Gold Standard Methodology

Retrofit Energy Efficiency Measures in Shipping

Version 1.0 – Published July 2017

Table of Contents

Inquiries should be directed to the Gold Standard Foundation secretariat at: info@goldstandard.org

Definitions and Abbreviations

Definitions

Beaufort Scale or Beaufort Wind Force Scale is an empirical measure for describing wind speed based mainly on observed sea.

Docking cycle: Ships are periodically placed in a dry dock in order to undertake maintenance of hulls, propellers and other surfaces that would normally be submerged, as well as to make any elective technology upgrades to the vessels. A docking cycle comprises the interval between successive dry dockings. A docking cycle for large cargo vessels is usually 60 months, though for some ships it can be 36, 30, 24, or even 12 months.

Ship speed can be defined in two ways:

- *Speed over the ground* (SOG) is the speed of the vessel relative to the surface of the earth.
- *Speed through water (STW)* is the speed of the vessel relative to the water.

Note that in this methodology, speed refers to speed over the ground.

Abbreviations

BAU	Business as Usual
CDM	Clean Development Mechanism
EE	Energy Efficiency
EEDI	Energy Efficiency Design Index
ERs	Emission Reductions
ESCO	Energy Service Company
ESD	Energy Saving Device
GHGs	Greenhouse Gases
GWP	Global Warming Potential
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquefied Natural Gas
MDO	Marine Diesel Oil
tkm	Ton-Kilometre
UNFCCC	United Nations Framework Convention on Climate Change

1.0 SOURCE AND APPLICABILITY

This methodology is applicable to a wide range of retrofit technical efficiency measures in shipping which reduce fuel usage and greenhouse gas (GHG) emissions. Implementation of one or multiple measures has the potential to achieve significant efficiency improvements in shipping. This methodology therefore encompasses the application of multiple technical efficiency options measuring the compound outcome. The methodology allows for the application of one or multiple efficiency measures simultaneously. In most cases, the efficiency measures are applied during dry docking with docking cycles going for 12 to 60 months depending on vessel types, but it is also possible that some of these measures are applied during the docking cycle.

This baseline and monitoring methodology is based on elements from the following approved baseline and monitoring methodologies:

- GS Methodology "Reducing Vessel Emissions Through the Use of Advanced Hull Coatings", Version 2.0;
- GS Methodology "Installation of Flow Improvement Equipment on Ships", Version 1.0;
- CDM "Tool for the demonstration and assessment of additionality", Version 7.0.0;
- CDM "Guidelines for Determining Baselines for Measure(s)", Version 01.0;
- CDM Methodological Tool "Tool to determine the remaining lifetime of equipment", Version 01.0

The eligible technical efficiency measures are installed individually or as bundles custom-tailored for a given ship to improve fuel efficiency in shipping. The eligible retrofit measures include[1]:

- **Design related measures:**
  This category includes engine derating[2], reconfiguration of the bulbous bow[3], interceptor trim plates[4], optimisation of hull openings[5], superstructure aerodynamics, aft waterline extension[6], and air lubrication[7].

---

[1] This is a non-conclusive list of eligible measures. The project developer may submit non-listed efficiency measures with justification and clear cause-effect chain for inclusion in the Project Design Document. The listed Grouping categories are based on Wartsila, Energy Efficiency catalogue / Ship Power R&D, 2009

[2] Adjustments in the fuel injection timing are made allowing the engine to continue operating at its P_{max} but at a lower power/speed level.

- **Propulsion measures:**
  This category includes pre/post-swirl devices including boss cap fins[8], vane wheel, presswork ducts, Mewis duct[9] and stator fins; propeller/rudder integration including propeller rudder bulb and propeller nozzles[10], propeller rudder matching/combination, and asymmetric rudder and propeller modifications including advanced blade sections[11], winglets/Kappel[12] and propeller section optimisation[13]; propeller modifications; Usage of wind power with sails, Flettner rotor[14], kites etc.[15]

---

[3] A bulbous bow can potentially reduce wave-making resistance and thus the hull resistance. The bulb design needs to be in accordance with the expected range of operating drafts and speeds as it can potentially also result in increasing resistance.

[4] A metal plate fitted vertically to the transom of a ship which bends the flow over the aft-body of the ship downwards creating a lift effect similar to a conventional trim wedge.

[5] The water flow disturbance from openings to bow thruster tunnels and sea chests is minimized e.g. through installing a scallop behind each opening or a grid that is perpendicular to the local flow direction. This results in lower power demand.

[6] The effective waterline is lengthened making the wetted transom smaller and reducing the resistance of the ship.

[7] Air cavity via injection of air under/around the hull to reduce wet surface and thereby reducing the ship's frictional resistance between the water and the hull surface.

[8] Small fins attached to the propeller hub recapturing some of the rotational energy which can then be used for propulsion work.

[9] A duct positioned ahead of the propeller and an integrated fin system within the duct. The duct straightens and accelerates the water flow into the propeller. The fin provides a pre-swirl to the ship propeller thereby increasing the propeller efficiency and reducing the hub vortex, tip vortex and rotational losses.

[10] Nozzles shaped like a wing section around a propeller can save energy at lower speeds.

[11] This improves the cavitation performance and frictional resistance of a propeller blade thus making it more efficient.

[12] Special tip shapes can improve propeller efficiency.

[13] The rudder generates about 5% of the ships overall drag. An advanced design can improve water flow and reduce drag from the rudder.

[14] Spinning vertical rotors convert wind power into thrust in the perpendicular direction of the wind i.e., in side wind the ship will benefit from the added thrust thus lowering fossil fuel consumption.

[15] Wind energy is used to add forward thrust thus reducing the fossil energy demand required for propulsion.

- **Machinery measures:** This category includes engine tuning[16] and common rail technology[17].

- **Operating measures:** This category includes variable speed operation for controllable pitch propellers[18], propeller surface finish/polishing[19], advanced hull surface coatings/paints[20], part load operation optimisation[21], vessel trim[22], and lubricants and fuel additives[23].

The following table presents the applicability conditions and the means of verification used to ensure compliance with the applicability condition.

Table 1: Applicability Conditions and Means of Verification

Applicability Condition	Mean of Verification
1. The project activity shall implement one or more retrofit efficiency measures. The measures may vary within ships included in the project and multiple energy efficiency measures can be applied on one individual ship. In most of the cases,	The project design document shall describe each measure to be implemented including a cause-effect relationship which demonstrates how the efficiency measure will result in fuel savings. The project design document shall also include the implementation

[16] The engine is tuned to give lower consumption at part load while still meeting NO_x emission limits by allowing higher consumption at full load which is seldom used.

[17] Common rail controls combustion so it can be optimised throughout the operation field, providing at every load the lowest possible fuel consumption.

[18] Reducing the number of revolutions at reduced ship speed will result in fuel savings.

[19] Regular in-service polishing reduces surface roughness on propellers caused by organic material and fouling.

[20] This methodology can only be applied to hull coatings/paints that do not contain biocidal materials. Also, for qualifying under this methodology, all of the environmental benefits of hull coatings/paintings should be clearly demonstrated and be independently verified through life cycle studies following ISO 14040 and ISO 14044.

[21] Protective coating can inhibit organic and inorganic growth on ship hulls, prevent the build-up of marine organisms and reduce hydrodynamic drag.

[22] The optimum trim is hull form, speed and draught dependent. The trim can be optimised by repositioning of the cargo or rearranging bunkers (taking ballast would increase displacement and therefore fuel consumption).

[23] The project design document needs to show that proposed lubricants and/or fuel additives comply with all required environmental standards and do not create environmental hazards.

these measures shall be implemented during the dry docking, yet it is also possible to add new measures during the docking cycle.	plan and details of the measures that would be implemented during the project docking cycle.
2. The ship has had at least one full docking cycle of operation prior to the implementation of measures i.e. the methodology is not applicable to new ships.	The project developer shall provide the evidences that prove the ship is not new, i.e. it had at least one full docking cycle of operation.
3. Biofuels can be used, however, no carbon credits are generated from the usage of biofuels through this methodology.[24] Emissions reductions would only apply to reduced petroleum fuel consumption, with no credits for biofuel use through this methodology. However, this methodology could be combined with another methodology to include emissions reduction through biofuel use.	The project developer shall provide records of fuel purchase indicating share of biofuel.
4. Only fuel consumption for ship propulsion can be used for emission reduction calculations. Fuel consumption for ship propulsion must therefore be separated clearly from fuel consumption for other uses.	The project design document shall indicate how ship propulsion fuel consumption is recorded separately from overall fuel consumption.
5. This methodology is not applicable for emissions reductions arising from fuel switching.	The project developer shall compare the propulsion fuel type used during the docking cycle before and after the implementation of efficiency measure(s) for each ship.
6. In the specific case that a project developer implements an advanced hull coating technology as a single retrofit measure, this methodology shall only be used for a crediting period limited to one single	The project developer to confirm if an "advanced hull coating" is the only measure applied and in this case the crediting period shall be limited to one single project docking cycle.

[24] This methodology may be combined with another methodology to include emissions reduction for biofuel use.

project docking cycle, to be consistent with the approved Gold Standard methodology "Reducing Vessel Emissions Through the Use of Advanced Hull Coatings (version 2.0)."	

The methodology is not applicable to:

1. Transport efficiency improvements e.g. increased load factor of the ship resulting in lower emissions per tkm.
2. Energy savings resulting from lower speed – this is factored out in the calculations used to determine emission reductions.
3. Technologies employed to improve combustion efficiency without improvements in engine efficiency.

The project developer shall bear the cost of a professional statistician contracted by The Gold Standard Foundation for the validation of

- the results of the regression analysis applied to the submitted project activity in line with the model(s) provided in the methodology;
- A new regression model presented for approval by the Gold Standard. It shall be assessed by an external expert prior to the submission of a project activity.

The methodology may be used to generate carbon credits to ship owners, shipping companies, charter operators, technology providers, aggregators, energy service companies (ESCOs) or 3rd parties i.e., there is no applicability condition relating to the ownership of carbon credits in this methodology. Any agreement between Parties with regard to ownership of carbon credits is private and confidential, however it needs to be monitored and verified during the project approval process and prior to issuance of carbon credits to avoid potential double counting. All Parties involved must formally commit to an agreement to not claim credits from the same ships as part of activities under other schemes to eliminate potential double counting of emission reductions.

It is the project developer's responsibility to ensure that all data and monitoring requirements are met. Thus, the shipping operator or charter must make fuel consumption and other needed data available to the equipment manufacturer if the latter is the aggregation entity. To this end, an agreement is needed between the manufacturer and ship owner/operator. The detailed data would be considered confidential, and would only be shared with the validation and verification entities and The Gold Standard Foundation, with the understanding that the information would not be publicly available. Summary statistics used to determine fuel savings and emissions reduction would be published in the verification reports and would be publicly available. Provided the results confirm fuel savings, they would contribute to increased confidence in efficiency measures, making them common practice.

2.0 BASELINE METHODOLOGY

1. Project Boundary

The spatial project boundary is the geographical location of project ships in which vessels are clearly identified by their unique IMO-Number. The project boundary includes the cruising part of a ship's route, but excludes stays in ports, dry docks and manoeuvring activities (except for cases where fuel consumption for navigation is not recorded separately; in these cases, the fuel consumption would include navigation and manoeuvring). In both baseline and project scenarios, the same project boundary for fuel consumption data should be used.

Emissions sources included in the project boundary

This methodology applies to efficiency measures that would reduce the consumption of Marine Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO) consumption in ships. The combustion of these fuels primarily produces carbon dioxide (CO_2) with small amounts of other greenhouse gases i.e., methane (CH_4) and nitrous oxide (N_2O). However the emission of these two GHGs are very minor compared to CO_2 emissions as shown in table 2. In the case of Liquefied Natural Gas (LNG) usage, CH_4 emissions are however significant and shall be included within the project boundary.

Table 2: GHG Emission Factors and GHG Share

GHG	Marine HFO		Marine MDO		Marine LNG	
	g/gfuel	% of total CO_{2e}	g/gfuel	% of total CO_{2e}	g/gfuel	% of total CO_{2e}
CO_2	3.11400	98.4%	3.20600	98.6%	2.75000	67.7%
CH_4	0.00006	0%	0.00006	0%	0.05120	31.5%
N_2O	0.00016	1.5%	0.00015	1.4%	0.00011	0.8%

Source: IMO, Reduction of GHG Emissions from Ships, 3rd IMO GHG Study 2014 – Final report, 07/2014, table 34 for emission factors in g/g fuel; % of total CO_{2e} based on GWP as of 1.1.2013 of IPCC (25 for CH_4 and 298 for N_2O)

Reduced fuel consumption in the project scenario will also reduce emissions of CH_4 and N_2O. Therefore, their non-inclusion in liquid fuels with exception of LNG is conservative. Emission sources and GHGs included are indicated in Table 3 overleaf.

Table 3: Emissions Sources in the Project Boundary

	Source	Gas	Included?	Justification / Explanation
Baseline	Fuel consumption of main ship engines used for propulsion during voyages	CO_2	Yes	Main emission source
		CH_4	No except for LNG	Excluded for simplification for liquid fuels except if LNG is used where CH_4 emissions are included as they are relevant
		N_2O	No	Excluded for simplification
Project	Fuel consumption of main ship engines used for propulsion during voyages	CO_2	Yes	Main emission source
		CH_4	No except for LNG	Excluded for simplification for all liquid fuels except if LNG is used where CH_4 emissions are included as they are relevant
		N_2O	No	Excluded for simplification

In case equipment is replaced with a more efficient one, project developer shall use the latest version of the CDM "Tool to determine the remaining lifetime of the equipment" to estimate the remaining lifetime of the new equipment or to estimate the remaining time that the existing equipment could operate for in the absence of the project activity. This only needs to be performed in the case of replacing equipment or when modifications in equipment change the remaining technical lifespan.

2. Selection of baseline scenarios and project scenarios

Baseline Scenario

The baseline scenario must match the most probable case in the absence of the project activity. The baseline is developed following a step-wise approach as outlined below. Step 1 and 2 involves identifying realistic and credible alternatives to the project activity. Step 3 involves assessing consistency with current laws and regulations.

Step 1: Baseline Cycle

The starting point is the individual ship's fuel efficiency based on the previous full docking cycle of operation (denominated as the "baseline docking cycle"). The baseline docking cycle is used to apply or adjust the Basic Model which, based on a regression analysis, characterises the relationship of baseline fuel to various explanatory variables. The Basic Model thereafter allows determination of the hypothetical fuel consumption during the project cycle based on monitoring the explanatory variables and the pre-established relationship of latter with fuel consumption. The baseline is thus determined in a dynamic manner based on observed variables and a regression model with parameters determined for each ship.

Step 2: Autonomous Technological Improvement

It is assumed that some technical improvements will be made at each dry docking independent of the availability of carbon credits. This includes not only standard dry docking maintenance measures such as hull cleaning which effectively allow the ship to recover to near-to-original efficiency or performance levels but includes also the adoption of additional improvement or retrofit measures such as those listed in Table 4. It is therefore assumed that at least some measures of technological improvement which go beyond standard maintenance would be adopted. This process is called autonomous technological improvement. Which measure is actually adopted is dependent on current fuel prices, ship owner/charterer structure, charter costs, access to finance, cost, decision making processes and subjective factors - an objective assessment ex-ante for each ship is therefore not feasible. Also, separating the effect of different interventions is extremely difficult as measures can interact both positively and negatively and monitoring cannot isolate the effect of individual measures. In addition, values concerning the impact of efficiency measures per ship are within a large uncertainty range and dependent on vessel type, speed and voyages. Therefore, the approach is taken, as is used in other CDM transport methodologies[25], of an autonomous technology improvement factor per docking cycle.

The Business as Usual (BAU) improvement rate is defined for retrofit measures and per docking cycle. The BAU rate is based on percentage rate of adopted retrofit fuel efficiency measures (based on a survey report) and the estimated impact per measure (see following table).

[25] e.g. ACM0016, AM0016, AM0101

Figure 1: Baseline Determination

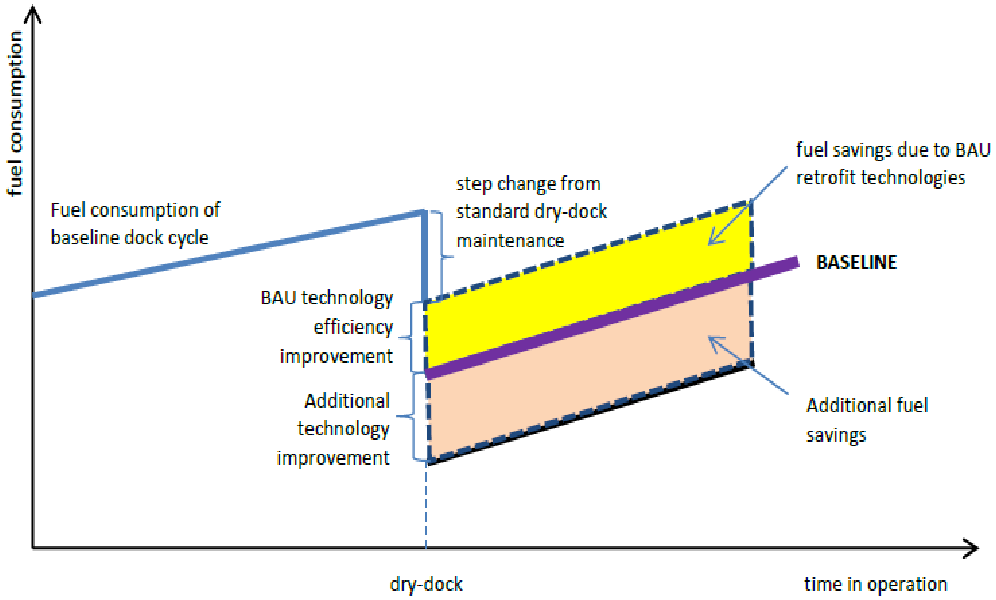


Table 4: Potential Efficiency Improvement Retrofit Measures per Docking Cycle[26]

Measure	Application share[27]	Improvement potential per docking cycle	Impact
Trailing edge, skeg shape	5%	2%	0.09%
Hull openings	2%	1%	0.02%
Aft waterline extension	2%	4%	0.09%
Shaft line arrangement	1%	2%	0.02%
Air lubrication	2%	8%	0.14%
Pre and post-swirl devices and advanced propeller blades	18%	3%	0.54%
Propeller/rudder integration and modifications	5%	2%	0.10%
Propeller modifications	10%	2%	0.21%
Hull streamlining/optimisation propeller/hull interaction	1%	4%	0.06%

[26] These are any efficiency improvement measures and not BAU measures. The BAU improvement rate is calculated by determining the actual application of these measures which, as shown below, range from 1% to 17% i.e. even the most "common" measure is NOT applied by > 80% of all ships and thus no measure in fact can be considered standard or BAU.

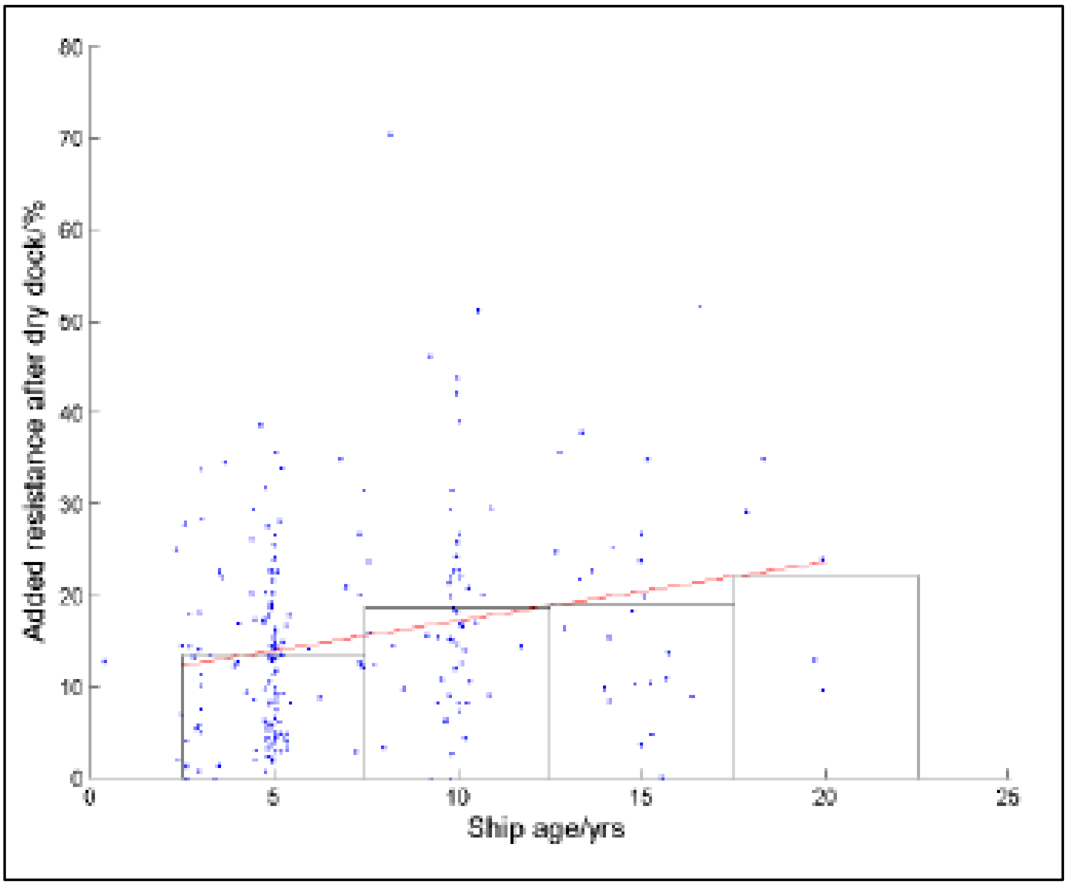
[27] This is defined as share of respondents who applied the measure during a retrofit (rounded values). Calculated as share of respondents who have applied this measure multiplied with share of respondents who have applied this measure as retrofit (versus application on new build ship).

Counter-rotating propellers	2%	3%	0.05%
Engine tuning	17%	0.5%	0.08%
Common rail	3%	0.5%	0.01%
Combined electric/diesel machinery	1%	6%	0.05%

Sources: *Application share calculated by Grütter using share per measure and share retrofit/new build based on N. Rehmatulla, Assessing the implementation of technical energy efficiency measures in shipping; Survey report, 05/2015, UCL Energy Institute; The improvement potential based on Wartsila, Boosting Energy Efficiency: Energy Efficiency Catalogue / Ship Power R&D, 2009; M. Khorasanchi et.al., What to expect from the hydrodynamic energy saving devices, Low Carbon Shipping Conference, London 2013; Smith et.al., Low Carbon Shipping – A systems Approach, Final Report, 2014; H. Wang et.al, Long-term Potential for Increased Shipping Efficiency through Adoption of Industry-Leading Practices, ICCT White Paper, 2013*

The combined result is 1.45% efficiency improvement per docking cycle. This does not take into account that the total impact might be less than the sum. Ship performance also has an underlying deterioration trend which goes beyond hull fouling as can be seen in the figure below.

Figure 2: Relation Ship Age and Increased Resistance



Source: *T. Dirksen, A statistical study of dry dockings, hull cleanings, and propeller polishes, Propulsion Dynamics, 05/2015*

Data scattering is quite wide with low correlations, however, a certain level of wear and tear concerning not only hull and propeller but also the engine is technically undisputed. Taking a conservative estimative, a wear and tear figure of 0.5% per docking cycle is assumed[28]. The rounded BAU improvement of fuel efficiency due to retrofit measures is therefore determined as being 1% per docking cycle[29]. This factor is for fuel efficiency improvement per docking cycle i.e. it is assumed that under an autonomous technology improvement pathway, ships would increase their fuel efficiency per docking cycle by 1%. This does not include common maintenance practice at dry dock like hull cleaning[30] and is solely the impact of retrofit measures.

The baseline applied is therefore the calculated baseline using the regression model with fuel consumption reduced by 1% per docking cycle. This value can be used by projects applying this methodology up to 5 years after the date of the methodology publication. After this period the value shall be revised and project developers intending to apply this methodology shall submit a revision to the methodology for future projects. The projects already registered are not required to update the BAU improvement in their crediting period. However, at the time of 2nd crediting period the project developer shall update the BAU improvement factor based on the latest methodology version.

Step 3: Compliance with the Energy Efficiency Design Index (EEDI) Requirements

The International Maritime Organization (IMO) adopted mandatory energy efficiency measures for all new ships of 400t (gross tonnage) or above built after 01.01.2013. The Energy Efficiency Design Index (EEDI) requires a minimum energy efficiency level per capacity mile according to ship type and size segments. For ships built after 01.01.2013, only energy efficiency improvements which go beyond

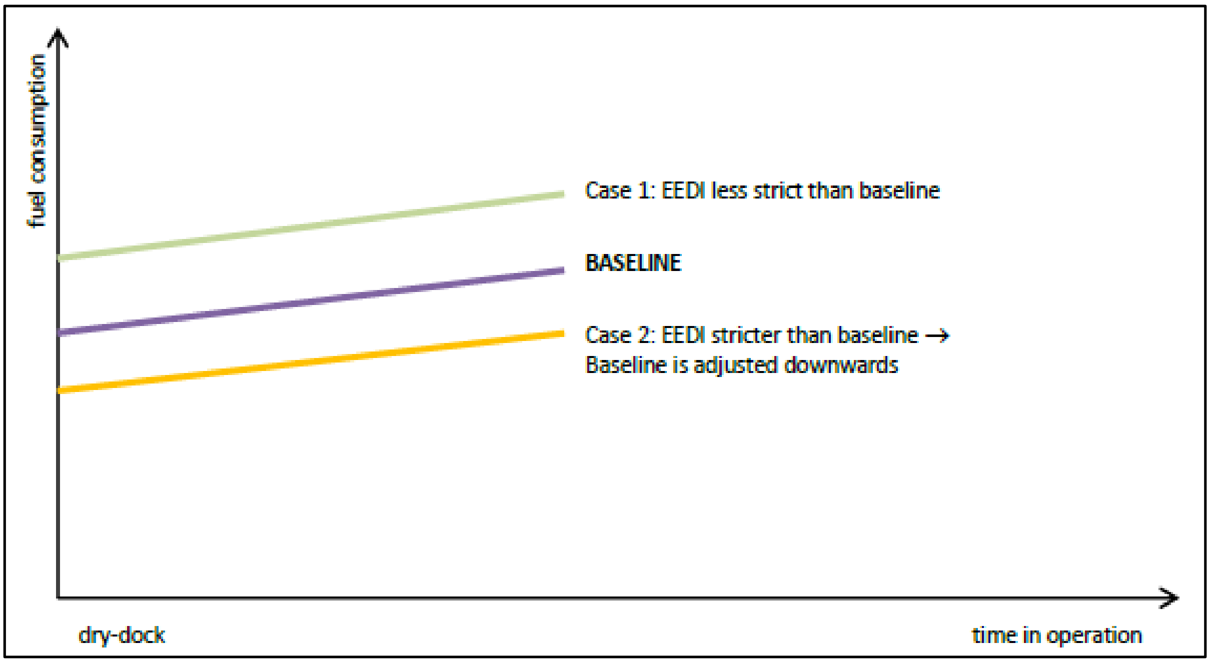
[28] T. Dirksen, A statistical study of dry dockings, hull cleanings, and propeller polishes, Propulsion Dynamics, 05/2015

[29] The methodology applicability is not limited to one docking cycle. The 1% BAU improvement is applied to each docking cycle. It means every time, the ship enters a docking cycle 1% BAU improvement is accounted for. For example: the ship starts with baseline emissions 100 tCO_2 eq. The baseline emissions, due to the application of BAU Improvement Factor, is 99 tCO_2 eq. Therefore, the emission reductions are the difference between baseline emissions (99 tCO_2 eq) – project emissions. At the 2 docking cycle, BAU Improvement Factor of 1% shall be applied again but to the docking cycle 1 baseline emissions (99 tCO_2 eq). It means the updated baseline emission for docking cycle 2 is 98.01 (99*0.99) and the emission reductions are emission reductions are the difference between new baseline emissions (98.01 tCO_2 eq) – project emissions. Since, the BAU Improvement Factor (%) is a percentage of a docking cycle the methodology can be applied to various docking cycles.

[30] This is made at all cycles and therefore the impact is already included in baseline data.

the EEDI requirement can be taken into consideration for the generation of carbon credits. The EEDI in principle should not influence the baseline as, hypothetically, new-built ships should comply with EEDI and therefore this should be expressed in the data of the baseline docking cycle. However, the EEDI is used as minimum required baseline and in case ships built after 01.01.2013 do not comply with this measure the EEDI baseline is used as this latter is effectively a regulatory requirement. See Figure 3 for two example cases.

Figure 3: EEDI and Baseline



In Case 1 (EEDI standard is less strict than the baseline i.e. the energy efficiency is better under the baseline case) no adjustment is required i.e. the baseline remains as determined under Step 2.

In Case 2 (EEDI standard is stricter than the baseline i.e. the energy efficiency is better under the EEDI case) the baseline is adjusted downwards to the EEDI standard.

Step 3 therefore ensures that a conservative baseline value is chosen for vessels impacted by EEDI requirements.

Step 4: Compliance with National Regulations

Countries or group of countries may impose fuel efficiency conditions for ships travelling to/from these countries which might go beyond the baseline as determined under Step 2. In these cases, the stricter (more ambitious) fuel efficiency standard of these countries is taken for the distance the vessel moves within the boundaries of these countries.

The baseline developed is thus a dynamic vessel related baseline using a regression model with parameter values specific for each ship determined through the previous docking cycle. An autonomous technology improvement factor expressed as a percentage rate is introduced to account for BAU energy efficiency improvements.

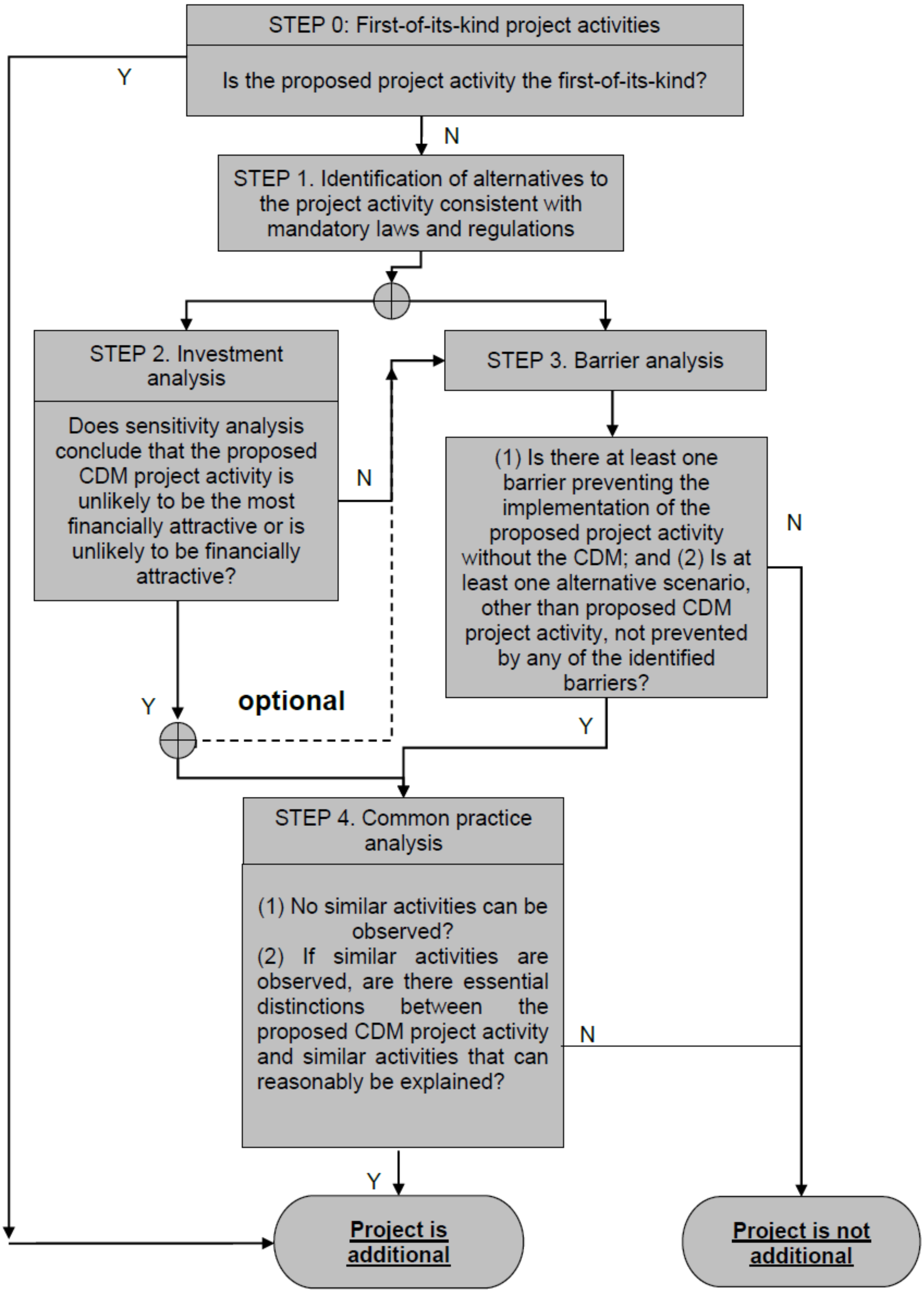
No common practice analysis is required for this methodology. This is embedded in the autonomous technology improvement factor which has included energy efficiency improvements that are common practice and subtracted their impact from the emission reductions.

The separation is therefore based on the estimated average overall impact of applying BAU retrofit energy efficiency technologies. This allows for a bundled energy efficiency approach commensurate with industry practice.

3. Additionality

The methodology allows for the implementation of one or multiple retrofit efficiency measures, some of which may be BAU. This is captured through the autonomous technology improvement rate which effectively cancels out the impact of baseline efficiency measures and takes their hypothetical impact into account, even if the specific vessel does not implement them. The project shall demonstrate that, at a minimum, one measure taken is additional following the most recent version of the UNFCCC "Tool for the Demonstration and Assessment of Additionality".

Figure 4: Additionality Flowchart



4. Baseline Emissions

Baseline emissions are those that would have occurred after BAU retrofit energy efficiency measures have been implemented. Baseline emissions are calculated separately for individual project ship. If a project or programme involves a number of ships the baseline emissions must be calculated per ship.

Baseline emissions are determined in a dynamic manner and involve the following steps:

1. Determination of the ship-specific relationship between baseline fuel consumption and explanatory variables (as detailed below) based on historical data of the last docking cycle;
2. Application of the regression model using the coefficient values determined under the step 1 and thereby determining the hypothetical baseline emissions for the project docking cycle under the vessels actual, monitored, operating conditions. The fuel used to operate the ship under project scenario, but without efficiency improvements is calculated;
3. Apply the BAU technological improvement factor to baseline emissions i.e., baseline emission calculated under step 2 are multiplied with the factor 0.99 per docking cycle;
4. Application of the emission factor per fuel type to calculate GHG emissions.

The approach used under step 1, 2 and 4 are identical to the approved Gold Standard methodology "Reducing Vessel Emissions Through the Use of Advanced Hull Coatings (version 2.0)".

$$BE_y = \sum_i BFC_{i,y} \times COEF_{i,y} \times IF \quad (1)$$

where:

BE_y	Baseline emissions in year *y* (tCO_{2e})
$BFC_{i,y}$	Baseline fuel consumption of fuel type *i* in year *y* (t)
$COEF_{i,y}$	GHG emission coefficient of fuel type *i* in year *y* (tCO_{2e}/t fuel)
IF	BAU improvement factor of 0.99 per docking cycle

The GHG emission coefficient is determined by:

$$COEF_{i,y} = NCV_{i,y} \times EF_{CO2,i,y} + EF_{CH4,LNG,y} \quad (2)$$

where:

$COEF_{i,y}$	GHG emission coefficient of fuel type *i* in year *y* (tCO_{2e}/t fuel)
$NCV_{i,y}$	Net Calorific Value of fuel type *i* in year *y* (GJ/t)
$EF_{CO2,i,y}$	CO_2 emission factor of fuel type *i* in year *y* (tCO_2/GJ)
$EF_{CH4,LNG,y}$	CH_4 emission factor of *marine LNG* in year *y* (tCO_{2e}/t fuel)

The CH_4 emission factor is only included in case of using LNG.

The baseline fuel consumption is based on a statistical model called the "Basic Model" approved under the other GS approved methodology[31]. The relationship is:

$$FCy = a \times V^n \quad (3)$$

where:

FC_y	Fuel consumption in year *y* for a 24 hour period (t)
V	Average daily speed through water
a,n	Coefficients *a* and *n* determined through regression analysis of previous docking period

Regression coefficients *a* and *n* are only valid over the range of speeds in the data set upon which the regression is based. Therefore, this range of speed should be noted, together with the estimation of the coefficients. The regression model is valid for predicting fuel consumption only in this range of valid ship speeds.

The "Basic Model" or any other mathematical model which is used to determine the relationship between fuel consumption and other observed variables including but not limited to speed shall have a coefficient of determination (R^2-value) for the generated speed-fuel consumption curves above 0.8.

Only days which fulfil the statistical requirements of the Basic Model (filter conditions) are included. Any days that are excluded are excluded for both baseline and project emissions which is therefore conservative. The filter conditions of the Basic Model are described in Appendix A of the cited methodology[32]. Fuel consumption is excluded for baseline and project emissions for:

- Stormy days – Beaufort Scale > 6;
- For ships operating on long voyages, and recording "Noonday data", days with less than 23 hours of voyage on the day are excluded from the analysis.
- For ships operating on short voyages, and recording "Voyage data", this exclusion is not applicable.

---

[31] The Basic Model is included in that methodology under Appendix A and is not repeated here. Identical to the approved cited methodology the project proposal can also be based on another model to determine the relationship between fuel consumptions and other observed variables including but not limited to speed if this model can explain and determine better the relationship and reduce uncertainty. Any model which is not the "Basic Model" needs to be approved by the Gold Standard prior to application.

[32] Reducing Vessel Emissions Through the Use of Advanced Hull Coatings (version 2.0). Please refer to this methodology for further details on Basic Model, alternative options and additional requirements.

The filtering approach is commensurate with the new ISO Standard ISO/DIS 19030-3 for “Ship and marine technology – Measurement of changes in hull and propeller performance” Part 3 alternate methods.

The decision on whether to use the filters and procedures in Part 2 (default) or Part 3 (alternate) of ISO 19030 is informed by the specification of the data that is available:

- Part 2: data must be available that is acquired at high frequency (at least once every 15 seconds), and include a set of primary parameters (vessel speed through water, delivered power) as well as a number of secondary parameters (defined in Section 5.1 of ISO 19030-2)
- Part 3: data can be acquired at lower frequency (for example every 24 hours), and whilst vessel speed and delivered power are still required, the number of secondary parameters and their specifications are less onerous (defined in Section 5.1 of ISO 19030-3)

Therefore:

$$BFC_y = \sum_k BFC_k \qquad (4)$$

where:

BFC_y	Baseline fuel consumption in year *y* (t)
BFC_k	Baseline fuel consumption in day k for a 24 hour period (t)
k	Days which fulfil the criteria of the Basic Model and are not filtered out

Vessels and ship owners which manage and collect data according to the ISO/DIS 19030-2 default approach should use the default approach as determined in the ISO standard Part 2 to determine baseline fuel consumption.

5. Project Emissions

Project emissions are determined by emissions associated with actual fuel consumption for ship propulsion (specifically for navigation, i.e. excluding port and manoeuvres). In cases, where the project can demonstrate that navigation fuel is only used for navigation and manoeuvring activities, total fuel consumption can also be used. In both cases, the same "boundary" for fuel consumption data must be used both in the baseline and project scenario. Project emissions are determined using the same process as for baseline emissions:

$$PE_y = \sum_i PFC_{i,y} \times COEF_{i,y} \qquad (5)$$

where:

PE_y	Project emissions in year *y* (tCO_{2e})
$PFC_{i,y}$	Project fuel consumption of fuel type *i* in year *y* (t)
$COEF_{i,y}$	GHG emission coefficient of fuel type *i* in year *y* (tCO_{2e}/t fuel)

Project fuel consumption is excluded for the same days as for baseline fuel consumption. Therefore:

$$PFC_y = \sum_k PFC_k \qquad (6)$$

where:

PFC_y	Project fuel consumption in year *y* (t)
PFC_k	Project fuel consumption in day k for a 24 hour period (t)
k	Days which fulfil the criteria of the Basic Model and are not filtered out

Project emissions are calculated per ship. If the activity includes a number of ships, project emissions must be calculated per ship.

6. Leakage Emissions

The rebound or take-back effect is included as a leakage source. This refers to the phenomena that financial savings due to lower fuel consumption can be used to cruise at a higher speed thus offsetting the fuel savings.

The approach used to compensate for this rebound effect is based on the regression model which is only valid for a specific range of speeds. For ship speeds above the specified range of valid speeds, i.e. the ship has significantly increased speeds compared to the previous docking period, the model is not valid. The days when this occurs are excluded and no credits are gained. The same is applied for lower speeds, although in this case this is not a rebound effect but might be caused by economic circumstances and low travel demand.

The valid days are included in the baseline and project emission determination under the parameter *k*. All other days including those which could be attributed to a rebound effect, are already filtered out at the level of project and baseline emissions.

Upstream leakage effect of gaseous fuel usage is not included as this occurs in the baseline and project case. Due to fuel savings, leakage in the baseline case will be higher than in the project case thus its non-inclusion is conservative.

7. Emission Reductions

Emission reductions are the difference between baseline and project emissions per ship. As a control measure, emission reductions can be calculated on a daily basis thus ensuring the exclusion of the same days for baseline and project fuel consumption. Emission reductions are calculated per ship. If the activity includes a number of ships the total emission reductions are the sum of individual ship emission reductions.

8. Data and Parameters not monitored over the crediting period

Data / Parameter:	NCV_i
Data unit:	GJ/t
Description:	Net calorific value of fuel type i
Source of data:	IPCC default values at the lower limit of the uncertainty at a 95% confidence interval as provided in Table 1.2 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories
Measurement procedures (if any):	None
Monitoring frequency:	Any future revision of the IPCC Guidelines should be taken into account
QA/QC procedures:	None
Any comment:	The parameter is used for baseline and project emissions

Data / parameter:	$EF_{CO2,i,y}$
Data unit:	tCO_2/GJ
Description:	CO_2 emission factor of fuel type *i* in year *y*
Source of data:	IPCC default values at the lower limit of the uncertainty at a 95% confidence interval as provided in Table 1.4 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories
Measurement procedures (if any):	None

Monitoring frequency:	Any future revision of the IPCC Guidelines should be taken into account
QA/QC procedures:	None
Any comment:	The parameter is used for baseline and project emissions

Data / parameter:	$EF_{CH4,LNG}$
Data unit:	tCO_{2e}/t fuel
Description:	CH_4 emission factor of marine LNG expressed in CO_2 equivalents
Source of data:	IMO, Reduction of GHG Emissions from Ships, 3rd IMO GHG Study 2014 – Final Report, 07/2014, table 34 for emission factors in g/g fuel; For CO_{2e} based on GWP as published by IPCC and approved by CMP
Measurement procedures (if any):	None
Monitoring frequency:	Any future revision of the IPCC GWP of CH_4 should be taken into account; Any future revision of the CH_4 emissions from LNG from ships published by IMO should be taken into account
QA/QC procedures:	None
Any comment:	Calculation as per October 2015: IMO value for CH_4 emissions: 0.05120 gCH_4 per gfuel IPCC GWP CH_4: 25 Result: 1.28 gCO_{2e} per gfuel The parameter is used for baseline and project emissions; The parameter is only applied in case marine LNG is used a fuel for propulsion

3.0 MONITORING METHODOLOGY

Vessels and ship owners which manage and collect data according to the ISO/DIS 19030-2 default approach shall follow the data measurement procedures, data acquisition, storage, preparation and quality control as detailed in the aforementioned ISO standard, whilst other project developers shall follow either those parameters detailed below, or as detailed in the standard ISO.

Data / parameter:	Ship identification number
Data unit:	n/a
Description:	Unique ship identification numbers assigned by the International Maritime Organisation (IMO)
Source of data:	Ship operator, IMO, third party websites
Measurement procedures (if any):	n/a
Monitoring frequency:	n/a
QA/QC procedures:	None
Any comment:	Each IMO number is a unique reference for a ship, registered ship owners and management companies. IMO numbers were introduced under the International Convention for the Safety of Life at Sea (SOLAS) to improve maritime safety and security and to reduce maritime fraud. For ships, the IMO number remains linked to the hull for its lifetime, regardless of a change in name, flag, or owner.

Data / parameter:	V
Data unit:	Knots (nautical miles per hour)
Description:	Average daily speed over the ground
Source of data:	Ship operator
Measurement procedures (if any):	Calculated from daily distance operated and daily steaming time (DD/DT; see below) e.g. based on noonday reports
Monitoring frequency:	Daily
QA/QC procedures:	None as calculated

Any comment:	The parameter is used for baseline and project emissions and is measured for a full docking cycle (baseline period) prior project activity start (if available) and for docking cycles after retrofit (project crediting period). If full baseline docking cycle data is not available, enough data must be available for the regression to be valid. The criteria for a valid regression analysis are set out in the approved GS methodology "Reducing Vessel Emissions Through the Use of Advanced Hull Coating" Version 2.0 in Annex A.

Data / parameter:	**DD**
Data unit:	Nautical miles
Description:	Daily distance travelled
Source of data:	Ship operator
Measurement procedures (if any):	AIS /GPS
Monitoring frequency:	Daily
QA/QC procedures:	None
Any comment:	For ships that operate mostly on shorter distances, "Voyage data" are recorded in ship logs. The objective is the same as in the case of Noonday data, to determine the rate of fuel consumption and average speed. In this case DD is recorded per voyage and corresponds to the distance between departure and arrival ports. The parameter is used for baseline and project emissions and is measured for a full docking cycle (baseline period) prior project activity start (if available) and for docking cycles after retrofit (project crediting period). If full baseline docking cycle data is not available, enough data must be available for the regression to be valid.

Data / parameter:	**DT**
Data unit:	Hours
Description:	Daily hours of sailing
Source of data:	Ship operator
Measurement procedures (if any):	GPS
Monitoring frequency:	Daily
QA/QC procedures:	None

Any comment:	For ships that operate mostly on shorter distances, "Voyage data" are recorded in ship logs. The objective is the same as in the case of Noonday data, to determine the rate of fuel consumption and average speed. In this case DT is recorded per voyage and corresponds to the hours of navigation between departure and arrival port (if not available the total voyage time). The parameter is used for baseline and project emissions and is measured for a full docking cycle (baseline period) prior project activity start (if available) and for docking cycles after retrofit (project crediting period). If full baseline docking cycle data is not available, enough data must be available for the regression to be valid. The criteria for a valid regression analysis are set out in the approved GS methodology "Reducing Vessel Emissions Through the Use of Advanced Hull Coating" Version 2.0 in Annex A .

Data / parameter:	**Beaufort Scale**
Data unit:	Beaufort number
Description:	Sea state based on Beaufort scale
Source of data:	Ship operator
Measurement procedures (if any):	Observation
Monitoring frequency:	Daily
QA/QC procedures:	None
Any comment:	Used to determine k for days which are filtered out (Beaufort scale > 6 are days filtered out). For ships that operate mostly on shorter distances, "Voyage data" are recorded in ship logs. In this case the observations per voyage are included. Any voyage with 1 or more observations of a Beaufort scale > 6 is filtered out. The parameter is used for baseline and project emissions and is measured for a full docking cycle (baseline period) prior project activity start (if available) and for docking cycles after retrofit (project crediting period). If this information is not available, the days for which information is missing shall be excluded from the assessment in both baseline and project scenario.

Data / parameter:	BFC_i
Data unit:	Tons
Description:	Baseline fuel consumption of fuel type *i*
Source of data:	Ship operator
Measurement procedures (if any):	Fuel flow meter Only inclusion of main engine fuel consumption for propulsion
Monitoring frequency:	Daily
QA/QC procedures:	Calibration of fuel flow meter; periodic dip test on tanks (if tanks are also used for auxiliary engines then dip tests need to be compared with the total of fuel flow measurements)
Any comment:	For ships that operate mostly on shorter distances, "Voyage data" are recorded in ship logs. The objective is the same as in the case of Noonday data, to determine the rate of fuel consumption and average speed. In this case PFC corresponds to the fuel consumption for the voyage. The parameter is used for baseline and project emissions and is measured for a full docking cycle (baseline period) prior project activity start (if available) and for docking cycles after retrofit (project crediting period). If this information is not available, the days for which information is missing shall be excluded from the assessment in both baseline and project scenario.

Data / parameter:	PFC_i
Data unit:	Tons
Description:	Project fuel consumption of fuel type *i*
Source of data:	Ship operator
Measurement procedures (if any):	Fuel flow meter Only inclusion of main engine fuel consumption for propulsion
Monitoring frequency:	Daily
QA/QC procedures:	Calibration of fuel flow meter; periodic dip test on tanks (if tanks are also used for auxiliary engines then dip tests need to be compared with the total of fuel flow measurements)

Any comment:	For ships that operate mostly on shorter distances, "Voyage data" are recorded in ship logs. The objective is the same as in the case of Noonday data, to determine the rate of fuel consumption and average speed. In this case PFC corresponds to the fuel consumption for the voyage. The parameter is used for baseline and project emissions and is measured for a full docking cycle (baseline period) prior project activity start (if available) and for docking cycles after retrofit (project crediting period). If this information is not available, the days for which information is missing shall be excluded from the assessment in both baseline and project scenario.

References:

A. Bows-Larikin et.al., High Seas, High Stakes; Tyndall Centre for Climate Change Research, 2014

P. Deligiannis, Ship Performance Indicator (http://www.lowcarbonshipping.co.uk/files/ucl_admin/SCC/Ship-Performance-Indicator.pdf)

T. Dirksen, A statistical study of dry dockings, hull cleanings, and propeller polishes, DSNAME meeting, 14/05/2015

IMO, Reduction of GHG Emissions from Ships; 3rd IMO GHG Study 2014 – Final Report, 2014

ISO/DIS 19030-1/2/3, Ships and marine technology – Measurement of changes in hull and propeller performance (Part1: General principles; Part 2: Default method; Part 3: Alternative methods), 2016

M. Khorasanchi et.al., What to expect from hydrodynamic energy savings devices, Low Carbon Shipping Conference London, 2013

Marine Guidance Note MGN 462 (M+F), Pollution – Entry into Force of the Energy Efficiency Design Index

N. Rehmatulla, Assessing the implementation of technical energy efficiency measures in shipping; Survey Report, UCL, 2015

I. Rojon et.al., On the attitudes and opportunities of fuel consumption monitoring and measurement within the shipping industry and the identification and validation of energy efficiency and performance interventions, UCL, 2014

T. Smith, Technical energy efficiency, its interaction with optimal operating speeds and the implications for the management of shipping's carbon emissions; Carbon Management, 3:6. 589-600, 2012

T. Smith et.al., Low Carbon Shipping – A Systems Approach, Final Report, 2014

V. Stulgis et.al., Hidden Treasure: Financial Models for Retrofits, The Carbon War Room / UCL, 2014

H. Wang et.al., Long-Term Potential for Increased Shipping Efficiency Through the Adoption of Industry-Leading Practices, ICCT White Paper, 2013

Wartsila, Boosting Energy Efficiency, Energy Efficiency Catalogue /Ship Power R&D, 2009