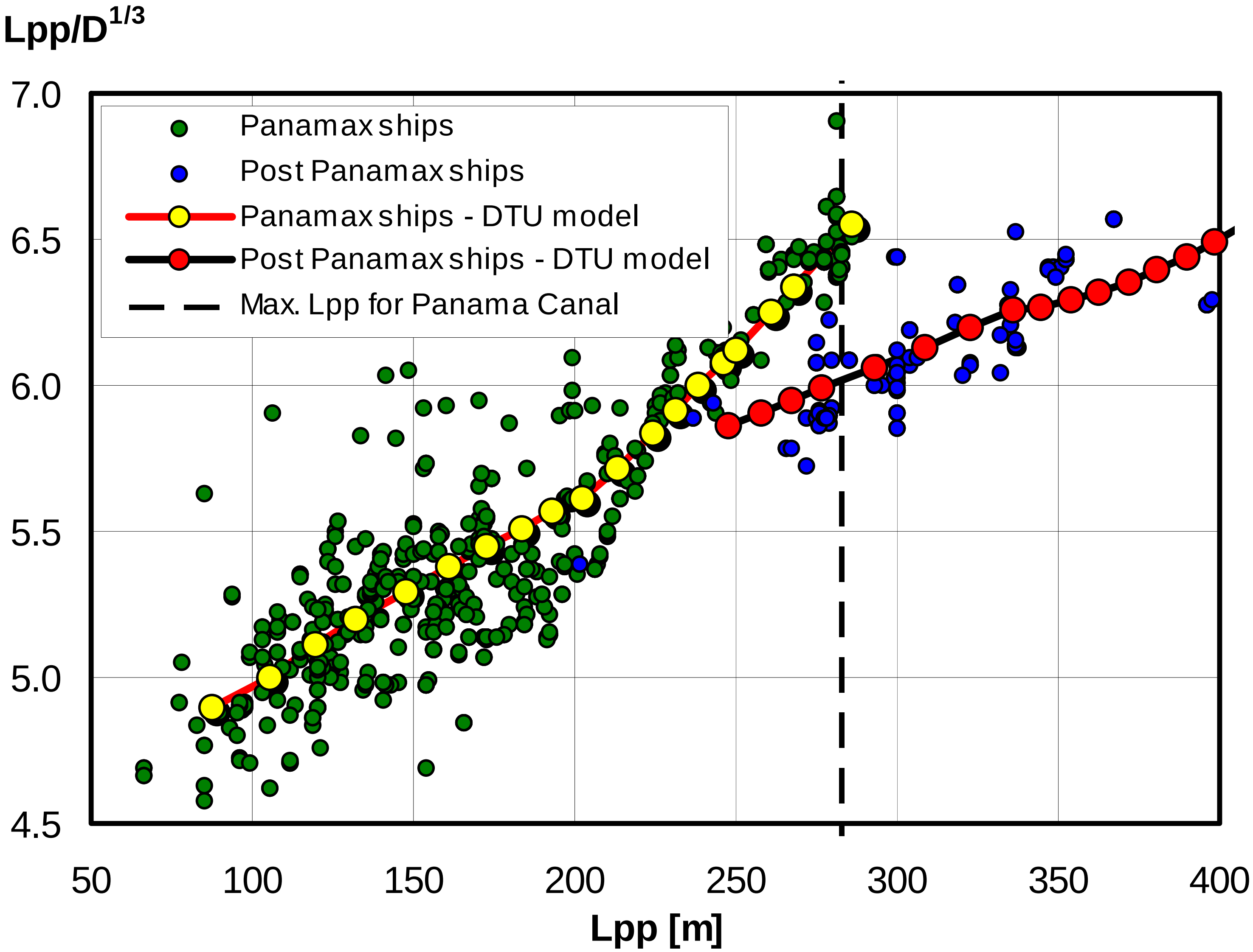
Maximum DWT/TEU versus Lpp

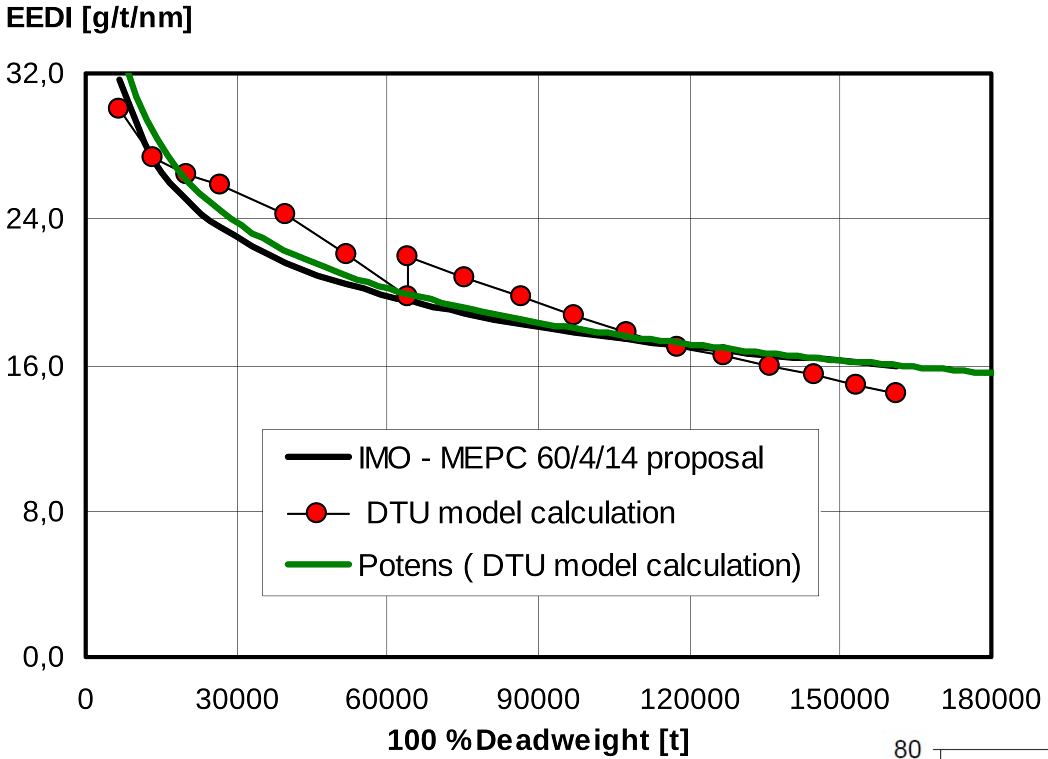


Machinery weight for container ships

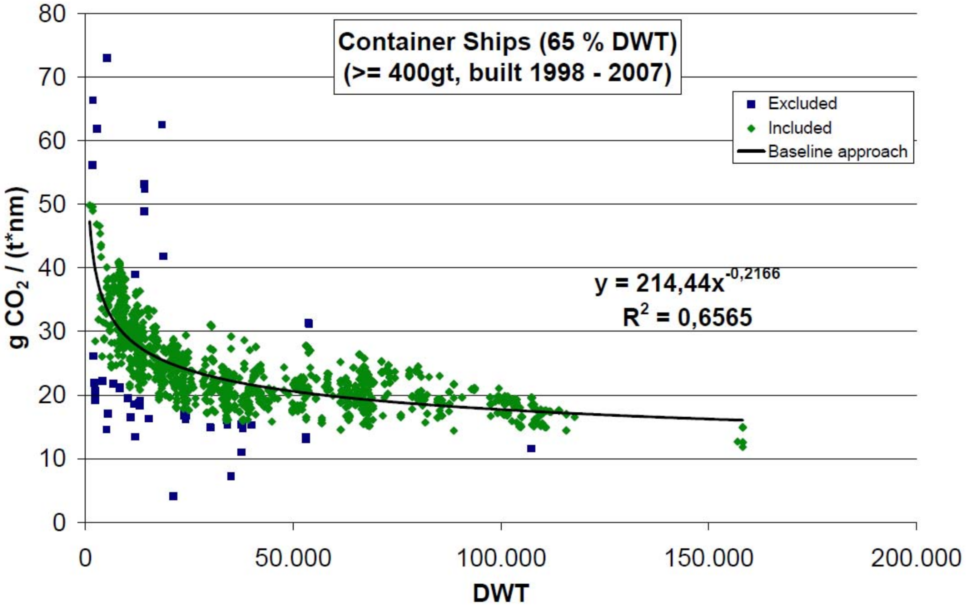


Slenderness ratio – Lpp / Displ.volumue$^{1/3}$

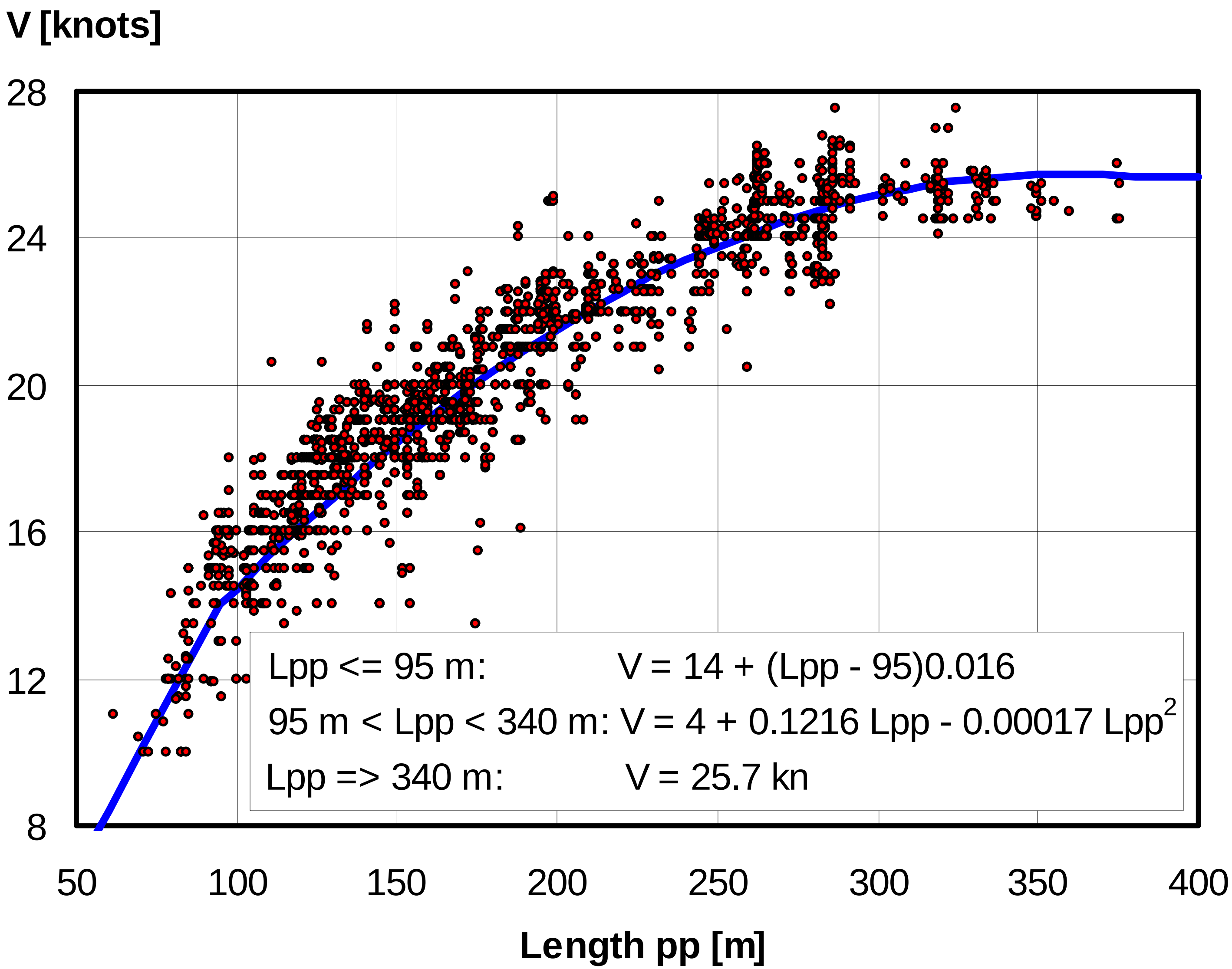




EEDI model data versus IMO baseline

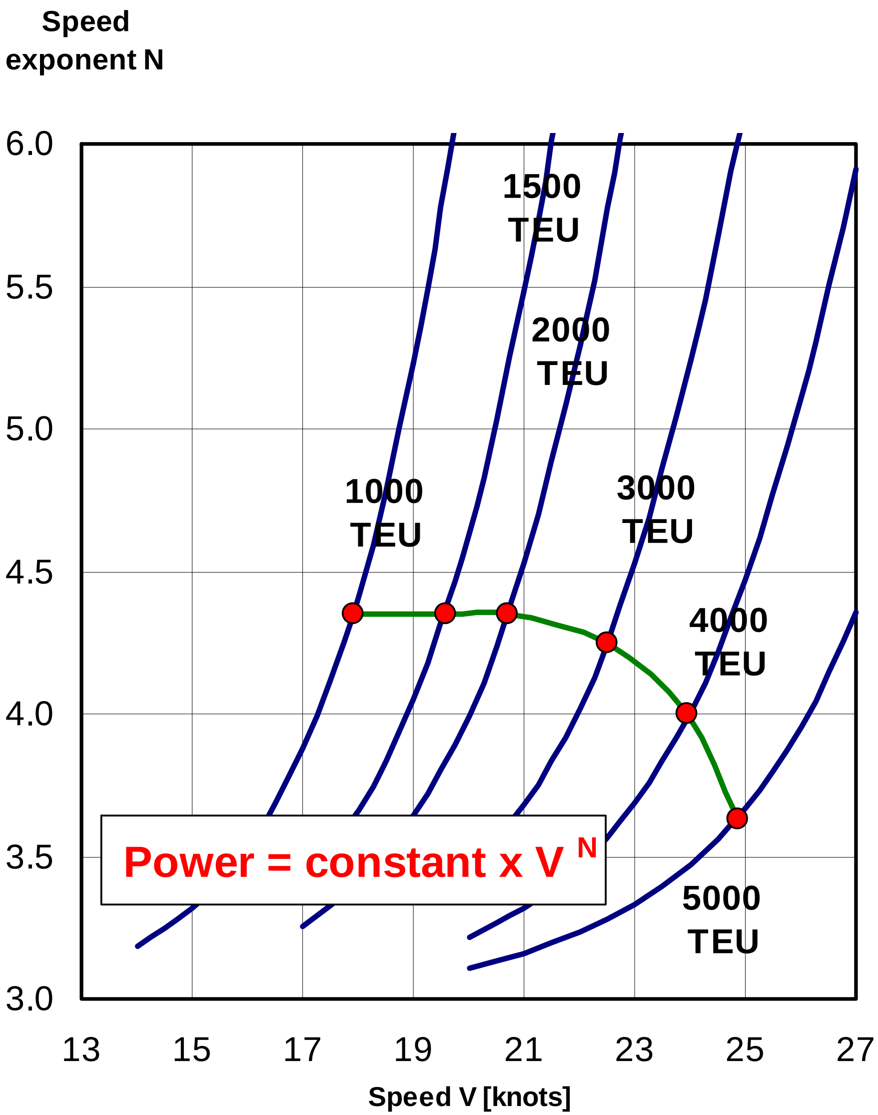


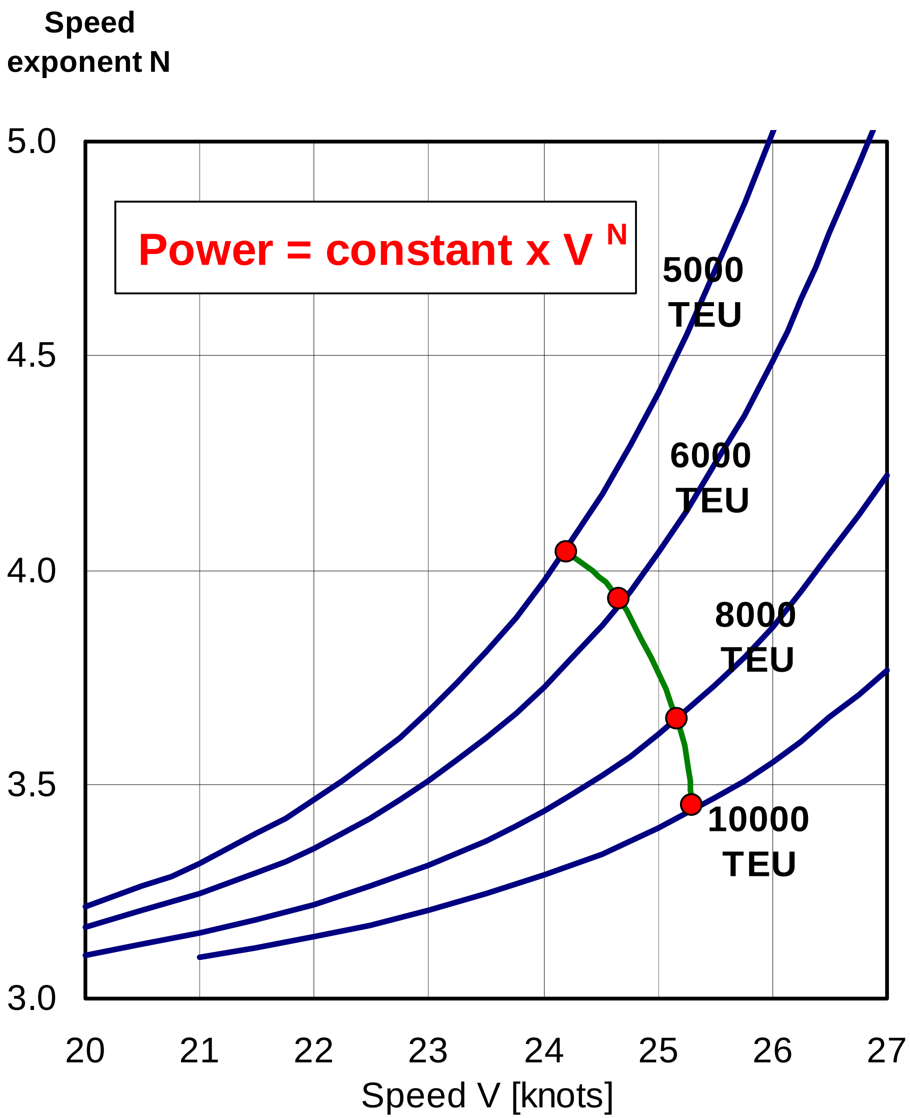
Speed



V [knots]
28
24
20
16
12
8
50
100
150
200
250
300
350
400
Length pp [m]
Lpp <= 95 m: V = 14 + (Lpp - 95)0.016
95 m < Lpp < 340 m: V = 4 + 0.1216 Lpp - 0.00017 Lpp2
Lpp => 340 m: V = 25.7 kn

Speed exponent N

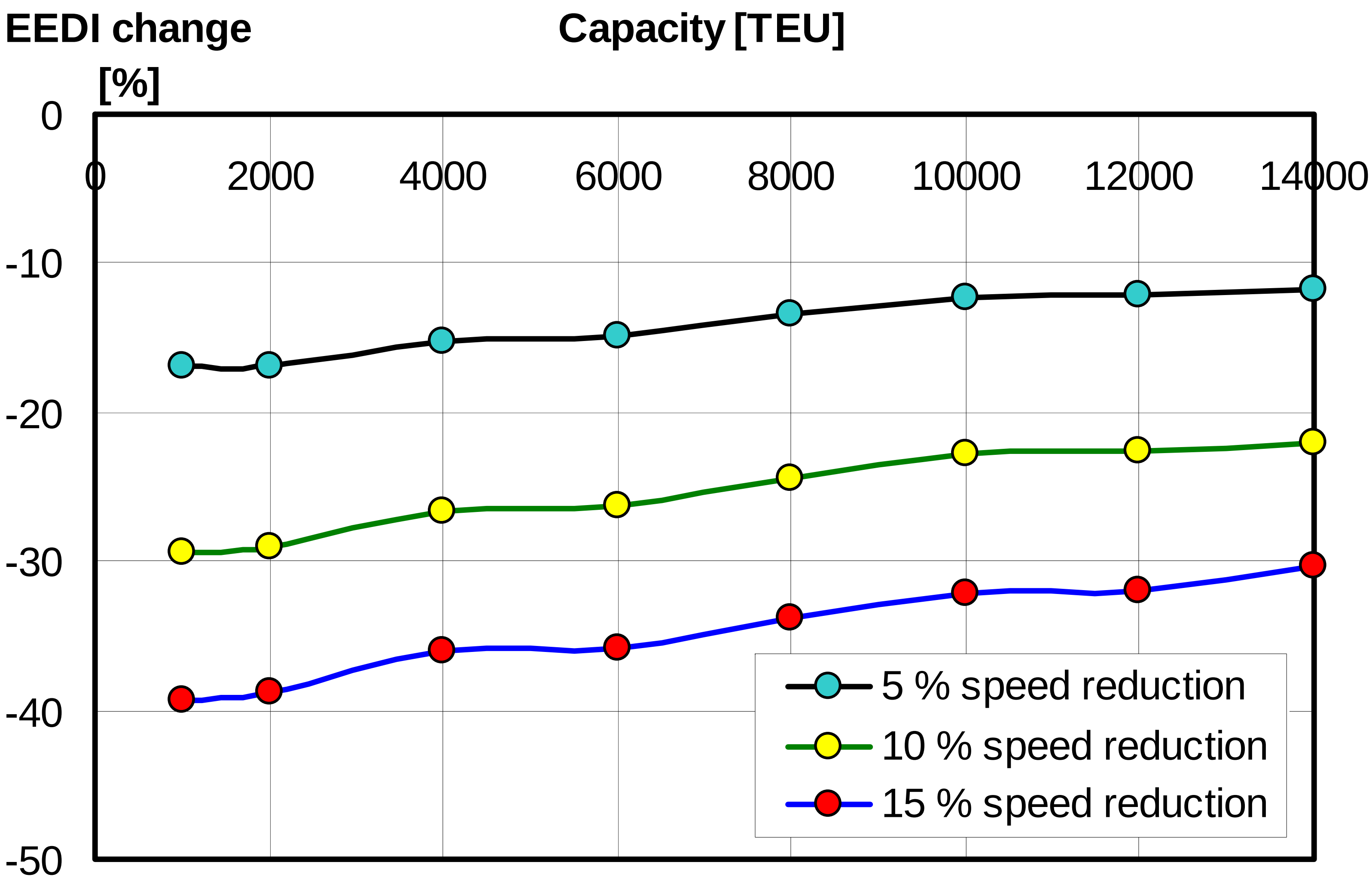




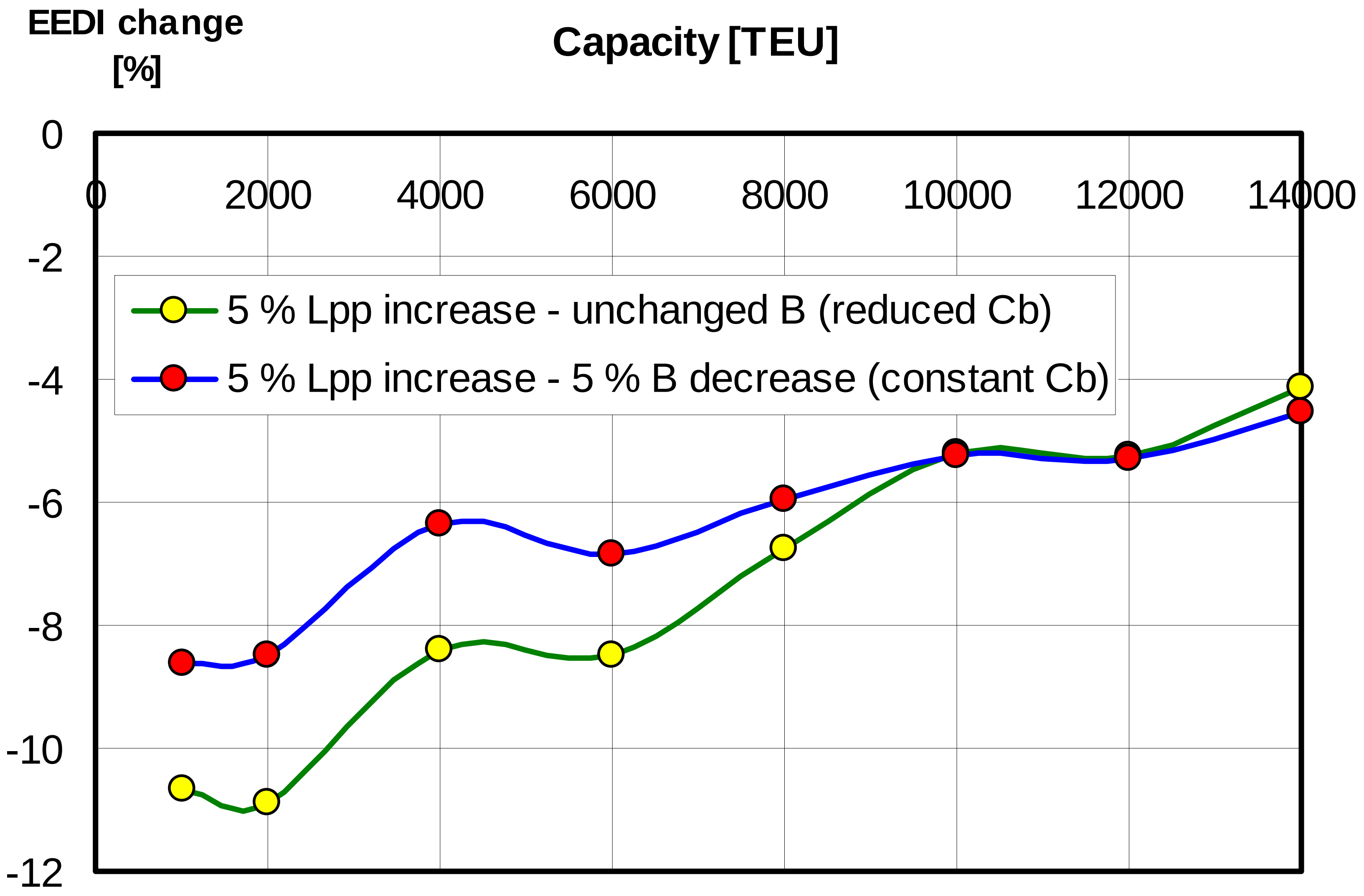
EEDI and speed

$$\text{EEDI} = \frac{\text{Constant x Power}}{\text{Transport capacity x speed}} = \frac{\text{Constant x speed}^{N}}{\text{Transport capacity x speed}} = \frac{\text{Constant x speed}^{(N-1)}}{\text{Transport capacity}}$$

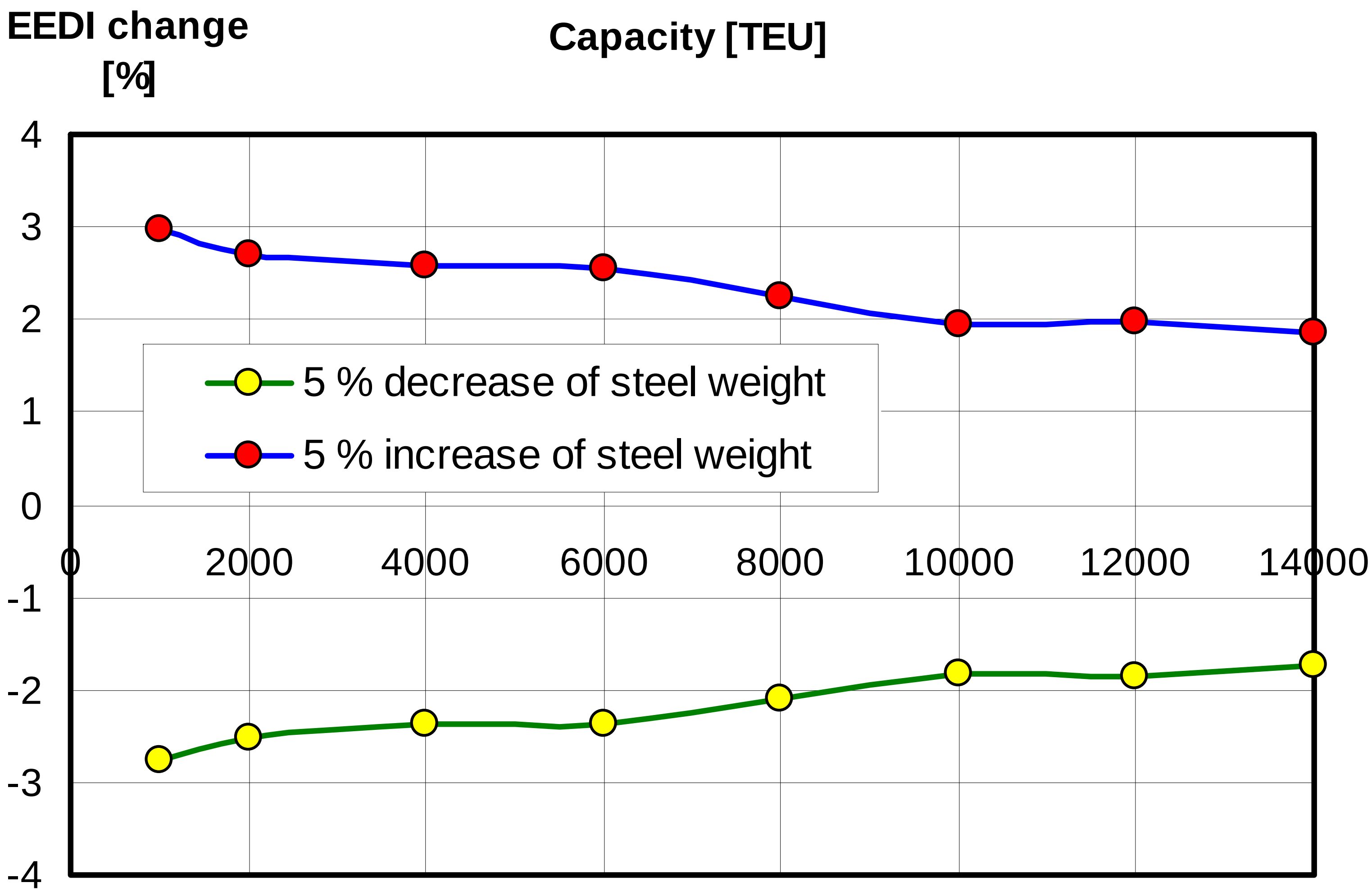
Influence of speed on EEDI



EEDI reduction by increased ship length



EEDI reduction by changed steel weight



Obtainable EEDI reductions

Design option for improvement of EEDI	4000 TEU	8000 TEU	12000 TEU
Ship designed for normal service speed with 10 % sea margin on resistance and ME engine running 90 % MCR in service condition	**0**	**0**	**0**
Ship designed for normal service speed with **NO sea margin** on resistance and ME engine running 90 % MCR in service condition	8	8	8
Ship designed for normal service speed with NO sea margin on resistance and **derated ME engine** running 100 % in service condition	17	17	16
5 % lengthened ship designed for normal service speed with NO sea margin on resistance and derated ME engine running 100 % MCR in service condition	24	22	21
5 % lengthened ship designed for **10 % speed** redution with NO sea margin on resistance and derated ME engine running 100 % MCR in service condition	41	39	37
5 % lengthened ship designed for 10 % speed redution with NO sea margin on resistance and derated ME engine running 100 % MCR in service condition. **3 % steel weight reduction**	41	40	38
5 % lengthened ship designed for 10 % speed redution with NO sea margin on resistance and derated ME engine running 100 % MCR in service condition. 3 % steel weight reduction and **5 % improved propeller efficiency**	44	42	41

Summary of EEDI reductions (No change of sea margin)

Option 1:

Use of derated engine

3 % steel weight optimization

5 % propulsion improvement

20 – 23 % EEDI reduction

Option 2:

Use of derated engine

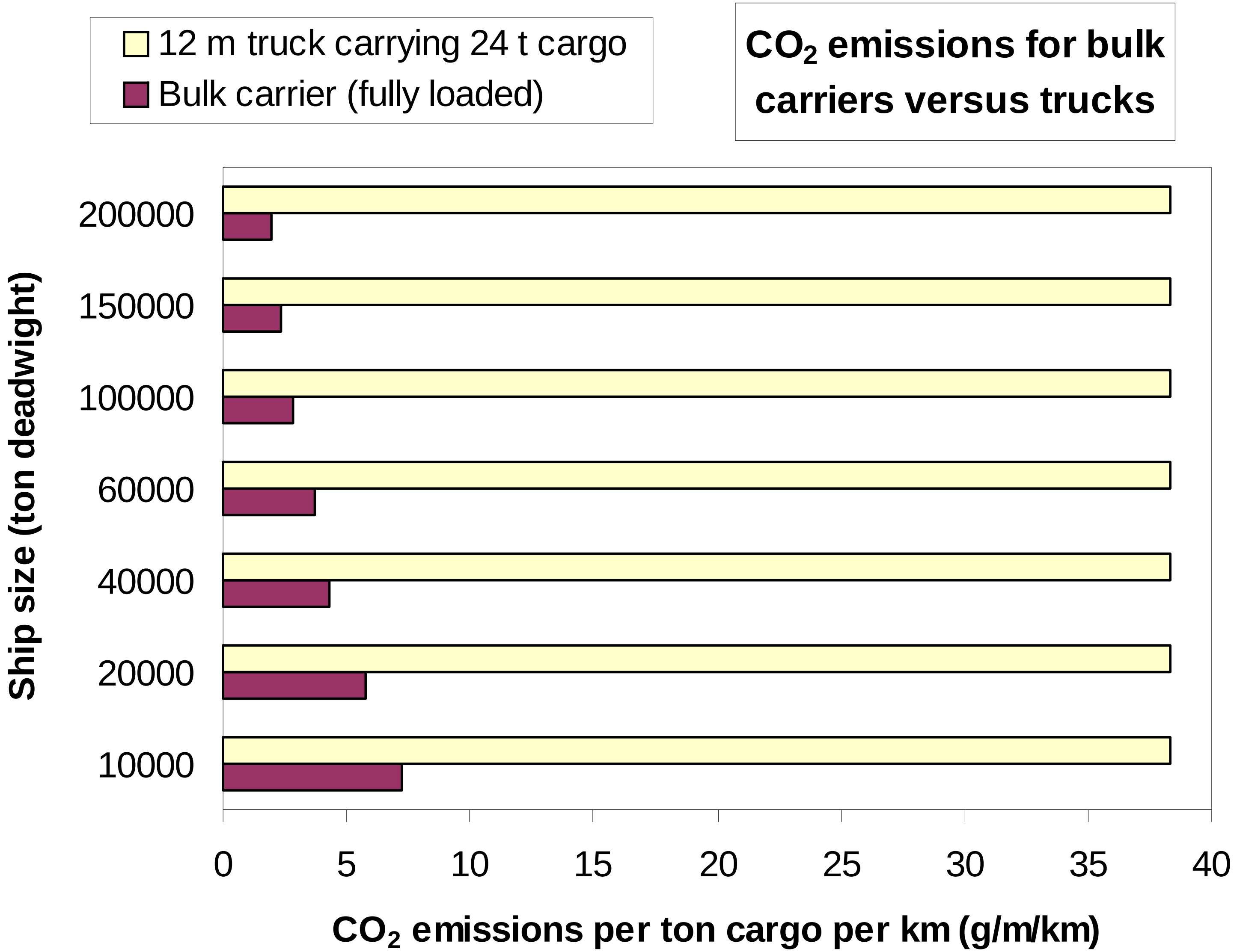
3 % steel weight optimization

5 % propulsion improvement

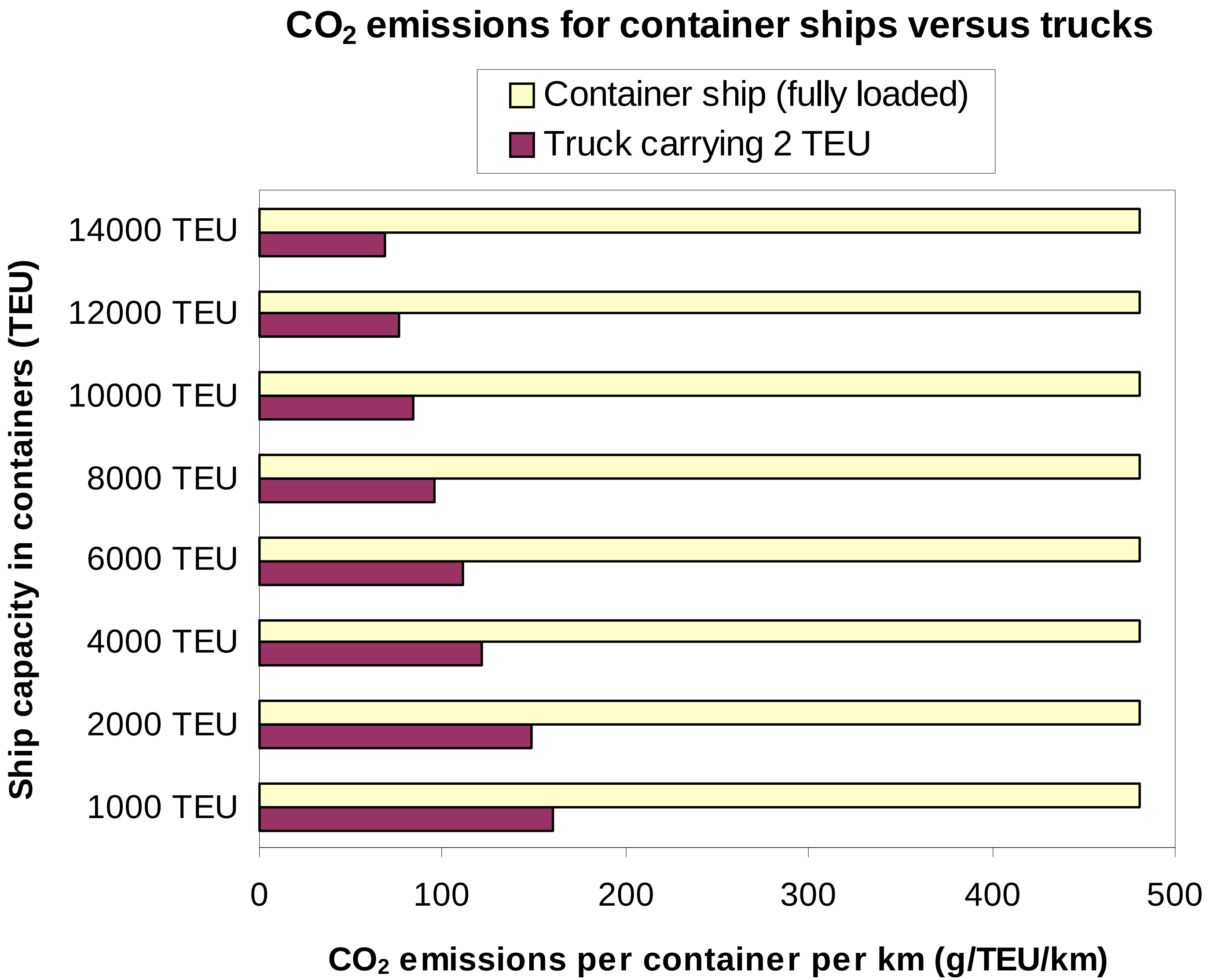
10 % speed reduction

37 – 42 % EEDI reduction

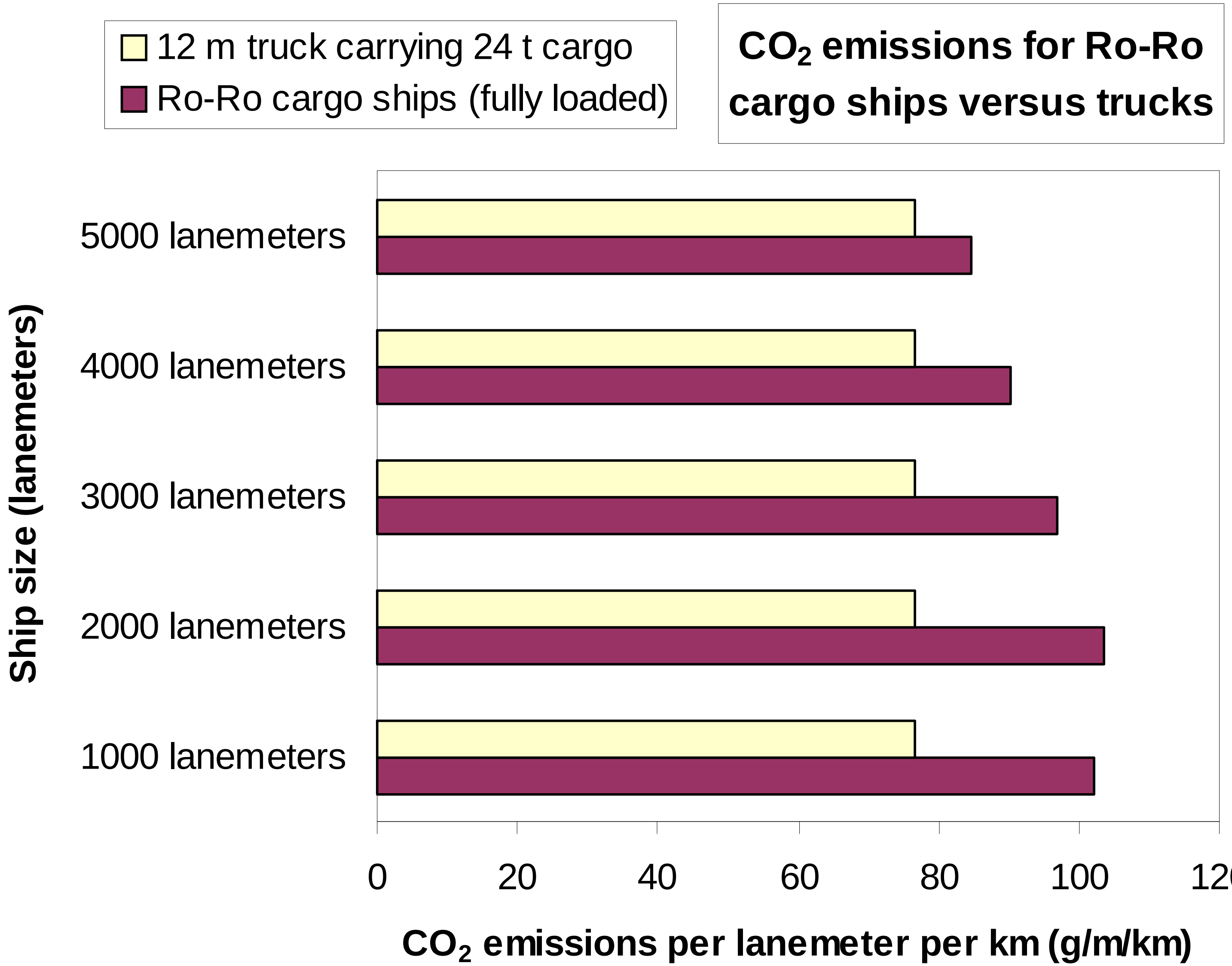
CO_2 emissions for ships versus trucks



CO_2 emissions for ships versus trucks



CO_2 emissions for ships versus trucks



Thank you !