

# **Resizing Study of Main and Auxiliary Engines of the Container Vessels and their Contribution to the Reduction of Fuel Consumption and GHG**

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The maritime industry has great potential for improving energy efficiency in both new builds and existing ships. It is, therefore, necessary to identify the areas where improvements can be made to reduce fuel consumption, and influence to the shipowners, shipyards and designers of ships on the need to implement these improvements in energetic efficiency and to achieve a reduction of between 25% and 75% of CO<sub>2</sub> emissions as IMO report 2009 provides, making ships even more environmentally friendly.

The study was conducted focusing on one type of ship such as containership, compiling a database of these ships built from 2000 to 2014. The 3618 ships comprising the study were taken from the database of Lloyd's Register of Shipping. With all the technical data on each of the ships, we proceeded to relate the main and auxiliary power, with the operating speed of the vessel, its displacement and GT, by size, age and generation ships.

All the above comparisons were made according to ship sizes, graphically and analytically in which interesting conclusions could be drawn in the relevant dimensioning of the main and auxiliary engines, as well as the operation of the ship. Because of the current crisis some owners have already begun to change their size criteria of propulsion and auxiliary engines of these vessels, their management and operation as well as their speed.

Another significant finding was the identification of some shipyards that build their ships with an oversize and exaggerated power of the main and auxiliary engines, regardless of the effect on increasing fuel consumption and impact on the environment.

Finally, we have performed a comparative study of EEOI of these vessels by size and age to determine the environmental signature and their evolution.

All this leads us to determine a set of measures to be applied, for example, power reduction or derating, etc. on existing ships and applied to new designs, thus reducing the propulsion and auxiliary power of these ships and collaborating to reduce greenhouse gases.

**Keywords:** Energy efficiency; Energy management; Energy policy; Shipping economic.

## **1. INTRODUCTION**

As explained in the abstract, the objective of this study is to further deepen the measures that can be implemented in container ships during its design and construction, and later in its operational life.

The first step in this study was to perform a database of all existing container ships, and then classified by size, age and generation, from 2000 until 2014.

The database used has been to Fairplay that is associated with the classification society Lloyd's Register of Shipping, and it is the most complete and reliable that exists in the maritime world. The total number of vessels including all sizes is 5119, and they all took their characteristic data such as identification IMO, dimensions, displacement tonnage (GT), propulsion and auxiliary power and speed.

The classification was made of container ships by size is as follows: Feeder (100-500 TEU), Handy (1.000-2.000 TEU), Sub-Panamax (.2000-3.000 TEU), Panamax (over 3.000 TEU) , Post-Panama (over 4.000 TEU) and Super-Post-Panamax (over 10.000 TEU).

Once realized the database container ships from 2000 to 2014, and the classification by size has come to make, for each vessel size, relationship and comparison of the propulsive power to the auxiliary power; of the propulsive power to auxiliary power and speed; propulsive power to the auxiliary power and displacement; propulsive power with the auxiliary and the GT; propulsion power with displacement and velocity; propulsion power and speed with GT.

## 2. FEEDER

In Figure 1 the propulsion and auxiliary power is related to the speed, called feeder container ships which have entered 474 vessels with a gross tonnage of between 499-10.965 GT, and we can observe the following: the propulsive power is from 1.800 kW to 9.500 kW. In this power range we can consider five groups: the first in a propulsive power of 3.500 kW, a second 6.200 kW, 7.200 kW a third, a quarter of 8.500 kW and 9.500 kW fifth.

It can be inferred that the range of propulsive powers that cover this type of ship is divided into the five powers before mentioned with the exception of extreme cases in both directions.

In the same Figure 2 the speed of this type of vessels ranging from 12 to 20 knots, and it is found that there is a strong parallel between the propulsion power and speed in which we highlight four groups: the first one has a 6.200 kW propulsion power for a displacement of 12,000 t; Then, propulsion power of 7.200 kW for a displacement of 13.000 t; the third, a propulsion power of 8.500 kW and a displacement of 15.800 t, and the last group has a propulsion power of 9.500 kW for a displacement of 17.500 t. All this indicates that to cover the range of feeder vessels are several series that cover according to the above values except in exceptional cases.

Regarding the auxiliary power of these vessels, it goes from 300 kW to 2.500 kW with a few exceptions ranging from 3.500 kW to 5.000 kW, very high powers which may be due to the supply of electricity to large number of reefer containers. If we compare the electrical power of these ships with propulsive power, the range is from 6% to 13.8% of the propulsion power.

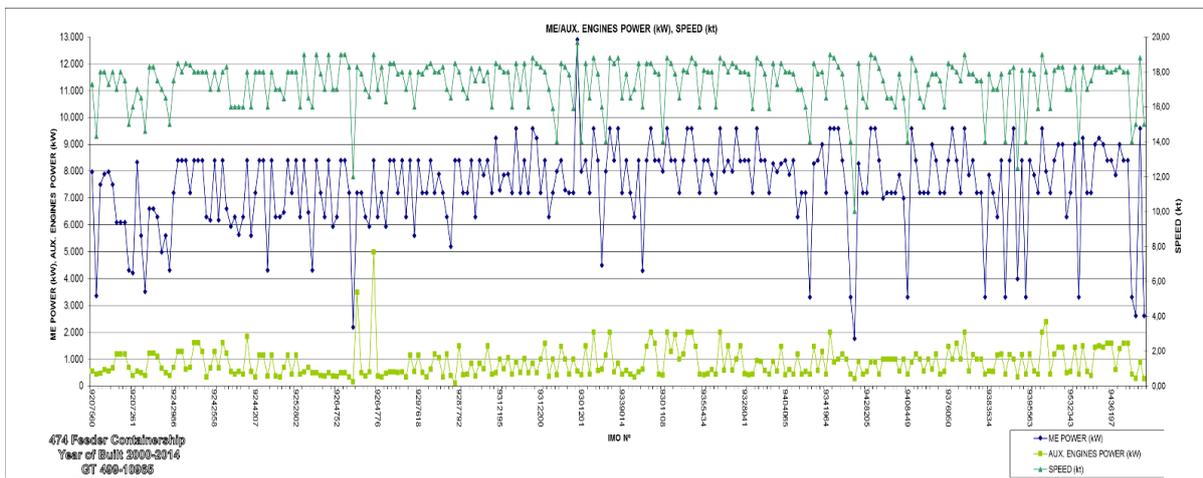


Figure 1

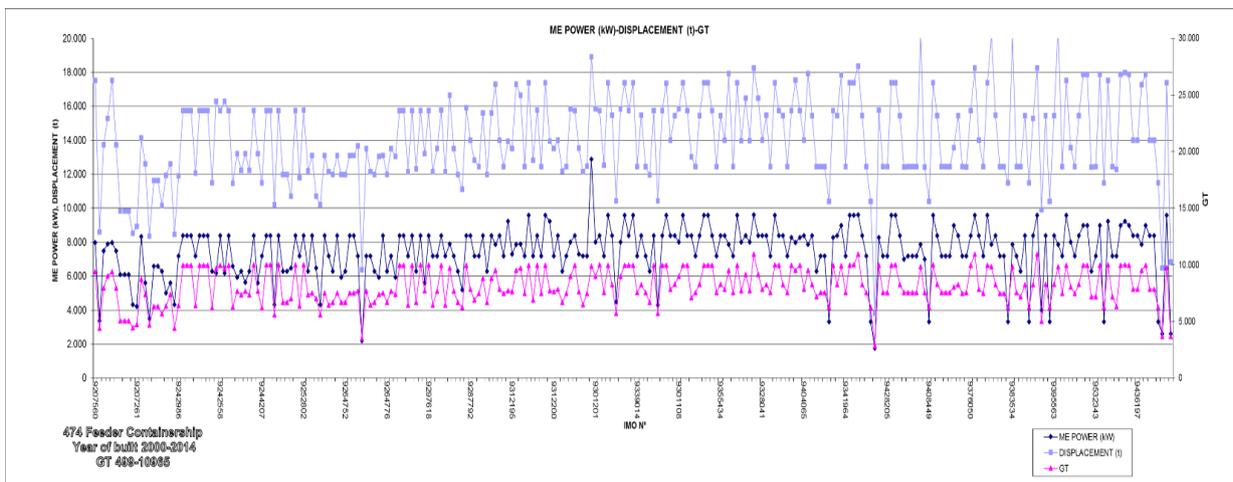


Figure 2

### 3. HANDY

In Figures 3 and 4 are compared the propulsion power, auxiliary power and displacement of these ships and we can establish the following: the range of propulsion power ranges from 6.000 kW to 21.700 kW, and can establish six series of groups such vessels linking the propulsion power and displacement. The first is that of vessels with propulsion power of 7.500 kW and a displacement of 17.500 tonnes, the second propulsion power of 11.000 kW and 22.500 t displacement, the third of propulsion power of 12.500 kW and 25.000 t displacement, fourth of between 16.000 and 17.000 kW for a displacement of 32.000 t, the fifth for propulsion power of 19.000 kW and a displacement of 37.000 t and the last of propulsion power of 21.500 kW and a displacement of 35.000 t.

In the above groups can be seen that this type of vessels, Handy, are quite segmented within the capacity range of containers that move ( between 1.000 and 2.000 TEU ).

The speed range of these vessels is broad and ranges from 15.5 to 21 knots, and there are cases of ships with speeds between 22 and 23 knots , requiring high speeds and high propulsion power of up to 21,500 kW , which an increase of fuel consumption very high.

The auxiliary power of these vessels ranging from 500 kW to 2.000 kW with a range of between 5% and 9% of the propulsive power, low values, since such vessels do not usually have loading and unloading , so that your electrical needs are moderate. There are vessels in which its subsidiary powers are higher , reaching up to 3.000 kW possibly by an increase in electricity demand to transport a large number of reefer containers .

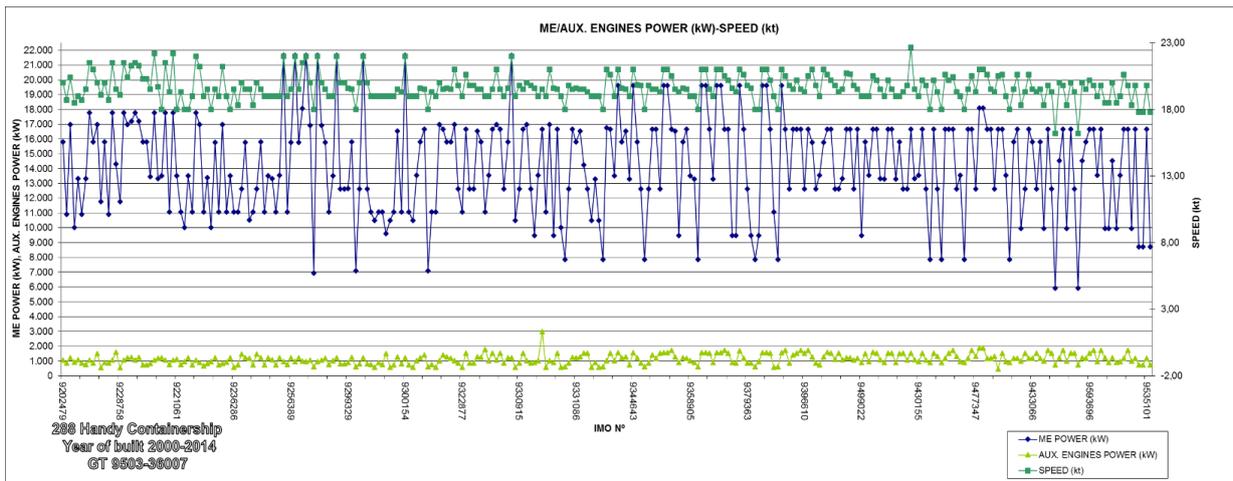


Figure 3

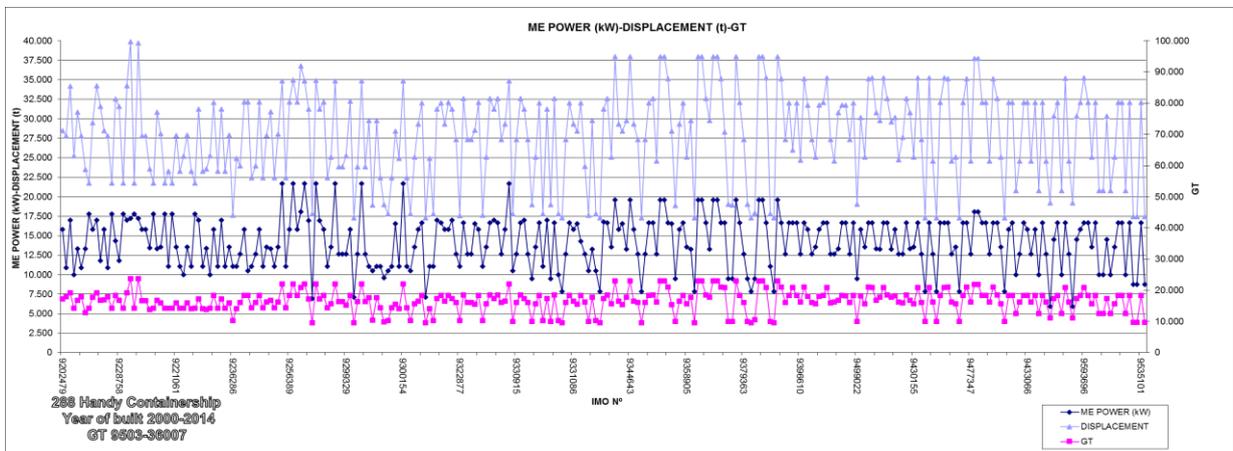


Figure 4

## 4. SUB-PANAMAX

In these ships the propulsion power range goes from 13.500 kW to 32.000 kW. Looking at Figures 5 and 6, the first one we can see that in this type of vessel we can establish six series of propulsive power covering called vessels sub -panamax and that would be 18.000 kW , 20.000 kW , 21.000 kW , 21.700 kW, 25.000 kW and 29.000 kW. The largest is 21.700 kW followed by 25.000 kW. There are also isolated cases at both ends where the propulsion power is 13,500 kW or 32.000kW. These two extremes of power are marked by a small or very high speed.

Speeds for the propulsion power of these vessels ranging from 21.5 to 23.5 knots, very high speeds, requiring propulsion powers like the above with excessive fuel consumption.

In these ships there are also low speeds like 16 knots you only require a propulsion power of 13.500 kW for a displacement of 43.000 t , which is the best example of efficiency in fuel consumption and environmental friendliness . Otherwise we have a vessel with a speed of 25 knots requiring power 32.000 kW for a displacement of 48.000 t, clear example of high fuel consumption and air pollution.

Comparing powers of propulsion vessels displacement in this type of vessel is as follows: for the propulsion power of 18.000 kW displacement is 42.000 t, for between 20.000 and 21.000 kW displacement is 45.000 t, for the displacement of 21.700 kW is between 47.000 and 52.000 kW, 25.000 kW for the displacement ranges from 52.000 to 55.000 t, and the displacement of 29.000 kW ranges from 52.000 to 57.000 t. It is noted that this type of vessel rewards speed with some dire consequences for the environment because the speed from 20 knots penalized exponentially to the 4th power demanding high propulsion power for the same displacement with consequent overconsumption of fuel.

In regards to the electrical power of these vessels, this ranges from 1.000 kW to 2.500 kW, which means between 5% and 11.6 % of the propulsion power .

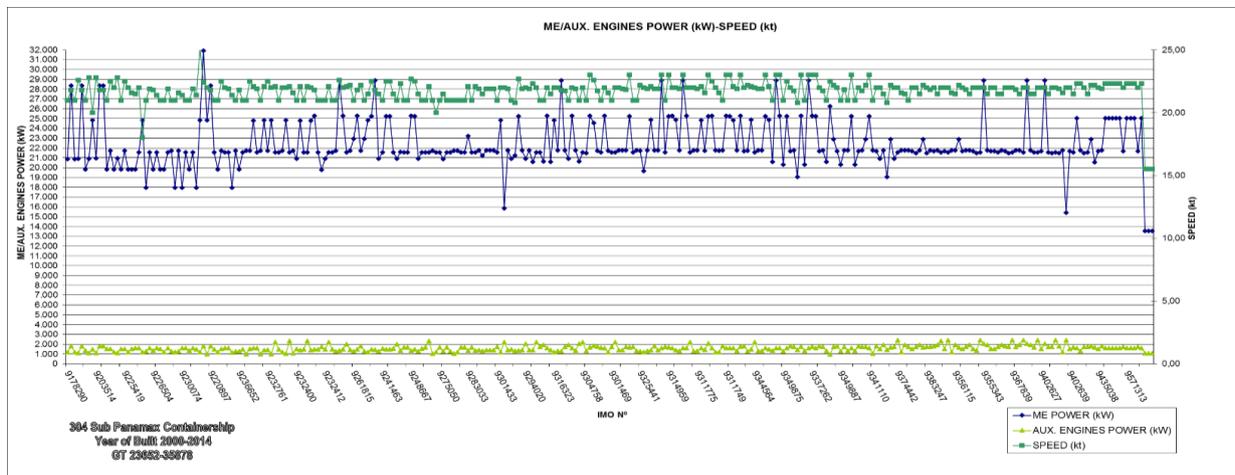


Figure 5

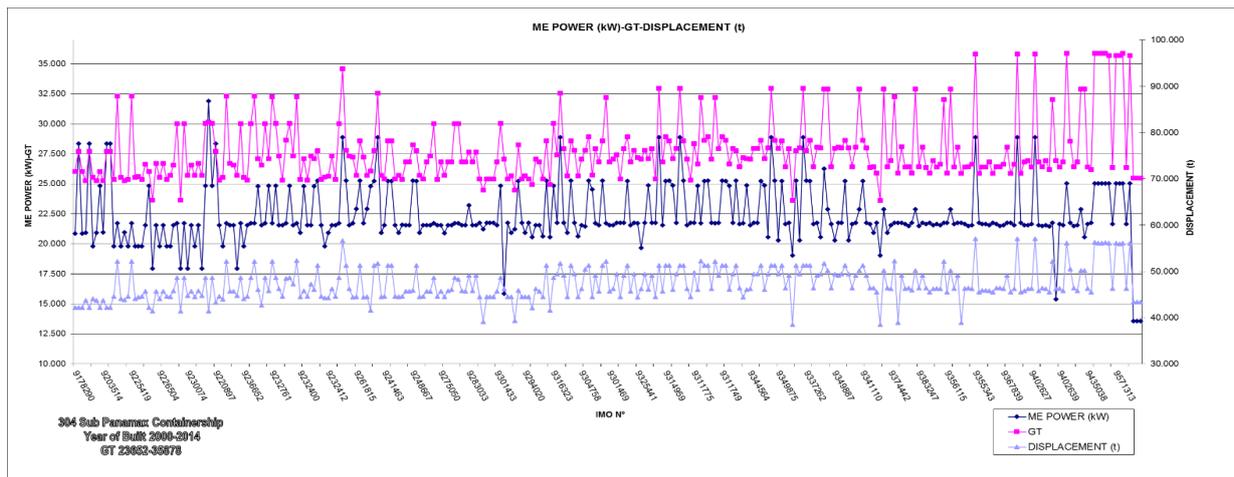


Figure 6

## 5. PANAMAX

Figures 7 and 8 relate us propulsive power with the auxiliary, the velocity and displacement of the Panamax container ships. In the first one the propulsion power series of vessels up to Panamax category and see that this ranges from 25.000 kW to 69.000 kW, and can be grouped into several groups being the first one that goes from 26.000 kW to 29.000 kW, 32.000 kW the second, the third and the largest having 36.000 kW, the fourth which ranges from 40.000 kW to 41.000 kW, 46.000 kW fifth, the sixth of 52.000 kW and the seventh of 69.000 kW.

This type of vessel has increased its capacity in terms of economies of scale and in turn speed that has led to its potency were to increase in an excessive manner which has resulted in high fuel consumption and consequently a high air pollution. The speed of the vessels is from 20 to 26 knots, with higher speeds using the 22, 23 and 24,5 knots. All these very high speeds, rather than cause further economic performance, with high fuel prices and the drop in the number of containers to be transported, causing a rise in costs and high pollution.

In regard to the relationship between the motive power and the displacement of these vessels have the first group having a propulsion power of between 26.000 and 32.000 kW for a displacement of 56.000 t, the second with a power of 36.000 kW displacement 67.000 t, the third to a power between 40.000 and 41.000 kW, a displacement of 87.000 t, fourth to 46.000 kW power a displacement of 87.000 t, the fifth group for a power of 52.000 kW a displacement of between 78.000 and 85.000 t, and the last group with a power of 69.000 kW a displacement of 85.000 t.

In the relationship between propulsion power and movement we can see that the driving power increases with the displacement up to vessels greater propulsion power but no major displacement and this is due to the high speed that has been given to this type of vessel.

The auxiliary power of these vessels ranging go from 1.000 kW to 4.500 kW, the average value is 2.000 kW and the propulsion power ratio of between 4% and 7.7%. Very moderate powers because these vessels do not possess ancillary services such as loading and unloading, among others, demanding a higher electrical power.

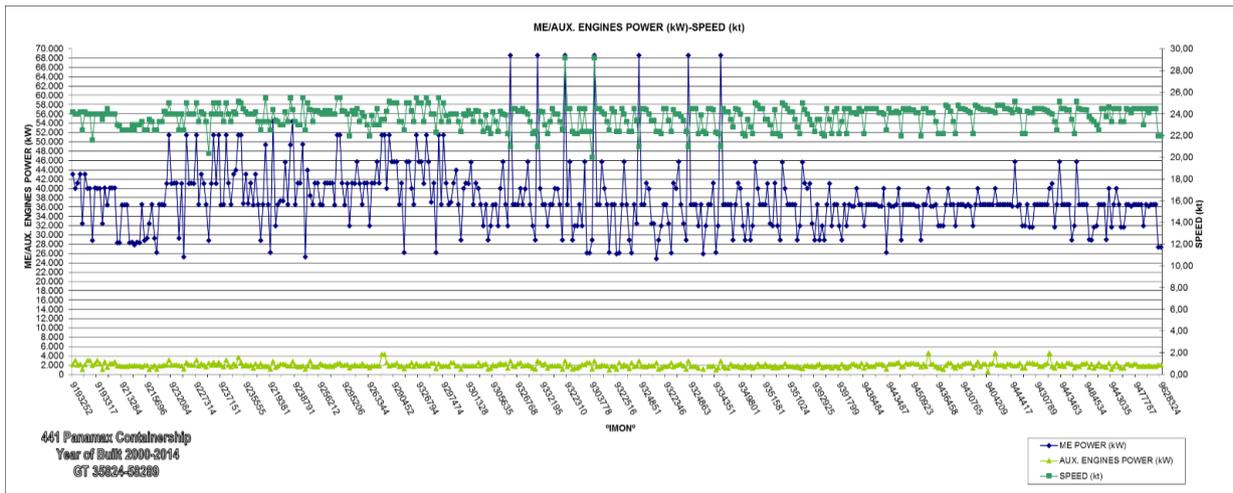


Figure 7

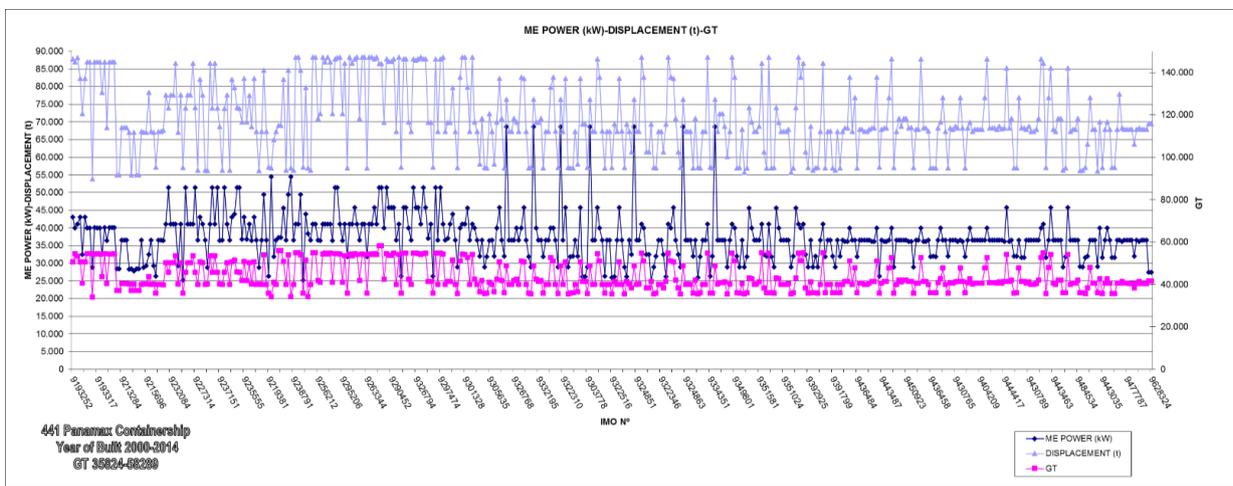


Figure 8

## 6. POST-PANAMAX

For Post- Panamax vessels propulsion power ranges from 27.000 kW to 77.000 kW and series that make up this type of vessels grouped them into seven groups: the first with a propulsion power of 42.000 kW, 45.000 kW the second , the third of 55.000 kW 58.000 kW fourth , the fifth and largest 62.000 kW and 77.000 kW last, a high power which are demanded due to the high speed of these vessels .

The speed of the Post-Panamax vessels ranging from 22 to 26.5 knots, the velocity of the increased use of 23 knots, all of which are also very high unnecessary for sustainable development.

If we relate the displacement and propulsion power, we need to propulsive power between 42.000 kW and 45.000 kW displacement is between 98.000 and 120.000 t, to power 55.000 kW and 58.000 kW displacement is between 105.000 and 125.000 t for the 62.000 kW power a displacement of 120.000 tons , the propulsion power of 68.000 kW a displacement of between 155.000 and 175.000 t, and to the power of 77.000 kW a displacement of 170.000 kW .

The auxiliary power of these vessels ranging from 2.000 kW to 7.000 kW, which is about the propulsion power of between 4.5 % to 7.1%, with a rate mean of 3.000 kW.

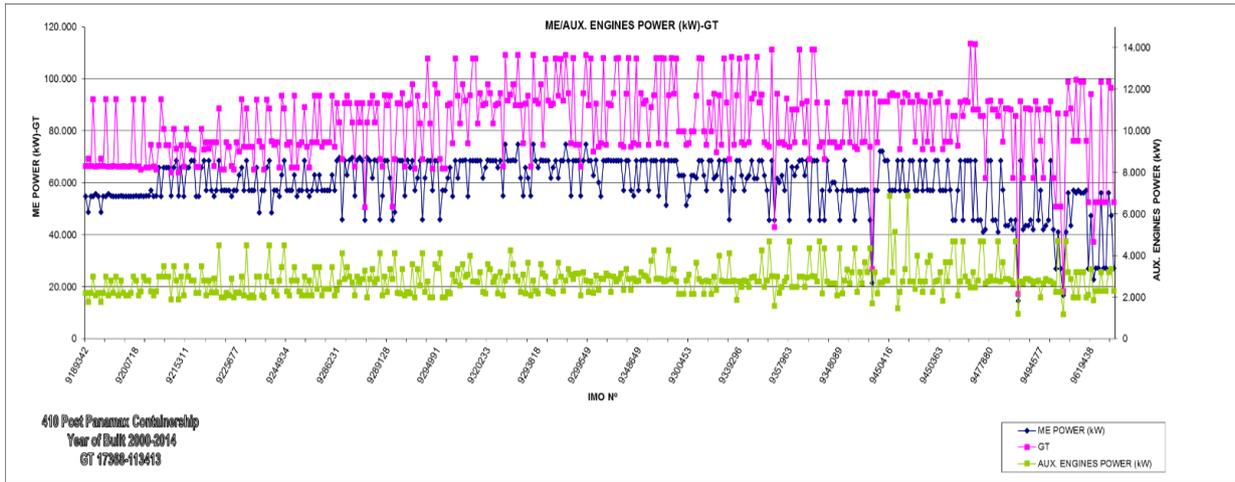


Figure 9

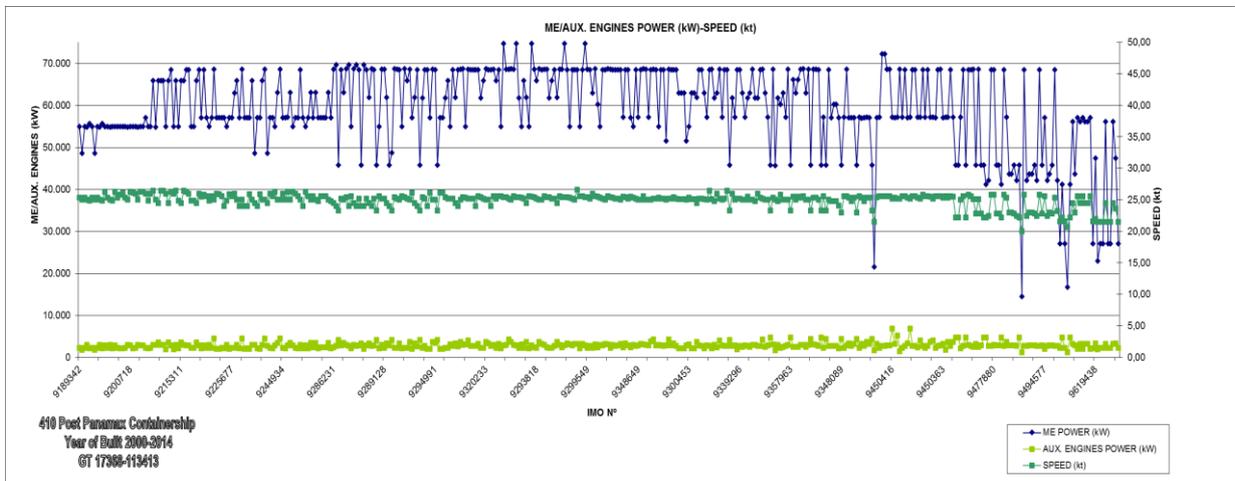


Figure 10

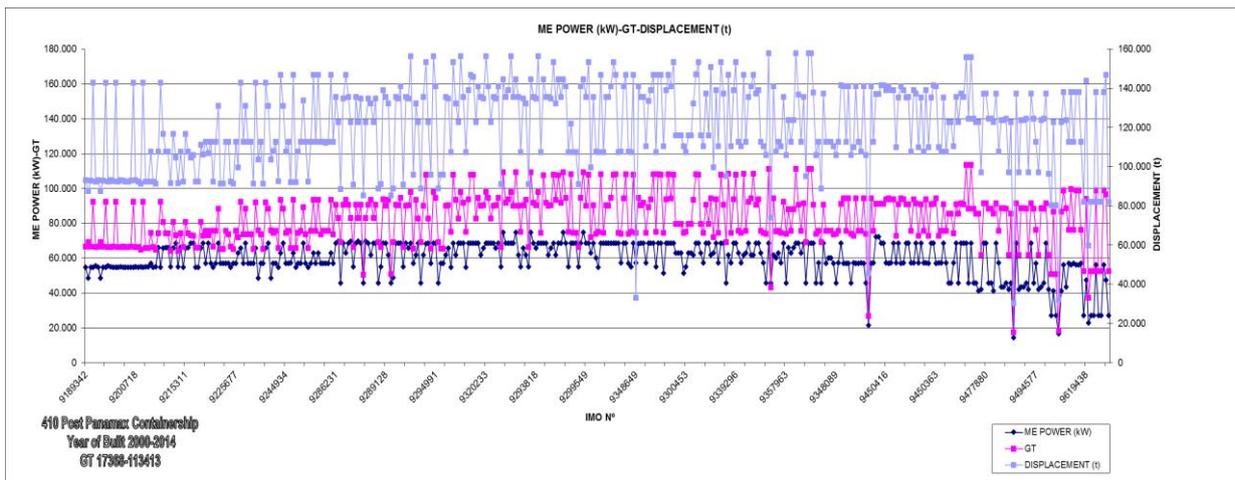


Figure 11

## 7. ULSC

Finally we have the Ultra Large Ship Containers ships having propulsion power between 58.000 kW and 80.000 kW, and grouped them into three series, the first one for the propulsion power of 62.000 kW, 72.000 kW the second and third 80.000 kW. All Propulsion power of which have qualified as those of previous vessels outrageously high.

The speed of these vessels ranges from 24 to 26 knots, been the most common of 25 knots.

The relationship between the propulsion power and displacement are set into a first group of propulsive power of 62.000 kW at a displacement of 110.000 to 120.000 t, the second with a power of 72.000 kW and a displacement of 125.000 t and the third to a power 80.000 kW and a displacement of 135.000 t.

The electrical power ranges from 2.200 kW to 6.000 kW, being between 3.2% and 5.3 % of the propulsion power, and with an average value of between 3.800 kW and 4.200 kW.

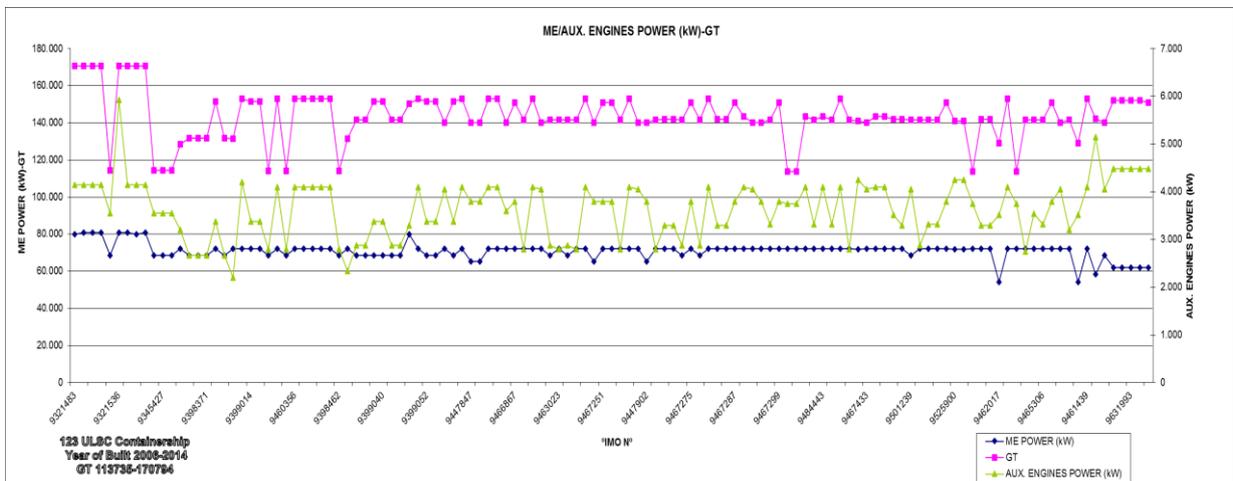


Figure 12

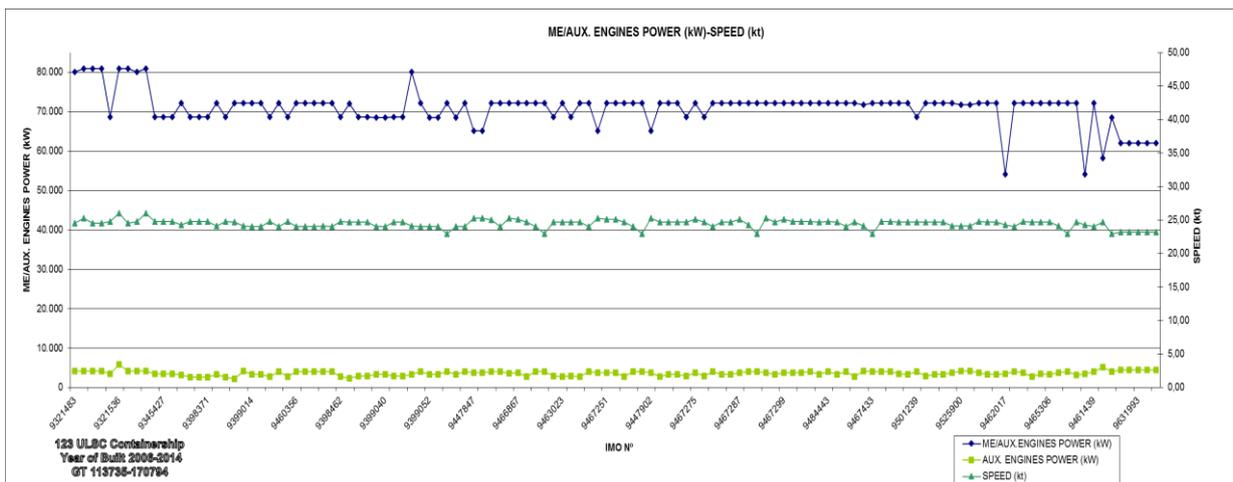


Figure 13

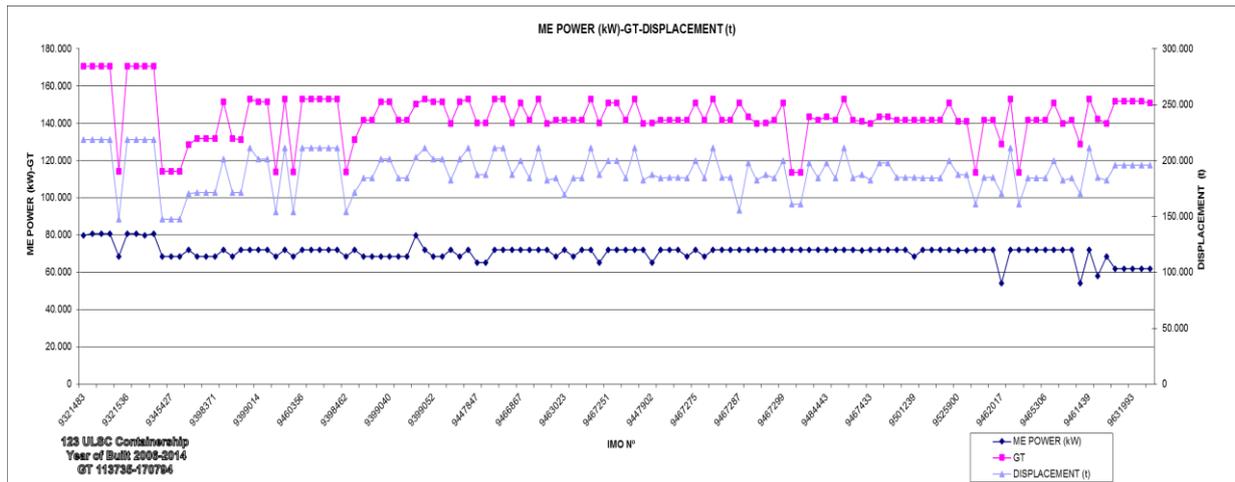


Figure 14

## 8. Efficiency Energy Operation Index EEOI

Has been carried out to calculate the energy efficiency operational index, EEOI, of each type of container ship considering a day of sailing at its maximum speed, the total number of containers that can transporter, fuel consumption at maximum power and engine auxiliaries of considering 50% of the installed auxiliary power and the values obtained are:

IMO N°	Feeder	Handy	SubPanamax	Panamax	PostPanamax	ULSC
EEOI	0,00036	0,00026	0,00022	0,00022	0,000155	0,0001078
tCO <sub>2</sub> /TEU NM						

Of course, these values are approximate, but very close to reality, and they can see that CO<sub>2</sub> pollution per TEU and nautical mile sailed is lower in larger container ships, but this is misleading, since it is due the economy of scale to be increasing the number of containers and reduce the cost of transporting them, but if we were to reduce the speed of these vessels between 2 and 4 knots, EEOI would be substantially reduced and the operation of the vessel would remain almost at the same level, and at the same time would reduce greenhouse gases.

## 9. Conclusions

Container ships are characterized by being designed to operate in general terms, as a ship with high speed.

The high speeds at which these vessels operate, and fundamentally the cause larger potencies of these are excessively high, because going from 20 knots of speed, propulsion power is increased exponentially to fourth power.

The high power to that sail these ships, the daily fuel consumption is higher than 300 t, representing a daily air pollution exceeding 1000 t CO<sub>2</sub>.

Although there is a certain parallelism between propulsion power and displacement, this is broken by increasing the rate of one or two knots.

The auxiliary electrical power of this type of vessel is medium size because, in general, have no means of loading and unloading

The experience and the current economic crisis has shown that the oversized power of these vessels due to its high speed, has been a serious error of design and planning of the operation of the vessel, causing the de-rating of the propulsion engines to reduce power and breakdowns.

Powers and speeds show, generally speaking, good correspondence between them. There are isolated cases that show big variations with very high main and auxiliary power that can be due to severe operation conditions.

In many instances, main and auxiliary powers are oversized and this can be explained for different reasons like a lack of detailed study for each ship and submission to the conditions of the yard or the engine builder. There are yards that generally install oversized powers.

The relationship between main power and electric power varies of the following way:

	Feeder	Handy	SubPanamax	Panamax	Postpanamax	ULSC
MAIN ENGINE (kW)	1800-9500	6000-21700	13500-32000	25000-69000	27000-77000	58000-80000
AUX. ENGINE (kW)	300-2500	500-2000	1000-2500	1000-4500	2000-7000	2200-6000

It is the possibility to adjust main and auxiliary powers to a minimum values in order to have a substantial fuel saving and, thus, of greenhouse gases.

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