Waste Heat Recovery Systems: Reducing Shipping Carbon Emissions under Real Operative Conditions

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Background

Shipping contributes in 3.3% of the total CO_2 emissions, it is the transport mode with the highest growth. If nothing is done now, by 2050 the shipping CO_2 emissions could grow up to 400% compared with 2007 levels.

The International Maritime Organization (IMO) created the Energy Efficiency Design Index (EEDI)- applied only to new ships- to measure and control shipping CO_2 emissions. As can be observed in figure 1, as time increases the CO_2 emissions reference line (red line) is reduced.

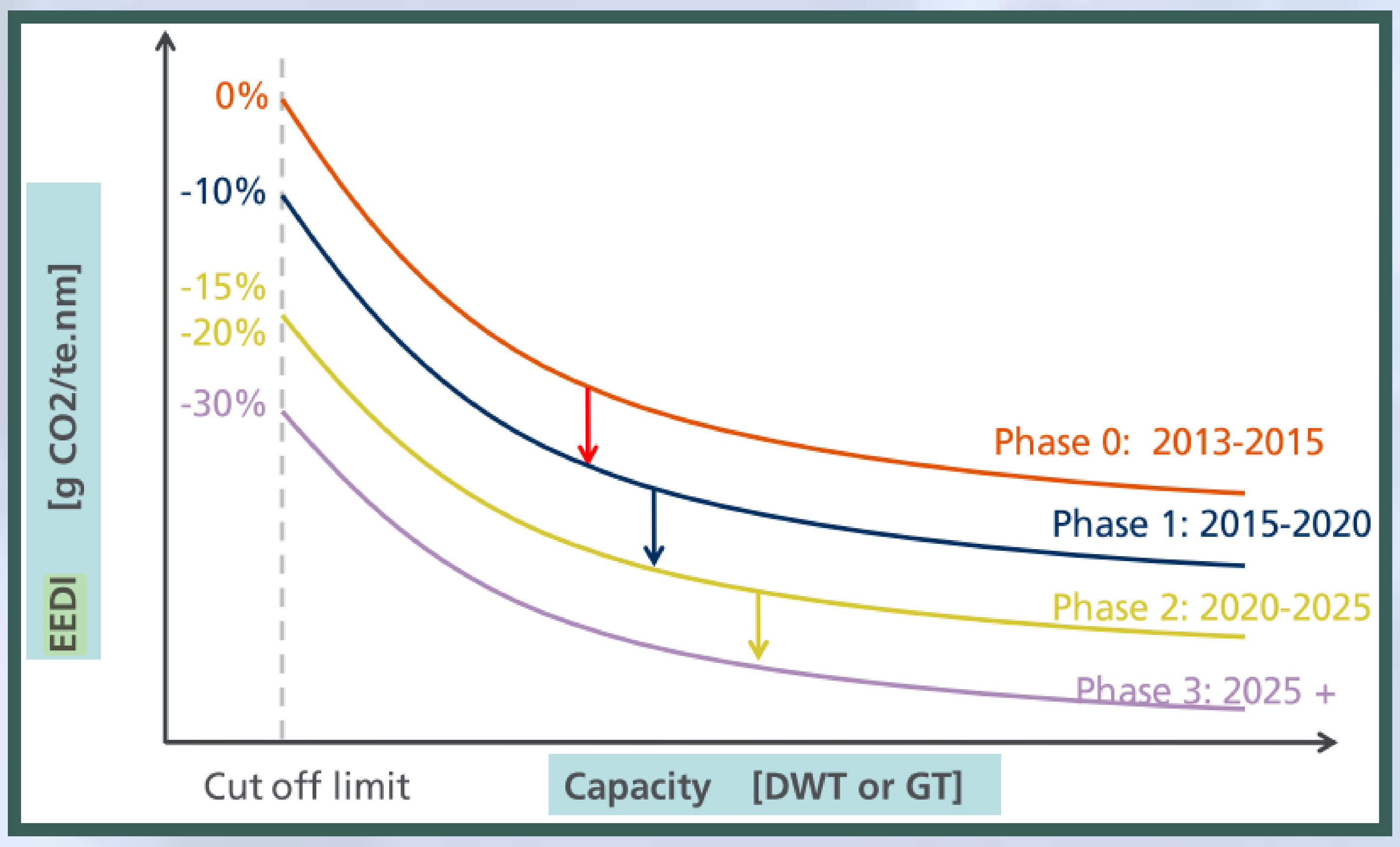

Figure 1.- EEDI versus the ship's capacity. DWT: Dead Weight Tonnage, GT: Gross Tonnage [1].

It is therefore that green and intelligent solutions, need to be created and assessed. The aim of this research project is to increase ship's efficiency using the low/medium temperature waste heat available from the ship engine's exhaust gas, cooling water and scavenge air, reducing CO_2 emissions in new ships.

Efficiency will be achieved using thermodynamic Waste Heat Recovery Systems (WHRS). This represents a greater challenge than in land based plants: 1) changing operative conditions (i.e. variable engine loading depending in the voyage strategy), 2) ambient conditions (i.e. ocean and air temperature) and 3) size and weight constraints.

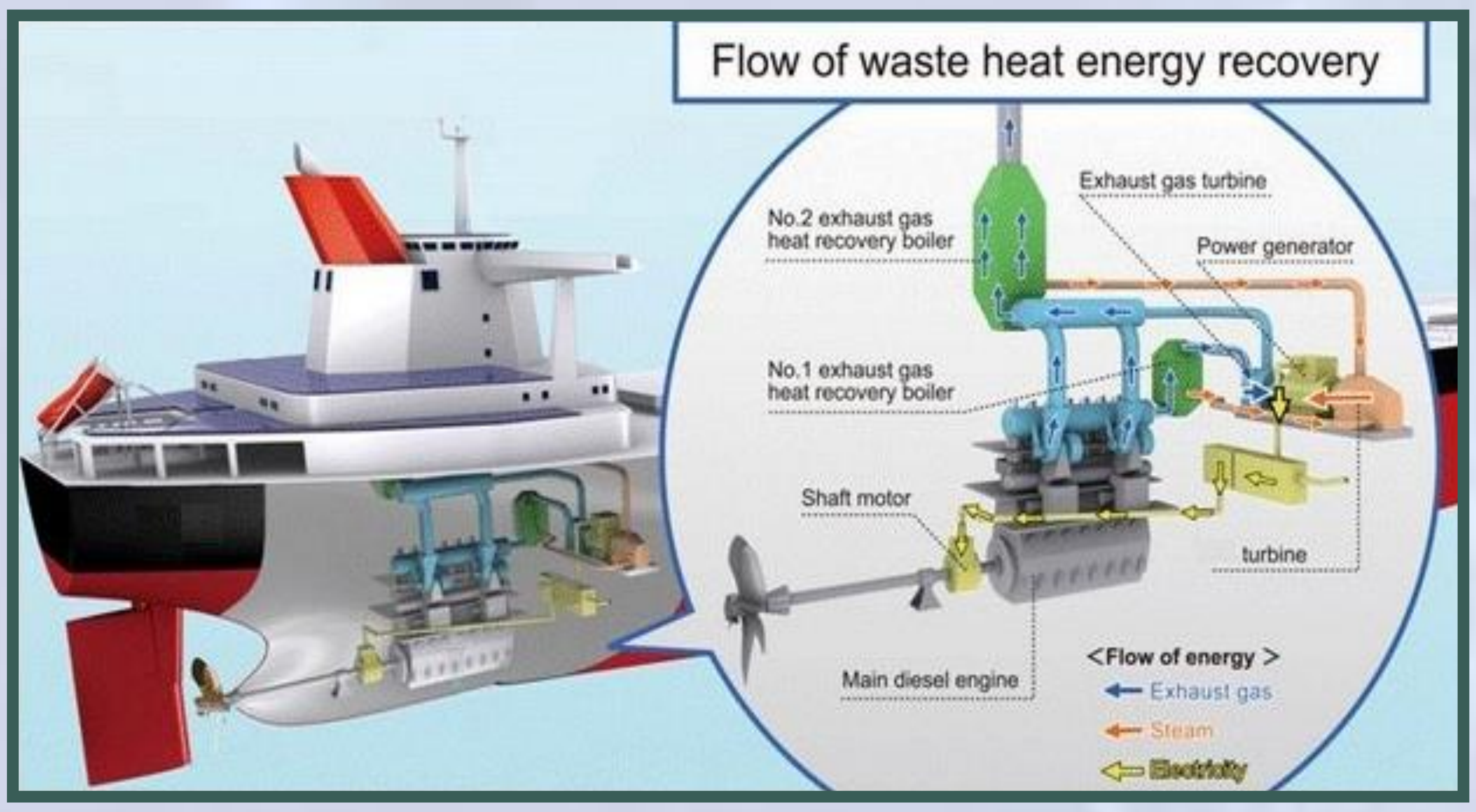

Figure 2.- Ship WHRS schematic with its energy flow [2].

Previous efforts have been done by MAN and Wärtsilä. The companies manufacture ship's WHRS based in a water Rankine cycle (RC). However, as ship engines efficiencies increase, and other green house gases reduction technologies come into play, the availability and quality of waste heat is reduced, making harder for the water RC WHRS to operate at a good thermal efficiency level. Does other WHRS offer a better option?

Methods

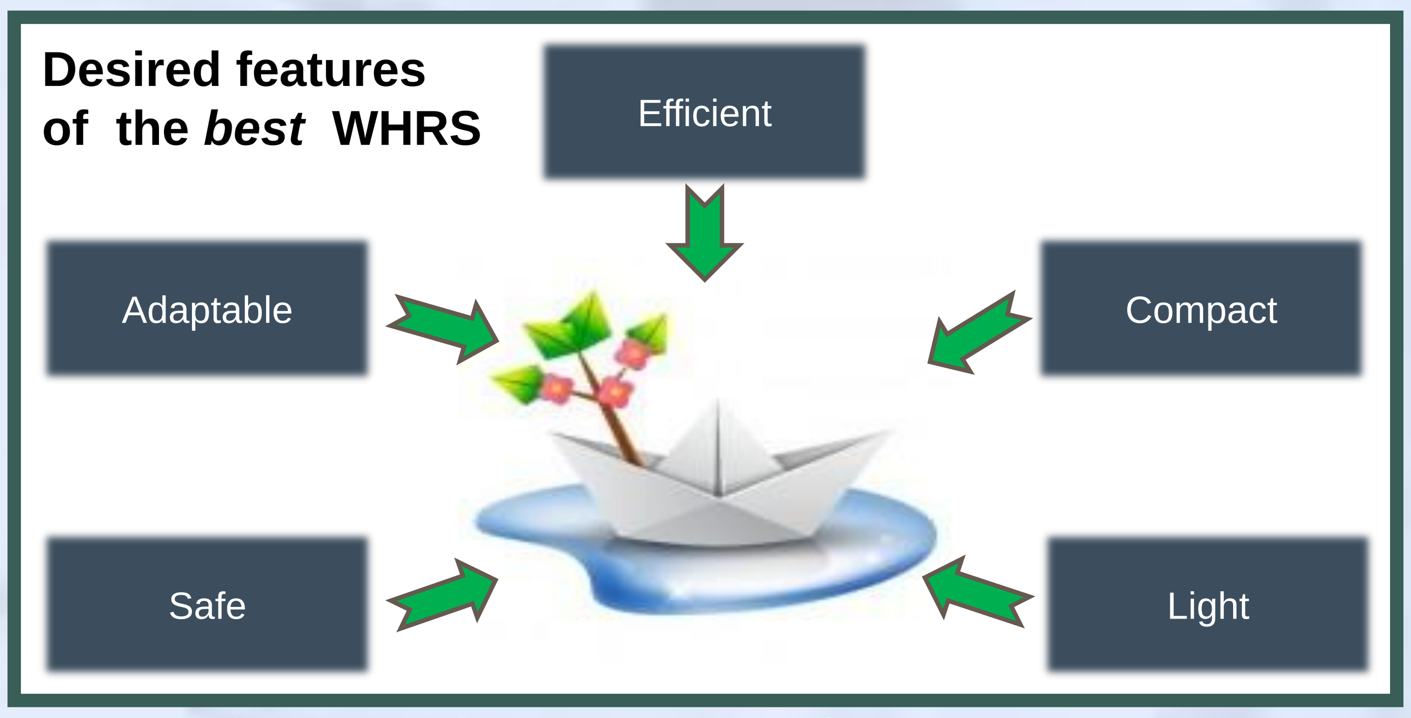

Figure 3.- Ship's WHRS has to be safe, delivering high performance at different voyage conditions while being compact and light.

This research explores organic Rankine (ORC), Kalina (KC) and Stirling (SC) cycles under realistic ship operating conditions. Previous comparisons have been made for land based systems but application into shipping environment has not been yet explored.

From the literature review a qualitative comparison tells which WHRS is not attractive for vessel operation. A quantitative simulation using Matlab and based on the laws of thermodynamics and pinch point analysis will detect the characteristics and performance of different WHRS. Finally, It will be possible to determine which WHRS is the *best* option for reducing CO_2 emissions in different kind of ships.

Preliminary Results

The qualitative analysis compared different cycles against the water based RC. It assessed important WHRS characteristics for shipping: size and thermal efficiency, among others. ORC systems performed better overall, while KC presents attractive characteristics such as adaptability and high thermal performance. Size and cost ruled out the SC.

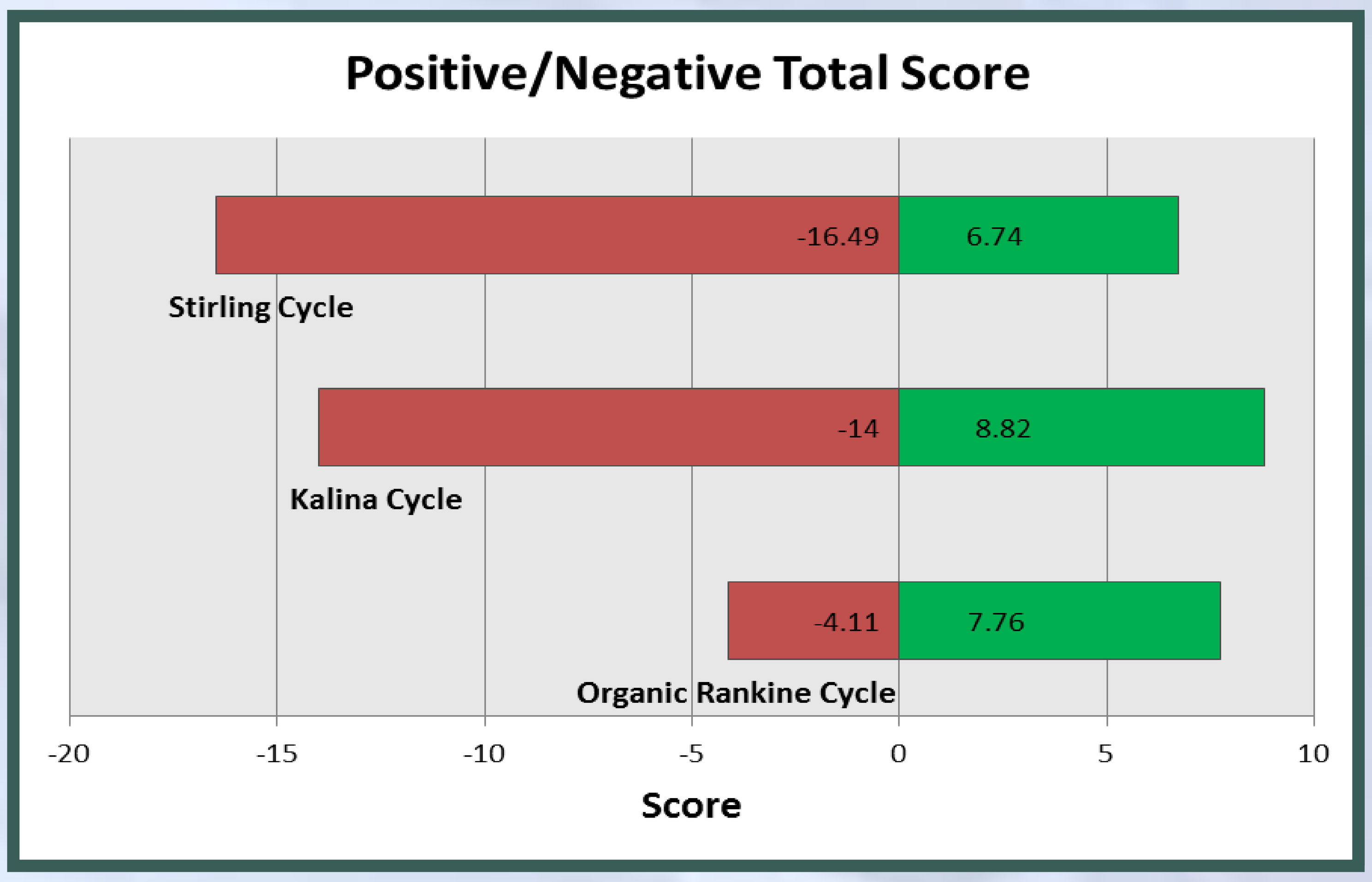

Figure 4.- Qualitative results from literature review. Positive scores (green) mean that the WHRS performed better than a RC.

Conclusions

Preliminary analysis suggest that alternative WHRS do offer attractive and better characteristics for shipping than the traditional water based RC. Results obtained from the qualitative comparison show that ORC, followed by the KC are interesting candidates to outperform the RC in the construction of greener shipping. These results will be tested against computational simulations in future stages of the research project.

References

1. Lloyd's Register. Implementing the Energy Efficiency Design Index (EEDI). Lloyd's Register; 2012.
2. Mitsui O.S.K. Lines, Ltd. MOL Completes Concept for Series of New Generation Vessels; 2010. http://www.molhk.com/news/detail/122

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