Energy Efficiency Design Index (EEDI) Impact on Super Yacht Design.

By: Sabah Alwan

University Supervisors: Prof. D. Boote & Prof. M Ferrando.

External Supervisors: Mr. Emanuele Camporese.

Benetti
ITALIAN EXCELLENCE SINCE 1873

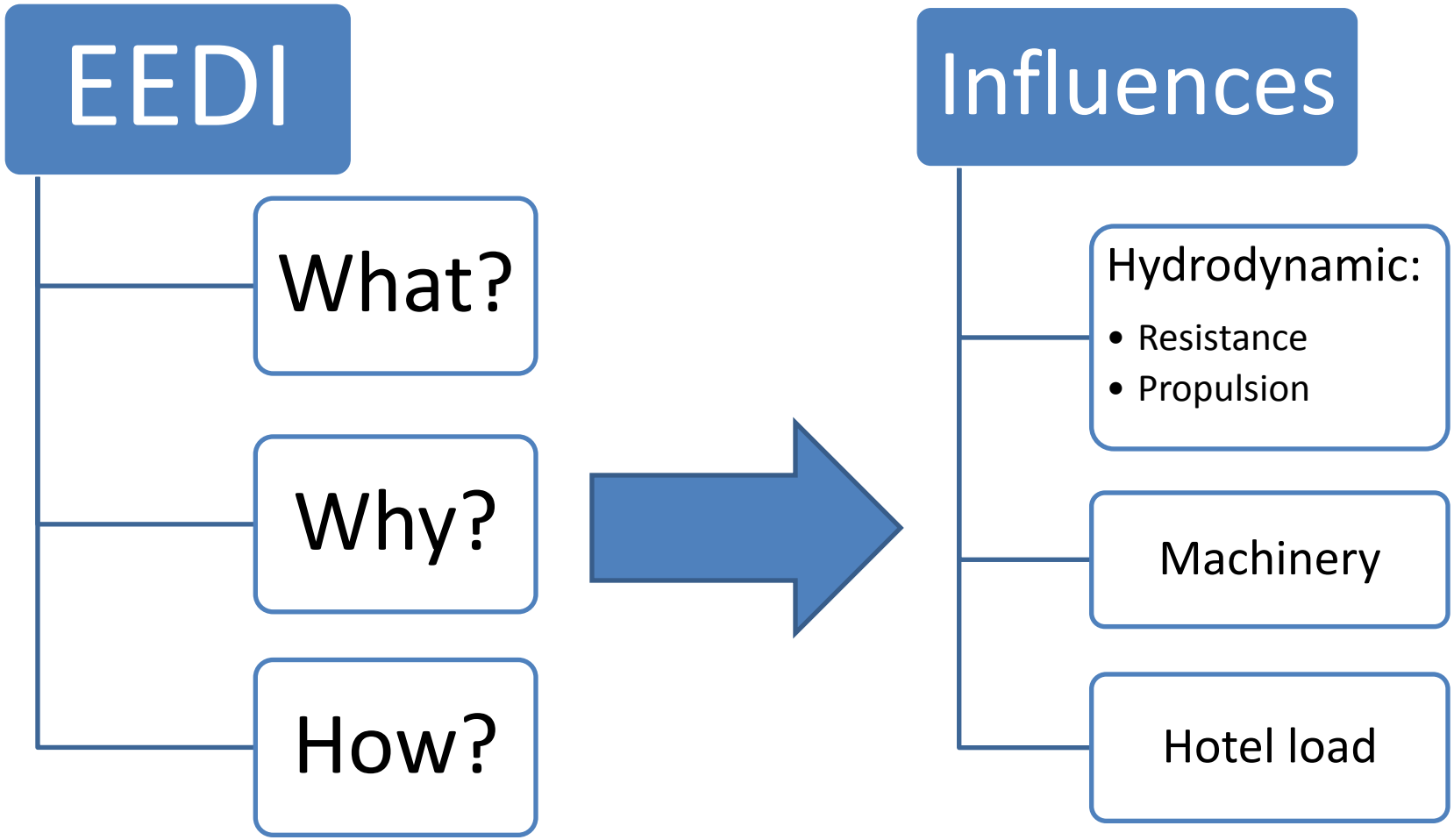
EMship
Advanced Design

Université de Liège

ECN
Centrale Nantes

UNIVERSITÀ DEGLI STUDI DI GENOVA

Content

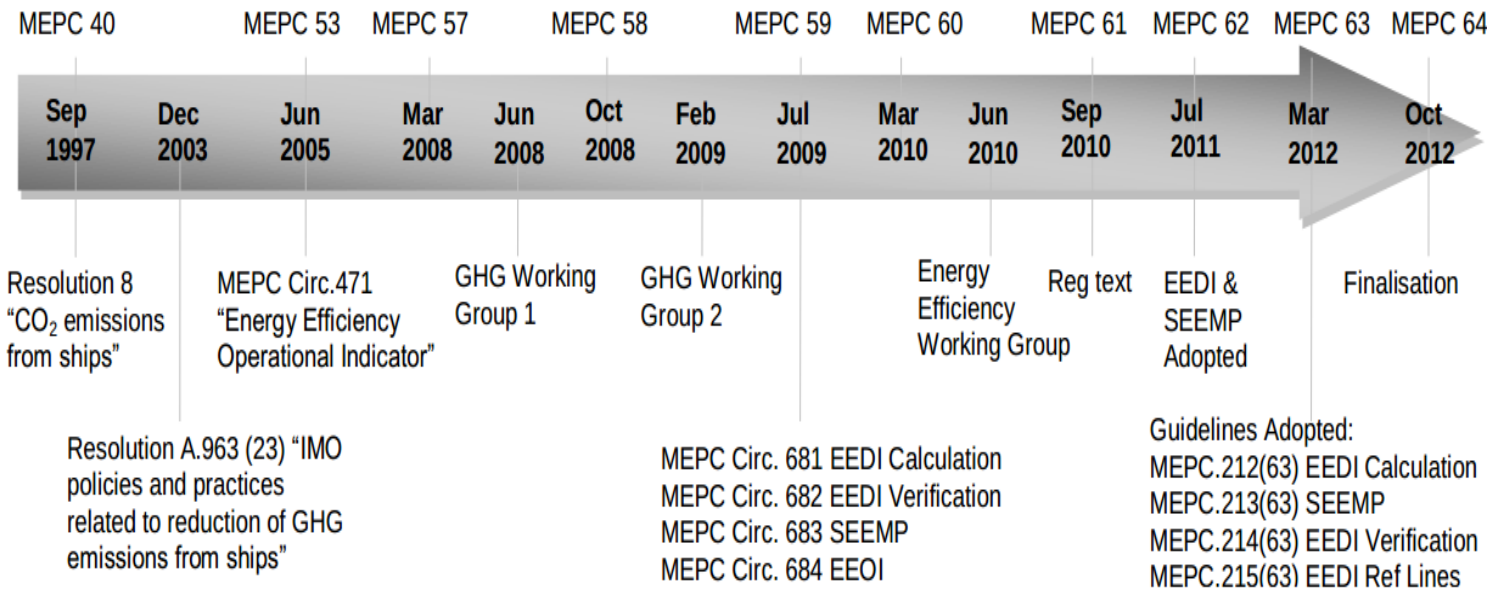

EEDI
What?
Why?
How?
Influences
Hydrodynamic:
• Resistance
• Propulsion
Machinery
Hotel load

What?

- Energy Efficiency Design Index.
- The International Maritime Organization (IMO).
- An early design stage measures for ships efficiency.
- Ships are ranked according to their type, functionality and size.
- EEDI is the ratio of the environmental impact by means of CO_2 Emissions against ships benefit to society.

History of the EEDI

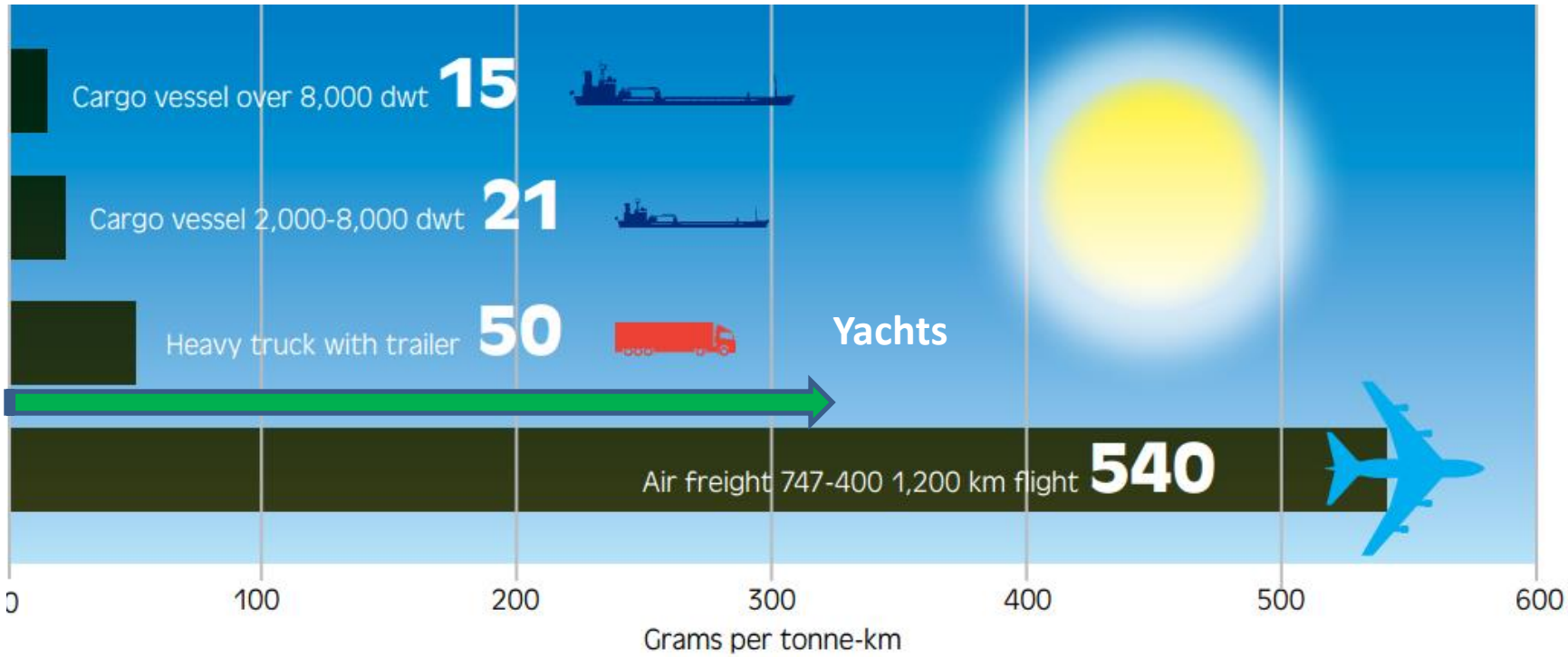
- IMO Timeline



Why?

- Environmental awareness.
- CO_2 Emissions from shipping can be greater than 3% of the global green house gas (GHG) emission.
- By 2050 Emissions an increase of 200% to 300%.
- This sums up to 1,118 million tonnes of carbon dioxide have been emitted since 1960.
- This figure becomes comparable to the figures from some developed nation such Belgium.

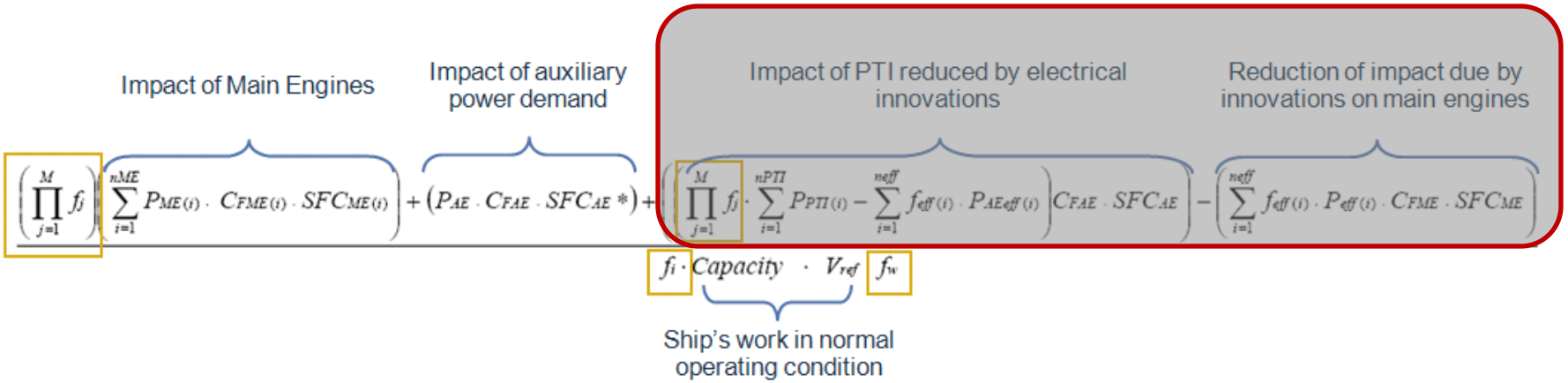
Swedish study comparing various modes of transport.



How?

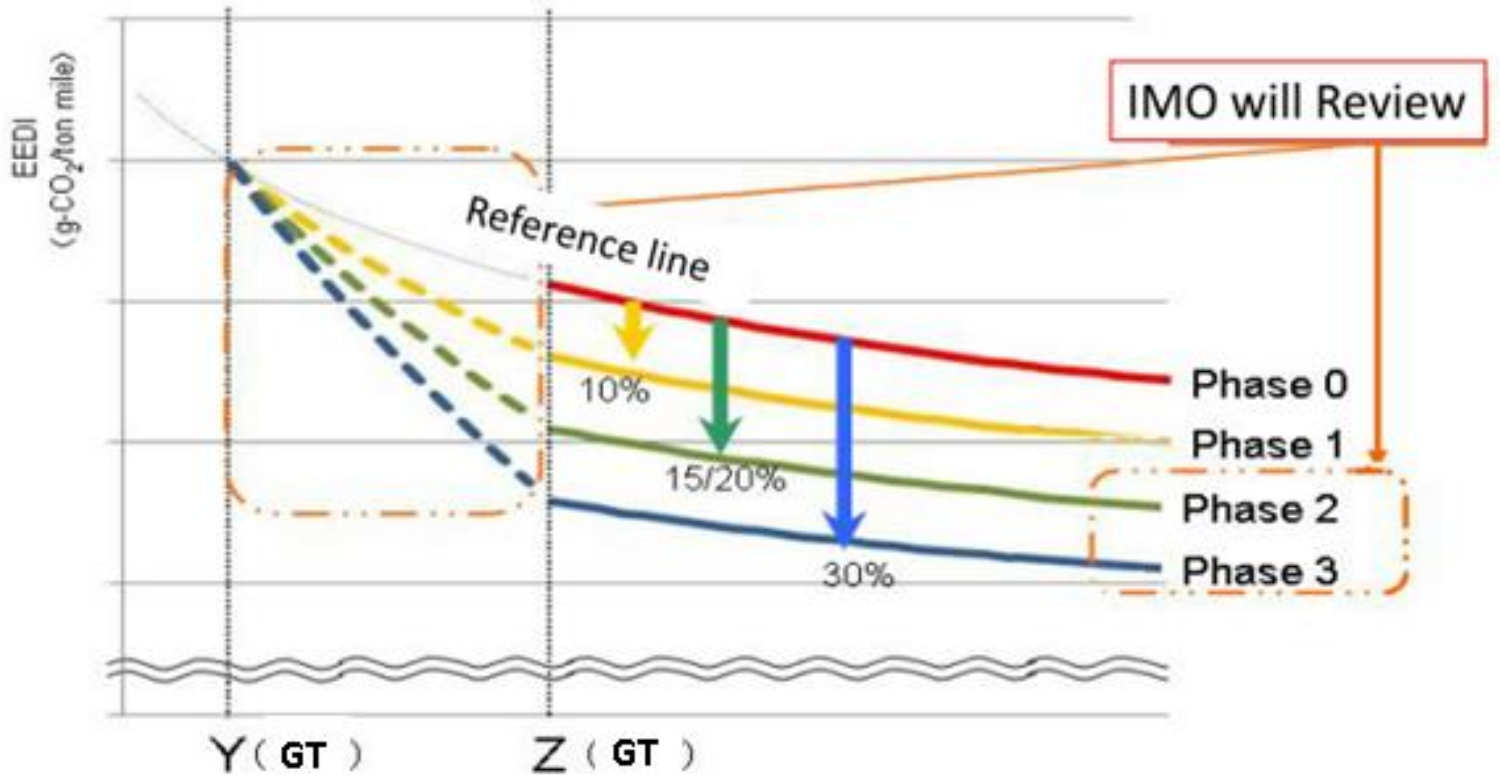
- IMO guidelines: MEPC 60/WP 5, MEPC 60/4/7, MEPC 60/4/3, MEPC.1/Circ.681 , MEPC 60.WP/09. 5 GHG.WG 2/2/7, etc.
- Classification society guidelines: Lloyd's register, Germanischer Lloyd, ABS and BV, etc.
- Main engine group: Power (P_{ME}), specific fuel consumption (SFC), non-dimensional fuel conversion factor (C_f).
- Auxiliary group: Power (P_{AE}), specific fuel consumption (SFC) and non-dimensional fuel conversion factor (C_f).
- Transport work group: For yachts Gross Tonnage and Speed in knots.

How?

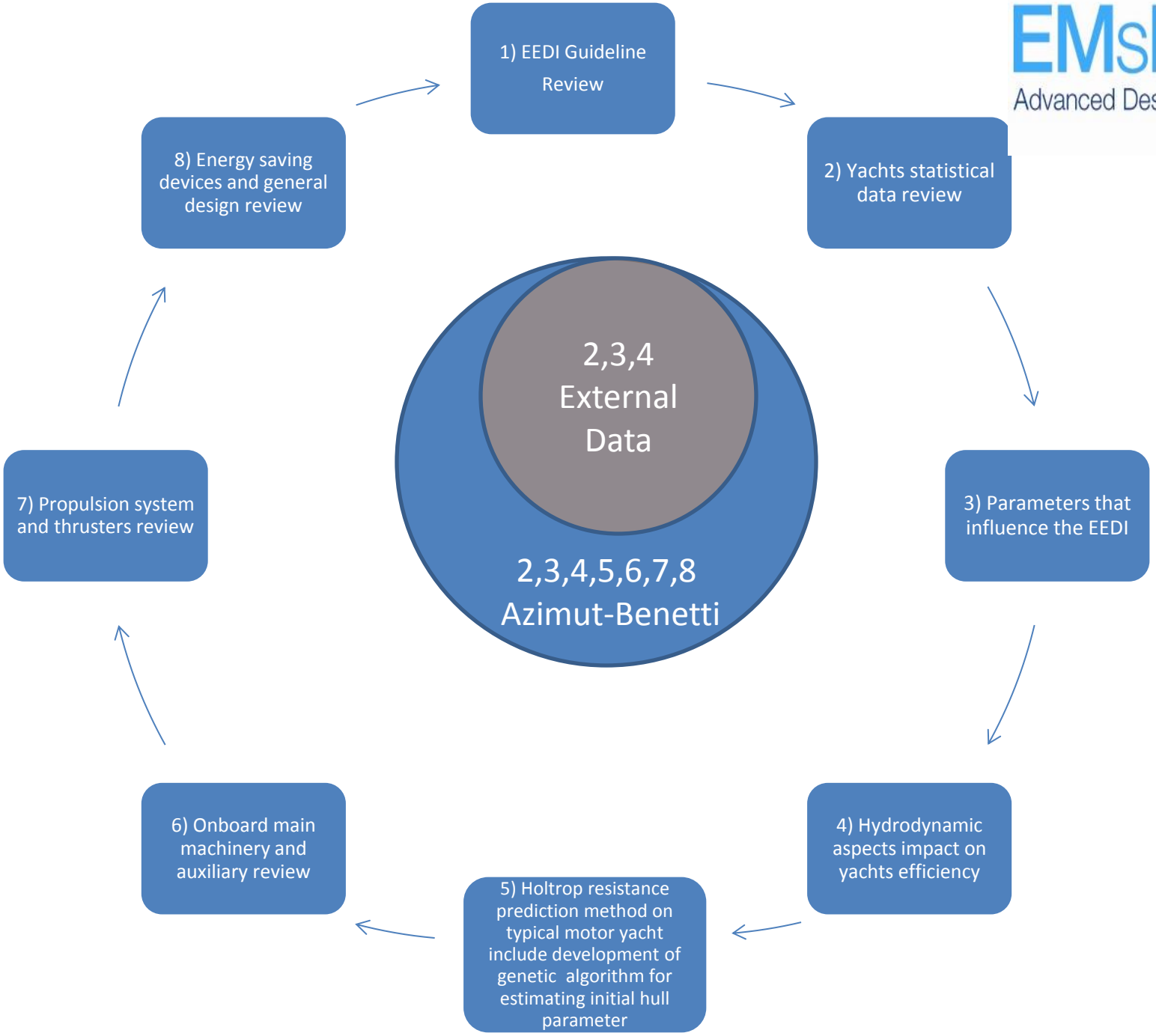


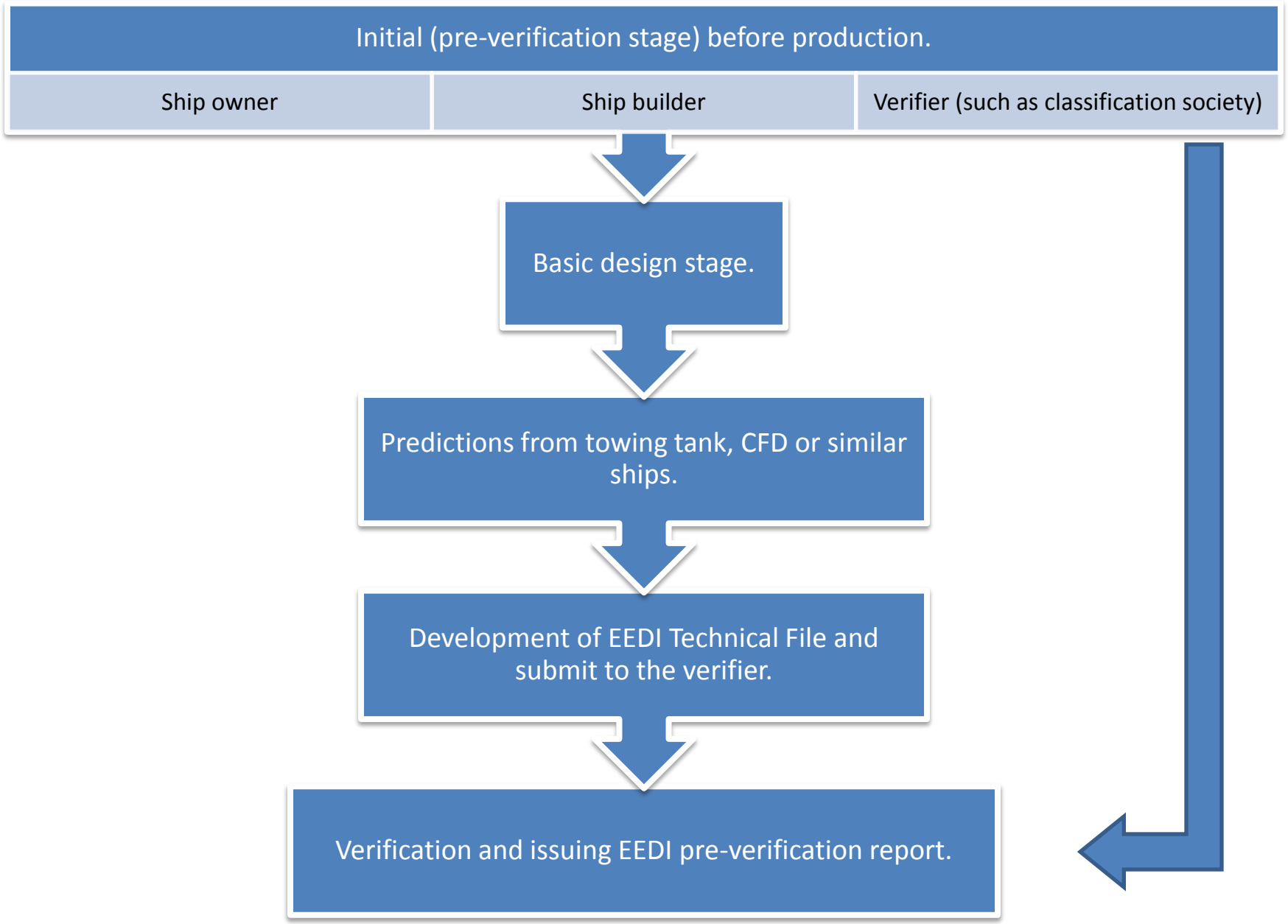
- No power take out/power take in in majority of yachts.
- For the time not many innovations on main engines.

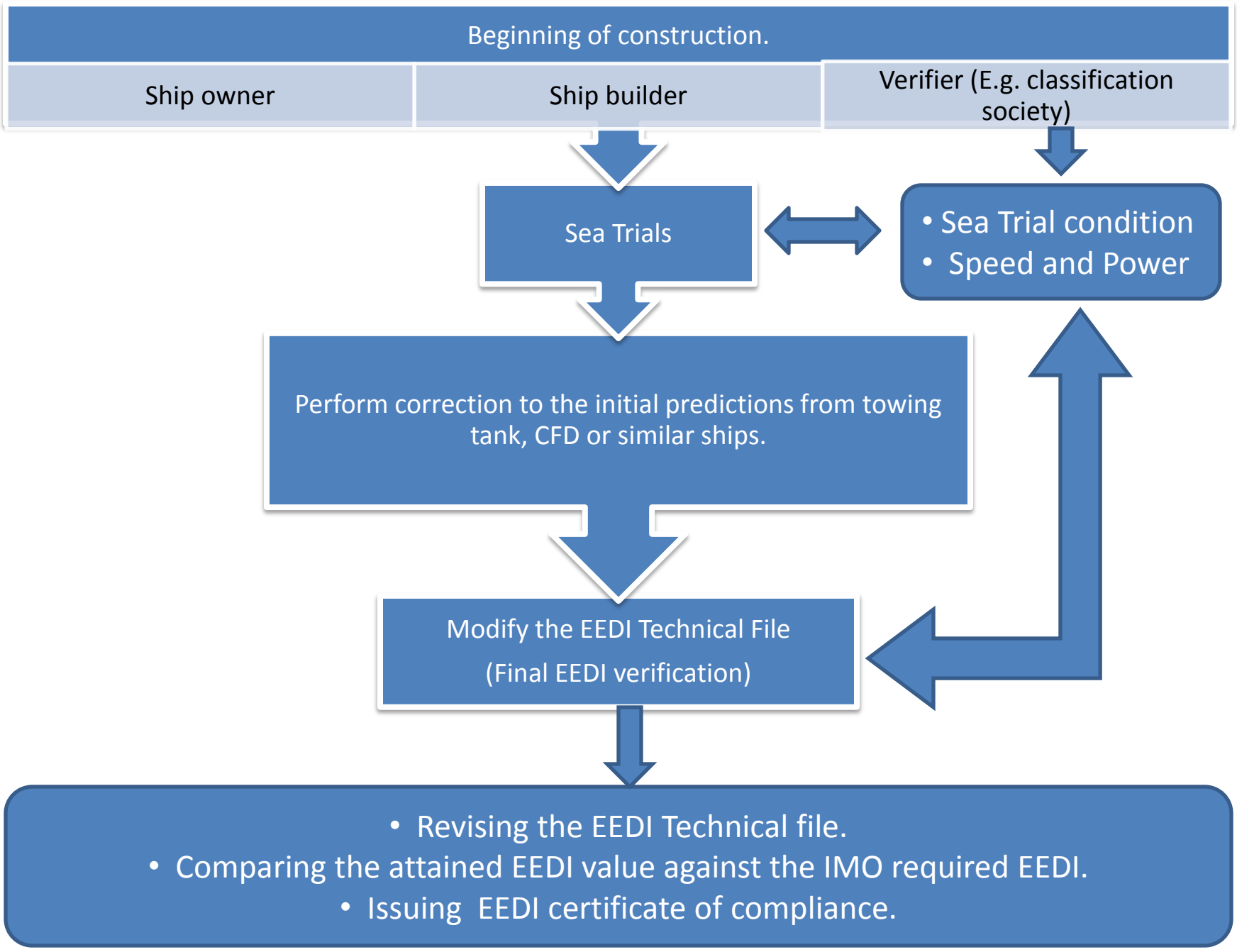
How?



Attained EEDI ≤Required EEDI (Reference line)


1) EEDI Guideline Review
2) Yachts statistical data review
3) Parameters that influence the EEDI
4) Hydrodynamic aspects impact on yachts efficiency
5) Holtrop resistance prediction method on typical motor yacht include development of genetic algorithm for estimating initial hull parameter
6) Onboard main machinery and auxiliary review
7) Propulsion system and thrusters review
8) Energy saving devices and general design review
2,3,4 External Data
2,3,4,5,6,7,8 Azimut-Benetti


Initial (pre-verification stage) before production.
Ship owner
Ship builder
Verifier (such as classification society)
Basic design stage.
Predictions from towing tank, CFD or similar ships.
Development of EEDI Technical File and submit to the verifier.
Verification and issuing EEDI pre-verification report.


Beginning of construction.
Ship owner
Ship builder
Verifier (E.g. classification society)
Sea Trials
• Sea Trial condition
• Speed and Power
Perform correction to the initial predictions from towing tank, CFD or similar ships.
Modify the EEDI Technical File
(Final EEDI verification)
• Revising the EEDI Technical file.
• Comparing the attained EEDI value against the IMO required EEDI.
• Issuing EEDI certificate of compliance.

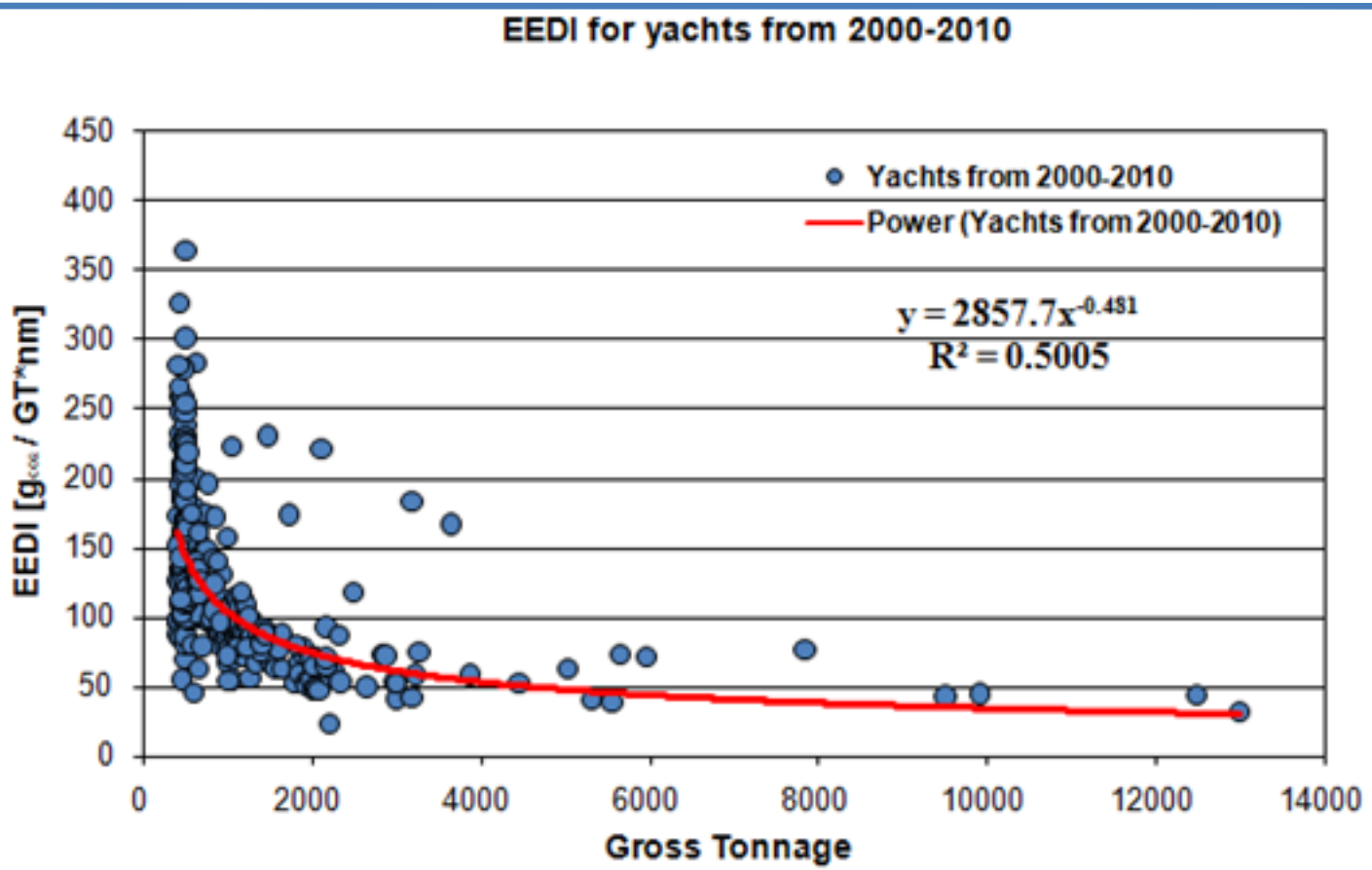
The EEDI

- There is no IMO reference line for yachts.
- EEDI was calculated for over 400 yachts.
- The majority were built between 2000 and 2010.
- Smallest yacht (400 GT, 38 m LBP).
- Largest (13000 GT and 160 m LBP).

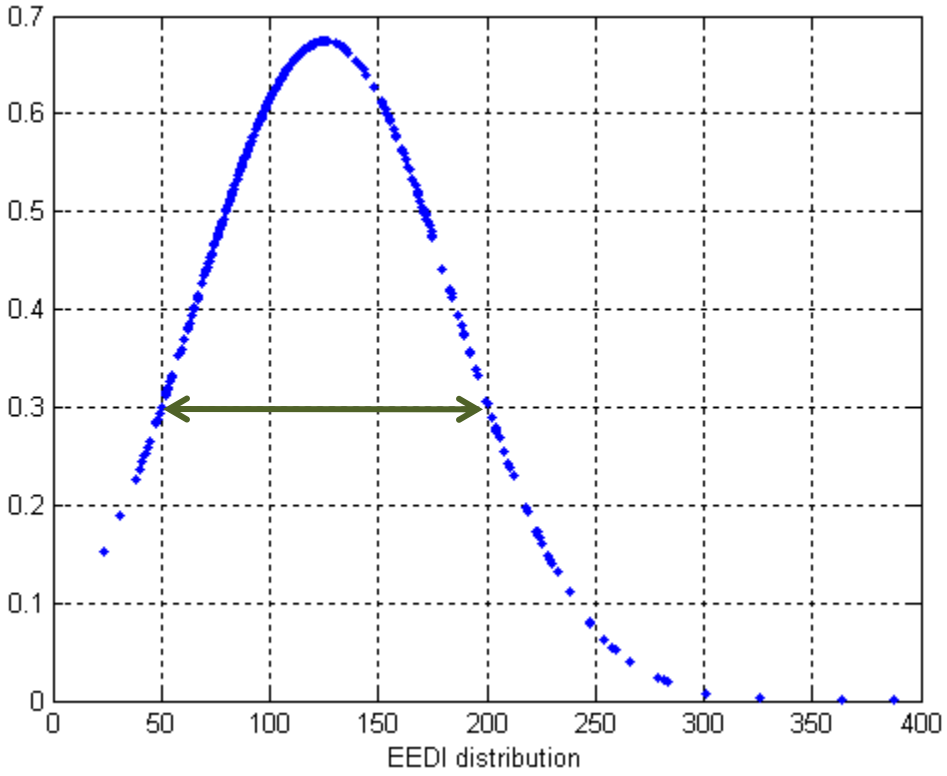
The EEDI

- Specific fuel consumption (SFC): Average specific fuel consumption 215 g/kWh. Variations from 230 g/kWh to 201 g/kWh.
- Fuel mass to CO_2 mass conversion factor for Diesel 3.206 t-CO2/t-Fuel as per IMO guidelines.
- Maximum continuous rating of main engines (MCR).
- Generators power was calculated using the following:
  - If the installed power greater than 10000 kW, PAE = 0.025 * MCR + 250 (as per IMO guidelines)
  - If the installed power less than 10000 kW, PAE = 0.05 * MCR (as per IMO guidelines)
- Speed: V_{ref} was used as reported from various sources.
- Capacity as gross tonnage (GT).

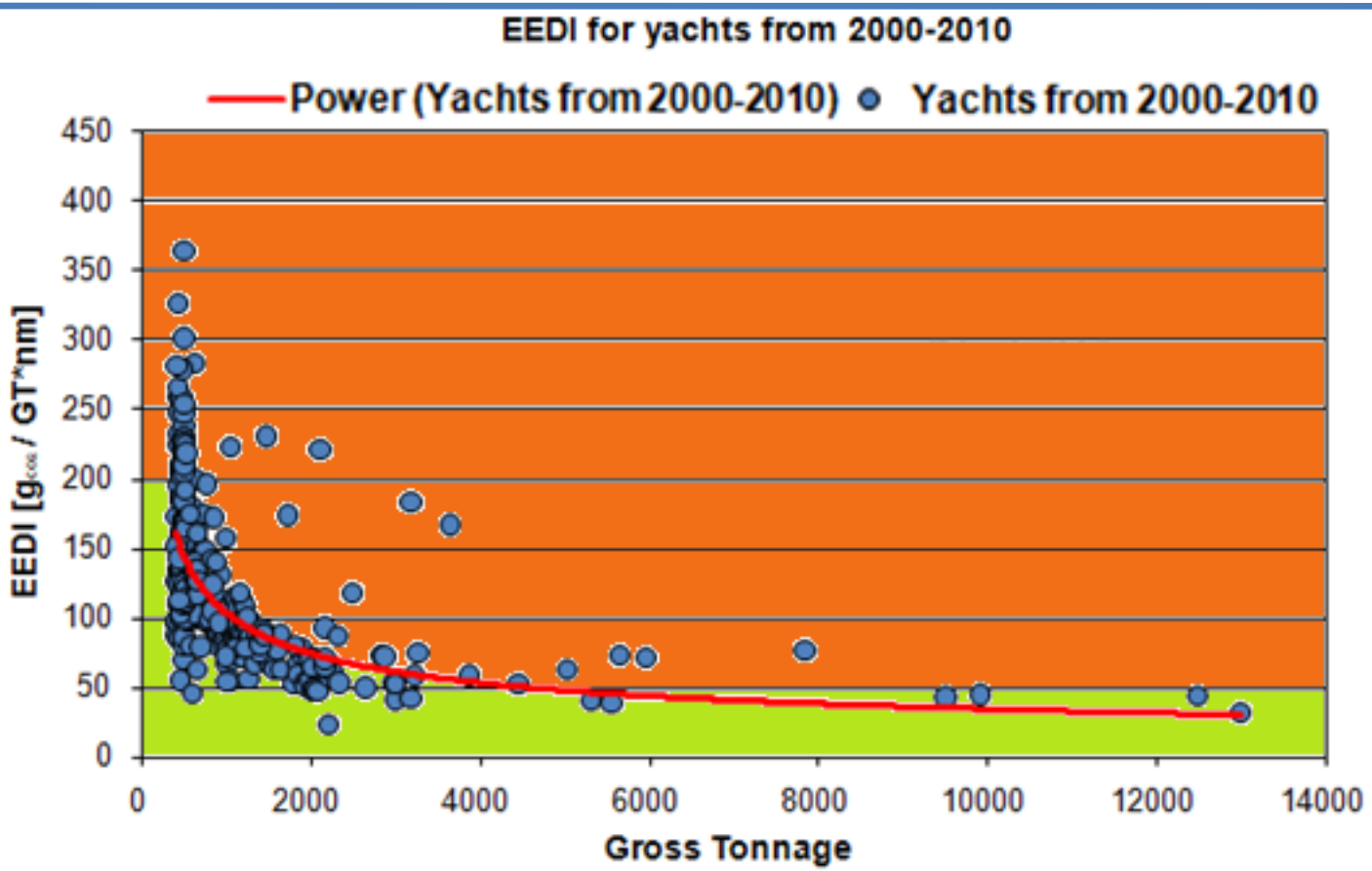
The EEDI


EEDI for yachts from 2000-2010
EEDI [g$_{CO2}$ / GT*nm]
450
400
350
300
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
12000
14000
Gross Tonnage
Yachts from 2000-2010
Power (Yachts from 2000-2010)
$y = 2857.7x^{-0.481}$
$R^2 = 0.5005$

The EEDI


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
EEDI distribution

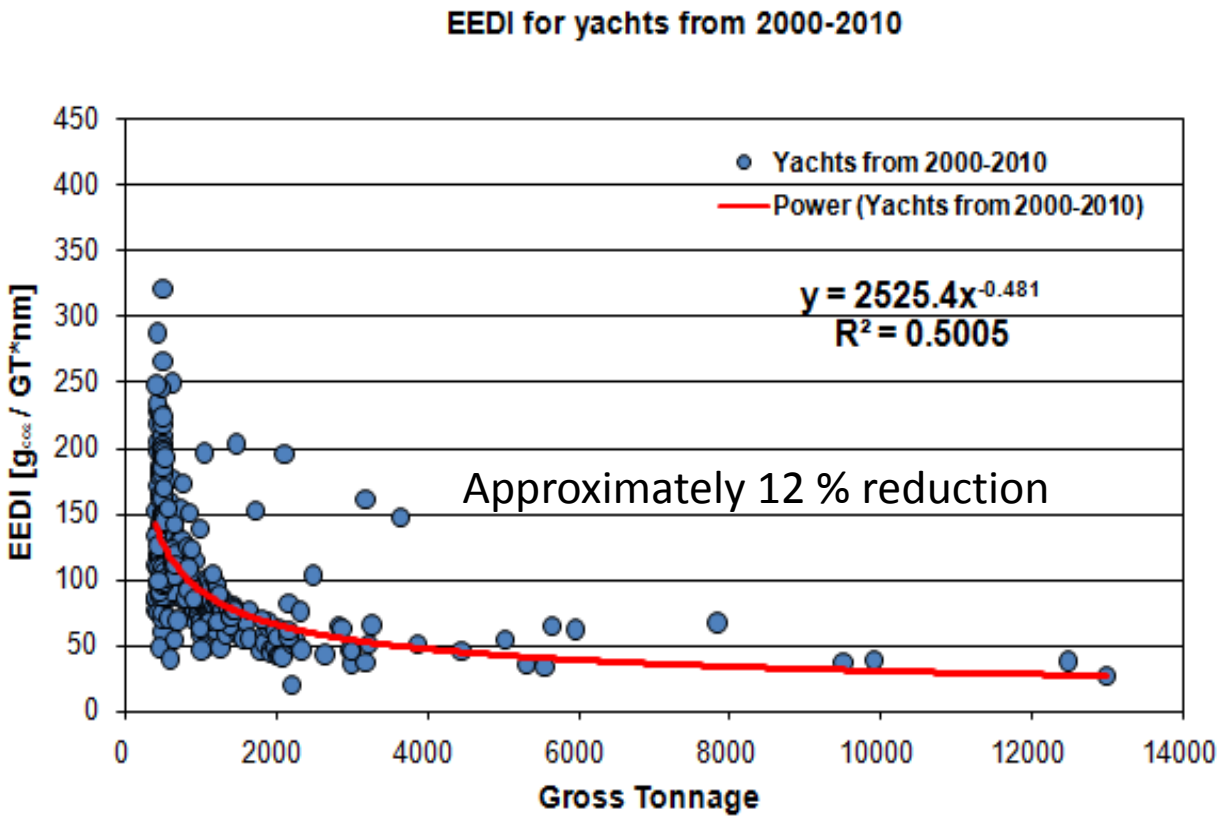
The EEDI



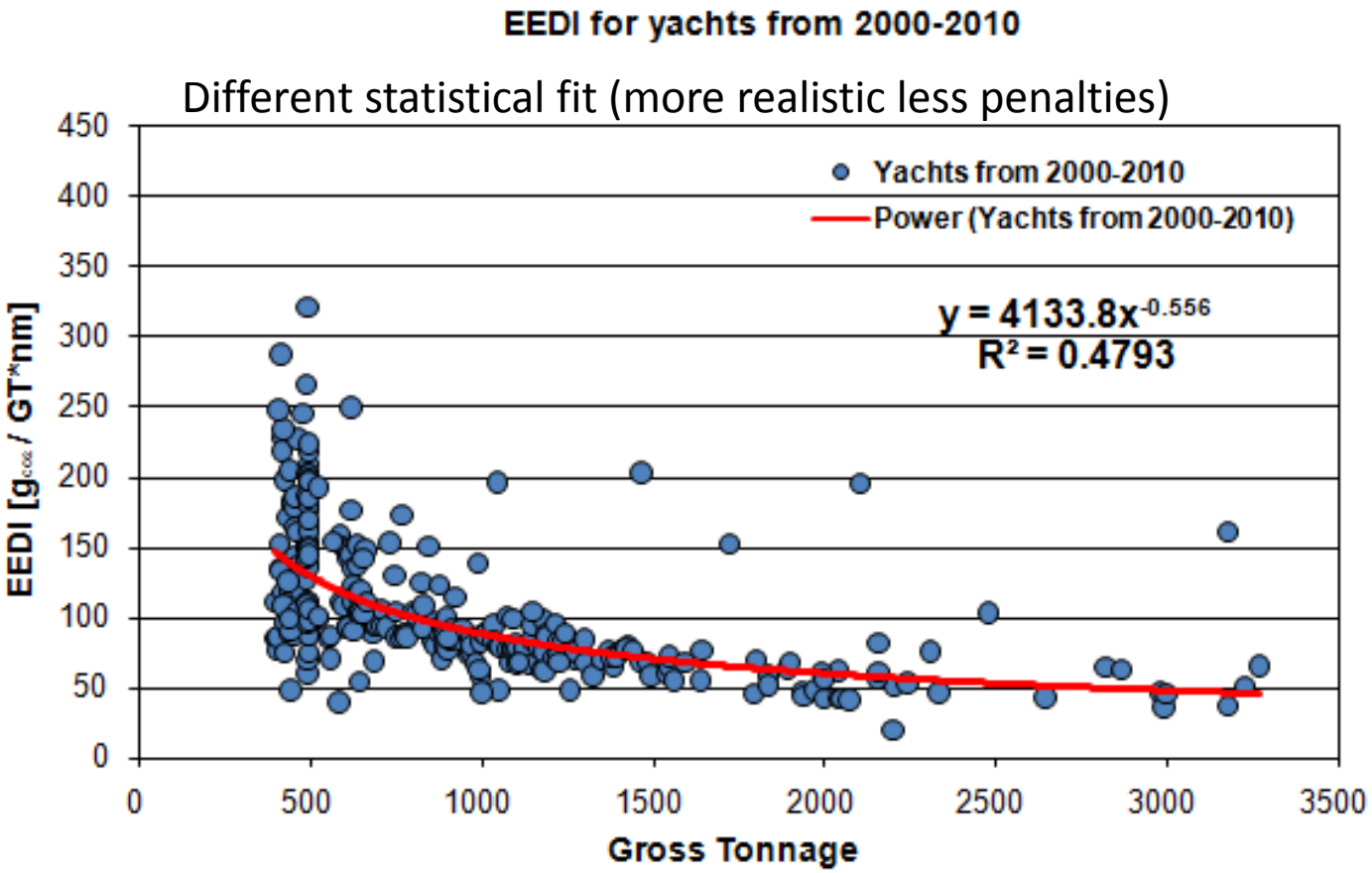
Undesired region.

Acceptable region.

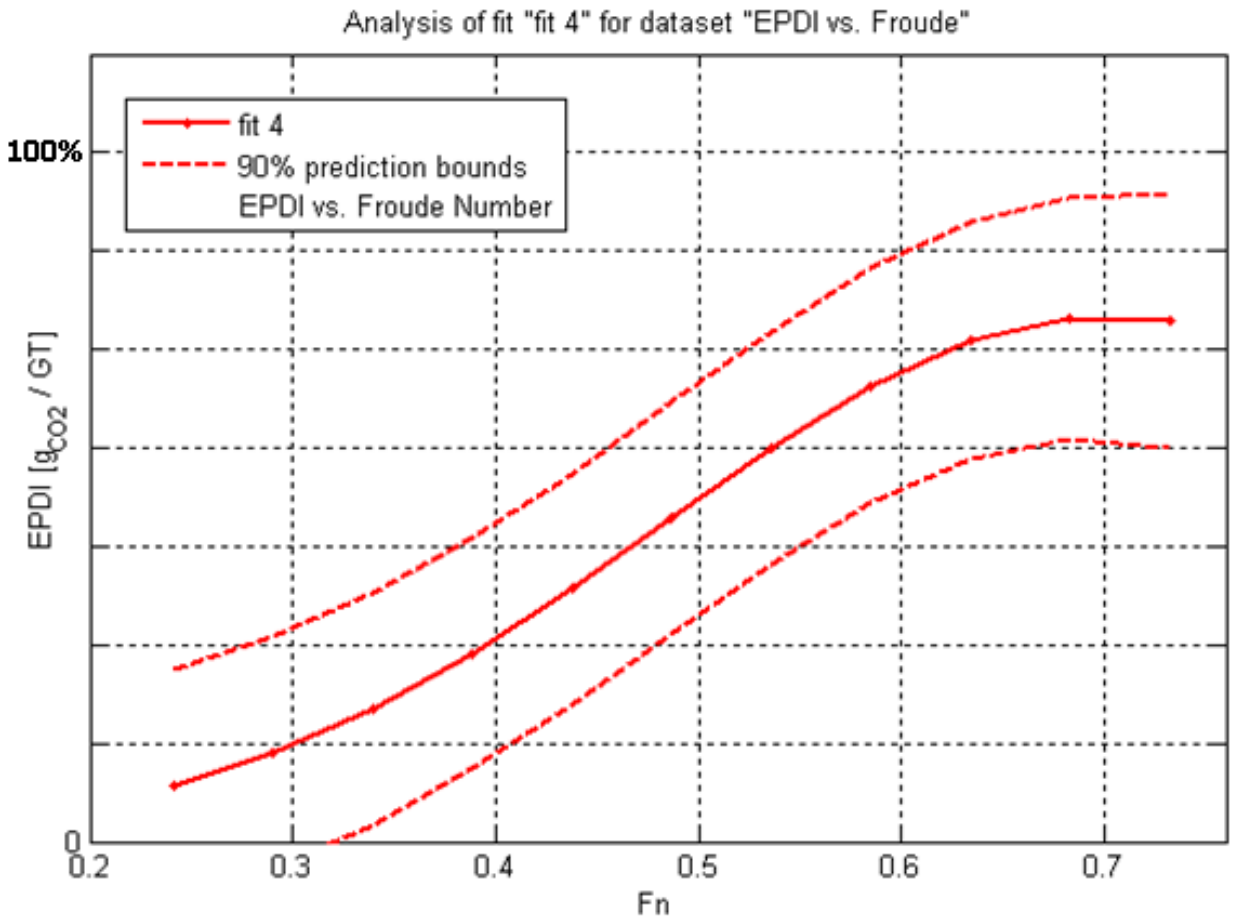
Influences: SFC impact on the EEDI



EEDI for less than 3300 GT.

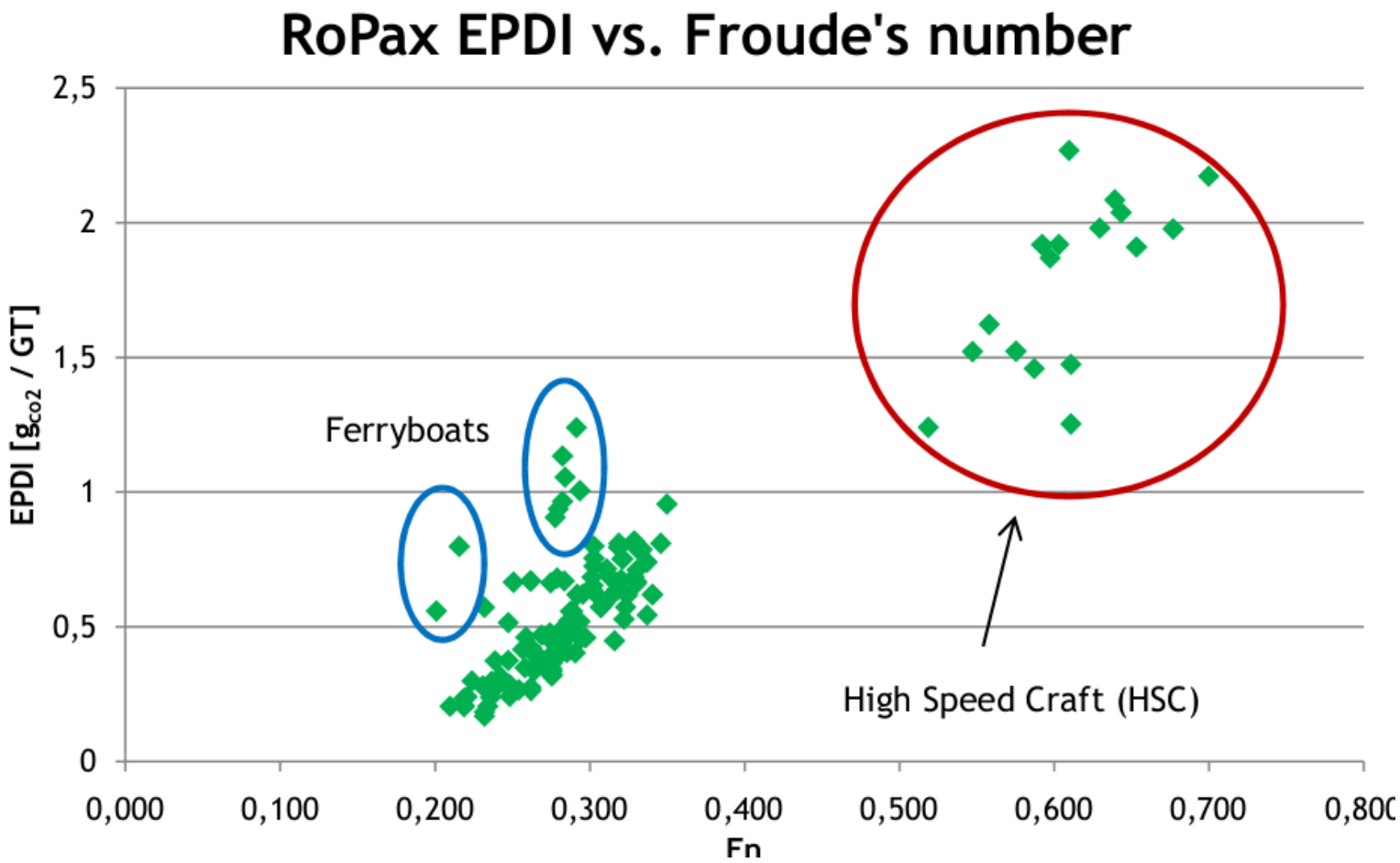


Hydrodynamics

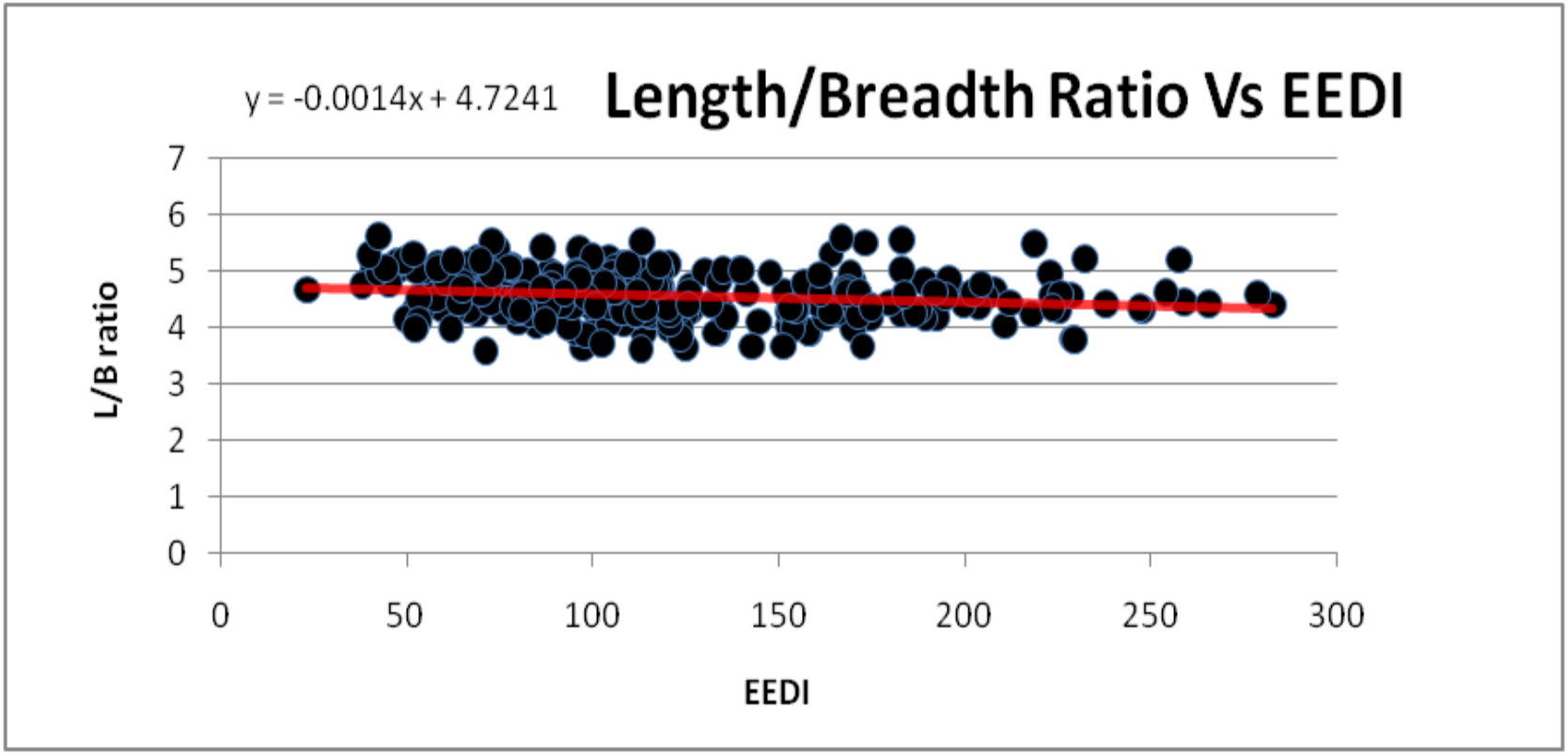


EPDI: Installed power divided by the gross tonnage and plotted against the Froude number.

EPDI: Installed power divided by the gross tonnage and plotted against the Froude number.



L/B Vs EEDI.


y = -0.0014x + 4.7241
Length/Breadth Ratio Vs EEDI
L/B ratio
7
6
5
4
3
2
1
0
0
50
100
150
200
250
300
EEDI

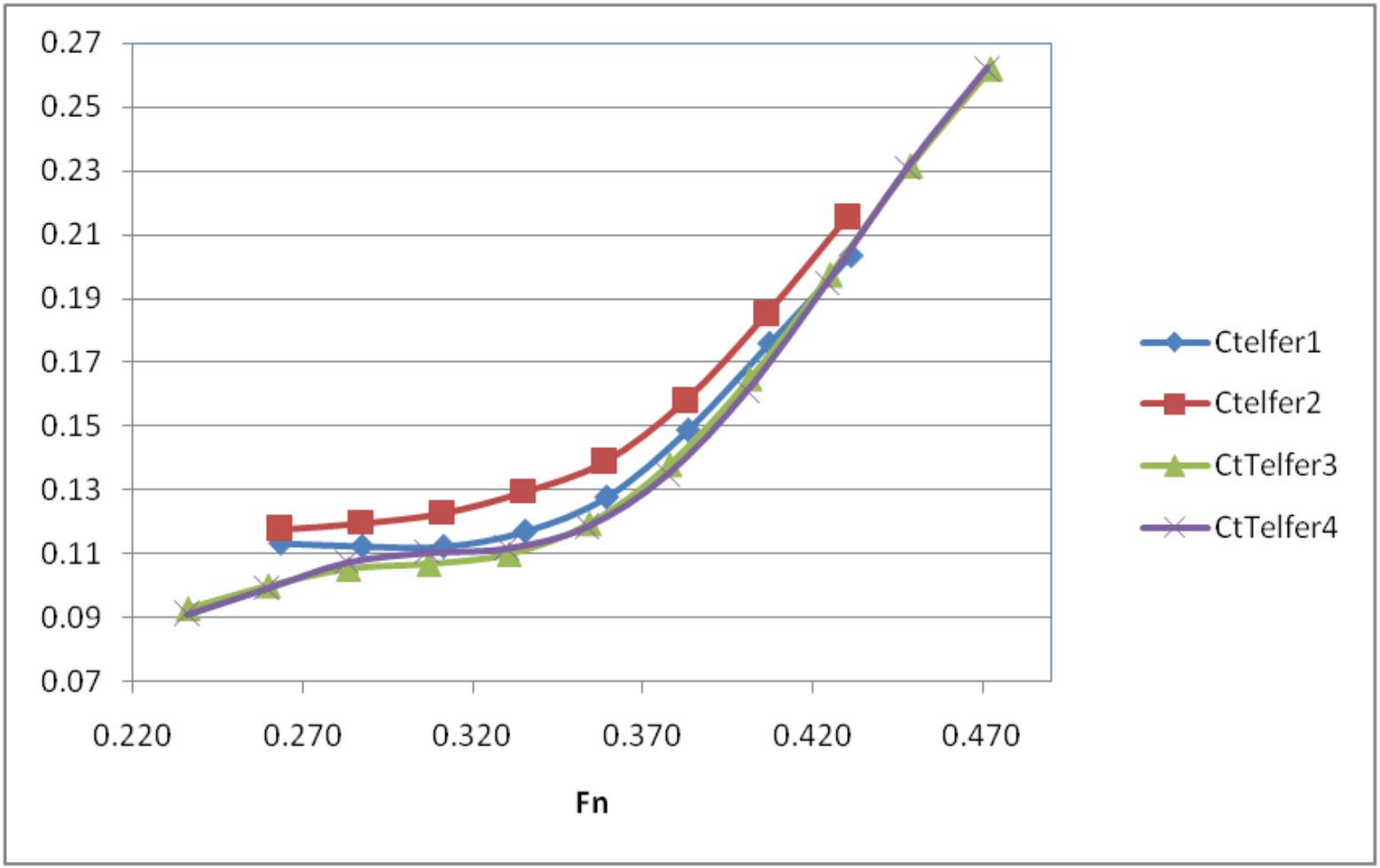
Telfer coefficient, © coefficient and R/ Displacement for hulls comparison

- Telfer 1963 and the ITTC (Subject 7 presentation of resistance and propulsion data):

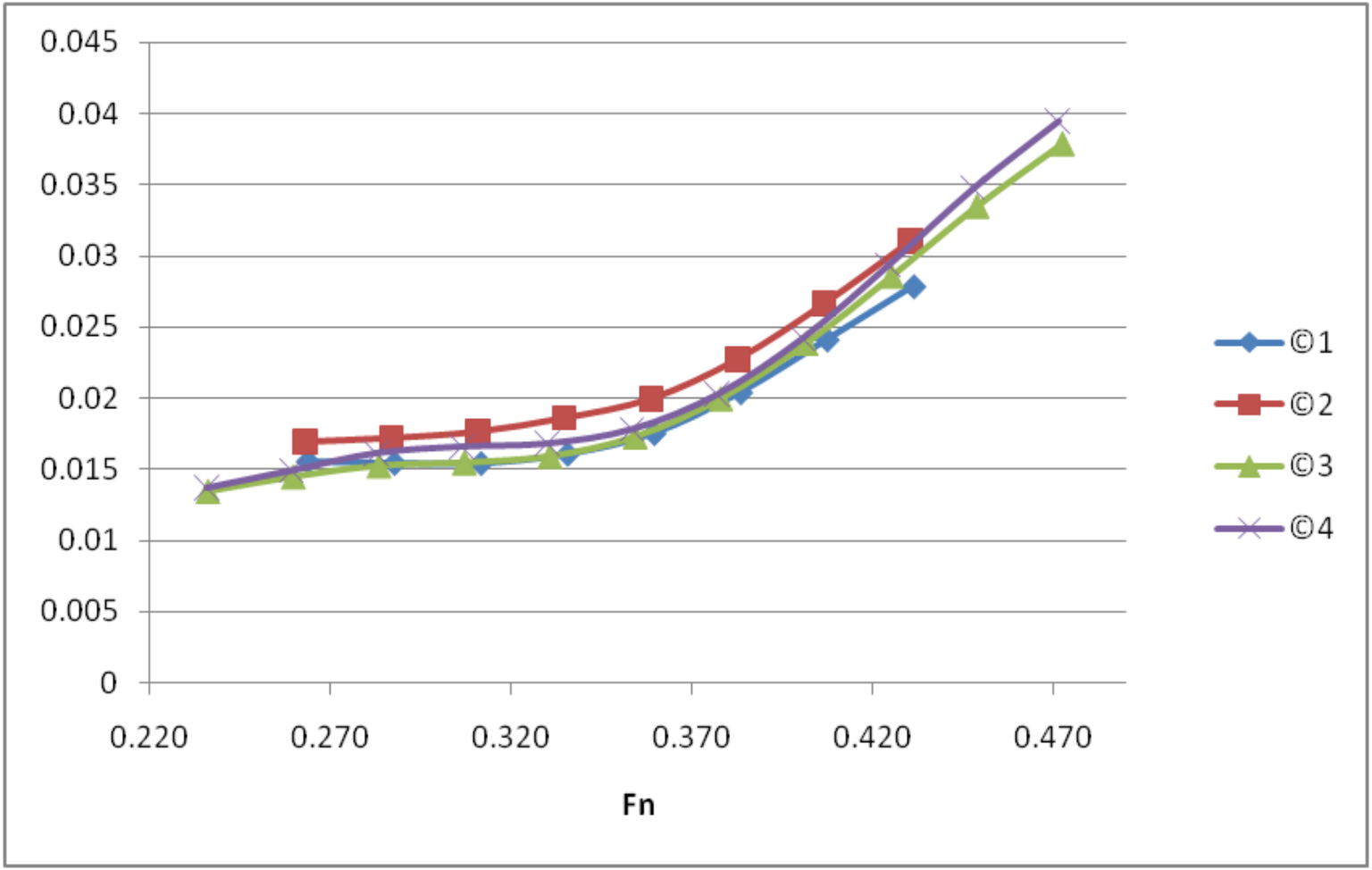
$$© = \frac{R}{\rho \nabla^{\frac{2}{3}}} \times \frac{1000}{4\pi}$$

$$C_T = \frac{2}{\frac{L}{\nabla^{\frac{1}{3}}} \times \frac{S}{\nabla^{\frac{2}{3}}}} \times \frac{\frac{R}{\Delta}}{fn^2}$$

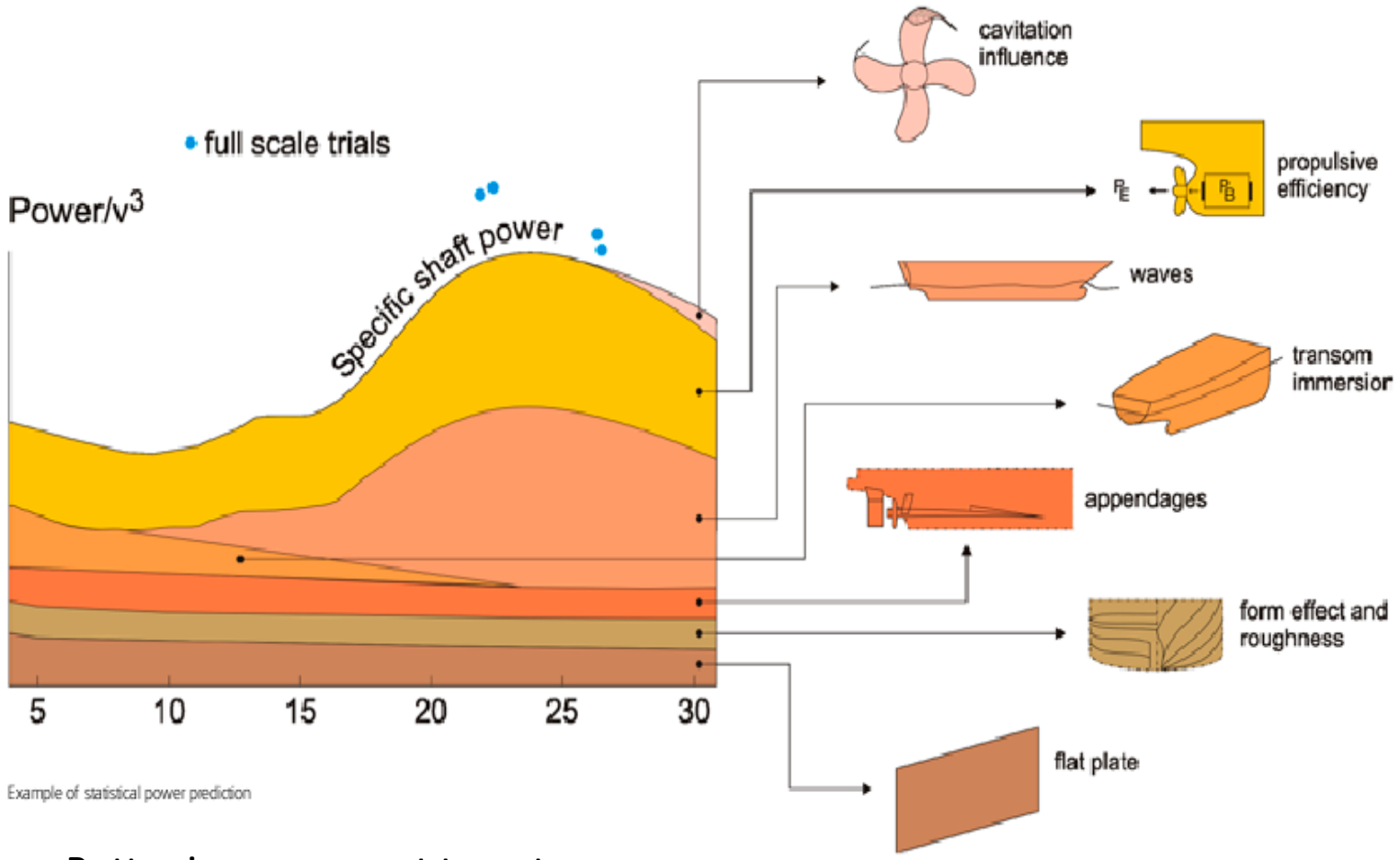
Telfer coefficient, © coefficient and R/ Displacement for hulls comparison



Telfer coefficient, © coefficient and R/ Displacement for hulls comparison



Utilisation of the Holtrop and Mennen:



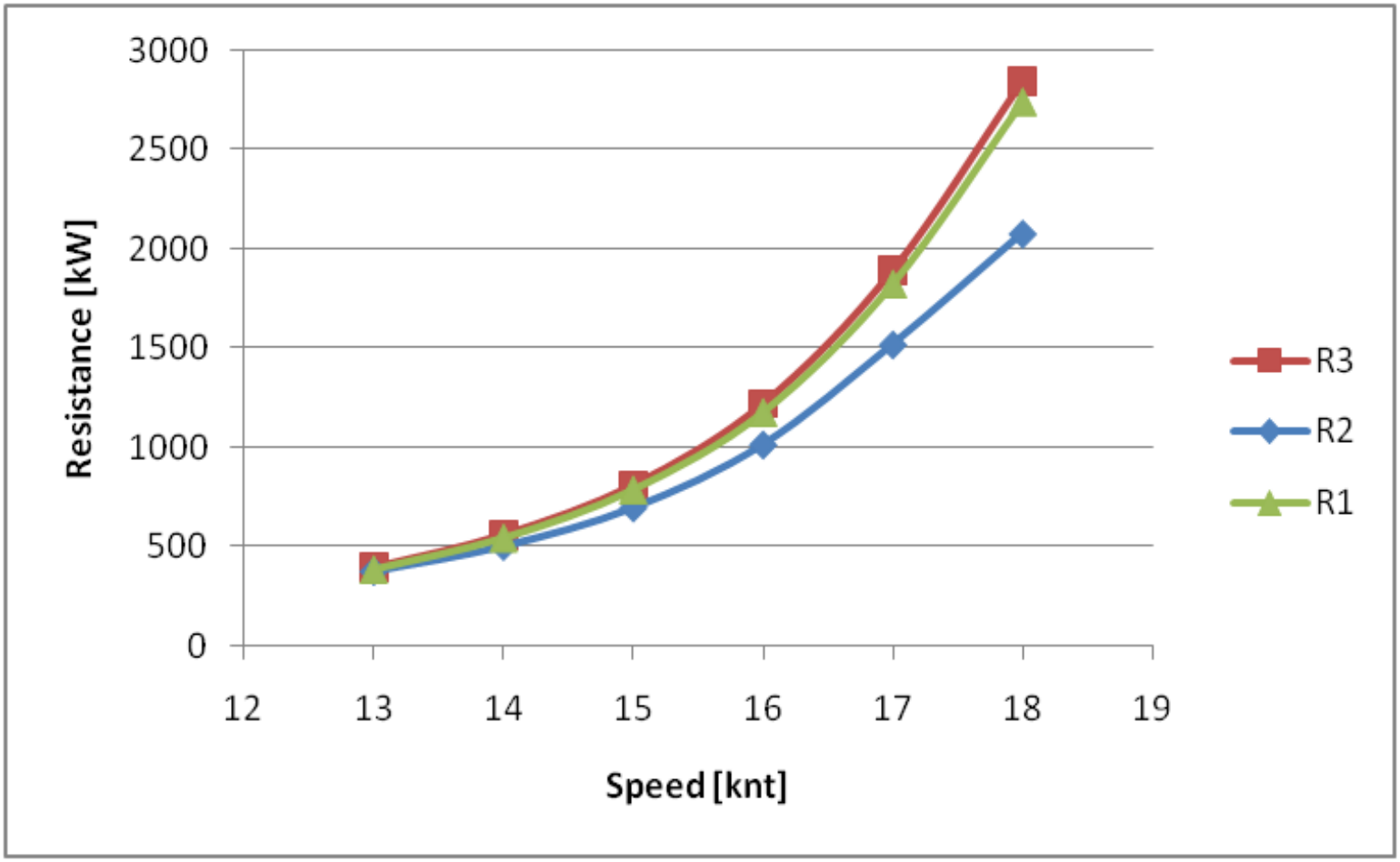
Better improvement target.

Holtrop and Mennen:

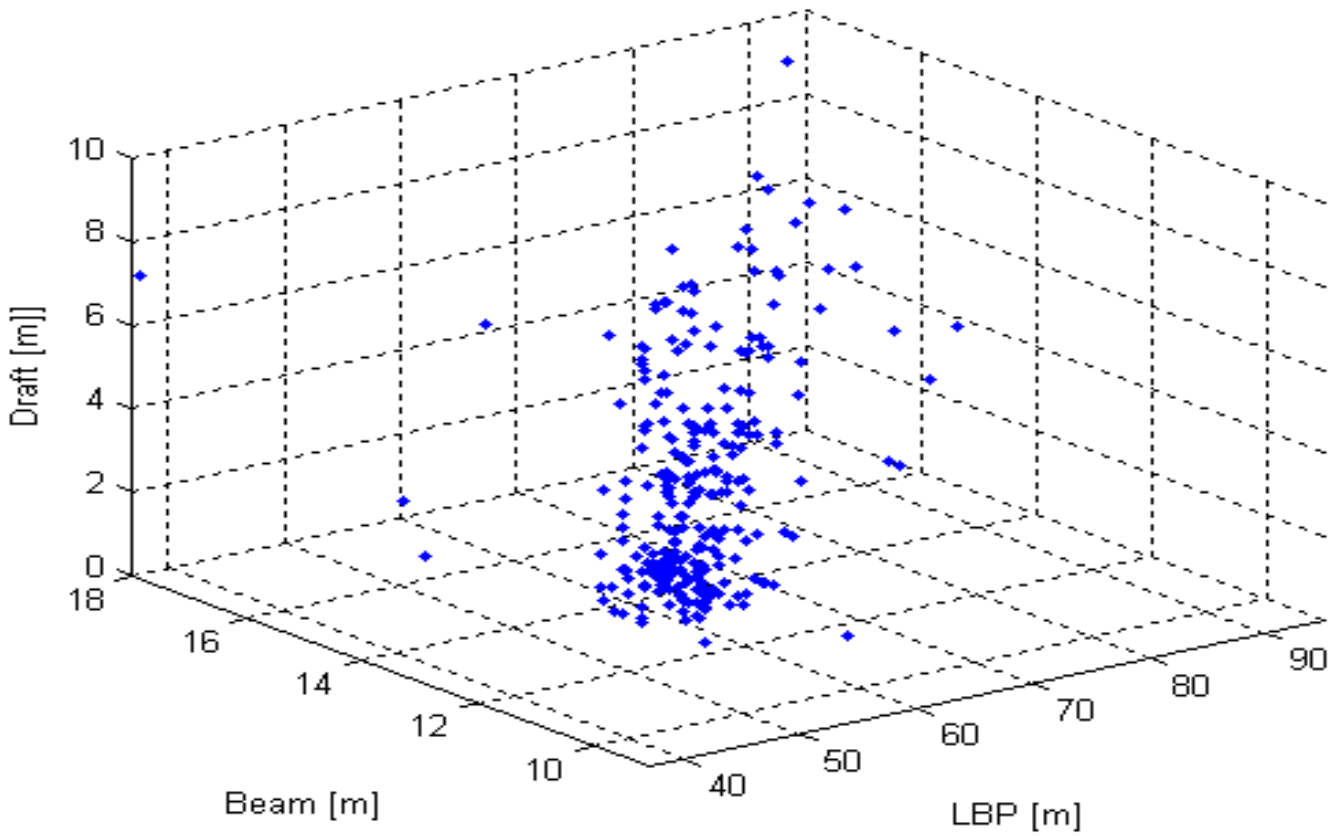
Trial #	Lwl (m)	Beam (m)	T (m)	Cp	Cb
R1	48.355	9.8	2.84	0.582	0.523
R2	48.855	9.6	2.64	0.576	0.568
R3	47.855	10	3	0.588	0.490

V (knt) x10	R1(kW) x10	R2(kW) x10	R3(kW) x10
13	57	55.99	59
14	75	69.5	77.7
15	101.5	90	105
16	142.6	123	148
17	208.2	173.4	216
18	295.7	224.1	306.6

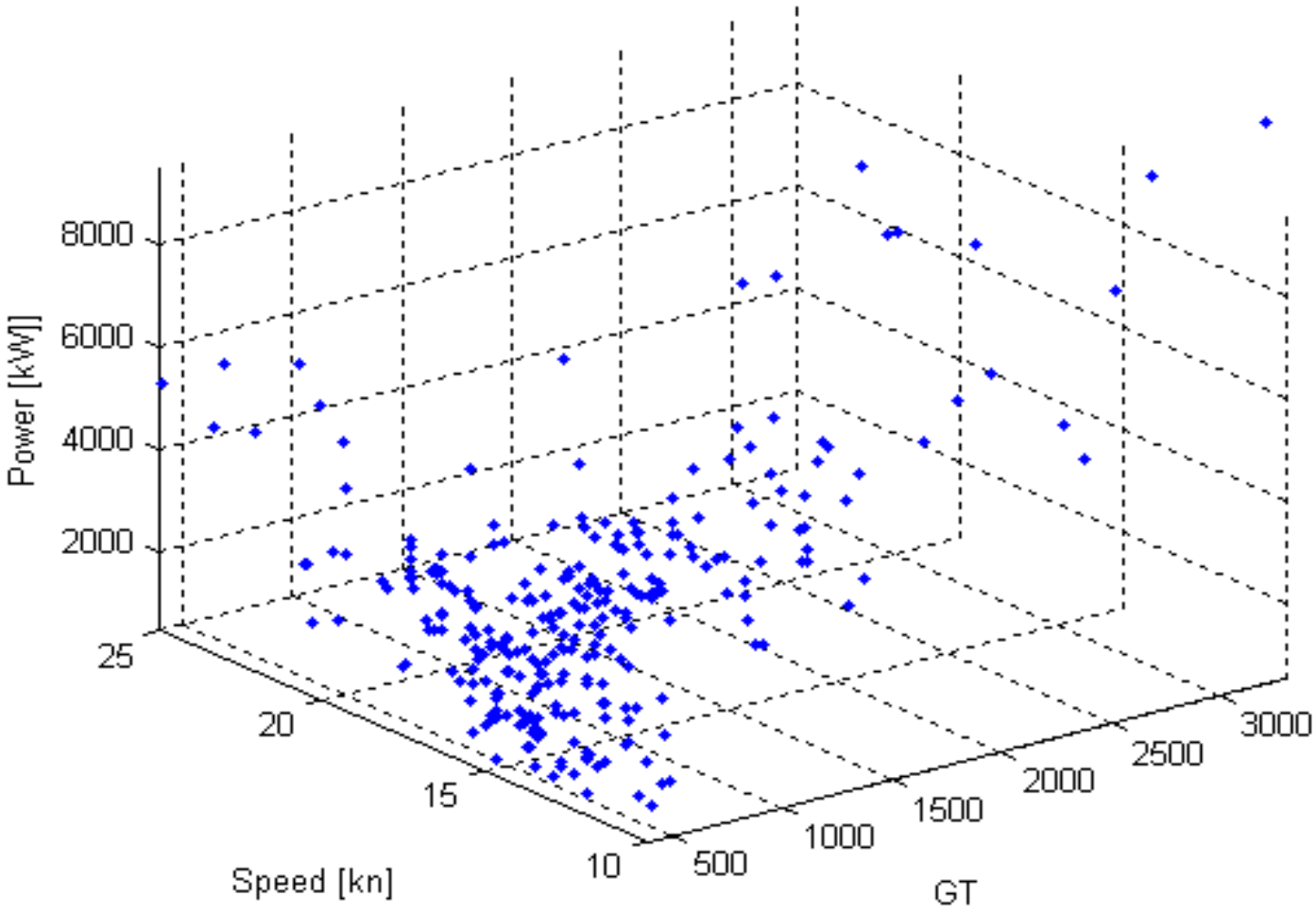
Holtrop and Mennen:



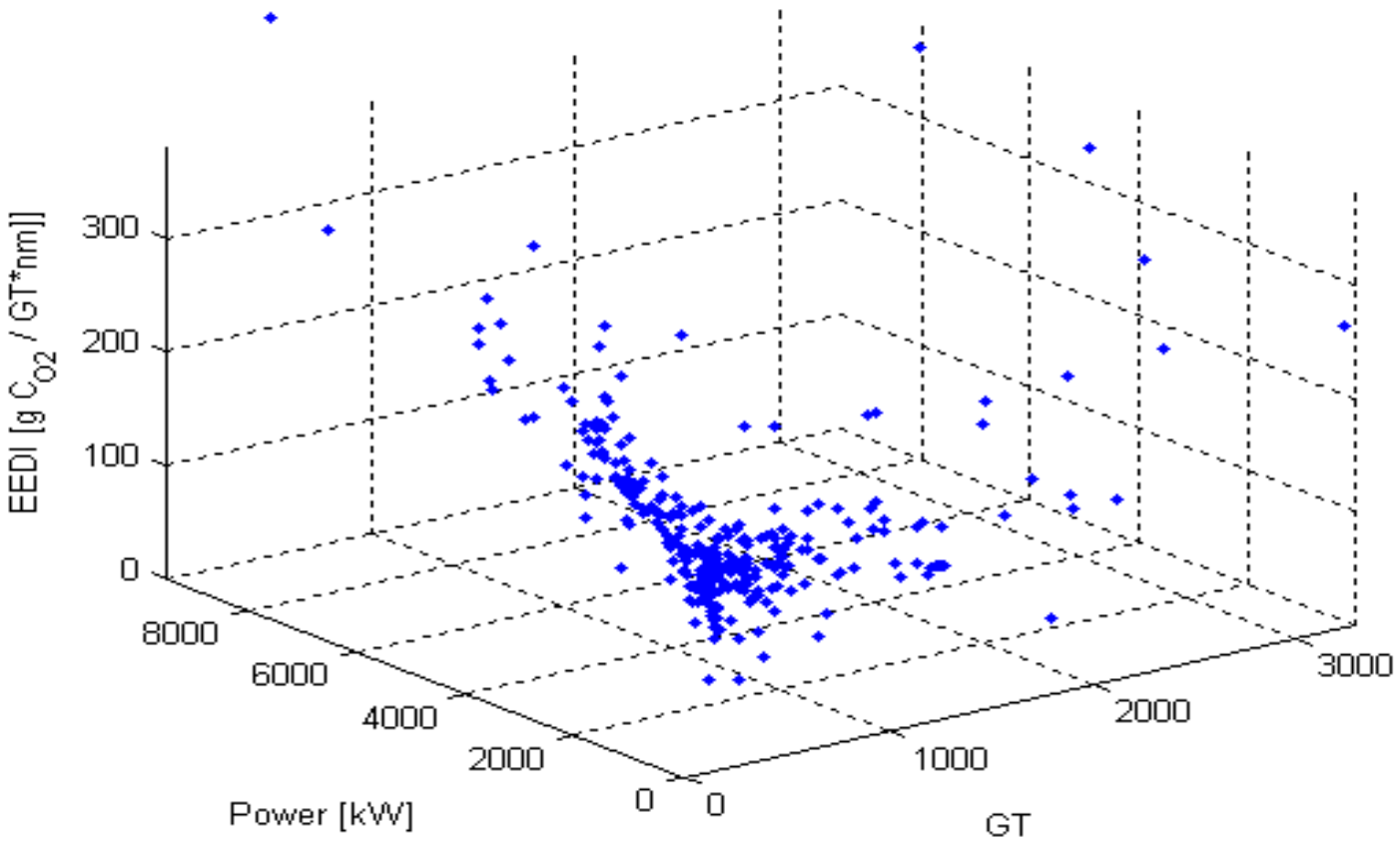
Holtrop and Mennen with (MOGA) multi objective genetic algorithms



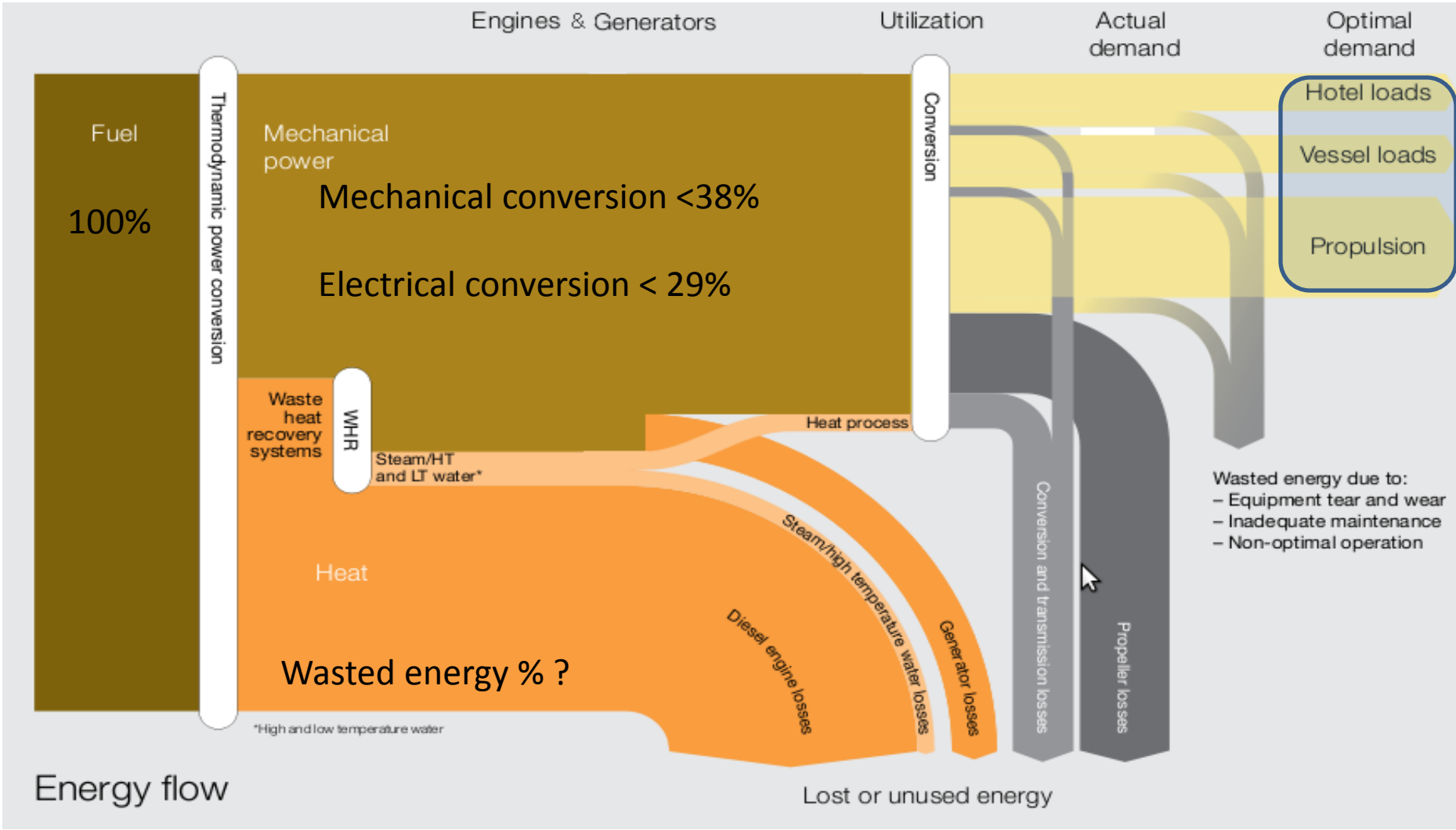
Holtrop and Mennen with (moga) multi objective genetic algorithms



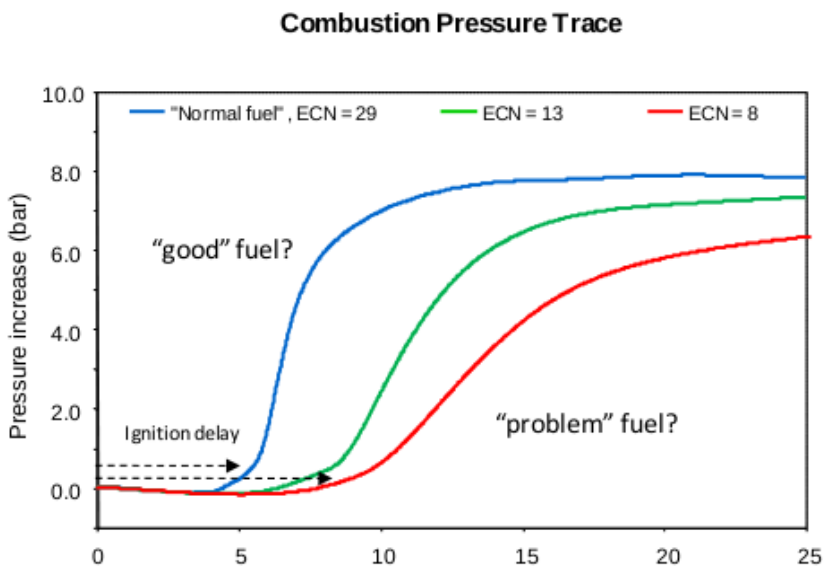
Holtrop and Mennen with (moga) multi objective genetic algorithms

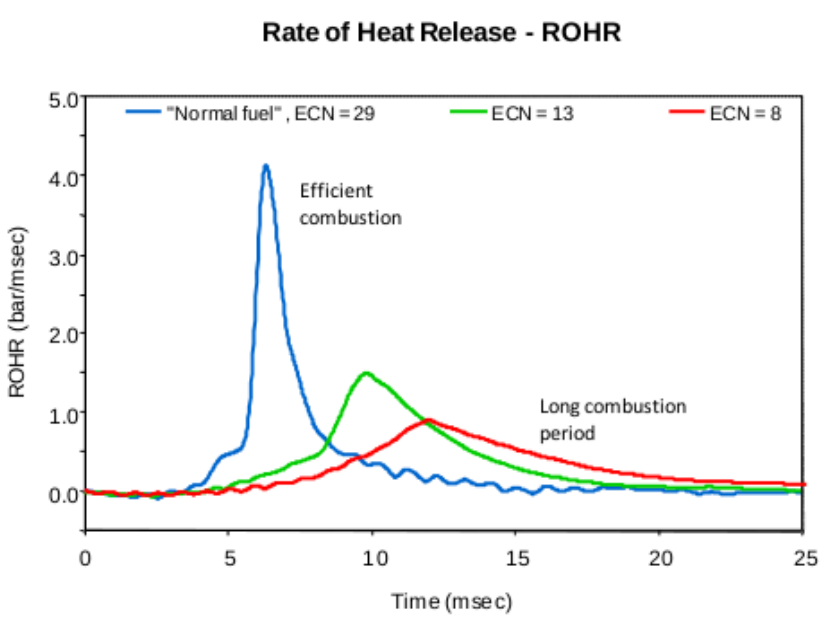


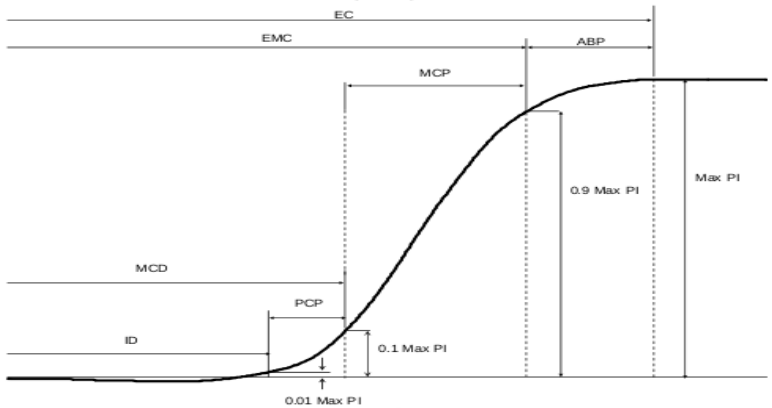
Machinery: Energy flow.

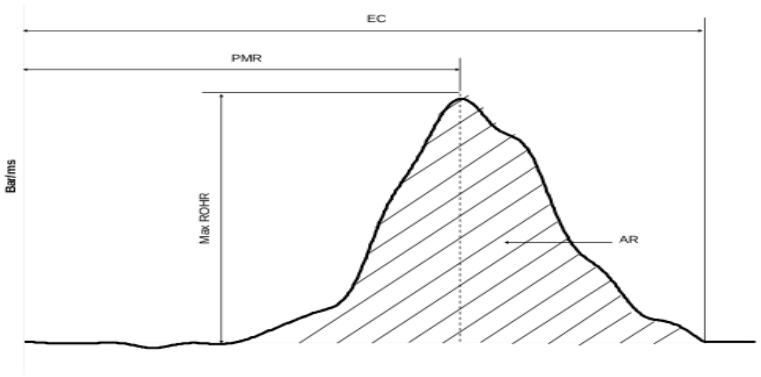


Machinery: Fuel.



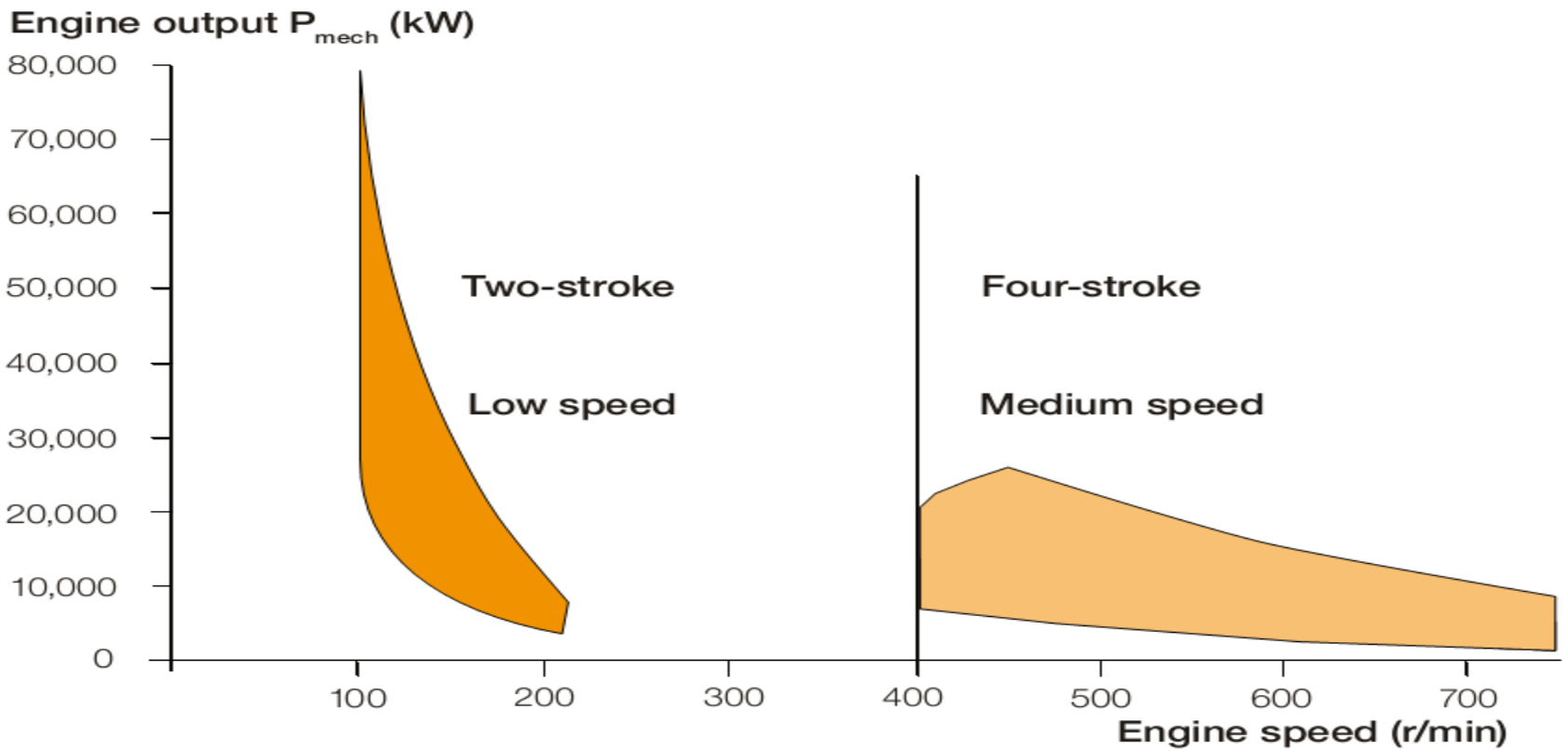






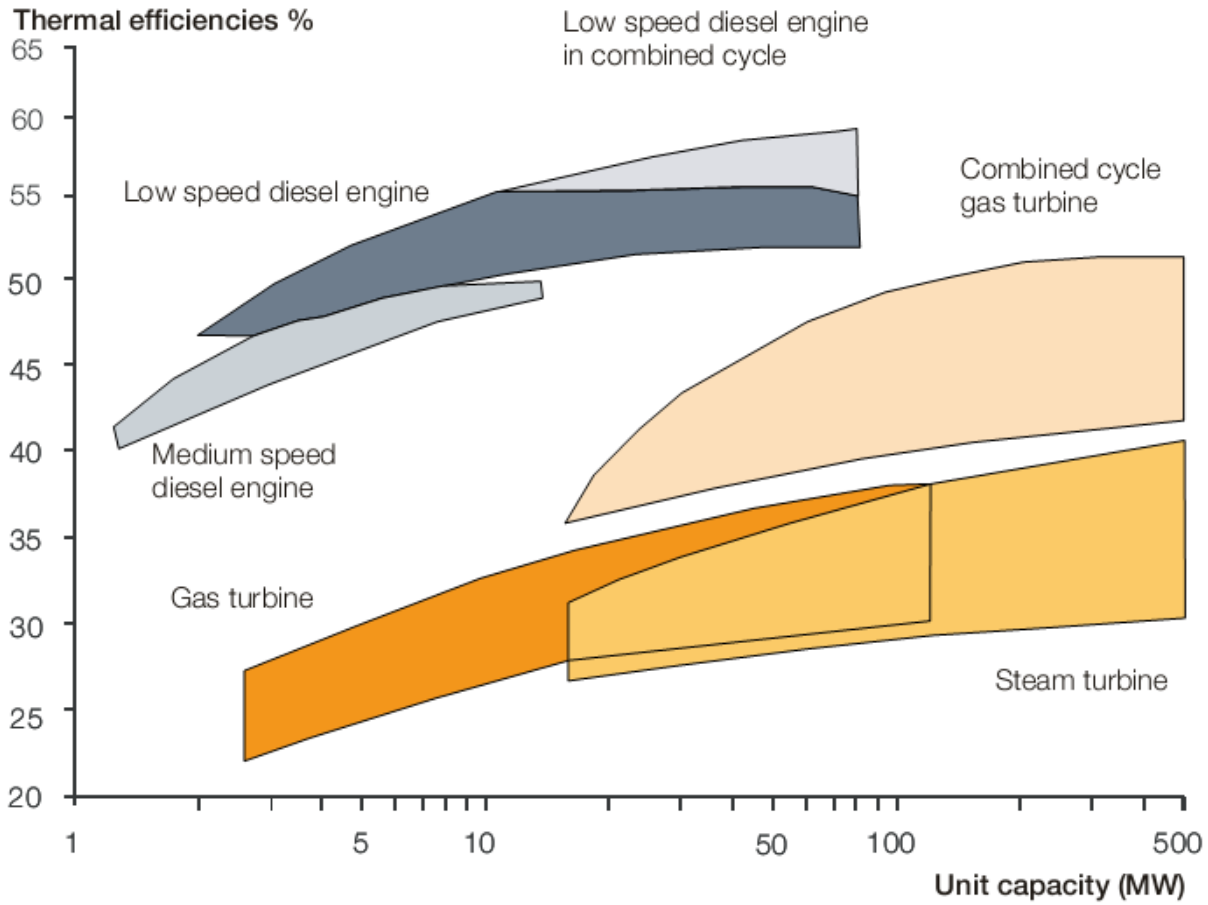
Fuel quality impact on combustion

Machinery: Types



Types of Engines.

Machinery:



Types of Engines.

Hotel Load

- Different HVAC principals were investigated. Multistage HVAC Vs single stage HVAC. Multistage was found to be significantly more effective (Compartments can be cooled independently during winter with smaller independent chiller at the fore section, the rest of the yacht can be heated with direct diesel boiler)
- Examples: Diesel boiler system for water heating and heating during winter. Efficiency gain up to 65% compared to electrical heating.
- Feasibility of the double glazing system also investigated, 3% improvement on the hotel load can be achieved. It was found that cost and weight will exceed the efficiency gain.
- Heat recovery system by mean of scrapper system was also investigated. It was found that the operational profile and space in the engine room will overweigh the efficiency gain.

Conclusion:

- Estimate of the EEDI reference was calculated. Sensitivity to various parameters were investigated.
- As shown that efficiency onboard a yacht is the sum of different aspects with small percentage of contribution.
- Energy saving possibilities were investigated from machinery, hydrodynamics, HVAC system and energy on board.
- EEDI is not yet enforced on yachts. However, it is the way of the future. Azimut-Benetti takes an early initiative to serve the best quality yachts to their clients.

Sensitivity to the environment.