E

INTERNATIONAL MARITIME ORGANIZATION

MARINE ENVIRONMENT PROTECTION COMMITTEE
69th session
Agenda item 5

MEPC 69/INF.11
28 January 2016
ENGLISH ONLY

AIR POLLUTION AND ENERGY EFFICIENCY

Study on the optimization of energy consumption as part of implementation of a ship energy efficiency management plan (SEEMP)

Note by the Secretariat

SUMMARY

Executive summary:	This document provides at annex the report of a Study on the optimization of energy consumption as part of implementation of a ship energy efficiency management plan (SEEMP), undertaken to identify best practice developed by the shipping industry, particularly since 1 January 2013 with the introduction of the mandatory requirement for ships to keep on board a ship-specific SEEMP
Strategic direction:	7.3
High-level action:	7.3.1
Output:	No related provisions
Action to be taken:	Paragraph 5
Related documents:	None

Introduction

1 In 2011, the Organization adopted, by resolution MEPC.203(62), a suite of technical and operational measures which together provide an energy efficiency framework for ships. These mandatory measures entered into force as a package on 1 January 2013, as chapter 4 of MARPOL Annex VI.

2 By resolution MEPC.203(62), the Energy Efficiency Design Index (EEDI) was made mandatory for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships. A SEEMP provides a possible approach for monitoring ship and fleet efficiency performance over time and some options to be considered when seeking to optimize the performance of the ship.

3 Following the adoption of resolution MEPC.203(62), IMO also adopted the *2012 Guidelines for the development of a Ship Energy Efficiency Management Pan (SEEMP)* by resolution MEPC.213(63) in order to assist ship's masters, operators and owners to develop the SEEMP. In these Guidelines, "planning", "implementation", "monitoring" and "self-evaluation and improvement" are introduced as a framework and structure of the SEEMP.

4 A Study on the optimization of energy consumption as part of implementation of a ship energy efficiency management plan (SEEMP), using funds provided to IMO by Transport Canada for analytical studies and other activities pertaining to the control of air related emissions from ships, has been undertaken to identify best practice developed by the shipping industry, particularly since 1 January 2013 with the introduction of the mandatory requirement for ships to keep on board a ship-specific SEEMP. The report of the Study is set out in the annex.

Action requested of the Committee

5 The Committee is invited to note the information provided.

***

Report No.: RE20157474-01-00-A

STUDY ON THE OPTIMIZATION OF ENERGY CONSUMPTION AS PART OF IMPLEMENTATION OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP)

Authors: Maria Bännstrand, Anna Jönsson, Hannes Johnson, Roger Karlsson

SSPA

YOUR MARITIME SOLUTION PARTNER

About SSPA.

SSPA offers a wide range of maritime services, including ship design, energy optimisation, finding the most effective ways to interact with other types of transportation, and conducting maritime infrastructure studies together with safety and environmental risk assessments. Our customers include shipowners, ports, shipyards, manufacturers and maritime authorities worldwide.

SSPA Sweden AB has about 115 employees and is a maritime consultant partner which acts as a bridge between research and maritime industry implementation, providing unbiased expertise and advice as well as hydrodynamic test facilities. We contribute to a secure sustainable development through appropriate risk management, and offer optimal energy efficiency by combining financial, environmental, human and technological factors.

Welcome to SSPA - www.sspa.se

REPORT

Date:
2016-01-25

SSPA Report No.:
RE20157474-01-00-A

Project Manager:
Maria Bännstrand

Author:
Roger Karlsson, Anna Jönsson, Maria Bännstrand & Hannes Johnson
maria.bannstrand@sspa.se
+46-31-772 90 70

International Maritime Organization
General Store
4 Albert Embankment
London
SE1 7SR

Reference:
Mr E. Hughes, Head, Air Pollution and Energy Efficiency, Sub-Division for Protective Measures, Marine Environment Division

Study on the optimization of energy consumption as part of implementation of a Ship Energy Efficiency Management Plan (SEEMP)

On behalf of the International Maritime Organization (IMO), SSPA Sweden AB has performed a study on the optimization of energy consumption as part of implementation of a Ship Energy Efficiency Management Plan (SEEMP). Emphasis was given to identification of best practices developed in the shipping industry, particularly since the introduction of the mandatory requirement to carry on board a SEEMP from 1 January 2013.

This study was carried out using funds provided to IMO by Transport Canada for analytical studies and other activities pertaining to the control of air related emissions from ships.

The findings of the study are presented in this very report.

SSPA Sweden AB

Maria Bännstrand
Project Manager
Maritime Operations

SSPA Sweden AB

Johan Algell
Vice President
Maritime Operations

Summary and recommendations

On behalf of the International Maritime Organisation (IMO), SSPA Sweden AB has performed a study with the objective to conduct a study on the optimisation of energy consumption as part of implementation of a Ship Energy Efficiency Management Plan (SEEMP). Emphasis was given to identification of best practices developed in the shipping industry, particularly since the introduction of the mandatory requirement to carry on board a SEEMP from 1 January 2013. Methods used included a web-based survey, in-depth interviews and literature studies and furthermore, this study has taken advantage of the project team member´s and SSPA's in-house experience of the process of energy efficiency of ships, both in way of a range of studies made, but also from the project member´s operational experience. In addition, reference has been made to current research in the field covering recent studies on the areas investigated in this study. The study is qualitative, with the focus on finding best practises and the sample of shipping companies chosen for collection of data is information-based; companies are selected for their renowned progressive work with energy and environmental management. As a consequence, the result from the web-based surveys and the in-depth interviews do not and are not intended to represent any statistical data representative for the whole shipping industry or for any specific ship-segment.

Four major shipping segments formed the basis of the gathered data; Tanker, Bulk, Container and Ro-Ro. In addition to this, ship management companies and operators handling several segments, amongst others including the above four majors, were included to gain further information on possible differences between various segments in dealing with the SEEMP.

One conclusion drawn from the result of the interviews is that there is no real difference between segments in how to work with energy management systems. However, there are varieties between smaller and larger companies due to organizational setups; where smaller companies rely on, and make sure to motivate, personal engagement to a bigger extent while large companies have the possibility to allocate divisions focusing merely on the SEEMP and related matters with centralised systems where collected data are analysed by shore based expertise and the results including recommendations are spread to the fleet. What goes for all the interviewed companies is that human awareness, involvement and education are main success factors for a well-functioning work on improving energy efficiency.

Further conclusions include that all of the interviewed have a system for energy efficiency in place beside the SEEMP and most companies already had a system in place when SEEMP became mandatory, but the SEEMP has been a trigging factor for intensifying work on energy efficiency.

As for KPI's, the EEOI is not seen as a sufficient KPI for the daily improvement work and some of the companies in this study has developed their own KPI's. In

addition to this, many companies expressed that they would like IMO to help in developing tools for setting goals and more operative KPI's.

It stands clear that apart from environmental reasons one main driver for energy efficiency is economic; improving energy efficiency can often improve profitability. Regulations on energy efficiency management systems can have a mitigating effect on speed increases in times even when the oil price is low.

As for best practises the study brings out different solutions as the best ones, partly depending on the trade of the relevant vessels, but reduced speed is an operational measure frequently brought forward as having major impact. Since the energy need is very dependent on speed even small speed reductions can reduce energy consumption considerably. The speed reduction has to be balanced versus the need for delivery on time, and calls for a good voyage planning and transparency between the vessel and the vessel operator.

Another operational measure brought forward as a best practise is, for controllable pitch propeller installations, is to run the system using a "combinator curve" with optimized pitch settings and propeller speed, making it possible to operate the total propulsion system with optimum efficiency.

As for technical solutions the installations of Energy Saving Devices of different kinds is highlighted, including PBCF:s, ducts, and in some cases changing bulbous bows. Also, reducing electricity consumption on-board by running large consumers at optimum speed and by turning of unnecessary equipment and lights is an important measure. Cleaning of hull and propellers and usage of proper coatings is also vital for providing for as smooth surfaces as possible.

On the system level performance monitoring systems is vital to enable analysis of performance quality and making it possible to take the right action. Increased awareness of the importance of energy efficiency issues also plays a large role in energy efficiency, as well as education of staff so they can operate all systems in a good way.

During the interviews a number of recommendations for development of the Energy Efficiency work have been voiced. The main ones are the following:

- Make the SEEMP more as a guideline/handbook for the industry with clearer procedures;
- Support needed in setting realistic and useful goals;
- Support needed in developing effective KPI's that can be used in the daily improvement work; and
- Needs for guidelines on effectiveness of technical and operational solutions and products. There is a multitude of products on the market, and it is often hard for the individual company to judge which the best ones are for them.

Table of contents

Preface

On behalf of the International Maritime Organization (IMO), SSPA Sweden AB has performed a study on the optimization of energy consumption as part of implementation of a Ship Energy Efficiency Management Plan (SEEMP). Emphasis was given to identification of best practices developed in the shipping industry, particularly since the introduction of the mandatory requirement to carry on board a SEEMP from 1 January 2013.

The study has been performed by using a web-based survey combined with in-depth interviews of representatives from shipping companies and ship management companies.

The responsibility for the content of this report rest with the authors, listed below.

Maria Bännstrand	SSPA Sweden AB	Project Manager

Master Mariner, M.Sc. in Shipping Systems and Technology. 20 years within various fields of shipping including; sea-going experience serving as Chief Officer and 2nd officer on tankers, Operations Manager at a tanker shipping company, Hull insurance and projects within energy efficiency, alternative fuels and vessel safety.

Anna Jönsson	SSPA Sweden AB	

Master Mariner, M.Sc. courses in Maritime Energy Management as well as Maritime Environment and Environmental Management. Seagoing experience from serving as 2nd Officer and Chief Officer onboard product tankers.

Roger Karlsson	SSPA Sweden AB	

Naval Architect, M.Sc. Experience from many different areas of shipping for 35 years including R&D, ship design, shipbuilding and regulatory work within safety and environment. 10 years as Technical director and COO in a tanker shipping company.

Hannes Johnson	Chalmers University of Technology	PhD researcher

M.Sc. Engineering Physics, PhD student in Maritime Energy Management. Hannes Johnson does research on energy efficiency in shipping in close collaboration with the shipping industry. He has published several articles in the field in leading international peer-reviewed journals.

Acknowledgements

SSPA Sweden AB would like to thank the participating shipping companies, all renowned for their best practice and high technical standard, for providing valuable information and deeper understanding of how the shipping industry has optimized the implementation of SEEMP.

SSPA Sweden AB would like to highlight the importance of the shipping companies participating in the study. SSPA Sweden AB highly appreciate their time, effort and expertise contributing to the results of this study.

The participating shipping companies who have expressed their willingness of being presented with names are listed below. In addition a number of companies participated in the study but chose to be treated with full anonymity.

Erik Thun Group

Exmar

Furetank Rederi AB

GoTa Ship Management AB

Höegh Autoliners AS

Laurin Maritime

Maran Gas Maritime Inc.

Marinvest Shipping AB

MOL TANKSHIP MANAGEMENT (EUROPE) LTD.

Northern Marine Management Ltd

Reederei Nord B.V.

Stena Line Scandinavia AB

TransAtlantic AB

Wallenius Marine

List of abbreviations and acronyms

C/P	Charter Party
CPP	Controllable Pitch Propeller
CO_2	Carbon Dioxide
ECA	Emission Control Area
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EMS	Environmental Management System
EMSA	European Maritime Safety Agency
EnMS	Energy Management System
ETA	Estimated Time of Arrival
EU	European Union
GT	Gross Tonnage
IMO	International Maritime Organization
INTERTANKO	The International Association of Independent Tanker Owners
ISM Code	International Safety Management Code
KPI	Key Performance Indicator
MARPOL	The International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee of the IMO
MRV	Monitoring, reporting and verification
NO_X	Nitrogen Oxides
OCIMF	Oil Companies International Marine Forum
OPS	Onshore Power Supply
PBCF	Propeller Boss Cap Fins
SEEMP	Ship Energy Efficiency Management Plan
SO_X	Sulphur Oxides
T/C	Time Charter

1 INTRODUCTION

Energy Efficiency, connected to air pollution and reduction of greenhouse gas emissions, has been an issue within the IMO for a considerable time. The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI was adopted in 1997, at that time mainly focusing on air pollution and especially NO_X and SO_X emissions were targeted.

The next step was to focus on greenhouse gas emissions. In 2011, IMO adopted by resolution MEPC.203(62), a suite of technical and operational measures which together provide and energy efficiency framework for ships. These mandatory measures entered into force as a "package" on 1 January 2013, as Chapter 4 of MARPOL Annex VI. Further amendments to those requirements mean that ship types responsible for approximately 85% of carbon dioxide (CO_2) emissions from international shipping are to be subject to strengthening requirements for energy efficiency and, together, they represent the first-ever, mandatory global regime for CO_2 emission reduction in an entire industry sector.

By resolution MEPC.203(62), the Energy Efficiency Design Index (EEDI) was made mandatory for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships by regulation 22 stating that *"Each ship shall keep on board a ship specific Ship Energy Efficiency Management Plan (SEEMP). This may form part of the ship's Safety Management System (SMS)"*.

The SEEMP provides a possible approach for monitoring ship and fleet efficiency performance over time and some options to be considered when seeking to optimize the performance of the ship. At MEPC 62 also MEPC.1/Circ.684 "Guidelines for voluntary use of the Ship Energy Efficiency Operational Indicator (EEOI)" was prepared for circulation.

During MEPC 63 IMO also adopted the *2012 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)* by resolution MEPC.213(63) in order to assist ship´s masters, operators and owners to develop the SEEMP. In these Guidelines, "planning", "implementation", "monitoring" and "self-evaluation and improvement" are introduced as a framework and structure of the SEEMP.

More background information on the Energy Efficiency Measures can be found at IMO:s web-page, www.imo.org.

1.1 Objective of the study

The objective of the study is to conduct a study on the optimization of energy consumption as part of implementation of a SEEMP and focus on good practice developed in the shipping industry, particularly since the introduction of the mandatory requirement for ships to keep on board a SEEMP from 1 January 2013.

1.2 Components and structure of the study

Chapter 1 contains the introduction and objective of the study.

A short description of the components and structure of the study is given in this section, which aims at serving as a reading guide to the report.

In chapter 2 an overview of energy efficiency in shipping is given in order to provide a description of a few basic issues that is important for an enhanced understanding of the topic. In addition, a review of previous studies on energy efficiency in ship operations and the Ship Energy Efficiency Management Plan (SEEMP) is given.

In chapter 3 the method used in the study is described. In short, a combination of methods have been used including a web-based survey, in-depth interviews, literature studies and references to current research in the field. In addition, the study has taken advantage of the project team member´s and SSPA´s in-house experience.

In chapter 4 the main result of the study is presented in terms of measures highlighted by the participating shipping companies as best practices. The result is divided into technical measures, operational measures, human resource development, systems for management and development and other measures.

In chapter 5 the discussion and conclusions are presented; including a short description on where the participating companies stands today in their work with energy efficiency, drivers and barriers and finally some comments on upcoming regulations.

Chapter 6 compiles the list of references.

Chapter 7 consist of an **Appendix** which provides a detailed review of the result from the web-based survey and the in-depth interviews. The appendix gives a comprehensive review of all the questions included in the web-based survey as well as additional information gained from the in-depth interviews.

The appendix is aimed at readers who are interested in gaining a deeper understanding of the result and could be read in addition to the report.

2 ENERGY EFFICIENCY IN SHIPPING: AN OVERVIEW

Energy Efficiency is a complex topic, and it can be addressed at many different levels. The EEOI, being the suggested KPI in the SEEMP, is an aggregated figure on a high level describing the CO_2 emissions for the transport work performed by the ship, whereas improvements of the energy efficiency is often discussed on a much lower level like operational speed, propeller efficiency or specific fuel consumption of an engine. The different factors, on different levels and in different fields, are also affecting each other. A technical solution optimized for a specific trade and operational pattern will most probably not be optimal if the trading pattern is changed, for instance by changing operational area, speed or cargoes.

Below a few basic issues that we see as important for the understanding of the topic are briefly described, for a fuller understanding some of the references can possibly be of help. Education and awareness is a prerequisite for a successful work on improved Energy Efficiency, this of course also includes a good understanding of the basic facts.

2.1 Energy efficiency and emissions

When discussing energy efficiency there is often a tendency to set an equality sign between Energy and Emissions. The Energy Efficiency Design Index (**EEDI**) and Energy Efficiency Operational Indicator (**EEOI**) are, for instance, measures of CO_2 emissions and not measures of energy efficiency. There is of course a connection between energy and emissions, but the distinction should be made clear.

As an example; Powering a vessel with electric motors fed by batteries, operated on electrical power produced with no CO_2 emissions would give an EEOI (and EEDI) of 0, but it will not mean that the vessel does not consume energy. Indeed most “purely” electrical vessels are heavier than diesel powered ones since the needed batteries adds a large weight, and they do therefore actually consume more energy.

Given the design of the EEOI and EEDI we will anyhow to some extent use the “equality sign” in this report.

2.2 Hydrodynamics

A very important part of a vessel’s energy efficiency is its hydrodynamic properties. Below is therefore a very short introduction to some of the basic aspects of the hydrodynamic properties of a propeller powered ship.

2.2.1 Hydrodynamic efficiency

To make a vessel efficient from a hydrodynamic point of view three main steps are taken:

1) Hull optimization;

2) Propeller optimization; and

3) Hull-propeller interaction.

The hull and its main dimensions are optimized to reduce the two main resistance parts, namely the frictional (or viscous) resistance and the wave resistance.

The frictional resistance is caused by the water movement along the hull, where the viscosity of the water creates friction between the water and the hull side. The frictional resistance is proportional to the speed squared, i.e. doubling the speed will increase the resistance fourfold (and the needed power with a factor 8).

The frictional resistance is also dependent of the roughness of the surface, above a certain roughness the resistance increases. Therefore a smooth surface, without fouling, is important to minimize the friction, and antifouling paints with as small roughness as possible is therefore (sometimes together with polishing of hull and propeller) an area where energy savings can be done.

The wave resistance is caused by the hull pushing the water to the sides when passing through it, creating waves. The wave resistance is much more speed dependent than the resistance. At very low speeds it is almost negligible, for slow vessels like tankers it is often about 10% of the total resistance whereas it for fast ships can be the dominating part of the vessel resistance.

Because of these factors vessels are designed differently depending on their intended speed.

Slow vessels like tankers and bulkers are normally quite full in their shape. This reduces the wetted surface of the hull, thereby reducing the total needed power since wave resistance is small.

Fast ships on the other hand are normally more slender and longer. Both the slenderness and the length reduce the wave resistance making them less power consuming, although the wetted surface is larger than for the slow vessel of corresponding capacity. To reduce the wave resistance even further bulbous bows (and bulbous aft body) are normally fitted. The bulb makes the waterline length larger which reduces the wave resistance, and with a proper design the interaction between the four main wave systems surrounding the vessel can be optimized to further reduce the wave resistance.

In general it can also be said that large vessels are more efficient than smaller ones, i.e. the energy consumption per transport work is reduced with size. This is mainly due to the fact that the wetted area increases (in principle) with the length squared, whereas the cargo capacity increases with the length in cube, so the power demand grows slower than the transport capacity.

The larger (longer) vessel can also operate at higher speeds before running into the problem of large wave resistance. Figure 1 below illustrates the dependency of speed and size of vessels for their energy consumption. See especially the size dependence for tankers, both regarding energy need and maximum economic speed.

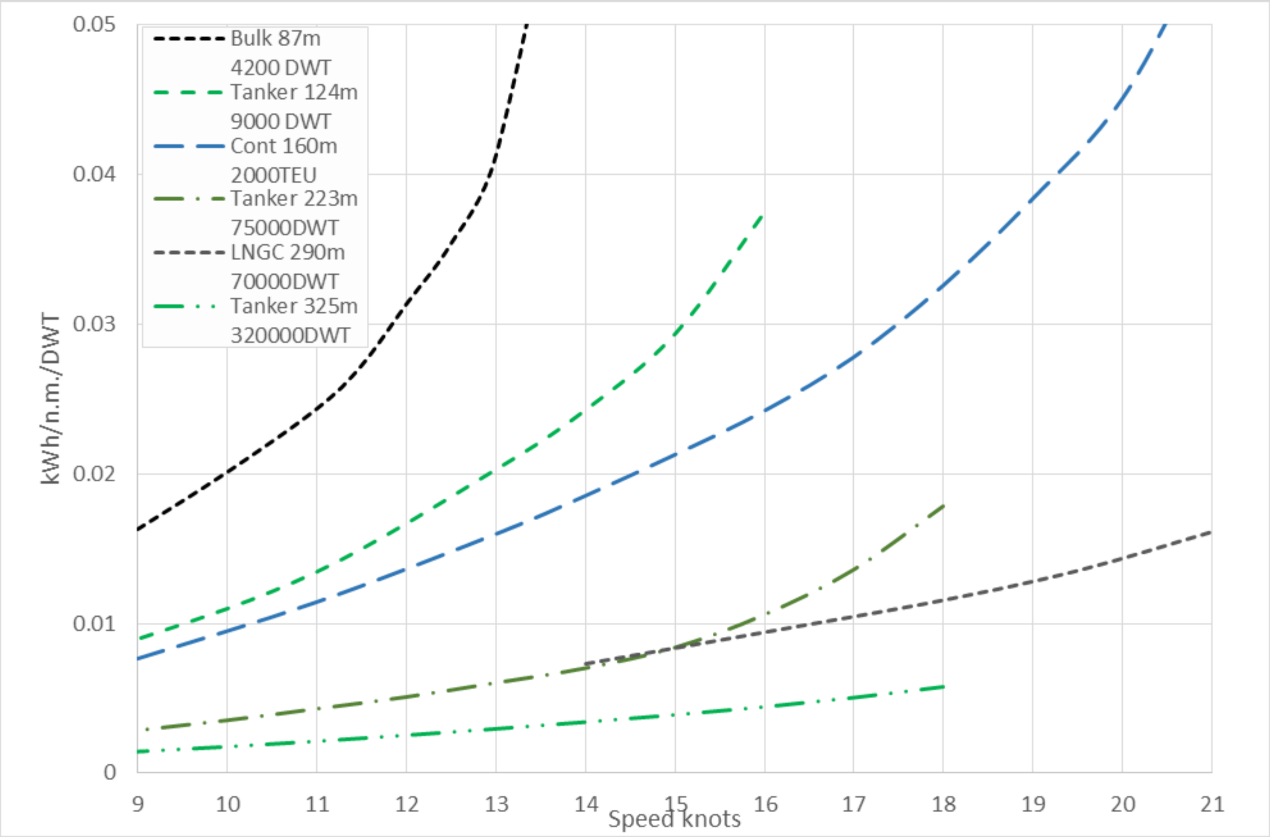


Figure 1: Energy consumption per tonne-km for a few examples of ships.

The propeller is optimized to give high efficiency with good cavitation characteristics and not causing large vibrations on-board. Unfortunately these three aspects counteract each other, and a good propeller will always have to be a compromise. For high efficiency the normal way to go is a propeller with large diameter and low rotational speed. To get good properties regarding cavitation and vibrations is a complex task and will not be covered here.

One factor that is often overseen is the operation of vessels with Controllable Pitch Propellers (CPP). A CPP has blades that can be rotated to reduce the trust delivered, and also to reverse the trust to go aft. Especially for short sea shipping CPP:s are very frequently used since they improve manoeuvrability when operating in constrained waters and for mooring etc. Vessels with CPP solutions often have a generator connected to the main engine, and to get a constant electric frequency the engine (and hence the propeller) is running at constant speed with speed reduction done by reducing the pitch of the propeller. The problems with this are that:

- The propeller efficiency reduces to a big extent when the pitch is reduced by more than 10-15%. If the speed is reduced by more than 30-40% from the design speed the fuel consumption per distance normally actually increases instead of decreasing.
- Running an engine at full speed with low load makes the combustion less efficient and the specific fuel consumption is increasing.

The interaction between hull and propeller is also very important for a good efficiency. With the right design some of the losses that the hull and propeller have when operating by themselves can be regained, especially some of the frictional losses of the hull are regained by placing the propeller aft of the hull in the so-called wake. To improve the situation further Energy saving devices are today often placed around the propeller, see more about this in a coming chapter.

2.2.2 Speed dependency

A slow ship is more energy efficient than a fast one. As mentioned above the power needed to propel a ship is approximately proportional to $speed^3$, at higher speeds (high Froude's number) the power increases even faster because of the increasing wave resistance. A speed reduction of 10% will therefore typically result in a reduction of fuel consumption/per distance of about 20%. The most direct way to reduce the EEOI is therefore to reduce speed. Slow steaming that is widely practiced today is therefore a very efficient way to reduce energy consumption. Also see figure 1 above.

Whether the slow vessel is more efficient when logistic, economic and other factors are also considered is however another issue. Discussing efficiency without taking speed into account, which is basically what is done in the EEOI and EEDI, is therefore not a complete way of describing the problem and can sometimes result in faulty conclusions. If design efficiency is to be compared it has to be done comparing vessels operating at the same speed. These issues will not be covered here, but are of course main factors for the operator of a vessel. Some operational aspects are covered in 2.4.

2.2.3 Energy saving devices

Energy saving devices are typically different types of arrangements around the propeller to improve the performance. Many of these that have been developed in later years are devices to reduce the rotational losses. When the propeller rotates to create the needed thrust the water flow gets a rotation which often constitutes a loss of 10-15% of the power. By inducing a rotation in the opposite direction some of the losses can be regained.

Typical systems are wings in front of the propeller and twisted rudders. Also contra-rotating propellers work in the same way. They do at the same time reduce the propeller loading which can further increase the efficiency.

Other systems aim at creating a more uniform flow to the propeller to improve efficiency. This can be done by ducts or other devices in front of the propeller. The Mewis duct is a combination of a duct and wings that has gained popularity, with considerable savings reported in some cases.

Propeller Boss Cap Fins, fitted at the propeller hub, can break up the vortices aft of the propeller and thereby regain some of the losses.

2.3 Machinery

To provide the power for the propeller there is a large number of technologies available. The efficiency of an engine is a result of a large number of parameters, ranging from the basic principles to the optimization of the systems. Efficiencies range from 25-30% for steam turbine systems to above 50% for modern 2-stroke diesel engines. Using waste heat recovery systems can further enhance the efficiency, and efficiencies up to 56-58% are viable with today's technology.

The choice of engine is normally a result of weighing different aspects of the operation, but diesel engines are today definitely the dominating choice.

Alternative fuels are becoming more frequently used, with LNG and Methanol as two options that can decrease the emissions, partly CO_2 but more important for some cases SO_X, NO_X and particulate matter.

Electricity production on board is usually done either by using auxiliary engines or by installing a (shaft) generator on the main engine. The way these systems are operated can affect the efficiency to a big extent, and an optimization can save considerable amounts of energy.

Electricity consumption on board can in some vessels also be a large part of the energy consumption. By running systems in an optimal manner, together with turning off unnecessary consumers, large savings can be done.

2.4 Operational aspects

Operational measures can have substantial impact on energy efficiency. Voyage planning and, for liner traffic, to adjust time tables including keeping speed as low as possible, is an effective measure. However, how charter party terms are stipulated effect the vessels possibility to optimize their energy consumption. Efforts have been made on contractual regulations on energy efficiency. In year 2011, Intertanko and OCIMF launched virtual arrival processes and simultaneously BIMCO implemented a slow steaming clause, aiming for fuel saving through speed reduction. Despite standard clauses being included in charter parties there are still considerations to be made to cover all operational aspects. Clauses related to where, when and within which time frame the voyage should be executed need to be taken into account, as well as clauses related to the vessels performance and guarantees on speed and bunker consumption. Also demurrage and dispatch clauses as well as ready berth clauses provides examples on factors aggravating contracts on energy efficiency through speed reduction (IVL, SSPA & Chalmers, 2013).

Performance monitoring is another measure with possible substantial impact, but this requires thorough follow-up and ability to adjust when needed. To fully comprehend the own ships properties in way of optimum speed, load factor and trim is also a way to energy efficiency, and this applies to as well on board as operational shore personnel, and certainly for ship owners since ships performance being a vital part in contractual discussions with charterers.

Also, when a vessel operates in waves and wind the energy consumption increases. By using weather forecasts in so-called weather routeing systems and by planning the voyage in the best possible way the increase in consumption can be limited. Also currents, effects of shallow water etc. can be taken into account in these systems.

2.5 Previous studies on energy efficiency in ship operations and the Ship Energy Efficiency Management Plan

Energy efficiency in ship operations attracted general interest in the shipping industry in the mid 00's as oil prices started to rise, and then throughout the years after the economic crises at the end of the decade in response to the overcapacity of ships. A similar surge of interest was seen after the oil crises of the 70s, which spurred a lot of commercial and academic interest as well as government support in different means of energy conservation efforts (Bertram and Saricks, 1981).

Many assessments, like this very report, have been done in support for international and regional public policy the climate change impact of the shipping sector. Some have focused on operational energy efficiency and topics that would fall in the scope of the SEEMP (e.g. Maddox Consulting, 2012), and some have larger scope, but most pre-date the time for the mandatory SEEMP implementation (Faber et al., 2009).

Little knowledge has unfortunately been gathered specifically on SEEMP implementation experiences in practice. The studies that have been performed after 1st of January 2013 typically have a larger scope and have focused on energy management practices in general. Two consequent annual survey studies by DNV-GL suggested that for many, the SEEMP document is primarily driven by the need to comply with regulations; in itself, it does not drive energy management efforts (DNV-GL, 2014; DNV-GL, 2015). In peer-reviewed literature, there is likewise little material as of yet. Johnson et al. (2013) predicted that the SEEMP may have little impact due to the few requirements it carried, based on a comparison with ISO 50001 and the ISM Code. The interview study performed by Poulsen and Johnson (2016) in the Danish shipping sector suggested support to the claim that implementing the SEEMP is mostly a matter of compliance, not a matter of improving energy management practices.

The studies suggest that energy efficiency in the operations of ships is still not altogether straightforward for shipping companies. Poulsen and Johnson (2016) saw that building up competence and achieving success in energy efficiency was a process that took several years, and also that certain business practices made energy efficiency more difficult to achieve. In particular, this applied to companies that had vessels on short-term charter and a high turnover of crew. The DNV-GL studies showed that only a minority of the companies in their study had set and achieved ambitious targets for energy efficiency (DNV-GL, 2014; DNV-GL, 2015).

Energy efficiency in ship operations is not only technically complex, as outlined in the previous sub-sections, but also complex due to the ways shipping markets and companies are organised. Information on the performance of vessels as well as on potential measures to be implemented is often lacking. Lack of ability to monitor performance under contractual relationships creates market failures in the form agency problems, e.g. when the party that pays the fuel bill is not able to tell the difference between vessels that perform differently (Rehmatulla and Smith, 2015). Agnolucci et al. (2014) showed in a study of how only a share of savings from more energy efficient ships are accrued by the ship owner when the cargo owner pays the fuel bill.

3 METHOD

In order to fulfil the objective of this study, a combination of methods have been used including a web-based survey, in-depth interviews and literature studies. Furthermore, this study has taken advantage of the project team member´s and SSPA's in-house experience of the process of energy efficiency of ships, both in way of a range of studies made, but also from the project member´s operational experience. In addition, reference has been made to current research in the field covering recent studies on the areas investigated in this study.

The aim of the study was to identify best practices developed in the shipping industry. Therefore, the sample of shipping companies chosen for collection of data is not random. Rather the selection is information-based (Flyvbjerg, 2006): they were selected based on their renown for progressive and proactive work with energy and environmental management. As a consequence, the result from the web-based surveys and the in-depth interviews do not and are not intended to represent any statistical data representative for the whole shipping industry or for any specific ship-segment. The result from the web-based surveys and the in-depth interviews are intended to offer insights into a selection of renowned shipping companies work and experience in conjunction with the implementation of SEEMP.

A two-tier data collection strategy was chosen. First, a web-based survey was performed followed by semi-structured interviews, to further explore themes of relevance to the study.

3.1 Survey

The aim of the web-based survey was to gather data with regards to the SEEMP process during the four SEEMP stages *"planning", "implementation", "monitoring"* and *"self-evaluation and improvement"* and to identify and evaluate best practices developed in the shipping industry.

The web-based survey consisted of 48 questions in total, divided into three parts as described below;

- **Part 1** – Identification and evaluation of ***technical measures*** for optimizing the energy efficiency of existing ships (ships for which the building contract was placed before 1 January 2013) in terms of the SEEMP first three elements "planning", "implementation" and "monitoring".
- **Part 2** – Identification and evaluation of ***operational measures*** for optimizing the energy efficiency of all ships in terms of the SEEMP first three elements "planning", "implementation" and "monitoring".
- **Part 3** – Identification and evaluation of ***systems***, both manual and automated, for management and development of on-board energy efficiency optimization to support the fourth stage of the SEEMP; "self-evaluation and improvement".

The questions in the survey followed the framework and structure of the SEEMP, as introduced by resolution MEPC.213(63); *2012 Guidelines for the development of a ship energy efficiency management plan (SEEMP)*. The general aim of the questions for each stage is as follows:

- *Planning stage:* Which ship and company specific measures were contemplated by the respondents in both technical and operational terms in order to improve the energy efficiency of their vessels?
- *Implementation stage*: To what extent and also how were the contemplated measures implemented?
- M*onitoring stage*: What type of monitoring tools were used by the respondents in order to obtain a quantitative indicator of energy efficiency of a ship and/or fleet in operation, i.e. how were the results of implemented measures monitored?
- *Self-evaluation and improvement stage*: What type of systems for management and development of on-board energy efficiency optimization were the respondents using, in order to evaluate the results of the planned measures and their implementation for further development of the SEEMP?

The questions in the survey were both “closed”, where the respondents were asked to give short answers, and “open”, where the respondents could elaborate more thoroughly.

The web-based survey was sent out to high-level operational executives at 20 renowned shipping companies from each of the following ship-segments; tanker, container, ro-ro and bulk. In addition, a couple of technical management companies handling large fleets, were contacted as well, enabling input of a wide perspective on measures for various ship types. 12 written replies to the survey was received.

In order to enable subsequent follow-up interviews the respondents were asked to fill in name, position/title, company and means of contact. However, due to confidentiality reasons and commercial aspects, the findings are presented in generic terms and all respondents are treated anonymously.

It should be noted that even if all the companies contacted at the first stage did not reply in writing, the content of the survey was covered during interviews.

3.2 In-depth interviews

In order to gain a deeper understanding of how the shipping industry has optimized the implementation of SEEMP in general, as well as reaching for an enhanced understanding of the SEEMP process at the selected companies in particular, a total of 22 in-depth interviews were held with high-level operational executives at companies representing the selected segments; tanker, container, ro-ro and bulk. A couple of technical management companies handling large fleets were interviewed as well, enabling input of a wide perspective on measures for various ship types. In total, the companies contributing to this study represents a number of 2495 ships. Like the sample for the survey, the selected companies were all chosen due to their renowned focus on best practice and their high technical standard.

Some interviews were conducted in person and some by telephone and video calls, lasting for about an hour.

4 RESULT

Technical, operational, educational and other measures that have been identified and implemented by the shipping companies are listed in 4.1 to 4.5. A full list of measures can be found in the Appendix (chapter 7).

Many of the companies have also pointed out that specific individual measures are hard to state as the “best”, since the improvement of energy efficiency is an ongoing work where a multitude of technical, operational and other measures cooperate to give the final result.

Without being an exhaustive list, the best practices that have been mentioned by the participating companies are;

Technical

- Optimizing propulsion system for slow-steaming
  - Retuning of engine for lower power
  - Running vessels with CPP system at variable RPM to improve propeller and engine efficiency
  - Change of propeller/propeller blades, change of bulbous bow
- Energy saving devices (PBCF and Mewis Duct mentioned by a number of respondents)
- Performance monitoring equipment
- Electricity saving

Operational

- Voyage planning and execution, especially to keep speed as low as possible while still fulfilling charterers demands.
- Adjustment of time tables for line traffic (again to keep speed down)
- Performance monitoring to be able to see when rectifications are needed
- Optimizing transport, i.e. increase load factor, right trim, reduce ballast voyages, right speed.

Human resources development

- Motivation of all involved
- Education on general as well as specific topics
- Improved awareness in all segments of the company
- Involvement of staff

Systems for management and development

- Performance monitoring
- Development of easily understandable KPI’s for the specific vessels as well as for the fleet

More information on implemented measures is available in 4.1 to 4.5 as well as in the Appendix (chapter 7).

4.1 Technical measures

The aim of this component of the study was to identify and evaluate technical measures for optimizing the energy efficiency of existing ships (ships for which the building contract was placed before 1 January 2013) in terms of the SEEMP first three elements "planning", "implementation" and "monitoring".

Ships for which the building contract was placed after 1 January 2013 have to comply with EEDI regulations and are assumed to have considered and adopted some of the technical measures to some extent. Therefore, in this study, identification and evaluation of technical measures applies to existing ships only.

Identified technical measures

Below is a list of technical measures, divided into ship and company specific measures that have been identified by the respondents during the planning stage. See section 7.1.1 and 7.1.2 in the Appendix for further reference.

Machinery measures (ship specific)

- Monitoring systems
- Component changes
- Derating of main engine
- Engine tuning
- Frequency converters
- Enable vessel to do super slow-steaming
- Optimizing combinatory curve for CPP systems

Hull/propeller measures (ship specific)

- Polishing
- Coating systems
- Energy saving devices
- Change of bulb
- Optimized combinator curve
- Monitoring system
- New rudder
- New propellers

Fuel measures (ship specific)

- Fuel quality
- Water emulsion
- Alternative fuels like LNG or methanol

Emission abatement measures (ship specific)

- Catalysts
- Scrubbers
- LNG as fuel

Other technical (ship specific) measures

- Voyage optimization program based on weather forecasts and simulation software
- Frequency converters for fans and pumps
- LED lights
- Performance monitoring systems
- Hull and propeller monitoring systems
- Maintenance and monitoring agreements with equipment manufacturers
- Weather routeing
- Trim optimization program
- Advanced adaptive autopilot

- Becker or modified rudder
- Light weight ballast pipes
- Frequency controlled fans and pumps
- Energy management system (data logging system)
- Electrical production and consumption
- Optimized heat production and consumption
- Wind power
- Solar power
- Power factor correction
- Fuel emulsion system
- Turbocharger cut-out systems for large Main engines when slow-steaming
- Cylinder lub-oil optimization systems
- Shore side connection (OPS Onshore power supply) at longer port stays
- One vessel to be converted to use LNG as fuel

<u>Performance control hardware (company specific)</u>

- Weather routeing systems
- Adaptive auto pilot
- Voyage planning tools
- Data logging system
- Performance monitoring systems
- Ballast optimization system
- Routeing optimization system
- Trimming software
- Real time monitoring
- Automatic data collection system

<u>Other (company specific) technical measures</u>

- Boss cap fin
- Variable speed drives
- Power factor correction
- Remote monitoring of equipment
- Trim optimization program
- Converting the electrical production system that it can handling floating frequencies
- Reduce idle time of equipment as much as possible
- Appropriate use of boilers
- Fuel management system
- “Energy efficient cargo handling”
- New main dimensions as a result of wider Panama Canal.
- Design for service
- Training for officers

Implemented technical measures

Below is a list of implemented technical measures, also evaluated during the evaluation stage. See section 7.1.6 in the Appendix for further reference.

<u>(Ship specific)</u>

- Propeller Boss Cap Fins (PBCF)
- Mewis Duct
- Bulb change
- Propeller change
- Rudder change
- Mass flow meters
- Frequency converters
- Hull coatings / active selection of anti-fouling
- Follow up of hull and propeller performance trends as input to corrective maintenance and selection of fouling systems

- Follow up of main engine performance, perform relevant corrective actions
- Hull cleaning
- Propeller polishing
- Performance Monitoring
- Use of alternative fuels (LNG/Methanol…)
- Heat use and production optimization
- Variable Speed Drives
- Adaptive autopilot
- Machinery component changes and monitoring
- Main engine tuning
- Turbo-charger cut-out during slow steaming
- Hull and propeller monitoring
- Power factor correction
- Scrubber

(Company specific)

- Performance monitoring and analysis systems
- Trim optimization system
- Voyage planning system
- Shore side electricity (regular port calls)
- Shore side electricity if under repair
- Bulb change
- Propeller change
- Hull cleaning
- Solar film on cabin windows
- Frequency controlled pumps and fans
- Developed decision support tool for ballast optimization
- Fuel management system
- Speed optimization
- In-house developed and implemented performance monitoring and analysis system

Monitoring

With regard to monitoring, below listed monitoring tools are used by the respondents in order to verify savings/success in quantitative terms. See section 7.1.7 in the Appendix for further reference.

Commonly used monitoring tools used by the respondents in order to verify savings/success in quantitative terms are analysis of voyage reports, performance monitoring systems and on board measurements. A majority of the respondents stated a combination of monitoring tools.

Some respondents base their performance evaluation on noon reports, excel sheets or similar and some uses more advanced performance monitoring systems. There are also some respondents who uses performance management systems to some extent but prefers to process the data by other means such as business intelligence systems for example.

Additional information provided by the respondents regarding monitoring tools consisted of:

- Analyses of noon reports versus periodical trials and tests
- Internally developed daily reporting scheme using excel sheet
- Engine Management systems

- Voyage Analysis
- Fuel monitoring system
- Real time monitoring system
- Speed performance monitoring system
- Optimizing autopilot system
- Performance tests are performed every month at a certain load, compared with earlier results
- Important to Measure – Monitor – Implement

During the in-depth interviews the monitoring process were discussed further with the respondents. The process was described in general terms by one of the respondent as daily reporting from the vessels on fuel consumption for main engines and boilers, CO_2, NO_X and SO_X emissions. The reports were sent on a monthly basis to the company and the company reverted with trend reports to the vessels each quarter.

The importance of having reliable data input were highlighted by several respondents. Mass flow meters were one of the measures pointed out as being important to have installed in order to get accurate measurements.

Other comments expressed by several respondents during the interviews included a request for a performance monitoring system which logs all data signals automatically but provides means for the user to process and analyse the data in a system of their own in a way that is suitable for the specific user need.

The difficulty of comparing data being derived from different sea and weather conditions was highlighted as a problem by some respondents. As expressed by one of the respondents;
"…if you just sort out data from good weather, you get very little data since it is often bad weather."

4.1.1 Best practices, technical measures

Below is a short description of both ship and company specific technical measures evaluated as best practices and implemented by the shipping companies participating in the study. These measures have all been implemented on existing vessels.

Optimization of systems for changed operational pattern (mainly slow-steaming)

A number of different measures to optimize ships for changed operational patterns, normally lower speeds, have been implemented and found to be very efficient. Among these the following have been especially mentioned.

- Retuning of engine for lower power.
  The retuning (in some cases a derating of the engine, i.e. the maximum power is reduced) can improve the efficiency of the main engine considerably at the new optimization point. Normally this retuning will increase the fuel consumption at other engine loads. If a derating of the

engine is done it can further improve the situation but this will also limit the available power.

- Running vessels with CPP system at variable RPM to improve propeller and engine efficiency.
  As described in 2.2.1 a Controllable Pitch Propeller loses efficiency quite fast when the pitch is decreased. A number of companies have installed systems for making it possible to run at variable RPM and with optimum pitch. Apart from lower fuel consumption this has often also reduced sound and vibrations on-board.
- Change of propeller/propeller blades, change of bulbous bow.
  Propellers and bulbs are normally optimized for a specific speed. When changing the operational speed large gains are possible by modifying or changing these, although it is associated with large costs. A number of companies who have done these kind of alterations have found it very successful and economically viable.

Energy Saving Devices

Energy Saving Devices have been introduced on numerous vessels. A number of respondents have mentioned Propeller Boss Cap Fins and Mewis Ducts as best practices, seen as cost-effective and reducing energy consumption considerably.

Performance monitoring equipment

Systems for follow-up and/or as decision support on-board and ashore are seen as both a technical and an operational measure. Regarding the technical equipment on-board the components that have been seen as most useful and considered as best practices are fuel meters with high accuracy, shaft torque meters to measure power and logging systems to enable automatic performance data collection.

Electricity saving

The electricity consumption on-board ships vary greatly with the type of vessel. Although it is in some cases a quite small part of the energy consumption it is also one area where many respondents have seen that there are many cost-efficient solutions available. Apart from housekeeping in the form of turning of unnecessary lights, fans pumps etc. best practices has been identified in the form of frequency controlling larger consumers like fans and pumps and improving the production of electricity by running generators at the proper load.

Evaluation of technical measures

Planning phase

The evaluation during the planning phase is normally done as “desktop studies” where suggested measures are evaluated and compared regarding expected performance from technical, environmental and economical view. Information is also gathered from providers, business partners etc. to get as good as possible a picture regarding expected performance. Different solutions are then ranked and the ones fulfilling the criteria are selected for implementation.

As can be seen in the sections above a large number of technical measures have been evaluated, the list presented is not "complete" since many ideas are discarded at a very early stage and not mentioned in a study like this one.

Implementation phase

When implementing new equipment trials are normally done to assess the performance and clarify whether it is as expected from the evaluation at the planning stage. These can be done as shop trials, sea trials or real operation during a test period, sometimes with assistance by the provider. Often the tests are done on one vessel, in many cases with temporary measurement equipment installed, for later (possible) implementation on the entire fleet.

The implemented measures are also many, and the results are varying. The measures cited as "best practices" are solutions that have been mentioned by a large number of companies as successful. It has to be noted though that the results of installing different solutions is always dependent on the situation before installation. A vessel with less favourable design or operational settings may benefit more from a change than a vessel with better starting conditions. It is therefore not surprising that a solution that has been stated as very good by some respondents has been rejected by others. A thorough analysis and testing is therefore always necessary before doing changes to avoid costly mistakes.

Monitoring phase

The evaluation during normal operation, the monitoring phase, is done as part of the SEEMP. This is done to assess the long time performance of the system as well as to assure that the equipment works as planned/expected. Typically existing performance monitoring tools are used, either manual or automated ones.

4.2 Operational measures

The aim of this component of the study was to identify and evaluate operational measures for optimizing the energy efficiency of all ships in terms of the SEEMP first three elements "planning", "implementation" and "monitoring".

Identified operational measures

Below is a list of operational measures, divided into ship and company specific measures that have been identified by the respondents during the planning stage. See section 7.2.1 and 7.2.2 in the Appendix for further reference.

<u>Voyage planning (ship specific)</u>

- Speed
- ETA
- Timing
- Cargo distribution
- Weather based route optimization

<u>Voyage execution (ship specific)</u>

- Weather routeing
- Route optimization

- Trim tables
- Slow steaming
- Optimizing ballast distribution

Other (ship specific)

- Just in time
- Correct ballasting
- Voyage optimization
- Proper settings and use of auto pilot
- Efficient use of auxiliary consumers
- Reduced idle time of consumers
- Proper cargo handling with regard to energy savings

Transport arrangements (company specific)

- Charter agreements
- Choice of vessels
- Time tables
- Reduced port times

Voyage optimization (company specific)

- Adjusted speed
- Reduced ballast legs
- Filling ratio
- Trim optimization for ballast legs

Route optimization (company specific)

- Weather routeing
- Timing
- Virtual ETA

Implemented operational measures

Several of the ship and company specific operational measures identified by the respondents during the planning phase were implemented during the implementation phase. Below is a list of implemented operational measures by the respondents, divided into different areas:

See section 7.2.5 in the Appendix for further reference.

Voyage planning;

- Just in time

Voyage execution;

- Voyage optimization / Voyage optimization system
- Weather routeing / Weather routing system
- Weather routeing assistance from land-based office for the whole fleet
- Eco speed on ballast legs;
    - Extensive trials for various percentage of load. 20/30/40/50% etc. Logging of what % gives what speed, measured for each ship.

Other

- Trim optimization
- Ballast optimization
- Cargo handling
- KPI identification and regular fine tuning of KPI´s

- If the vessel is at anchor or waiting for one week, the practice is to shut down everything and run on minimum load on boilers, ME etc.

Implementation practice

The *implementation practice* regarding operational measures varies among the respondents as per below:

- During on-board awareness sessions.
- Via email to the ships.
- Operational measures are covered in the SMS and on-board checklists.
- Training courses in the office
- SEEMP presented by superintendents on-board
- In docking or during voyage/in port depending on type of measure.
- Research then implement based on ROI and cost.
- Via open dialogue and crew involvement, information given via seminars prior implementation.

Monitoring of implemented measures

With regard to monitoring of implemented operational (and technical) measures, the monitoring processes as described by the respondents are presented below. See section 7.2.6 in the Appendix for further reference.

- Use of performance monitoring systems
- Use of noon reports
- Use of noon reports and periodical tests which are monitored and processed. The conclusions are fed back ashore and on-board, eventually resulting in remedial action.
- Use of advance performance data gathering system, where the data is sent to the office for analysis using business intelligence systems.
- Analysing sister vessels for performance differences
- Comparing performance of vessels with and without energy saving devices
- Biannual SEEMP reviews and annual environmental reports
- Use of Admiralty Coefficient
- Creating upper and lower limits on baselines
- Monitor and make analysis the year around

4.2.1 Best practices, operational measures

Below is a short description of both ship and company specific operational measures evaluated as best practices and implemented by the shipping companies participating in the study.

With regard to voyage planning and execution, there are a list of measures used by the participating companies which have high potential for energy savings. The most common voyage optimization measures used by the respondents are speed optimization (slow steaming/eco speed) and reduced ballast legs. Since the energy need is very dependent on speed even small speed reductions can reduce energy consumption considerably. The speed reduction has to be balanced versus the need for delivery on time, and calls for a good voyage planning and transparency between the vessel and the vessel operator.

Agreements on slow steaming

Charter agreements regarding slow steaming, "just in time" and "Virtual ETA" are commonly strived for in order to keep speed as low as possible while still fulfilling charterers' demands. Since quite many respondents listed Virtual ETA as a route optimization measure in the web-based survey, this was further discussed during the in-depth interviews in order to find out what the practice is in the industry at the moment and if there is any indication of development and change. The findings were a bit scattered; according to one of the respondents Virtual ETA is becoming common practice and included in the C/P and considered it as an evolving process, while another respondent didn´t consider it as a standard and seldom used it. One of the respondents had noticed a difference in attitude by the charterers, where some charterers being very cooperative and open towards using Virtual ETA whilst other charterers are more hesitant.

Virtual ETA or Virtual Arrival is a process that involves an agreement to reduce a vessels speed on voyage to meet a Required Time of Arrival when there is a known delay at the discharge port. By adopting to this later arrival time the fuel consumption can in some cases be reduced considerably. The economic gain is then split between the Owner and Charterer. First tested by BP in cooperation with Maersk Tankers in 2009 (where fuel savings of 27% were reported in one case) it has later been formalized and introduced wider by Intertanko and OCIMF. Further information can for instance be found in http://www.ocimf.org/media/8874/Virtual Arrival.pdf

Decision support tools

Also, in the interviews, a number of respondents expressed that there are possibilities to optimise the operation outside formal clauses, but due to the organisation of shipping operations where different companies own, manage and operate the ships it not always clear to the different entities how their respective decisions affect the end result, and finding the optimum solution becomes hard. Weather routeing is identified as an optimization measure with regard to voyage planning and execution, and a majority of the respondents are using different types of weather routeing systems.

The use of ballast optimization programs provides a good decision support tool in order to achieve optimum trim conditions for fuel efficiency, whereas at the same time ensuring compliance with stability requirements and optimum steering conditions.

Adjustment of time tables and cargo transport factors

A best practice developed by some of the respondents involved in liner traffic, consisted of revision and adjustment of timetables in order to facilitate for as early departure as possible which could increase the allowance for reduced speed.

Best practices with regard to the cargo transport includes measures such as increasing the load factor and strive for optimized load condition (taking into consideration optimum cargo distribution, ballast and trim). Depending on vessel type and cargo to be carried, means to achieve energy efficient cargo handling differs accordingly. As a general practice, the use of auxiliary systems should be minimized in order to reduce the energy consumption.

Evaluation of operational measures

Planning phase

As with technical measures the evaluation during the planning phase is normally done as "desktop studies" where suggested measures are evaluated and compared regarding expected performance. Since the operational measures often involves connecting to other systems for data collection and data transfer the compatibility with existing administrative as well as technical systems is also very important.

Often these tools/measures can be tested without cost, therefore it is more common to do simple trials already during the planning phase. Different solutions are then ranked and the ones fulfilling the criteria are selected for implementation

As listed in the beginning of this chapter/section, the respondents identified a wide range of operational measures during the planning phase in order to improve the energy efficiency of their vessels.

As stated by many of the respondents operational measures is an area where very large savings can be achieved. Since so many different interests are involved these savings are often not fully reached, but all respondents have a process ongoing. The effectiveness is also affected and controlled by the understanding from different actors, therefore education and awareness (see section 4.4) is also very important to make operational measures effective.

Implementation phase

Experiences expressed from the implementation phase are that new systems or routines takes time, but by means of complementary training sessions and by thorough planning the implementation phase runs smoother. One respondent with an energy savings program department has lots of resources and enables support in the implementation phase.

A majority of the respondents stated that they had evaluated and/or ranked the identified operational measures for implementation in a specific manner; either by economic or environmental criteria or by a combination of these two.

The following evaluation measures were used:

- Predefined limitation of payback time
- Reduced bunker and reduced CO_2 emissions

- Fuel consumption
- Hull & Propeller condition

Monitoring

When the implementation is done and systems are in operation the evaluation of their effectiveness is to a big extent done through the systems for management and development. Specific evaluations are however done, especially regarding the "effectiveness" of the systems in view of user-friendliness, stability of installed systems, data transfer volumes etc.

4.3 Systems for management and development

The aim of this component of the study was to identify and evaluate systems, both manual and automated, for management and development of on-board energy efficiency optimization to support the SEEMP elements self-evaluation and improvement. In addition, this section includes systems and processes developed by the participating shipping companies to support continuous improvement and development of the energy efficiency plan.

Below is a list of identified systems commonly used by the participating companies for management and development of energy efficiency optimization. See section 7.3.1 in the Appendix for further reference. They have normally not been mentioned as "best practices" by the respondents but rather as important parts of the SEEMP follow-up:

- Performance monitoring systems
    - Real time monitoring
- Analysis systems
- Energy management system (ISO 50001)
- Audits
- Regular performance tests of propulsion and machinery
- Monthly reports and discussion on-board
- Experience-, exchange- and best practices program

<u>Performance monitoring</u>

The use of performance monitoring systems enables a proper analysis of performance quality and facilitates for the operator to take the right action. In addition, performance monitoring systems are useful tools in order to evaluate and discover when rectifications are needed.

The systems used vary widely. Some systems utilize the manually collected data from Noon and Voyage reports whereas other are more automated with sensors for important data being logged regularly and accumulated for analyses.

Using real time monitoring system enables direct control of energy efficiency optimization. Systems used by the respondents include fuel oil meters and fuel consumption figures and main engine parameters displayed on the bridge and in the engine control room.

The data are normally also sent ashore, in some cases this transfer is also almost real time. This makes it possible for the office to do analyses, send feedback and suggest improvements.

Analysis systems

The data gathered through the performance monitoring can be analysed in different ways. Some companies use in-house developed systems whereas others use commercially available systems, often delivered as part of the performance monitoring.

In the analysis systems Performance Indicators are normally calculated and compared both to historic data as well as trial data. If the KPI’s deviate from the expected these results are used for taking decisions on measures to improve the situation. The systems can normally also generate data for reports, both environmental and economic.

Energy Management Systems

As of today, it is quite common for many companies to have an Environmental Management System (EMS) in place under ISO 14001 and some companies also have an Energy Management System (EnMS) in place under ISO 50001. With regard to the surveyed companies, a few companies are certified according to ISO 50001 and some are working according to the standard but are not certified due to the costs involved.

One of the respondents had experience from using an Energy Management System (EnMS ISO 50001) where the SEEMP was integrated into the system. The respondent´s experience was that it facilitated the process of integrating the energy efficiency work into the company’s daily operations as well as *“making it easier to cope with what is needed to be done”,* as expressed by the respondent. Other respondents had the same approach with regard to integrating the SEEMP into a management system.

Audits

One identified, and used, way to follow-up the development of systems both on-board and ashore is audits. The results from an audit can improve the audited entity as well as spreading knowledge to others. It has been pointed out that, for maximum benefit, these audits should be done by experienced auditors (typically chief engineers and/or captains) and with the expressed objective to be an integrated part of the development work, not a control procedure.

Regular performance tests of hull and propulsion

Regular testing of main and auxiliary machinery has been a standard since a long time back to find irregularities and avoid breakdowns. By also performing regular tests on the total propulsive system, including the hull, trends can be identified and analysed. A number of companies do these tests in form of short trials during normal operation. One main question this can answer is when propeller and hull cleaning is necessary as well as identifying other problems.

Monthly reports and discussion on-board

Compiling monthly reports and discussing the reports during on-board meetings after feedback from office enables development and improvement of efficiency optimization, in addition to the important process of involving and raising the awareness of the crew.

Experience-, exchange- and best practices program

Gathering data from sister ships or on fleet basis facilitates the process of developing and improving systems for management and development of on-board energy efficiency optimization.

In order to evaluate the systems used for management and development, following means are most commonly used by the participating companies;

- Monthly review
- Regular reviews by sea staff of the procedures and the best practices
- Reported data from ship, processed in the office and discussions with the crew
- Emerging system included in the quality system
- By measuring results
- Test and follow up
- User feedback

The evaluation process requires allocation of time and resources in order to provide for adequate actions and improvement.

The outcome of most of the technical, operational and other changes are very much dependent on the people operating them. Apart from systems for management and development most companies are mentioning the importance of the participation, awareness and engagement of all involved staff. To ensure this engagement education, regular follow-up and top level interest is mentioned as critical success factors.

4.4 Human resource development

In addition to technical and operational measures; education and awareness, motivation as well as crew and management involvement are all identified and evaluated in our surveys and interviews as main success factors which lays the foundation for achieving a well-functioning work on improving energy efficiency.

Findings from both the web-based survey and the in-depth interviews shows that education and awareness are seen as crucial by a majority of the companies participating in the study. See also section 7.1.3 and 7.2.3 in the Appendix for further reference

Education and Awareness

The respondents listed a wide range of human resource development measures in connection to education and awareness. One of the listed measures evaluated as best practise consisted of increased awareness throughout the whole organization. In order to achieve increased awareness, training are to be performed at all levels and departments with regard to energy efficiency and energy management. In addition, the crew will gain an increased understanding if ad hoc on-board training are provided in using implemented (both technical and operational) "energy efficiency tools" such as the Performance Management System in an efficient way. If the crew are familiar with the systems they are supposed to use, increased motivation would be a presumable positive synergy effect from providing ad hoc training.

Involvement

Other means in order to achieve increased awareness are crew and ship management seminars where the topic is dedicated to energy efficiency as well as information campaigns regarding the SEEMP, planned energy efficiency targets, KPI´s etc.

Motivation is another area being evaluated from the result of this study as a main success factor crucial for optimization of energy efficiency. Findings from several of the in-depth interviews shows that many of the surveyed companies highlights the importance of involving the crew and exchange best practices in order to motivate their personnel in the work with energy efficiency. However, some respondents expressed that they experienced some difficulties in "*getting on-board*" the crew in the energy efficiency work, since the crew viewed it as an increased workload and administrative burden.

As can be read in section 5.1 ("*General maturity of the participating companies"*), small and large shipping companies are often managed differently. With regard to small to medium size shipping companies who often base their action on personal engagement, it is imperative to include the vessels crew in the SEEMP planning and implementation. As expressed by one of the respondent;

> *"They (the crew) have greater physical awareness of the vessels machinery and any limitations. By giving the crew ownership there is a sense of purpose and greater execution of the plan."*

Other best practices in place regarding motivation of personnel described by one of the respondents during the interviews included having a proposal committee in the company for energy efficiency measures. In order for the personnel to have an incentive for proposals, the person in question who came up with the proposal will gain from receiving a certain percentage of the corresponding savings.

Co-operation

Co-operation between ship and shore based personnel are of-course required for all shipping companies irrespective of size and management. Provision on feedback on performance was highlighted by several respondents and it plays a critical role in order to evaluate and work with continuous development to improve the ship´s energy efficiency.

The personnel onshore should facilitate for the on-board crew in order to minimize the administrative burden, a best practice therefore is to allocate adequate resources for this task. Findings from the web-based survey and the in-depth interviews shows that several companies participating in the study have performance management departments, energy saving departments, dedicated fuel efficiency manager or similar as part of their organisations. In addition some companies have appointed an Environmental Officer. Other examples given by one respondent where a voluntary appointment of an "Energy Champion" on-board.

In addition to the human resource measures listed above, one of the respondents highlighted careful planning as a "key to success".

4.5 Other measures

Goal setting is the last part of the planning element of the SEEMP. Since goal setting is voluntary it was of interest to investigate if the participating companies are setting any goals regarding the implementation of SEEMP. The result from the web-based survey shows that all respondents participating in the survey had set goals related to the implementation of SEEMP.

According to the resolution MEPC.213 (63) *"2012 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)",* adopted by IMO, the goals should be measurable and easy to understand.

The survey shows that fleet and ship specific EEOI targets are set by some respondents as well as baseline for EEOI measurement and expected improvement. Other examples of commonly set goals are reduced fuel consumption based on internally developed KPI´s. More examples of goals set by the respondents are provided in the Annex section 7.1.4 Planning stage – Goal setting (Q11).

Many companies however finds it hard to identify KPI's that really reflect the Energy Efficiency of the vessels and its development over time. External factors like weather, different load conditions and market changes are hard to incorporate in a way that makes it possible for people on-board and ashore to make correct judgements of the results. The specific areas where many respondents have asked for further development are:

- Development of easily understandable KPI's for the specific vessels as well as for the fleet
- Specific KPI's for performance monitoring

A practice regarding the target setting process was described during the in-depth interviews by one of the respondent as per below:

- First target – set as per sea trial result

- 2nd year target – set as “real” targets based on actual result
- … targets – set as new realistic targets (continuous developing)

The implementation process where evaluation of suggested energy efficiency measures are performed depends on the initiative and what kind of solution to be implemented including cost of the project and to what extent. However, based on the findings from the survey a general implementation process described by some respondents includes starting with a pilot project on one ship, continuing with evaluation of the results, thereafter followed by fleet-wide implementation depending on the result.

Implementation are followed by monitoring and findings from the survey shows that commonly used monitoring tools used by the respondents in order to verify savings/success in quantitative terms are analysis of voyage reports, performance monitoring systems and on board measurements. A majority of the respondents stated a combination of monitoring tools. Also the Energy Efficiency Operational Indicator (EEOI) was used as a monitoring tool by the respondents, but not as common as the other tools.

The importance of having reliable data input were highlighted by several respondents. Mass flow meters were one of the measures pointed out as being important to have installed in order to get accurate measurements.

5 DISCUSSION AND CONCLUSIONS

In this chapter a general discussion regarding the findings from the study is given, including a description on where the participating shipping companies stands today in their work with energy efficiency. Findings regarding drivers and barriers are being discussed and some comments are given on the SEEMP in itself as well as on upcoming regulations, i.e. the EU-MRV Regulation. Finally, main conclusions derived from the findings of the study are presented.

5.1 General maturity of the participating companies

In order to gain a deeper understanding of how the shipping industry has optimized the implementation of SEEMP, a short description of where the participating companies stand today in their work with energy efficiency is given in this section.

When analysing the outcome and findings from this study, no notable difference were found between the selected shipping segments (tanker, bulk, container and ro-ro vessels as represented by the participating shipping companies in the study) with regard to the approach towards energy efficiency. Many of the participating shipping companies have worked with improving energy efficiency for many years and views it as a part of their daily business, regardless of which shipping segments they are operating in.

This could partly be explained by the strategical selection of participating shipping companies in the study, all renowned for their progressive and proactive work with energy and environmental management. Again, it should be noted that the result of the web-based survey and in-depth interviews do not represent any statistical data representative for the whole shipping industry or for any specific ship-segment.

However, it is the authors' conclusion that increased focus and awareness regarding energy efficiency is growing in the whole shipping industry, which further could explain that there are no notable difference between shipping segments. Energy efficiency is for most actors a part of the daily business, both for environmental but also for economic reasons.

Small and large companies are often managed differently due to natural differences in the organisational structure. One of the findings from the in-depth interviews indicates that small shipping companies more often base their action on personal engagement, where specific individuals on vessels or ashore can make a big difference. On the other hand, larger shipping companies more often practice centralized management and often works with centralised systems where collected data are analysed by shore based expertise and the results including recommendations are spread to the fleet.

One of the questions being discussed during the in-depth interviews concerned if and how the implementation of the SEEMP had affected the respondents work. The findings were a bit scattered; some of the respondents stated that the SEEMP has been a trigging factor for intensifying their work with energy efficiency and that they had been more organized and formalized in their work with energy efficiency after the SEEMP was implemented, while others considered it as "business as usual" since they had worked with these issues for many years. Periodical reviews and more frequent monitoring of data were some examples of how the companies had been more organized in their work. In addition, an indication was given that all actors in the shipping business are more involved in achieving enhanced energy efficient shipping nowadays, such as Class, Charterers etc.

The finding that several companies stated that they already had a system in place when the SEEMP became mandatory and didn´t considered the implementation of SEEMP as a changing factor for their work with energy efficiency, could be explained by the fact that the participating companies are all working in a proactive manner. By having upcoming legislations in mind, such as the implementation of SEEMP, it is likely to believe that the participating companies have been preparing for the implementation in such a due time that they don´t connect their work with energy efficiency with the implementation of SEEMP.

About half of the respondents participating in the survey stated that they had updated their SEEMP since it was implemented. Updating of targets and energy efficiency measures where the most common reasons for updating the manual as well as evolving the SEEMP in a general sense by reviewing all procedures regularly and incorporate the input from the crew on-board.

5.2 Drivers and barriers

Economy is a main driver, many companies has mentioned that investments in improved energy efficiency in many cases are profitable.

The growing environmental awareness and concern is another driver, and energy efficiency is seen as a competitive advantage although most respondents state that there is almost never an economic bonus for being the best performer.

A barrier for improvement is often the relationship between ship operator, cargo owner and other involved parties. Even though there is awareness that an efficient voyage planning, including the possibility to run at lower speed, is beneficial for reducing energy consumption, the commercial set-up and responsibility issues between the different actors often hinders an optimal voyage execution.

Another barrier, connected to the first one, is the set-up of charter parties and likes. Costs and benefits for changes and improvements often fall on different actors. A typical example is when the cargo owner pays for the fuel in the charter agreement. Investments in new technology will then be a cost for the vessel owner, whereas the benefit of reduced cost for fuel is for the cargo owner.

5.3 Comments on SEEMP, EEOI, KPI´s etc.

Regarding the SEEMP in itself many of the respondents comments that they have worked with these issues for a long time, and that the introduction as such has not really affected them to a big extent. At the same time the discussions leading to the SEEMP has of course been a trigger for some companies in their work. As mentioned in section 5.1 the development and discussions within IMO was also a signal to the industry making them focus on the energy efficiency.

There are quite a number of comments asking for more hands-on guidelines, among others regarding:

- Listing of different measures and their effect. This kind of lists are presented by companies, class societies and others, a well worked through guideline from the independent IMO would be appreciated.
- The EEOI is recommended in the SEEMP guidelines as a means for assessing performance. The result of the data collection is that the EEOI is seen as a KPI more for "high level" decisions, which is not so relevant or useful for daily work on vessels and on the company level. Some companies had developed these kinds of KPI's for their operation, but many respondents are still looking for these kinds of KPI's and see a need for support.
- A number of companies would also appreciate more support in setting realistic and efficient goals for both long and short time development.

It has also been discussed previously in literature that the requirements in the SEEMP can be improved in terms of data collection and analysis.

5.4 Comments on upcoming regulations

As can be read in the Appendix (chapter 7), several of the respondents mentioned the upcoming *"EU-MRV Regulation"* during the in-depth interviews and elaborated on what the regulation will bring when the reporting requirements will come into force as of 1 January 2018.

The European Union (EU) MRV Regulation 2015/757 was adopted on 29 April 2015, in order to create an EU-legal framework on the monitoring, reporting and verification (MRV) of CO_2 emissions from the maritime transport sector. The EU-MRV Regulation aims to quantify and reduce CO_2 emissions from shipping (European Commission & Lloyd´s Register Marine, 2015). According to the European Commission´s impact assessment, the MRV Regulation is estimated to reduce CO_2 emissions by up to 2% compared with a "business as usual" situation (European Commission, 2015). The EU-MRV regulation applies to merchant ships greater than 5,000 gross tonnage (GT), irrespective of flag. Shipping companies are required to have a monitoring plan in place by 31 August 2017, for each of their ships that falls under the jurisdiction of the regulation. As of 1 January 2018, shipping companies will be required to monitor the CO_2 emissions of their vessels per voyage, for all voyages conducted into, between and out of EU ports (DNV GL, 2015).

The monitored aggregated annual CO_2 emissions, together with additional data such as cargo and energy efficiency parameters, shall be verified by an independent third-party organization and sent to a central database, presumably managed by the European Maritime Safety Agency (EMSA). The (verified) annual aggregated ship emission and efficiency data are then to be published by the European Commission on the consecutive year (DNV GL, 2015).

In May 2015, IMO´s Marine Environment Protection Committee (MEPC) held its 68th session meeting (MEPC 68), where progress was made on the development of full text for a data collection system for fuel consumption of ships, which can be readily used either for voluntary or mandatory application of the system. The purpose of the proposed data collection system is to analyse energy efficiency and the methodology for collecting the data are to be outlined in the ship specific Ship Energy Efficiency Management Plan (SEEMP). However, at this stage further considerations including transport work and/or proxies for inclusion in the data collection system and confidentiality issues are to be investigated and discussed further (IMO, 2015a).

According to Lloyd´s Register Marine (2015), the EU MRV will not be in conflict with potential future IMO regulations since the EU MRV Regulation will be adjusted in accordance with the review clause to avoid double reporting.

This is defined in Article 22 (International cooperation) in the EU-MRV Regulation 2015/757 as (EUR-Lex, 2015):

> *"In the event that an international agreement on a global monitoring, reporting and verification system for greenhouse gas emissions or on global measures to reduce greenhouse gas emissions from maritime transport is reached, the Commission shall review this Regulation and shall, if appropriate, propose amendments to this Regulation in order to ensure alignment with that international agreement."*

5.5 Conclusions

The objective of the study was to conduct a study on the optimization of energy consumption as part of implementation of a SEEMP and focus on good practice developed in the shipping industry. In this section the main conclusion drawn from the result of the study is presented.

In the field of technical measures for optimizing the energy efficiency of existing ships there are several measures available on the market that has potential to improve the energy efficiency. A wide range of technical measure are implemented by the participating shipping companies in this study, where optimization of the propulsion system for slow steaming are considered to have a major impact. Installations of Energy Saving Devices of different kinds including PBCF:s, ducts, and in some cases change of bulbous bows are other examples of technical measures highlighted in the study as well as cleaning of hull and propellers and usage of proper coatings for providing for as smooth surfaces as possible.

A conclusion drawn from the result of the study is that it is important not only to focus on the big consumers such as the main engine and the propulsion system, but also not to forget the minor consumers such as the electricity in the accommodation for example.

There is also a wide range of measures identified in the field of operational measures which are implemented by the participating shipping companies, in order to improve the energy efficiency. Reduced speed has a major impact since the energy need is very dependent on speed. Therefore, even small speed reductions can reduce energy consumption considerably. The speed reduction has to be balanced versus the need for delivery on time, and calls for a good voyage planning and transparency between the vessel and the vessel operator. Improved awareness regarding the importance of energy efficiency issues throughout the whole organisation as well as motivation, education and involvement of crew and management are all concluded as main success factor for a well-functioning work on improving energy efficiency.

With regard to systems, for management and development of on-board energy efficiency optimization to support “self-evaluation and improvement” of a SEEMP, performance monitoring systems are vital decision-support tools to enable analysis of performance quality and making it possible to take the right action. As for KPI’s, the EEOI is not seen as a sufficient KPI for the daily improvement work and some of the companies in this study has developed their own KPI’s. In addition to this many companies expressed that they would like IMO to help in developing tools for setting goals and more operative KPI’s.

The improvement of energy efficiency is an on-going work for many shipping companies, where a multitude of technical, operational and other measures co-operate to give the final result. Therefore, many of the participating shipping companies in the study pointed out that it is difficult to list specific individual energy efficiency measures as a key success factor or best practice.

One conclusion drawn from the result of the interviews is that there is no real difference between segments in how to work with energy management systems. However, there are varieties between smaller and larger companies due to organizational setups; where smaller companies relies on, and make sure to motivate, personal engagement to a bigger extent while large companies have the possibility to allocate divisions focusing merely on the SEEMP and related matters with centralised systems where collected data are analysed by shore based expertise and the results including recommendations are spread to the fleet.

Further conclusions include that all of the interviewed have a system for energy efficiency in place beside the SEEMP and most companies already had a system in place when SEEMP became mandatory, but the SEEMP has been a trigging factor for intensifying work on energy efficiency.

6 LIST OF REFERENCES

Note: There are numerous Regulations, Resolutions, Circulars, meeting documents and reports etc. published by IMO. They are not listed here, but information about them can be found at www.imo.org and at https://docs.imo.org/

Agnolucci, P., Smith, T., Rehmatulla, N., 2014. Energy efficiency and time charter rates: Energy efficiency savings recovered by ship owners in the Panamax market. Transportation Research Part A: Policy and Practice 66, 173-184.

Bertram, K.M., Saricks, C., 1981. Summary of international maritime fuel-conservation measures. Argonne National Lab., IL (USA).

DNV-GL, 2014. Energy management study 2014.

DNV-GL, 2015. Energy management study 2015.

DNV GL (2015). *EU-MRV Regulation*. Retrieved 2015-12-10 from https://www.dnvgl.com/maritime/mrv-regulation.html

EUR-Lex (2015). *Regulation (EU) 2015/757 of the European Parliament and of the Council of 29 April 2015 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending Directive 2009/16/EC.* Retrieved 2015-12-10 from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2015.123.01.0055.01.ENG

European Commission (2015). *Reducing emissions from the shipping sector.* Retrieved 2015-12-07 from http://ec.europa.eu/clima/policies/transport/shipping/index_en.htm

Faber, J., Eyring, V., Selstad, E., Kågeson, P., Lee, D.S., Buhaug, O., Lindstad, H., Roche, P., Graichen, J., Cames, M., Schwarz, W., 2009. Technical support for European action to reducing Greenhouse Gas Emissions from international maritime transport. CE Delft.

Flyvbjerg, B., 2006. Five misunderstandings about case-study research. Qualitative Inquiry 12, 219-245.

IMO (2015a). Marine Environment Protection Committee (MEPC), 68th session, 11 to 15 May 2015. Retrieved 2015-12-10 from http://www.imo.org/en/MediaCentre/MeetingSummaries/MEPC/Pages/MEPC-68th-session.aspx

Intertanko&OCIMF, 2011. Virtual Arrival - Optimising Voyage Management and Reducing Vessel Emissions - an Emissions Management Framework, http://www.ocimf.org/media/8874/Virtual Arrival.pdf

IVL, SSPA and Chalmers (2013). Energy efficiency in Swedish Shipping. (Energieffektiv svensk sjöfart)

Jasper Faber, Maarten 't Hoen, 2015. Historical trends in ship design efficiency. Delft, CE Delft.

Johnson, H., Johansson, M., Andersson, K., Södahl, B., 2013. Will the ship energy efficiency management plan reduce CO_2 emissions? A comparison with ISO 50001 and the ISM code. Maritime Policy & Management 40, 177-190.

Lloyd´s Register Marine (2015). *EU MRV LR Guidance*. Retrieved 2015-12-09 from http://www.lr.org/en/_images/213-57004_LR_EU_MRV_Guidance_v4_0_-_May_2015.pdf

Maddox Consulting, 2012. Analysis of market barriers to cost effective GHG emission reductions in the maritime transport sector. CLIMA.B.3/SER/2011/0014. European Commission, Brussels.

Poulsen, R.T., Johnson, H., 2016. The logic of business vs. the logic of energy management practice: understanding the choices and effects of energy consumption monitoring systems in shipping companies. Journal of Cleaner Production 112, 3785-3797.

Poulsen, R.T., Sornn-Friese, H., 2015. Achieving energy efficient ship operations under third party management: How do ship management models influence energy efficiency? Research in Transportation Business & Management 17, 41-52.

Rehmatulla, N., Smith, T., 2015. Barriers to energy efficiency in shipping: A triangulated approach to investigate the principal agent problem. Energy Policy 84, 44-57.

Singapore Registry of Ships (2015). *Incentive Schemes. Green Ship Programme.* Retrieved 2015-12-03 from http://www.srs.sg/register-with-srs/incentive-schemes

7 APPENDIX

In this section the results from the web-based survey and the in-depth interviews are being presented.

7.1 PART 1 - IDENTIFICATION AND EVALUATION OF TECHNICAL MEASURES

Ships for which the building contract was placed after 1 January 2013 have to comply with EEDI regulations and are assumed to have considered and adopted some of the technical measures to some extent. Therefore, it was clearly stated in the web-based survey that Part 1 applies to existing ships; i.e. ships for which the building contract was placed before 1 January 2013.

7.1.1 Planning stage - Ship specific technical measures (Q1-Q5)

With regard to the ***"planning"*** element of SEEMP, five questions in the survey were related to ***ship specific technical measures*** that have been identified by the respondents during the planning stage in order to improve the energy efficiency of their vessels. The questions were as follows:

- Q1. Have you identified any ship specific ***machinery*** measures that you think can improve the energy efficiency of your vessels?
- Q2. Have you identified any ship specific ***hull/propeller*** measures that you think can improve the energy efficiency of your vessels?
- Q3. Have you identified any ship specific ***fuel*** measures that you think can improve the energy efficiency of your vessels?
- Q4. Have you identified any ship specific ***emission abatement*** measures that you think can improve the energy efficiency of your vessels?
- Q5. Have you identified any ***other*** technical ship specific measures that you think can improve the energy efficiency of your vessels?

The most common measures with regard to *machinery measures* were monitoring systems and component changes. Other listed measures were derating of main engine, engine tuning, frequency converters, enable vessel to do super slow-steaming and optimizing combinator curve for CPP systems.

With regard to hull/propeller measures, the most common measures were polishing, coating systems and energy saving devices. Other listed measures were change of bulb, optimized combinator curve, monitoring system, new rudder and new propellers.

Findings from the in-depth interviews indicates that hull and propeller cleaning are prioritized measures by several of the respondents. Hull and propeller cleaning are performed at least once a year according to a vast majority of the respondents, some even states that propeller polishing are performed every 6 months. According to one of the respondents, hull and propeller cleaning is performed after one month at anchor.

A slight indication was given by some respondents that dry docking intervals appears more frequently, one respondent stated every 3rd year.

Fuel measures identified by several respondents consisted of fuel quality and alternative fuels like LNG or methanol. Water emulsion was listed by one respondent.

During the follow up in-depth interview the work with water emulsion was discussed further with one of the respondents. It had been tested a couple of times with different results and were currently under investigation on one vessel.

Only a few respondents listed *emission abatement measures*. Measures listed were catalysts, scrubbers and LNG as fuel

All respondents listed examples of *other technical ship specific measures* that they had identified during the planning stage, covering a wide range of measures. The listed measures are given below:

- Voyage optimization program based on weather forecasts and simulation software
- Frequency converters for fans and pumps.
- LED lights
- Performance monitoring systems
- Hull and propeller monitoring systems
- Maintenance and monitoring agreements with equipment manufacturers
- Weather routeing
- Trim optimization program
- Advanced adaptive autopilot
- Becker or modified rudder
- Light weight ballast pipes
- Frequency controlled fans and pumps
- Energy management system (data logging system)
- Electrical production and consumption
- Heat production and consumption
- Wind power
- Solar power
- Power factor correction
- Fuel emulsion system
- Turbocharger cut-out systems for large Main engines when slow-steaming
- Cylinder lub-oil optimization systems
- Shore side connection (OPS Onshore power supply) at longer port stays
- One vessel to be converted to use LNG as fuel

One respondent stated that several other technical measures had been evaluated but not implemented due to a very long return of investment. Examples of these technical measures stated by the respondent during the in-depth interview were Mewis Duct, bulb and propeller change.

7.1.2 Planning stage - Company specific technical measures (Q6-Q7)

With regard to the ***"planning"*** element of SEEMP two questions in the survey were related to ***company specific technical measures*** that have been identified by the respondents during the planning stage in order to improve the energy efficiency of their vessels. The questions were as per below:

- Q6a. Have you ***identified the need for any performance control hardware*** that you think can improve the energy efficiency of your vessels?
- Q6b. If yes in question 6a, please elaborate.
- Q7. Have you identified any other company specific technical measures that you think can improve the energy efficiency of your vessels?

A majority of the respondents stated yes to the question whether that they had *identified the need for any performance control hardware*. In the follow-up question the respondents were asked to elaborate on performance control hardware identified and a majority stated weather routeing systems and two respondents stated adaptive auto pilot.

Other performance control hardware listed by the respondents consisted of different voyage planning tools, Energy Management System (data logging system), performance monitoring systems, ballast optimization system, routeing optimization system, trimming software, real time monitoring and automatic data collection system.

A majority of the respondents listed examples of *other technical company specific measures* that they had identified during the planning stage, covering a wide range of measures. The listed measures are given below:

- Mewis duct
- Boss cap fin
- Variable speed drives
- Power factor correction
- Remote monitoring of equipment
- Trim optimization program
- Converting the electrical production system that it can handling floating frequencies
- Reduce idle time of equipment as much as possible
- Appropriate use of boilers
- Fuel management system
- “Energy efficient cargo handling
- New main dimensions as a result of wider Panama Canal.
- Design for service
- Training for officers

7.1.3 Planning stage - Human resource development (technical measures) (Q8-Q10)

With regard to the ***"planning"*** element of SEEMP, three questions in the survey were related to (technical) ***human resource development*** measures that have been identified by the respondents during the planning stage in order to improve the energy efficiency of their vessels. The questions were as per below:

- Q8a. Have you identified any specific skills to search for during ***recruiting of personnel*** that you think can improve the energy efficiency of your vessels?

- Q8b. If yes in Q8a, please specify what type of skills and for which personnel (on-board/ashore and position).
- Q9. Have you identified any human resource development measures concerning ***education*** that you think can improve the energy efficiency of your vessels? (Please define what type of education and who the contemplated participants where (position in the company).)
- Q10. Have you identified any ***other*** human resource development measures that you think can improve the energy efficiency of your vessels?

Only a few respondents stated that they had identified any specific skills to search for during recruiting in relation to improvement of energy efficiency of their vessels. Some of the skills specified consisted of IT skills for measuring, data collection, monitoring and analysis. In addition, communication skills in order to increase awareness were highlighted. Other comments concerned previous experience from the specific vessel type.

One respondent stated that a Fuel Efficiency Manager were working within the company and that they educate and train their crew members.

When it comes to education, a majority of the respondents stated several measures concerning education being identified during the planning stage. The most common measures were basic understanding of SEEMP, company environmental management system, company environmental policy, energy management course, company environmental procedures and company philosophy. Also environmental and energy indices were mentioned by some respondents.

Other human resource development measures highlighted by the respondents concerned awareness, which was mentioned by several respondents. Both energy awareness and commitment in general throughout the whole organisation were mentioned, which, according to one of the respondents, will lead to increased focus on energy efficiency and most likely improved energy efficiency. Besides awareness, training were highlighted by the respondents.

Findings from the in-depth interviews indicated a need to understand new technology which in turn requires training and education on the technical systems to be implemented on-board.

7.1.4 Planning stage - Goal setting (Q11)

According to the resolution MEPC.213 (63) *"2012 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP"),* adopted by IMO;

> […] *"It should be emphasized that the goal setting is voluntary, that there is no need to announce the goal or the result to the public, and that neither a company nor a ship are subject to external inspection. The purpose of goal setting is to serve as a signal which involved people should be conscious of, to create a good incentive for proper implementation, and then to increase*

commitment to the improvement of energy efficiency. The goal can take any form, such as the annual fuel consumption or a specific target of Energy Efficiency Operational Indicator (EEOI). Whatever the goal is, the goal should be measurable and easy to understand."

As clearly stated in MEPC.213 (63), the goal setting is voluntary. It was therefore of interest to include the following questions in the survey:

- Q11a. Have you set any goals regarding the implementation of SEEMP?
- Q11b. If YES in Q11a; please elaborate on planned goal settings.

All respondents stated yes to the question related to if any goals had been set regarding the implementation of SEEMP. When asked to elaborate on planned goal setting following information were provided:

- Fleet and ship specific EEOI targets.
- Set baseline for EEOI measurement and expected improvement.
- Best practice / Experience exchange cases to be distributed.
- Reduced consumption based on internally developed KPI's.
- Use of ISO 50001 Energy Management System with internally developed KPI's named Energy Performance Indicators (EnPI´s). The main one is to run at slow steaming based on a company elaborated slow steaming program where costs are weighed in.
- EnPI's: both the kg/nm and the kWh/nm shall not be allowed to become more than 10% higher than baseline in good weather.
- 2, 5 % reduced fuel consumption compared to previous year.
- A combined technical and operational target.
- We have specific yearly targets set for our baselines.
- Continuous developing.
- Number of sea staff members to have completed Energy Awareness sessions.

Goal setting was discussed further during the in-depth interviews. A practice regarding target setting process was described by one of the respondent as per below:

- First target – set as per sea trial result
- 2nd year target – set as "real" targets based on actual result
- … targets – set as new realistic targets (continuous developing)

Another respondent explained their target setting process as each ship having a ship specific SEEMP with ship specific energy efficiency targets which were reviewed every quarter. At the end of the year another review was performed of individual targets for each ship.

7.1.5 Planning stage – Evaluation (Q12-13)

Two questions in the survey were related to evaluation of technical measures, see below:

- Q12a. Evaluation of suggested measures (Are the measures listed above (ship specific/company specific/human resource development) evaluated or ranked for implementation in any specific manner?)
- Q12b. If YES in Q12a; what are the main criteria used for the evaluation/ranking?
- Q13. Please add additional information regarding how you evaluated and/or ranked your planned measures.

A majority of the respondents stated that they had evaluated and/or ranked listed technical measures for implementation in a specific manner such as environmental and/or economical. Most of the respondents stated both environmental and economical as the main criteria used for the evaluation, only a few respondents stated only economical or only environmental as the main criteria.

Additional information provided by the respondents regarding their evaluation process concerned payback periods and performing cost-benefit-analysis with regard to implementing the measures that generates the greatest environmental and economical savings to the lowest cost. In addition, commercial and operational factors such as docking and sailing schedules have to be taken into consideration before implementing planned measures.

An example of a very straightforward evaluation process were given by one of the respondents, namely the use of a simple energy efficiency impact and implementation chart showing required effort/cost level in relation to achieved energy efficiency. Different measures are put into the matrix which facilitates investment decisions, see figure 2.

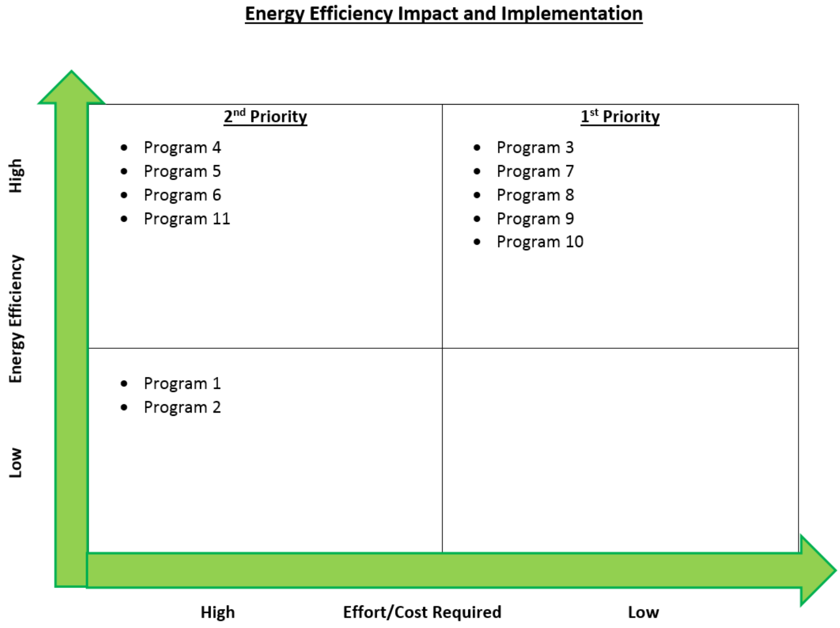


Figure 2. Energy efficiency impact and implementation chart

(Northern Marine Management Ltd.)

7.1.6 Implementation stage (Q14-Q18)

The respondents were asked to describe their implementation process of technical measures as per the questions below:

- Q14. What ***ship specific technical measures*** were implemented?
- Q15. What ***company specific technical*** measures were implemented?
- Q16. What ***(technical) human resource development*** measures were implemented?
- Q17. ***How*** were the technical measures/solutions implemented?
- Q18. ***What are the experiences*** from the implementation phase?

Implemented ***ship*** *specific technical measures* identified during the planning stage and evaluated during the evaluation stage consisted of a wide range of technical measures listed by the respondents, see list below:

- Propeller Boss Cap Fins (PBCF)
- Mewis Duct
- Bulb change
- Propeller change
- Rudder change
- Mass flow meters
- Frequency converters
- Hull coatings / active selection of anti-fouling
- Follow up of hull and propeller performance trends as input to corrective maintenance and selection of fouling systems
- Follow up of main engine performance, perform relevant corrective actions
- Hull cleaning
- Propeller polishing

- Performance Monitoring
- Use of alternative fuels (LNG/Methanol…)
- Heat use and production optimization
- Variable Speed Drives
- Adaptive autopilot
- Machinery component changes and monitoring
- Main engine tuning
- Turbo-charger cut-out during slow steaming
- Hull and propeller monitoring
- Power factor correction
- Scrubber

During the in-depth interviews, a discussion was held regarding possible savings due the Propeller Boss Cap Fins (PBCF) with the respondents who had contemplated this measure or already had installed PBCF on their vessels.

One respondent stated that the result should be 3 % improvement according to the "believers", however their experience shows 0.1 knot speed improvement at the same bunker consumption. Another respondent stated 5-7% less consumption.

Implemented ***company*** *specific technical measures* identified during the planning stage and evaluated during the evaluation stage consisted of a wide range of technical measures listed by the respondents, see list below;

- Performance monitoring and analysis systems
- Trim optimization system
- Voyage planning system
- Shore side electricity (regular port calls)
- Shore side electricity if under repair
- Bulb change
- Propeller change
- Hull cleaning
- Solar film on cabin windows
- Frequency controlled pumps and fans
- Developed decision support tool for ballast optimization
- Fuel management system
- Speed optimization
- In-house developed and implemented performance monitoring and analysis system

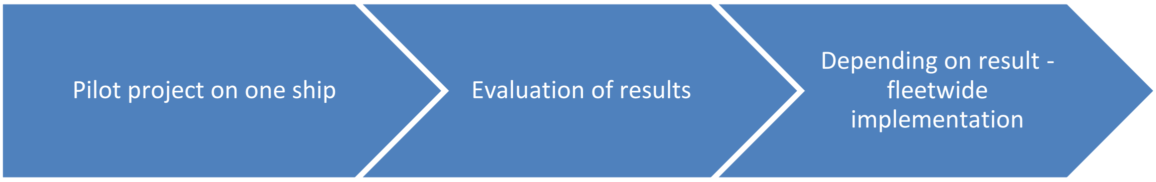
Listed implemented (technical) *human resource development measures* identified during the planning stage and evaluated during the evaluation stage by the respondents consisted of;

- Increasing awareness through energy management and SEEMP training (superintendents, senior officers, crew)
- Performance Management department / Energy savings department / Fuel Efficiency Manager
- Crew training
- Seminars
- Integrated training and awareness campaign across the fleet

- Focused campaigns on reducing consumption through operational measures. Information to officers.
- E-learning (SEEMP, Environment)
- ISO 50001 training

When asked *how the technical measures/solutions were implemented* the response from the respondents were quite diversified. By nature, the implementation process depends on the initiative and what kind of solution to be implemented including cost of the project and to what extent.

A general implementation process described by some respondents could be outlined as;



Below is a list of comments regarding the implementation process as expressed by the respondents:

- On a trial basis on one ship before fleet wide implementation.
- Tested on individual ships, if results are positive then installation on sister vessels and so on.
- Depending on solution. Some projects are test installation and trials and some are fleet wide.
- Depending of the cost of the project, we first evaluate the possible upside, perform an analysis, possible CFD and tank tests before we go ahead with a pilot project on one ship. Then we evaluate the results and consider implementation on other sips.
- Voyage optimization & weather routing : across the fleet on all ships
- PBCF's on selected ships depending the commercial concept, e.g. Time Charter or Spot charter
- Training and awareness sessions: on all ships
- Trim optimization program: on selected ships only, depending on the number of sister ships
- Vessels Crew and Vessel Manager are responsible for developing the SEEMP and implementation
- Sea trials
- Depending of the cost of the project, we first evaluate the possible upside, perform an analysis, possible CFD and tank tests before we go ahead with a pilot project on one ship. Then we evaluate the results and consider implementation on other sips.
- Use of data logging system
- Depending on initiative

The response from the respondents regarding *the experience from the implementation phase concerning technical measures* could be summarized as expressed by one of the respondents; "*challenging, positive, and exciting*".

Other comments from the respondents included:

- Good feedback from the vessels and proactive personnel.
- It is very important to analyse and perform tests before any decision is made. What some suppliers "promise" is not always reflected once implemented.
- All ships which were audited for the ISO 50001 certification passed the test successfully, and Certificate issued.
- Installations are always more costly than expected.
- A decrease in bunker consumption of about 10-20% as a result from optimizing the settings of the CPP system (in connection with installing a system for operating the shaft generator with floating frequency).
- Energy target fulfilled every year.
- Many projects have been implemented on several vessels.
- Depending on initiative.
- Improvement not quantified yet.

7.1.7 Monitoring stage (Q19)

With regard to monitoring, the respondents were asked to answer following questions:

- Q19a. What ***type of monitoring tools*** were used in order to ***verify savings/success in quantitative terms?***
- Q19b. Please add additional information regarding monitoring tools.

Commonly used monitoring tools used by the respondents in order to verify savings/success in quantitative terms are analysis of voyage reports, performance monitoring systems and on board measurements. A majority of the respondents stated a combination of monitoring tools. Also Energy Efficiency Operational Indicator (EEOI) were used as a monitoring tool by the respondents, but not as common as the other tools.

Some respondents base their performance evaluation on noon reports, excel sheets or similar and some uses more advanced performance monitoring systems. There are also some respondents who uses performance management systems to some extent but prefers to process the data by other means such as business intelligence systems for example.

Additional information provided by the respondents regarding monitoring tools consisted of:

- Analyses of noon reports versus periodical trials and tests
- Internally developed daily reporting scheme using excel sheet.
- Engine Management systems

- Voyage Analysis
- Fuel monitoring system
- Real time monitoring system
- Speed performance monitoring system
- Optimizing autopilot system.
- Performance tests are performed every month at a certain load, compared with earlier results.
- Important to Measure – Monitor – Implement

During the in-depth interviews the monitoring process were discussed further with the respondents. The process was described in general terms by one of the respondent as daily reporting from the vessels on fuel consumption for main engines and boilers, CO_2, NO_X and SO_X emissions. The reports were sent on a monthly basis to the company and the company reverted with trend reports to the vessels each quarter.

The importance of having reliable data input were highlighted by several respondents. Mass flow meters were one of the measures pointed out as being important to have installed in order to get accurate measurements.

Other comments expressed by several respondents during the interviews included a request for a performance monitoring system which logs all data signals automatically but provides means for the user to process and analyse the data in a system of their own in a way that is suitable for the specific user need.

The difficulty of comparing data being derived from different sea and weather conditions was highlighted as a problem by some respondents. As expressed by one of the respondents;

> *"…if you just sort out data from good weather, you get very little data since it is often bad weather."*

7.2 PART 2 - IDENTIFICATION AND EVALUATION OF OPERATIONAL MEASURES

It was clearly stated in the web-based survey that Part 2 applies to all ships. The discussions held during the in-depth interviews concerned all ships as well.

7.2.1 Planning stage – Ship specific operational measures (Q20-Q22)

With regard to the ***"planning"*** element of SEEMP three questions in the survey were related to ***ship specific operational measures*** that have been identified by the respondents during the planning stage in order to improve the energy efficiency of their vessels. The questions were as follows:

- Q20. Have you identified any ship specific ***voyage planning*** measures that you think can improve the energy efficiency of your vessels?

- Q21. Have you identified any ship specific ***voyage execution*** measures that you think can improve the energy efficiency of your vessels?
- Q22. Have you identified any ***other*** ship specific operational measures that you think can improve the energy efficiency of your vessels?

A majority of the respondents listed speed, ETA and timing as *voyage planning* measures. In addition, cargo distribution were listed by some respondents. One respondent listed weather based route optimization.

The process of voyage planning were discussed during the in-depth interviews. According to one of the respondents the vessel provides the operator with data, which then falls back to further discussions with charterers.

With regard to *voyage execution* a majority of the respondent's stated both weather routeing and route optimization. Other listed measures were trim tables, slow steaming and optimizing ballast distribution.

Other ship specific operational measures identified during the planning stage by the respondents were just in time, correct ballasting, voyage optimization and proper settings and use of auto pilot. In addition, other measures listed by the respondents were efficient use of auxiliary consumers, reduced idle time of consumers and proper cargo handling with regard to energy savings. One respondent stated that they had wind energy under research.

7.2.2 Planning stage – Company specific operational measures (Q23-Q30)

With regard to the ***"planning"*** element of SEEMP seven questions in the survey were related to ***company specific operational measures*** that have been identified by the respondents during the planning stage in order to improve the energy efficiency of their vessels. The questions were as follows:

- Q23. Have you identified any company specific ***transport arrangement*** measures that you think can improve the energy efficiency of your vessels?
- Q24. Have you identified any company specific ***voyage optimization*** measures that you think can improve the energy efficiency of your vessels?
- Q25. Have you identified any company specific ***route optimization*** measures that you think can improve the energy efficiency of your vessels?
- Q26a. Have you identified any company specific measures concerning ***definitions of KPI´s*** that you think can improve the energy efficiency of your vessels?
- Q26b. If YES in Q26a; please ***elaborate on KPI's used***.
- Q27. Have you contemplated ***logging of vessel data in order to set/use KPI´s for trend analysis*** that you think can improve the energy efficiency of your vessel?
- Q28. ***Long term trends***: do you have any ideas about how to analyse vessel data to be able to identify when remedial action is needed?
- Q29. Have your ***company implemented any company specific criteria regarding vessel data/KPI´s*** that has been identified to improve the energy efficiency of your vessel?

- Q30. Have you identified any ***other*** company specific operational measures that you think can improve the energy efficiency of your vessels?

Company specific operational measures concerning *transport arrangements* listed by some respondents consisted of charter agreements and choice of vessels. A few respondents listed time tables and one respondent listed reduced port times.

Charter agreements were discussed during several of the in-depth interviews. One respondent stated that various contracts stipulated possibilities to operate efficiently, but instead the company discussed with the charterers about speed and consumption agreements.

Adjusted speed and reduced ballast legs are the most common *voyage optimization* measures listed by the respondents. Some respondents listed filling ratio and trim optimization for ballast legs.

With regard to *route optimization* a majority of the respondents listed weather routeing and few respondents listed timing. In addition, quite a number of the respondents listed Virtual ETA.

Since quite many respondents listed *Virtual ETA* as a route optimization measure, this was further discussed during the in-depth interviews in order to find out what the practice is in the industry at the moment and if there is any indication of development and change. The findings were a bit scattered; according to one of the respondents Virtual ETA is becoming a “standard practice” which is included in the C/P and considered it as an evolving process, while another respondent didn´t consider it as a standard and seldom used it. An indication was given towards a change and development for some charterers being very cooperative and open towards using Virtual ETA whilst other charterers are more hesitant. One respondent stated that Virtual ETA was used for T/C voyages for one of their charterers.

About half of the respondents stated that they had identified company specific measures concerning *definitions of KPI´s*. When asked to elaborate on KPI´s used, following information were stated by the respondents:

- EEOI
- Deviation from benchmark/baseline (based on sea trial data or similar)
- If looking at the benchmark curve – only input data for good weather in order to have a trend
- Deviation from benchmark line, were every noon report is taken into account, filtered and sorted depending on weather conditions.
- TCP Performance requirements
- Fleet emissions
- Hull & Propeller performance index
- Main engine performance index
- Oil fuelled boiler performance index

- Bunker consumption per trip
- Bunker consumption per nautical mile
- Nautical miles per ton
- Speed vs. consumption
- Speed vs. minimum power
- Yearly bunker reduction in percentage
- Want to know the performance on a daily basis (gap)
- KPI´s are adjusted from time to time

Definitions of KPI´s and the EEOI were discussed further during some of the in-depth interviews. An indication was given by several respondents that EEOI was considered more of a calculation than a useful tool and did not consider the EEOI as a particularly good KPI since it was perceived difficult to interpret the figures in terms of what level it corresponds to. The EEOI seemed to be used more on a company level than on a ship specific level.

A majority of the respondents stated that they had contemplated *logging of vessel data in order to set/use KPI`s for trend analysis*. In terms of analysing the vessel data and look at long term trends in order to be able to identify when remedial action is needed the practices varies among the respondents. A list of identified practices are given below:

- Use of advanced performance monitoring systems
- Use of basic analysis tools developed in-house
- Use of “Admiralty Coefficient”
- Comparing speed vs. main engine consumption, speed vs. power, power vs. consumption
- Monthly performance tests
- Trending the deviation from benchmark in order to decide on correct timing for in water cleaning and propeller polishing.

A gap was identified by one of the respondents in order to find a monitoring system that has the ability to filter out the effects of wind and sea state in a credible way.

*Company specific criteria regarding vessel data/KPI´*s were widely implemented among the respondents.

Other comments expressed by the respondents regarding company specific operational measures included:

- Implementing fleet EEOI target.
- Having a structured communication scheme with the charterers in order to enhance the instructions to the vessels and avoid ambiguity.
- Looking at port vs. sea ratio in order to minimise time spent in port.
- Reducing the use of light switched on 24/7.

- Applying new type of coating (50% more expensive, but gives less consumption (no figure on anticipated reduction))

7.2.3 Planning stage – Human resource development (operational measures) (Q31-Q33)

Following questions in the survey were related to human resource development with regard to operational measures in the planning stage:

- Q31. Have you identified any human resource development measures concerning ***education*** that you think can improve the energy efficiency of your vessels?
- Q32. Have you identified any human resource development measures concerning ***motivation of personnel*** that you think can improve the energy efficiency of your vessels?
- Q33. Have you identified any ***other*** human resource development measures that you think can improve the energy efficiency of your vessels?

Education concerning company goals and visions was listed by all of the consulted respondents in the survey. A majority of the respondents stated education concerning KPI´s and quite a number stated software as an education measure. Other educational measures covered CBT training on board as well as seminars and courses.

Feedback and bonus systems are practices commonly used by the respondents in order to *motivate their personnel*. According to indications from the in-depth interviews, it is difficult to get a fair bonus system.

Other practices in place regarding motivation of personnel described by one of the respondents during the interviews included having a proposal committee in the company for energy efficiency measures. In order for the personnel to have an incentive for proposals, the person in question who came up with the proposal will gain from receiving a certain percent of the corresponding savings.

Findings from several of the in-depth interviews shows that many of the surveyed companies highlights the importance of involving the crew and exchange best practices in order to motivate their personnel in the work with energy efficiency.

Some respondents expressed that they experienced some difficulties in “getting on-board” the crew in the energy efficiency work, since the crew viewed it as an increased workload and administrative burden.

Other comments regarding human resource development measures stated by the respondents in the web-based survey included:

- Training
- Involvement of crew members and provision of feedback on performance.
- EEOI target to be anchored high up in the organisation, in order to ensure focus on all levels.
- Voluntarily appointment of an “Energy Champion” (on-board).

7.2.4 Planning stage – Evaluation (Q34-Q35)

The survey included following questions regarding evaluation of operational measures identified during the planning stage:

- Q34a. Evaluation of suggested measures - are the (operational) measures listed above evaluated and/or ranked for implementation in any specific manner?
- Q34b. If YES in Q34a; what are the main criteria used for the evaluation/ranking?
- Q35. Please add additional information regarding how you evaluated and/or ranked your planned measures.

A majority of the respondents stated that they had evaluated and/or ranked the identified operational measures for implementation in a specific manner. A combination of environmental and economical criteria's were stated by several respondents as the main criteria used for evaluation and/or ranking. Either economic or environmental were equally distributed by the remaining respondents.

Additional information provided by the respondents regarding the evaluation/ranking process consisted of:

- Predefined limitation of payback time
- Reduced bunker and reduced CO2 emissions
- Fuel consumption
- Hull & Propeller condition

7.2.5 Implementation stage (Q36-Q40)

The respondents were asked to describe their implementation process of operational measures as per the questions below:

- Q36. What ship specific operational measures where implemented?
- Q37. What company specific operational measures where implemented?
- Q38. What human resource development operational measures where implemented?
- Q39. How were the operational measures implemented?
- Q40. What are the experiences from the implementation phase?

Several of the *ship and company specific operational measures* identified by the respondents during the planning phase were implemented during the implementation phase. Below is a list of implemented measures by the respondents, divided into different areas:

- Voyage planning;
    - Just in time
- Voyage execution;
    - Voyage optimization / Voyage optimization system

- Weather routeing / Weather routing system
- Weather routeing assistance from land-based office for the whole fleet.
- Eco speed on ballast legs;
    - Extensive trials for various percentage of load. 20/30/40/50% etc. Logging of what % gives what speed, measured for each ship.

- Other;
    - Trim optimization
    - Ballast optimization
    - Cargo handling
    - KPI identification and regular fine tuning of KPI´s
    - If the vessel is at anchor or waiting for one week, the practice is to shut down everything and run on minimum load on boilers, ME etc.

Other comments from one of the respondents included findings with regard to officers reluctant to change their plans according to suggestions from decision support tools such as weather routeing systems. Other issues pointed out by some respondents concerned commercial and operational constrains due to Charter requirements.

One of the areas identified during both the survey and the in-depth interviews were the importance of involving the crew and raising the awareness regarding energy efficiency throughout the whole organisation. This is reflected from the answers regarding implemented *human resource development measures* listed under different areas as per below:

- Education;
    - Awareness training at various occasions such as crew introduction prior joining the vessel, crew conferences, on board training by riding coach.
    - Focused information campaigns.
    - CBT Training
    - Energy management training
    - Senior Officers holds a course in fuel efficiency
    - Senior Officers participate in an energy management course
    - One person is working full time with internal training, visits all vessels in the fleet.
    - Training is performed at all levels/departments; including operations, purchase, travelling etc.
    - Crew receives training in the Performance Management System
    - Information regarding SEEMP and planned targets
    - Perform training on-board
- Motivation of staff;
    - Reward system
    - Proposal committee

    - Energy efficiency competition
    - Plaque for the most energy efficient vessel in her class.
- Other;
    - Topic on senior conference
    - Ship management conference
    - Yearly targets

The *implementation practice* regarding operational measures varies among the respondents as per below:

- During on-board awareness sessions.
- Via email to the ships.
- Operational measures are covered in the SMS and on-board checklists.
- Training courses every 6 months in the office
- SEEMP presented by superintendents on-board
- In docking or during voyage/in port depending on type of measure.
- Research then implement based on ROI and cost.
- Via open dialogue and crew involvement, information given via seminars prior implementation.

The *experience* expressed by some of the respondents *from the implementation phase* indicates that changing attitudes takes time and that it sometimes could be difficult to get the crew involved due to lack of time and interest. On the other hand, other respondents stated that the crew are very pro-active in the planning and implementation. Several respondents stated that an in-depth implementation of projects takes long time. Other comments from the respondents included good experiences, no big issue, that it depends on the initiative to be implemented and that there had been some technical difficulties to implement some projects,

A best practice suggested by one of the respondents in order to facilitate the implementation process were to include complementary ad hoc superficial training sessions. One of the respondents stated that the company focuses on these issues and therefore has lots of resources thanks to their energy savings program department. Another example of best practices expressed by one of the respondents was that *"planning is a key to success".*

7.2.6 Monitoring stage (Q41)

In question 41 the respondents were asked to *describe the monitoring process of implemented measures in qualitative and quantitative terms*. The results are listed below:

- Use of performance monitoring systems
- Use of noon reports

- Use of noon reports and periodical tests which are monitored and processed. The conclusions are fed back ashore and on-board, eventually resulting in remedial action.
- Use of advance performance data gathering system, where the data is sent to the office for analysis using business intelligence systems.
- Analysing sister vessels for performance differences
- Comparing performance of vessels with and without energy saving devices
- Six months SEEMP reviews and annual environmental reports
- Use of Admiralty Coefficient
- Creating upper and lower limits on baselines
- Monitor and make analysis the year around

During one of the in-depth interviews the process of monitoring eco speed on ballast legs was described by the respondent. Extensive trials for various percentage of load such as 20/30/40/50% etc. had been performed and data regarding what load percentage gives what speed had been logged. This monitoring project had been implemented during the last two years and are now measured for each vessel in the fleet.

7.3 PART 3 - IDENTIFICATION AND EVALUATION OF SYSTEMS FOR MANAGEMENT AND DEVELOPMENT

Part 3 applies to all ships, which was clearly stated in the survey. The discussions held during the in-depth interviews concerned all ships as well.

7.3.1 Self-evaluation and improvement stage (Q42-Q48)

Seven questions in the survey concerned the ***self-evaluation and improvement phase*** of the SEEMP as per below:

- Q42. What systems are used for management of on-board energy efficiency optimization?
- Q43. What systems are used for development of on-board energy efficiency optimization?
- Q44. By which means are the above systems evaluated?
- Q45. What are the result of the evaluation in terms of energy savings? (Where there any quantifiable savings etc..?)
- Q46. What are the result of the evaluation in terms of quality of installed systems/software? (In terms of accuracy, availability, user friendliness, service organization...?)
- Q47a. Have you updated the SEEMP since it was implemented?
- Q47b. If YES in Q47a; what was the reason for updating?
- Q48. Have you any other valuable information regarding your SEEMP process that can contribute to the development of best practice procedures in the shipping industry?

Following *systems are used for management of on-board efficiency optimization* by the respondents:

- Performance monitoring systems
- Energy management system (ISO 50001)
- Monthly performance tests of propulsion machinery
- Environmental reporting
- Audits
- Fuel oil meters, fuel consumption figures displayed on the bridge and in the engine control room. Feedback also sent directly from the office. Main engine tuning parameters displayed both on bridge and in engine control room.
- Monthly reports and discussion on-board.

Following *systems are used* by the respondents for *development of on-board efficiency optimization*:

- Performance monitoring systems
- Real Time monitoring
- Energy Management System (ISO 50001)
- In-house developed analysis system
- Experience, exchange & best practices - program
- Monthly performance tests of propulsion and machinery
- Environmental reporting
- The system used is mainly dialogue with the personnel on-board together with feedback and evaluation of implemented measures.
- Electronic reporting tool

The respondents *evaluates their systems for management and development by the following means:*

- Regular monthly review
- Emerging system included in the quality system.
- Regular reviews by sea staff of the procedures and the Best Practices.
- By measuring results
- Test and follow up
- Reported data from ship, processed in the office and discussions with the crew.
- User feedback
- Improvement from the developer
- Systems not yet evaluated

The respondents were asked to *describe the results of the evaluation of their systems for management and development in terms of energy savings* and if they had any quantifiable savings. The results are listed below:

- PBCF - up to 5% improvement in fuel efficiency.

- Yes there were savings, but all depending on which measure that was implemented. Improvement ranging from 0 to 6%.
- Advanced hull / propeller cleaning schedules through the use of performance monitoring systems.
- Early intervention with daily monitoring of speed / performance.
- There were quantifiable savings!
- Many external influencers make it difficult to determine the net effect of our own measures.
- KPI's should be developed so that external influences are excluded.
- Main Engine FO
- Main Engine Cylinder oil
- Generator - power reduction
- LED lighting
- Bunker control
- Not known yet

In addition to energy savings, the respondents were asked to *describe their results of the evaluation of their installed systems/software for management and evaluation in terms of quality* such as accuracy, availability, user friendliness, service organisation etc. The comments expressed by the respondents are given below:

- KPI's are reviewed and improved regularly in order to ensure that cause and effect are clearly reflected without too much of influences from factors which master and staff have no control.
- The performance monitoring program has found to be an excellent tool in forward planning of hull / propeller maintenance.
- Accuracy, data quality, availability is always a challenge.
- Accuracy changes depending on the vessel - some have lots of fuel meters, torque meters etc. and some don't.
- The quality of the reported data is usually high so we trust it when several reports have been analysed.
- User friendliness has improved with development.
- It was a new system with initial problems but good now.
- Good
- Not known yet

About half of the respondents participating in the survey stated that they had *updated their SEEMP since it was implemented. Their reasons for updating* are given below:

- Company standard is to review all procedures regularly and incorporate the input from sea staff.
- Included new EnPI's
- Targets and different measures.

- New initiatives has been identified and implemented
- Development of vessels, changes of vessels
- Adding programs
- Splitting for vessel types.
- Evolving the SEEMP in a general sense

In the final question in the web-based survey the respondents were given the opportunity to *add valuable information regarding their SEEMP process that could contribute to the development of best practice procedures in the shipping industry*. The comments as expressed by the respondents are given below:

- It is imperative to include the vessels crew in SEEMP planning - they have greater physical awareness of the vessels machinery and any limitations. By giving the vessels crew ownership there is a sense of purpose and greater execution of the plan.
- Adapt the EEOI so it's more useful than just a number.
- If using an Energy Management System (EnMS ISO 50001) it is much easier to cope with what is needed to be done.
- Our SEEMP is our EnMS according to ISO 50001.
- SEEMP has not added much value for driving energy efficiency in our company. We have had processes and incentives for working with energy efficiency since long before SEEMP. Further SEEMP is too focused on on-board management, whereas we practice centralized management which we have found more successful.
- SEEMP for us is nothing new, we have been working with energy savings the last 10 years. So the SEEMP regulation did not change much. The driver is cost savings (and environment).

7.4 Additional information from the in-depth interviews

In this section additional information gained from the in-depth interviews are presented.

The key question in the in-depth interviews concerned which the *key success factors are in relation to optimization of energy consumption*. The respondents were asked to list their *best practices* and the findings and comments from the respondents are given below:

- Mewis Duct *(Saving 6 % bunker according to the respondent.)*
- Bulbous bow change *(Success! Especially in lower speeds, new bulb designed for new operational speed.)*
- Modification to make it possible to run CPP vessels with variable RPM *(Savings up to and over 20% when slow steaming)*
- Ballast optimization program *(Provides good decision support tool.)*
- Weather routeing
- Review timetables
- As early departure as possible in order to be able to reduce speed.
- Important to engage the crew.
- People on-board need to be aware, the mind set have to change.
- People onshore facilitate for on-board crew.
- Awareness Program
- Mass flow meters

- Torque meters
- Constant monitoring (including galley consumption etc.)
- Ceramic paint for insulation of pipes and other hot/cold surfaces.
- Insulation pipe
- Power Factor Correction (cos φ corr.) – To reduce losses in cabling due to high currents.
- Lub Oil Analysis
- Look at "minor" consumers such as HVAC, lighting etc.
- Using waste heat to the largest extent possible.
- Work in an innovative manner

One of the main questions discussed during the in-depth interviews concerned *whether the implementation of the SEEMP had been a trigger for the companies to work with energy efficiency*. Many of the respondents stated that they had worked with energy efficiency for many years and therefore didn´t consider the SEEMP as a trigger for energy efficiency. However, some respondents stated that the implementation of SEEMP had provided input to further work and increased the energy efficiency awareness in the shipping industry in general.

One respondent stated that some flag states provides different incentives in relation to energy efficiency and emission abatement. One example is Singapore where an incentive is taken to reduce carbon dioxide (CO_2) and sulphur oxides (SO_X) emissions. A reduction of Initial Registration Fees and a rebate on Annual Tonnage Tax is provided for Singapore-flagged ships that adopt energy efficient ship designs exceeding IMO´s Energy Efficiency Design Index (EEDI) and/or adopt approved SO_X scrubber technology exceeding IMO´s emission requirements (Singapore Registry of Ships, 2015).

Another main area being discussed during the in-depth interviews concerned *if and how the implementation of the SEEMP had affected the respondents work*. The intention with this question was to investigate whether the SEEMP provides the structure and framework as intended and if it´s being applied by the shipping business or if they carry on with "business as usual". The findings were a bit scattered; some of the respondents stated that their work with energy efficiency had been more organized and formalized after the SEEMP was implemented, while others considered it as "business as usual" since they had worked with these issues for many years. Periodical reviews and more frequent monitoring of data were some examples of how the companies had been more organized in their work. A common opinion expressed by several respondents was that the implementation of SEEMP hasn´t changed anything in practice and it was not considered as a useful tool for the daily work, however it provides a mean to present data for the crew on-board. On the other hand, an indication was given that all actors in the shipping business are more involved in achieving enhanced energy efficient shipping now, such as Class, Charterer´s etc.

Both *crew and management involvement* were discussed during the in-depth interviews. Findings from the interviews indicates that the management are involved to a large extent in the work with energy efficiency. Examples of management involvement given by the respondents includes:

- The management holds quarterly meetings and annual reviews.
- Working process were the shore staff facilitates for the crew on-board.
- Energy Savings Project Department – working full time with "energy savings" and scans the market for mostly technical energy efficiency measures.
- The work with the SEEMP is managed and coordinated via a "performance team" ashore where experience from the vessels are received, analysed and informed back to the fleet. The approach taken from the management are "more carrot than stick".
- Managers from the on shore organization visits the vessels and guides the officers into enhanced energy efficient operations, such as best practice regarding number of auxiliary engines in use during loading operations etc.
- Shore staff receives best practices developed by the vessels, analyse it and distribute the information fleet wide.

Other comments given by one respondent in relation to crew and management involvement includes the need of having the willingness and support from the crew, that it is important not to forget the operational aspects.

As of today, it is quite common for many companies to have an *Environmental Management System (EMS)* in place under ISO 14001 and some companies also have an *Energy Management System (EnMS)* in place under ISO 50001. With regard to the surveyed companies, a few companies are certified according to ISO 50001 and some are working according to the standard but are not certified due to the costs involved.

The practice regarding the *energy saving working process* were briefly described by one of the respondents. The respondent divided the process into three stages; where focus were put on the big consumers, normally the main engine and propulsion system in the first stage. In the second stage, focus were put on middle consumers such as auxiliary engines, cargo and ballast systems, HVAC systems and larger support systems in the engine room. Minor consumers such as electricity in accommodation, other lighting, smaller pumps and secondary ventilation etc. were treated in the third stage.

Several of the respondents mentioned the upcoming *EU-MRV Regulation* and elaborated on what the regulation will bring when the reporting requirements will come into force as of 1 January 2018.

Findings regarding *environmental improvement and/or energy efficiency drivers, barriers and challenges* were identified when analysing some of the comments given by the respondents during the in-depth interviews.

One of the drivers identified were ECA, which was considered the individually largest legal measure by one of the respondents. Another driver identified by one of the respondent were the end consumer who puts demands on the transport.

Reluctance to change was one of the main barrier identified. The challenge expressed by one of the respondents were that it will take time to change mind set, since especially the older crew consider the work with the SEEMP as an increased workload. Other barriers expressed by the respondents includes legal issues such as C/P clauses and slow steaming and challenges in educating new crewmembers when there are large crew turnovers.

A general barrier could be summarised as *"what´s in it for me?"* This attitude or barrier is especially applicable in situations when the charterer pays for the bunker, then there are no incentives for the owner according to one respondent. Further on, the respondent stated that the SEEMP is potentially a good thing, but for now it is more or less a "manual on master´s library with no further attention put to it".

Other general comments expressed by the respondents during the in-depth interviews are given below:

- The EEDI is very complex
- Need to adapt the EEOI to be more than just a number, it is based on transport work and there is no baseline to judge against. As for now we are collecting useless data for auditing. Perhaps there should be a possibility to compare EEOI with other companies, but could be difficult from a commercial point of view.
- New legislations from IMO are not discussed with Owner´s etc. in beforehand, should have been implemented in co-operation with the industry.
- We perform energy audits were suggestions to owners are made regarding possible savings and payback time.
- Difficult to interpret and compare figures given by the Performance Monitoring System (PMS) – what does the figures mean?
- Important to have reliable data input
- Important to Measure – Monitor - Implement
- Mass flow meter – important in order to get accurate measurements
- The difficult part is to measure the data correctly, not the analysis part
- Yard design: Research centre collects feedback & work on improvements, e.g. hull design, pipe flanges etc.
- The company work with CSR research, has full centre for innovation.