

UCL ENERGY  
INSTITUTE



Assessing the implementation  
of technical energy efficiency  
measures in shipping

Survey Report

Dr Nishatabbas Rehmatulla

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- Greek Shipping Co-operation Committee
- Sustainable Shipping Initiative

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## MARITIME TRANSPORT RESEARCH AT THE UCL ENERGY INSTITUTE

The shipping research group at UCL Energy Institute consists of fifteen researchers and PhD students, involved in a number of on-going projects, including the Research Council UK Energy funded Shipping in Changing Climates (~£4m) and Energy Technologies Institute (ETI) funded Heavy Duty Vehicles programme (~£2m). In addition, we work closely with industry and policy makers through a number of sponsorships and consultancy projects, including: IMO 3rd GHG Study, Shell, INTERTANKO, ISO, Lloyd's Register, WWF, European Bank of Reconstruction & Development, Carbon War Room, Sustainable Shipping Initiative, Institute for Sustainability, BMT and International Paint.

We undertake research both using models of the shipping system (GloTraM), shipping big data (including satellite Automatic Identification System data) and qualitative and social science analysis of the policy and commercial structure of the shipping system. All research activity is centred on understanding patterns of energy demand in shipping and how this knowledge can be applied to help shipping transition to a low carbon future.

## ABOUT UCL AND THE UCL ENERGY INSTITUTE

UCL is one of the UK's premier universities and is ranked in the world's top five. It is a world-class research and teaching institution based in London whose staff and former students have included twenty Nobel Prize winners. Founded in 1826, and now with an annual turnover exceeding £600 million, it is an inspiring university in which to work and study. UCL Energy Institute is a multidisciplinary institute with around 70 faculty and staff. It brings together multidisciplinary teams, providing critical mass and capacity for large projects. In particular, the UCL Energy Institute develops and undertakes research in the areas of energy-demand reduction and energy systems, to improve energy security and facilitate a transition to a low-carbon economy.

For inquiries about this study contact;  
Dr Nishatabbas Rehmatulla  
+44 203 108 5965  
UCL Energy Institute  
Central House  
14 Upper Woburn Place  
London  
WC1H 0NN

For more information visit our internet pages;  
[www.bartlett.ucl.ac.uk/energy/research](http://www.bartlett.ucl.ac.uk/energy/research)

## SHIPPING IN CHANGING CLIMATES

This study is part of the Shipping in Changing Climates (SCC), a multi-university, multi-disciplinary consortium of leading UK academic institutions and maritime stakeholders focused on addressing the interconnected research questions that arise from considering shipping's possible response over the next few decades due to changes in:

- Climate (sea level rise, storm frequency)
- Regulatory climate (mitigation and adaptation policy)
- Macroeconomic climate (increased trade, differing trade patterns, higher energy prices)



Building on RCUK Energy programme's substantial (~2.25m) investment in this area: Low Carbon Shipping and High Seas projects, this research provides crucial input into long-term strategic planning (commercial and policy) for shipping, in order to enable the sector to transition the next few decades with minimum disruption of the essential global services (trade, transport, economic growth, food and fuel security) that it provides.

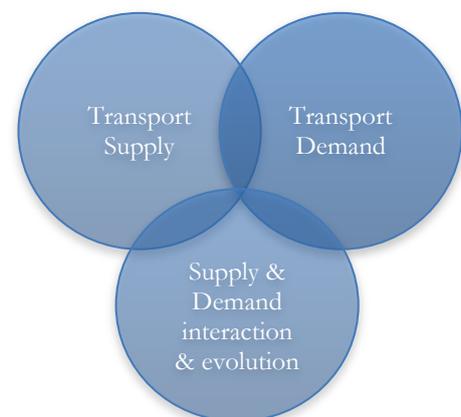
Shipping is a global industry and its challenges must therefore be considered in a global context. However, to provide focus, the research concentrates on the application of our global modelling and analysis for understanding the impacts of changing climates on three key specific sub-global components of the system: UK, SIDS (Small Island Developing States) and BRICS shipping. The UK, for its importance to the funder and the UK stakeholders engaged in our project, the BRICS and SIDS because of their central role in the policy debate due to their high sensitivity to changing climates

The research undertaken is both quantitative and qualitative, applies for the first time new data and modelling techniques through a series of cross cutting themes:

Theme 1: Understanding the scope for greater energy efficiency on the transport's supply side – the ship as a system.

Theme 2: Understanding demand side drivers and trends – trade and transport demand.

Theme 3: Understanding supply/demand interactions – transition and evolution of the shipping system



For more details visit: [www.lowcarbonshipping.co.uk](http://www.lowcarbonshipping.co.uk)

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## INTRODUCTION

### AIMS AND OBJECTIVES

This study aims to assess the implementation of technical energy efficiency measures in shipping that are used to improve energy efficiency, reduce emissions and respond to changing market conditions e.g. high fuel prices.

Currently there is good data available on which ships are slowing down and by how much (using Satellite Automatic Identification System S-AIS), as well as general survey responses on operational efficiency (Rehmatulla 2012). However, operational energy efficiency is only one aspect of efficiency and this research attempts to check whether this is in combination or separate from interventions with technology.

The data generated will be used to create or calibrate the baseline for the GloTraM<sup>1</sup> model, a holistic model to better understand the shipping system including the relationship between its principal components, transport logistics and ship design. It therefore also serves 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). This study goes further than the general level implementation of technical energy efficiency measures by assessing the implementation at a ship level (e.g. by ship type and ship size) and at the company level (e.g. type of company and size of company) thus enabling to build an accurate picture of the take-up of these measures.

This study forms part of a series of other methods for collecting data on implementation of technical energy efficiency measures, which include;

1. Individual shipowner case studies

2. Classification societies: data regarding newbuild designs/EEDI, approvals and installations of retrofits
3. Technology suppliers: data regarding sales and/or installations
4. Shipyards & ship repair yards: data on retrofit installations during drydock/ad-hoc
5. Banks and insurance providers: data on approvals and/or financing projects

### SURVEY DESCRIPTION

#### BACKGROUND

Before delving further into the specifics of the survey it is important to understand the context and the backdrop of the period in which the survey was conducted. 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% to 0.1% in the Sulphur Emission Control Areas (SECAs) (see Figure 1) or adopting alternative solutions that achieve an equivalent effect. The effect of this regulation could be that shipping companies could be prioritising their investment to meet the Sulphur regulations over energy efficiency investments. The same effect can be suggested for the impending ballast water regulations.

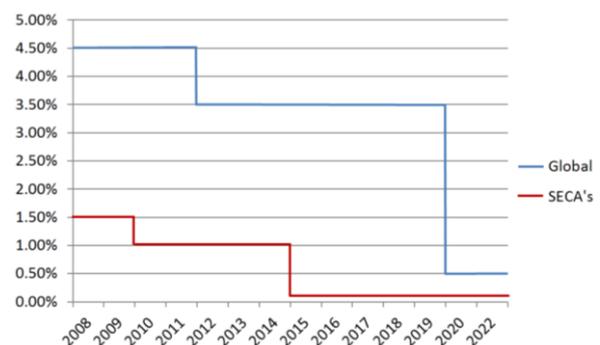


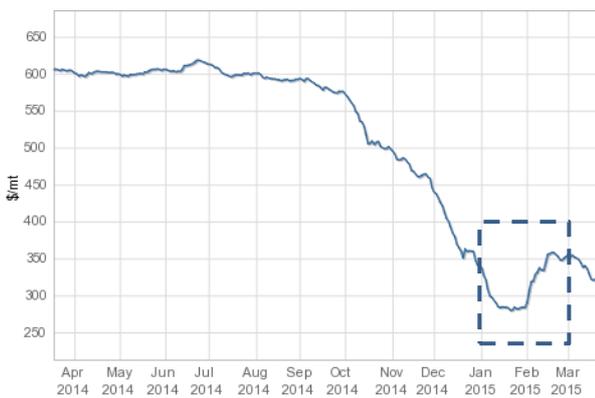
Figure 1: IMO Sulphur cap

Secondly, the IMO Energy Efficiency Design (EEDI) Phase 1 (2015 -2019) also took effect in

<sup>1</sup> <https://www.ucl.ac.uk/energy-models/models/glotram>

January 2015, requiring a 10% reduction in EEDI relative to the EEDI reference line for each ship type and size category. This would have a bias on the implementation of energy efficiency measures for newbuilds over existing ships.

Finally, the HFO fuel price dipped to its lowest during the beginning of the year, which has an effect of increasing the payback period of various energy efficiency measures and therefore potentially affecting the investment decisions of firms considering their implementation.



**Figure 2: HFO fuel price trend**

Source: Bunkerworld

## SAMPLING STRATEGY

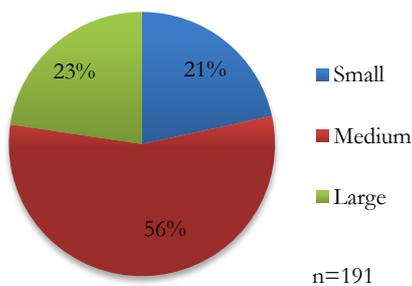
In order to be representative, the study mainly uses a stratified sampling approach, complemented by a non-random sampling approach (e.g. memberships of associations). A list of all shipping companies globally was acquired from Clarksons Shipping Information Network database and this was stratified according to the company's size, its sector of operation and geographical location of the headquarters. This study mainly focusses on the tanker (wetbulk), drybulk and container sector and firms with greater 90% of their fleet engaged in any of these sectors were included in the sample. Table 1 shows the number of firms which operated in each sector and size broken down by their geographical location (by headquarters). Small size companies (fleet of 10 ships and under) are not split by region and do not include one ship companies.

	Europe	N & S America	Asia	Far East	Total
Wetbulk Large	9	6	2	10	27
Wetbulk Medium	88	6	14	33	141
Drybulk Large	4	3	1	10	18
Drybulk Medium	75	11	6	49	141
Container Large	13	0	0	11	24
Container Medium	37	4	2	14	57
Mixed Large	23	1	4	21	49
Mixed Medium	80	1	8	54	143
	<b>329</b>	<b>32</b>	<b>37</b>	<b>202</b>	<b>600</b>
Wetbulk small					942
Drybulk small					685
Container small					146
Mixed small					163
					<b>2536</b>

**Table 1: Sampling frame**

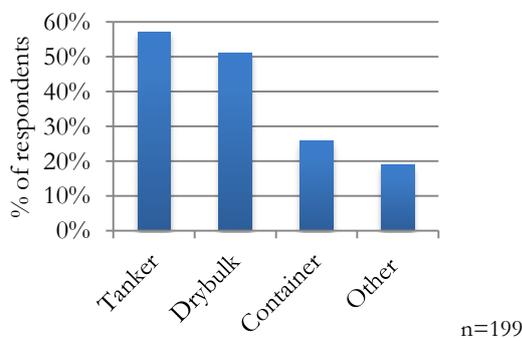
## RESPONDENT DEMOGRAPHICS

This section provides further information on the characteristics of the respondents to the survey. 270 companies were contacted by phone and almost 200 companies responded, resulting in a 72% response rate. The remainder responses were received from various other sources e.g. membership databases and third party mailing lists. The survey received 275 responses in total representing almost 20% of the bulk and container fleet (28,000 ships, Third IMO GHG Study). Figure 3 shows that the responses from medium sized companies are approximately in proportion to the population but the survey possibly under-represents small firms in the shipping sector.



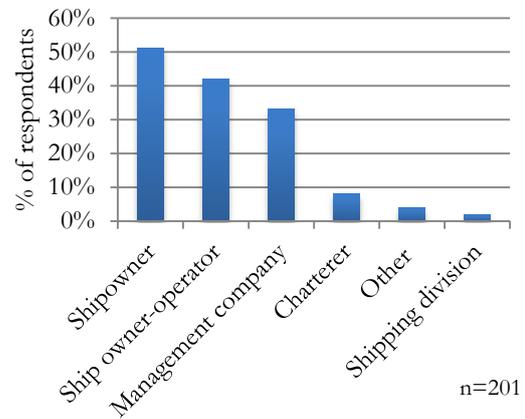
**Figure 3: Respondents by size**

Since the survey was primarily focussed on the wetbulk, drybulk and container sectors, the responses from these sectors are representative of the population referred to in Table 1. The question did not have mutually exclusive choices, hence the number of firms solely operating in the wetbulk, drybulk or container is slightly lower.



**Figure 4: Respondents by sector**

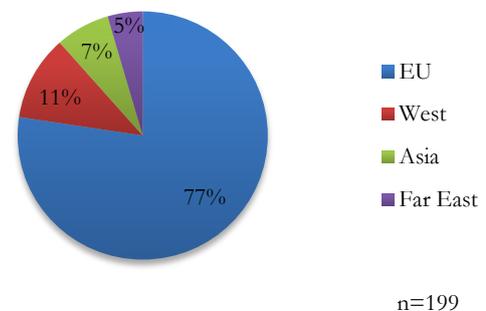
The primary respondents to the survey were shipowners, shipowner-operators and management companies. The survey also had responses from charterers that have ships on long-term time charter and cargo owning companies that own a shipping fleet to move their own cargoes.



**Figure 5: Type of shipping company**

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 6 shows the geographical dispersion of the respondents. The majority of the responses were from companies headquartered in the EU, mainly in Greece and Germany, followed by North America, Asia and the Far East.



**Figure 6: Respondents by region**

## STUDY RESULTS

This section provides a brief analysis of the results grouped by the different type of measures available to improve energy efficiency. Almost fifty measures were included in the survey and grouped in the following categories;

- Design related measures
- Hydrodynamic measures
- Machinery measures
- Alternative energy sources
- Maintenance measures
- After-treatment measures

## ENERGY EFFICIENCY STRATEGY

The first question sought to understand the company's overarching strategy to improve energy efficiency. Figure 7 shows that newbuilding and retrofitting existing ships were by far the most prominent strategies for over half the respondents. This is followed by the firms entering the second hand sale and purchase market to shed inefficient ships and buying more efficient ships. 5% of the respondents did nothing or had no strategy for improving energy efficiency. Other measures cited by respondents included operational measures, which were not in the scope of this survey. For uptake of operational measures refer to Rehmatulla 2012.

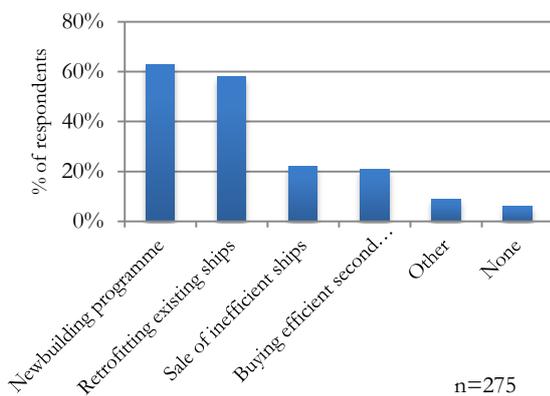


Figure 7: Energy efficiency strategy

Figure 8 illustrates that size of the company has some influence over the strategy that is adopted. More of the larger firms opted for newbuilding and

retrofitting existing ships to improve energy efficiency, whereas smaller firms opt for buying efficient second hand ships. Over 10% of the small firm respondents opted to do nothing to improve energy efficiency of ships. Other strategies preferred by large and medium size companies included laying up inefficient ships. Figure 9 on the other hand does not suggest variance or a similar pattern in the strategy by company type.

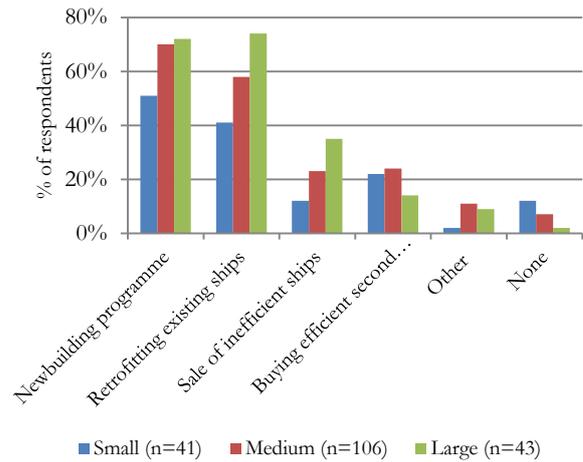


Figure 8: Energy efficiency strategy by size

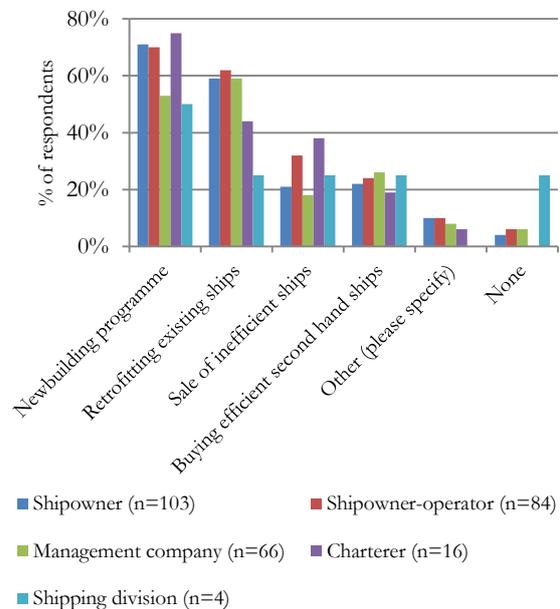


Figure 9: Energy efficiency strategy by company type

## DESIGN MEASURES

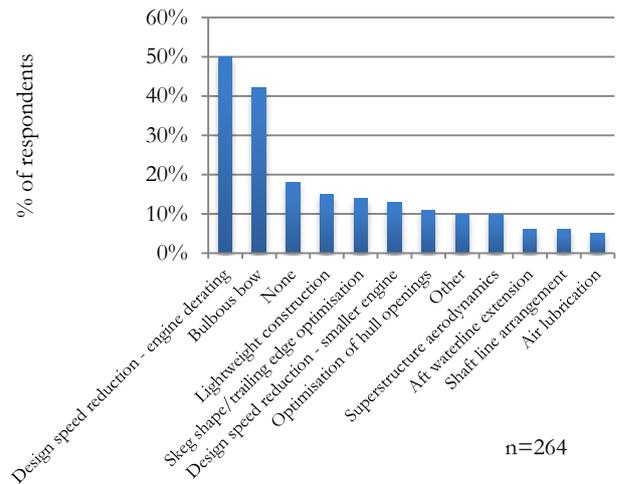
Figure 10 illustrates that the highest implemented design measures were design speed reduction achieved through engine de-rating and reconfiguration (or removal) of the bulbous bow. Note that the implementation is not by number of ships but by number of respondents. Further analysis of the data suggests that these two measures had the highest proportion of respondents who had implemented it across the entire fleet or a large part of the fleet, compared to other measures which were implemented between 1 – 10 ships in the fleet.

Figure 11 suggests that in general all the measures had higher implementation in the bulk sectors, followed by containerships, although the two most implemented measures had relatively higher implementation in containerships. Across all the measures, containerships also had the highest implementation of design speed reduction achieved through smaller engines. Air lubrication had implementation which ranged 1 – 5 ships of company's fleet, suggesting that the technology is still being trialled predominantly in the drybulk ships, given their higher frictional resistance due to their hull forms.

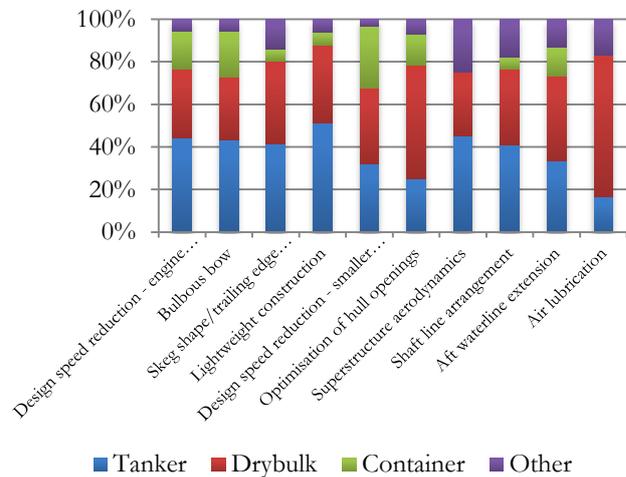
Figure 12 shows that on average more of the design based measures were implemented in newbuilds, which is understandable given their relevance at the design stage. However, the two most implemented measures coupled with skeg shape/trailing edge optimisation, aft waterline extension and air lubrication have around 35%-40% implemented as retrofits.

*"We will not go for engine and turbocharger modifications as it reduces vessel max speed potential and thereby 2nd hand value"* Medium size European bulk carrier shipowner-operator

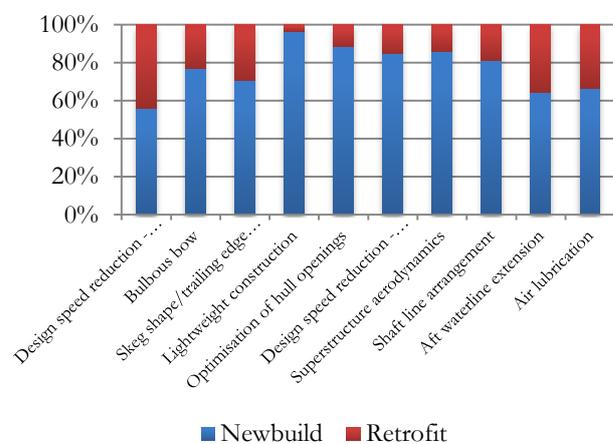
*"We have made several investigations into the derating the main engine of existing vessels in connection with fitting of new propellers, but this method of saving fuels has shown to have too long payback time, although savings were considerable. The conversion cost has simply been too high"* Large European tanker & drybulk operator



**Figure 10: Implementation of design related measures**

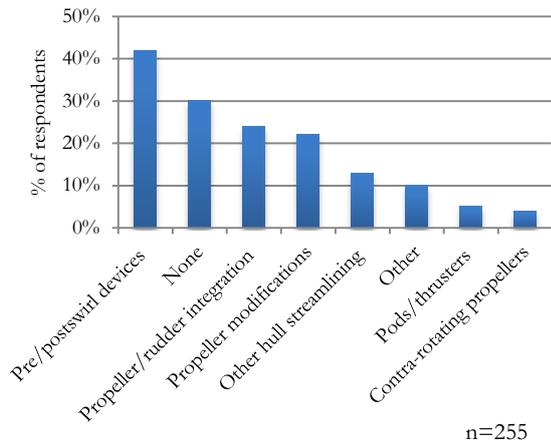


**Figure 11: Implementation of design measures by ship type**

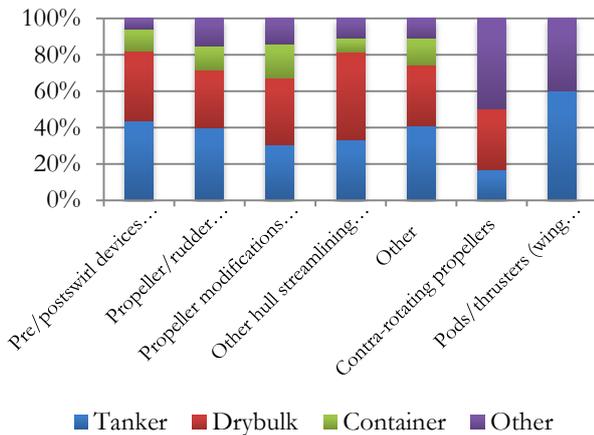


**Figure 12: Implementation of design measures by retrofit & newbuild**

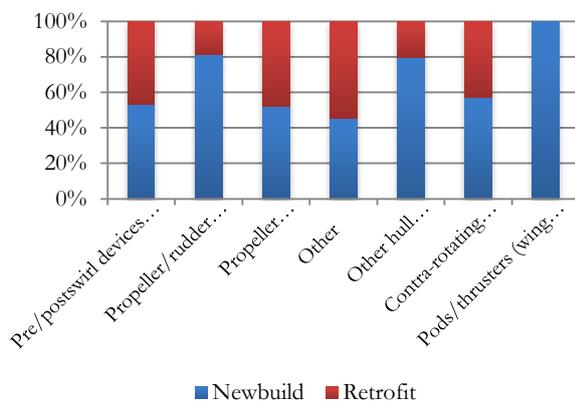
## HYDRODYNAMIC MEASURES



**Figure 13: Implementation of hydrodynamic measures**



**Figure 14: Implementation of hydrodynamic measures by ship type**



**Figure 15: Implementation of hydrodynamic measures by newbuild & retrofit**

Figure 13 illustrates the implementation of the hydrodynamic measures. Pre/post swirl devices, which included boss cap fin, vane wheel, presswork ducts, mews duct and stator fins, had the highest implementation. This is followed by propeller/rudder integration, which included propeller rudder bulb, propeller rudder matching/combination, and asymmetric rudder and propeller modifications, which included advanced blade sections, winglets/Kappel and prop section optimisation. A relatively higher proportion of respondents compared to implementation of design measures, did nothing to improve energy efficiency through hydrodynamic measures. Further analysis of the responses suggests that pre/post swirl devices had higher implementation across a larger number of ships within a company's fleet compared to just over 40% of respondents who had implemented it in between one and five ships within their fleet. The same is also the case with propeller/rudder integration measures and other hull streamlining measures, which included low profile openings and optimisation of water flow openings.

Figure 14 illustrates the varying degree of implementation of hydrodynamic measures across the sectors. Contra-rotating propellers though applicable to all ship types have higher implementation in the other ship types. On average over two thirds of the measures were implemented in newbuilds, perhaps suggesting that these devices are sold as a package by the shipyards, to improve energy efficiency (Figure 15), although this is difficult to verify because of the lack of information in the EEDI technical files of newly built ships and data reported in IMO (2015).

*"For newbuildings, it is the yard that proposes the devices that will be installed for energy saving. For company's existing fleet, we are selecting the energy saving systems that will reduce fuel consumption. For the time being we have seen this proved for the mewis duct only. But until the end of the year we may have results for VFD's and Antifouling's"*  
Large mixed fleet European shipowner-operator

## MACHINERY MEASURES

The most popular energy efficiency measures in this category were engine tuning, energy saving lighting, speed control of pumps and fans, waste heat recovery and common rail technology and around 40% of the respondents had implemented these machinery related energy efficiency measures. In contrast to other groups of measures relatively fewer respondents did not do anything in this group of measures. For the most implemented measures on average 30% of the respondents had implemented them as a small percentage of the fleet, suggesting that they were trialling these measures. Despite the typically long-term payback period, energy saving lighting (though strictly not a machinery measure) had one of the highest implementation, which could be due to the ease of implementation and the proven nature of the technology. Figure 18 suggests the majority of its implementation was through retrofits.

Figure 17 shows the implementation of the measures by ship type. With the exception of low loss power distribution, the measures had mostly been implemented in the tanker sector (average 40%), followed by drybulk (average 30%) and container. Combined Diesel Electric Drive and common rail technology had high implementation in the drybulk sector. On average 70% of the machinery energy efficiency measures were implemented in newbuilds (Figure 18). Further analysis of the top five measures by implementation shows that a large proportion (around 40%) is for ship sizes in the range of 10,000 – 50,000 DWT.

*“We buy generic ship types of standard designs which have already been optimised e.g. Crown 63”*  
Small drybulk European shipowner

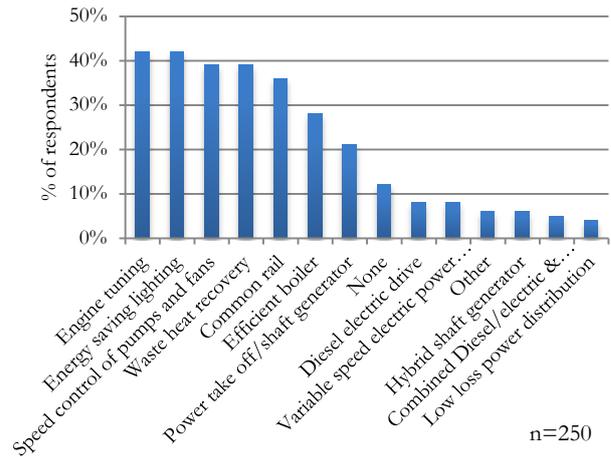


Figure 16: Implementation of machinery measures

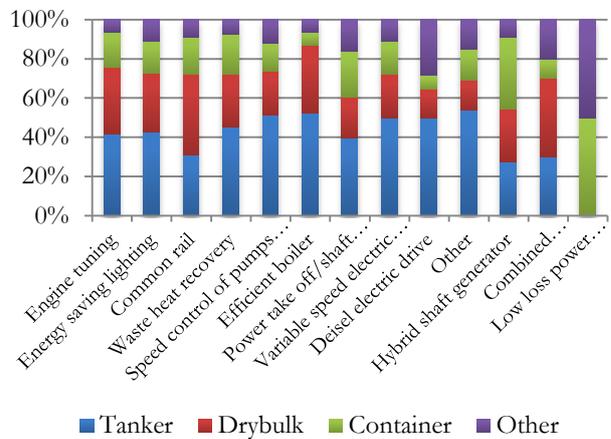


Figure 17: Implementation of machinery measures by ship type

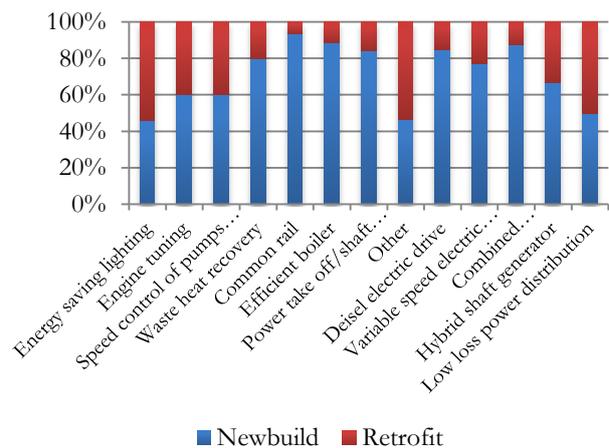
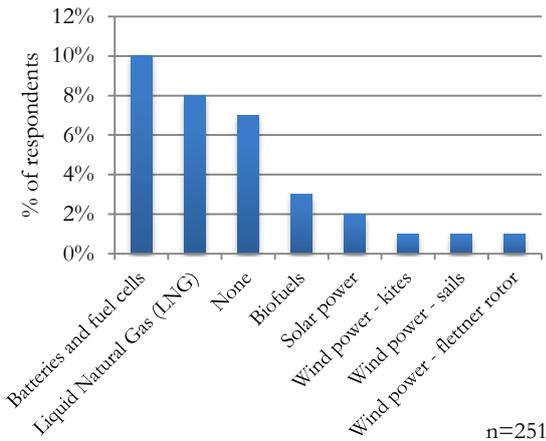
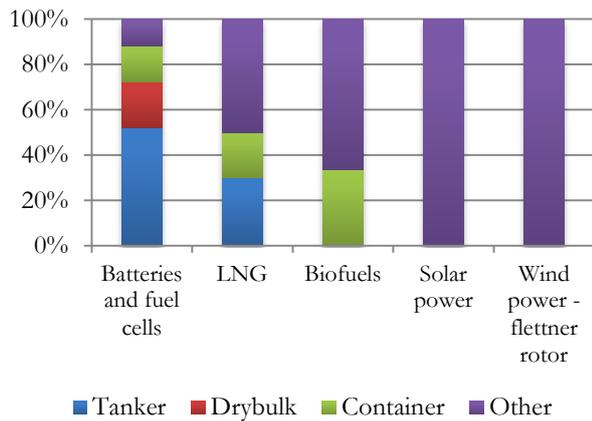


Figure 18: Implementation of machinery measures by newbuild & retrofit

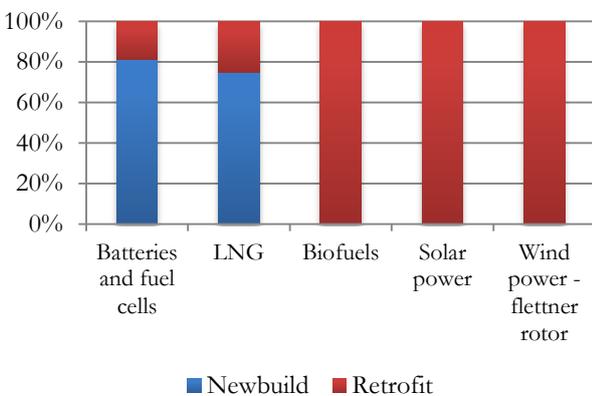
## ALTERNATIVE ENERGY SOURCES



**Figure 19: Implementation of alternative energy sources**



**Figure 20: Implementation of alternative energy sources by ship type**



**Figure 21: Implementation of alternative energy sources by newbuild & retrofit**

Other than the traditional fuel sources, respondents were asked if they had implemented in their fleet any alternative fuel solutions. It is interesting to note the slightly higher implementation of batteries and fuel cells over LNG. Twenty five respondents had implemented this measure at some level within their fleet. Further analysis of the implementation of batteries and fuel cells suggests an even spread over the different size categories with 30% of responses being for 10,000-50,000 DWT category.

Figure 20 illustrates the implementation by ship type and it can be observed that batteries and fuel cell have been implemented across the different ship types compared to the other measures which are predominant in specific ship types or sectors. LNG has been implemented mainly in the 'other' ship types followed by tankers and containerships and the same is the case for solar and wind power. The implementation of biofuels in the container sector has been implemented in six to ten ships by one owner operator for ships below the size of 10,000 DWT. Solar power implementation has been implemented between one and five ships by one owner operator of large ships.

Both, batteries and fuels cells and LNG are predominantly implemented on newbuilds with a small proportion of respondents retrofitting these two measures in contrast to solar power and flettner rotor which have only been retrofitted onto existing ships.

*"Not yet proven technology vis-a-vis cost investment and operational stability of the equipment over a period of time"*  
Small European tanker shipowner-operator

*"We have conducted preliminary design of an LNG-powered variant of an existing design. The probability of its adoption was vastly reduced, when construction of the liquefaction facility was cancelled"*

Medium size American mixed fleet shipowner-operator

## EMISSION TREATMENT MEASURES

Respondents were asked about the implementation of after-treatment or emission treatment measures. Figure 22 clearly shows that over 70% of the respondents did not implement any treatment measures despite the further tightening of Sulphur content in the Sulphur Emission Control Areas. Thus, most have opted for the fuel blend with the correct Sulphur content. This is most likely due to the fall in price of low sulphur fuel as well as the continuously developing technology and evolving guidelines/regulations.

Around 15% of the respondents had implemented some form of scrubber and NOx treatment system. Figure 23 shows that a large proportion of SOx and NOx treatment measures were in the tanker sector. The implementation of both SOx and NOx measures were clustered around the smaller ship types, 60% - 70% were for the under 10,000 DWT and 10,000 – 50,000 DWT category.

80% of the NOx treatment measures were implemented between one and ten ships, whereas SOx treatment measures had slightly higher implementation within a company's fleet. SOx treatment measures also had a relatively higher implementation as a result of retrofits compared to NOx treatment measures.

*“After-treatment measures have not been implemented because our vessel's operating profile is not standard and rules and regulations covering these technologies are still vague”*

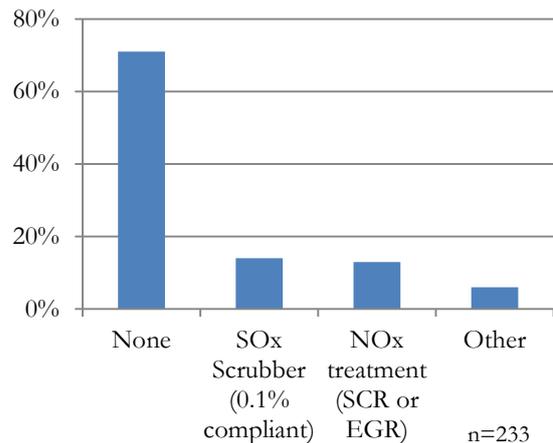
Medium size European management company

*“Carried out SOx scrubber design project but did not install the equipment on the ship”*

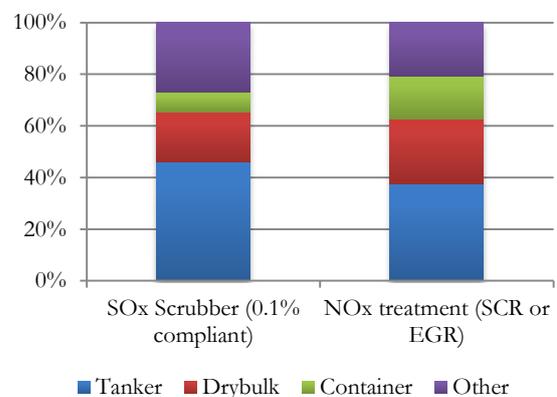
Medium size US based tanker shipowner-operator

*“SCR is specified in our new building vessels”*

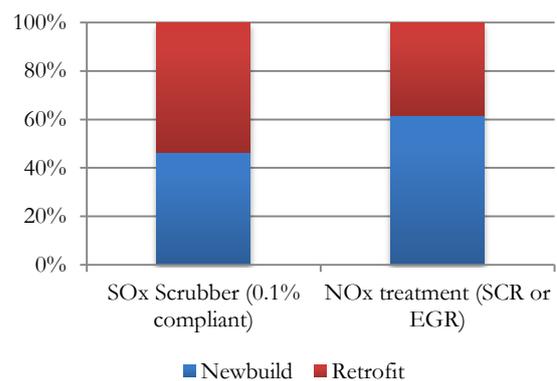
Medium size Asian tanker shipowner-operator



**Figure 22: Implementation of emission treatment measures**



**Figure 23: Implementation of emission treatment measures by ship type**



**Figure 24: Implementation of emission treatment measures by retrofit & newbuild**

## DRIVERS & CHALLENGES TO IMPLEMENTATION

This section discusses some of the drivers and challenges to implementation of the technical energy efficiency measures. Respondents were given the opportunity to provide additional comments on the implementation of the measures.

### PAYBACK AS AN INVESTMENT APPRAISAL METHOD

Responses suggested that payback was the most often used investment appraisal tool, although it was not clear what the payback period was for evaluating the investments. Payback period is by far also the most common investment appraisal tool used in many industries (Pike 1996; Lefley 1996). There is some anecdotal evidence of very short payback periods, e.g. 12- 18 months (HSH Nordbank 2014; Lloyds List 2011) being used within the shipping industry, despite the average ownership of vessels varying from five years for second-hand shipowners to ten years for newbuild shipowners (Stott 2013). The impact of a shorter investment horizon is investigated in Rehmatulla & Smith (2012).

*“Willingness to fit an energy savings device is directly related to expected payback period for same, either in improved time charter rate or better spot performance”*

Large US tanker shipowner-operator

*“Payback time is too long - not financially viable”*

Medium sized European tanker shipowner-operator

*“We have made several investigations into the derating the main engine of existing vessels in connection with fitting of new propellers, but this method of saving fuel has shown to have too long payback time, although savings were considerable. The conversion cost has simply been too high”*

Large European tanker & drybulk shipowner-operator

*“We are looking at vessels age and the payback time before making large investments”*

Medium size drybulk management company

*“Scrubber installation is still planned, however not yet done, as the yearly fuel consumption on the feeder vessels is too small to get a payback in a period of 3 to 5 years”*

Medium size European container line shipowner-operator

### LACK OF INCENTIVES

Investment in energy efficiency technologies may be forgone because of the division of capital and operating costs of a vessel e.g. the time charter. The degree to which the split incentive is an issue depends on whether or not shipowners are rewarded through higher time charter rates for more efficient ships. Agnolucci, Smith & Rehmatulla (2014) show that on average around 40% in the panamax sector is recouped by shipowners through higher time charter rates for the period 2008 – 2012, for £1000 saved on fuel, the shipowner sees an increase of £400 in the charter rate.

*“Major retrofits are done by class on owned vessels. A few charter vessels have been upgraded, but the focus so far on time charters has been operational”*

Large European container line shipowner-operator

*“As vessels are under time charter (and fuel is paid by the charterer), the charterer will only forward a part of the savings to the shipping company after installing a scrubber”*

Medium size European container line shipowner-operator

*“Did not install scrubbers despite spending close to \$100,000 because time charterer would not contribute in any way to the installation cost. Therefore since charterers pay the fuel cost of a time chartered vessel, the charterers wanted us to pay approx. 4 million to fit the scrubber and allow them to use IFO380 instead of diesel fuel which would have saved them the delta between the prices of IFO and MGO but didn't want to pay owners any more to charter hire the ship (Daily Rate)”*

Medium size US tanker shipowner-operator

*“Not beneficial to owners in current T/C market. Charterers purchase fuel”*

Medium size US drybulk shipowner-operator

Respondents also suggested market factors such as low earnings and lower fuel prices as a potential reason for the lack of implementation; low fuel prices have an adverse effect on the payback of energy saving technologies.

*“Considering the present market, the implementation of additional energy efficiency measuring in not sustainable”*

Medium size tanker and drybulk shipowner-operator

*“The recent reduction in oil prices have had a significant effect on vessel management. Spot chartered vessels are now operating at a great variety of speeds/loads depending on*

*market conditions. For example, ballast passages often require a vessel to perform ultra-low load steaming in order to minimise costs on ballast legs that have significant time to laycan. However, on laden passages voyage daily time charter equivalent (TCE) earnings are actually maximised in most cases by the vessel proceeding laden at maximum service speed. Current climate shows seems to show little benefit for investment in super-eco ships. As in past evidence over the long term, vessels that are flexible (fast when needed and slow/economical when not) seem to generate the most for their owners”*

Large US tanker management company

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## ACCESS TO CAPITAL

Most of the aforementioned energy efficiency technologies are capital intensive thus requiring firms to finance them through their balance sheet or have access to favourable borrowing, neither of which are easy in the current market. Many of the traditional shipping banks have been decreasing their loan books and very few are willing to participate in the retrofit finance. There is lack of evidence for increased uptake of technologies despite the existence of third party financing models, such as the Self financing fuel saving mechanism (SFFSM) and Save as you sail (SAYS). Refer to Stulgis et al. (2014) for an in-depth analysis of these third party financing models.

*“Most energy efficiency measures are quite expensive to implement without help from investors, banks or charterers. Due to short charter periods most of the charterers for smaller vessels are not interested to invest into the vessels”*

Small drybulk and container shipowner

*“Cost constraints and poor earnings in current market prevent in investing any capital for energy efficient measures”*

Small Asian tanker shipowner-operator

*“Most important reason why not more measures are taken is finance. Shipping is in crisis since sept 2008, and many vessels earn just enough to pay OPEX. There are no additional financing possibilities for vessels which are financially under water”*

Medium size European drybulk & container shipowner-operator

*“No implementation of energy efficiency measures due to missing possibility of refinancing”*

Medium size European tanker shipowner-operator

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## LACK OF INFORMATION

A key barrier to implementation of technical energy efficiency measures is the lack of reliable information on costs and savings of a particular technology. Rehmatulla & Smith (2015) shows evidence of lack of reliable information on costs and savings inhibits the uptake of operational energy efficiency measures. This general lack of information stems from shortage of publically available, detailed and transparent data, bespoke and non-standardised measurement techniques, high degree of operational specificity (ship types and sizes) and wide variability in day to day performance Rojon & Smith (2014). Thus, any energy efficiency technology manufacturers claims are treated with utmost caution and even perceived as misleading. Therefore, performance monitoring has become a business in itself as an increasing number of companies including classification societies provide software tools to record vessel performance, with further pressure from operators on shipowners to get involved with fuel performance monitoring (Lloyds List 2012). A number of respondents pointed towards this and their response to overcome the barrier.

*“Another major concern, considering that our industry is very reluctant of adopting new technologies, is the proven reliability and proof of gain that in many cases are not well and adequately guaranteed by the makers of every system. Traditional shipping reliability and prices are the main concerns”*

Medium size European drybulk & container shipowner-operator

*“We have installed sensor based performance monitoring system accessible from shore office on 5 tankers and bulk carriers as a pilot project to gauge its success factor”*

Medium size US tanker & drybulk shipowner-operator

*“Auto-data-logging system to measure performance”*

Large European tanker shipowner-operator

*“On new buildings we have systems for closely monitoring the performance on worldwide vessels. On coastal trade it is more difficult and of less interest”*

Medium size European tanker shipowner-operator

*“Implementing fuel measurement system...and monitor engine performance”*

Medium size European general cargo shipowner-operator

## CONCLUDING REMARKS

This study seeks to improve upon previous estimates of implementation of technical energy efficiency measures in shipping in a number of areas:

- Obtaining a representative sample of the firms involved in owning and operating ships
- Assessing the implementation of technical energy efficiency measures at a ship level (e.g. ship type, ship size)
- Assessing the implementation of technical energy efficiency measures at the company level (e.g. type of company, size of company).

The overarching conclusion from this study is that within each category of technical energy efficiency measures there are a handful of options that clearly have the highest implementation amongst the firms, given the current market conditions (low fuel price and low earnings). As an example for the design based measures, design speed reduction (engine de-rating) and bulbous bow reconfigurations were the top most implemented measures and within the hydrodynamic measures pre/post swirl devices had the highest implementation. However, the responses also reflect the heterogeneity within the sector with almost all measures having some sort of implementation. Overall the most common strategy was to buy energy efficient newbuilds and retrofit existing ships with a linear relationship with the size of the firm.

Most of the energy efficiency measures considered are applicable to both newbuilds and retrofits but the findings suggest a consistent pattern where newbuilds are adopting more of the measures compared to retrofits. This is most likely because a number of the measures can only be installed whilst on dry-dock, generating a time lag in the implementation. Furthermore, newbuilds see a higher uptake of these technologies as they are generally offered in 'standardised' designs or sold as a package and included in the newbuild price. Nonetheless, given the market conditions, there is increasing pressure on existing ships to compete

directly with more efficient newbuilds (which are generally around 20% - 30% more efficient than those built over five years ago) and avoid being classed at the bottom of the two-tier market. Thus, retrofitting offers a solution to inefficient vessels for remaining competitive and preventing them from being laid up or being scrapped prematurely.

The energy efficiency measures are most commonly implemented in the bulk sectors, however because the survey responses are not weighted at this stage conclusions regarding the implementation by ship type cannot be generalized to the whole industry. Due to the brief nature of this report further analysis regarding the implementation by absolute numbers and implementation by type of charter has not been presented. These analyses will be presented in forthcoming industry conferences and academic journals.

These findings are important to improve the modelling of take-up of energy efficiency measures. The key question would be to forecast longer term scenarios around technology uptake in order to meet the challenge of curbing emissions from the shipping sector. It is possible that an 80-90% reduction in energy efficiency on today's levels is required by 2050 if the sector is to maintain its current share of 2-3% of global CO<sub>2</sub> emissions and in light of existing globally agreed targets. Given this deep decarbonisation challenge, technological energy efficiency measures need to be exploited at all levels in tandem with system wide operational energy efficiency measures as crucial first strategies for the shipping sector to control its emissions.

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