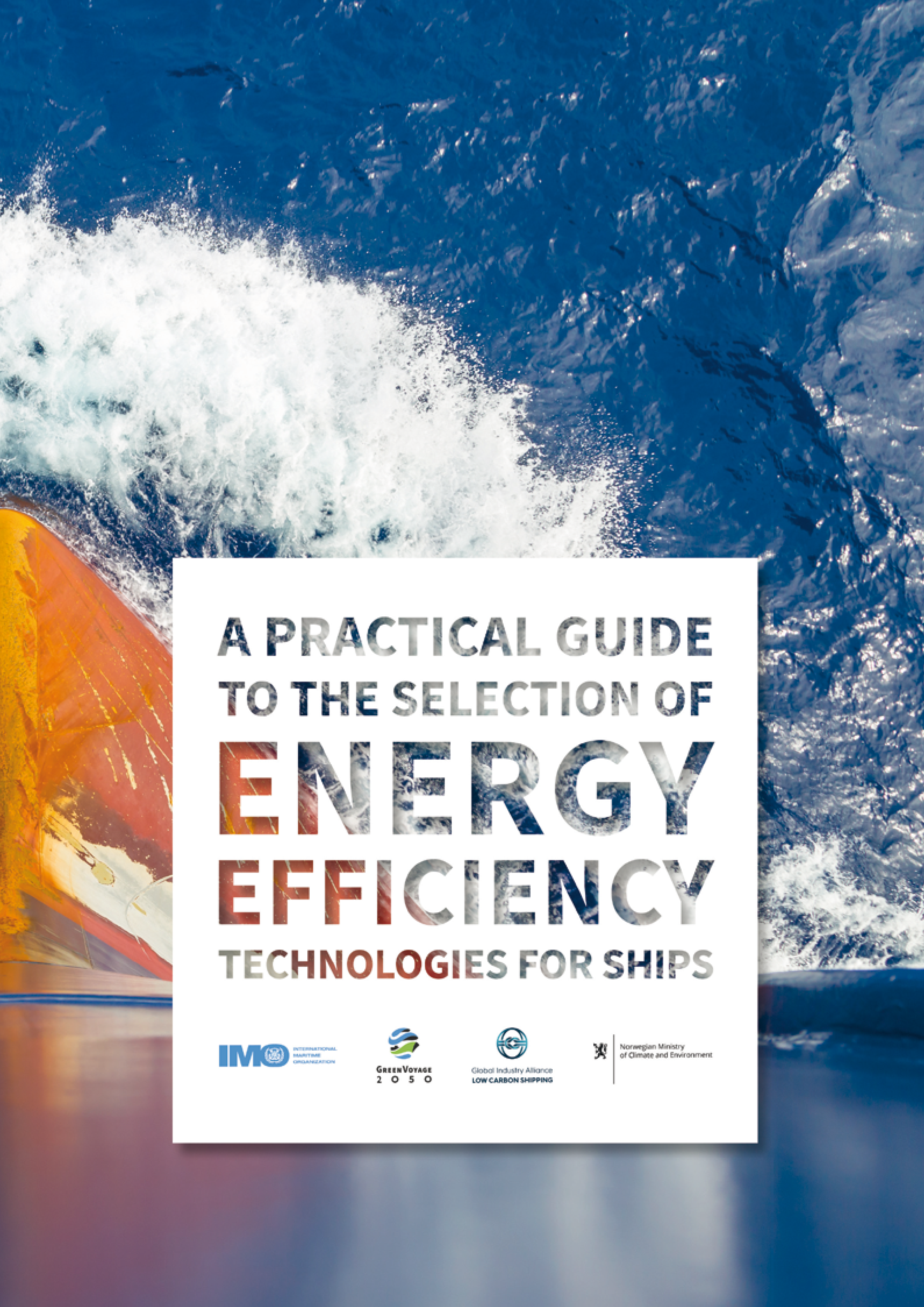

A PRACTICAL GUIDE TO THE SELECTION OF ENERGY EFFICIENCY TECHNOLOGIES FOR SHIPS

INTERNATIONAL MARITIME ORGANIZATION

GREENVOYAGE 2050

Global Industry Alliance
LOW CARBON SHIPPING

Norwegian Ministry
of Climate and Environment

A Practical Guide to the Selection of Energy Efficiency Technologies for Ships

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The IMO-Norway GreenVoyage2050 Project is an initiative to support the shipping industry's transition towards a low-carbon future. The project supports developing countries, including small island developing States and least developed countries, to reduce greenhouse gas (GHG) emissions from shipping by promoting the effective implementation of key IMO policy documents relating to GHG emissions, namely the Initial IMO Strategy on Reduction of GHG Emissions from Ships (adopted through resolution MEPC.304(72)) and resolution MEPC.323(74) encouraging voluntary cooperation between the port and shipping sectors to contribute to reducing GHG emissions from ships.

The Low Carbon GIA was officially launched in 2017, its aim being to develop innovative solutions to address common barriers to decarbonization of the shipping sector. The Low Carbon GIA was established under the Global Maritime Energy Efficiency Partnerships (GloMEEP) Project, a joint project of the Global Environment Facility, the United Nations Development Programme and IMO, and now continues to operate under the framework of the IMO-Norway GreenVoyage2050 Project.

For more information, please visit https://greenvoyage2050.imo.org.

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ARCSILEA
A Specialist Maritime Consultancy

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Executive summary

This guide is designed to provide users seeking to improve the energy efficiency of their ships with helpful guidance on considerations and operational practices that should be taken into account when selecting relevant technologies. It offers a simple yet flexible methodology for shortlisting the technologies and manufacturers that are most likely to be able to deliver on their savings and performance claims.

The guide has benefited from input and review by the members of the Global Industry Alliance to Support Low Carbon Shipping, a public-private partnership operating under the GreenVoyage2050 Project.

It should be noted that the guide is not meant to be read in isolation, but intentionally refers to relevant IMO resolutions and circulars, as well as to various guides and studies, some of which were prepared and conducted for IMO.

Before proceeding to the selection of energy efficiency technologies, it is recommended that attention be paid to the Ship Energy Efficiency Management Plan (SEEMP), as discussed in the first two sections of chapter 2. In particular, the SEEMP should be updated and revised to reflect the ship's current operational profile. Some of this work would need to be done in conjunction with the development of an implementation plan for achieving carbon intensity indicator-related targets, which should be incorporated into SEEMPs by 1 January 2023 in line with new standards for the shipping industry.

A range of operational measures are then introduced that have the potential to generate substantial savings – in most cases, savings that are greater than those which may be obtained by retrofitting energy efficiency technologies (section 2.3). Such measures should be implemented to the extent possible first, before considering retrofits. Once again, some of these may be addressed as part of the implementation plan in the update of the SEEMP that is required by Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL).

Chapter 3 is dedicated to the contextualization of savings claims and provides relevant terminology. It explains why claimed savings may not always materialize in practice. This is meant to help users of the guide to make comparisons on a like-for-like basis and to translate savings claims into actual impact on the ship. The impact of savings claims in the context of retrofitting in accordance with the Energy Efficiency Existing Ship Index (EEXI) and in relation to carbon intensity indicators is also examined (sections 3.6 and 3.7). The main point is that claimed savings are much diminished when EEXI and carbon intensity requirements are applied. This is due to the calculation methodology and needs to be taken into account, especially if the main objective is to achieve compliance with the regulations.

Finally, a high-level assessment methodology is introduced in chapter 4, which sets out each of the eight evaluation categories – similarity, plausibility, accuracy, overall and specific volume of orders, repeat orders, consistency and compatibility – and explains how energy efficiency technologies should be assessed using a "traffic light" scoring system (section 4.2). The methodology is designed to be user-friendly, does not require specialist technical knowledge (though having such knowledge would be an advantage) and is able to provide some results even where only manufacturers' websites and brochures have been consulted.

This is followed by a step-by-step example of the assessment methodology, including screenshots of the accompanying Excel tool (section 4.3), and some further considerations to bear in mind before and after placing the contract with the manufacturer for the selected energy efficiency technology (sections 4.4 and 4.5).

Abbreviations and definitions

AER	Annual Efficiency Ratio – one of two carbon intensity indicators to be applied from 2023 onwards, with deadweight as capacity, defined in the *2021 Guidelines on operational carbon intensity indicators and the calculation methods (CII Guidelines, G1)* (resolution MEPC.336(76)).
CFD	computational fluid dynamics – used to model and simulate fluid flows
cgDIST	One of two carbon intensity indicators to be applied from 2023 onwards, with gross tonnage as capacity, defined in the *2021 Guidelines on operational carbon intensity indicators and the calculation methods (CII Guidelines, G1)* (resolution MEPC.336(76)).
CII	carbon intensity indicator – used to drive improvements in the carbon intensity per transport work so as to achieve the levels of ambition in the *Initial IMO Strategy on reduction of GHG emissions from ships* (resolution MEPC.304(72)). Further details may be found in regulation 28 of the revised MARPOL Annex VI, which will enter into force on 1 November 2022.
DWT	deadweight tonnage
EEDI	Energy Efficiency Design Index – mandatory for certain types of new ships since 2013; see regulations 22 and 24 of MARPOL Annex VI.
EEOI	Energy Efficiency Operational Indicator – for voyage-based efficiency monitoring; see the *Guidelines for voluntary use of the Ship Energy Efficiency Operation Indicator (EEOI)* (circular MEPC.1/Circ.684).
EET	energy efficiency technology – in this guide, the term broadly covers technologies that have a hydrodynamic effect, e.g. ducts, stators, fins, rudder bulbs, air lubrication or propeller modifications or replacement.
EEXI	Energy Efficiency Existing Ship Index – for existing ships, based on EEDI and in force from 2023; see regulations 23 and 25 of MARPOL Annex VI.
GEF	Global Environment Facility
GHG	greenhouse gas
GRIP project	Green Retrofitting through Improved Propulsion project
HVAC	heating, ventilation and air conditioning
ISO	International Organization for Standardization
Low Carbon GIA	Global Industry Alliance to Support Low Carbon Shipping
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee (of IMO)
operational efficiency	This refers to efficiency achieved by operational choices such as speed, weather routing, payload, hull cleaning frequency, etc., and is measured by metrics which are collectively termed carbon intensity indicators, such as AER, cgDIST and EEOI.

P_{AE}	power of auxiliary engine(s)
P_{ME}	power of main engine(s)
SEEMP	Ship Energy Efficiency Management Plan – this covers planning, implementation, monitoring and self-improvement, along with data collection for the IMO Ship Fuel Oil Consumption Database, and the implementation plan for achieving the annual operational carbon intensity indicator targets during the next three years; see regulations 26 and 27 of the revised MARPOL Annex VI, which will enter into force on 1 November 2022.
SFOC	specific fuel oil consumption – in grams of fuel per kilowatt-hour
$SFOC_{AE}$	specific fuel oil consumption of auxiliary engine(s)
$SFOC_{ME}$	specific fuel oil consumption of main engine(s)
technical efficiency	This generally refers to design and equipment choices to improve ship efficiency and is measured by metrics such as EEDI or EEXI.
TRL	technology readiness level
UNDP	United Nations Development Programme
V_{ref}	reference speed

1 Introduction

In line with resolutions adopted by the International Maritime Organization (IMO), the international shipping industry is required to make progress towards reducing greenhouse gas (GHG) emissions by at least 50% compared with 2008 levels by 2050. This requires a combination of improvements in operational efficiency and alternative low-carbon fuels, but also the enhancement of technical energy efficiency through more efficient ship design and the use of energy efficiency technologies (EETs).

While most new ships built from 2013 onwards under the framework of the IMO Energy Efficiency Design Index (EEDI) typically incorporate a range of EETs, older ships built before the advent of EEDI often do not. Choosing the most appropriate technology or vendor with a view to retrofitting entails certain challenges:

- Proving the effectiveness of technologies can be difficult owing to varying conditions that influence fuel consumption (for example, draught, trim, loading condition, speed, fouling and adverse weather), but also because of varying data accuracy.
- Shipowners tend not to share the results of equipment trials, either because the data is not available or for reasons of confidentiality.
- Performance estimation and measurement protocols vary widely.
- Measurements may have been carried out on a different ship type.
- There is no standardized format or terminology for performance claims – a 5% improvement could be described in terms of fuel savings, energy savings or power savings, and that improvement could be relative to main engine consumption only, or in laden condition only.

This guide is aimed at helping to establish best practices in the selection of EETs. It sets out basic actions that should be taken before considering the use of such technologies, followed by an introduction to the regulatory framework (chapter 2) and a contextualization of savings claims (chapter 3). It then proposes a methodology for the selection of EETs based on a set of criteria that may be applied to readily available information (such as brochures or websites), the aim being to enable fairer comparisons between different technologies and savings claims (chapter 4).

Use of the above-mentioned methodology and the associated Excel-based high-level assessment tool will help in narrowing down and ranking the available choices according to the level of confidence that shipowners may have in the ability of a given technology to deliver on the vendor's performance claims.

1.1 Scope and application of the guide

In general, this guide proposes that the sequence to be followed when contemplating the retrofitting of EETs is first to monitor performance and apply operational improvements as far as possible before taking any decision on retrofitting. This is because the operational profile is a key input when estimating the savings that can be achieved with EETs and gauging the effectiveness of these. A methodology is provided in chapter 4 to assist with the evaluation of technologies offered by manufacturers, and in particular during the shortlisting and selection process.

The methodology has been designed primarily for hydrodynamic technologies, such as ducts, stators, fins, rudder bulbs, air lubrication or propeller modifications and replacement. However, the underlying concept may be applicable to other innovative technologies as well. Bespoke items, such as bulbous bows, ducktails and novel hull forms, which are specifically developed after a rigorous design process may not fall entirely within the scope of the assessment methodology.

The methodology is suited to technologies with a higher technology readiness level (TRL).[1] Low-TRL technologies will in most cases score poorly in the assessment and pose higher risk and uncertainty in terms of efficacy and reliability. Such technologies and equipment should be shortlisted only where the appropriate technical expertise is available.

This methodology should primarily be used for the retrofitting of EETs on board existing ships. It may be less suitable for use with newbuilds.

Although they fall outside the scope of this guide, estimates of cost-benefit analysis, payback time and cost per tonne of carbon dioxide (CO_2) abated may also be used to help choose between EETs.

1.2 Target audience

It is expected that the main users of this guide will include:

- shipowners and ship operators (especially those with limited technical capability to assess the energy-saving potential of EETs); and
- equipment suppliers (which may use the Excel tool to improve the equipment that they offer).

Shipowners with a track record of trialling EETs may have their own structured process and evaluation methodology, and this guide is not primarily aimed at them.

Other stakeholders who may benefit from the guide include those who need to consider climate, financial and compliance risks, such as:

- charterers;
- financial institutions;
- flag State administrations; and
- “green scheme” providers.

[1] Higher TRL scores indicate mature technologies and lower scores less mature ones.

2 Preparations before implementing energy efficiency technologies

The main objective of this guide is to improve the energy efficiency of existing ships, and in particular to provide a structured methodology for assessing and comparing EETs fairly.

However, before implementing EETs, certain systems and practices need to be put in place in order to maximize the effect of such technologies. It should also be noted that energy efficiency may be improved and optimized by operational and low-cost means even without the addition of EETs, and it is therefore important that these be considered first as far as possible.

In many cases, operational efficiencies can lead to greater fuel savings than are achievable through the retrofitting of a single technology.

2.1 Ship Energy Efficiency Management Plan

The first measure that should be implemented is a plan for the improvement of energy efficiency. A good starting point is resolution MEPC.346(78) of the IMO Marine Environment Protection Committee (MEPC), which contains the *2022 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)*. The 2022 Guidelines feature a new mandatory section (part III) on carbon intensity indicators (CIIs) that includes an implementation plan detailing how the ship will achieve the required CII rating. Chapter 4 of the 2022 Guidelines covers the framework and structure of the SEEMP, while chapter 5 provides guidance on best practices for the fuel-efficient operation of ships.

All ships of 400 gross tonnage and above are required to have an SEEMP on board, approved by the ship's Administration. However, implementation of part I of the SEEMP in operations is voluntary.

The SEEMP framework consists of four steps:

1. planning;
2. implementation;
3. monitoring; and
4. self-evaluation and improvement.

Planning involves determining the current status and source of ship energy usage, the operating profile and any existing measures that have been implemented. This planning is crucially also the starting point of any investigation into the retrofitting of EETs.

While monitoring is presented as the third step in the SEEMP framework, the data and insights from monitoring are also key to establishing a benchmark against which improvements may be measured.

The IMO publication *Study on the Optimization of Energy Consumption as Part of Implementation of a Ship Energy Efficiency Management Plan (SEEMP)*, which sets out a wide range of technical and operational best practices collected from shipping companies, may also be useful in this context.

2.2 Monitoring

It has been suggested as a general principle that "if you can't measure it, don't buy it", and this is particularly relevant to EETs.

Monitoring or measuring energy efficiency may be done in a variety of ways, from the simple to the sophisticated, and there are also many third-party providers that offer performance monitoring as a service, providing insights and recommendations on how to improve energy efficiency. The ISO 19030 standard, Measurement of changes in hull and propeller performance, is recommended for further reading: it provides detailed and comprehensive guidance.

In order to encourage greater uptake of the monitoring of energy efficiency, this guide proposes a simplified monitoring system that makes use of existing processes and documents.

Ships of 5,000 gross tonnage and above are mandated by regulation 27 of MARPOL Annex VI to collect, verify and report fuel consumption and distance travelled. For verification purposes, fuel consumption is typically broken down into voyages or voyage legs, as may be seen in the sample form below, which is taken from resolution MEPC.292(71) on the *2017 Guidelines for Administration verification of ship fuel oil consumption data*.

Date from (dd/mm/yyyy)	**Date to* (dd/mm/yyyy)**	**Distance Travelled (n.m)**	**Hours Underway (hh:mm)**	**Fuel Consumption (Metric tons)**						
				DO/GO	**LFO**	**HFO**	**LPG(P)**	**LPG(B)**	**LNG**	**Others(C_F)**
01/01/2019		210	24:00	2	3	19	0	0	0	0
02/01/2019		283	24:00	2	0	20	0	0	0	0
03/01/2019		321	24:00	2	0	18	0	0	0	0
04/01/2019		221	24:00	1	0	19	0	0	0	0
05/01/2019		320	18:00	2	0	13	0	0	0	0
06/01/2019		302	24:00	2	0	17	0	0	0	0
07/01/2019		210	24:00	1	0	19	0	0	0	0
08/01/2019		302	24:00	1	0	20	0	0	0	0
09/01/2019		280	24:00	2	0	21	0	0	0	0
10/01/2019		50	01:00	3	0	2	0	0	0	0
11/01/2019		198	24:00	3	0	21	0	0	0	0
•		•	•	•	•	•	•	•	•	•
•		•	•	•	•	•	•	•	•	•
•		•	•	•	•	•	•	•	•	•
30/12/2019		320	24:00	0	0	20	0	0	0	0
31/12/2019		213	24:00	1	0	17	0	0	0	0
Annual Total										

Figure 1: *Appendix 2 of resolution MEPC.292(71)*

This template may be used as a basic monitoring system for fuel consumption and efficiency. In many cases the source of the data is daily noon reports, and care should be taken to ensure consistency, repeatability and accuracy when recording date, time, distance and fuel consumption.

Higher-frequency data automatically logged from sensors can provide a finer-grained understanding of a ship's efficiency, but is not always available. When such data is forthcoming, more time and/or a higher level of technological sophistication will be required to aggregate and analyse it, and care must be taken to ensure the quality of the data and proper calibration of the sensors.

It is worth noting that in manual systems, the transfer of data from a noon report into a spreadsheet template for aggregation also introduces the possibility of data entry errors. Shipping companies should make sure that they validate their data in such cases.

Additional information, such as weather and loading conditions, can also be recorded to facilitate like-for-like comparison. More detailed data may be added, such as speed (over ground and/or through water), date since last dry dock, record of hull cleaning, fuel consumption of the auxiliary engine and boiler recorded separately from that of the main engine, and tagging each entry to indicate vessel condition (e.g. laden or ballast voyages), whether the ship is at anchor or in port, discharging and weather conditions (e.g. current information and significant wave height). An example of a modified template is shown below:

Start Date and Time from (DD-MM-YY HH:MM) (UTC)	**End Date and Time from (DD-MM-YY HH:MM) (UTC)**	**Hours Underway (h)**	**Distance Travelled (nm)**	**Average Speed (knots)**	**Mean draft (m)**	**Trim (m) aft is -ve**	**M/E Consumption (metric tonnes)**			**A/E Consumption (metric tonnes)**			**Observations (e.g. hull cleaned, propeller polished, ice voyage, bad weather encountered)**
							MDO/ MGO	**HFO**	**Others**	**MDO/ MGO**	**HFO**	**Others**	
1-Jan-2020 2:00	1-Jan-2020 3:24	0.00	0.0							0.3			
1-Jan-2020 3:24	2-Jan-2020 9:12	29.80	342.7	11.5	8.2	-0.4		31.2		8.6			
2-Jan-2020 9:12	6-Jan-2020 15:00	101.80	997.6	9.8	8.1	-0.6		110.7		27.4			
6-Jan-2020 15:00	10-Jan-2020 7:00	0.00	0.0							23.2			
10-Jan-2020 7:00	15-Jan-2020 18:30	131.50	1341.3	10.2	7.9	0.1		151.2		31.2			
15-Jan-2020 18:30	17-Jan-2020 10:00	0.00	0.0							11.2			

Figure 2: *Example of a template to record data with additional fields*

The purpose is to enable an overview and comparison of fuel consumption between different voyages, which could also be enhanced by calculating simple ratios such as fuel consumption per distance, or carbon intensity metrics such as Annual Efficiency Ratio (AER)[2] or Energy Efficiency Operational Indicator (EEOI)[3] as long as the capacity (deadweight or gross tonnage) and cargo mass are available.

Comparison of different voyages enables investigations into why fuel consumption is better in some voyages than in others, and the effectiveness of operational and technical measures may also be tracked.

It is important to note that the variability between voyages (typically caused by weather conditions, draught, trim and speed) may be quite significant and obscure the improvements arising from measures, especially if an EET is providing a relatively small increase in efficiency. With data based on noon reports and an EET providing smaller efficiency gains, it can take a longer period, say one to two years, to demonstrate conclusive improvements.

[2] The methodology for calculating the AER may be found in the *2022 Guidelines on operational carbon intensity indicators and the calculation methods (CII Guidelines, G1)* (resolution MEPC.352(78)).

[3] EEOI is referenced in the *2022 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)* (resolution MEPC.346(78)), while the calculation methodology is to be found in the *Guidelines for voluntary use of the Ship Energy Efficiency Operational Indicator (EEOI)* (circular MEPC.1/Circ.684).

2.3 Operational measures

There are a number of basic operational measures which should be implemented as soon as possible and before any EETs are considered. This is because such measures generally have a fuel-saving potential greater than that achievable by most EETs and are relatively inexpensive. Failure to implement them may also make it difficult to accurately determine the impact of EETs. Some of these measures could conceivably be incorporated into the implementation plan within the mandatory part III of the SEEMP, which needs to be in place by 1 January 2023 in accordance with the revised MARPOL Annex VI. The basic operational measures that should be considered are set out, in no particular order, in the following non-exhaustive list.

Hull and propeller cleaning

Biofouling accumulation on the hull and propeller is not only a source of invasive species, but also a major cause of poor energy efficiency. Fouling may easily increase fuel consumption by 10% to 20%, and even higher percentages are possible if the problem is not addressed, as can be seen from the following figure based on the preliminary results of a study on the *"Impact of ships' biofouling on greenhouse gas emissions"*, undertaken by the Global Industry Alliance for Marine Biosafety as part of the Building Partnerships to Assist Developing Countries to Minimize the Impacts from Aquatic Biofouling (GloFouling Partnerships) project, a joint project of the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and IMO.

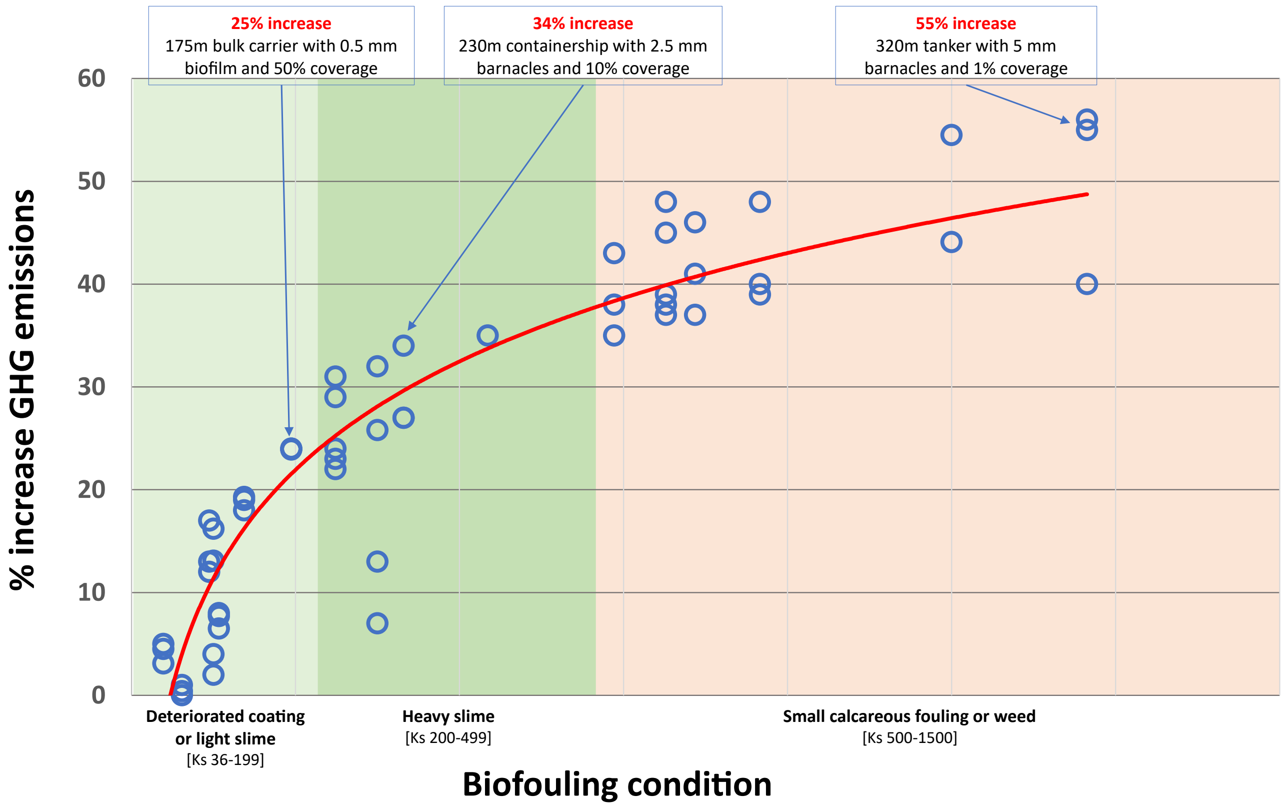

Figure 3: *Impact of ship hull biofouling on GHG emissions (data and analysis from GloFouling Partnerships Project)*

In the preliminary report of the study it is pointed out that "a layer of slime as thin as 0.5 mm covering up to 50% of a hull surface can trigger an increase of GHG emissions in the range of 20 to 25%, depending on ship characteristics, speed and other prevailing conditions."

The key takeaway here is that the increase in fuel consumption caused by biofouling exceeds by far the typical improvements that can be achieved through the retrofitting of EETs. Cleaning should of course be performed carefully and in line with relevant international and local regulations and guidance, and care should be taken not to damage the coating itself. The proper application of effective anti-fouling coatings may also minimize the fouling rate.

Once finalized, the report of the aforementioned GloFouling Partnerships study will provide an overview of currently available industry practices for biofouling management, such as the use of fouling control coatings, hull cleaning, propeller polishing and ultrasonic antifouling systems.

Speed optimization

A rule of thumb is that ship power is proportional to the cube of the speed. Therefore, a small reduction in speed leads to a much larger reduction in power and associated fuel consumption.

However, as speed is reduced away from the design speed range of a vessel, this cubic relationship begins to weaken as a result of decreasing propeller efficiency and the lower effectiveness of the bulbous bow. Running engines at a lower load also increases the specific fuel oil consumption, with the consequence that further decreases in speed lead to diminishing returns.

Hence the preferred approach is to aim for an optimal speed for a given set of considerations. This also reflects the fact that shipping is part of a logistics and transportation chain in which specific quantities of cargo and passengers have to be delivered within a fixed timescale.

A shipowner, operator or charterer may consider earlier departures and later arrivals in order to achieve a slower overall transit speed. The GEF-UNDP-IMO Global Maritime Energy Efficiency Partnerships (GloMEEP) Project and members of the Low Carbon GIA have produced a publication entitled *Just In Time Arrival Guide: Barriers and Potential Solutions*, which provides guidance on just-in-time arrivals to facilitate speed optimization.

If typical operational speeds have fallen considerably below the original design and intended service speed of a ship, the ship's fundamental hydrodynamics should be addressed first – for example, through re-optimization or replacement of propellers and bulbous bows. The effect of these replacements also typically exceeds the gains that can be achieved by retrofitting EETs, though in the case of propeller retrofits, some manufacturers offer integral upgrades as well, such as rudder bulbs or boss cap fins.

Weather routing

Weather routing is the practice of using weather forecasts to optimize a ship's route so as to minimize exposure to bad weather and/or to allow it to benefit from favourable wind and current directions or weather conditions. Weather routing is typically offered as a service.

Optimum trim

As indicated in the *2022 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)*:

> Most ships are designed to carry a designated amount of cargo at a certain speed for a certain fuel consumption. This implies the specification of set trim conditions. Loaded or unloaded, trim has a significant influence on the resistance of the ship through the water and optimizing trim can deliver significant fuel savings. For any given draft there is a trim condition that gives minimum resistance. In some ships, it is possible to assess optimum trim conditions for fuel efficiency continuously throughout the voyage. Design or safety factors may preclude full use of trim optimization.

Generator rationalization

Ships generally have three or more generators that provide electrical power to run machinery, heating, ventilation and air conditioning (HVAC), pumps, lights, hydraulics, and so on. Standard practice is typically to run two or more generators, often at a low load in order to provide a degree of redundancy in case of problems with a generator.

However, operating two generators at a low load leads to a higher fuel consumption than if only one generator were operating at a higher load, because of the shape of the curve of specific fuel oil consumption of the engine. Therefore, the number of generators in operation should be reduced wherever it is safe and practicable to do so.

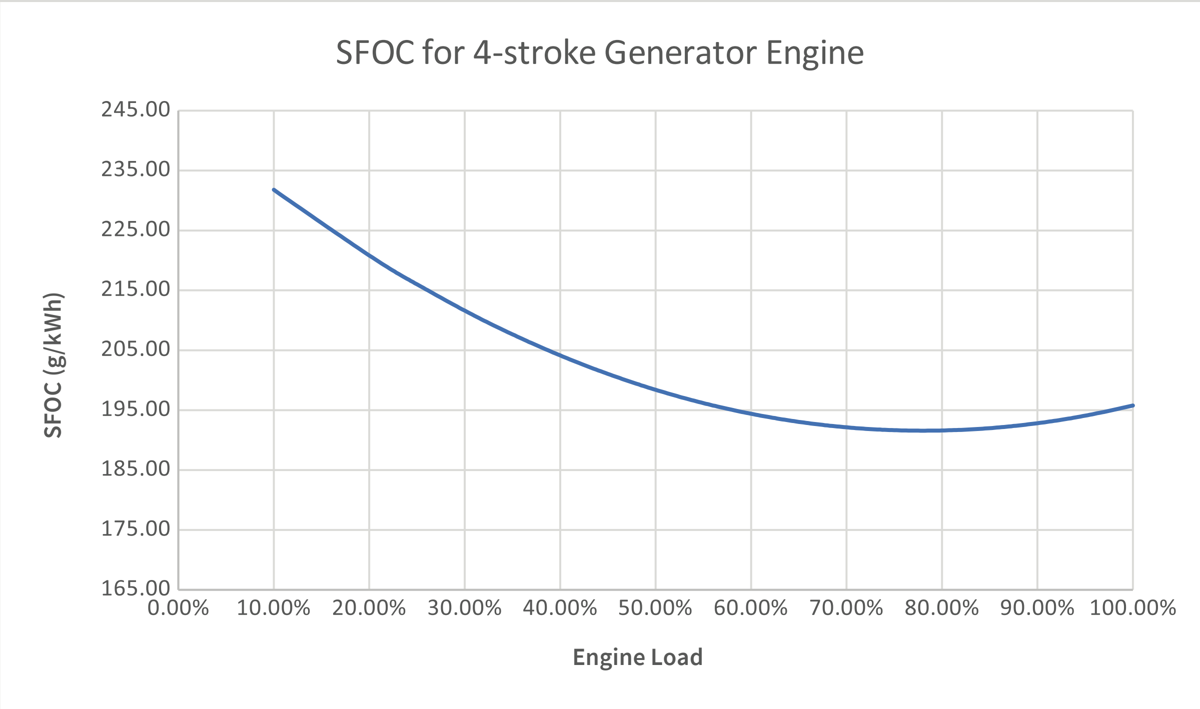

Figure 4: *Indicative specific fuel oil consumption (SFOC) for a four-stroke engine*

Once these basic preparations have been implemented as far as possible, it is appropriate to begin considering the retrofitting of EETs. However, the next chapter will first examine some challenges associated with performance claims.

3 Putting performance claims into context

When discussing the efficacy of technical or operational measures, a wide range of similar terms are used, such as:

- fuel savings;
- energy savings;
- improved energy efficiency; and
- reduction in engine power, or power savings.

These are then typically accompanied by a percentage figure, for example, *"xx technology provides fuel savings of up to 5%."*

The first thing to note is that these terms all typically refer only to **propulsion** fuel consumption or power, but do not include the fuel consumption of generators or boilers.

3.1 Difference between power and fuel savings

Power or energy savings do not equal fuel savings, though it is not always clear whether these terms are being accurately used in equipment brochures. For example:

> Assume that a ship needs 10,000 kW to achieve service speed before retrofitting of the technology. If a technology provides 5% power savings, after retrofitting, the ship only requires 9,500 kW. However, the engine is now operating at a lower load on average and the specific fuel oil consumption may have increased by 1%, hence the fuel savings would be smaller than the claimed power savings.

Some technologies require electrical power to operate, and thus a claim may indicate a net power saving that takes into account the additional electrical power input. However, conversion to fuel savings should be carefully considered in view of the difference in specific fuel oil consumption of the main engine and the generators.

3.2 Savings ranges

Phrases such as "up to 5% fuel savings" lead to an expectation that savings will be around 5%, but in most cases, they are likely to be in the order of 2% to 3% and only exceptionally reach 5%.

This problem also exists if savings ranges are used. For example, a savings claim of "between 2% and 5%" does not indicate the average level of savings.

3.3 Influence of loading and operational conditions

A claim of 5% fuel savings may be based on a sea trial at ballast draught after retrofitting compared with the original ballast sea trial. The savings at any other draught are likely to vary. One would expect this to be a common situation as equipment suppliers seek to demonstrate the efficacy of the technology and possibly to meet contractual terms. However, trials in laden or design condition are not always feasible or practicable. Savings obtained at any other trims and speeds may also vary substantially.

In some cases, savings are quoted as being "across the operating profile", which means that an attempt has been made to measure the effect of the technology over a longer period of time and for a range of loading conditions and speeds. However, if a candidate ship has an operating profile which significantly diverges from these parameters, the savings will also vary.

3.4 Total fuel consumption

As mentioned above, savings claims are generally made with reference to main engine or propulsion fuel consumption. When ships are under way, propulsion may account for 90% (or more) of total fuel consumption, leaving 10% of fuel consumption for generators and boilers.

Thus, a **5%** fuel saving relative to propulsion fuel consumption only would become a **4.5%** fuel saving relative to total fuel consumption.

However, ships are not always under way, and some ships also consume significant amounts of fuel for cargo maintenance (reefers, cargo heating, HVAC systems on passenger ships) or cargo handling (discharge pumps, cranes).

In such cases, propulsion may account for only 70% of total fuel consumption or less, which means that the **5%** fuel saving relative to propulsion becomes just **3.5%** relative to total fuel consumption.

The consideration of savings relative to total fuel consumption is bound to become increasingly important because regulatory requirements such as CII ratings and any potential market-based measures take total fuel consumption into account.

3.5 Indicative savings

As an indication of the plausible range of propulsion energy savings, a chart from the GRIP (**G**reen **R**etrofitting through **I**mproved **P**ropulsion) project under the European Union's Seventh Framework Programme for Research and Technological Development is reproduced below. The chart is based on 130 review sheets for EETs adjusted for confidence level (computational fluid dynamics, model test and full-scale results). The final report of the project is recommended for further reading.[4] It should be noted that this report was published in 2015 and does not cover newer technologies.

The vertical axis shows what is termed energy saving ratio[5] in the final report of the GRIP project and is based on energy saved in propulsion. Adjusting these ratios from propulsion energy saving to propulsion fuel saving will slightly reduce the average savings further. The blue bars represent the average propulsion energy savings, while the black whiskers represent the uncertainty. The experience of Low Carbon GIA members suggests that the typical savings achieved may be less than the averages indicated.

It is worth noting that the GRIP project did not investigate air lubrication and that the savings from the latter can also vary widely.

[4] GRIP Consortium, Green Retrofitting through Improved Propulsion (GRIP): GRIP final report, FP7-284905-GRIP. Available at: https://cordis.europa.eu/docs/results/284/284905/final1-grip-final-report-v10-mp-18052015f.pdf.

[5] Amount of energy saved divided by the total energy used before installation of the EET. All values are measured in calm water for the design condition of the EET (not necessarily the original design condition of the ship).

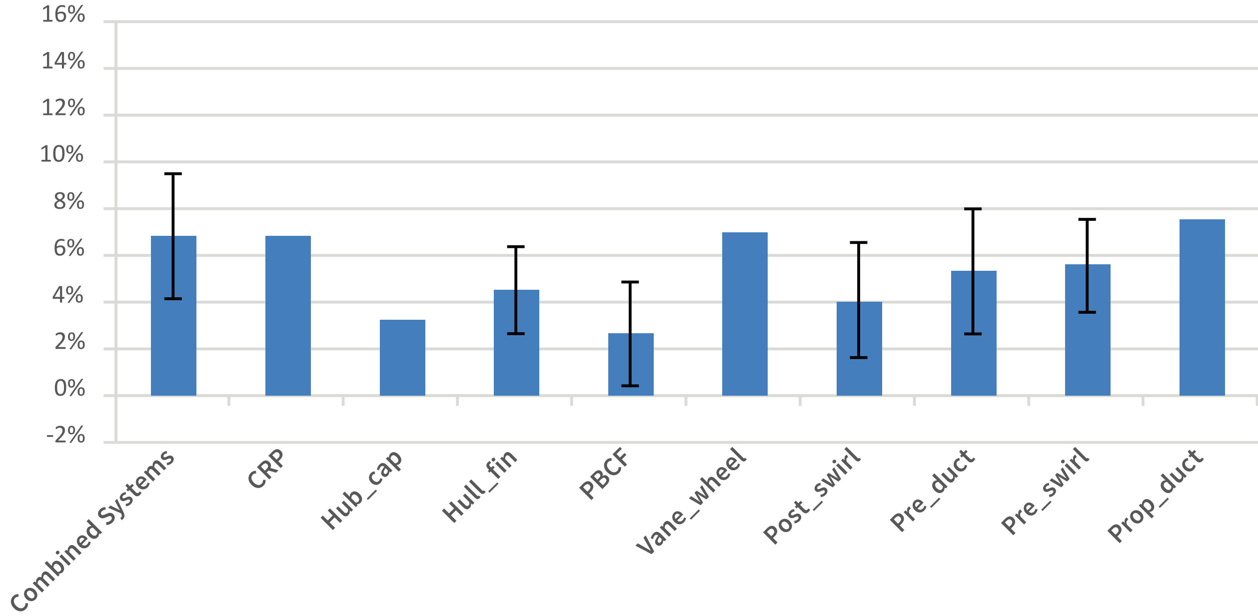

Figure 5: *Average energy saving ratio and standard deviation for a range of EETs (data and analysis by GRIP project)*

3.6 Energy Efficiency Existing Ship Index

This guide does not cover the Energy Efficiency Design Index (EEDI), since it is meant to be used to help with retrofitting, rather than newbuilding. However, as the entry into force of requirements pertaining to compliance with the Energy Efficiency Existing Ship Index (EEXI) approaches, increased interest in the retrofitting of EETs is expected.

The baselines and formulas for EEDI and EEXI are identical, but some of the calculation assumptions for EEXI differ.

EEXI calculations are carried out at a specific speed and loading condition – maximum draught, no wind/waves, 75% of the engine's maximum continuous rating, or 83% if shaft or engine power limitation is implemented. This takes into account the effect of any hydrodynamic EETs, otherwise defined as category A innovative EETs in the *2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI* (circular MEPC.1/Circ.896)[6]. Air lubrication falls under category B-1 in the Guidance and has a specific term allowed for it in the equation.

With regard to the retrofitting of EETs, paragraph 2.2.3.6 of the *2021 Guidelines on the method of calculation of the attained Energy Efficiency Existing Ship Index (EEXI)* (resolution MEPC.333(76)) stipulates:

> Notwithstanding the above, in cases where the energy saving device is installed, the effect of the device may be reflected in the ship speed V_{ref} with the approval of the verifier, based on the following methods in accordance with defined quality and technical standards:
>
> 1 sea trials after installation of the device; and/or
>
> 2 dedicated model tests; and/or
>
> 3 numerical calculations.

There is one issue that needs to be clarified in relation to this index. EEXI reduction rates are set relative to the EEDI baseline. In the example shown in figure 6 below, for this specific vessel marked with an "X", the EEXI requirement is 30% below the baseline. However, the vessel only achieves an attained EEXI value that is 25% below the baseline. It should be noted that these percentages are measured relative to the baseline.

[6] For further information on these categorizations of Innovative Energy Efficiency Technologies please see MEPC.1/Circ.896, Annex, page 3: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/MEPC.1-Circ.896.pdf

The immediate conclusion is that one could implement an EET offering an improvement in energy efficiency of around 5% in order to meet the requirement. However, that would fall short for three reasons:

1. There will be some inherent uncertainty in the savings demonstrated using one of the three methods from the 2021 Guidelines given above, and in sea trials there are certain unpredictable factors, such as weather conditions on the day, which means that a certain margin is required.
2. More critically, for a device saving 5% in hydrodynamic terms, that percentage is measured against the ship baseline, rather than the EEDI baseline, and when the value is adjusted to be measured against the EEDI baseline, it becomes just 3.75%.
3. Auxiliary power accounts for up to 6.25% of the EEXI calculation for non-passenger ships, and more for passenger ships, and so a 5% reduction in propulsion power for the same speed does not result in a 5% reduction in the attained EEXI value.

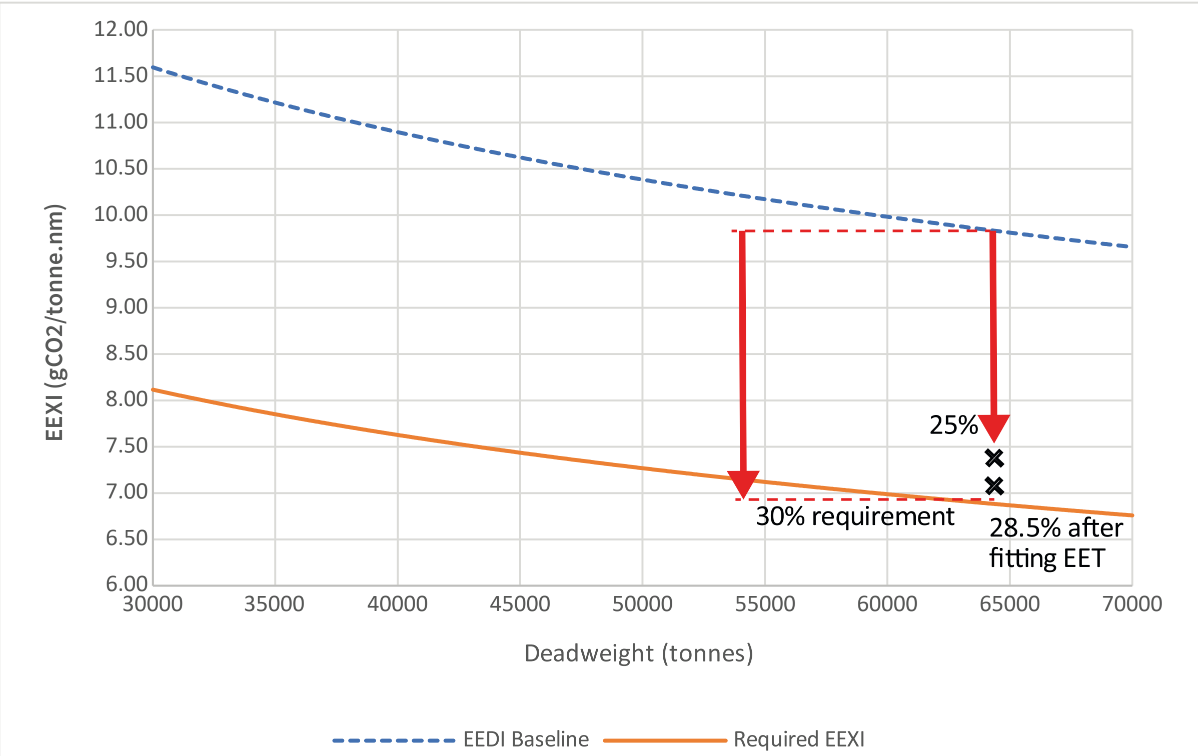

Figure 6: *Effect on attained EEXI value when retrofitting an EET*

A worked example is provided below to illustrate this more clearly. Assume a ship with the following parameters:

Deadweight	64,000 tonnes
Installed power	15,000 kW
P_{ME}	11,250 kW
P_{AE}	625 kW
$SFOC_{ME}$	165.5 g/kWh
$SFOC_{AE}$	215 g/kWh
V_{ref}	13.55 knots

The baseline EEXI value is 9.84 and the attained EEXI is 7.38, that is, the ship has an attained EEXI which is 25% better than the baseline.

If we implement an EET which reduces P_{ME} by 5.0% without changing the speed, the attained EEXI becomes 7.04, that is, the ship has an attained EEXI which is 28.5% better than the baseline.

In this case, the EET that reduced the power requirement by 5.0% improved the attained EEXI by only 3.5%.

The underlying mechanism is that the effect of EETs decreases as attained EEXI improves relative to the baseline.

In practice, for purely hydrodynamic EETs to benefit from a reduced P_{ME} in the EEXI calculation, engine or shaft power limitation would need to be implemented as well as the EET. If this is not done, the calculation will instead change to increasing the reference speed (V_{ref}) while keeping P_{ME} constant. Reworking the above example using a constant P_{ME} and an increase in V_{ref} would result in an attained EEXI of 7.26, that is, 26.2% better than the baseline. In other words, the effect of the EET has gone from 5% in practice to 1.2% in the calculation.

The situation is different for air lubrication because there is a specific term in the EEXI calculation for such innovative technologies that work to reduce engine power directly.

It is worth noting that if the ship already has EETs fitted, caution should be exercised in adding further technologies of this kind as these may in some cases conflict with the existing ones.

3.7 Carbon intensity indicators and related initiatives

The implementation of carbon intensity indicators (CIIs) from 2023 onwards, together with their use by other entities such as banks (Poseidon Principles) and charterers (Sea Cargo Charter), may be driving interest in the retrofitting of EETs.

The CIIs implemented by IMO are calculated as:

$$\frac{\text{total fuel consumption} \times \text{carbon factor}}{\text{total distance travelled} \times \text{capacity}}$$

where capacity may be either deadweight tonnage or gross tonnage, depending on ship type.

As mentioned above, the savings arising from EETs are generally compared against **propulsion**-only fuel consumption; they turn out to be smaller when compared against **total** fuel consumption. Since the CIIs are based on **total** fuel consumption, the same issue occurs when implementing EETs to improve attained CII.

It should be noted that the work carried out to define the baselines and rating boundaries of the CII framework revealed significant scatter in CII performance. This led to the development of five rating bands for ships, ranging from A (the most efficient) to E (the least efficient) (see figure 7).

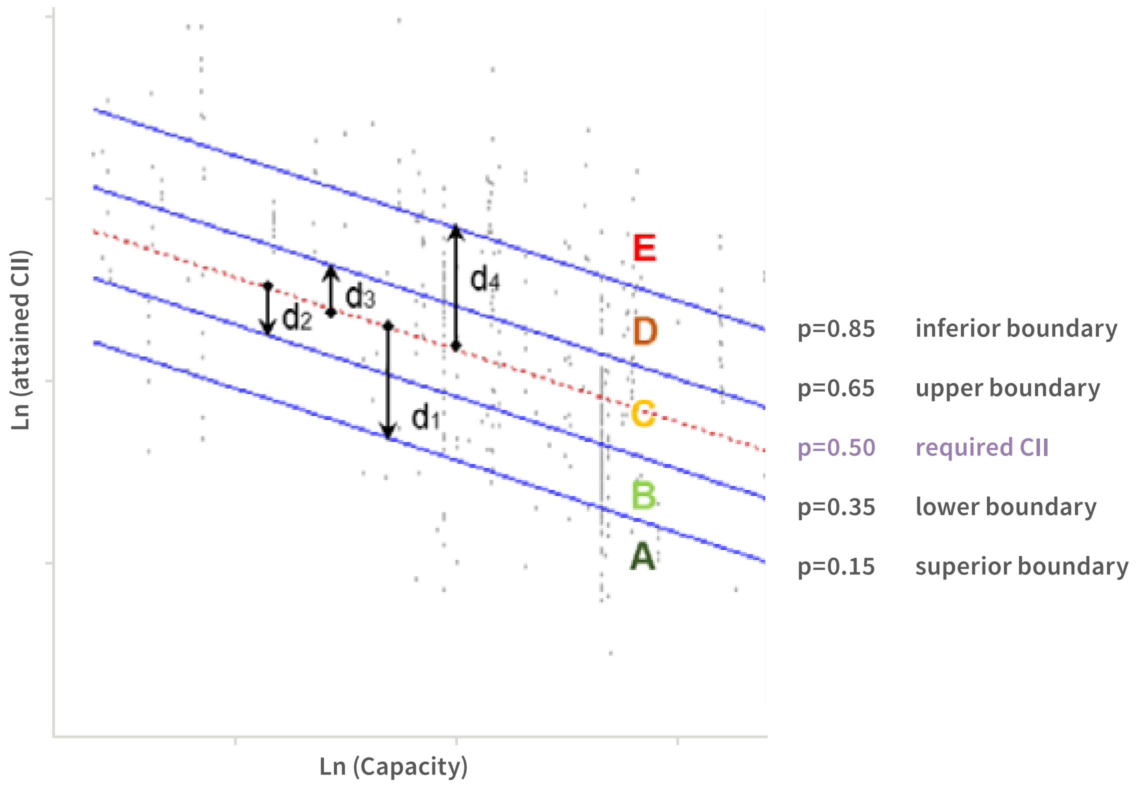

Figure 7: *Illustration of CII rating boundaries from the 2021 Guidelines on the operational carbon intensity rating of ships (CII rating guidelines, G4) (resolution MEPC.339(76))*

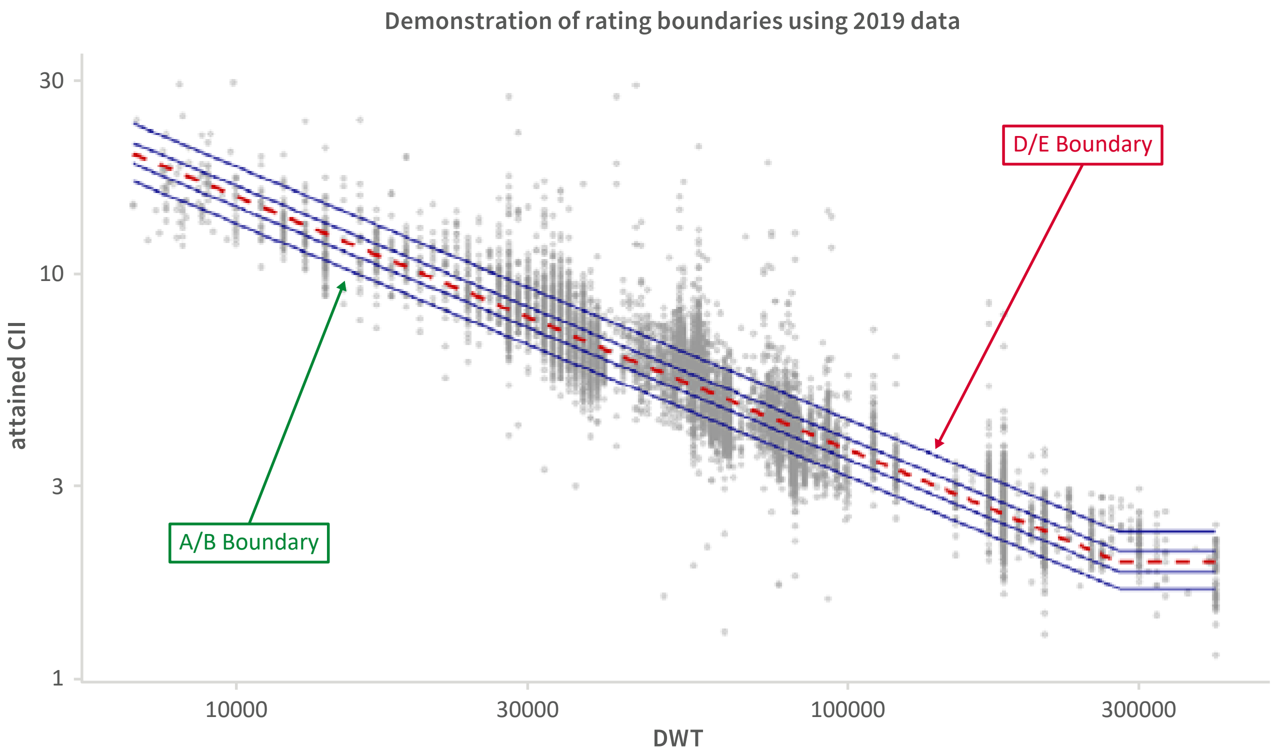

Figure 8: *CII scatter and rating boundaries for bulk carriers from "Reduction of GHG emissions from ships: technical report on CII guidelines development" (document MEPC 76/INF.10)*

In figure 8 above, the D/E boundary is 18% above the median quantile regression represented by the red dashed line, while the A/B boundary is 14% below the median quantile regression. The difference between these two boundary lines is therefore 32%, representing 70% of the bulk carrier fleet.

The possible 3.5% improvement in total fuel consumption provided by an EET as explained in section 3.4 may, for context, be directly compared with this 32% value. This gives an indication of the relative influence of operational parameters such as speed, weather and fouling.

The range of scatter for other ship types can be larger. For example, tankers have a range of 46% between the A/B and D/E boundaries. The full list of rating boundaries may be found in the *2022 Guidelines on the operational carbon intensity rating of ships (CII rating guidelines, G4)* (resolution MEPC.354(78)).

At the same time, the CII framework also includes annual reduction rates relative to the required CII represented by the red dashed line in figure 8. These are:

- 2023 5%
- 2024 7%
- 2025 9%
- 2026 11%

The critical point to note here is that while EETs may be part of the solution to achieve better attained CII values and to help meet the annual reduction rates, the influence of operational parameters, especially distance travelled in the year, and of reduction factor requirements is still greater. These aspects require careful management even after EETs have been retrofitted.

4 Methodology for the selection of energy efficiency technologies

This chapter will go through the steps of a systematic process to guide users in consistently gathering relevant information about different EETs so as to facilitate comparisons. The process also provides means of qualitatively assessing the information obtained. The goal is to increase confidence in EETs and manufacturers and, thereby, to support the decision-making process.

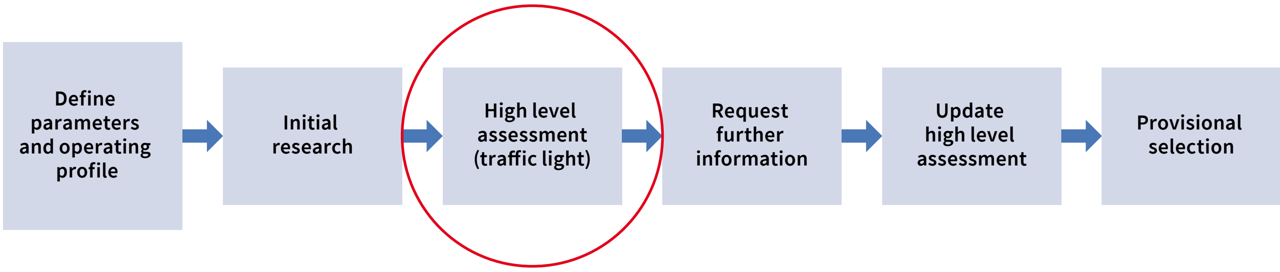

Figure 9: *Flow chart of assessment process*

With reference to the above chart:

- The definition of parameters and the operating profile is a key step in gathering relevant information to ensure a thorough understanding of the candidate ship, which is necessary for the selection and implementation of EETs.
- Initial research should consist of desktop research aimed at obtaining an overview of candidate technologies. This research will feed into the high-level assessment.
- The high-level assessment is based on a "traffic light" scorecard for a set of criteria and seeks to provide an at-a-glance overview of the relative merits of different EETs, and to facilitate shortlisting. An Excel-based tool covering both the definition of parameters/operating profile and the high-level assessment has been developed to accompany this guide.
- At the stage of requesting further information, contact may be made with equipment providers to obtain further generic details, which may be used to update the high-level assessment.
- The provisional selection may consist of one or more potential technologies.

Up to the provisional selection stage, the information used in the assessment is most likely to be generic, and not specific to a project.

Further detailed discussions may take place after this, possibly resulting in estimates and calculations being developed for the specific project.

If a contract is placed, this may contain performance targets the attainment of which will need to be proved in accordance with an agreed methodology.

4.1 Definition of parameters and operating profile

The first step of the process is to define the basic parameters and operating profile of the retrofit candidate, that is, the ship for which EETs are being considered. While it may seem trivial, this is in fact a highly critical step because the selection, customization and optimization of an EET very much depend on having a thorough understanding of the starting point. Additionally, in line with the SEEMP concepts, the objectives (goal-setting) of the retrofit project should also be defined.

This step is useful not only for the shipowner, but also for the eventual equipment supplier who will need this information to be able to customize the EET to the retrofit candidate.

The data to be collected and consolidated should include the following to the extent possible (some of this information may be found in an EEDI or EEXI technical file):

General

- vessel type (e.g. bulk carrier, tanker, etc.);
- deadweight tonnage;
- gross tonnage;
- length;
- breadth;
- draught;
- block coefficient;
- design speed and draught;
- propeller description;
- number of propeller blades;
- propeller status (original or retrofitted);
- details of any existing EETs;
- details of any relevant ship-specific design characteristics (changes to bulbous bow, ice class features, location of appendages, etc.);
- drawing – general arrangement;
- drawing – lines plan or derivative;
- report – model test report;
- report – sea trial report; and
- if available, current speed and power relationship for laden and ballast conditions.

Operating profile

- percentage of time (over a year) under way;
- percentage of time (over a year) in ballast (if relevant);
- percentage of time (over a year) laden (if relevant);
- percentage of time (over a year) in port;
- operating speed distribution;

- average ballast speed (if relevant);
- average laden speed (if relevant);
- annual fuel consumption of main engine – laden and ballast split if possible;
- annual fuel consumption of generator;
- annual fuel consumption of boiler; and
- annual distance travelled.

In this step, some specific questions also need to be answered:

1. Has the ship's design been optimized to reflect the current operational profile?
2. Will the operational profile of the ship change in the future? If so, describe the likely changes.

The answers to these two questions will have an impact on the selection and choice of solution.

These parameters may be recorded on the first tab of the high-level EET assessment tool, as shown in figure 10 below.

Parameters and Operating Profile

Collection of basic parameters and operating profile - this is a highly critical step to obtain a thorough understanding of the starting point, useful for shipowner and equipment supplier alike.

GENERAL PROJECT INFORMATION

Vessel Type

e.g. Bulk Carrier

Deadweight	GT	Length	Breadth
tonnes		m	m

Summer Load Line	Block Coefficient	Design Speed	Draught at Design Speed
m		knots	m

Propeller Description	No. of Propeller blades

OPERATING PROFILE

% time (over a year)

Underway	In ballast	Laden	In port	Distance Travelled
%	%	%	%	nm

Annual Consumption (Tonnes)

	Main engine	Genset	Boiler
HFO	tonnes	tonnes	tonnes
LFO	tonnes	tonnes	tonnes
MGO	tonnes	tonnes	tonnes
LNG	tonnes	tonnes	tonnes

DRAWINGS & DATA

General arrangement	Yes / No
Lines plan or derivative	Yes / No
Model test report	Yes / No
Sea trial report	Yes / No
Current speed power relationship for laden and ballast	Yes / No

Figure 10: *Screenshot from the Excel-based high-level EET assessment tool*

4.2 High-level assessment

The high-level assessment consists of a number of criteria against which EETs under investigation should be assessed using a traffic-light scorecard. A list of criteria was proposed by Arcsilea and gradually refined in consultation with the Low Carbon GIA. In order to use the high-level assessment methodology, information about the EET corresponding to the criteria should be collected through desktop research and discussion with suppliers.

If insufficient or no data is available for any of the criteria, these aspects may be left unassessed. The criteria are ordered such that those easiest to assess against come first.

The choice of a simple traffic-light scorecard is deliberate, as it does not require a high level of technical knowledge on the user's part. Moreover, it enables the use of readily available data for the assessment.

Note that the assignment of colours is subjective and qualitative. We would suggest that the thresholds provided be treated as indicative – that is, they may be adjusted as necessary. After an initial assessment, some calibration of the thresholds may be required depending on the technologies under investigation.

The suggested eight criteria are:

1. Similarity;
2. Plausibility;
3. Accuracy;
4. Overall volume of orders;
5. Specific volume of orders;
6. Repeat orders;
7. Consistency; and
8. Compatibility.

It should be more straightforward to obtain the information required for criteria 1 to 4 than for criteria 5 to 8.

4.2.1 Similarity

Application of this criterion will help to ensure that the technologies shortlisted are suitable for the retrofit candidate.

Savings claims may only be reasonably valid if the evidence for them comes from a similar ship type, design, size and operation. For example:

- "Red" should be assigned if the available evidence refers to a completely different ship type from that of the intended project – for example, a single-screw bulk carrier versus a twin-screw roll-on/roll-off passenger ship.
- "Amber" could be assigned if the ship types are similar but not identical – for example, two different types of hull form and slow-speed ships such as a bulk carrier and tanker.
- "Green" should be assigned if the ship types are the same – for example, if the ship from which the evidence was obtained and the retrofit candidate are both bulk carriers.

If after the initial assessment the scores are close, the criteria could be refined such that "green" is only assigned if both the ship type and deadweight range (and/or some other design criteria, such as year of build) are similar.

Websites and brochures usually indicate the range of ship types in which the EET has been installed, or provide case studies. If the relevant ship type is not listed, the manufacturer should be approached for clarification.

4.2.2 Plausibility

As shown in section 3.5 above, indicative savings from the GRIP project may be used to assess whether performance claims are plausible or unlikely. Using the example of a pre-duct which is shown to generate average savings of 5.5% but with an uncertainty of around $\pm$ 2.5% to 3%:

- A performance improvement claim of 4% or less is likely and could be assigned "green".
- A performance improvement claim of 5.5% might be possible, but is less likely and could be assigned "amber".
- A performance improvement claim of 7% or more is unlikely and could be assigned "red".

These are just examples: the actual thresholds should be adjusted depending on the comparison being made.

If ranges of performance claims are provided, the assessment could be based on the degree of overlap of the range with that provided by the GRIP project.

There are instances in which, owing to a change in operating speed, the effect of the EET is increased because the comparison is made against an off-design point of the propulsion system, or because the effect of the speed reduction is included in the technology's claimed effect. Unless the basis of the claim matches the situation of the retrofit candidate (that is, with regard to the change in operating speed), the savings claim should be assessed as above.

Sometimes manufacturers may offer combinations of EETs that are complementary, which may lead to higher savings than if the technologies were to be used individually. The overall savings are unlikely to be the sum of the savings arising from the individual devices if these are located in a similar area of the ship; indeed, these may even partly cancel one another out, making the assessment more difficult.

Manufacturers typically provide generic savings or savings ranges on their website and brochures which can be used to assess plausibility. Only savings claims specific to the ship type of the retrofit candidate should be used, and if this information is not publicly available, the manufacturer should be asked to provide it.

In some cases, savings claims are verified by third parties. Where these are independent and reputable, an adjustment to the colour assigned could be considered.

4.2.3 Accuracy

Performance claims typically indicate how the savings have been derived. For hydrodynamic EETs, the determination of savings is likely to be based on computational fluid dynamics (CFD), model tests, sea trials or longer-term performance monitoring.

- Although CFD is widely used to derive the energy-saving potential of EETs, there is a wide range of methodologies and critical assumptions, which can lead to variable results – that is, the CFD result can range from accurate to inaccurate. This makes it very difficult for the non-specialist to evaluate whether the savings claim is accurate. It is therefore recommended that claims based on CFD **not be scored** but left blank. Note that this refers to CFD-based claims in the assessment and shortlisting phase. Once a contract has been placed with an equipment supplier, they will very likely use CFD to provide a specific estimate of the energy-saving potential as well as to optimize the EET design.
- Model tests are also widely used. However, it can again be difficult for the non-specialist to judge the accuracy owing to scale effects and details related to the actual conduct of the test and any corrections that are applied. In view of this, we would recommend assigning "red".
- Sea trials are likely to provide a higher accuracy if done properly. For stand-alone sea trials only carried out after a retrofit, we would suggest assigning "amber"; if trials are conducted both before and after the retrofit, we would suggest assigning "green".
- Longer-term performance monitoring, both before and after the retrofit, is likely to be the most accurate and should be assigned "green".

In the case of sea trials and longer-term performance monitoring, hull condition may significantly influence the results, especially if hull cleaning occurs at the same time as the fitting of the EET, which will lead to optimistic or exaggerated savings.

Note that some performance claims may be based on CFD or model tests but validated by some other method. In such cases, the colour should be assigned on the basis of the better method.

Websites and brochures sometimes indicate how the savings claims have been derived. Otherwise, the manufacturer should be asked to provide this information, but it needs to be specific to the ship type of the retrofit candidate.

4.2.4 Overall volume of orders or installations

Application of this criterion involves assessing the number of orders or installations of the EET. Devices with a large number of installations are likely to be more credible than devices with only a limited number. This also means that an EET with a low technology readiness level will score poorly.

In general, a larger number of orders or installations reflects greater experience on the part of the equipment supplier, which manifests itself in better predictions of energy savings, as well as experience with the retrofitting process, obtaining class approval and after sales support.

Thresholds for assigning colours will be subjective, so the following should only be used indicatively:

- "Red" should be assigned if there are up to 5 installations of the device in total.
- "Amber" may be assigned if there are between 6 and 20 installations of the device.
- "Green" may be assigned if there are more than 20 installations of the device.

The above scheme assesses the total number of orders for the specific device.

Websites and brochures often provide an indication of the total number of installations; otherwise, the manufacturer should be asked to supply this information.

4.2.5 Specific volume of orders or installations

Application of this criterion involves assessing the specific number of orders or installations of the EET fitted in ships similar to the retrofit candidate. This represents the current market's appraisal of the suitability and efficacy of an EET as regards ship types similar to the retrofit candidate.

Thresholds for assigning colours will be subjective, so the following should be treated as merely indicative:

- "Red" should be assigned if there are up to two installations on the specific ship type of the retrofit candidate.
- "Amber" may be assigned if there are between three and five installations on the specific ship type of the retrofit candidate.
- "Green" may be assigned if there are six or more installations on the specific ship type of the retrofit candidate.

Websites and brochures often give an indication of the total number of installations, but there is seldom a breakdown according to specific ship types, so the manufacturer should be asked to provide this information.

4.2.6 Repeat orders

A criterion closely related to volume is the concept of repeat orders. Essentially, this means that the number of units ordered correlates with the level of confidence that a particular shipowner may have in a specific EET.

- If an equipment manufacturer received five orders from five different shipowners or shipyards, and none has so far placed a new order (that is, no repeat orders), this indicates that the EET is being trialled. In such a case, "red" should be assigned.

- If the manufacturer has received an order for five ships from a single entity, this indicates that at least one party has a higher level of confidence in the equipment, though it does not count as a repeat order. "Amber" may be assigned.
- However, if after having ordered one unit, the shipowner or shipyard has come back to the manufacturer to order four more units, this indicates that the initial trial was successful. "Green" may therefore be assigned.

Clearly, for many suppliers the situation may be a mix of the above categories, and colour assignment should be based on the best case.

The numbers of repeat orders are not typically reported on websites or in brochures but may be indicated in press releases. Obtaining this information will most likely involve putting a specific question to the manufacturer.

4.2.7 Consistency

Application of this criterion involves assessing whether the savings claims are consistently achieved, or where there are wide variations. Savings claims are typically provided as ranges, such as "1% to 5%", with no indication of the average or likely savings. The assessment of consistency could be performed as follows:

- Where savings claims for different projects vary widely, "red" should be assigned.
- Where saving claims vary by between $\pm 1\%$ and 2%, "amber" may be assigned.
- Where savings claims vary by less than $\pm 1\%$, "green" may be assigned.

As indicated above, the percentage thresholds are indicative and may need to be adjusted. Consistency should be evaluated only for ships similar to the retrofit candidate, which implies the same ship type and, if possible, deadweight range. If the savings claims are derived through CFD or model tests, consistency should not be evaluated.

It should be noted that proving the efficacy of EETs is rather challenging, particularly as the level of uncertainty of the measurement/prediction methods is of a similar magnitude to the performance improvements, and also because ships operate in widely varying conditions in terms of draught, speed, trim and weather, all of which have an influence on the result.

Another challenge lies in the fact that ships often undergo various kinds of interventions in dry dock, such as hull cleaning and blasting and the application of a new coating, in addition to the fitting of one or more EETs, which makes it difficult to attribute savings to each individual intervention.

If several case studies have been provided that are based on sea trials after dry dock, where the number of interventions may range from single to several, the result of applying several of the aforementioned criteria would be as follows:

- As regards plausibility, "amber" or "red" would be assigned, since the performance claim may be higher than expected.
- As regards accuracy, "amber" would be assigned, since the performance claim is based only on sea trials after dry dock.
- As regards consistency, "red" would be assigned if the savings claims varied, while "green" would be assigned if the performance claims were similar.

Gathering data to assess consistency will involve addressing a specific request to the manufacturer regarding savings claims for cases similar to the retrofit candidate because information at this level of detail and specificity is not usually made public.

4.2.8 Compatibility

If the retrofit candidate has already implemented some EETs, the compatibility of any further devices with the existing ones should be evaluated.

- "Red" should be assigned if the new device is incompatible with the existing ones, or if compatibility is not known.
- "Amber" may be assigned if there is some uncertainty or variation with regard to compatibility.
- "Green" may be assigned if the devices are compatible.

Compatibility should be investigated directly with the manufacturer. For EETs with fewer installations, the evidence base may not be sufficient and the assessment will need to be based on technical justification. Alternatively, "red" could be assigned.

4.3 High-level assessment: step-by-step example

As indicated in the flow chart in figure 9 above, the starting point is to define the parameters and operating profile of the retrofit candidate, in order to establish the baseline and objectives.

This is followed by desktop research aimed at drawing up a list of possible EETs and collecting data which may be used for assessment in relation to the eight criteria. This is likely to involve web searches and brochure requests at first.

The results of this preliminary research should be consolidated in a high-level assessment using the Excel tool provided. The example below lists three candidate EETs, including two of the same type from different manufacturers. The example is given simply to illustrate how answers might be used in the assessment.

Tabulating in this way allows easy comparison of the devices by colour score. The data used to assess an EET against the first four criteria is more likely to be generally available than for the remaining ones. The results of the initial research may therefore lead to some blanks in the assessment table, as shown above.

Shortlisting based on this partial assessment should not be carried out at this point. Instead, contact should be made with the manufacturers to ask specific questions and to undertake further research.

High Level Assessment

Ship Type	e.g. Bulk Carrier	**Example**	**Example**	**Example**
Type of Technology		**A**	**A**	**B**
Manufacturer		**M1**	**M2**	**M3**

*Note that this high level assessment should be used in conjuction with the Guide.

Criteria	Question	Assessment	Assessment	Assessment	Guidance
Similarity	**Are the savings claims provided for a ship type similar to the retrofit candidate?**	Identical	Identical	Similar	Red should be assigned if the evidence is of a different ship type to the retrofit candidate Yellow could be assigned if the ship types are similar but not identical, Green if ship types are identical
Plausibility	**How does the performance claim compare with indicative savings from the GRIP project?**	Higher	Similar	Lower	Red if higher, yellow if similar, green if lower
Accuracy	**How have the performance claims been derived?**	CFD	Performance Monitoring	Post retrofit trials	Red for model tests, yellow for post retrofit trials, green for trials before and after drydock and performance monitoring. CFD not evaluated
Overall Volume of Orders	**How many installations have been delivered?**	9	5	300	Red for up to 5 installations of the energy saving device Yellow for between 6 and 20 installations Green if there are more than 20 installations
Specific Volume of Orders	**How many installations for ships similar to the retrofit candidate have been delivered?**	3			Red if there are up to 2 installations of the energy saving device Yellow if there are between 3 and 5 installations Green if there are more than 5 installations
Repeat Orders	**Have there been repeat orders?**				Red if no repeat orders, yellow if there are single orders for multiple units, green for multiple orders from the same customer
Consistency	**Are the savings consistently achieved for similar ships?**				Not evaluated if CFD or tank test based, otherwise red if inconsistent, yellow if within 1-2% and green if within 1%, but thresholds may be adjusted
Compatibility	**Is the potential EET compatible with existing EET on the retrofit candidate?**				Red if not compatible, yellow if compatible but with some uncertainty, green if compatible

Figure 11: *Example of initial high-level assessment*

The outcome of further research should result in the completion of the assessment as follows.

High Level Assessment

		Example	Example	Example
Ship Type	e.g. Bulk Carrier			
Type of Technology		A	A	B
Manufacturer		M1	M2	M3

*Note that this high level assessment should be used in conjuction with the Guide.

Criteria	Question	Assessment	Assessment	Assessment	Guidance
Similarity	**Are the savings claims provided for a ship type similar to the retrofit candidate?**	Identical	Identical	Similar	Red should be assigned if the evidence is of a different ship type to the retrofit candidate Yellow could be assigned if the ship types are similar but not identical, Green if ship types are identical
Plausibility	**How does the performance claim compare with indicative savings from the GRIP project?**	Higher	Similar	Lower	Red if higher, yellow if similar, green if lower
Accuracy	**How have the performance claims been derived?**	CFD	Performance Monitoring	Post retrofit trials	Red for model tests, yellow for post retrofit trials, green for trials before and after drydock and performance monitoring. CFD not evaluated
Overall Volume of Orders	**How many installations have been delivered?**	9	5	300	Red for up to 5 installations of the energy saving device Yellow for between 6 and 20 installations Green if there are more than 20 installations
Specific Volume of Orders	**How many installations for ships similar to the retrofit candidate have been delivered?**	3	3	5	Red if there are up to 2 installations of the energy saving device Yellow if there are between 3 and 5 installations Green if there are more than 5 installations
Repeat Orders	**Have there been repeat orders?**	Order for multiple units	No	Yes	Red if no repeat orders, yellow if there are single orders for multiple units, green for multiple orders from the same customer
Consistency	**Are the savings consistently achieved for similar ships?**	CFD	Between 1-2%	Inconsistent	Not evaluated if CFD or tank test based, otherwise red if inconsistent, yellow if within 1-2% and green if within 1%, but thresholds may be adjusted
Compatibility	**Is the potential EET compatible with existing EET on the retrofit candidate?**	Yes - proven	Yes but uncertain	No	Red if not compatible, yellow if compatible but with some uncertainty, green if compatible

Figure 12: *Example of updated high-level assessment after making enquiries with the manufacturers*

From the updated table above it may be concluded that technology B should not be shortlisted because it is not compatible with the EETs already fitted on the ship.

It then comes down to a choice between manufacturers M1 and M2 for a similar technology. There are several options at this stage:

- One option is to enter into negotiations with both manufacturers.
- Another option is to refine the assessment, perhaps lowering the savings claims for manufacturer M1 to the same level as for manufacturer M2.

In this particular example, the assessment scores are fairly close. However, in a real-life application of the methodology, the results may be more clear-cut.

4.4 Pre-contract discussions

Upon completion of the high-level assessment and shortlisting, more detailed discussions will follow with the chosen manufacturers during which details of the retrofit candidate that were collected will need to be shared. A key part of this engagement is the provision of predictions of savings, which may involve the use of tools such as CFD or model tests combined with previous experience, to give an indication of savings specific to the retrofit candidate.

Although it was previously explained under the accuracy criterion that claims based on CFD should not be scored but left blank, this was because it is deemed to be very difficult for the non-specialist to judge CFD-based findings, and not because the method is incapable of accuracy. Therefore, shipowners should not be unduly worried by the use of CFD or model tests at this stage.

In the case of performance predictions, confidence may be increased by agreeing contractual terms that cover how savings estimates will be demonstrated. Typically, this could be done through sea trials or longer-term performance monitoring.

The following checklist of questions has been developed which may be used during pre-contract discussions to increase understanding of the EET and confidence in the chosen company.

#	Question	Guidance on replying and/or how to interpret the answer
1	When was the company established?	The answer is meant to give an understanding of the experience and reliability of the manufacturer.
2	How does the company ensure the quality of its products in its processes?	The answer is meant to confirm that there are adequate control standards. Reference may also be made to ISO standards or other quality standards.
3	What kind of analyses did the company perform before earlier installations, and what standard research will the company undertake before a new prospective installation?	The answer is meant to give an understanding of the process to be followed and the validity of the savings claimed.
4	Will the EET be designed specifically for the ship and its operational profile?	The answer is meant to give an understanding of the applicability and validity of the alleged savings in relation to the specific ship, and of whether the manufacturer has considered specific design and operational characteristics.
5	How will the efficacy of the EET be demonstrated?	The answer is meant to give an indication of how the manufacturer intends to demonstrate the performance of the EET (e.g. sea trials, performance monitoring).
6	Is maintenance required?	Some EETs may require maintenance, calibration or the adjustment of certain settings. This may entail additional costs. Some EETs may also be affected to a greater extent than others by the condition of the ship.
7	Will maintenance services be provided to the client?	Some EETs will require specific maintenance to function optimally.
8	Will guidance on optimal use be provided to the client?	With some EETs it may be necessary to provide guidance so that they can be used in an optimal way and achieve maximum savings.
9	Will aftersales support be provided?	It is considered important to select a manufacturer that will provide aftersales support, where necessary.
10	Will performance guarantees be provided? If so, what form will they take?	The manufacturer should stipulate the conditions under which such a guarantee is provided. If the level of confidence in an EET is low, a guarantee may be more important to mitigate part of the risk.
11	Is extra consumption or power generation needed to make the EET effective? Is there a penalty in power requirements for "OFF" condition?	Some EETs require additional power to be generated and/or have a penalty in "OFF" condition (e.g. air lubrication and some wind-assisted propulsion technologies). The power consumption of these EETs should be taken into account when evaluating the potential savings.
12	Does the EET degrade over time?	Some EETs degrade over time, which entails additional costs. In such cases, the average anticipated effectiveness over time should be considered.

4.5 Contract and post-installation

During the pre-contract phase, there would almost certainly have been discussions on either performance guarantees and/or methods for demonstrating the efficacy of the EETs.

Some performance guarantees involve a model test which may be concluded before the fitting of the EET. This should only be regarded as indicative and not as a replacement for trials and/or performance monitoring.

In the post-installation phase, there are broadly only two full-scale measurement options: sea trials and performance monitoring. However, there are further details to clarify, such as what should be used as a comparison point (baseline) and how the collected data is processed and analysed. These choices can all affect the outcome significantly. Greater accuracy generally comes with both a financial cost and a time requirement (e.g. conducting sea trials not just after dry dock, but also before).

The two measurement options are not necessarily incompatible – one may choose to use a sea trial to fulfil contractual terms, but still undertake performance monitoring (whether installed by the equipment manufacturer or implemented by the company or by a third party) that allows comparisons to be made over a longer period.

As emphasized in chapter 2, the retrofitting of EETs is one small part of a larger “package” of continuous operational optimization and implementation of best practices. Performance monitoring is an important tool for bringing about continuous improvements in energy efficiency.

If performance monitoring is implemented by the shipping company or a third party, rather than by the EET manufacturer, it is worth considering making such performance data available to the manufacturer over a longer time period. This provides an important feedback loop that can help manufacturers to enhance and optimize the equipment that they offer.

MORE INFORMATION?

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