Installation of Flow Improvement Equipment on Ships

Version 1.0

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Definitions

For the purpose of this methodology, the following definitions apply:

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

Bunker fuel is technically any type of fuel oil used aboard ships. It's name is derived from the containers that it is stored in; in the days of steam there were coal bunkers but now there are bunker fuel tanks. Since No. 6 fuel oil (**or heavy fuel oil**) is the most common, **'bunker fuel'** is often used as a synonym for No. 6.

Draught: Vertical distance from the waterline to that point of the hull which is deepest in the water.

Design draught: The draught the vessel is designed for. This is a theoretical figure considered the most efficient for the hull in terms of resistance and propulsion.

Ballast draught is draught of the vessel considering the weight of the hull, all equipment, machinery and boilers, but without cargo.

Energy saving device (ESD): A device that improves propulsion efficiency (e.g. by optimizing hydrodynamic flow conditions) of a vessel and thus reduces the energy (fuel) consumption for propulsion.

Heavy fuel oil: The fuel used in most ships. Heavy fuel oils are blended products based on the residues from various refinery distillation and cracking processes. They are viscous liquids and require heating prior to combustion. Heavy fuel oils are used in medium to large industrial plants, marine applications and power stations, etc. Two most common types are Number 5 and Number 6 fuel oils defined below1[1]. See also **Marine diesel**.

> **Number 5** fuel oil is a residual-type industrial heating oil requiring preheating to between 170 and 220 degrees Fahrenheit (about 75 to 105 ^{0}C) for proper atomization at the burners. This fuel is sometimes known as Bunker B.
>
> **Number 6** fuel oil is a high-viscosity residual oil requiring preheating to between 220 to 260 degrees Fahrenheit (about 105 to 125 ^{0}C). Residual means the material remaining after the more valuable cuts of crude oil have boiled off. This fuel may be known as residual fuel oil (RFO)

In recent years, low sulphur heavy fuel oils (LS HFO) have been introduced. Their lower sulphur content reduces sulphur oxide emissions from fuel combustion. The properties of LS HFO are slightly different from traditional heavy fuel oils.

International water-borne navigation (International bunkers) emissions: Emissions from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. Include emissions from journeys that depart in one country and arrive in a different country.[2]

Marine diesel: Fuel typically used by medium speed and medium/high speed marine diesel engines.

Ship categories: There are many types of cargo and passenger ships. Their characteristics determine the effect of the energy saving device. The specific saving in energy consumption is determined in the tank test for each ship series.

[1] Source: IPCC (2006), vol. 2, Chap. 3, Table 3.5.1, p. 3.48.
[2] Source: IPCC (2006), vol. 2, Chap. 3, Table 3.5.1, p. 3.48.

Ship series: Series of ships of the same type, all constructed according to the same general design.

Sister ship: Ships of the same series and of virtually identical design to each other. Sister ships share a near-identical hull and superstructure layout, similar displacement, and roughly comparable features and equipment.

Tank test: Model test conducted by a hydrodynamic research institute comprising of a self-propulsion test with and without the energy saving device at specified drafts and specified speeds. The tank test is used to measure the impact of the energy saving device on fuel consumption and thus CO_2 emissions. The tank test is conducted with a model ship.

SECTION I: SOURCE AND APPLICABILITY

This methodology is applicable to micro-scale programmes or activities that involve the installation of special energy saving devices (ESD) that improve water inflow into the propeller - achieving a higher overall propulsion efficiency. The propulsive efficiency improvement leads to a reduction in fossil fuel consumption and hence greenhouse (GHGs) emission reductions.

An example of an energy saving device (e.g. duct installed in front of propeller) is Becker Mewis Duct.

The following conditions apply:

- The present methodology is applicable to project activities on vessels, which reduce CO_2 emissions through an installation of propulsion efficiency improvement measures; i.e. a device that improves the flow conditions at the propeller to achieve a higher overall propulsion efficiency.
- Measures within a micro programme of activities are limited to those that result in emission reductions of less than or equal to 10,000 tCO_{2e} annually.
- The International Maritime Organization (IMO) adopted mandatory energy efficiency measures applicable to all new ships of 400 gross tonnage or above and built after 1 January 2013. The Energy Efficiency Design Index (EEDI) aims at promoting the use of more energy efficient (less polluting) equipment and engines. The EEDI requires a minimum energy efficiency level per capacity mile (e.g. tonne mile) for different ship types and size segments. Hence, for ships built after 1 January 2013, only the energy savings generated by the ESD in addition to the EEDI requirements are applicable for the generation of carbon credits by this methodology.
- Certain countries or groups of countries may impose fuel efficiency conditions for ships travelling to and from these countries. In those cases, emission reductions would not continue to be eligible for those routes. This is set from the date of application of the regulations. For more information see step 1b of the Section 'Identification of the baseline scenario and demonstration of additionality'.
- If biofuel blends are used, the % of fossil and biofuel components of each fuel purchase should be recorded. Emissions reductions would only apply to reduced fossil fuel consumption, with no credits for biofuel use through this methodology. However, this methodology could be used in combination with another methodology to include emissions reduction through biofuel use.
- If different fuel types are used, the share of each fuel type (of the total fuel consumption) needs to be recorded. The fuel type determines the CO_2 emission factor to be used for the calculation of the baseline and project emission.
- Data as needed for the application of the proposed methodology is to be confirmed by official documentation and provided as evidence in time for validation (e.g. results of tank test for the project vessel or the corresponding sister ship). Moreover, fuel supply dates and quantities need to be made available at the time of validation, in order to allow for cross checking the ship's log data on fuel consumption.
- Fuel consumption of the ship's main and auxiliary engines is measured directly so as to exclude other uses of the same fuel as well as other fuels. Note that cruise ships may use the same fuel for propulsion as for other uses. In these cases, the fuel consumption for ship propulsion must be carefully separated.
- Evidence needs to be provided, proving that the characteristics (shape, surface, positioning) of the ESD fitted to the ship is in line with the design parameters of the ESD used in the tank test. This evidence may consist of photographs or sign offs.
- Evidence needs to be provided concerning other energy saving installations that might have an influence on the performance of the applicable ESD.
- If the performance of the ESD depends on the propeller type, the characteristics of the propeller type have to be indicated when the propeller is considerably different from the model for which

the tank test was conducted (for applicability of same tank test to ships with different propellers see annex: tank test).

- In order to aggregate emission reductions and make the project activity viable, the methodology may be used to provide carbon credits to the manufacturer of the ESD and not to the individual ships or shipping companies or charter operators, who in fact would be reducing fuel consumption and thereby reducing emissions. However, the methodology is also applicable to ship owners and operators, considering that some companies may own sufficient number of vessels for them to apply for carbon credits directly, without requiring the manufacturer as an aggregation entity.
- When the ESD manufacturer is the aggregation entity, for the determination of carbon credits, shipping operator must make fuel consumption data available to the ESD manufacturer. To this end, an agreement is needed between the ESD manufacturer and the purchaser of the ESD that covers the following issues:
  - Benefits to the shipping company: The ESD manufacturer would share with the shipping company or charter operator a part of the carbon credits (e.g. through a discount on the purchase of the ESD). All must formally commit in this agreement to not claim credits from the same ships as part of activities under another scheme.
  - Obligations of the shipping company or charter operator: In order to determine emissions reduction, 'Noonday' data on fuel consumption, ship speed and other data are needed for the entire crediting period, following the application of the ESD. Thus, the shipping owner or charter operator is obliged to provide the needed data, as part of its formal agreement with the ESD manufacturer. 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. Provided the results confirm fuel savings, they would contribute to increase confidence in ESD, making them common practice.

  While the agreement between shipping company/operator and ESD manufacturer is confidential, it needs to be monitored and verified during the project approval process and prior to the issuance of carbon credits.

  In all cases, the contract between the ESD manufacturer and ship owner/operator would be made available to The Gold Standard Foundation by the time of registration of any project activity (at the very latest).

  To summarize: the owner of the carbon credits generated by projects using this methodology may be the ship owners, the ship operators or the ESD suppliers. Ownership of the project and the resulting carbon credits must be clearly defined via signed agreements between the relevant parties. These agreements may include provisions for the supply of data, discounts, or other benefits.

SECTION II: BASELINE METHODOLOGY

1. Project Boundary

The project boundary is the physical, geographical location of the ships on which the ESD is installed (Fig. 1). The vessels are clearly identified by their unique IMO-Number. The project boundary covers the sea passages (from the start to the end of sea passage) where each ship consumes fuel and where emissions occur. Thus, the project boundary includes the cruising part of a ships route, but excludes stays in ports, dry docks and manoeuvring activities.

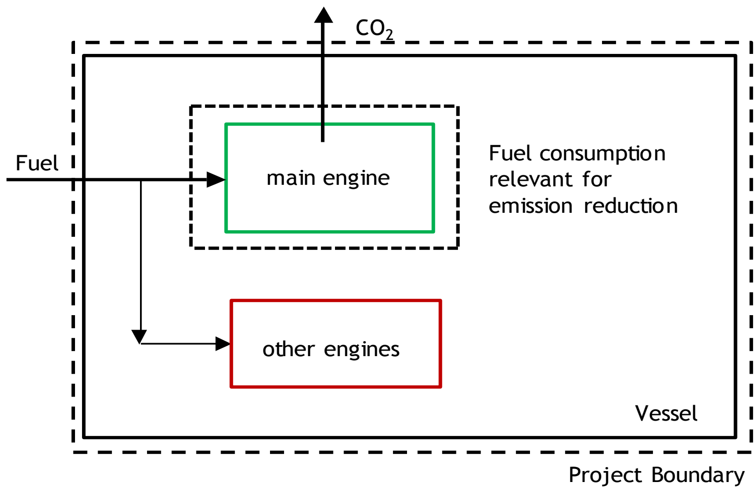

Fig. 1. Project boundary, indicating that only fuel input to and emissions from the main engine are relevant for the monitoring

Emissions sources included in the project boundary:

This methodology applies to an energy efficiency measure that would reduce the consumption of marine diesel or fuel oil consumption for ship propulsion. The combustion of these fuels also produces small amounts of two other greenhouse gases: methane (CH_4) and nitrous oxide (N_2O). When less fuel is burnt in the project scenario as compared to the baseline scenario but the combustion system is not modified by the project activity, there would be reductions in methane and nitrous oxide emissions as well as from reduced fuel use. However, for reasons of conservativeness these emission reductions are neglected.

Production and installation of the ESD on a ship involves energy consumption and causes greenhouse gas emissions. The amount of electricity consumed for these activities, undertaken only once for each ship, is insignificant compared to the energy used by the ship engines. Therefore, for simplicity, the energy consumption for production and installation of the ESD are excluded both from the baseline and the project scenarios.

Emissions sources and GHGs included and excluded are indicated in Table 1.

Table 1. GHGs included/excluded from project boundary

	Source	**Gas**	**Included?**	**Justification / Explanation**
Baseline	Fuel consumption by ship engines during international voyages	CO_2	Yes	Major emission source.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.
	Source	**Gas**	**Included?**	**Justification / Explanation**
Project	Fuel consumption by ship engines during international voyages	CO_2	Yes	Major emission source.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.

2. Identification of baseline scenario and demonstration of additionality

The latest version of the CDM Tool for the demonstration and assessment of additionality[3] is used as the basis for the identification of the baseline scenario and evaluation of additionality.

Step 1: Identification of alternatives to the project activity consistent with current laws and regulations

Define realistic and credible alternatives to the project activity(s) through the following Sub-steps:

Sub-step 1a: Define alternatives to the project activity:

The project activity comprises of installing an ESD on a ship that improves water flow. Possible baseline alternatives considered should at a minimum be:

1. The project activity itself, i.e. applying the specific ESD, without carbon credits;
2. Installing another comparable ESD
3. No installation of any ESD

Outcome of Step 1a: Identified realistic and credible alternative scenario(s) to the project activity

Sub-step 1b: Consistency with mandatory laws and regulations:

Review mandatory laws and regulations applicable to an ESD that might eliminate one of the alternative baseline scenarios. For instance, if a law prohibits the use of a certain ESD, then the corresponding alternative can be excluded from the list of possible baselines.

If there are laws and regulations that require the installation of an ESD, then the corresponding scenario can be excluded.

At the time of releasing this methodology there are no laws and regulations specifically requiring the use of an ESD for the improvement of the propulsion efficiency.

The International Maritime Organisation (IMO) has been and remains in charge of greenhouse-gas (GHG) emissions regulation in shipping following the UNFCCC meeting in Cancun in December 2010. The IMO has imposed mandatory limits on shipping emissions by introducing the Energy Efficiency Design Index (EEDI) for new ships built after 1 January 2013 and the Ship Energy Efficiency Management Plan (SEEMP) for all ships[4].

In order to eliminate double counting of emission reductions that are part of the EEDI requirements, only emission reductions generated by the ESD that exceed the EEDI requirements are eligible under this methodology and count towards carbon credits. In addition, the IMO introduced the Ship Energy Efficiency Management Plan (SEEMP), an operational measure that intends to improve the energy efficiency of all ships. As the SEEMP is solely a management tool and does not impose any mandatory requirements, it has no effect on the eligibility of emissions reductions under this methodology.

The Project Design Document (PDD) needs to analyze the regulations applicable at the time of submission of a project activity, including those regulations that have been established but are not yet in effect, to evaluate their impact on the baseline and additionality. For instance, following the application (i.e. date of going into effect) of any regulations from the EU, requires installation of ESD, any ships installing an ESD would only be able to obtain carbon credits on routes not affected by the regulations. Since the emission reductions are determined from actual ship fuel consumption on a daily basis, subject to certain data filters

[3] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v7.0.0.pdf/history_view

[4] Mandatory energy efficiency measures for international shipping adopted at IMO environmental meeting. Marine Environment Protection Committee (MEPC) – 62nd session: 11 to 15 July 2011 http://www.imo.org/ourwork/environment/pollutionprevention/airpollution/pages/technical-and-operational-measures.aspx#3

to eliminate "invalid" data, it would be a fairly straightforward procedure to eliminate all the days corresponding to voyages affected by regulations. For instance, if the European Union limited emissions from certain categories of ships travelling to and from EU member states, to be effective from a certain date. Since the ESD can help meet this regulation, in order to be conservative fuel savings and emissions reductions for those voyages would not count towards carbon credits. This would take effect from the date that the regulations go into effect. The emission reductions that exceed regulatory requirements would still be eligible under this methodology. Thus if regulations require, e.g. a 5 % reduction in emissions for certain routes, then any emissions reduction over this value, would count towards carbon credits.

This process eliminates double counting of emissions reductions that are also part of a compliance regime.

If applicable laws and regulations eliminate no alternative baselines, then all alternatives remain valid and need to be considered in the following steps.

Outcome of Step 1b: Identified realistic and credible alternative scenario(s) to the project activity that are in compliance with mandatory legislation and regulations - taking into account the enforcement in the region or country and Executive Board decisions on national and/or sectoral policies and regulations.

Step 2: Investment analysis

Please follow the details as outlined in the CDM Additionality Tool

AND/OR Step 3: Barrier analysis

Please follow the details as outlined in the CDM Additionality Tool

Step 4: Common practice analysis

Step 4.1: Identify the total number of ships in category "i" that have already installed the specific ESD and have started commercial operation before the start date of the project. Note their number $N_{ESD,i}$. Project activities registered under Gold Standard shall not be included in this step. However, projects registered under other voluntary markets should be included since the applicability conditions may be very different..

Step 4.2: Identify those ships that apply no ESD or an ESD based on technologies different than the technology applied in the proposed project activity. Note their number N_{diff}.

N_{diff} is considered to be all ships that have no ESD or an ESD based on a different technology. This can be illustrated by an example involving one category of ships: cruise ships. Suppose there are 2000 cruise ships in all (N_{all}) of which 40 already have the project activity ESD $(N_{ESD,i})$ and another 70 have an ESD based on a different technology. Then considering the project activity with the specific ESD, N_{diff} would be 2000 - 40 = 1960.

Step 4.3: Calculate factor $F = 1 - N_{diff}/N_{all}$ representing the share of ships (of the same category) using a technology similar to the technology used in the proposed project activity. The proposed project activity is a "common practice" if the factor F is greater than 0.2 and $N_{all} - N_{diff}$ is greater than 3.

Considering the previous example, the proposed project activity achieves a factor F = 1 – 1960/2000 = 0.02. Thus, the project activity would not be considered common practice. However, once a value of F has been reached for any ship, as explained above, no further ships from that category would qualify for carbon credits under this methodology.

As noted earlier, some or all ships, or ships on certain voyages, may be disqualified from carbon credits as a result of regulatory changes. Moreover, a quantitative common practice analysis also limits the number of ships in each category that may qualify for carbon credits in the future.

3. Project emissions

Project emissions are determined by emissions associated with the actual fuel consumption in ship propulsion following the application of the ESD (project activity). Any other uses of fuel, e.g. electricity generation, should be separated prior to the determination of project emissions. In cases where a PP can demonstrate, by providing convincing and documented argumentation, that navigation fuel is only used for navigation and maneuvering activities, the total fuel consumption can also be used to estimate the project emissions. In both cases, the same "boundary" for fuel consumption data should be used in both baseline and project scenario. Project emissions are determined directly and are therefore discussed first. Baseline emissions correspond to the baseline scenario, which is calculated retrospectively based on the actual project emissions. Please refer to the baseline emissions for details.

The total actual annual carbon dioxide emissions due to the propulsion of the ship following the application of the ESD is calculated as follows:

$$PE_{j,y} = \sum_{i} FC_{p,i,j,y} * NCV_{i,y} * EF_{i,CO2}$$

……………………………………….(eq-1)

Where

$PE_{j,y}$ = CO_2 emissions from fossil fuel consumption in ship type j during the year y (tCO_2/y)

$FC_{p,i,j,y}$ = Quantity of fuel type i combusted in ship type j during the year y (Mass or volume unit/y)

$NCV_{i,y}$ = Weighted average Net Calorific value of fuel type I in the year y (GJ/tonne)

$EF_{i,CO2}$ = Weighted average CO_2 emissions factor of fuel type I during the year y (tCO_2/GJ)

i = Fuel type combusted in the year y

j = Ship Type

The daily data for the fuel consumption on a sea passage is recorded in the log abstracts. With respect to these data the annual fuel consumption for the propulsion will be calculated each year. The calculated actual annual fuel consumption needs to be accompanied by error bars, to show the uncertainties of measuring the fuel consumption.

Several data filters shall be applied in order to examine the performance of the vessel under normal operating parameters, which are the basis for the energy savings by the ESD determined through the tank test.

Stormy days: on stormy days, the ship faces unusual forces from wind and wave, and the relationship with ship speed (which basically determines the effect of the ESD) may not hold. To eliminate this uncertainty, days where the Beaufort Scale (wind force) was above 6, are to be excluded.

Speed validity range: It is possible that ship operators limit the benefits of the savings obtained through the ESD, by operating the ship at a higher speed after the project implementation. As ships consume more fuel per mile at high speed and the increase in fuel consumption is not linear. Higher speeds would therefore induce additional fuel consumption. To compensate for this “rebound” effect, the following approach shall be followed:

> For some days the measured average ship speed (in the project scenario) may be above the range of ship speeds for which the tank test was conducted and fuel saving was determined. These days should be excluded from the determination of the overall fuel savings. On other days, the average speed on a given day may be below the valid range of speeds. This is not a case of rebound effect, since lowering the speed would reduce fuel consumption. However the fuel saving determined in the tank test is not valid for speeds below the validity range of the tests. These days should also be excluded from the determination of the overall fuel savings.

Once the relevant fuel consumptions have been calculated for each day, the parameter $FC_{i,y}$ is determined by summing the fuel consumption over the operational days in the entire year.

The emission factor $EF_{i,CO2}$ and net calorific value $NCV_{i,y}$ is applied as per fuel type used. Please refer to chapter 5.7 Data and Parameters not monitored during the crediting period, for appropriate emission factors.

4. Baseline Emissions

Baseline emissions correspond to baseline fuel consumption, which is the fuel that the ship would have consumed, if the ESD had not been installed.

Baseline missions are estimated retrospectively based on measured fuel consumption and the determined impact of the ESD. This approach is chosen, because due to the variable engine load for propulsion, an exact prediction of the fuel consumption for propulsion is not possible (inter alia it depends on the chosen routes and weather conditions). Thus the baseline emissions are estimated as follows

$$BE_{j,y} = \frac{\sum_i (FC_{p,i,j,y} * NCV_{i,y} * EF_{i,CO2})}{(1 - S_{rel})}$$

……………………………………….(eq-2)

where the days excluded for the determination of project emissions are also excluded from the determination of baseline emissions.

Where

$BE_{j,y}$ = CO_2 emissions from fossil fuel consumption in ship type j during the year y (tCO_2/y)

$FC_{p,i,j,y}$ = Quantity of fuel type i combusted in ship type j during the year y (Mass or volume unit/y)

$NCV_{i,y}$ = Weighted average Net Calorific value of fuel type i in the year y (GJ/tonne)

$EF_{i,CO2}$ = Weighted average CO_2 emissions factor of fuel type i during the year y (tCO_2/GJ)

S_{rel} = Relative saving for power consumption for propulsion

i = Fuel type combusted in the year y

j = Ship type

The relative saving describes the decrease of generated power for the propulsion to operate the vessel at specified speed. It is expressed by the following formula:

$S_{rel} = 1 - (P_p/P_b)$ ……………………………………….(eq-3)

Where

S_{rel} = Relative saving for power consumption for propulsion

P_p = Power output for the propulsion with ESD in the project scenario

P_b = Power output for the propulsion without ESD in the baseline scenario

The fuel consumption rate is the specific fuel consumption of the engine multiplied by the engine power. Typical main engine performance curves show, that under the applicable speed ranges (speed range valid for the tank test) it can be assumed that the relative savings in power requirements for propulsion are equivalent to the relative savings in fuel consumption. Therefore;

$S_{rel} = 1 - (P_p/P_b)$

$= 1 - ((FC_{p,i,j,y} / (FC_{b,i,j,y})$ ……………………………………….(eq-4)

Where

$FC_{p,i,j,y}$ = Quantity of fuel type i combusted in ship type j during the project scenario year y

$FC_{p,i,j,y}$ = Quantity of fuel type i combusted in ship type j during the baseline scenario year y

With the implementation of the ESD the vessel would require less power to operate at the same speed. The decrease of the power requirement depends on the draught. To ensure a conservative approach the relative saving in power consumption, which is used in the following calculations, is the minimum savings of the relative savings at design draught and the relative savings at ballast draught. Therefore one has:

$S_{rel} = \min\left(S_{rel,DD}, S_{rel,BD}\right)$ ……………………………………….(eq-5)

Where

S_{rel} = Relative saving for power consumption for propulsion

$S_{rel,DD}$ = Relative saving for power consumption for propulsion at design draught

$S_{rel,BD}$ = Relative saving for power consumption for propulsion at ballast draught

5. Emissions reductions

The emission reduction *ERy* is determined as the difference between the retrospectively calculated baseline emissions and the actual project emissions. It is determined as follows;

$ER_y = BE_y - PE_y$ ……………………………………….(eq-6)

Where,

ER_y = Emission reductions in the year y (tCO_2,y)

BE_y = Sum of baseline emissions for all ship types in the year y (tCO_2,y)

PE_y = Sum of project emissions for all ship types in the year y (tCO_2,y)

6. Leakage

Since the project activity comprises of the installation of an ESD to improve flow conditions, no leakage emissions are expected. Note that the discussion of the rebound effect is considered in the section of Project Emissions, and therefore is not part of leakage.

7. Data and parameters not monitored during the crediting period

Data and parameters not monitored include the properties of fuels used for marine propulsion, allowing the determination of emissions from the combustion of these fuels.

Data / Parameter:	$EF_{i,CO2}$
Data unit:	tonnes CO_2 / GJ fuel
Description:	CO_2 emissions factor of fuel type i, please refer to table below for fuel types
Source of data used:	IPCC, 2006, Volume 2, Table 3.5.2
Value applied:	Refer to the table below
Justification of the choice of data or description of measurement methods and procedures actually applied :	
Any comment:	Standard fuel use IPCC data, alternatively IMO data may be used. See details below

One source of the parameters is IPCC (2006) where the parameters are the net calorific value (NCVi) of each fuel "i" expressed in TJ/Gg (terajoules per gigagramme or gigajoules per tonne) and the CO_2 emissions factor of the fuel "i", expressed in t/GJ. The values for the main marine fuels from this source are given below.

Table.2 Fuel type, NCV and CO_2 emission factor

Fuel Type	**NCV (TJ/Gg = GJ/tonne)**	**Emission Factor (tCO_2/GJ)**	**Emission Factor (tCO_2/ t Fuel)**
Residual fuel oil	40.4	0.0774	3.127
Marine diesel	43.0	0.0741	3.186
Low-sulphur heavy fuel oil	40.4	0.0774	3.127
Liquefied natural gas	48	0.0561	2.693

Source: IPCC, 2006, Volume 2, Table 1.2 & Table 3.5.2

Another source of data for parameters to determine emissions from the combustion of marine fuels is the International Maritime Organisation (IMO, 2009). In this case, the emissions factors are given directly in terms of tonnes of CO_2 per tonne of fuel, for five possible marine fuels (see last column in table below). Note, that the equations require the emission factors in terms of tonnes of CO_2 per GJ of fuel (energy content). The equations can be adjusted accordingly to adopt the IMO's emission factors.

Table.3 Fuel type and CO_2 emission factor

Type of fuel	**Reference**	**Carbon content**	**Emission Factor (tCO_2/ tFuel)**
1. Diesel /Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206
2. Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.151

3. Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.114
4. Liquid Petroleum Gas (LPG)	Propane Butane	0.819 0.827	3.000 3.030
5. Liquid Natural Gas (LNG)		0.75	2.750

Source: IMO, 2009b, p. 10.

A comparison of the last columns of the two tables above indicates that the emissions factors determined from the two data sources are similar but not identical.

1. Within each category of fuel, small differences in composition would imply that the emissions factors are not always the same. However, as vessels are trading internationally with the capability to pick up bunker fuels at any port in the world, a set of internationally recognized average values is the appropriate way to adopt.

2. For standard fuel the IPCC emission factors can be used. Alternatively, the IMO emission factors shall be used for any given ship. In any case, for consistency and in order to avoid bias, the same data source should be used for all ships in a given project activity to determine the baseline and project emissions. The data source and values should be clearly indicated in the data analysis presented.

Data / Parameter:	**Tank Test**
Data unit:	No Unit
Description:	Results of the tank test which is valid for the ship type j of the project activity
Source of data used:	Report of tank test exporter (the specific model test protocol is included in the tank test report)
Value applied:	
Justification of the choice of data or description of measurement methods and procedures actually applied :	The tank test determines the relative savings in power consumption due to the ESD, and is conducted for each series of ships individually.
Any comment:	For the specific ESD test results of the tank test as well as the sea trial may already be available for a certain type of vessel and propeller. For further details on the tank test see annex tank test.

Data / Parameter:	$S_{rel,DD}$
Data unit:	No Unit
Description:	Relative savings in power consumption at design draught
Source of data used:	Tank test
Value applied:	
Justification of the choice of data or description of measurement methods and procedures actually applied :	The relative savings in power consumption at design draught are determined by a tank test, which is conducted for each series of ships individually.
Any comment:	If the tank test is determined for a sister ship, then it must be shown that the project ship is from the same series as the ship for which the tank test was

	conducted (see details in annex: tank test). In order to choose a conservative relative saving factor, the tank test minus the measuring uncertainty shall be used for the calculation. For example, if the relative saving determined by the tank test is 7.1 % +/- 0.5%, the value 6.6% shall be used as the relative saving factor.

Data / Parameter:	$S_{rel,BD}$
Data unit:	No Unit
Description:	Relative savings in power consumption at ballast draught
Source of data used:	Tank test
Value applied:	
Justification of the choice of data or description of measurement methods and procedures actually applied :	The relative savings in power consumption at ballast draught are determined by a tank test, which is conducted for each series of ships individually.
Any comment:	If the tank test is determined for a sister ship, then it must be shown that the project ship is from the same series as the ship for which the tank test was conducted (see details in annex: tank test). In order to choose a conservative relative saving factor, the tank test minus the measuring uncertainty shall be used for the calculation. For example, if the relative saving determined by the tank test is 7.1 % +/- 0.5%, the value 6.6% shall be used as the relative saving.

SECTION III: MONITORING METHODOLOGY

All data collected as part of monitoring should be archived electronically and be kept for at least 2 years after the end of the crediting period. All the parameters should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

First each participating ship in the project and the used fuel are identified with the following data:

Data / Parameter:	j
Data unit:	None
Description:	Ship identification number for the jth ship in the project activity. Also name of ship.
Source of data to be used:	Ship owner or ESD manufacturer
Measurement procedures (if any):	None
Monitoring frequency:	Once, when the ESD is installed
QA/QC procedures to be applied:	None
Any comment:	This is a record of the ships where the ESD is applied

Data / Parameter:	Date of installation
Data unit:	Date
Description:	Date on which the ESD has been installed on ship j
Source of data to be used:	Ship owner or ESD installer
Measurement procedures (if any):	Recorded at the dry dock where the ESD is installed
Monitoring frequency:	Once, when the ESD is installed
QA/QC procedures to be applied:	None
Any comment:	Corresponds to beginning of project scenario

Data / Parameter:	Main engine fuel (i)
Data unit:	None
Description:	Main engine fuel in ship
Source of data to be used:	Ship operator
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures to be applied:	Fuel type should be confirmed with fuel purchase invoices
Any comment:	Corresponds to both baseline and project scenarios. Any changes from baseline to project scenario should be noted.

Data / Parameter:	Auxiliary engine fuel (j)
Data unit:	None
Description:	Auxiliary engine fuel in ship j
Source of data to be used:	Ship operator

Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures to be applied:	Fuel type should be confirmed with fuel purchase invoices
Any comment:	Corresponds to both baseline and project scenarios. Any changes from baseline to project scenario should be noted.

For each day of the project period, i.e. ship operation following the installation of the ESD, the following data variables should be recorded. These are referred to as 'Noonday data' in shipping.

Data / Parameter:	Date
Data unit:	-
Description:	Calendar date
Source of data to be used:	Ship operator, log abstract
Measurement procedures (if any):	None
Monitoring frequency:	Daily
QA/QC procedures to be applied:	None
Any comment:	

Data / Parameter:	Daily distance (nautical miles)
Data unit:	Nautical miles
Description:	Distance travelled in last day, since last daily record
Source of data to be used:	Ship operator supplemented by charter party agreements, (as applicable), log abstract
Measurement procedures (if any):	AIS / GPS: record of vessel position and course at time of daily measurements
Monitoring frequency:	Daily
QA/QC procedures to be applied:	None
Any comment:	Error bars shall be added to the data, in order to show the data measurement uncertainties.

Data / Parameter:	Daily steaming time (hours)
Data unit:	Hours
Description:	Hours of sailing since last daily record
Source of data to be used:	Ship operator, log abstract
Measurement procedures (if any):	None
Monitoring frequency:	Daily
QA/QC procedures to be applied:	None
Any comment:	Error bars shall be added to the data, in order to show the data measurement uncertainties.

Data / Parameter:	v
Data unit:	Knots

Description:	Average daily speed through water since last daily record
Source of data to be used:	Ship operator, log abstract
Measurement procedures (if any):	Calculated from previous two data variables.
Monitoring frequency:	Daily
QA/QC procedures to be applied:	None
Any comment:	Error bars shall be added to the data, in order to show the data measurement uncertainties.

Data / Parameter:	Sea state (Beaufort scale)
Data unit:	Beaufort number
Description:	Sea state, noted at the time of daily data recording
Source of data to be used:	Ship operator, log abstract
Measurement procedures (if any):	Observation
Monitoring frequency:	Daily
QA/QC procedures to be applied:	None
Any comment:	Error bars shall be added to the data, in order to show the data measurement uncertainties.

Data / Parameter:	Vessel condition
Data unit:	Ballast/Loaded, or displacement
Description:	Loading condition of ship at the time of data recording
Source of data to be used:	Ship operator, log abstract
Measurement procedures (if any):	As appropriate
Monitoring frequency:	Daily. However, value will not change significantly during any voyage
QA/QC procedures to be applied:	None
Any comment:	Error bars shall be added to the data, in order to show the data measurement uncertainties.

Data / Parameter:	$FC_{,I,d}$ (ME)
Data unit:	Metric tonnes
Description:	Fuel (i) consumption of the main engine (at sea) since last daily record
Source of data to be used:	Ship operator
Measurement procedures (if any):	The Chief Engineer or another designated person is responsible for the measurement (fuel flow meter) and recording of daily fuel consumption of the main engine. Main engine fuel consumption shall be monitored from start of sea passage to end of sea passage (parameter in the log abstract: ME: HFO at sea), in order to determine the exact amount of fuel consumed for propulsion during cruising.
Monitoring frequency:	Daily, from start of sea passage until end of sea passage (at sea)
QA/QC procedures to be applied:	Calibration of fuel flow meter, periodic dip test on tanks. The measured data shall be compared with the data of the neighbour tanks (service tank, settling tank, storage tank) in order to recognize immediately a malfunction.
Any comment:	When the same tank supplies for more than one engine, or other non-engine

	equipment, the dip test can only be compared with the sum of all flow meters. Error bars shall be added to the data, in order to show the data measurement uncertainties.

Data / Parameter:	$NCV_{,i}$
Data unit:	GJ / tonne fuel
Description:	Net calorific value (net specific energy) of main engine fuel
Source of data to be used:	Ship operator, lab analysis report
Measurement procedures (if any):	Lab analysis of bunkered fuel used for main engine (propulsion)
Monitoring frequency:	Analysis of fuel at each refuelling
QA/QC procedures to be applied:	Net calorific value of bunkered fuel shall be confirmed with report of the lab analysis
Any comment:	

Data / Parameter:	$FC_{i,day}$ (AE)
Data unit:	Metric tonnes
Description:	Fuel (i) consumption of the auxiliary engine(s) since last daily record
Source of data to be used:	Ship operator
Measurement procedures (if any):	The Chief Engineer or another designated person is responsible for the measurement (fuel flow meter) and recording of daily fuel consumption of the auxiliary engine(s)
Monitoring frequency:	Daily
QA/QC procedures to be applied:	Calibration of fuel flow meter, periodic dip test on tanks. The measured data shall be compared with the data of the neighbour tanks in order to recognize immediately a malfunction.
Any comment:	When the same tank supplies for more than one engine, or other non-engine equipment, the dip test can only be compared with the sum of all flow meters. Error bars shall be added to the data, in order to show the data measurement uncertainties.

Under prevailing conditions the main engine is only responsible for the propulsion of the ship. Under these circumstances the fuel consumption of the main engine is equivalent with the consumed fuel for the propulsion. If only overall fuel consumption is monitored, the fuel consumptions of the auxiliary engines are to be subtracted from the total fuel consumption, in order to isolate the fuel consumption of the main engine.

Using the daily data for the fuel consumption on sea passage in the log abstracts, the annual fuel consumption will retrospectively be calculated in regular intervals. The annual fuel consumption due to the propulsion of the ship shall be determined directly by fuel meter measurements at the main engine. The use of a monitoring system, e.g. the EEOI, is possible.

Regulations

There are no current regulations affecting the fuel efficiency of existing ships, so that the eligibility of car-bon credits as determined by this methodology is not affected. However, future regulations may be relevant. Thus, all future regulations relating to fuel efficiency or CO_2 emissions from shipping should be monitored on a continual basis and reported annually, as part of the Monitoring Report. Regulations that might affect carbon credits, to be included inter alia, are listed below:

EU ETS regulations on ships travelling to and from EU ports:
These could require that certain classes of ships travelling to and from ports in EU member countries must comply with regulations affecting their greenhouse gas emissions. If such regulations were put into place, certain voyages would not be eligible to claim carbon credits under this methodology, or be limited to regulatory surplus. Thus, for each voyage, ports of departure and arrival will need to be recorded. Thus days of sailing for the affected voyages would be excluded from the determination of project and base-line emissions, and emissions reductions limited to regulatory surplus.

Regulations from other entities:
Review the regulations in order to determine the impact, if any, of these regulations on carbon credits under this methodology.

New IMO standards on energy efficiency of new ships that may require or imply the use of ESD:
On July 15, 2011, the International Maritime Organization adopted mandatory energy efficiency measures to be applicable to all new ships of 400 gross tonnage and above. These regulations entered into force on 1 January 2013[5]. They impose mandatory limits on shipping emissions by introducing the Energy Efficiency Design Index (EEDI), for ships. In order to eliminate double counting of emission reductions that are part of the EEDI requirements, only emission reductions generated by the ESD that exceed the EEDI requirements are eligible under this methodology and count towards carbon credits. In addition, the IMO introduced the Ship Energy Efficiency Management Plan (SEEMP), an operational measure which intends to improve the energy efficiency of all ships. As the SEEMP is solely a management tool and does not impose any mandatory requirements, it has no effect on the eligibility of emissions reductions under this methodology. If these regulations change or new regulations are introduced, eligibility for carbon credits through the installation of ESD may further be affected. Therefore future IMO regulations should be monitored.

[5] Mandatory energy efficiency measures for international shipping adopted at IMO environmental meeting. Marine Environment Protection Committee (MEPC) – 62nd session: 11 to 15 July 2011
http://www.imo.org/ourwork/environment/pollutionprevention/airpollution/pages/technical-and-operational-measures.aspx#3

Section IV: Reference

IMO, MEPC.1/Circ 684 (2009): Guideline for Voluntary Use of the Ship Energy Efficiency Operational Indicator (EEOI), International Maritime Organization.

http://www.mardep.gov.hk/en/msnote/pdf/msin0924anx2.pdf (02 July 2013).

IMO (2011): Mandatory energy efficiency measures for international shipping adopted at IMO environment meeting Marine Environment Protection Committee (MEPC) – 62nd session: 11 to 15 July http://www.imo.org/ourwork/environment/pollutionprevention/airpollution/pages/technical-and-operational-measures.aspx#3 (27 May 2013).

IPCC (2006): IPCC Guidelines for National Greenhouse Gas Inventories. vol. 2 (Energy) Chapter 3 (Mobile combustion). http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Annex 1: Tank Test

The tank test is a model test conducted by a hydrodynamic research institute comprising a self-propulsion test with and without the ESD at specified drafts and specified speeds. The tank test is used to measure the impact of the ESD on fuel consumption and thus CO2 emissions. The tank test is conducted with a model ship.

The test shall be performed by an accepted independent hydrodynamic research institute, experienced in the field of energy saving devices, and is a member of the International Tower Tank Conference (ITTC). The ITTC Quality Systems Manual can be downloaded from the ITTC homepage (http://ittc.info/download/qualitysystemsmanual)

The size of the tank is important for the scale of the ship and propeller model. The model propeller shall have a diameter of at least 220 mm to be applicable. The model test shall comprise of a self-propulsion test with and without the ESD at specified drafts and specified speeds, including error bars. If sea trials with the ESD of a sister ship exist, these results shall be used to correlate the tank test conditions in order to increase the accuracy of the tank test. The tank test report of the institute is respectively attached to each project activity (VPA). If more than one type of ships is bundled in a single VPA, then the tank test reports of each type of ship have to be attached to the VPA. They are to be treated as confidential.

Ships of the same series, in this case that means explicitly that they have the same design and the same main engine (sister ships), are permitted to refer to the same model test. Hence, one single model test for one particular ship is valid for all other ships of the same series (sister ships). However, the performance of the ESD may depend on the form of the propeller. In this case, as a sister ship has a different propeller (concerning diameter, revolutions per minute, thrust load), the influence of the ESD must be determined by further tests, e.g. by CFD (Computational Fluid Dynamics) calculations. The test will be compared with the original tank test, and only if the influence of the new propeller is considerable high, a new tank test for the corresponding ship shall be conducted. The threshold for retesting shall be determined by the CFD expert. In general, retesting is considered necessary, where the diameter of the propeller is different by more than 500mm or where the pitch changes by more than 3%. For each new project (series of sister ships), a new tank test is conducted, in order to determine the most appropriate characteristics of the ESD.

If the tank test has been determined for a sister ship, then it must be shown that the project ship is from the same series as the ship for which the tank test was conducted. In addition, evidence needs to be provided, proving that the characteristics (shape, surface, positioning) of the ESD fitted to the ship is in line with the design parameters of the ESD used in the tank test. This evidence may consist of photographs or sign offs. The classification society shall check the main dimensions of both ESD´s (model & full scale) according to a drawing that which is provided by the maker.