MARINE ENVIRONMENT PROTECTION COMMITTEE
69th session
Agenda item 5

MEPC 69/INF.8
14 January 2016
ENGLISH ONLY

AIR POLLUTION AND ENERGY EFFICIENCY

The implementation of technical energy efficiency measures in shipping

Submitted by the Institute of Marine Engineering, Science and Technology (IMarEST) and the Royal Institution of Naval Architects (RINA)

SUMMARY

Executive summary:	This document focuses on the implementation of technical energy efficiency measures. The data are derived from a cross-sectional survey of 275 shipowners and operators covering around 5,000 ships. This is an important undertaking given that very little data exists on the take-up of energy efficiency technologies for both, newly built and existing ships. The main conclusions of this document are set out below.
Strategic direction:	13
High-level action:	13.0.3
Output:	13.0.3.1
Action to be taken:	Paragraph 5
Related documents:	MEPC 67/INF.4 and MEPC 68/INF.13

Background

1 The Institute of Marine Engineering, Science and Technology (IMarEST), in collaboration with the Royal Institution of Naval Architects (RINA) and the University College London (UCL) working as part of the Shipping in Changing Climates (SCC) project, funded by the Research Councils UK (RCUK), produced this document which focuses on the implementation of technical energy efficiency measures. The data are derived from a cross-sectional survey of 275 shipowners and operators covering around 5,000 ships.

2 The annex to this document provides information on the implementation of four categories of energy efficiency technologies mainly for bulk carriers, tankers and containerships.

Cross-sectional survey

3 A survey of 275 shipowners and operators, in total representing almost 20% (5,000 ships) of the wetbulk, drybulk and container fleet, was conducted to assess the implementation of design related measures, hydrodynamic measures, machinery measures and alternative fuels for both existing ships (retrofits) and new ships. A stratified sampling strategy is used to fairly represent the shipping sector by ship types, size of companies and regions. The survey data has been further broken down by ship sizes and whether they have been implemented on new ships and/or retrofits. The results have been presented in a publicly available report.

Survey results

4 For design related technologies, the use of bulbous bows (and their reconfiguration) had the highest implementation amongst all the design measures. The use of pre/post swirl devices had the highest implementation amongst the hydrodynamic measures. For machinery measures, a larger range of options were being implemented compared to other types of technology. Engine tuning and engine derating as well as waste heat recovery are being widely implemented. Design speeds are being reduced by reducing engine output power. The current use of alternative fuels and renewable energy sources is low.

Action requested of the Committee

5 The Committee is invited to note the information provided in this document and to take action as appropriate.

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ANNEX

THE IMPLEMENTATION OF TECHNICAL ENERGY EFFICIENCY MEASURES IN SHIPPING

1 Introduction

1.1 Shipping in Changing Climates

The Shipping in Changing Climates (SCC) project, funded by Research Councils UK (RCUK), connects the latest climate change science with knowledge, understanding and models of the shipping sector in a whole systems approach. It seeks to explore the potential to improve energy efficiency through the use of technical and operational changes in shipping and to understand how the sector might be able to transition to a more resilient and low-carbon future; it also seeks to explore different climate change scenarios and related food and fuel security issues to gain an understanding of the direct and indirect impacts of climate change on the shipping sector. These scenarios can be used to build evidence and understanding around the range of potential future directions that the shipping industry may take.

The project brings together researchers from the universities of University College London (Energy Institute, Mechanical Engineering and Law dept.), Manchester, Southampton, Newcastle and Strathclyde Universities, in close collaboration with a core industry stakeholder group of Shell International Trading and Shipping, Lloyd's Register, Rolls Royce, British Maritime Technology and Maritime Strategies International, but drawing on the expertise and connections of over 35 companies and organisations worldwide. This paper represents the collective opinions of the authors and should not be assumed to represent the views of all the researchers across the project or the project's industry partners and their organisations.

1.2 Context and objective of this paper

The results presented in this paper are from a cross-sectional survey that aimed to assess the degree to which technical energy efficiency measures have been implemented. The data generated will be used to create or calibrate the baseline for GloTraM[1], a holistic model to better understand the shipping system including the relationship between its principal components, transport logistics and ship design. They therefore also serve as an important validation for the algorithms in the modelling of longer term scenarios around technology uptake.

Various attempts have been made to assess the uptake of technical energy efficiency measures (HSH Nordbank 2013; Rojon & Smith 2014; DNV GL 2014; IMarEST & Colfax 2015) and the uptake of operational measures (Rehmatulla 2012; Rehmatulla 2014). However, this study goes further than a general assessment of the implementation of technical energy efficiency measures since it assesses the uptake at the ship level (e.g. by ship type, ship size and number of ships), at the company level (e.g. type of company and size of company) and across regions, thus producing a more accurate picture of the take-up of energy efficiency measures in shipping. More details of the survey and complementary analysis can be found in Rehmatulla (2015).

[1] https://www.ucl.ac.uk/energy-models/models/glotram.

The survey was conducted between January 2015 and March 2015, which was a period of regulatory and economic changes. The new IMO regulations on sulphur emissions were effective from January 2015, requiring a reduction on marine fuel sulphur content from 1.00% to 0.10% in the Emission Control Areas (ECAs) (see Figure 1) or adopting alternative solutions that achieve an equivalent effect. The effect of this regulation could be that shipping companies that operate in ECAs could prioritise their investment and ration capital to meet the mandatory regulations over voluntary operational energy efficiency investments from retrofits as suggested by some survey respondents. The IMO Energy Efficiency Design Index (EEDI) Phase 1 (2015 -2019) also took effect in January 2015, requiring a 10% reduction in EEDI relative to the EEDI reference line for each ship type and size category. This can potentially introduce a bias on the implementation of energy efficiency measures for new ships over existing ships. Finally, the HFO fuel price dipped to its lowest during the beginning of the year (Figure 2), which has the effect of increasing the payback period of various energy efficiency technologies and therefore potentially affecting the investment decisions of firms considering their implementation at the design stage or for retrofitting.

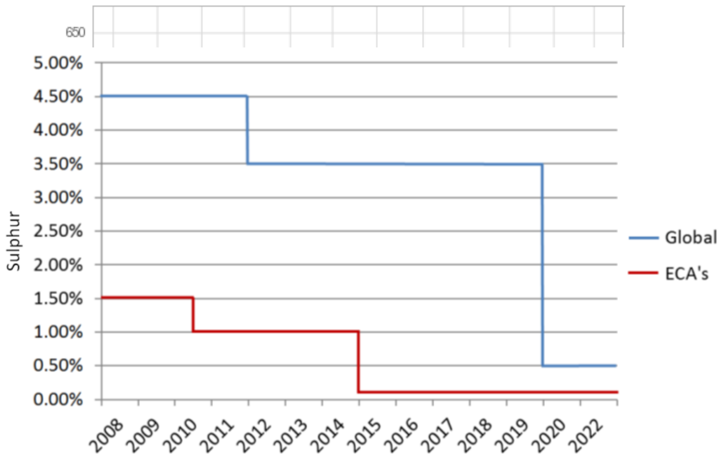

Figure 1: ECA regulations

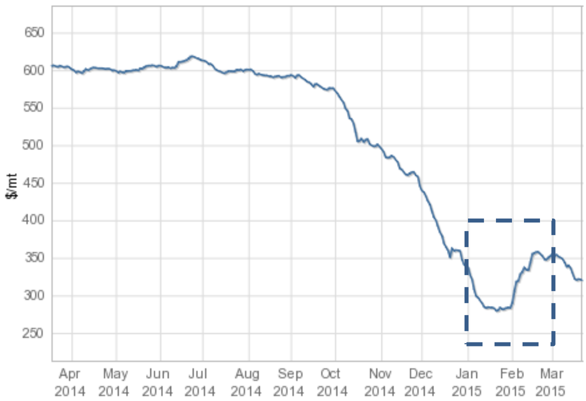

Figure 2: HFO fuel price trend. Source: Bunkerworld

1.3 Sampling frame

The purpose of this section is to show how fairly the shipping industry has been represented by the survey. In order to be representative, the study mainly uses a stratified sampling approach, complemented by a non-random sampling approach (e.g. memberships of associations). A list of all shipping companies globally was acquired from Clarksons Shipping Information Network and this was stratified according to the company's size, its sector of operation and geographical location. This study focusses on the tanker (wetbulk), drybulk and container sector. Table 1 shows the target population i.e. number of firms which operated in each sector and size of ships which they operate, broken down by their geographical location (by headquarters).

Large firms (with fifty ships and above) represent only 5% of the population (just over 100 companies) but control almost 33% of the fleet. Similarly, medium size firms (between eleven and forty nine ships) represent around 20% of the population (around 500 companies) but control almost 33% of the fleet. Small size firms (10 ships and under) represent almost 75% of the population (just under 2000 companies) and control 33% of the fleet (Stopford 2009). Therefore for the large organisations (118 companies) and medium sized companies (482 companies) the census approach was taken i.e. all the companies were included in the sample, called a census tracts approach. For the remaining 2000 small firms a simple random sampling was used as shown in Figure 3.

Table1: Sampling frame

Sector	Size	Europe	N & S America	Asia	Far East	Total
Large	Wetbulk	9	6	2	10	27
Large	Drybulk	4	3	1	10	18
Large	Container	13	0	0	11	24
Large	Mixed	23	1	4	21	49
Medium	Wetbulk	88	6	14	33	141
Medium	Drybulk	75	11	6	49	141
Medium	Container	37	4	2	14	57
Medium	Mixed	80	1	8	54	143
Small	Wetbulk					942
Small	Drybulk					685
Small	Container					146
Small	Mixed					163

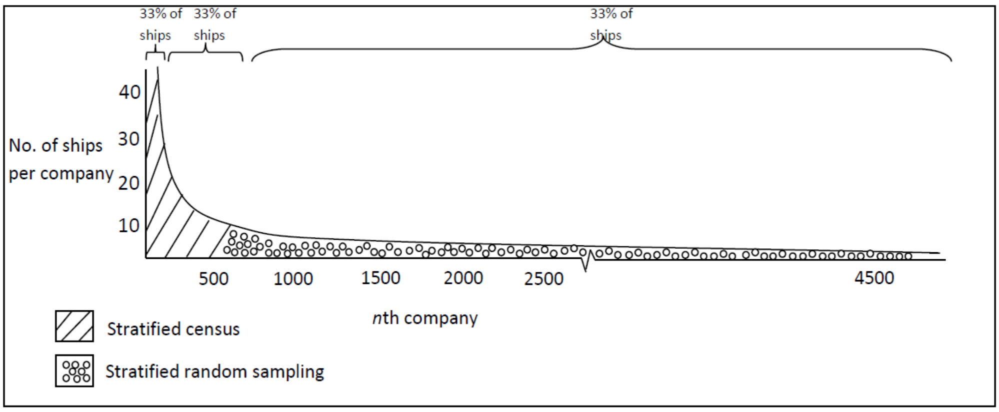

Figure 3: Population frame and sampling strategy

1.4 Respondent demographics

270 companies were contacted by phone and 199 companies (72%) responded. Further 76 responses were received from various other sources e.g. membership databases and third party mailing lists. Thus in total, the survey received 275 responses representing almost 5,000 ships (20% by number of ships) of the wetbulk, drybulk and container fleet (28,000 ships according to Third IMO GHG Study).

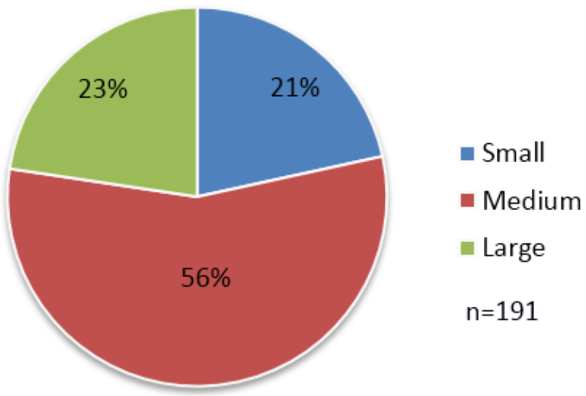

Figure 4: Respondents by fleet size[2]

Figure 4 shows the distribution of companies that responded by their size (the sample size may vary per question due to missing responses for the demographic questions). Compared to the data shown in section 1.3, the responses for large and medium size companies are over-represented in the sample. However, the increased focus on the large and medium sized companies results in higher number of ships being covered. In business surveys this strategy is common due to the difficulty in reaching small companies (Eurostat 2008).

The following demographic questions asked the respondents to identify the fleet they operate and which company types would best describe their company structure. The questions did not have mutually exclusive choices i.e. had multiple response data. Figure 5 shows that the majority of the respondents were mainly from the sectors that were of interest for this survey, i.e. tanker, drybulk and container sectors.
Figure 6 shows the majority of the respondents to the survey were shipowners, shipowner-operators and management companies. The survey also had responses from charterers that have ships on long-term time charter and companies that own a shipping fleet to move their own cargoes. Over half of the respondents were from senior level management consisting of technical directors, technical managers and fleet managers. They were followed by technical superintendents (including senior superintendents), sustainability or energy efficiency managers and project managers. Figure 7 shows the geographical dispersion of the respondents. The majority of the responses were from companies headquartered in the EU, mainly in Greece and Germany.

[2] Although in total 275 responses were received, the number of respondents may vary per question due to missing responses, especially for the demographic questions at the end of the survey.

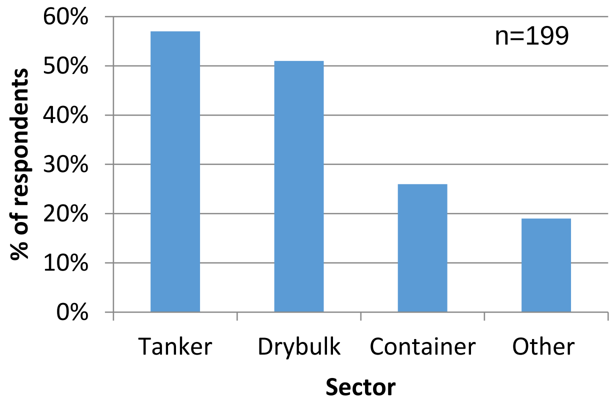

Figure 5: Respondents by sector[3]

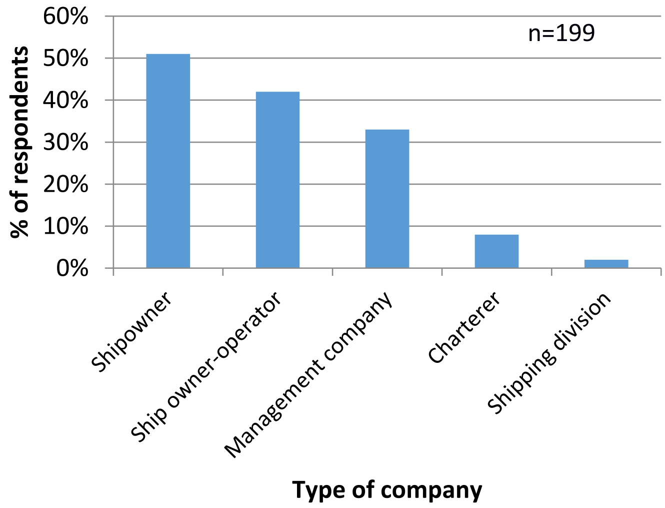

Figure 6: Respondents by type of shipping company

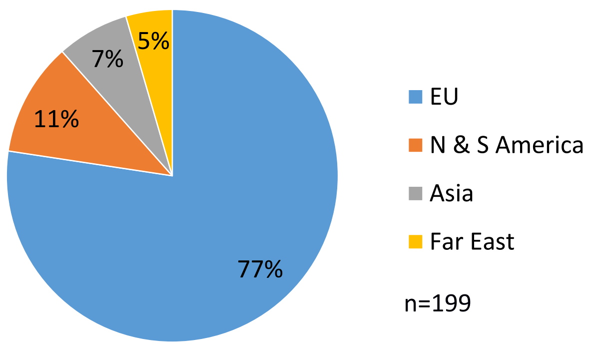

Figure 7: Geographical distribution of survey respondents

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3 The data presented in Figure 5 and 6 did not have mutually exclusive choices i.e. had multiple response data.

2 Energy efficiency technologies

This section provides a brief analysis of the results, grouped by the different types of technologies available to improve energy efficiency. Forty four measures were included in the survey and grouped in the following categories[4]:

- Design
- Hydrodynamic
- Machinery
- Alternative energy

The Y axes of figures 8, 9, 10 and 11 show the total number of ships in which these measures have been implemented by the sampled respondents. This is given as a range (max and min) because the survey question contained categorical variables such as 1-5 ships, 6-10 ships, etc. to minimise respondent burden.

2.1 Design technologies

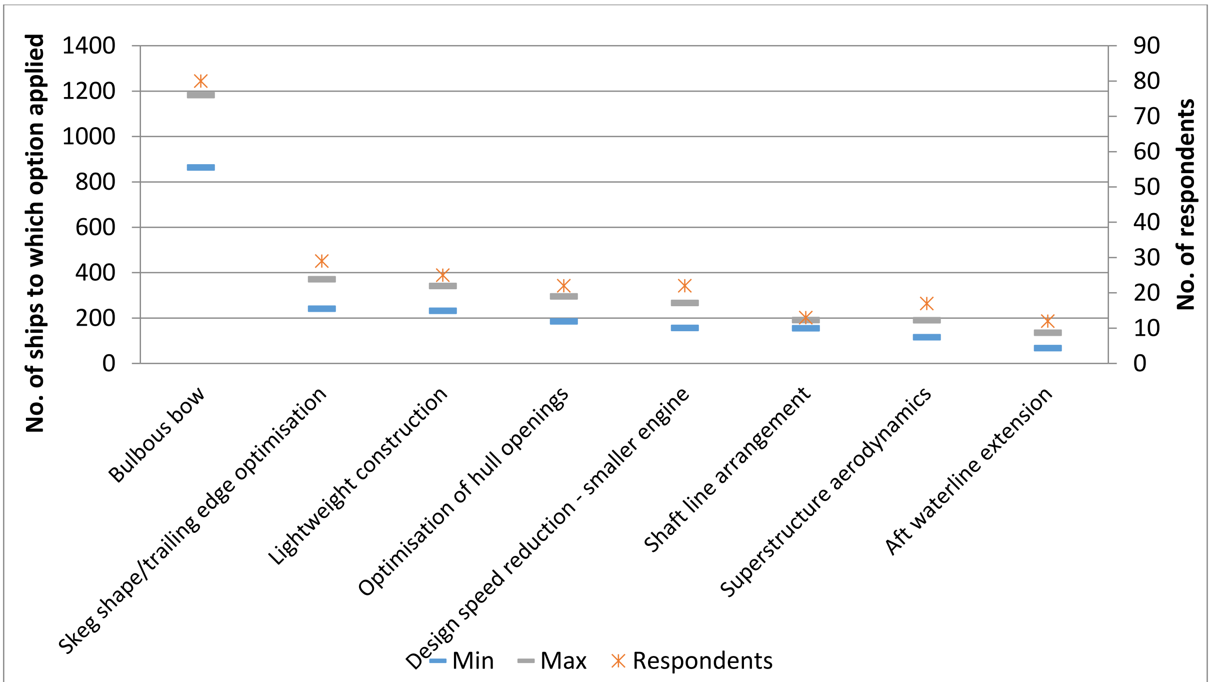

Figure 8: Implementation of design technologies

The use of bulbous bows is widespread, however the way in which they can impact fuel consumption can be complex. The change in a ship's resistance caused by the bulbous bow depends both on the form and size of the bulb and on the form and speed of the ship (Bertram & Schneekluth 1998). Bulbous bows need to be considered carefully with speed and draught. At low speeds the increased area of the wetted surface due to a bulbous bow increases the frictional resistance, which is usually greater than the reduction in residual resistance, resulting in an increase in total resistance (Bertram & Schneekluth 1998). This may mean that in some cases, particularly for ships that operate at lower Froude numbers, there may be a benefit in not having a bulbous bow (Calleya 2014).

4 The survey also included maintenance measures/strategies (including hull paint technologies) and after-treatment measures which are not presented in this submission.

2.2 Hydrodynamic technologies

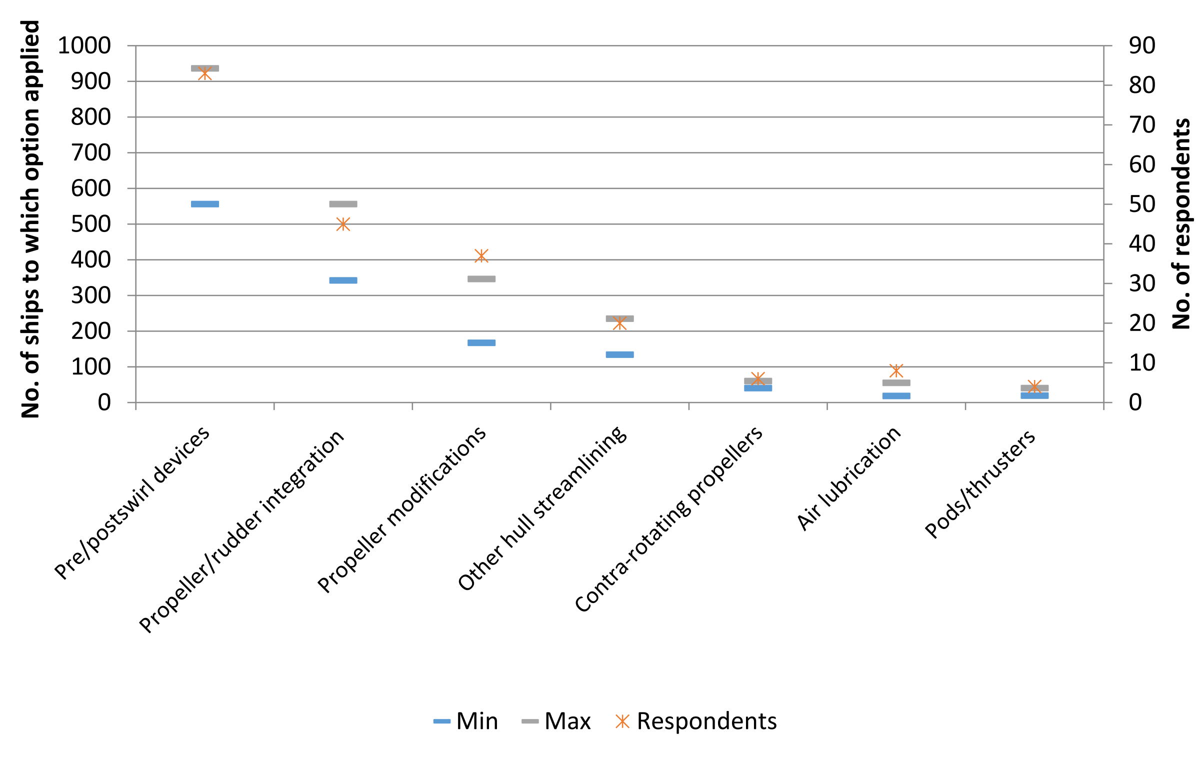

Figure 9: Implementation of hydrodynamic technologies

The adoption of pre/post-swirl devices (which included boss cap fin, vane wheel, presswork ducts, Mewis duct and stator fins), had the highest implementation compared to other hydrodynamic measures available. Further analysis of the data (presented in Rehmatulla 2015) shows that the high implementation is as a result of a relatively higher ratio of retrofits to newbuilds when compared to other measures. As with design measures, the effectiveness of these devices is dependent on the particular ship that is being used. For example, a ship with a bad aft-end could be easier to improve. Benefits from pre/post-swirl devices, that could increase the propulsive efficiency, possibly by improving the flow of water into the propeller, should outweigh the increase in wetted surface area that increases the frictional resistance of the ship.

2.3 Machinery technologies

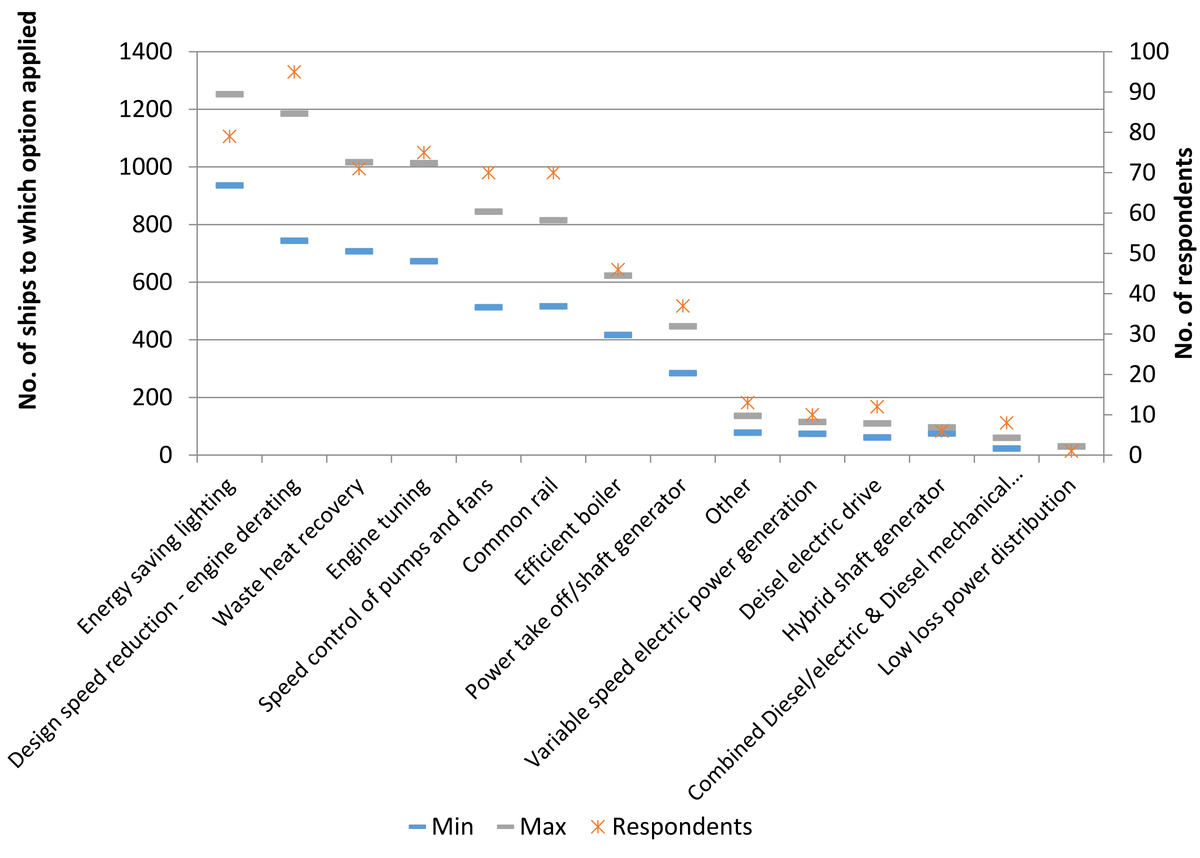

Figure 10: Implementation of machinery technologies

In contrast to Figure 8 and Figure 9, the machinery measures (Figure 10) shows that there are several measures that have been widely adopted by the respondents. The reduction in fuel consumption from energy-saving lighting on a ship is likely to be very small (less than 1%) but it is easily implemented and it is a mature technology. The reduction in fuel consumption through the use of waste heat recovery over an operating profile can be small, but it is widely used. The effectiveness of some of the machinery measures can depend on the operating profile of the ship that is being considered. For example, diesel electric drive is less likely to be used on some cargo trades where ships operate at a narrow band of speeds.

Speed reduction through engine derating and engine tuning are popular strategies to reduce fuel consumption. The survey contained options for fitting 'design speed reduction - smaller engines' (Section 2.1) and 'design speed reduction – engine derating' but the majority of the respondents selected the latter option which suggests that the respondents are using derated engines when considering changes in design speed. Derated engines, although relatively expensive, are being implemented probably because they have lower SFCs.

The second IMO GHG study (Buhaug et al. 2009) explains how derating and engine upgrades can be used to potentially reduce an engine's Specific Fuel Oil Consumption by approximately 4.3% and up to 3%, respectively. Engine upgrades are normally applied as part of a package that includes changes in the turbo charger, pistons and pumps (Buhaug et al. 2009). Any substantial changes to the engine, as mentioned above, for new or existing ships have to meet NO_X requirements and will have to have their EEDI verified.

2.4 Alternative energy sources

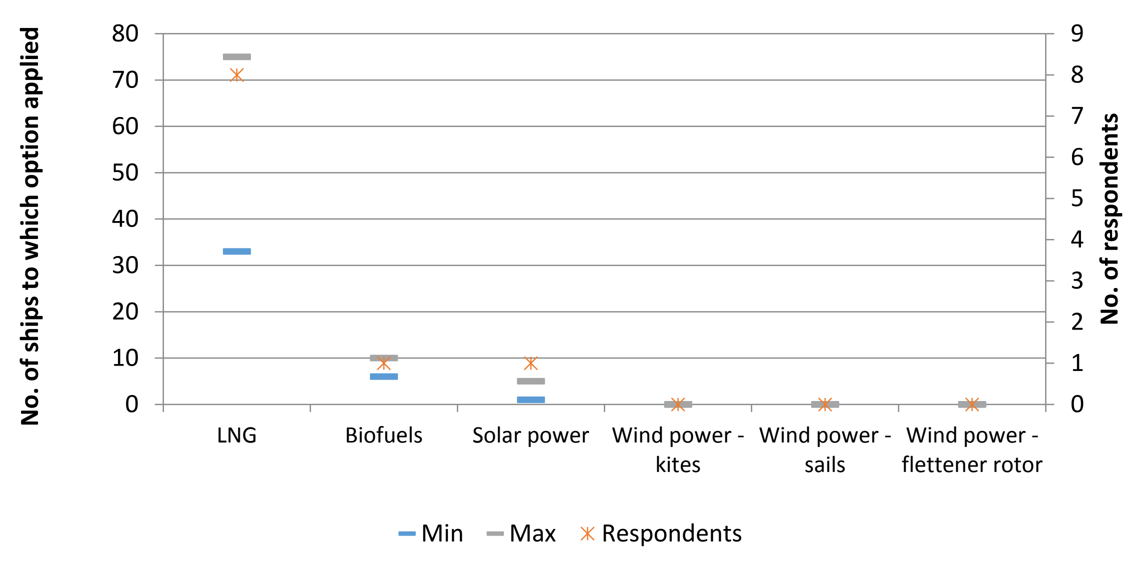

Figure 11: Implementation of alternative sources of energy

A small number of ships are using LNG and a very small number of ships are using biofuels and solar power. The reduction in fuel consumption from using solar power for propulsion could be up to 3.7% depending on the ship (Calleya, 2014), though the higher savings in this area are unlikely to be cost effective. Wind assisted propulsion has much potential to reduce fuel consumption (or possibly allow a ship with a given EEDI to increase its speed), however these technologies have not been adopted by any ships covered by the survey due to the technical risks involved, the costs and informational problems (Rehmatulla et al. In Press).

3 Conclusions

Generally, the uptake of energy efficiency technologies is low and the technologies that have higher uptake have small energy efficiency gains at the ship level. Some of the findings may be obvious but the survey has helped to confirm some preconceptions, the main findings are:

- Bulbous bows are widely used.
- Pre/post-swirl devices are being widely adopted.
- Engine tuning and engine derating are being widely adopted.
- Design speeds are being reduced by reducing engine output power.
- Waste heat recovery is widely used.
- There is no use of wind energy amongst the survey sample, which has a large potential increase in energy efficiency and a reduction in EEDI.

4 References

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