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# AIR POLLUTION AND ENERGY EFFICIENCY

## Goal-based approach to fuel and $CO_2$ emissions monitoring and reporting

**Submitted by the Institute of Marine Engineering, Science and Technology (IMarEST)**


**SUMMARY**

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| *Executive summary:* | This document provides information relating to a goal-based approach to "fuel consumption measurement". The goal-based approach covers three key attributes, namely: accuracy of monitoring, complexity and relative through-life costs. In addition the paper uses ISO 14064-1:2006[1], principles for greenhouse gas (GHG) monitoring and reporting. The document identifies four possible approaches for the conduct of fuel monitoring. The goal-based attributes recognize that the applicability of the various monitoring approaches varies across a wide range of ship types and operating profiles. The key challenge in a goal-based approach is the trade-off between acceptable accuracy, complexity, and corresponding relative through-life cost. |
| *Strategic direction:* | 7.3 |
| *High-level action:* | 7.3.2 |
| *Planned output:* | 7.3.2.1 |
| *Action to be taken:* | Paragraph 6 |
| *Related documents:* | MEPC 63/23 and MEPC.1/Circ.471 |


## Introduction

1 MEPC 63 invited further submissions on specific aspects of an IMO performance standard for fuel consumption measurement for ships (MEPC 63/23, paragraph 5.59). This document provides information relating to a goal-based approach to "fuel consumption measurement", and uses the term *monitoring* to indicate an overall approach and the term *measurement* to indicate a direct measure at one specific point in time.

1 ISO 14064-1:2006 – "Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals".

2 Using a goal-based approach and recognizing the International Standardization Organization's (ISO) principles for greenhouse gas (GHG) monitoring and reporting (ISO 14064-1:2006), this document identifies four possible approaches to fuel monitoring:

.1 Bunker Fuel Delivery Note (BDN),[2] and periodic stocktakes of fuel tanks;

.2 bunker fuel tank monitoring on-board;

.3 flow meters for applicable combustion processes; and

.4 direct emissions measurements.

3 The goal-based approach covers three key attributes, namely: accuracy of monitoring, complexity, and relative through-life costs. The goal-based attributes recognize that the applicability of the various monitoring approaches varies across a wide range of ship types and operating profiles. The key challenge in a goal-based approach is the trade-off between acceptable accuracy, complexity and corresponding relative through-life cost.

4 The determination of fuel consumption, and hence $CO_2$ emissions, based on the use of the BDN, as provided for in MARPOL Annex VI, together with periodic stocktakes of fuel tanks, is the simplest form of consistent fuel monitoring. It is already an accepted, widely used and recognized global process.

5 This document also highlights some issues that Member States may wish to take into consideration when developing a goal-based approach to fuel monitoring and $CO_2$ emissions inventory procedures.

**Action requested of the Committee**

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

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[2] Bunker Fuel Delivery Note (BDN) – a document received with the bunkers when purchased, which sets out the name and International Maritime Organization (IMO) number of the receiving ship, the port at which the fuel was taken on, the date of delivery and fuel quantity data. BDNs are required by regulation (for Party States) and must be kept on-board and be available for inspection at any time.

# ANNEX

# GOAL-BASED APPROACH TO FUEL AND $CO_2$ EMISSIONS MONITORING AND REPORTING

**Alastair Fischbacher; Anne-Marie Warris; John Aiken; Jonathan Holloway; Katharine Palmer; Ken Reid; Niels Björn Mortensen, Per Tunell[3]**

## 1 Outline

1.1 This information paper has been developed by a group of individuals acting in their personal capacity to provide information to the International Maritime Organization (IMO) Marine Environmental Protection Committee (MEPC), as requested in MEPC 63/23, paragraph 5.59 relating to an IMO performance standard for "fuel consumption measurement".[4] Note the paper uses the term *monitoring* to indicate an overall approach and the term *measurement* to indicate a direct measure at one specific point in time.

1.2 Using a goal-based approach and recognizing the International Standardization Organization (ISO) ISO 14064-1:2006[5] principles for greenhouse gas (GHG) monitoring and reporting, this information paper identifies four possible approaches to fuel monitoring:

.1 Bunker Fuel Delivery Note (BDN) and periodic stocktakes of fuel tanks;

.2 Bunker fuel tank monitoring on board;

.3 Flow meters for applicable combustion processes; and

.4 Direct emissions measurements.

1.3 The information paper also highlights some issues that Member States may wish to take into consideration when developing a goal-based approach to fuel monitoring and $CO_2$ emissions inventory procedures.

1.4 The goal-based approach covers three attributes, namely: accuracy of monitoring, together with complexity and relative through-life costs. The link between the goal-based attributes and the four approaches can be illustrated as below in figure 1.

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3 The authors are writing in their personal capacity only and the views expressed in this paper do not necessarily represent those of and are not to be attributed to their organizations.

4 IMO MEPC 63/23 paragraph 5.59: "The Committee agreed that development of an IMO performance standard for fuel consumption measurement for ships could be a useful tool and that the Committee could consider it further at future sessions, and invited further submissions on specific aspects of such a standard to future sessions".

5 ISO 14064-1:2006 – **"**Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals".

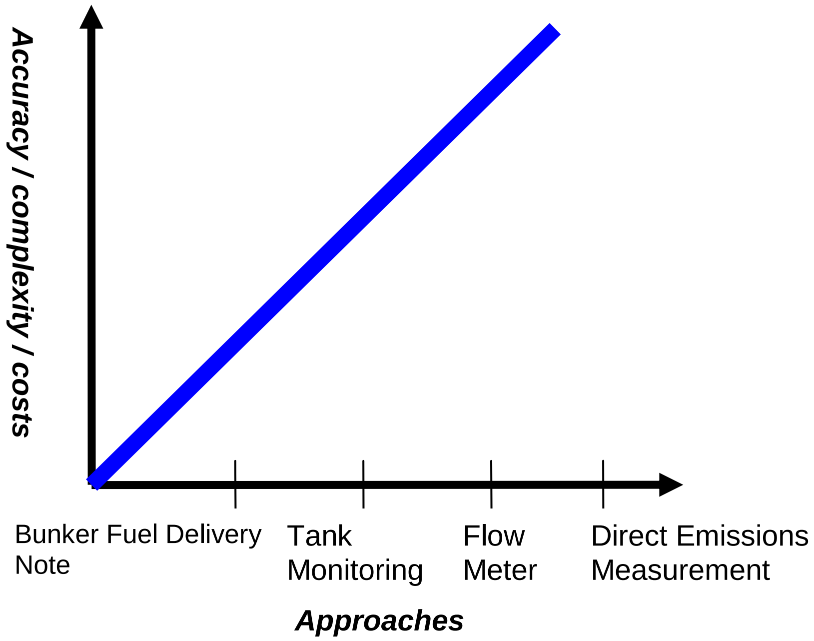


Figure 1: *Simplified relationship between fuel-monitoring approaches and goal-based attributes (accuracy, complexity and relative through-life costs)*

1.5 Fuel quantities are converted to carbon dioxide ($CO_2$) emissions using standard carbon conversion factors. For vessel operation, $CO_2$ is the main GHG and it is the only GHG considered in this information paper. Six GHGs are currently recognized as part of the work of the Intergovernmental Panel on Climate Change (IPCC).

1.6 As figure 1 illustrates, the determination of $CO_2$ emissions based on the use of the BDN,[6] as provided for in MARPOL Annex VI, together with periodic stocktakes of fuel tanks, is the simplest form of consistent fuel monitoring. It is already an accepted, widely used and recognized global process.

1.7 The key challenge in a goal-based approach is the trade-off between acceptable accuracy, complexity, and corresponding relative through-life cost. Expectations of a given accuracy may not be possible within a reasonably cost-effective and practicable monitoring and reporting approach.

1.8 Further work is necessary to establish boundaries for the accuracies and detailed through-life cost implications for the various fuel-monitoring approaches and for evaluating the consequences of the various approaches across the world fleet.

1.9 It is likely that there will be continued development towards more accurate and technically advanced methods of monitoring. With time this will broaden the choices that owners/operators can consider in achieving a goal-based approach to monitoring and reporting. Any Member State or IMO requirements should be goal-based, with the principle that vessel owners can choose the monitoring approach most suited to their own operations while still meeting the goal-based aims. The goal-based aims need to be practical and achievable.

[6] Bunker Fuel Delivery Note (BDN) – a document received with the bunkers when purchased, which sets out the name and International Maritime Organization (IMO) number of the receiving ship, the port at which the fuel was taken on, the date of delivery and fuel quantity data. BDNs are required by regulation (for Party States) and must be kept on-board and be available for inspection at any time.

## 2 Potential approaches for determining fuel consumption and hence $CO_2$ emissions

2.0 Based on a review of processes currently employed on-board, the following four approaches for quantifying fuel consumption and $CO_2$ emissions are considered. As illustrated in figure 1, these are considered in order of increasing complexity, accuracy and relative through-life costs, as follows:

.1 BDN and periodic stocktakes of fuel tanks;

.2 Bunker fuel tank monitoring on-board;

.3 Flow meters for applicable combustion processes; and

.4 Direct emissions measurements.

### 2.1 Approach 1 – BDN and periodic stocktakes of fuel tanks

2.1.1 This approach uses the quantity and type of fuel as defined on the BDN combined with periodic stocktakes of fuel tanks based on tank readings. The fuel at the beginning of the period, plus deliveries, minus fuel available at the end of the period, together constitute the fuel consumed over the period.

2.1.2 The BDN is mandated under existing MARPOL Annex VI regulations and relevant records are maintained[7] and available. The periodic stocktake of fuel tanks on-board is based on fuel tank readings. It uses tank tables relevant to each fuel tank to determine the volume at the time of the fuel tank reading. Accuracy and consistency of BDN data vary depending upon how the fuel quantity stated on the BDN is determined.[8]

2.1.3 The accuracy and consistency of the fuel tank readings may vary depending on the means by and conditions under which they are carried out; for example, by locally using dip tapes and soundings, or remotely by using automated systems, and vessel conditions, such as trim/heel and other external influences, such as the weather. Calibration of the gauging system and the accuracy of the tank tables will also influence the accuracy of the reading.

2.1.4 The key assumption associated with this approach is that all fuel purchased and determined during the stocktakes of the fuel tanks will be fully consumed. It does not take into account any differential between volume of fuel purchased and the actual volume of fuel consumed. There may be differences in the two quantities due to:

.1 sludge and water removed from the fuel following on-board fuel treatment processes and disposed of without incineration;[9]

.2 de-bunkered fuel;

.3 BDN accuracy;

.4 adequacy of BDN data regarding fuel composition; and

.5 non-availability of BDN.

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[7] According to MARPOL Annex VI, chapter III/18.6, a BDN shall be retained on-board for three years after the delivery of the bunker fuel and be readily available. Additionally chapter III/18.9.3 requires local bunker fuel suppliers to retain a copy of the BDN for at least three years for inspection and verification by the port State as necessary.

[8] For example, a mass flow meter may deliver more accurate results than a volumetric flow meter due to the additional uncertainty through measuring temperature and density manually.

[9] ISO 8217 fuel standard is maximum 0.5% water; LR FOBAS indicates that less than 1% of tested fuel samples exceed this limit.

2.1.5 This may lead to a tendency to over-estimate fuel usage and hence $CO_2$ emissions. It is suggested that the sludge and removed water difference can be accommodated by using agreed correction factors based on industry-available data supplied by bunker analysis organizations. Additional considerations are required where cargo is used as a fuel, for example, liquefied natural gas (LNG) boil-off.

2.1.6 One benefit of this approach is that it is common practice for many operators who currently use this approach to track and report fuel data.

2.1.7 Implementation is reasonably straightforward on a global scale, since this approach relies on existing legal frameworks prescribed by the IMO.

2.1.8 $CO_2$ emissions for a specific period are calculated based on the fuel consumption determined from BDNs and stocktakes of the fuel tanks for the period, multiplied by the corresponding carbon conversion factor.[10]

## 2.2 Approach 2 – Bunker fuel tank monitoring on-board

2.2.1 This approach is based on fuel tank readings for all fuel tanks on-board. The tank readings occur daily or at a defined time or geographical location.

2.2.2 The accuracy and consistency of this approach will vary; this is similar to the stocktake of fuel tanks in approach 1. But this approach 2 is more sensitive to these inaccuracies as it relies on fuel tank readings only. This is also similar to approach 1, in that there may be discrepancies between the tank volume determined and the actual volume consumed, for example, due to on-board fuel treatment processes.

2.2.3 The benefit of this approach compared to the BDN is that many ships take fuel tank readings on a daily basis for the purpose of stability and performance monitoring, and for cross-checking and confirmation of fuel consumption.

2.2.4 Implementation is less straightforward on a global scale since this approach may need a new formal IMO framework. Supporting guidance would have to cover a range of options and methods. However, from a ship operator's perspective, on-board systems and processes are, in the main, available.

2.2.5 The determination of $CO_2$ emissions would be the same as that for approach 1.

[10] IMO Conversion Factors taken from IMO Circular MEPC./Circ.471.

| Fuel Type | Reference | Factor (t-$CO_2$/t-Fuel) |
|---|---|---|
| Heavy fuel oil (HFO) | ISO 8217 Grades RME through RMK | 3.1144 |
| Marine Diesel Oil (MDO) | ISO 8217 Grades DMX through DMC | 3.2060 |
| Light Fuel Oil (LFO) | ISO 8217 Grades RMA through RMD | 3.15104 |
| Liquefied natural gas (LNG) | Methane | 2.7500 |
| Liquefied petroleum gas(LPG) | Propane | 3.0000 |
| LPG | Butane | 3.0300 |
| Biofuels | The conversion factor for biofuels is adjusted for blends that include fossil fuels in proportion to the fossil fuels and their $CO_2$ conversion factor | [TBC] |

### 2.3 Approach 3 – Flow meters for applicable combustion processes

2.3.1 This approach involves the installation of flow meters on-board. The data from all the various flow meters would be collated and combined to determine all fuel consumption for a specific period. The installation of flow meters on-board vessels is not routine practice, although some vessel operators have experience of such systems and they are often included in modern fuel systems. This approach identifies the net fuel delivered and consumed; therefore the configuration of the metering system has to facilitate this. A wide variety of flow meters is available; these operate on a number of different principles and deliver results of varying degrees of accuracy.

2.3.2 As this is a technology-based approach, there is an increase in relative through-life cost, as well as additional maintenance and calibration requirements, with a subsequent need for a higher degree of on-board operator capability. Practical experience has shown that some shore-based metering systems may not be suited to and do not perform well in the maritime environment. It would be necessary to define a 'fall-back' methodology (approach 1 or 2), as a contingency, in the event of the primary flow-metering system failing.

2.3.3 Accuracy and consistency of this approach may vary depending on the choice of flow-metering system, the installation, maintenance and calibration requirements of the system and on-board operator competence. Since this approach accounts for only the fuel consumed in the fuel combustion system, it could potentially be more accurate than approaches 1 and 2.

2.3.4 The benefit of this approach is that it would only account for the actual fuel consumed in the combustion processes, provided the meters are carefully situated and correctly calibrated and maintained, since any losses due to on-board fuel treatment, etc., have already been accounted for.

2.3.5 Implementation is less straightforward on a global scale, since this approach may need a new formal IMO framework. Verification by flag state may also be more complex than for approaches 1 and 2. Additional time would be needed to allow shipowners to add flow-metering equipment to ships that would be covered by such a new legal framework.

2.3.6 The determination of $CO_2$ emissions would be the same as that for approach 1.

### 2.4 Approach 4 – Direct emissions measurement

2.4.1 In this approach, $CO_2$ emissions measurement occurs in exhaust gas stacks (funnels). $CO_2$ emissions are determined directly through direct measurement, rather than by using fuel quantity as a proxy.

2.4.2 Direct measurement of $CO_2$ emissions is in its infancy within the maritime sector and in land-based industries. Direct measurement of $SO_x$ and $NO_x$ emissions is a recognized approach in the land-based power industry, and specifically in the USA for their regulated $SO_x$ programme. There is some experience of $CO_2$ emissions direct measurement in the European refinery industry related to the cracking process.

2.4.3 Direct emissions measurement is a step change in technology from the previous approaches. There are technological challenges, such as those related to volumetric flow measurements at low engine loads, during vessel manoeuvring, and the capability to handle multi-exhaust configurations. Direct emissions measurement will require substantial increased capital costs due to the additional equipment needs, requirement for on-board calibration and increased information technology (IT) infrastructure on-board and possibly on shore in order to support the operation of the installation. There will be greater requirements for on-board operator capability, together with the need for remote back-up systems.

2.4.4 The benefit of this approach is that it does have the future potential to provide a higher level of accuracy of direct $CO_2$ emissions from associated exhaust streams.

2.4.5 Implementation is significantly less straightforward on a global scale, since this approach would need a new formal IMO framework. In addition, such a proposal would require provision of direct measuring equipment and associated systems on-board which currently lack maturity.

## 3 Principles for monitoring and reporting

3.0 In defining the aim of the goal-based approach to monitoring and reporting, it is necessary to consider principles in addition to the approaches discussed above. Commonly used principles for GHG monitoring and reporting are defined in the international standard ISO 14064 -1:2006 "Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals". The principles are: relevance, completeness, consistency, accuracy and transparency. The section below looks at the ISO principles in context of shipping and provides some thoughts for issues that need to be considered.

### 3.1 Relevance

3.1.1 **Relevance** determines the boundaries, the types of GHG to be reported and exclusions that apply to monitoring and reporting. The issues that need consideration include:

.1 ship types;

.2 ship sizes;

.3 possible exclusions from international shipping;

.4 which data and what goal-based aims; and

.5 exclusions, such as operations for the purpose of rescuing lives.

### 3.2 Completeness

3.2.1 **Completeness** determines which $CO_2$ emissions as defined in "relevance" are to be included. The issues that need consideration include:

.1 what fuels, including issues associated with use of bio-fuels;

.2 which combustion process?

  .1 main engines;
  .2 auxiliary engines;
  .3 boilers;
  .4 inert gas generators; and
  .5 incinerators.

### 3.3 Consistency

3.3.1 **Consistency** relates to using a repeatable process to monitor and determine the $CO_2$ emissions. The issues that need consideration include:

.1 What is necessary to ensure monitoring meets the requirements and generic principles of the goal-based approach?

.2 What level of detail is necessary in relation to how the monitoring and reporting processes work, and, where the inputs to the calculations originate from, e.g., different fuel tanks, fuels, engines and other combustion processes, how this is managed, including when different fuel grades are blended?

.3 Design of an effective data set for fuel records and $CO_2$ emissions may include considerations such as:

.1 reasonable measures to prevent data gaps;

.2 consistent, comparable measurement methodologies;

.3 transparent and repeatable management of data within defined limits; and

.4 ensuring that records and process can meet reasonable assurance[11] requirements for verification.

.4 Processes and procedures to ensure that applicable records:

.1 are retained;

.2 are maintained through changes in class, flag and ownership; and

.3 are retained with adequate detail and information for audit purposes.

.5 Which industry-standard calculation and associated conversion factors to use? and

.6 Conversion factors from various volumetric measurements to tonnes.

### 3.4 Accuracy and uncertainty

3.4.1 ***Accuracy*** is commonly defined as: the closeness of the agreement between the result of a measurement and a true value of the measurand. Determining the accuracy of a measurement usually requires calibration of the analytical method with a known standard.

3.4.2 ***Uncertainty*** is associated with the result of a measurement, and it characterizes the dispersion of values that could reasonably be attributed to the measurand. It is typically expressed as a range of values in which the value is estimated to lie, within a given statistical confidence, but it does not attempt to define or rely on a unique *true* value.

[11] "Reasonable assurance" is a concept used in financial accounting and in ISO 14065 "Greenhouse gases – Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition".

3.4.3 Uncertainty associated with a monitoring system takes into account the specified uncertainty of the applied measuring instruments, calibration processes, and operational use of measuring instruments used throughout the bunker supply chain and during on-board consumption processes.

3.4.4 The issues that need consideration for the two terms above include:

.1 *uncertainty* –

.1 capability of the average ship to achieve the uncertainty level as defined in a goal-based approach to monitoring;

.2 how to ensure that maximum uncertainty levels are met;

.3 how to ensure that the equipment used to measure fuels is identified and maintained, and to define appropriate calibration standard; and

.4 how to minimize uncertainty.

.2 *Accuracy* –

.1 link between cost-effectiveness and goal-based defined accuracy; and

.2 cost and simplicity of the approach selected and the decisions made in relation to "relevance" and "completeness".

**3.5 Transparency**

3.5.1 **Transparency** is related to provision of sufficient information to allow users of the data to make decisions with reasonable confidence that the data on which they are basing their decisions are a fair reflection of reality, and are complete and suitable. The elements to be considered in relation to reporting processes are:

.1 length of the reporting period;

.2 processes must not systematically over- or underestimate the actual fuel quantities and $CO_2$ emissions;

.3 records in cases where the ship is responding to emergencies;

.4 records in case the ship suffers an emergency itself; and

.5 defined and consistently applied ship-specific reporting and control processes.

**4 Conclusion**

4.1 This information paper looks at four different approaches to fuel monitoring and determination of $CO_2$ emissions within a goal-based framework. The different approaches have varying accuracy, complexity and relative through-life costs. The key challenge in a goal-based approach is the trade-off between acceptable accuracy, complexity and corresponding relative through-life cost. Goal-based attributes need to recognize that the applicability of the approaches varies across a wide range of ship types and operating profiles.

4.2 Further work is necessary to establish boundaries for the accuracies and detailed through-life cost implications for the various fuel-monitoring approaches and for evaluating the consequences of the various approaches across the world fleet.

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