

IMO Train the Trainer (TTT) Course
on
Energy Efficient Ship Operation

**Module 6 – Energy Management Plans
and Systems**



I M O

ACKNOWLEDGEMENTS

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MODULE 6

Energy Management Plan and System

Module Aims and Learning Objectives

This module is intended to provide awareness, knowledge and skills required of ship-board and office-based staff on ship energy management systems and plans and their implementation. It aims to provide general information on shipping management systems, details of IMO 50001 on Energy Management System (EnMS), ship and company related management systems and plans and specific tools for monitoring of ship energy performance including energy reviews and audits, performance monitoring, data collection, monitoring and reporting including the IMO data collection and EU Monitoring, Reporting and Verification (MRV).

The overall learning objectives and outcomes of this module are to enable you to appreciate, discuss and explain the following topics:

- Broad aspects of management systems and their main features including the continuous improvement cycle and plan-do-check-act aspects;
- General aspects of ISM code and ISO 140001 as typical shipping management systems;
- Energy management systems, main elements and details of ISO 50001 approach to energy management;
- A shipping Company Energy Management Systems (CEnMS), its differentiation with IMO SEEMP, and main features such as energy policy, energy review and so on;
- IMO data collection system, status and experience together with EU MRV system and their comparisons;
- Techniques for conducting a ship energy audit or review; and
- Ship performance monitoring and its application techniques for hull, engines and voyage performance evaluation.

To support your learning process, a list of references is provided at the end of each Section. Referring to them will allow you to go deeper in areas that may be of most interest to you.

The material presented herein is current at the time of preparations of this document. Because of the evolving nature of regulations, technologies and future studies in area of MARPOL Annex VI and in particular energy efficiency of ships, some aspects may require updating over time.

The views expressed in this document are purely those of the author(s) and may not in any circumstances be regarded as stating an official position of the organizations involved or named in this document.

This document is subject to change by the IMO.

Dr Zabi Bazari, EnEmSol, January 2016

CONTENTS

1	OVERVIEW OF MANAGEMENT SYSTEMS	6
1.1	INTRODUCTION	6
1.1.1	<i>Main aspects of a management system</i>	6
1.1.2	<i>PDCA cycle of continuous improvement</i>	6
1.1.3	<i>Management systems and shipping</i>	7
1.2	ISM CODE	8
1.3	STANDARDS OTHER THAN ISM	9
1.3.1	<i>ISO 9001: Quality Management System (QMS)</i>	9
1.3.2	<i>ISO 14001: Environmental Management System (EMS)</i>	9
1.3.3	<i>OHSAS 18001: Occupational Health and Safety Assessment Specification</i>	10
1.3.4	<i>ISO 50001: Energy Management System (EnMS)</i>	10
1.4	COMMONALITIES BETWEEN MANAGEMENT STANDARDS	10
1.4.1	<i>On “objectives and policies”</i>	11
1.4.2	<i>On “system management”</i>	11
1.4.3	<i>Continual improvement aspects</i>	11
1.4.4	<i>Human resources/personnel</i>	12
1.4.5	<i>Ship maintenance system</i>	12
1.4.6	<i>Verification and inspections</i>	13
1.4.7	<i>Performance monitoring</i>	13
1.4.8	<i>Management reviews</i>	13
1.5	CERTIFICATION AND OTHER ASPECTS	14
1.6	REFERENCES AND FURTHER READING	14
2	ISO 50001 ENERGY MANAGEMENT SYSTEM	16
2.1	OVERVIEW	16
2.2	TARGET SETTING AND PERFORMANCE CRITERIA	18
2.3	SCOPE OF ENMS	18
2.4	CERTIFICATION	18
2.5	RESPONSIBILITIES	19
2.6	ENERGY POLICY	19
2.7	PLANNING	20
2.8	MONITORING	21
2.9	MANAGEMENT REVIEW	21
2.10	SUMMARY POINTS	21
2.11	REFERENCES AND FURTHER READING	22
3	SHIPPING COMPANY ENERGY MANAGEMENT	23
3.1	OVERVIEW	23
3.1.1	<i>Introduction</i>	23
3.1.2	<i>Fuel (energy) cost</i>	23
3.1.3	<i>Climate change</i>	24
3.1.4	<i>Scope for energy saving</i>	24
3.1.5	<i>Shipping companies approach</i>	25
3.1.6	<i>CEnMS and SEEMP scope of application</i>	26
3.2	SHIP-LEVEL ENERGY MANAGEMENT PLAN (SEEMP)	26
3.2.1	<i>EEMs at the core of a SEEMP</i>	26
3.2.2	<i>Implementation of EEMs</i>	27

3.2.3	<i>Continuous improvement approach</i>	27
3.3	COMPANY-LEVEL ENERGY MANAGEMENT SYSTEM (CENMS).....	28
3.3.1	<i>Company “energy policy”</i>	29
3.3.2	<i>Energy review</i>	30
3.3.3	<i>Energy efficiency monitoring and reporting</i>	30
3.3.4	<i>Energy efficiency training of staff</i>	31
3.4	SUMMARY MAIN FEATURES OF COMPANY ENERGY MANAGEMENT SYSTEM	31
3.5	REFERENCES AND FURTHER READING	32
4	ENERGY AUDIT AND REVIEW	34
4.1	INTRODUCTION	34
4.2	TYPES OF ENERGY AUDIT	35
4.3	SHIP ENERGY AUDIT PROCESS	36
4.3.1	<i>Overview</i>	36
4.3.2	<i>Ship energy audit phases</i>	37
4.4	TYPICAL DATA ANALYSIS	38
4.4.1	<i>Ship operation profile</i>	38
4.4.2	<i>Fuel consumption profile</i>	38
4.4.3	<i>Hull performance assessment</i>	39
4.4.4	<i>Engine performance assessment</i>	39
4.5	TECHNO ECONOMIC ANALYSIS	40
4.5.1	<i>Technical feasibility assessment</i>	40
4.5.2	<i>Economic cost-effectiveness assessment</i>	41
4.5.3	<i>MACC and its development</i>	42
4.6	REFERENCES AND FURTHER READING	44
5	SHIP PERFORMANCE MONITORING AND REPORTING	46
5.1	INTRODUCTION	46
5.2	BENEFITS OF SHIP PERFORMANCE MONITORING.....	46
5.3	PERFORMANCE MONITORING SYSTEM DESIGN	47
5.4	TYPES OF PERFORMANCE MONITORING SYSTEMS	49
5.5	HULL PERFORMANCE MONITORING	51
5.5.1	<i>Introduction</i>	51
5.5.2	<i>Methodology</i>	52
5.6	ENGINE PERFORMANCE MONITORING.....	54
5.6.1	<i>Introduction</i>	54
5.6.2	<i>Methodology</i>	55
5.7	AUXILIARY MACHINERY MONITORING	56
5.8	VOYAGE PERFORMANCE ANALYSIS	57
5.9	MONITORING AND REPORTING TO EXTERNAL BODIES.....	58
5.9.1	<i>IMO data collection system</i>	58
5.9.2	<i>EU MRV</i>	59
5.10	REFERENCES AND FURTHER READING.....	62

LIST OF FIGURES

Figure 1.1 – PDCA cycle of continuous improvement.....	7
Figure 2.1 – ISO 50001 energy management cycle [ISO 50001].....	17
Figure 2.2 – Structure of ISO 50001 [Bazari 2012].....	17
Figure 2.3 – ISO 5001 energy planning process [ISO 50001].....	20
Figure 3.1 – Typical ship costs and fuel costs	23
Figure 3.2 – The concept of step-by-step approach to energy management	27
Figure 3.3 – Cost and payback for measures under step 1 to step 3.....	28
Figure 4.1 – Energy audit or review process [Bazari 2012].....	36
Figure 4.2 – Ship energy audit – Example areas to be assessed [DNV 2011]	37
Figure 4.3 – Typical ship’s operation profile by operation mode	38
Figure 4.4 – Ship fuel consumption profile by system.....	39
Figure 4.5 – Speed-power curve analysis [Bazari 2012]	39
Figure 4.6 – Typical on-board cylinder pressure measurement [Bazari 2012].....	40
Figure 4.7 – Typical MACC for international shipping [DNV 2010].....	43
Figure 5.1 – The general concept for a ship performance monitoring [Hideyuki Ando , NYK].....	48
Figure 5.2 – Performance monitoring data collection, analysis and presentation concepts	48
Figure 5.3 – Automatic systems using satellite navigation [Kongsberg]	51
Figure 5.4 – Development of added resistance normally expected as a function of time [Torben Munk].....	52
Figure 5.5 - Fuel consumption penalty of hull fouling and benefits of condition-based cleaning [Torben Munk]	52
Figure 5.6 – Example of speed-power curve development [Bazari 2012].....	53
Figure 5.7 – Added resistance method used by Propulsion Dynamics [Torben Munk].....	54
Figure 5.8 - Typical engine indicator diagram.....	55
Figure 5.9 – Typical on-board in-cylinder measurement [Bazari 2012].....	56
Figure 5.10 - Machinery utilisation [Bazari 2012].....	57
Figure 5.11 - Overview of a ship operation from one port to next port using performance monitoring [Hideyuki Ando, NYK].....	58
Figure 5.12 – MRV scheme overview [Lloyd’s Register 2015].....	61

1 Overview of Management Systems

1.1 Introduction

1.1.1 Main aspects of a management system

The cornerstone of good management is commitment from the top management and dedication from the operating personnel. In matters of safety, pollution prevention and energy saving, it is the commitment, competence, attitudes and motivation of individuals at all levels that determines the end result. The foundation of the ISM¹ Code is largely based on the philosophy of quality management, the key fundamentals of which include:

- Management commitment;
- Staff/personnel empowerment; and
- Continuous improvement.

The role of the top management is crucial when improving the quality or safety or environmental protection or conservation of resources of a company is concerned. Firstly, the management is responsible to set a company policy which describes where and how the company should aim and perform in terms of quality, safety, environmental and energy conservation issues. Secondly, the management is responsible for providing adequate resources and tools in order to ensure that the company policy could be successfully implemented. Also, the management is responsible for setting realistic and achievable targets for the company's quality, safety, environmental and energy performance. The performance should be reviewed on a regular basis and the previous targets should be updated on the basis of actual performance.

The involvement of the personnel is a pre-requisite for a successful management system. Employees should have a feel of ownership in this regard. This is normally achieved by providing an opportunity for them to participate in establishing, implementing and operating the management system at various organisational levels. In many organisations, it is not necessarily lack of knowledge and awareness that is responsible for poor performance but it is the lack of this feel of ownership and motivation to act and commitment that leads to poor performance in various areas.

1.1.2 PDCA cycle of continuous improvement

The concept of "continuous improvement" requires that a company improves the quality of its products and services on a continuous basis and at all organisational levels. A common approach to continuous improvement is the PDCA (Plan – Do – Check – Act) process as shown in **Figure 1.1**.

¹ ISM stands for International Safety Management

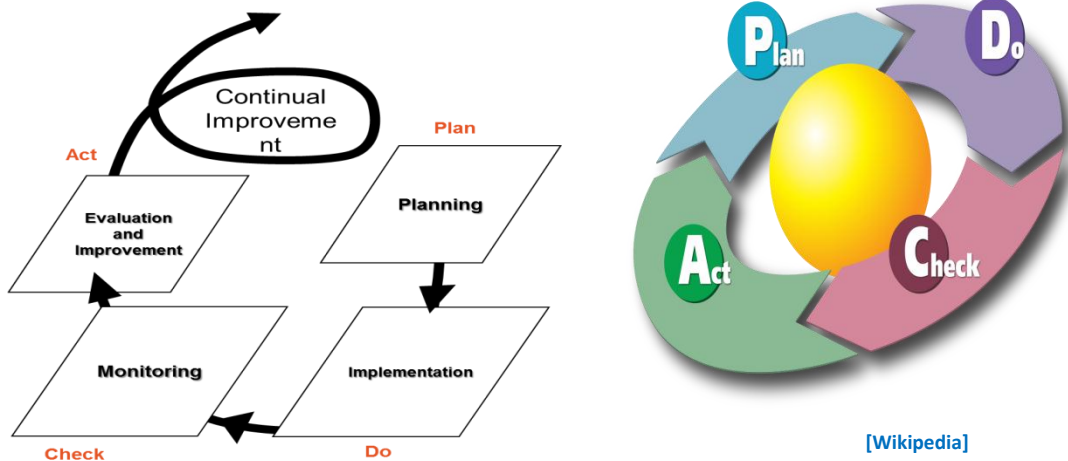


Figure 1.1 – PDCA cycle of continuous improvement

The 4 major phases of the continuous improvement cycle are:

- **Plan:** During this first phase of the PDCA cycle, an action plan of the activities that need to be done is prepared together with all relevant implementation details. For this purpose, the company need to have a policy statement and should define the objectives and targets, plan on how to achieve these targets and identify how to implement and how to monitor various activities when the plan is implemented.
- **Do:** In the second phase, the implementation of the selected and documented measures should be carried out in a systematic way. In other words, this is the execution phase of the action plan developed. To be successful, project management of various measures under implementation is very important and the action plan should be executed within the schedule and budget.
- **Check:** In the third phase, one should measure or analyse the results of the implementation via effective monitoring and checking. This is the step under which the results of implementations are measured and monitored to ensure that the perceived objectives are achieved. Without this step, there is no way to know if the implementation has been satisfactory or not. Data collection and analysis plus various aspects of audits and surveys could be used for this purpose.
- **Act:** In in last phase the assessment of the effectiveness of plan is done. The plan is reviewed against the achievements and new targets are set for next cycle of PDCA. If the check shows that the plan that was implemented led to improvements, then new standard or baseline or targets for future cycle of PDCA activities are set. Otherwise, the reasons for not meeting the objectives need to be evaluated and the plan adjusted according and the new cycle to be started.

The above PDCA cycle principles apply to any management system irrespective of area of application. In this module, it will be shown frequently that various shipping related management systems also follow the above generic principles.

1.1.3 Management systems and shipping

The concept of “management system” is not new to the shipping industry. One of the most prominent management system that is already mandatory in shipping is the ISM Code that as the name implies deals with shipping safety at its core. There are other management systems that although not mandatory, are widely adopted by the shipping companies including the following:

- Quality management system, mainly known as ISO 9001
- Environmental management system, mainly known as ISO 14001
- Health and safety systems such as those based on OHSAS 18001.
- Energy management system such as those specified under ISO 50001.

In the following parts of this section, a brief overview of these standards together with their similarities and overlapping aspects will be given.

1.2 ISM Code

According to IMO, the main objective of the ISM code is to provide an international standard for the safe management and operation of ships and for their pollution prevention [IMO Website]. Accordingly:

- Governments are required to take the necessary steps to safeguard the shipmaster in the proper implementation of his/her responsibilities with regard to maritime safety and the protection of the marine environment.
- Recognised the need for the shipping companies to set up appropriate management system to enable them to respond to the need of those on board ships to achieve and maintain high standards of safety and environmental protection.

The ISM code is effectively a shipping-specific International rules and regulations with the ultimate objectives:

- To ensure safety at sea
- To prevent human injury or loss of life
- To avoid damage to the environment and to the ship.

The ISM code is based on some general principles and objectives. These are expressed in broad terms so that ISM code can have a widespread application to all different type of organisations involved in shipping despite their diverse business. Clearly, different levels of management, whether shore-based or ship-board, will require varying levels of knowledge and awareness of the items outlined.

SOLAS² adopted the ISM code in 1994 and incorporated it into its chapter IX. By 2002 almost all of the international shipping community was required to comply with the ISM code. In order to comply with the ISM code, each ship must have a working Safety Management System (SMS). Each SMS would consist of the following elements:

- Commitment from top management
- A top level defined policy manual
- A “procedures manual” that documents what is done on board the ship, during normal operations and in emergency situations
- Procedures for conducting both internal and external audits to ensure that the ship is doing what is documented in the “procedures manual”
- A designated person ashore to serve as the link between the ship and shore staff and to verify the SMS implementation

² SOLAS stands for the International Convention for the Safety of Life at Sea.

- A system for identifying where actual practices do not meet those that are documented; and the associated corrective actions.
- Regular management reviews.

Another requirement of the ISM code is for the ship to be maintained in conformity with the provisions of relevant rules and regulations and with any additional requirements which may be established by the shipping company itself. As part of ISM code, compliance verification should be in place. Each ISM compliant ship is audited, first by the company itself (internal audit) and then each 2.5 to 3 years by the flag State “maritime administration” to verify the effectiveness of the SMS. Once SMS is verified and it is working and effectively implemented, the ship is issued with a Safety Management Certificate (SMC).

It should also be noted that a ship’s planned maintenance scheme is a statutory requirement of the ISM code. The ISM code requires that the ship’s management provide sufficient resources to maintain the ship safely and the company must supply the necessary resources in the way of parts or shore-side assistance to do this. Poor maintenance can mean that either the ship cannot meet its commercial obligations (for example unable to meet the minimum speed requirements defined in the contract) or can pose a potential safety or environmental hazard. The management should ensure regular audits of ships to verify that the maintenance required by the planned maintenance system is being carried out. This inspection of the ship should be part of the internal audits required by the ISM code and should not be left for statutory or class surveys at a later stage.

1.3 Standards other than ISM

There are a number of management system standards developed mainly by the ISO that have been extensively used. These are standards and not rules and regulations and as such their use is mostly voluntary. However, some of these well-known standards are widely used by most industries including shipping and will be briefly introduced.

1.3.1 ISO 9001: Quality Management System (QMS)

The ISO 9000 series of standards are related to quality management systems and designed to help organizations ensure that they meet the needs of their customers / clients and other stakeholders while meeting statutory and regulatory requirements related to their delivered products or services. The ISO 9001 certification is highly oriented towards “process improvements” taking into account the customer needs.

ISO 9001 is the most commonly utilised standard for quality management. Its wider application started initially in manufacturing companies in 1980s. Later on, its application expanded into service business and public administration mainly in the middle of the 1990s. In shipping, many companies so far have adopted the ISO 9001 quality standard as the basis for their company’s “quality management system”.

1.3.2 ISO 14001: Environmental Management System (EMS)

ISO 14000 series of standards relate to environmental management and has been developed to help organizations to minimize the negative impacts of their operation on the environment via ensuring compliance to prevailing applicable laws, regulations, and other environmentally oriented requirements as well as best practice. ISO 14001 requires the organization to assess all of its environmental aspects related to the company’s activities, products and services. So, in a nutshell, ISO 14001 main requirement is that the significant environmental aspects of a company should be identified, documented and managed.

The first international version of ISO 14001 was published in 1996. Like any other of widely used management system standard, ISO 14001 has evolved over time and the current version of the ISO 14001:2015 includes the concept of continuous improvement process approach.

In a shipping company, the company policy may include the implementation of ISO 14001 on its vessels which contains procedures for selecting the best environmental measures for a particular vessel and then sets objectives for the measurement of relevant parameters along with relevant control and feedback features. The implementation of ISO 14001 has the main advantage of reducing a company's environmental impacts.

As many ships and companies already have an ISM code related management system that should include environmental protection, it would make sense for these companies to have an ISO 14001 compliant environmental management system; however as discussed before this is not mandatory and care should be exercised not cause complications with regard to ISM related Flag State and Port State Control inspections. Once an environmental procedure becomes part of the ship's SMS, it is mandatory to follow the processes even if the requirements are not mandatory in other statutory legislation.

1.3.3 OHSAS 18001: Occupational Health and Safety Assessment Specification

OHSAS³ 18001 is a British Standard (BS) that is used globally and provides a specification for occupational health and safety management in any organization. The OHSAS 18001 is widely used internationally and is intended to help organizations to control occupational health and safety risks. OHSAS 18001 focuses on the need to identify all occupational health and safety hazards for personnel related to the company's activities and facilities and do relevant risk assessment. The result of these assessments is then used to identify the hazards that have to be eliminated or controlled.

The OHSAS 18001 has been harmonized with the ISO 9001 and ISO 14001 standards so that to help organizations to integrate the quality, environmental and safety management systems easier into one common management system.

1.3.4 ISO 50001: Energy Management System (EnMS)

ISO 50001 is an international standard for an energy management system. The standard specifies the requirements for establishing, implementing, maintaining and improving an energy management system (EnMS). The purpose of EnMS is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance in their organisation. ISO 50001 establishes systems and processes to improve energy performance and as a result, enable reductions in energy costs, GHG emissions and other environmental impacts. ISO 50001 is the subject of detailed description in the next section.

1.4 Commonalities between management standards

Although the above categories of standards deal with different management aspects, their overall requirements, processes and procedures have similarities and overlap. Understanding of their similarities and overlaps helps with an integrated approach to their implementation. In this section, some of these aspects are clarified such that if a trainee is familiar with one of these management systems or standards, he/she could relate the other standards to this one as an aid for quicker and deeper understanding. Also, this section aims to provide more information on the requirements of each standard, complementing what mentioned about them in previous section.

³ OHSAS stands for Occupational Health and Safety Assessment Specification

The commonalities of these standards are so much that there are many publications that compare them and there are many companies who offer an integrated service in dealing with their implementation and certification. In shipping, for example, ABS guidelines for such services [ABS 2012] are written as a unified one that includes all of the above standards in one guideline. DNV also in its publication [DNV 2013] offers a good and systematic comparison of these standards in terms of their common aspects and also their complementary aspects. The following comparisons are mainly a shortened version of the DNV comparisons in this regard [DNV 2013] that is hereby acknowledged.

1.4.1 On “objectives and policies”

This aspect relates to the role that top-management of the company must play. Many aspects of the requirements for top management roles in the ISM code and the other management standards are similar. Accordingly, the top management shall define policies relevant to the nature of the business and as a framework for objectives and targets. As a minimum, objectives and targets should demonstrate the company’s goals for health and safety protection, environmental concern, energy performance and so on. In addition to the above, specific objectives and targets are required by the various standards for compliance purposes.

1.4.2 On “system management”

The “system management” refers to management procedures and assignment of roles and responsibility. Instructions and procedures are required to be in place in order to operate ships safely, protect the environment, control its occupational health and safety risks and comply with relevant international and flag State legislation. Defined levels of authority, responsibility, lines of communication, resources and support, plans for key shipboard operational procedures, risk assessments, accidents and nonconformity reporting procedures, emergency procedures, internal audits and management reviews are all part of the system requirements. For this purpose:

- The ISM code requires designated person(s) to be appointed.
- For ISO 9001, it is required to identify a quality management representative and describe elements in the ISO 9001 standard that not already addressed in the existing safety management system. The customer should be defined and a system for measuring and monitoring the service provided to satisfy the customer’s needs have to be put in place.
- For ISO 14001, it is a requirement for top management to appoint an environmental management representative and provide resources to manage and control the environmental system. All environmental aspects shall be assessed, by considering normal and abnormal operations and potential emergency conditions. The significant aspects shall then be identified and managed. Procedures for receiving, documenting and responding to communication from external interested parties shall be established.
- For OHSAS 18001 and similar to ISO 14001, all occupational health and safety hazards must be identified and assessments of risks carried out. A safe system of work must be established, employing a hierarchy of controls. Employee consultation and participation is required.
- As for ISO 50001, the main goal of the standard is a reduction in energy use. This is achieved through continual improvement in energy performance. The organization is required to conduct and document energy planning via an energy review, establish an energy baseline, performance indicators, objectives, targets, action plans etc.

1.4.3 Continual improvement aspects

The following could be related to ISM code and other standards:

- As part of ISM code, objectives to continually improve safety management skills ashore and on-board via analysis of nonconformities, accidents and hazardous situations need to be achieved. Procedures for maintenance of the ships in the fleet are required. Use of risk assessment techniques is necessary.
- As for ISO 9001, customer needs, expectations and requirements have to be taken into account. A procedure for analysis of data to improve the quality effectiveness of the management system is required. Procedures for eliminating the causes for potential non-conformities are also required.
- For ISO 14001, the company should establish an environmental management programme that addresses all of its objectives and targets including schedules, resources and responsibility for achieving them. The environmental programme helps the company improve its environmental performance and meet its commitment to continual improvement.
- For OHSAS 18001, the company should establish an occupational health and safety programme that addresses all of its objectives and targets, including schedules, resources and responsibilities for achieving them.
- For ISO 5001, the company is required to plan its energy use when working to achieve its energy targets. This means to develop and carry out an energy review and establish energy baselines. The company is required to use performance indicators. Checking and monitoring is done against the indicators.

1.4.4 Human resources/personnel

On human resources and staff, all the management systems give significant priority to train and motivate the staff in related areas:

- For ISM code, the company should ensure that seafarers are qualified, certified and medically fit.
- As for ISO 90001, the organization shall assign personnel to ensure that those who have defined responsibilities are competent. The company should also evaluate the effectiveness of training.
- As for ISO 14001, all employees shall be trained in and be aware of their roles and responsibilities and the significant environmental impact of their work etc.
- As for OHSAS 18001, all employees shall be aware of their roles and responsibilities, the occupational health and safety consequences of their work activities etc.
- As for ISO 15001, employees should be familiar with their roles and responsibilities. Training in energy management system, benefits of energy management etc. is required. This extends to contractors and third parties working on-board that may be affecting energy use.

1.4.5 Ship maintenance system

The ship maintenance management is also part of the management standards including:

- For the ISM code, maintenance procedures covering at least all items that are subject to class, statutory and additional company requirements are required.
- For ISO 90001, planning and control of appropriate procedures are required, as are purchasing procedures. The maintenance must extend to include care for customer property, including where work on-board affects customer property indirectly.

- For ISO 50001, maintenance plans extends to areas identified and considered as significant energy users in order to avoid a failure affecting the energy performance.

1.4.6 Verification and inspections

Measurement, monitoring, verification and inspections are part of all the management systems.

- Based on ISM code, regular on-board verifications and inspections are required.
- In ISO 14001, the company must have a systematic approach to measure, monitor and evaluate its environmental performance.
- In OHSAS 180001, the company must have a systematic approach to measure, monitor and evaluate its occupational health and safety performance.
- For ISO 50001 compliance, the company should define and regularly review energy measurement needs. An energy measurement plan is required. Measurement equipment must be calibrated with records retained. Standard gives minimum requirements to be considered.

1.4.7 Performance monitoring

Common to all standard, effective procedures for reporting non-conformities and hazardous situations are required. New requirements for e.g. energy management should be reflected in the company management system. Data analysis, implementation of preventive actions and continual improvement procedures are required.

- For ISM code purposes, there is a requirement to have a designated person ashore to monitor safety and pollution prevention aspects.
- For ISO 90001, ways of measuring and monitoring operational performance are required. This includes establishing data analysis processes, improving system effectiveness and continual improvement.
- For ISO 140001, procedures for regular monitoring and measuring key operations that have significant environmental impacts are required. Evaluating compliance with relevant environmental legislation and regulations is also required.
- For OHSAS 180001 compliance, procedures for monitoring and measuring occupational health and safety performance on a regular basis. Evaluating compliance with relevant legislation and regulations is also required.
- As ISO 50001, the company should identify energy performance indicators based on the energy review and the energy baseline. Measurement will be carried out against these performance indicators.

1.4.8 Management reviews

Common to all, the company should verify compliance and evaluate the efficiency and effectiveness of the management system. Management reviews covering all of the company's systems at defined intervals, are required, including input from master.

- For ISO 90001, monitoring and measurement of management system performance including customer satisfaction is a requirement.
- For ISO 14001, the organisation shall evaluate the environmental performance and the conformance with the environmental policy, objectives and targets. Evaluating compliance with relevant environmental legislation and regulations.

- For OHSAS 18001, the organisation shall evaluate the health and safety performance and the conformance with the policy, objectives and targets. Evaluating compliance with relevant legislation and regulations.
- For ISO 50001, the management review will evaluate the energy performance, the suitability of the performance indicators and whether or not targets have been met. It will also look at projected energy performance. Outcomes may include changes in baseline, performance indicators, resource allocation etc.

1.5 Certification and other aspects

As indicated above, all the shipping related management systems, whether mandatory such as ISM or voluntary such as ISO 140001 and ISO 50001, have general features that are common between them. This is despite the fact that different systems focuses on different aspects of safety, environment or energy efficiency. Management certification is one way of demonstrating, in particular to external parties, that the company is complying with the above standards.

In shipping the main bodies that provide management system certification services to the industry are classification societies. As indicated by two examples [ABS 2012 and DNV 2013], class societies use integrated processes and guidelines to deal with all the above standards. For example, ABS has published a marked-up version of their guidelines on “Guide for Marine Health, Safety, Quality, Environmental and Energy Management” that shows how for example “energy management” has been added to the previously used guidelines that have been dealing with “Marine Health, Safety, Quality and Environmental” only.

Some class societies have published dedicated rules for certification of “ship energy management” that only deals with SEEMP aspect of energy management. Chinese Classification Society (CCS), in 2011, published their “Rules for Certification of Ship Energy Management” that deal with all aspects of certification including system requirements, data requirements, certification and energy audit for ship-board energy management.

On energy efficiency side, all classification societies provide services in “energy management system certification” and a number of companies have been certified so far. Being a new standard (i.e. ISO 50001), the number of certified shipping companies are not many yet. However, it is expected that with time and due to the significance on climate change debates, more and more companies will allocate resources to deal with energy saving and energy efficiency over the time.

1.6 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. “IMO train the trainer course material”, developed by WMU, 2013.
2. Wikipedia, “PDCA “, <https://en.wikipedia.org/wiki/PDCA>, cited September 2015.
3. ABS 2012, “Guide for Marine Health, Safety, Quality, Environmental and Energy Management (The ABS Guide for Marine Management Systems), APRIL 2012 (Updated February 2014), American Bureau of Shipping publication Cited September 2015.
4. China Classification Society 2011, “Rules for Certification of Ship Energy Management”, 2011, Beijing, website, cited September 2015.
5. DNV 2013, “Seamless Guidelines for Implementing and Auditing Management Systems - Integrating ISO And ISM Certification”, Rev, 1.3-2013

6. Jouni Lappalainen "Transforming Maritime Safety Culture - Evaluation of the impacts of the ISM Code on maritime safety culture in Finland", Turku, 2008.
7. IMO website "ISM Code and Guidelines on Implementation of the ISM Code 2014", <http://www.imo.org/en/OurWork/HumanElement/SafetyManagement/Pages/ISMCode.aspx>, cited September 2015.
8. ISO 50001:2011 "Energy management systems -- Requirements with guidance for use", ISO publications.
9. ISO website, "ISO 14000 - Environmental management", <http://www.iso.org/iso/home/standards/management-standards/iso14000.htm>, cited September 2015.

2 ISO 50001 Energy Management System

2.1 Overview

ISO 50001⁴ is a voluntary international standard developed by the International Organization for Standardization (ISO) to provide various organizations with an internationally recognized framework to manage and improve their energy performance. The standard addresses the following:

- Energy use and consumption evaluation via conducting energy reviews and development of energy policies.
- Measurement, documentation and reporting of energy use and consumption.
- Design and procurement practices for energy-using equipment, systems, and processes.
- Development of an energy management plan and other factors affecting energy performance that can be monitored and influenced by the organization.

ISO 50001 applies to all different types of companies and industry sector. It provides a framework for an “Energy Management System (EnMS)” through which each organization can set and pursue its own goals for improving energy performance. From the ISO 50001 perspective, an EnMS is a series of processes that enables an organization to use data and information to maintain and improve energy performance, while improving operational and energy efficiencies and reducing environmental impacts.

Using the ISO 50001 framework provides a systematic approach to managing energy within a company. Conformance to the standard provides proof that a company has implemented international energy management systems, completed and developed a baseline of its energy use and is committed to continual improvement in energy performance. ISO 50001 is designed for widespread use by all industries (power, oil and gas, manufacturing, transport, etc.), buildings and other organizations; thus it is applicable beyond shipping. The use of ISO 50001 is expected to be driven by factors such as regulatory/legislative developments, corporate social responsibility (CSR), environmental management programs as well as the economic benefits of energy and CO₂ reductions.

As discussed in previous section, ISO 50001 is based on a standard management system model based on the Plan-Do-Check-Act approach already employed in ISO 9001, ISO 14001 and IMO SEEMP. **Figure 2.1** shows the continual improvement process of the ISO 50001.

⁴ Most of the material in this section are from ISO 50001:2011



Figure 2.1 – ISO 50001 energy management cycle [ISO 50001]

The Plan-Do-Check-Act features of the IMO 50001 are best shown in Figure 2.2 where various sections of ISO 50001 are shown together with the standard relevant headlines.

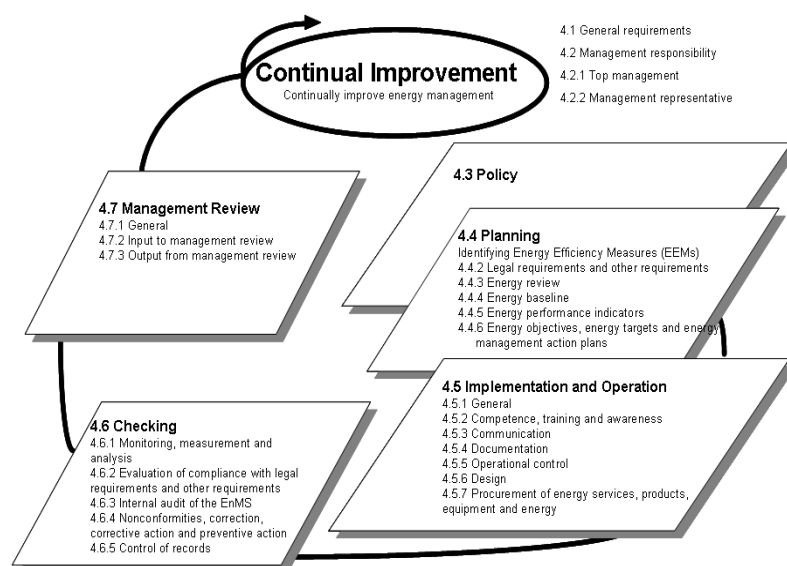


Figure 2.2 – Structure of ISO 50001 [Bazari 2012]

In order to develop and implement the ISO 50001, normally some level of preparatory work needs to be undertaken. These include, inter alia, aspects such as:

- Development of an energy policy that includes commitment to the EnMS from top management
- Assignment of a management representative to lead the implementation of the EnMS
- Establishment of a team from various departments that have influence on ship fuel procurement, treatment, storage and use.

Upon completion of the preparatory work, the steps towards planning for implementation of an EnMS could include aspects such as:

- Undertaking an energy review to identify significant energy users, their energy consumption, and opportunities for improvement
- Establishment of energy baselines for the company and various facilities
- Identification of energy performance indicators and benchmarks for tracking energy performance improvement against the baseline.

2.2 Target setting and performance criteria

ISO 50001 does not prescribe specific performance criteria or target levels with respect to energy efficiency performance; however, it requires the organization to continually improve energy performance. For a shipping company this practically implies that it should select key performance indicators in order to demonstrate improved energy performance. IMO has developed the Energy Efficiency Operational Indicator (EEOI), see **Module 2**, that may be used as a performance indicator for a company when applying the EnMS to shipping. Of course, other indicators may be used for this purpose.

2.3 Scope of EnMS

A shipping company EnMS will include features that need to be undertaken both at head office and on-board ships. The ship-related aspects include:

- Defining each ship's energy efficiency measures (EEMs).
- Documenting each ship EEMs and their implementation, monitoring and improvement processes.
- Implementation of energy saving projects on-board ships.

The above will normally be included in a ship's SEEMP (See **Module 2**). The shipping company's EnMS should also include provisions for activities at shore-based offices. These include, but not limited, to the following activities:

- Planning improvement and management of the whole fleet energy efficiency.
- Gathering of fleet (all ships) information with a view to benchmarking and data sharing.
- Analysis and evaluation of actual state of energy use by ships in a fleet.
- Preparation of the SEEMP for each ship and its implementation and monitoring activities.
- Fleet benchmarking, monitoring and reporting to top management.

As will be argued in the following **Section 3**, the application of EnMS in a shipping company should be fully in harmony with ship-board SEEMP and vice a versa.

2.4 Certification

There are a large number of companies who offer ISO 50001 certification. These are normally accredited certification bodies via their national standardisation agencies (e.g. British Standard in the case of UK) that are competent to certify organizations for conformance to ISO 50001. These companies normally employ certified ISO 50001 auditors to assess an organization's or company's compliance to ISO 50001. As discussed earlier, in shipping, normally classification societies provide these services.

It should be noted that ISO 50001 certification is voluntary and companies are free to take action to start improving energy management without becoming certified. However, certification to ISO 50001 provides a structured approach that incorporates energy management into company culture, resulting in sustained energy savings and continual improvements in energy performance over time.

This can help justify initial investments in energy projects and ensure return on investment. Without a structured approach, there is no guarantee that energy savings will be sustained or that return on investment will be maximized. As such, the certification is a useful exercise and is highly recommended.

2.5 Responsibilities

Within ISO 5001, definition of roles and responsibilities for various activities are foreseen. Amongst these, the responsibility of top management is crucial. Within ISO 50001, a significant responsibility is given to top management. Accordingly, top management shall demonstrate its commitment to support the EnMS and to continually improve its effectiveness by:

- Defining, establishing, implementing and maintaining an energy policy;
- Appointing a management representative and approving the formation of an energy management team;
- Providing the resources needed to establish, implement, maintain and improve the EnMS and the resulting energy performance;
- Identifying the scope and boundaries to be addressed by the EnMS;
- Communicating the importance of energy management to those in the organization;
- Ensuring that energy objectives and targets are established;
- Ensuring that “energy performance indicators” are appropriate to the organization;
- Considering energy performance in long-term planning;
- Ensuring that results are measured and reported at determined intervals;
- Conducting management reviews.

Top management should also appoint a management representative(s) with appropriate skills and competence with responsibility and authority to:

- Ensure the EnMS is established, implemented, maintained, and continually improved;
- Identify person(s), to work with the management representative in support of energy management activities (energy team);
- Report to top management on the actual and the performance of the EnMS;
- Ensure that the planning of energy management activities is designed to support the organization's energy policy;
- Define and communicate responsibilities and authorities in order to facilitate effective energy management;
- Determine criteria and methods needed to ensure that both the operation and control of the EnMS are effective;
- Promote awareness of the energy policy and objectives.

Other roles and responsibilities needs to be defined according to the requirements.

2.6 Energy policy

ISO 50001 requires that a company should have an “energy policy”. Accordingly, the energy policy shall state the organization's commitment to achieving energy performance improvement. This energy policy shall be defined and endorsed by top management and ensure that it:

- Is appropriate to the nature and scale of the organization's energy use and consumption;
- Includes a commitment to continual improvement in energy performance;
- Includes a commitment to ensure the availability of information and of necessary resources to achieve objectives and targets;

- Includes a commitment to comply with applicable legal and other requirements;
- Provides the framework for setting and reviewing energy objectives and targets;
- Supports the purchase of energy-efficient products and services, and design for energy performance improvement;
- Is documented and communicated at all levels within the organization;
- Is regularly reviewed, and updated as necessary.

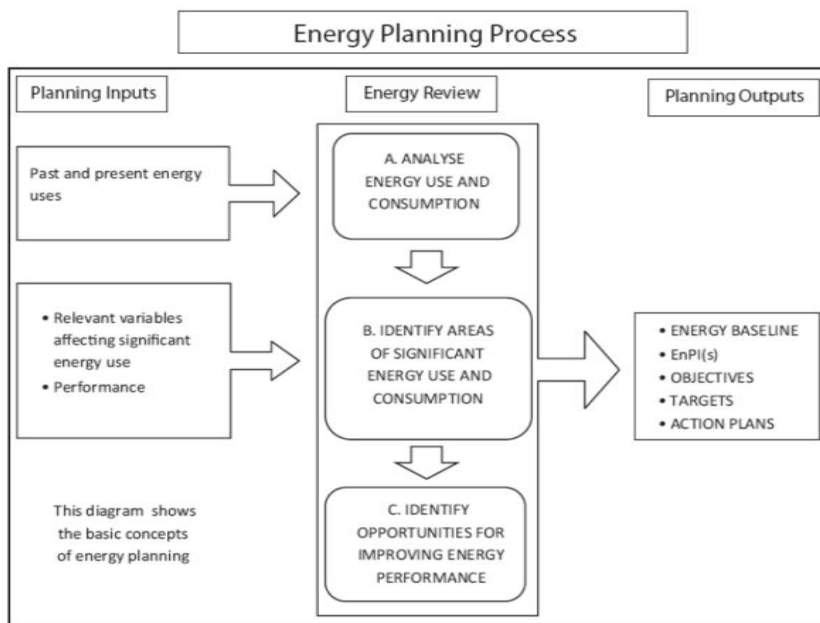
The energy policy is one of the first documents that need to be prepared as it will show the intentions of the top management. All other planning activities then will be based on energy policy.

2.7 Planning

ISO 50001 requires that the company shall conduct and document an “energy planning” process. Accordingly:

- Energy planning shall be consistent with the energy policy and shall lead to activities that continually improve energy performance.
- Energy planning shall involve a review of the organization's activities that can affect energy performance.

A concept diagram illustrating energy planning processes is shown in **Figure 2.3** that at its heart requires an “energy review” of the company.



Source: ISO 50001:2011

Figure 2.3 – ISO 5001 energy planning process [ISO 50001]

ISO 5001 stipulates that based on this, the company shall develop, record and maintain an energy review. The “energy review” advocated by ISO 50001 is similar to an “energy audit”; that is fully covered in **Section 4**. The output of energy review will include the following:

- Energy baseline(s)
- Energy performance indicators
- Objectives,
- Targets
- Energy efficiency measures

The above outputs will be directly used for the design and implementation of the EnMS.

2.8 Monitoring

ISO 50001 stipulates that the company shall ensure that the key characteristics of its operations that determine energy performance are monitored, measured and analysed at planned intervals. A combination of methods such as performance monitoring, etc. is advocated by the ISO 50001. The ship performance monitoring techniques are discussed in detail in **Section 5** together with relevant methods and technologies.

ISO 5001 also advocates the effective use of internal audits as a monitoring method. Accordingly, an audit plan shall be developed taking into consideration the importance of the processes and areas to be audited as well as the results of previous audits. Records of the audit results shall be maintained and reported to top management

2.9 Management review

Within ISO 50001, the management review has been clarified and is a requirement. For the review purposes, some inputs to management review meetings are required and some output is expected to be generated.

Inputs to the management review include:

- Follow-up actions from previous management reviews;
- Review of the energy policy;
- Review of energy performance and related indicators;
- Results of the evaluation of compliance with legal and other requirements;
- The extent to which the energy objectives and targets have been met;
- The EnMS audit results;
- The status of corrective actions and preventive actions;
- Projected energy performance for the following period;
- Recommendations for improvement.

Outputs from the management review are expected to be items such as:

- Changes in the energy performance of the organization;
- Changes to the energy policy;
- Changes to the energy performance indicators;
- Changes to objectives, targets or other elements of the EnMS.
- Changes to allocation of resources.

Based on the above outputs, a new cycle of continual improvement will begin.

2.10 Summary points

In this section, the main aspects of the ISO 50001 standard on “energy management system” are described. It was advocated that a company EnMS is a useful, structured and systematic way for improving the corporate energy performance. Although the development of an EnMS is a voluntary undertaking by a company, its implementation by shipping companies will help them with more effective compliance with the IMO energy efficiency regulatory framework, environmental (climate change) protection and energy (fuel) cost savings.

For the development of the company EnMS, ISO 50001:2011 provides the best-practice available framework. ISO 50001 requirements include development of an energy policy, performing energy reviews, identification of energy performance indicators and baselines, defining various energy efficiency projects and action planning and effective use of monitoring techniques and internal audits and management reviews. Also, ISO 50001 require full commitment by the top management that will be reflected in a written “energy policy” and effective review of the system in formal EnMS

performance review meetings. Certification for ISO 50001 is not mandatory but having a certificate is part of best-practice and a way of demonstrating to external organisations that company's EnMS is fully in place.

2.11 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. ISO 50001:2011 "Energy management systems -- Requirements with guidance for use", ISO publications.
2. ISO website, "ISO 50001 - Energy management",
<http://www.iso.org/iso/home/standards/management-standards/iso50001.htm>, cited September 2015.
3. ISO brochure "Win the energy challenge with ISO 50001 ",
http://www.iso.org/iso/iso_50001_energy.pdf, cited September 2015.
4. "IMO train the trainer course material", developed by WMU, 2013.

3 Shipping Company Energy Management

3.1 Overview

3.1.1 Introduction

Energy management includes planning and operation of corporate activities including all aspects of a company’s production, transport and service aspects with the main aim of reducing the energy use. The wider objectives of energy management are resource conservation, environmental (mainly climate global warming) protection and cost savings, while ensuring the security of supply of energy. As such, energy management is closely linked to environmental management, production management, logistics and other related business functions. Within this context, energy management may be referred to as “the proactive, organized and systematic coordination of a company’s (and its ships) use of energy to meet the requirements, taking into account environmental and economic objectives”.

The translation of the above for a shipping company will mean planning and operation of a fleet of ships with the aim of reducing the total ships’ fuel consumption or CO₂ emissions with due consideration for the company’s quality delivery of services to customers (under ISO 9001), safety and environmental objectives (under ISM code and ISO 14001) and risk avert and safety of personnel (under for example OHSAS 18001). Reduced fuel consumption is part of a two prong strategy of reducing GHG emissions from shipping as well as reducing fuel cost to shipping companies; thus it is a win-win strategy for environment and business profitability.

3.1.2 Fuel (energy) cost

In shipping, fuel management is an important part of a shipping company’s activities since a significant proportion (more than 30%) of a ship’s operational costs are related to fuel costs. **Figure 3.1a** shows typical costs for a tanker; showing high percentage of fuel cost in the overall ship’s operational costs. **Figure 3.1b** shows similar data for containerships but includes total cost inclusive of capital costs. Both show high percentage of fuel cost in the overall ship’s operational or total costs. The numbers presented are typical and percentages are a function of the ship type, ship size, bunker fuel prices as well as mode of operation of the ships.

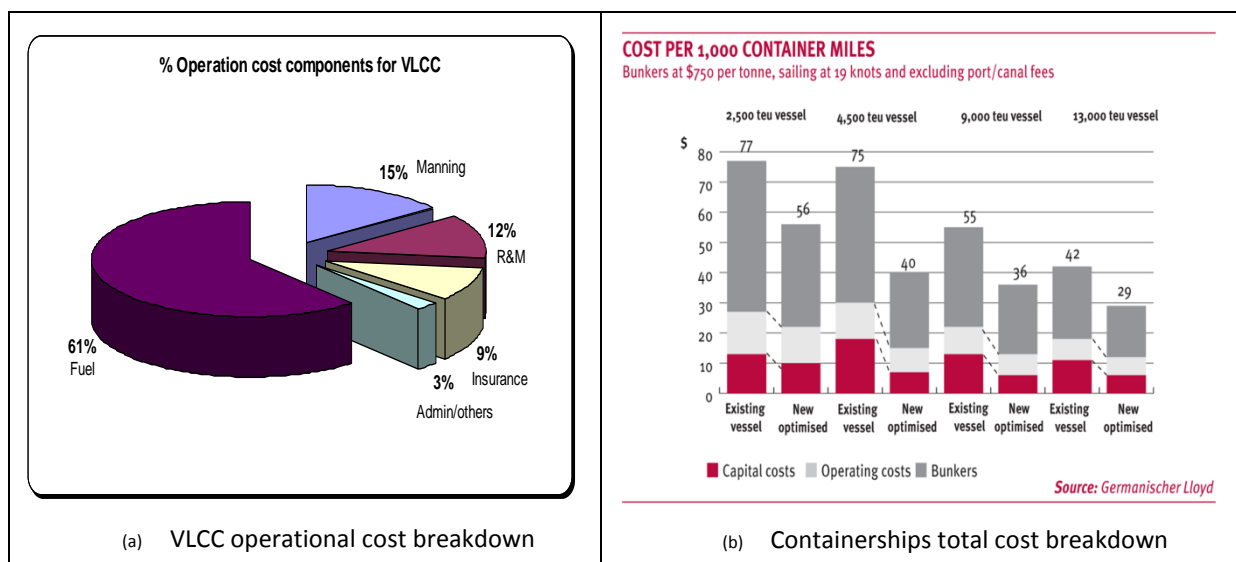


Figure 3.1 – Typical ship costs and fuel costs

3.1.3 Climate change

Apart from ship costs, the issue of environmental impact of shipping has been under scrutiny for a number of years. As discussed under **Module 1**, an estimate of the total emissions of exhaust gases from ships that can be attributed to international shipping was made by the IMO and indicated to be at 2.2% of global man-made GHG emissions in 2012 accordingly to IMO Third GHG Study 2014. Also, it was shown if no action takes place, the shipping GHG emissions will increase by 50% to 250% by 2050. This level of growth in shipping GHG emissions is not acceptable by the international community. Thus a way must be found to reduce shipping GHG emissions much below current day levels.

3.1.4 Scope for energy saving

The question of feasibility of reducing shipping fuel consumption has been the subject of numerous studies in the past 15 years. All studies show that on a wider scale, it is possible to significantly reduce the shipping fuel consumption and GHG emissions. **Table 3.1** shows an example of such studies.

	Saving of CO ₂ /tonne-mile	Combined	Combined
DESIGN (New ships)			
Concept, speed and capability	2% to 50% [†]		
Hull and superstructure	2% to 20%		
Power and propulsion systems	5% to 15%	10% to 50% [†]	
Low-carbon fuels	5% to 15%*		
Renewable energy	1% to 10%		25% to 75% [†]
Exhaust gas CO ₂ reduction	0%		
OPERATION (All ships)			
Fleet management, logistics & incentives	5% to 50% [†]		
Voyage optimization	1% to 10%	10% to 50% [†]	
Energy management	1% to 10%		

* CO₂ equivalent, based on the use of LNG.

[†] Reductions at this level would require reductions of operational speed.

Table 3.1 – Potential for shipping fuel consumption reduction [IMO Second GHG Study 2009]

There are a large number of operational energy efficiency measures for existing fleet that would yield the above mentioned energy savings. Examples are:

Enhanced ship's technical and operational management: Measures include:

- Enhanced weather routing.
- Optimized trim and ballasting.
- Hull and propeller cleaning.
- Better main and auxiliary engine maintenance and tuning.
- Enhanced voyage execution and performance measurement.
- Monitoring and reporting.
- Efficient operation of major electrical consumers.
- Deployment of cost effective propulsion, engines and auxiliary technology upgrades.

Enhanced logistics and fleet planning: Measures include:

- Combining cargoes, where possible, to achieve a higher utilisation rate,
- Use of combination carriers' (to reduce ballast voyages).
- Optimisation of logistic chains.

- Enhanced routing and itinerary.
- Fewer/shorter ballast legs.
- Larger cargo batches (better ship load factor).
- Just in time operation and slow steaming.
- Changes to charter-party contract formats between charterer and ship-owner to facilitate the above.

As an example of well-researched results, **Table 3.2** shows the potential for reduction of fuel consumption and GHG emissions from existing ships (operation) based on a study commissioned by IMO; indicating that a big potential for shipping energy use reduction.

Energy Efficiency Measure	Bulk carrier		Gas tanker		Tanker		Container ship		General cargo/Reefer	
	Handymax	Capesize	LNG	LNG	Panamax	VLCC	Panamax	NPX	~3.5k DWT	~10k DWT
	30-40k DWT	>100k DWT	125-155k m ³	>175k m ³	60-85k DWT	>200k DWT	(4-5k TEU)	(12-14k TEU)		
Engine tuning and monitoring	2.5	1.8	1.8	1.8	2.2	1.6	1.6	1.6	2.9	2.9
Hull condition	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Propeller condition	1.1	0.8	1.1	0.8	1.1	0.8	0.8	0.8	1.1	1.1
Reduced auxiliary power	0.6	0.9	0.7	1	0.6	1.7	0.8	1	2.6	1.1
Speed reduction (increased port efficiency)	15	15	12	10	13	12	10	11	21	13
Trim/draft	0.7	0.7	1	1.4	0.7	0.7	1.7	1.7	0.7	0.7
Voyage execution	2.5	3.4	2.5	3.4	2.5	3.4	1.4	1.4	2.5	2.5
Weather routing	0.1	1	0.1	1	0.2	1	1	0.8	0.1	1
Advanced hull coating	3	3	3	3	3	3	3	3	3	3
Propeller upgrade and aft body flow devices	3	3	3	3	3	3	3	3	3	3
SEEMP potential taking into acc. Overlaps	28.7	29.6	25.9	26.0	26.8	27.7	24.3	25.2	36.0	28.4

Table 3.2 – Operational energy saving potentials in % [LR and DNV]

The above energy efficiency measures and how they lead to energy saving and reduction of GHG emissions, have been explained in detail in other modules (see **Module 3** and **Module 4** for examples). The important point to make here is that without having a proper regulatory framework and a good management system in place, the above measures cannot be systematically and successfully implemented on existing ships. In this module, the topic of application of energy management system to a shipping company and its fleet will be discussed further in order to clarify how the above mentioned systematic approach may be pursued in a shipping company.

3.1.5 Shipping companies approach

The central aim of shipping energy management is to reduce energy costs and GHG emissions without compromising the operational and technical aspects of ships operations in particular the safety, availability and service life of the equipment and their reliable and ease of use.

The regulatory framework for shipping energy efficiency for new ships is to a large extent in place. For existing vessels, the SEEMP regulations are in place and work on “further operational measures” is underway and has progressed well so far. For existing vessels, there will be more regulations on data collection and reporting in the future. The regulatory framework for shipping energy efficiency for existing ships was fully discussed in **Module 2**. Accordingly, each ship should have a SEEMP on board. These regulatory aspects will not be discussed anymore here.

Within the IMO guidelines on SEEMP, the shipping companies are encouraged to have a “company energy efficiency management plan” in order to do the overall fleet optimisation and management of the relevant stakeholders. Although the company energy efficiency management plan is not a mandatory requirement, a question is normally raised that how a company energy efficiency management plan should be developed, documented and implemented. In this course, it is advocated that a company is best to develop such a company-level plan under the name of a Company Energy Management System (CEnMS). Also in this course, it is advocated that the CEnMS is best to be developed using principles as described within ISO 50001 as fully described in **Section 2**.

As the requirements for SEEMP (by IMO guidelines) and CEnMS (by ISO 50001) have already been presented and discussed, the aim of this section is to deal with more detailed and practical aspect of

application of SEEMP and CEnMS to a shipping company and its fleet to ensure that the company achieves what it has planned.

For a shipping company to succeed, it needs to implement SEEMP effectively at ship-level and CEnMS at the company-level. The SEEMP and CEnMS should work hand in hand to manage the overall processes.

3.1.6 CEnMS and SEEMP scope of application

Although CEnMS and SEEMP may be assumed to be similar by readers, in fact they are different and will have different scope. Some complementary aspects of the two are highlighted here:

- SEEMP is only applicable to a “specific ship” and is used mainly on-board ships. CEnMS is not for a specific ship but for a “specific company”. The CEnMS will be mainly implemented at shore office. Thus CEnMS will include more generic and higher-level activities than the SEEMP.
- SEEMP contents are primarily implementation oriented. This means that the strength of a SEEMP should be on how to implement the EEMs at the ship-level together with a good definition of what to be done and ship staff’s roles and responsibilities. Although aspects of planning, monitoring and self-assessment are included in the SEEMP, they are not normally the responsibility of the ship-board staff to implement.
- The CEnMP on the other hand is more oriented to planning, monitoring and self-assessment of the fleet’s SEEMPs effectiveness and other high level management activities relating to energy such as bunkering, provision of third party services to ships and so on. Thus it should provide company-wide and fleet-wide activities that ensure a better planning and energy management activities and a better monitoring and assessment of the results of implementation of these activities along with the external stakeholder management aspects. Along this scope of work, the following are mainly should be reflected in the CEnMS:
 - Energy planning activities for improvement of both CEnMS and SEEMPs.
 - Energy policy development for the company as a whole inclusive of ships in the fleet.
 - Definition of monitoring system and relevant KPIs, baselines, data collection and data analysis systems. Establishment of a monitoring and reporting system for energy efficiency data.
 - Methods for the self-evaluation (company level) of the effectiveness of various SEEMPs plus the CEnMS itself.
 - Coordination and collaboration with the major external stakeholders that influence fleet’s operation.

Based on the above, the scope of the CEnMS and ship-level SEEMPs will be different and they will be more complementary rather than overlapping. This is important for ensuring that the company does all elements of activities that are foreseen under IMO SEEMP and ISO 50001 in a harmonious way.

3.2 Ship-level energy management plan (SEEMP)

3.2.1 EEMs at the core of a SEEMP

In this section, ship-level energy management is discussed with specific reference to SEEMP. As discussed in **Module 2**, the methodology for the development of a SEEMP should be based on the IMO MEPC guidelines. Accordingly, the SEEMP development involves all aspects of planning including:

- Identification of current status of the ship in terms of energy use and performance.
- Target setting for energy use or energy performance of the ship (voluntary).

- Identification of EEMs (Energy Efficiency Measures).
- For each selected EEM for implementation, the following should be done:
 - Definition of implementation method,
 - Definition of monitoring method
 - Definition of assessment method
- Documentation of all the above in the SEEMP.

Under IMO SEEMP development guidelines, there is no requirement for the development of an “energy policy” and setting target for energy saving is also voluntary. Monitoring at the overall-level is advocated via use of the EEOI or another indicator but no references are made to the monitoring of individual EEMs. Additionally, it is mentioned that monitoring should be done by shore-based staff rather than ship-board personnel. Also, the SEEMP is ship-specific, thus for every ship a separate SEEMP that is compatible with ship systems, its operation pattern, etc. need to be developed.

3.2.2 Implementation of EEMs

The implementation of a SEEMP could take a variety of forms. It is argued here that each of the EEMs within a SEEMP needs to be implemented as if it is a form of a “technical and operational project”. The term project is used here to emphasise that each EEM need to have a starting date and end date, it would have a budget and responsible person(s), it would have criteria for monitoring and measuring success and so on. This approach is different from those currently practiced that just provide a listing of a number of EEMs in a SEEMP and leave them to goodwill of relevant managers and personnel to implement. Development of a CEnMS could help to organise this process.

As far as a shipping company’s energy management activities are concerned, the ship-board activities are mostly devoted to the implementation side. This means that various identified EEMs need to be implemented by ship staff. Planning, monitoring and self-assessment of ship-board activities are mainly done by the head-office staff and should be the subject of significant work within the CEnMS framework.

3.2.3 Continuous improvement approach

To include continuous improvement, the energy management systems will be done in steps through a number of cycles (see **Figure 3.2**).

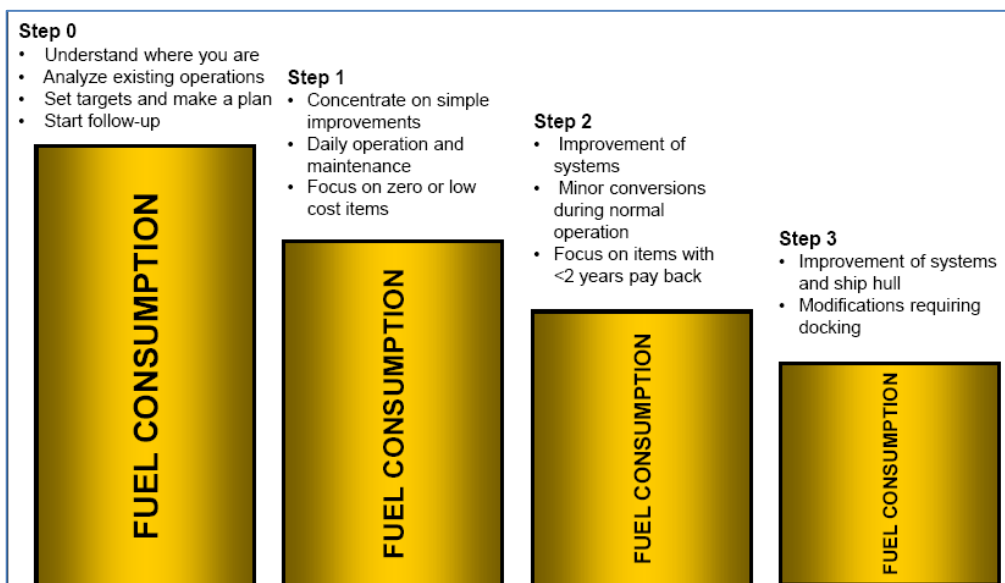


Figure 3.2 – The concept of step-by-step approach to energy management

As indicated above, typical steps could be:

- **Step 0 (initial planning):** Understand where the ship/company is, analyse potential for improvements and decide where the ship/company wants to save energy and start define the target and develop the energy management action plan.
- **Step 1 (low cost measures):** These are normally referred to EEMs that can be implemented at zero or very low cost. They are the so-called “low hanging fruits”. In this step, the concentration will be on these EEMs that may largely include aspects such as improvement to daily operations and maintenance activities. This implementation may require significant effort of cultural change on how things should be done as against how they are done now.
- **Step 2 (medium cost measures):** When step 1 targets are achieved, then EEMs that would involve some cost expenditure for implementation will need to be handled. These are measures that could offer a good return on investment and typically have payback periods of less than 2 years.
- **Step 3 (high cost measures):** These are measures that may have significant cost of implementation (e.g. technology upgrade) or commercial implications (e.g. slow steaming or itinerary changes). These measures need significantly more analysis, deliberations with stakeholders (e.g. charterers) and so on. In fact, the longer term potential for financial return for these measures may be higher compared to other measures but elements of risks are also higher.

The above step-by-step approach to the issue of energy management is compatible with continuous improvement cycle approach that is built in the SEEMP and ISO 50001. **Figure 3.3** shows the associated costs and payback related to the above three steps. As mentioned, latter steps will include measures that could be more costly as well as return on investment (payback) will not be necessarily in the short term.

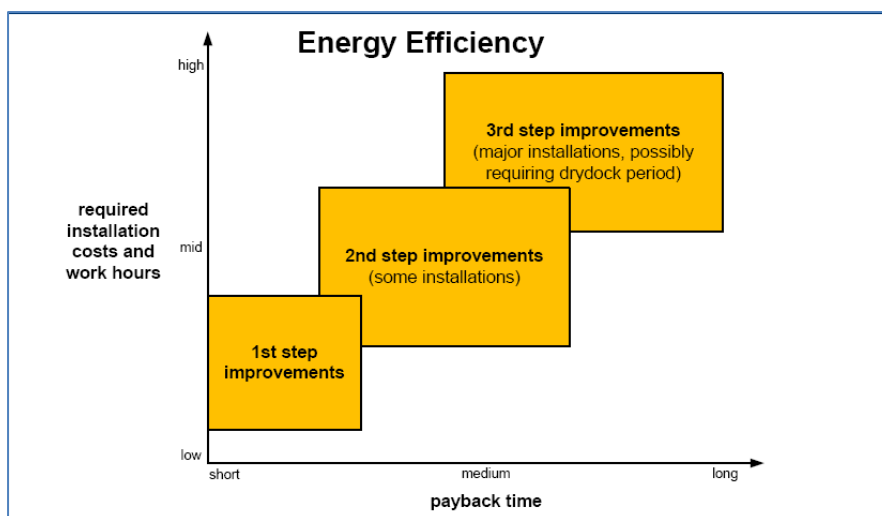


Figure 3.3 – Cost and payback for measures under step 1 to step 3

3.3 Company-level energy management system (CEnMS)

As advocated under IMO SEEMP in **Module 2**, a company needs to have a company energy management system in order to coordinate not only the fleet SEEMPs but also provide company-level coordination with external stakeholders such as charterer, shipper, shipbuilder, and other service providers. To do this, the best option will be to develop a CEnMS based on ISO 50001 principles.

The development of company-level CEnMS based on ISO 50001 would need to be defined by the company. As indicated before, the following areas need to be dealt with in a shipping company CEnMS:

- Energy policy, its communication and awareness raising on the subject.
- Monitoring system and its implementation inclusive of KPIs, baselines, data collection, data analysis and so on.
- Self-evaluation methods and how to evaluate the performance of various SEEMPs at top management level
- Training of staff at company-wide level. Increasing motivation and competence to deal with energy saving aspects.
- Reporting to external stakeholders including major clients and regulatory authorities

The above topics will be further discussed with a view to understand that a CEnMS is the home for delivery of the all the above in an integrated fashion while ship-level SEEMPs are exclusively devoted to implementation of EEMs.

3.3.1 Company “energy policy”

The company energy efficiency policy is of vital importance in determining and setting the agenda for GHG emissions and fuel cost reductions in the fleet. It must be recognised that the policy not only will give the top-level management endorsement and support for relevant activities but also will be a significant document for communicating company values and targets, awareness raising and securing commitment by other staff. The policy would include various important aspects including for example stakeholders’ management in particular the clients with whom the company intends to work most closely and effectively to achieve the objectives.

The energy policy will need to be prepared for the company as a whole. To achieve maximum reduction of GHGs, it is important that the management has a policy to improve the energy efficiency of all the ships it operates. Looking at individual ships in isolation will not reap the highest benefits. The company management should define and communicate the companies' values and aspirations in the policy and provide details of how they intend to achieve these objectives.

The content of the policy will be influenced and dictated by the company’s nature of business, the types of ships, the area of operation, the trade the ships are on, the size of the fleet and overall company strategies. The list below provides some aspects that could be included in the company’s energy policy:

- **Commitment at the highest level:** Creation of policy provides a significant signal by the company management, at the highest level, to demonstrate commitment to a GHG reduction and energy saving policy. This is very important as otherwise it will imply that top management is not taking this issue seriously. If the commitment of top management is not expressed clearly to staff, then it is very unlikely that the operational shore staff or ship’s crew will take energy saving activities seriously. One of the best ways to demonstrate the companies' commitment to energy efficiency is by including this commitment in the policy statement right from the beginning.
- **Company targets:** The policy would need to include targets, if any, to give credibility to the policy statement. Although a policy could be developed without specific targets, it would be much more effective to have targets and monitor progress at a later stage against the target. However, targets should be easy to understand and feasible to be achieved with foreseen workforce and financial resources.
- **Communication to staff:** The dissemination of information to internal workforce and wider international community is important for motivation of staff and branding of the company. The communication aspects need to be included in the policy statement.
- **Monitoring methods:** There have to be provisions in the policy how the monitoring of

achievements will be made. The company policy should clearly state how the company intends to monitor the energy efficiency activities. The company may decide to implement energy audits or other means for this purpose, it is best that these are mentioned in the policy document.

- **Reporting and communication to external stakeholders:** The policy document should detail how it intends to measure, monitor and report the energy efficiency activities to external bodies. The reasons/basis for sharing this information need to be mentioned to strengthen the policy statement.
- **Importance of ship specific SEEMPs:** The policy should also stress the importance of the ship specific SEEMPs for ship-level energy management activities and endorse management commitment to their full implementation.
- **Other specific aspects:** The policy is best to contain the strategic aspects for improving the utilisation of its fleet's capacity and stress the need for planning. This could include the reduction of long ballast voyages, port times, time it takes to load or discharge or the use of shore power or weather routing services. The policy could also include the replacement of older tonnage with new more efficient ships or technology upgrade aspects that would show financial commitment to future improvements. In short, anything important from top management point of view needs to be included.

The policy document, when developed and endorsed by top management, should be available to all of the employees. The document should be written clearly and unambiguously and set achievable and understandable objectives. The content of CEnMS and SEEMPs should be compatible with the policy statement.

3.3.2 Energy review

As part of SEEMP and also CEnMS developments, energy planning and reviews or audits need to be carried out (see **Section 2 on** energy planning). Energy reviews can be used either as part of planning or monitoring phases of the energy management activities. For planning phase purposes, the end result of energy review or audit would be a set of recommendations on best ways of saving energy in the form of a prioritized list of Energy Efficiency Measures (EEMs).

For monitoring phase purposes, the main aim of using energy review or audit would be to check if the implementation of various EEMs or overall reduction in energy performance indicators has undergone according to plan and if any quantitative savings have been accrued. Thus, for the two purposes, two different approaches may be used but techniques used for identifying the potentials will be the same.

The energy review involves a number of activities such as definition of energy baseline(s), energy performance indicators, energy objectives and targets and most of all the energy efficiency measures. The final choice of measures to be implemented will be decided by technical feasibility study as well as economic-cost-effectiveness assessment. The methodology and techniques for conducting an energy review or audit are described in detail in **Section 4**.

3.3.3 Energy efficiency monitoring and reporting

Energy efficiency performance monitoring should be done as part of SEEMPs or CEnMS for the company's internal purposes to ensure that various EEMs are properly implemented. Monitoring should be part of both SEEMPs and CEnMS with main emphasis on activities to be carried out at the head office. For monitoring of major EEMs and dealing with a large number of fleet wide EEMs, the monitoring could be more of a technical challenge and would involve provision of KPIs and their trends to identify how various ships are performing in relation to energy efficiency. In most cases, one or each set of EEMs (e.g. hull maintenance) will have its own methods and KPIs for monitoring

purposes. These technical aspects of ship performance monitoring are discussed in detail in **Section 5** and thus will not be further discussed here.

3.3.4 Energy efficiency training of staff

Increasing the energy efficiency awareness of the shore-based and ship-board staff by means of training can lead to a change in behaviour that has positive impacts on the reduction of ship-board energy use and fuel consumption. For effective implementation of the company's energy efficiency policy it is necessary to raise awareness and providing the necessary training both for shore based and shipboard personnel.

The company should ensure that as part of each crew member's initial on board familiarisation, they are instructed on the part that they each can play in reducing on-board ship fuel consumption. The company may also consider the implement 'Computer Based Training (CBT)' program and poster campaign to increase crew awareness of GHG emissions issues. There should be regular on board meetings with all the crew to discuss the effectiveness of the shipboard energy efficiency plan. Ideas of best practice received from the seafarers should be documented and passed back to shore so that they can be evaluated for use on other vessels and perhaps included in a company-wide energy efficiency bulletin.

It is often a good policy for officers and in particular senior officers joining company vessels to be briefed in the shore office by the superintendent responsible for implementing the energy efficiency plan. The senior officers should be asked to study the documented energy policy, relevant SEEMP and be familiar with CEnMS, if applicable. This familiarisation should be assessed and verified prior to joining the vessels. If this is not practical for officers at operating level, then they should be required to study the policy document on board and confirm that they have read and understood it. The designated on board environmental officer may consider regular on-board awareness and training programs for shipboard personnel which could form part of the on-board Safety Management System (SMS) training program. The results of these training sessions should be reported back to shore office for information.

Company management should also provide regular updates to explain how well the company is performing and if practical provide incentives for those ships or employees that demonstrate both results and commitment to the company's energy policy and objectives. The company magazine or other publicity documents could contain regular articles on not only the company's policies and objectives but general articles of the causes and effects of GHG emissions is a global problem that requires input and efforts by all.

3.4 Summary main features of company energy management system

A good energy management system will have the following main characteristics

- Corporate leadership:
 - Management understanding and commitment via a written energy efficiency policy.
 - Allocation of resources (man-power, funding etc.) for implementation.
 - Review of energy management performance and setting targets for continuous improvement.
- Planning aspects:
 - A documented energy efficiency plan is in place.
 - Energy efficiency plan is linked to policy, programme and targets on energy efficiency.
 - Energy efficiency measures are fully documented and ready for implementation.

- Human resources and training:
 - Energy management roles and responsibilities and team are defined and operational.
 - Increasing awareness through communication and training have created the personnel's commitment and support.
 - Recognition system for energy management achievements is in place.

- On technical and operation management
 - This includes considering energy efficiency in ship design, purchasing of material and equipment, maintenance and ship operation.
 - Accurate analysis of the energy use in all processes and equipment is in place.
 - Best-practice performance monitoring for assessment of success level.
 - Best-practice maintenance of equipment for energy efficiency.
 - Operation profile controls and ship itinerary (activity) management are important aspects in this regard.

- Information gathering and management
 - Company collects and keeps history of accurate energy use and performance data.
 - Clear and effective communication procedures are in place to keep the staff and external stakeholders informed of progress.
 - A proper information management system is implemented.

- Reviews and assessment
 - The organisation monitors and controls the energy management system performance on a continuous basis.
 - The organisation has in place appropriate KPI's for checking the energy management performance.
 - The organisation conducts management review on a regular basis to track the achievements and identify opportunities for further improvement.

3.5 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. "IMO train the trainer course material", developed by WMU, 2013.
2. IMO Third GHG Study 2014, MEPC 67/INF.27, published 2014.
3. IMO Second GHG Study 2009, published by IMO 2009.
4. LR and DNV, "Estimated CO₂ emissions reduction from introduction of mandatory technical and operational energy efficiency measures for ships", Report by Bazari Z and Tore Longva , IMO MEPC 63/INF.2, 31 October 2011.
5. "Estimated CO₂ emissions reduction from introduction of mandatory technical and operational energy efficiency measures for ships", IMO MEPC 63/INF.2, 31 October 2011.
6. IMO MEPC Resolution MEPC.213(63), "2012 Guidelines for the development of a ship energy efficiency management plan (SEEMP)" Adopted on 2 March 2012.
7. ISO 50001:2011 "Energy management systems -- Requirements with guidance for use", ISO publications.

8. IMO MEPC Resolution MEPC.203(62): Inclusion of regulations on energy efficiency for ships in MARPOL Annex VI, Adopted on 15 July 2011.
9. Lloyd's List, "CMA 2013: GL Eco Study Finds 4,500 TEU Boxships Deliver Biggest Savings", <http://www.lloydslist.com/ll/sector/ship-operations/article419461.ece>, cited September 2015
10. Lloyd's Register 2015, "European Union Regulation on Monitoring, Reporting and Verification of Carbon Dioxide from Ships", Lloyd's Register Summary – EU MRV, Version 4.0 – May 2015.
11. Regulation (EU) 2015/757 on "the monitoring, reporting and verification of carbon dioxide emissions from maritime transport", and amending Directive 2009/16/EC, adopted by the European Parliament and the Council of 29 April 2015

4 Energy Audit and Review

4.1 Introduction

Energy audits or reviews are key to a systematic approach to an effective planning for energy management. It represents a quantitative assessment of a company/facility/ship energy inputs and outputs and attempts to balance the total energy inputs, output and losses at top level as well as for major energy using systems and equipment. As such, it is used to assess all the energy streams in a facility (such as a ship) with the main objective of identifying ways to reduce its energy consumption, energy baselines and so on.

As discussed earlier, the main operational expenses of a ship is found to be fuel cost plus other costs such as maintenance and repair and crew wages. If a choice is made to reduce the operational costs via improving performance amongst the above three main cost items, energy would invariably emerge as a top preposition and thus energy management constitutes a strategic area for cost reduction.

Energy audit or review helps to understand in detail about the ways energy and fuel are used in any industry, thus helps in identifying the areas where waste can occur and where scope for improvement exists. The scope of an energy audit or review varies from industry to industry but generally could include supporting the corporate aspects such as reducing energy costs, reducing environmental impacts, ensuring availability and reliability of supply of energy, use of appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. Energy audit or review seeks to identify the technically feasible energy conservation solutions taking into account economic and other organizational considerations within a specified time frame.

Energy audit and reviews are mandated activities in some of the existing management standards. For example, in development of a CEnMS based on ISO 50001, carrying out energy review is a requirement, see **Section 2**. Another example is the EU Directive on Energy Efficiency [Directive 2012/27/EU] that makes energy audit of enterprises a requirement unless they are certified for ISO 50001 that implies they have already undertaken an energy review.

So, in terms of requirement, various standards may have a varied level of requirements on how energy audit or review should be done or documented. For example, on the need for documentation and certification, ISO 50001 advocates the following:

- The methodology and criteria used to develop the energy review shall be documented.
- The energy review shall be updated at defined intervals, as well as in response to major changes in facilities, equipment, systems, or processes.

However, technically speaking, energy audit and review are not that much different. As such, in this section, the techniques for carrying out an energy audit is described, assuming that same techniques could be used to perform energy reviews.

Energy audit is defined in EU Directive 2012/27/EU as:

“Energy audit means a systematic procedure with the purpose of obtaining adequate knowledge of the existing energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying cost-effective energy savings opportunities, and reporting the findings.”

EU has also developed European standards for energy audits. EN 16247:2012 series of standards provide more formal techniques for energy audits. An abstract of EN 16247-1:2012 states that [CEN website]:

“This European standard specifies the requirements, common methodology and deliverables for energy audits. It applies to all forms of establishments and organisations, all forms of energy and uses of energy, excluding individual private dwellings. This European standard covers the general requirements common to all energy audits. Specific energy audit requirements will complete the general requirements in separate parts dedicated to energy audits for buildings, industrial processes and transportation.”

4.2 Types of energy audit

The types of energy audit to be performed depend on:

- Function and type of industry (for example for shipping it will be somewhat different from a production factory).
- Depth and details to which the final audit is needed. This defines the scope of audit and what sort of output is expected from it.
- Potential and magnitude of cost reduction desired.

As a result, energy audit can have varied scopes; however in general terms energy audits are classified into the following two types.

- Preliminary energy audit
- Detailed energy audit

Preliminary Energy Audit: A preliminary energy audit is a relatively quick review of energy performance of facility that aims to:

- Establish overall energy consumption and its profile in the organization/facility.
- Estimate the scope for energy saving.
- Identify the most likely and the easiest areas that could provide saving potentials.
- Identify immediate (especially no or low-cost) improvements/ savings.
- Set a 'reference point' or establish a baseline for the organisation/facility.
- Identify areas for more detailed study/measurement for subsequent assessments.

For preliminary energy audit, normally existing or easily obtainable data are used and does not include any independent measurement campaign. A preliminary energy audit is sometimes referred to as a “walk-through energy audit” as it does not involve significant level of data analysis.

Detailed Energy Audit: A detailed energy audit provides a more comprehensive approach to the issue with detailed data gathering and data analysis for identifying and analysing the EEMs. It aims to provide enough information to enable decision making process or development and planning of energy saving projects. It effectively evaluates all major energy using systems. This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all energy saving measures, accounts for the energy use of all major equipment and includes detailed energy cost saving calculations and project costs.

In a detailed energy audit, one of the key elements is to establish the energy balance for the facility or organisation. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated energy use together with some degree of system modelling that compares well to the actual fuel and energy used; can provide insight into the way energy is procured and consumed.

4.3 Ship energy audit process

4.3.1 Overview

A ship energy audit is considered as a specific energy audit that is tailored made for evaluation of a ship energy performance and identification of a ship's Energy Efficiency Measures (EEMs). It is therefore a review and assessment of the overall fuel/energy consumption and efficiency of a ship with the main objective of identifying a set of EEMs⁵ that when implemented would lead to reduced ship's fuel consumption. Identification of EEMs is the first step for development and implementation of a ship-specific energy saving programme as well as developing an organisations' energy management system (i.e. CEnMS) and a ship's energy management plan (i.e. SEEMP).

In ship energy audit, the focus is on identifying the existing status of a ship's operational processes and technical activities, and their comparison to best-practice or benchmarks. The analysis, depending on scope of the energy audit, involves some level of data collection and data analysis. As a result, areas of energy savings are identified, analysed and documented. **Figure 4.1** shows the generic process diagram for such an energy audit / review.

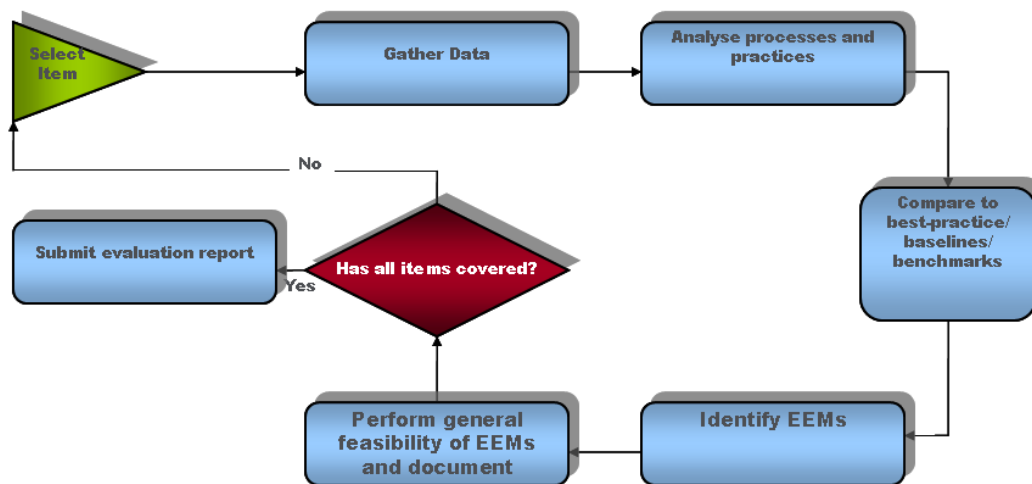


Figure 4.1 – Energy audit or review process [Bazari 2012]

In **Figure 4.1**, each “item” (see green triangle) could be a ship engineering system, machinery / equipment or operational activity that needs to be systematically analysed for energy efficiency. For each “item”, relevant data need to be collected and relevant benchmarks defined. **Table 4.1** and **Figure 4.2** show examples of main areas and aspects of a ship that should be investigated one by one as part of the ship energy audit.

Hull condition and performance
Ship's operation and fuel consumption profiles
Ship voyage management and weather routing
Main engine's condition and performance
Auxiliary engines' condition and performance
Ship's auxiliary electrical loads reduction
Auxiliary machinery utilisation and performance

⁵ The ship's EEMs refer to those operational, technical and technology upgrade aspects of a vessel that if implemented, would lead to improved energy performance of a ship.

Fuel quality and fuel treatment system
Lighting system and types of lamps
Compressed air system
Steam boilers
Steam system and piping condition
Technology upgrade potential (equipment retrofit)
Personnel training needs
Etc.

Table 4.1 – Ship energy audit – Example areas to be assessed

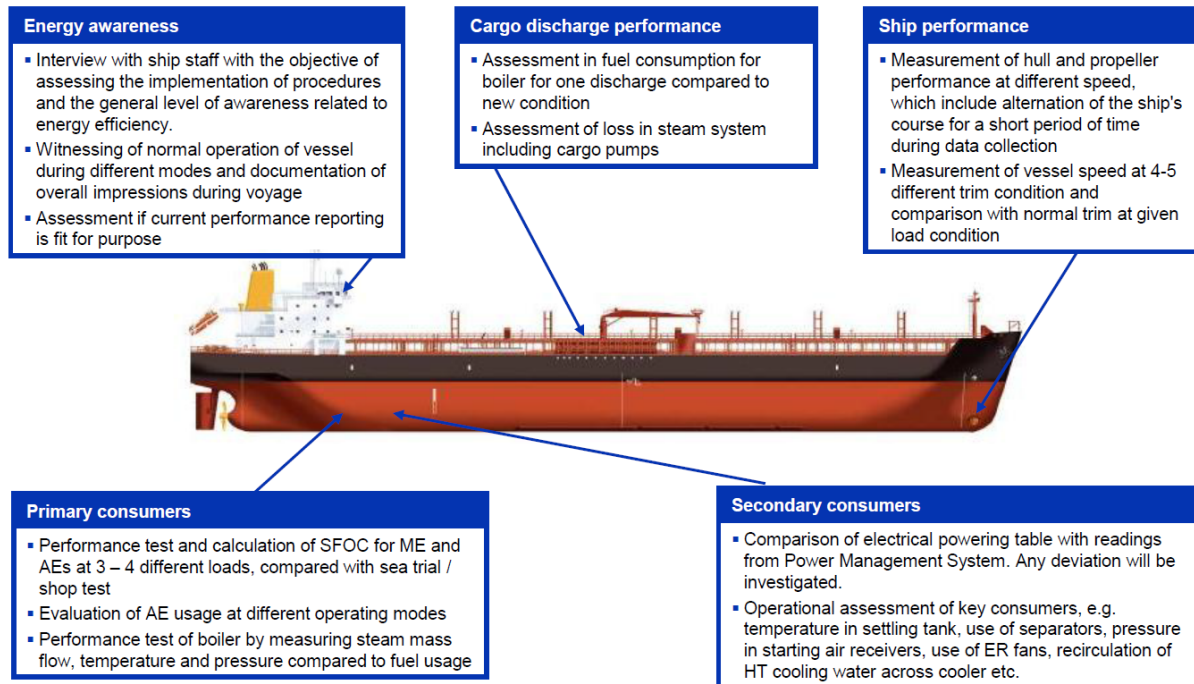


Figure 4.2 – Ship energy audit – Example areas to be assessed [DNV 2011]

4.3.2 Ship energy audit phases

Generally, a ship energy audit involves a ship-board survey and thus the audit as a whole may be carried out in three phases:

- **Phase I – Pre-audit:** This relates to all activities before the ship visit and survey. Activities under this phase could include:
 - Preliminary data gathering: The data would include ship’s design data, speed trials data and operational data.
 - Initial data review: The preliminary data gathered are reviewed, preliminary candidate areas for further investigation are identified, some benchmarks are developed and the ship-board “energy audit” plan is prepared.
- **Phase II - Audit:** This includes ship survey, data analysis and reporting. Activities under this phase could include aspects such as:
 - Ship energy survey: The ship is visited and the planned survey activities are carried out, facilitated by ship personnel. This stage consists of a number of activities that involve walkthrough of ship engine room, deck and cargo control room, brainstorming and discussion with relevant personnel in particular the master and chief engineer and detailed investigations and data gathering from relevant record books, manuals, digital archives, etc.

- Data analysis: Final data analysis is performed with the objective of identifying the final list of EEMs, their relevant energy saving level and the techno-economic feasibility analysis of each EEM.
- Energy audit report: A report inclusive of findings and supporting evidences is prepared.
- **Phase III – Post-audit**: This refers to activities that may be needed to support the post audit implementation by the client.

4.4 Typical data analysis

A ship energy audit/review involves a significant level of data analysis. The depth and breadth of data analysis depends on type of investigation and level of detail agreed. In this section, examples of such types of analysis are given.

4.4.1 Ship operation profile

For improved voyage management and itinerary optimisation, evaluation of ship operation profile is an important area. The objective of this evaluation is to make sure that the itinerary and voyage management are planned and performed according to best practise. The assessment of ship operation profile will normally give an indication of excessive waiting periods or lack of ship activity. For this purpose, the ship duration of stay in ports, anchorage, etc. is an important factor that needs to be evaluated. **Figure 4.3** shows an example of such a profile for an oil tanker.

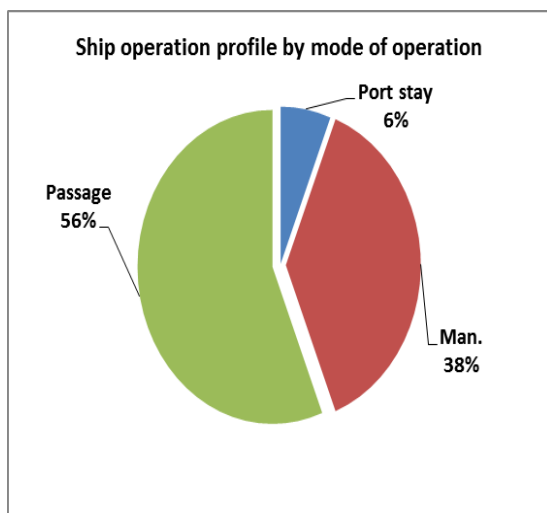


Figure 4.3 – Typical ship’s operation profile by operation mode

Analysis of the above timings for this tanker then need to be carried out against ideal cases with no waiting by considering time for loading, unloading and bunkering, etc. As a result, it could be decided if there are opportunities for improvement or not.

4.4.2 Fuel consumption profile

The ship fuel consumption profile represents the balance of fuel used by different combustion systems (e.g. main engines, auxiliary engines and boilers). It can give an indication if any of the ship systems consume relatively higher fuel compared to expected best-practice levels. This then could be a good lead for further investigations of the causes of excessive fuel consumption and thereby identification of energy efficiency measures.

Figure 4.4 shows an example of a ship’s fuel consumption profile; indicating percentages of fuel used by various systems. Comparing these with industry benchmarks and other ships in the fleet will indicate if any of the system may have been used inefficiently.

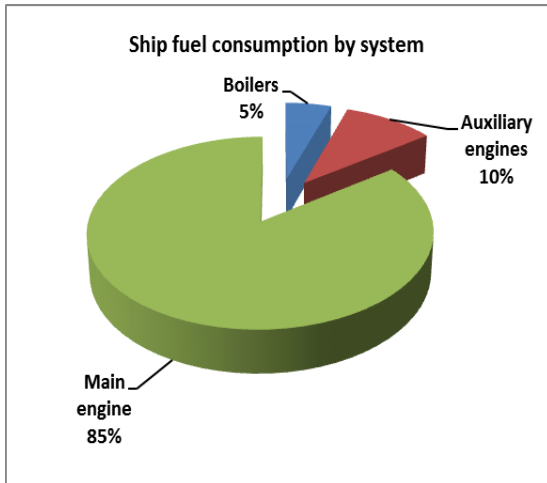


Figure 4.4 – Ship fuel consumption profile by system

4.4.3 Hull performance assessment

Analysis of a ship’s speed-power or shaft rpm-power is the main analytical way for identification of hull and propeller fouling (see **Figure 4.5**). Under-water inspection of hull and propeller is an alternative technique. The data analysis techniques used for this type of investigations are similar to those performed under “ship performance monitoring” that is covered in **Section 5**.

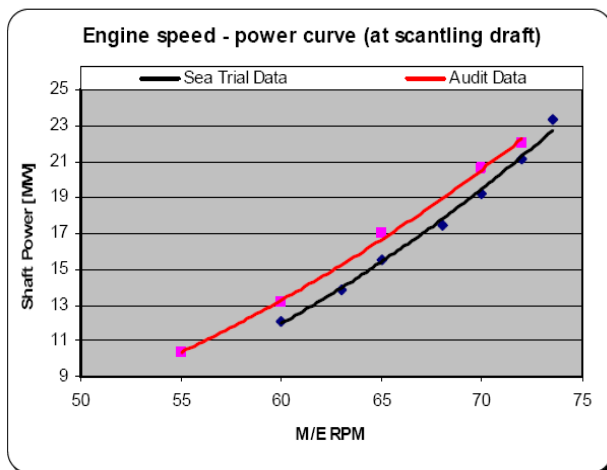


Figure 4.5 – Speed-power curve analysis [Bazari 2012]

4.4.4 Engine performance assessment

The methodology used for engine performance assessment (for both main and auxiliary engines) is based on what is normally used on-board for engine’s condition and performance monitoring. Almost all ships perform engine cylinder pressure measurement (see **Figure 4.6** as example). The system used normally analyse the cylinder pressure diagram and fuel injection profile (if measured) that would indicate anomalies with fuel injection system, cylinder liners, piston rings od engine valves. This test and its analysis are normally carried out on a monthly basis as part of the ship’s planned maintenance system.

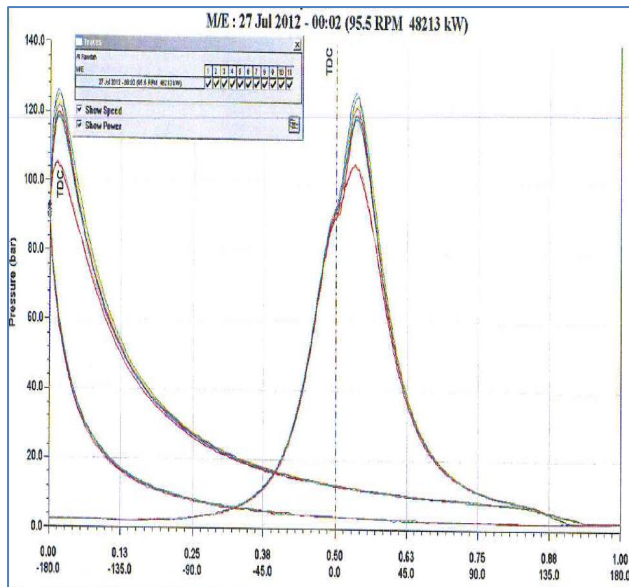


Figure 4.6 – Typical on-board cylinder pressure measurement [Bazari 2012]

Such monthly data are normally available on board ships and can be gathered and analysed for this purpose. Additionally, data such as turbocharger speed, scavenge pressure and temperature can be used to re-enforce if the engine is optimised or not. The techniques used during energy audit to assess the performance of the engines are similar to those used for engine performance monitoring as described in **Section 5**.

4.5 Techno Economic Analysis

Identification of EEMs and their potentials for energy saving does not warrant that the saving potential could be realised in practice. Technical aspects and/or economic aspects could act as barriers. Therefore, each EEM needs to be assessed both technically and economically to find out if they are feasible and cost-effective. As part of the energy audit, such preliminary techno-economic analysis of each identified measure may be carried out.

For a company who is serious about energy saving and efficiency, the techno-economic feasibility will be very important to be carried out correctly. The reason for this is that:

- The choice of EEMs for implementation purposes should be based on a sound technical feasibility assessment by the company. The barriers for proper implementation needs to be identified and planned to be resolved if the EEMs are going to be included in SEEMP and CENMS.
- Implementation of any measure for energy saving will involve cost either in the form of additional capital or operating expenditures plus additional staff time that can be converted to money as cost.
- Taking these costs in relation to energy saving and cost saving will indicate the cost-effectiveness of the adopted measure.

4.5.1 Technical feasibility assessment

The technical feasibility aspect focuses on mainly design, operation and technical aspects as well as ship board details such engineering changes needed, space availability, etc. The extent of technical feasibility study depends on the type of the measure. The preliminary feasibility can be assessed as part of the energy audit during ship survey; however, for major investment EEMs, the ship owner would normally carry out further technical feasibility studies before implementation.

For a specific case of slow steaming or virtual arrival, as suggested in the section on contract of

carriage a particular ship on a particular voyage on a particular contract may or may not be able to slow steam or apply virtual arrival techniques, which is why both the ship managers and chartering department must be involved in any policy decision or feasibility analysis of the proposal. Efficiency is also dependent on ships being of a suitable design and size for trade. There must however be sufficient transport demand. Use of large ships may be constrained by port, canal, lock, berth dimensions, cargo gear capacity and the depth of the approach channel. If this is the case the cargo may have to be trans-shipped from a hub port by feeder ships which are smaller and less efficient so negating the gain of using the larger ships particularly with the extra energy and cost of discharging and loading on to another vessel. So these are the aspects that need to be taken in the technical feasibility of this specific proposal.

4.5.2 Economic cost-effectiveness assessment

Perhaps the most important factor when considering energy management is the cost of fuel that can either make or break a GHG strategy particularly when it involves buying expensive equipment to reduce fuel costs. Some approaches to reduce GHGs emissions are only financially viable when oil prices reach a specific level and are expected to stay above that level long enough to provide an adequate financial return on the investment in the particular energy efficiency improvement method. There will therefore always be an element of financial risk or reward when deciding on such policies especially when the price of fuel is volatile. When the price of oil is high, many measures are becoming cost effective and return on investment is proportionally linked to fuel price and is higher.

The economic assessment of the measures is required to show if the measures are economically cost effective. For economic evaluation, capital costs and running costs (energy use, maintenance, manning, etc.), and fuel price need to be considered. Economic data is normally difficult to find and they are changing from one ship to another. The extent of economic assessment depends on the type of measure. Economic assessment could be based on simple pay-back period calculations or somewhat more involved methods such as Net Present Value (NPV) techniques. For preliminary feasibility analysis, simple pay back is sufficient. The main techniques are described below [MEPC 62/INF.7].

Payback period

The simplest method to evaluate investments is by estimating the payback period. The payback period is simply the investment divided by the net savings per period. The investment will include cost of technology plus installation. The net saving will include saving due to fuel cost minus any additional operating costs (personnel, maintenance, etc.). For example, an investment of \$1000 that saves \$400 annually has a payback period of 2.5 years. While the payback period is often used as a rule-of-thumb evaluation of investments, it has some disadvantages. First, it does not properly account for the time value of money as it has no discount rate. Second, it gives no information on the total profits over the life of the investment.

Net Present Value (NPV)

A more sophisticated way to evaluate new investments is the Net Present Value (NPV). It is an indicator of the value of an investment. By definition, this is the difference between the capital costs of an investment and the present value of the future flow of profits. The formula for NPV is:

$$NPV = R_0 + \sum_{t=1}^T \frac{R_t}{(1+i)^t}$$

Where:

- R_0 – the investment at $t=0$; to be given a negative number.
- T – the lifetime of the investment
- R_t – the net cash flow (cash inflows minus expenditures) at time t

- i – the discount rate

When calculating the NPV, assumptions must be made on the lifetime of the investment and the discount rate must be determined. The discount rate can be based on the company's borrowing rate or cost of capital or any other rate the company uses for such investments.

For example, an investment of \$500,000 today is expected to return net \$100,000 of cash each year for 10 years. The \$500,000 being spent today is already a present value. However, the future cash receipts of \$100,000 annually for 10 years need to be discounted to their present value. Let's assume that the receipts are discounted by 14% (the company's required return). This will mean that the present value of the future receipts will be approximately \$522,000. The \$522,000 of present value coming in is compared to the \$500,000 of present value going out. The result is a NPV of \$22,000 coming in.

Investments with a positive NPV would be acceptable and those with negative NPV value would be unacceptable.

Internal Rate of Return (IRR)

Another way to evaluate investments is to calculate the internal rate of return (IRR). It is an indicator of the yield of an investment, not of its value. By definition, the IRR is the discount rate for which the NPV is zero. Therefore the above formula for NPV can be used but this time $NPV=0$ and T that is the lifetime of investment is assumed to be known (e.g. 5 years). The term " i " here is referred to as IRR and needs to be calculated. This is a more sophisticated way of appraisal of investment than the pay-back period that does not consider any discount rate at all.

NPV is the most accurate approach to evaluate investments as it gives information on the total expected profits, and requires the cost of capital as an input in addition to the assumption on the lifetime of the investment. It is not the intention of this course to evaluate the differences between the above economic assessment methods. For those engaged in energy saving activities and not the economic decision making, the simplest method of pay-back period calculation will suffice.

4.5.3 MACC and its development

For overall presentation of cost effectiveness of results as well as potential CO₂ reductions for a ship or a fleet and for management purposes, development of MACC (Marginal Abatement Cost Curves) for the company fleet or ships will be a useful way of communicating the results and priorities on the basis of each EEM and as a whole.

Additionally and apart from ship energy audit, the economic assessment of the EEMs is of utmost importance in CO₂ reduction activities. Many organisations including IMO have carried out studies in this area. The basic requirement is that how much it costs to reduce CO₂ emissions when different measures are implemented. Of course the answer will be specific for each ship.

To answer the above quest, calculation of the Marginal Abatement Cost (MAC) is advocated. Also presentation of results in the form of MAC Curve (MACC) is commonplace. In shipping, SNAME and IMarEst collaboratively have conducted a comprehensive study of MAC. Some of the material in this part is taken from this report [MEPC62/INF.17].

What a MACC shows

Marginal Abatement Cost Curve (MACC) is used to show potential CO₂ reduction of various EEMs versus associated costs/benefits in a very visual and simple way. The MACC shows the reduction potential (tonne/year) and abatement cost (\$spent/tonne CO₂ reduction) on one diagram. A typical one developed for international shipping as a whole is shown in **Figure 4.7** as example. The X axis represents CO₂ reduction potential and Y axis shows the relevant costs per unit of CO₂ abatement.

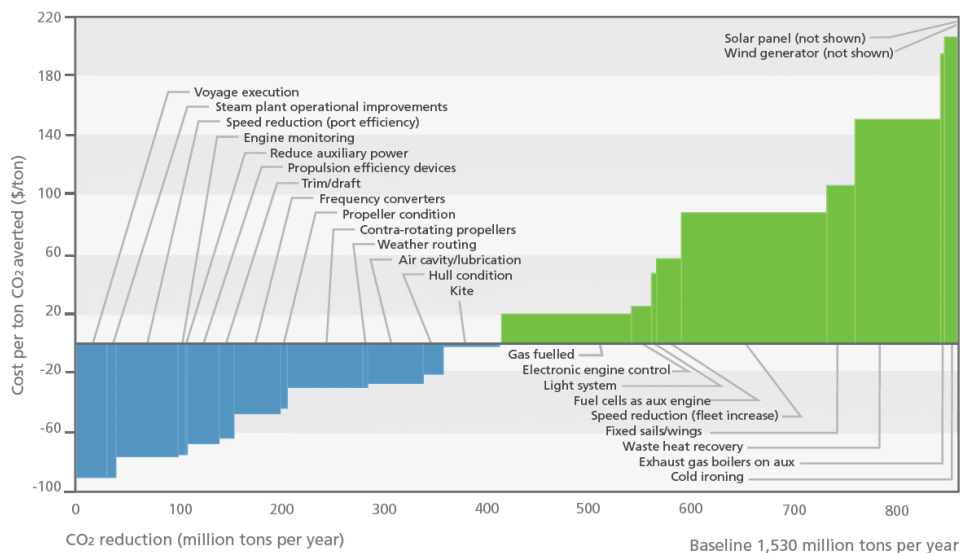


Figure 4.7 – Typical MACC for international shipping [DNV 2010]

How to develop a MACC

To develop the MAC curve as in **Figure 4.7** but for a single ship, the following steps need to be taken:

1. **Step 1** – Identify EEMs and their energy saving potentials in terms of for example percent reduction in the ship’s fuel consumption. This is best to be done via an energy audit or review as explained above. From fuel consumption reduction, one can calculate the CO₂ reduction level using relevant emission factor and normalise to an annual value. This will provide a number that later on could be used for X axis.
2. **Step 2** - Calculation of the cost-effectiveness of individual measures: Cost-effectiveness is by definition the ratio of costs to saving levels both measured financially. There are various financial methods to estimate the cost effectiveness including payback period, IRR and NPV as discussed earlier. However, and for CO₂ studies, a far more better method is use of Marginal Abatement Costs (MAC). The relevant calculations can be done as outlined below. The MAC calculation per unit of CO₂ reduction will be used for Y axis.
3. **Step 3** – Ranking and putting in order the EEMs from lowest MAC to highest MAC (i.e. lowest cost EEM to highest cost EEMs).
4. **Step 4** – Plotting the MACC. Use the ranking system, each EEM represented by a rectangle where its vertical side is the MAC and the horizontal side is the CO₂ reduction level. These rectangles will be next to each other as shown in **Figure 4.7**.

Thus MACC is formed by plotting of the cost effectiveness of measures against the resulting cumulative reduction in CO₂ emissions. For each combinations of ship type, size and age, there are a suite of technical and operational measures that can be applied, thus MACC for ships will change depending on their circumstances.

Simple formula for MAC development

The following formulas can be used to estimate the X and Y axis value for the MACC [MEPC62/INF.17].

$$\Delta C_j = K_j + S_j - E_j + \sum O_j \quad (1)$$

Where:

- ΔC_j is the change of annual cost of for the implementation of EEMj, estimated as per equation (1)
- K_j is the capital cost of the EEMj, discounted by the interest rate and written down over the service years of the technology or the remaining lifetime of the ship, whichever is shortest;
- S_j is the service or operating costs related to the application of EEMj.
- ΣO_j is the opportunity cost related to lost service time and/or space due to the installation of the EEMj such as the cost of days off hire for the vessel; and
- E_j is the fuel cost savings as a result of the EEMj, which is a product of the price of fuel and the saving of fuel as described in Equation (2).

$$E_j = \alpha_j \times F \times P \quad (2)$$

Where:

- α_j is the fuel reduction rate of EEMj (% reduction in ship fuel consumption);
- F is the pre-installation or original fuel consumption for a ship,
- P is the fuel price.

The MAC value is then calculated as the ratio of change in annual cost divided by the relevant reduction in CO₂ emissions as shown in equation (3).

$$MAC = \frac{\Delta C_j}{\alpha_j \times CF \times F} = \frac{K_j + S_j - E_j + \Sigma O_j}{\alpha_j \times CF \times F} \quad (3)$$

Where:

- CF is the carbon factor of fuel that shows the tonne CO₂ generated per tonne of fuel burnt.
- F is total annual fuel consumption.

As the above formulas indicate, the main inputs to formulas are the estimated fuel saving potential in percent, the capital and operating costs associated with implementation of the EEM, the total fuel consumption of the ship (or any other system under consideration) and most important of all, the fuel price. Any uncertainty in the input data will make the result uncertain. For this reason, in developing MACC, evaluation of the sensitivity to input parameters should be considered. As some of the parameters are uncertain in particular the future fuel prices, this sensitivity analysis will provide a way to making a better financial decision.

4.6 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. Bazari Z, 2012 "Ship Energy Efficiency – Developments and Lessons Learnt", Lloyd's Register Technical Association presentation, October 2012.
2. DNV 2011 "Energy efficiency in operations", Presentation to the Baltics Roadshow 2011, http://www.dnv.ee/binaries/Presentation%20EEDI,SEEMP,%20SEA%20and%20E%20Baltic%20Roadshow2011v1a_tcm172-477641.pdf, cited September 2015.
3. Wayne C. Turner (editor), "Energy Management Handbook Sixth Edition", April 2012, http://www.serviciilocale.md/public/files/Energy_Management_Handbook.pdf, accessed September 2015.

4. A Sarasquete, A Juandó, A Caldas, , F Zapata “Energy efficiency audits on ships: Hydrodynamic aspects for energy efficiency improvements”, Congreso Internacional de Diseño e Ingeniería Naval Cartagena de Indias, Colombia, March 2011.
5. Directive 2012/27/EU, “Energy Efficiency”, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, 25 October 2012.
6. CEN website, “European Standards for Energy Audits: helping companies to comply with requirements of the EU Energy Efficiency Directive” http://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT:35014&cs=149DEEE262998D2F15F2B882FFD9DDEE2, accessed September 2015.
7. “IMO train the trainer course material”, developed by WMU, 2013.
8. DNV 2010, “Pathways to low carbon shipping - Abatement potential towards 2030”, http://www.dnv.com/binaries/Pathways_to_low_carbon_shipping_tcm4-420472_tcm4-428628.pdf, cited September 2015.

5 Ship Performance Monitoring and Reporting

5.1 Introduction

In shipping industry, there has been a continuous demand and interest in ship performance monitoring (SPM) overall and also the monitoring of ship's major operations or machinery systems. When high fuel prices and air emissions control take centre stage in the marine industry, the urge to increase a ship's energy efficiency using SPM is normally higher. Additionally, the more sophisticated engines with their recent developments in the combustion process (with thermal efficiencies reaching up to 52%), waste heat recovery systems (with reported benefits of 10% extra energy efficiency), use of emission reduction technologies such as SOx scrubbers and the persistent issues of variable quality fuel; all dictate a closer monitoring on the fuel engine itself, and exhaust system as a matter of best practice. The propulsive (hull and propeller) efficiency can be improved significantly by reducing hull and propeller surface roughness. Frictional resistance forms about 70-90% of the total resistance of a ship for bulk carriers and tankers (approx. 50% for cruise liners and container vessels) and is directly affected by hull roughness, which in turn is affected by fouling. Keeping the hull and propeller smooth and free from fouling is therefore essential for optimal ship energy efficiency.

Hull fouling is affected by type of paints. In the past, hull fouling has been combated by antifouling coatings for example Tributyltin (TBT) that is now regarded as environmentally toxic. The complete ban on TBT in marine antifouling systems by the IMO in 2008 resulted in an increased use of biocide-free foul-release coatings. There is not extensive experience on the effectiveness and performance of new paint systems in terms of long-term frictional resistance and fouling in service. The effectiveness of the coatings can be assessed by doing SPM over a long period and comparing speed and power capabilities with clean-hull performance.

As a result of energy efficiency regulations (see **Module 2**), a large number of energy efficient technologies has been identified that could be used on board ships. However, uncertainty in level of savings due to each technology, and inaccuracies associated with measurement and verification of saving level are major barriers for use of such technologies. An effective SPM would support the uptake of these technologies.

In this section, various aspects of ship performance monitoring (SPM) are discussed. Various methods are proposed and main components of such systems are identified. The analysis methods, practical systems and scope of applications are discussed. The intention is to show that performance monitoring is a key technology for ensuring an effective ship energy management campaign that aims for a reduction in ships' fuel consumption and environmental pollutions.

5.2 Benefits of ship performance monitoring

Knowledge and understanding of a ship's performance and condition in terms of a ship's speed and power, engines' condition, voyage performance, port operation performance, etc. are useful both from economic and environmental points of views. The following overall capabilities and benefits may be attributed to an effective and integrated SPM system [Thijs Willem Frederik Hasselaar]:

- **Assessment of hull condition:** If a proper hull performance analysis system can be developed, it could be an invaluable tool for assessment of hull roughness, hull fouling, the quality of coatings and paints. Also, it could be very effective in determination of the economically optimum intervals for hull cleaning or dry-docking with due consideration for economic penalties and delays due to fouling, etc.
- **Assessment of engine condition:** With a proper engine performance monitoring, the effects of any adjustments in the timing of injection system, valve timing changes or important

engine faults such as worn or damaged piston rings, faulty injection, burned valves, fouled turbochargers, air filters, air coolers etc. can be evaluated and diagnosed. Such a system is needed for protection of the engines themselves that are high value costs and safeguards the safety of ships in addition to economics benefit of having the highest engine efficiency possible.

- **Feedback to a better ship design:** When the actual performance of a ship in service is known and the degradation after a number of years is evaluated, the correct service and engine margins can be estimated for definition of design point, definition of ship-propeller-engine matching as well as more informed choice of propeller and engine for future ships.
- **Improved commercial aspects for chartering and technology upgrade:** A more accurate estimate of the ship performance is essential not only for improvement to charter party agreements but also for use of energy efficient ships, and decision making on use of energy efficient technologies. When it is feasible to determine a ship's performance accurately with due consideration to operational environmental and loading conditions, agreements between charterers and ship-owners or technology supplier and owners (for technology upgrade activities) can be defined more precisely.
- **Long term operational optimisation:** When the ships' performance and process parameters are measured simultaneously at frequent intervals and over time, a large database could be organised which facilitates more effective monitoring of a ship's or fleet's performance. Trim, draft, autopilot and engine settings in different environmental conditions are examples of areas that can be optimised. Moreover, with the availability of reliable information of the vessel's sailing performance, the ship's crew would be able to obtain a better understanding of the impact of their actions.
- **Environmental assessment:** As a response to global pressures caused by environmental concerns on ship GHG emissions and the introduction of CO₂ indexing schemes such as the IMO Energy Efficiency Operational Indicator [MEPC.1/Circ484] and Ship Energy Efficiency Management Plan [MEPC.203(62) and MEPC.213(63)], and current debate at IMO on data collection system; all in all, the requirements for continuous performance monitoring and benchmarking of fuel consumption, ship energy efficiency and exhaust emissions have increased. An effective SPM will support this process.

5.3 Performance monitoring system design

To assess the performance of a ship and provide the benefits outlined above, tools that would provide simple but would provide technically robust results need to be established. In an ideal case, the tool will be a total-ship integrated performance monitoring system that would provide not only an overall performance assessment of the ship but also specific assessment results for the propulsion system, engines, machinery and voyage optimisation. **Figure 5.1** shows the basic concept of a ship performance monitoring system.

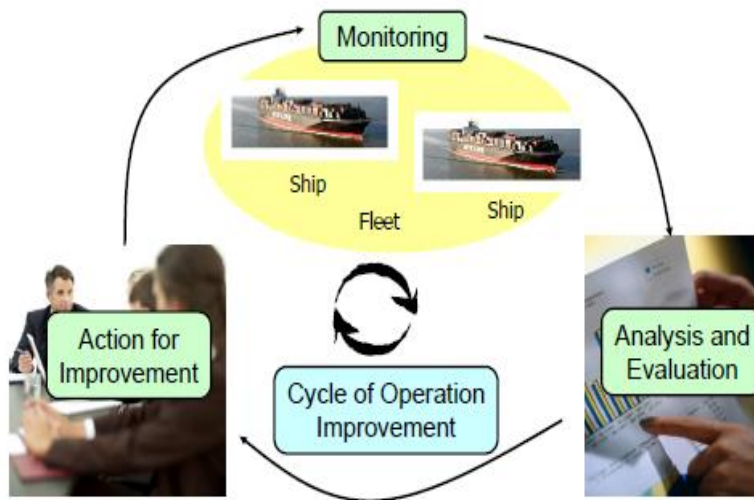


Figure 5.1 – The general concept for a ship performance monitoring [Hideyuki Ando , NYK]

At the heart of a ship performance monitoring system is the data gathering, data analysis and data presentation aspects. This is conceptually shown in **Figure 5.2**.

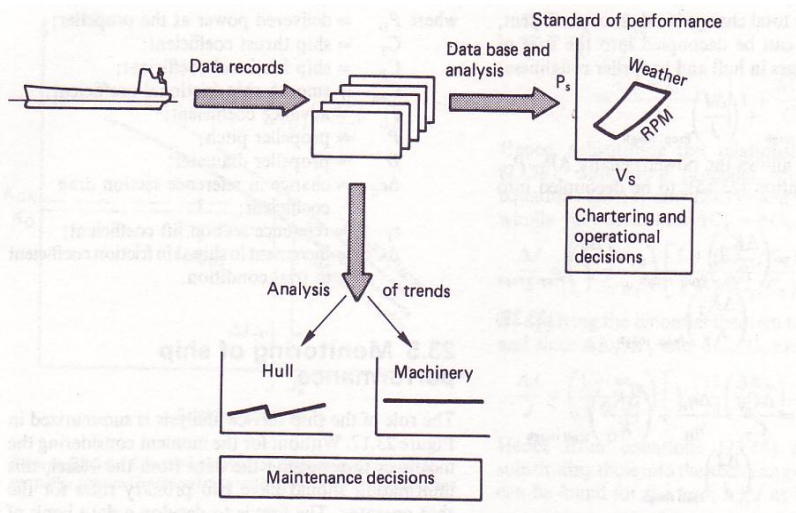


Figure 5.2 – Performance monitoring data collection, analysis and presentation concepts

A SPM, depending on its design and purpose, could provide various functionalities. Generally, a SPM may include modules that provide capabilities in performance monitoring of the below aspects of a ship:

- Ship voyage and operation
- Hull and propeller
- Engines
- Auxiliary machinery
- Etc.

For an integrated performance monitoring system, detail information by using automatic data collection and analysis are necessary. There is a need to go through feedback loops for operation performance improvement as indicated in **Figure 5.1**. The combined system, especially the combination between voyage performance, weather routing and performance monitoring is important. An integrated SPM provides organisational improvement process for energy efficient fleet operation that is in-line with IMO activities with regard to SEEMP, EEOI and future data collection and reporting.

The issue of design and development of such a system is out of scope of this section; suffice to say that a good design for a condition or performance monitoring will include [Hideyuki Ando, NYK]:

- Interface to existing on-board equipment and data systems is essential as already most of the required data are measured on-board ships.
- Automatic data processing and transferring to shore.
- Least additional work load on crews.
- High reliability and 24/7 operation.
- Low cost of implementation.
- Flexibility of customization to existing ship-board systems.

5.4 Types of performance monitoring systems

Broadly speaking, the SPMs can fall into the following three main categories based on their method of data collection and analysis:

- Manual: Systems with manual data logging, data analysis and reporting (for example once every 24 hours)
- Automatic: Systems with automatic data logging, data analysis and reporting (sampling can be every 1 sec or above and analysis can be either scheduled, continuous or on demand).
- Hybrid: Hybrid systems with some manual and automatic elements.

In practice, most of the systems are of hybrid nature with some elements of manual data logging or actions on data. Some are significantly on the manual side and some are significantly on the automatic side.

5.4.1 Manual systems

The manual systems normally rely on data that are gathered manually from various measurement devices or logbooks. On-board most merchant ships, daily logbooks are used to record the engine, fuel, navigation and cargo parameters for monitoring and regulatory purposes. Engine-logs are mainly of interest for engine maintenance and provide technical data to assess the condition of the engine and machinery. Deck- or navigation logbooks are used for voyage planning, insurance/safety and ship handling analysis, while loading logbooks are used for stability assessment, cargo planning etc. Additionally, there is significant additional ship-board information such as fuel oil analysis records, engine condition analysis records, etc. that could be utilised.

Engine and deck logbooks are traditionally filled-in either once a day (noon-noon logs) or every watch (4 hours) and averaged over 24 hours to form so-called 'abstract logs'. The number of variables that are logged depends on the requirements from the shipping company, the available instrumentation and the motivation and training of the crew [Thijs Willem Frederik Hasselaar]. A typical deck log contains information about the ship's position, speed, propeller revolutions, slip, draft, and sea state. A typical engine log book will include engine-related data such as power, rpm, temperatures, fuel oil consumption, etc.

Because logbooks are used on all ships, they are often used for performance and condition monitoring; primarily by the chief engineers. Their wider application for ship performance monitoring is limited since ship performance monitoring requires a higher level of data resolution and accuracy than what logbooks can provide. Also, the details in the logbook are average values for a long period of time (e.g. 24 hours) that hides some of issues from observation. The following shortcomings of manual data logging can be named [Thijs Willem Frederik Hasselaar]:

- **Uncertainty in the used instrumentation.** To increase redundancy, critical sensors for ship performance are often duplicated. Experience indicates however that duplicate instruments often show differences. Unless well described, this causes confusion in which instrument

indicates the best true representation and should be used for performance monitoring. Furthermore if the source of the instrument is unknown, the reliability of the logged data is low.

- **Wrong data collection timing:** A time lag of an hour in sampled data may represent two completely different performance conditions if environmental or sailing conditions have changed in this period. Most parameters, such as torque, are affected by even the smallest change in environment, and require therefore that all parameters are logged at the same time
- **Insufficient training:** If parameters cannot be measured using dedicated instruments, for example for measurement of sea wave characteristics, visual observations must be made. They can be accurate, if done by highly experienced officers, but change of shifts and quick changing vessel crew causes inconsistent observations.
- **Inaccurate data collection:** Certain parameters (wind, speed, torque etc.) must be averaged over a time period to be meaningful. Spot measurements result in errors. Furthermore, it is normal practice for officers to enter higher sea states than actually experienced in order to cover the vessel if delays are experienced (due to engine problems, strong currents, course alterations etc.). This may be done to avoid claims from the charterer on the level of a vessel's capabilities.
- **Limited logging frequency:** The high workload of the officers on duty limits the logging frequency for performance monitoring. With the recent increase in regulations, the number of administrative tasks and safety checks has increased dramatically with many officers complaining that there is little time left for watch keeping and optimal ship operation.
- **Errors in data entry:** Experience indicates that abstract logbooks frequently contain data inconsistencies, e.g. wind, water and ground speeds are mixed up, unrealistically high or low parameters are entered or relative wind instead of true wind speed is logged. The errors may be the result of unclear logging protocols, inaccurate sensors or insufficient training. In such cases, error tracking is difficult.

On the positive side, with the developments in satellite communication, internet and email, electronic logbooks have emerged and are used more and more. They replace paper abstract logbooks and enable logs to be send via email or web to shore, allowing ship performance to be analysed on a daily basis. Furthermore, with electronic communications, it is easier to identify anomalies directly at source and, if applicable, daily feedback of the ship's operation can be send back to the vessel. The data however still represents manual spot measurements with relevant key weaknesses.

5.4.2 Automatic system

With the introduction of electronic remote measurement and wireless data transmission from ships, it is now possible to collect many ship performance parameters electronically. A central data acquisition system interconnected to all necessary instrumentation can monitor and store data for either instantaneous or offline analysis (see **Figure 5.3** for the concept).

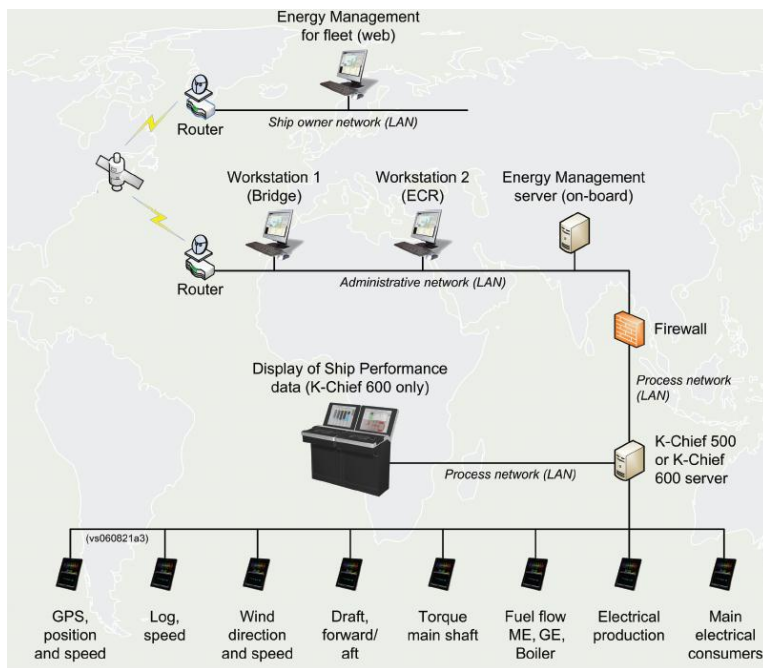


Figure 5.3 – Automatic systems using satellite navigation [Kongsberg]

The automation of data collection has the following advantages:

- Contributes significantly to the improvement of data quality.
- Allows signal validation, filtering and averaging for increased accuracy and reliability
- The source and characteristics of each sensor can be described and documented accurately, which reduces the uncertainty and errors in data entry
- Automatic data collection allows real-time data analysis, which can be used for monitoring for alarm in extreme operating conditions or real time feedback on vessel operation

An example of automatic data logging systems is a ship's Voyage Data Recorders (VDR). A VDR is an automatic data logging system for accident investigation collecting information concerning the position, speed, physical status, command and control of a vessel over the period leading up to and following an incident [Thijs Willem Frederik Hasselaar]. Based on IMO regulations, use of VDR (that is like a black box) is mandated on certain ship types and sizes. Many parameters logged by a VDR are required for performance monitoring. The use of the VDR data for performance monitoring is not advocated here; however, an automatic performance monitoring system will provide similar type of data collection functionality.

5.5 Hull performance monitoring

5.5.1 Introduction

It is well known that ship resistance increases with service life. **Figure 5.4** shows the ship resistance caused by degraded hull and propeller conditions, at design draft and design speed, as a percentage of the total ship resistance "as-new".

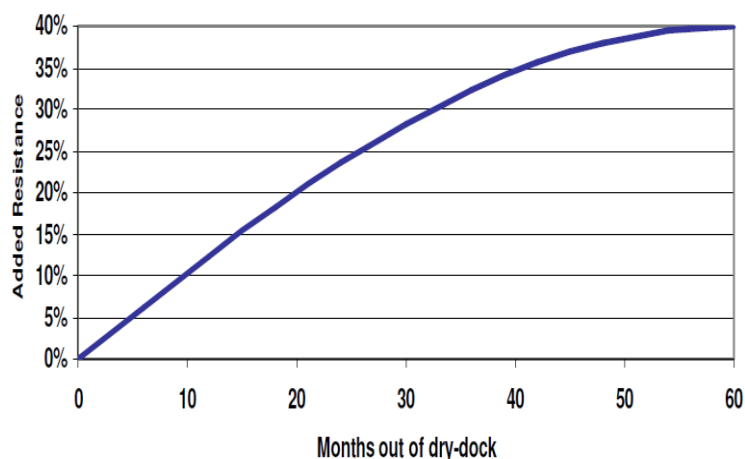


Figure 5.4 – Development of added resistance normally expected as a function of time [Torben Munk]

The addition of added resistance would lead to higher power required from the propulsion engine and thus higher fuel consumption. Typical increases reported is shown in **Figure 5.5** as example that indicates reduction of fuel consumption before and after hull brushing and cleaning.

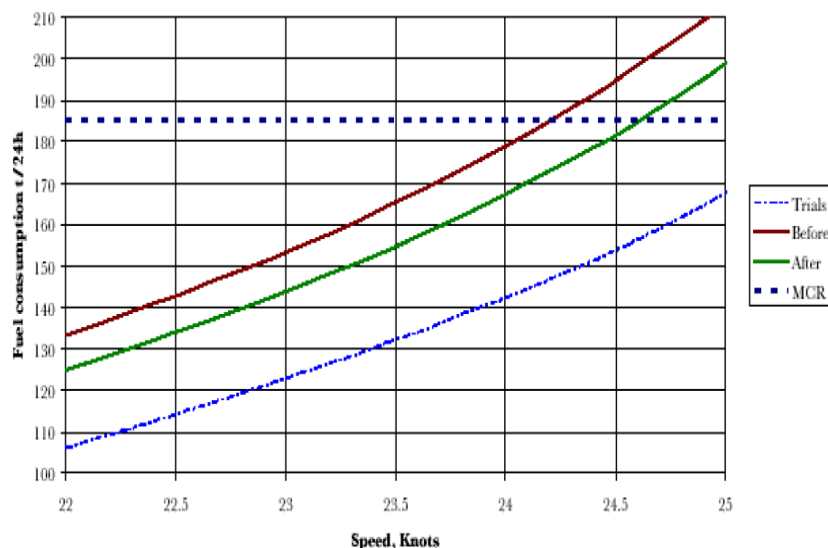


Figure 5.5 - Fuel consumption penalty of hull fouling and benefits of condition-based cleaning [Torben Munk]

Based on the above, the need to justify the importance of assessment of hull and ensuring that it remains clean during ship operation is self-evident. The main question to be answered is how the monitoring can be done and if current technologies and systems are effective.

5.5.2 Methodology

A variety of methods have been proposed for assessment of hull surface condition including:

- Assessment of ship speed-power curve relative to a baseline.
- Assessment of level of added resistance relative to a baseline (e.g. **Figure 5.5**)
- Use of divers to visually inspect the hull and propeller conditions and decide on the best course of action.
- Etc.

As an example, the 1st methodology above is described here. To monitor the propulsion performance of the vessel, a reliable and accurate speed – power curve should be developed. This

curve should then be compared to its counterpart as developed under commissioning speed trial⁶ (as baseline) to evaluate deviations from base line conditions. To enable this process the following data should be collected under a number of ship speeds (to cover full range of ship speed):

- Propulsion data
 - Propulsion shaft power and rpm
 - Ship speed both over ground and through water
 - Main engine fuel consumption and relevant properties.
- Environmental conditions
 - Wind (speed, direction, etc.)
 - Sea state (wave force, direction, etc.)
 - Etc.

The above list is only a guide and need to be more detailed for data collection purposes. Additionally, and for analysis purposes, some of the hull and superstructure data and ambient pressure and temperature will also generally be needed.

To collect the required data, ideally, the actual tests should be done in a way that the impact of sea currents is eliminated (using double run tests where the ship is sailed in opposite direction and then results are averaged). However, in practice, this is not commercially feasible; thus trials under calm sea conditions in areas with little currents are recommended.

To determine the actual speed – power performance of the ship in a changing ambient conditions an analysis method is required. To be effective, this method should eliminate the effect of wind and waves. Currently, evaluation of hull fouling is difficult due to unavailability of proper environmental correction methods.

Based on this methodology, ship speed power curves can be developed as show in in **Figure 5.6**.

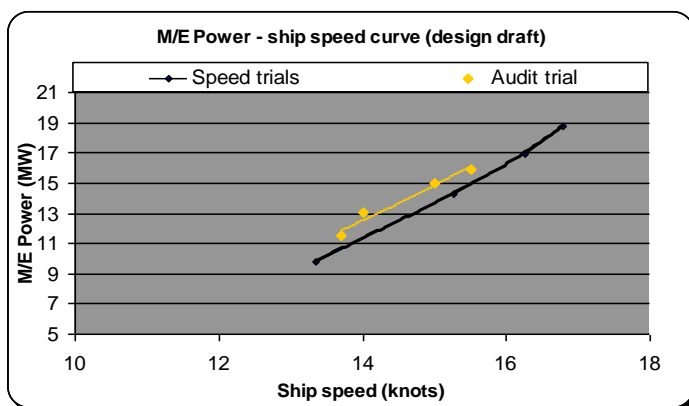


Figure 5.6 – Example of speed-power curve development [Bazari 2012]

This method is highly influenced by ship's ambient conditions; and data correction methods are still evolving. However, the use of this technique has been successful when tests are done under controlled conditions, well-defined test procedure and good sea conditions.

Propulsion Dynamics⁷ uses the notion of added resistance for their performance monitoring services. **Figure 5.7** shows example of their results and the way they predict hull fouling.

⁶ Speed trials here refer to initial trial of the vessel during commissioning tests that verifies the performance of a ship in attaining the contractual requirements between owner and builder. As part of these tests, the ship speed power cure under clean hull, no wind and calm sea conditions are developed.

⁷ <http://www.propulsiondynamics.com/our-service.html>

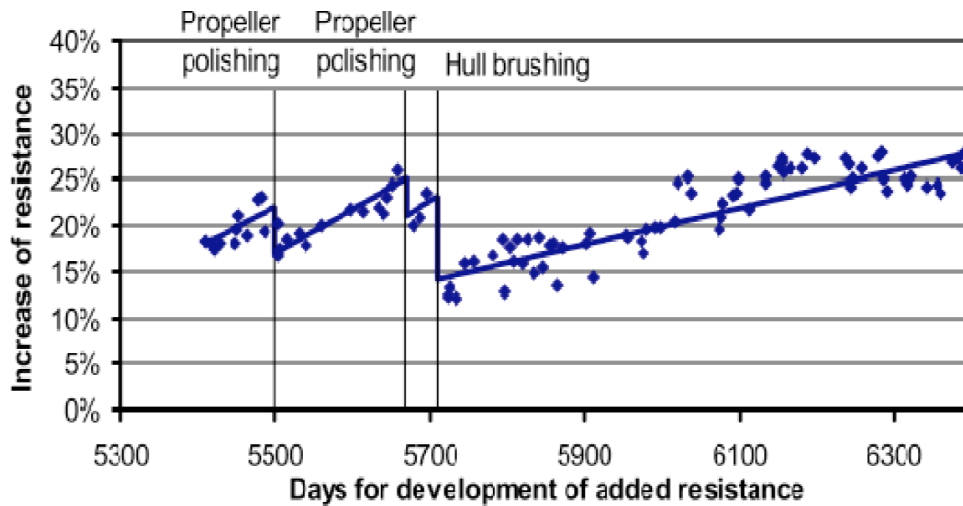


Figure 5.7 – Added resistance method used by Propulsion Dynamics [Torben Munk]

5.6 Engine performance monitoring

5.6.1 Introduction

The main purpose of a diesel engine performance monitoring system can be defined as “the monitoring, indication and subsequent assessment of the operational efficiency and performance levels of the diesel propulsion engine and its respective subsystems”. The objectives of this form of performance monitoring are:

- To facilitate the efficient, economic and optimal operation of the diesel engines.
- To reduce the possibility of "off design" operation that generally leads to degradation of both the individual components and the overall system reliability and service life

Diesel condition monitoring has longer history of application in marine diesel engines. It is regarded as “the monitoring of component or system wear and degradation in order to predict scheduled maintenance or at least to avoid catastrophic failure”. When dealing with condition monitoring, a number of techniques are normally used such as:

- Vibration monitoring
- Thermography monitoring
- Lube oil monitoring
- Performance process monitoring

Referring to the definition of performance monitoring, the last item of condition monitoring on “process parameter monitoring” closely ties up with performance monitoring. While in condition monitoring, the aim is to identify degradation in order to prevent failures and improve maintenance, in performance monitoring the constant strive is for economic or environmental efficiency of the system; thus it goes beyond simple condition monitoring or maintenance management.

It is important to note that when a process parameter monitoring system is to be applied, the success rate is determined by choosing the right parameters to monitor, select accurate sensors and signal processing systems and implement the output of the processing system.

5.6.2 Methodology

Engine performance monitoring mainly relies on monitoring of engine's in-cylinder conditions in particular the cylinder pressure diagram (or "indicator diagram" as commonly known historically). A very good indication of engine health as well as its energy efficiency is the maximum cylinder pressure. Lower than expected cylinder pressure generally means that engine settings are not optimal or its components may be faulty. Thus, use of measured cylinder pressure data forms the core of engine performance monitoring systems (as well as condition monitoring systems). **Figure 5.8** shows a typical cylinder pressure diagram, with important characterising parameters marked on it.

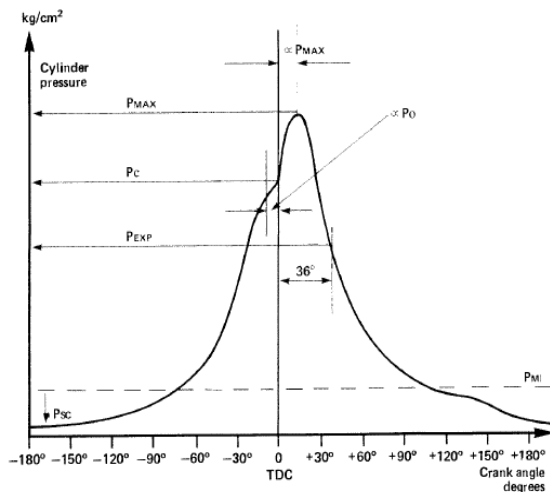


Figure 5.8 - Typical engine indicator diagram

The above diagrams can be measured digitally/electronically these days on the majority of commercial vessels (this is normally done on a monthly basis). Using the measured diagram as above, the following information can be extracted (automatically):

- Maximum cylinder pressure (P_{max})
- Angle of P_{max} – The angle at which P_{max} occurs.
- Cylinder compression pressure (P_{com}) – Pressure when piston is at Top Dead Centre position.
- Ignition angle – The angle at which combustion starts.
- Indicated power - Engine power as measured on top of the piston. Due to mechanical frictional losses, this indicated power is higher than the brake power that is measured at output shaft of the engine.
- Etc.

In addition to cylinder pressure diagrams, current day systems collect other data such as:

- Engine rpm
- Engine brake power
- Scavenge pressure
- Fuel injection pressure diagram and relevant information such as injection timing.
- Turbocharger rpm
- Etc.

Following the measurement of the above process data, they need to be corrected, if applicable, and compared to benchmark levels to identify if they are within the acceptable range. The benchmarks

are normally extracted from the engine shop test data. The engines' shop test⁸ results are generally measured and corrected for standard environmental conditions. Therefore to enable comparison of measured values against earlier corrected results, the parameters may need to be corrected to shop trial conditions. To calculate the engine's BSFC (Brake Specific Fuel Consumption), a correction for the density and heating value of the fuel will be required.

When the data have been collected and corrected, the relevant graphs are constructed in order to monitor and evaluate the engine's condition and performance. The following comparisons could form the basis for performance deviation diagnostic purposes:

Cylinder pressure: Low maximum combustion pressure relative to baseline is indicative of retarded injection timing or low scavenge pressure, provided that injectors, valves and rings conditions are evaluated as satisfactory.

Turbocharger speed: Higher turbocharger speed relative to reference data will indicate that engine settings may not be optimised. A high turbocharger speed may indicate the following:

- A retard injection with more energy going to exhaust rather than conversion to work in cylinder.
- A fouled turbine casing that may result in slightly higher engine back pressure.

Exhaust gas temperature: A higher than normal exhaust gas temperature could be due to few reasons such as high ambient temperature and high scavenge temperature (possibly due to charge cooling issues) or a retarded injection.

Figure 5.9 shows a sample of cylinder pressures monitored, showing anomaly with one of the cylinders (red line).

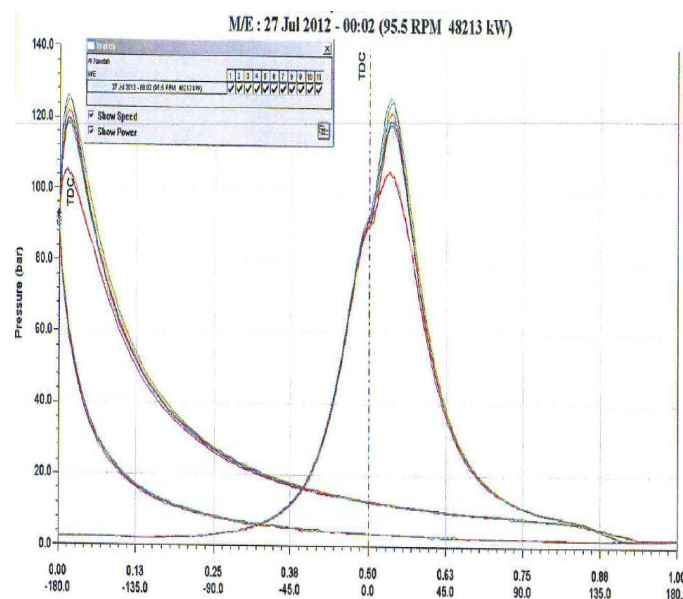


Figure 5.9 – Typical on-board in-cylinder measurement [Bazari 2012]

5.7 Auxiliary machinery monitoring

The monitoring of auxiliary machinery may be carried out in a variety of ways. For energy efficiency purposes, one way is to monitor the level of utilisation of machinery that is represented by their run hours. This will demonstrate if the ship's redundant parallel machineries are used too much beyond

⁸ Tests carried out originally by engine manufacturers and normally as part of engines' performance and emissions certification.

requirements. This is done via evaluation of utilisation factor and their comparison to benchmark values (see **Module 4** form more information).

Figure 5.10 shows an example of such an analysis for a number of auxiliary machinery; where the actual and reference utilisation factor for some major energy consuming machinery are shown.

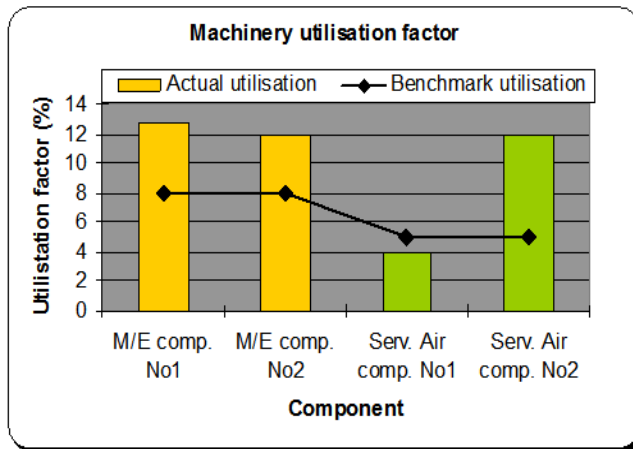


Figure 5.10 - Machinery utilisation [Bazari 2012]

Presentation of the above data over time will ensure optimisation and reduction of ship's auxiliary machinery run hours that would lead to not only lower energy use but less need for maintenance.

5.8 Voyage performance analysis

To improve the ship's itinerary and voyage management, a rigorous process that examines all aspects of the ship's operations needs to be in place. Data that could be used to evaluate the ship's operations should be collected and compared against developed benchmarks/baselines. The important data elements for voyage analysis will include analysis of ship operation events and their time durations (e.g. cargo loading, cargo unloading, port waiting, port berth times, passage operation, etc.).

To acquire such data, a computerised system will be required. However, such data are also available manually from deck logbooks as well as port reports that are available on-board ships. Additionally, full and continuous recording capability of voyage information as shown in **Figure 5.11**, inclusive of detailed propulsion system data, would support to optimise voyage operational performance.

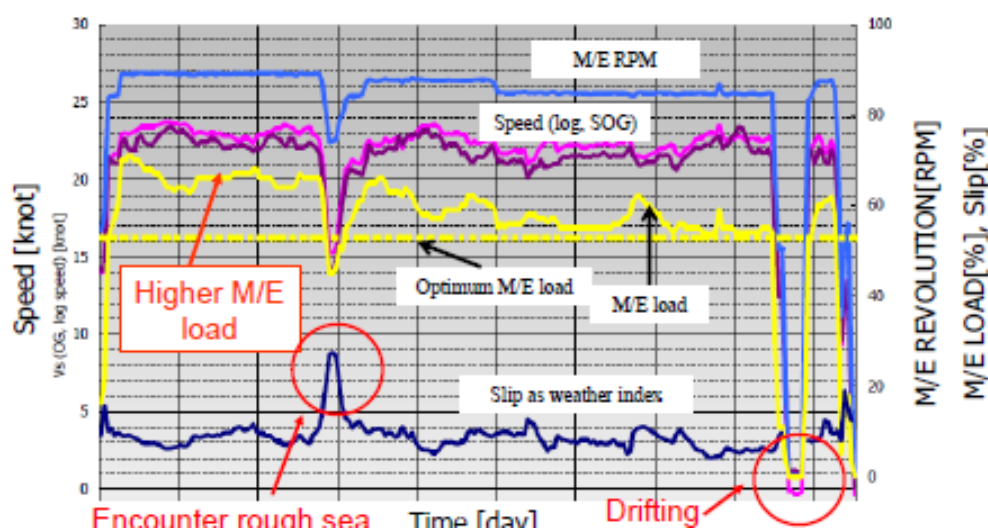


Figure 5.11 - Overview of a ship operation from one port to next port using performance monitoring [Hideyuki Ando, NYK]

For voyage performance analysis, these days, the weather routing service providers offer voyage performance analysis. In such a case, comparison between voyage plan and actual including ship performance (rpm, speed, fuel consumption) as a function of weather condition (wind and ship motion) are estimated and compared.

5.9 Monitoring and reporting to external bodies

The other aspect of energy performance monitoring mainly relates to obligation of the company to report to external stakeholders. The stakeholders could be the commercial clients or shippers or could be regulatory authorities. On the regulatory authority side, two initiatives are important for further consideration:

- IMO data collection system
- EU MRV (Monitoring and Reporting and Verification)

The above are further described in this section.

5.9.1 IMO data collection system

IMO MEPC Working Group on “further energy efficiency measures” has been working on the subject for some time and still continuing this work at the time of writing these texts. The approach advocates “data collection” as applied to ship fuel consumption and possibly other parameters. The system will have three main elements: (1) Data collection by ships (2) Flag State functions (data verification and submission) and (3) Establishment of a centralised database by the IMO and annual submissions.

The regulatory aspects of the IMO data collection and reporting system was introduced in **Module 1** together with progress so far in its development and adoption. The reader should refer to module 1 for details; however the main features of the scheme are summarily mentioned below as⁹:

- It will be applicable to ships greater than 5000 GT.
- The reporting period will be annually with no need for voyage data declaration.
- IMO number for ship will be part of the data for ship identification purposes.
- Ship’s registered owner will be responsible for submission of data to Administration. Responsibility of reporting remains with the ship.
- Flag Administration will be responsible for verification of the data; this can be delegated to Recognized Organizations (e.g. Class Societies).
- A Statement of Compliance (SOC) will be issued to the ship annually.
- Port State Control will examine the validity of SOC for enforcement.

Main aspects that have yet to be decided by the IMO MEPC in its future meetings are:

- Confidentiality of the data and who will have access to collected data.
- Guidelines will be developed to deal with various aspects of relevant regulations detailing main features of data collection method and data verification.
- The need for transport work data or energy efficiency indicator and other relevant data has yet to be debated and decided.

⁹ At the time of writing this course material, the IMO data collection were under debate at Imo and some of the features is expected to change until final decisions are made in future IMO MEPC meetings.

5.9.2 EU MRV

EU has for long worked as an advocate of reducing GHG emissions from international shipping. Because of this, EU not only supported the IMO regulatory developments but also has kept one step ahead in pushing forward the GHG reduction agenda. Generally, the EU plan of action is a phased approach to regulating CO₂ emissions as follows:

- **Phase 1:** Establish an agreed global energy efficiency standard as part of the IMO regulatory framework.
- **Phase 2:** Implement an MRV scheme to establish the fuel consumption and CO₂ emissions from international shipping, preferably within the IMO framework.
- **Phase 3:** Identify whether the efficiency standards are achieving the EU's desired absolute CO₂ emissions reductions from shipping, and if not, determine what else should be done, e.g. introduction of a Market Based Measure (MBM).

Phase 1 has already been accomplished and is in place in the form of IMO energy efficiency regulations for ships (fully covered in **Module 2**). It is phase 2 that is the subject of the IMO data collection system and EU-MRV. EU for some time have advocated that any plan to reduce shipping CO₂ emissions in the long term would have to be based on representative and accurate data on shipping fuel consumption and GHG emissions inventories. Within EU MRV, a reporting system is regulated that is going to provide such data. In effect, EU has developed and adopted its MRV legislation force certain ships to report their fuel consumption, energy efficiency performance and related data.

The EU MRV will be described in some detail in the following texts. Lloyd's Register in its summary publication in May 2015 entitled "European Union Regulation on Monitoring, Reporting and Verification of Carbon Dioxide from Ships" provides a succinct but comprehensive introduction to the EU MRV. The material in this section is mainly taken from this publication with some amendments; this is acknowledged here.

Applicability

EU legislation for the EU-MRV regulations was approved by the European Council in 29 April 2015 via amending the Directive 2009/16/EC [Regulation (EU) 2015/757]. Accordingly, the EU-MRV will be implemented in the EU regions and the ships that operate solely in this region or those travelling in and out of the region. The system will work according to the following:

- Irrespective of flag, the regulation applies to ships greater than 5,000 GT (with some exceptions¹⁰) undertaking one or more voyages into, out of and between EU ports.
- It requires per-voyage and annual monitoring of CO₂ emissions, as well as other parameters including energy efficiency indicators and amount of cargo carried.
- Annually, shipping companies must provide an emissions report for the previous calendar year's activity. In addition, this will include the technical efficiency of the ship for example in the form of its EEDI.
- Ships are exempted from the obligation to monitor this information on a per-voyage basis if they undertake more than 300 voyages within the reporting period or if all their voyages during the period either start or end at a port under the jurisdiction of an EU member state.

Implementation schedule

The following timescales have been set as part of the regulation for its implementation:

¹⁰ The exceptions are warships, naval auxiliaries, fish catching or processing ships, wooden ships of a primitive build, ships not propelled by mechanical means and government ships used for non-commercial purposes

- Preparation and adoption of supporting technical legislation in 2015/2016 including broad stakeholder and expert involvement.
- Accreditation of verifiers in 2017.
- 31st August 2017 – Monitoring plan for each ship to be prepared and submitted for approval by an accredited verifier.
- 1st January 2018 – Commence per-voyage and annual monitoring by applicable ships.
- 2019 onwards – By 30th April each year, submit a verified emission report to the EC and relevant flag State
- 30th June 2019 onwards – Ships will need to carry a valid Document of Compliance (DOC) relating to the relevant reporting period.
- 30th June each year – The EC will make each ship’s emissions reports publicly available including information specific to that ship, its fuel consumption, CO₂ emissions, technical efficiency (e.g. EEDI) along with other parameters.

Data collection

Each company will be required to produce a monitoring plan which will be used to monitor data on a per-voyage basis. This data will be aggregated annually and reported for all voyages conducted into, out of and between EU ports. The differing requirements for monitoring and reporting on a per-voyage basis and on a yearly basis are shown in **Table 5.1**.

Annual reporting requirements	Per voyage reporting requirements
Aggregated annual CO ₂ emissions from all voyages between, from and to ports under a Member State’s jurisdiction during the reporting period	Port of departure and arrival including the date and times in and out.
Aggregated annual CO ₂ emissions from all voyages between, from and to ports under a Member State’s jurisdiction during the reporting period	
Details of the method used for emissions monitoring	
Technical efficiency of the ship (EEDI or EIV as applicable)	
Vessel identification	
Total annual amount/weight of cargo carried	
Annual average efficiency (e.g. EEOI, fuel consumption per distance and cargo carried)	
Total annual fuel consumption	
Total CO ₂ emitted	CO ₂ emitted
Total distance travelled	Distance travelled
Total time spent at sea and at berth	Time spent at sea

Table 5.1 – EU MRV monitoring requirements [Lloyd’s Register 2015]

CO₂ emissions measurement

The most critical data in **Table 5.1** is CO₂ emissions measurement and reporting. The overall EU MRV processes are shown in **Figure 5.12** schematically.

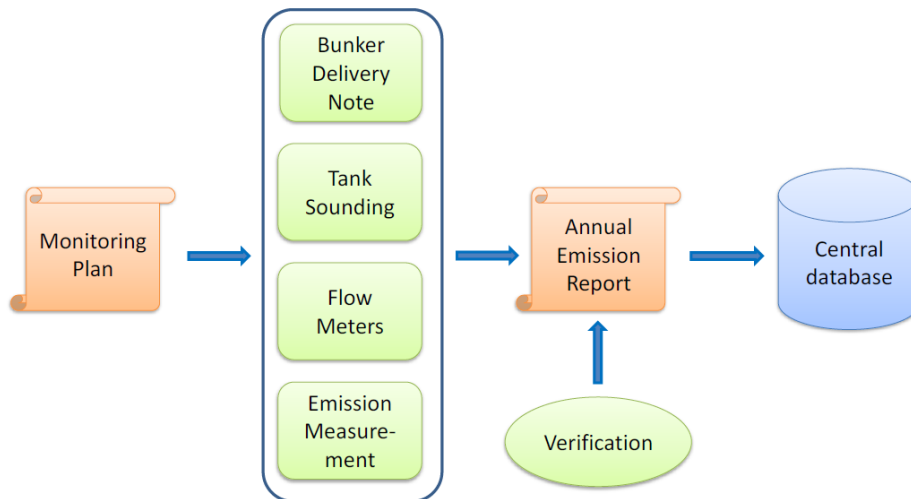


Figure 5.12 – MRV scheme overview [Lloyd's Register 2015]

As indicated in **Figure 5.12**, CO₂ emissions will be calculated based on:

- Either fuel consumption measurement (by (1) bunker delivery notes or (2) use of tank sounding or (3) use of fuel flow meters) and use of appropriate fuel related CO₂ emission factor for the fuel type being consumed,
- Or by direct emissions monitoring/measurement, with a back-calculation of the fuel consumption using the relevant emissions factor.

The above options are detailed in Annex I of the EU Directive [Regulation (EU) 2015/757]. As part of the monitoring plan, companies will be able to choose one or more of four methods shown in **Figure 5.12** for CO₂ calculations. Use of a combination of these methods is also permitted if it would improve the accuracy of the CO₂ emission measurement.

The EU MRV regulations also refer to energy efficiency as part of the monitoring and reporting requirements, including 'transport efficiency' and 'average energy efficiency'. These are defined within the Annex II to the EU Directive [Regulation (EU) 2015/757] and have similarities to the methodology for calculating the IMO's Energy Efficiency Operational Indicator (EEOI).

Verification

Tasks related to the check of monitoring plans, emission reports, communication with ship owners and operators and the issuance of Document of Compliance (DOC) will be done by accredited third party verifiers which most likely include classification societies. The EU Directive [Regulation (EU) 2015/757] sets out guidance on the requirements for verification and the main such requirements are summarised as follows:

- Verifying conformity of the monitoring plan against the requirements laid out in the regulation;
- Verifying conformity of the emission report with the requirements laid out in the regulation and issuance of verification report;
- Ensure that emissions and other climate-related data have been determined in accordance with the monitoring plan;
- Determining and making recommendations for improvement to the monitoring plan.

Certification

Upon satisfactory verification of the emission report, the verifier will then issue a Document of Compliance (DOC) to the company. The EU MRV regulations will not be a flag State requirement; instead it will be enforced through Port State Control within European ports.

5.10 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. IMO MEPC.1 Circ.684, "Guidelines for voluntary use of the ship energy efficiency operational indicator (EEOI)", 17 August 2009.
2. IMO, MEPC Resolution MEPC.203(62) "Amendments to the Annex of the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978" relating thereto (Inclusion of regulations on energy efficiency for ships in MARPOL Annex VI)", Adopted on 15 July 2011.
3. IMO MEPC Resolution MEPC.213(63), "2012 Guidelines for the development of a ship energy efficiency management plan (SEEMP)" Adopted on 2 March 2012
4. Hideyuki Ando (NYK Group), "Performance Monitoring and Analysis for Operational Improvements", International Conference on Ship Efficiency Conference, September 2011, Hamburg
5. Thijs Willem Frederik Hasselaar, "An investigation into the development of an advanced ship performance monitoring and analysis system", PhD Thesis, December 2010, School of Marine Science and Technology, Newcastle University, UK.
6. Kongsberg, "Ship Performance System", Kongsberg Maritime AS publication, 2013, [http://www.km.kongsberg.com/ks/web/nokbg0397.nsf/AllWeb/AB963D5AB36A752DC1257AF50041E9D4/\\$file/376812.pdf?OpenElement](http://www.km.kongsberg.com/ks/web/nokbg0397.nsf/AllWeb/AB963D5AB36A752DC1257AF50041E9D4/$file/376812.pdf?OpenElement), cited September 2015.
7. Torben Munk (Propulsion Dynamics), "A CO₂ Maintenance Index (Hull and Propeller Performance)", Ship Efficiency Conference, September 2009, Hamburg.
8. Bazari Z, 2012 "Ship Energy Efficiency – Developments and Lessons Learnt", Lloyd's Register, LRTA paper, September 2012.
9. Lloyd's Register 2015, "European Union Regulation on Monitoring, Reporting and Verification of Carbon Dioxide from Ships", Lloyd's Register Summary – EU MRV, Version 4.0 – May 2015.
10. Regulation (EU) 2015/757 on "the monitoring, reporting and verification of carbon dioxide emissions from maritime transport", and amending Directive 2009/16/EC, adopted by the European Parliament and the Council of 29 April 2015
11. "IMO train the trainer course material", developed by WMU, 2013.