EUROPEAN
COMMISSION

Brussels, 5.7.2021
SWD(2021) 189 final

COMMISSION STAFF WORKING DOCUMENT

Union submission to the 77th session of the International Maritime Organization's Marine Environment Protection Committee proposing to introduce life cycle guidelines to estimate well-to-wake greenhouse gas (GHG) emissions of sustainable alternative fuels to incentivise their uptake at global level

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PURPOSE

This Staff Working Document contains a draft Union submission to the International Maritime Organization's (IMO) 77th session of the Marine Environment Protection Committee (MEPC 77). The IMO has indicatively scheduled MEPC 77 from 8 to 12 November 2021.

The draft submission suggests to introduce life cycle guidelines to estimate well-to-wake greenhouse gas (GHG) emissions. These guidelines are proposed to be based on sustainability and GHG emissions saving criteria to incentivise the uptake of sustainable alternative fuels at global level.

The draft Union submission can serve as a basis for discussing the methodology. Its Annex I provides additional details and a model to establish a life cycle approach to evaluate the GHG emissions from shipping.

EU COMPETENCE

Regulation (EU) 2015/757[1] establishes the legal framework for an EU system to monitor, report and verify (MRV) CO_2 emissions and energy efficiency from shipping. The regulation aims to deliver robust and verifiable CO_2 emissions data, inform policy makers and stimulate the market uptake of energy efficient technologies and behaviours. It does so by addressing market barriers such as the lack of information. It entered into force on 1 July 2015 and started to be implemented in 2018.

The MRV regulation is currently based on a "tank-to-propeller" approach. Under Annex I of the MRV Regulation, the calculation of CO_2 emissions is directly based on actual fuel consumption, the latter being multiplied by an emission factor only reflecting combustion of the fuel concerned. Annex 1 of the MRV Regulation lists such emission factor for seven fossil fuels. It provides that "appropriate emission factors shall be applied for biofuels, alternative non-fossil fuels and other fuels for which no default values are specified".

Developing a methodology for the calculation of "well-to-tank" emissions in line with the draft Union submission would therefore remain fully within the scope of the rules contained in the MRV Regulation. It would modify the emission factors listed in Annex I, section A, to the MRV Regulation. The draft submission suggests life cycle guidelines to estimate well-to-wake greenhouse gas emissions, aiming to develop adjustment values for sustainable alternative fuels. The calculation of well-to-tank emissions would therefore directly affect the MRV Regulation.

Related delegated Commission regulations on verification and accreditation of verifiers and on the refinement of monitoring methods were adopted on 22 September 2016[2]. Two additional implementing regulations on cargo parameters and templates were adopted by the Commission on 4 November 2016[3]. The EU MRV Regulation provides for emission factors for fuels on board.

[1] OJ L 123, 19.5.2015, p. 55–76
[2] OJ L 320, 26.11.2016, p. 1–4 and OJ L 320, 26.11.2016, p. 5–24
[3] OJ L 299, 5.11.2016, p. 1–21 and OJ L 299, 5.11.2016, p. 22–25

In addition, the original Renewable Energy Directive (2009/28/EC)[4] establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020—a figure to be achieved through the attainment of individual national targets. All EU Member States must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.

The abovementioned Directive was revised by Directive (EU) 2018/2001[5], which entered into force in December 2018 as part of the Clean energy for all Europeans package. It aims to keep the EU as a global leader in renewables and, more broadly, to help the EU to meet its emissions reduction commitments under the Paris Agreement. The new Directive establishes a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023.

In addition, Directive 2014/94/EU[6] of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure requires Member States to ensure that LNG is available at EU core ports for seagoing ships as from the end of 2025. EU Member States have finalised national policy frameworks for the market development of alternative fuels and their infrastructure. These put a particular focus on the different supporting measures and initiatives for the promotion and development of LNG refuelling points for sea-going ships as well as on-shore power supply.

In light of all of the above, the present draft Union submission falls under EU exclusive competence.[7] This Staff Working Document is presented to establish an EU position on the matter and to transmit the document to the IMO prior to the required deadline of 6 August 2021.[8]

[4] OJ L 140, 5.6.2009, p. 16–62

[5] OJ L 328, 21.12.2018, p. 82–209

[6] OJ L 307, 28.10.2014, p. 1–20

[7] An EU position under Article 218(9) TFEU is to be established in due time should the IMO Maritime Safety Committee eventually be called upon to adopt an act having legal effects as regards the subject matter of the said draft Union submission. The concept of '*acts having legal effects*' includes acts that have legal effects by virtue of the rules of international law governing the body in question. It also includes instruments that do not have a binding effect under international law, but that are '*capable of decisively influencing the content of the legislation adopted by the EU legislature*' (Case C-399/12 Germany v Council (OIV), ECLI:EU:C:2014:2258, paragraphs 61-64).

[8] The submission of proposals or information papers to the IMO, on issues falling under external exclusive EU competence, are acts of external representation. Such submissions are to be made by an EU actor who can represent the Union externally under the Treaty, which for non-CFSP (Common Foreign and Security Policy) issues is the Commission or the EU Delegation in accordance with Article 17(1) TEU and Article 221 TFEU. IMO internal rules make such an arrangement absolutely possible as regards existing agenda and work programme items. This way of proceeding is in line with the General Arrangements for EU statements in multilateral organisations endorsed by COREPER on 24 October 2011.

MARINE ENVIRONMENTAL PROTECTION COMMITTEE
77th session
Agenda item 7

MEPC 77/7/XX
2 August 2021
Original: ENGLISH
Pre-session public release: ☒

CONCRETE PROPOSALS TO ENCOURAGE THE UPTAKE OF ALTERNATIVE LOW-CARBON AND ZERO-CARBON FUELS, INCLUDING THE DEVELOPMENT OF LIFE CYCLE GHG/CARBON INTENSITY GUIDELINES FOR ALL RELEVANT TYPES OF FUELS AND INCENTIVE SCHEMES, AS APPROPRIATE

Introducing life cycle guidelines to estimate well-to-wake greenhouse gas (GHG) emissions of sustainable alternative fuels to incentivise their uptake at global level

Submitted by the European Commission on behalf of the European Union

SUMMARY

Executive summary:	This document suggests the introduction of life cycle guidelines to estimate well-to-wake greenhouse gas (GHG) emissions. These suggested life cycle guidelines would be based on sustainability and GHG emissions saving criteria to incentivise the uptake of sustainable alternative fuels at global level.
Strategic direction, if applicable:	3
Output:	3.2
Action to be taken:	Paragraph 55
Related documents:	MEPC 74/7/6, MEPC 74/18; MEPC 75/7/2; ISWG-GHG 1/INF.2; ISWG-GHG 3/2; ISWG-GHG 5/4, ISWG-GHG 5/5; ISWG-GHG 6/5, ISWG-GHG 6/5/1, ISWG-GHG 6/5/2 and ISWG-GHG 7/5/9.

Introduction

1 The Initial IMO Strategy on reduction of GHG emissions from ships compels the maritime sector to peak GHG emissions and phase them out as soon as possible in this century. Furthermore, the Initial IMO Strategy sets an ambition to decline the carbon intensity of international shipping by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008. Total GHG emissions should peak a soon as possible, be reduced by at least 50% by 2050 compared to 2008 and phased out as soon as possible in this century. To meet these mid- and long-term targets, the IMO urgently needs to develop policies to incentivise the uptake of sustainable alternative low-carbon and zero-carbon fuels and thus the transition to net zero-GHG-emission ships. Net zero CO_{2eq} GHG emissions are the goal. Therefore, a methodology needs to be established on a well to wake basis. Shipping has to reach full decarbonisation as soon as possible to support the temperature

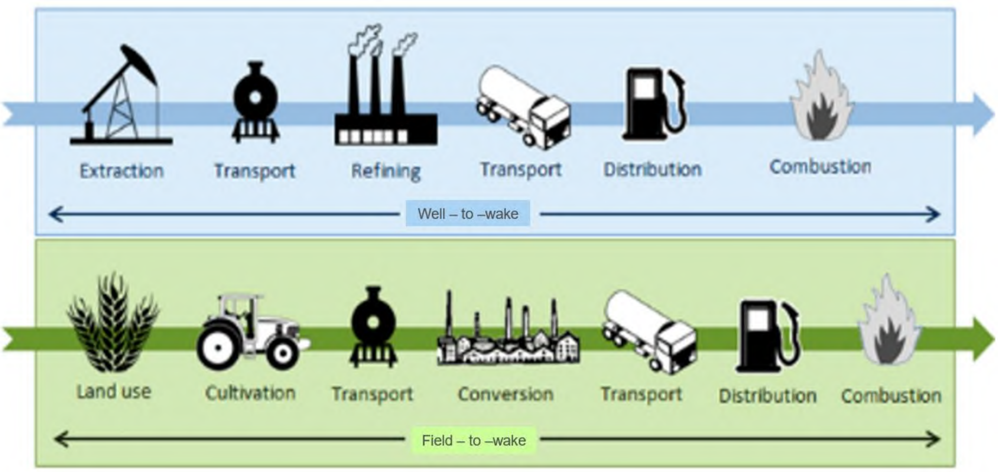
objectives set by the Paris Agreement. To do so, a robust and comprehensive methodology to account for the sector's emissions on full life-cycle basis must be introduced.

2 The terms of reference for ISWG-GHG 7, as approved by MEPC 74 (MEPC 74/18, paragraph 7.48), were inter alia, as follows: further consider concrete proposals to encourage the uptake of alternative low-carbon and zero-carbon fuels, including the development of lifecycle GHG/carbon intensity guidelines for all relevant types of fuels and incentive schemes, as appropriate. In MEPC 75/7/2, the ISWG-GHG remarked the importance of upstream emissions (Well-to-Tank) and invited for submissions on the matter. In ISWG-GHG 7/5/9, the European Union introduced a preliminary approach to the Guidelines providing certain definitions and principles for the assessment of the well-to-tank emissions.

Discussion

3 First, it is relevant to explain the role of the IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC Guidelines are specifically designed for countries to prepare and report inventories of greenhouse gases; furthermore, in the IPCC methodology waterborne emissions fits under IPCC Mobile Combustion Code 1.A.3.d.i International waters waterborne navigation, allocated to the specific transport activities. This methodology ensures that several principles (such as completeness, consistency and transparency) are fulfilled. However using a production based approach, whose relevance for the purpose of evaluating and – in consequence – reducing GHG impact from a specific economic activity such as shipping is debatable.

4 A Life Cycle Assessment (LCA), for its part, offers a holistic examination for the product/service/system from cradle to grave based on data in relation to the specific activity, while retaining all relevant features and principles of the IPCC methodology. LCA/WTW approach to GHG emissions is irrespective of the geographical region where the emissions are released and estimates the actual reduction of GHG emissions on a global scale. LCA is relevant for the purpose of the assessment of the GHG impact from shipping. The figure below depicts two possible pathways for fossil and bio fuels life cycle.



Fuel life cycle emissions

Fig.1 - *Source: International Civil Aviation Organization*

5 Life cycle GHG emissions following LCA methodology (Well-to-Tank (WtT)) approach aims to assess the total emissions of growing or extracting raw materials, producing, and transporting the fuel to the point of use. Tank-to-Wake (TtW), instead, represents the total emissions from combustion (including leakage) or from the use of other energy carriers for the propulsion of the ship. The combination of the two parts (WtT and TtW) allows estimating the total life cycle GHG emissions. The determination of the GHG emissions for the WtT and for the TtW requires applying the most appropriate path within the methodology for the estimations of the GHG emissions.

6 A LCA is well-established coded and straightforward procedure, which needs to be solidly anchored to an agreed definition of sustainable options (determining exclusion/eligibility). As an example, other transport sectors have already and since long opted for a LCA approach for the evaluation of the GHG impact of their activities. At European level, the RED/RED II[9] and the FQD[10] have defined (conservative) default values for a number of energy carriers as well as a calculation and reporting framework for LCA GHG emissions of energy carriers used in transport for determining the actual savings for demonstrating compliance with the minimum requirements in the RED/REDII and FQD for GHG emission reduction (for biofuels and Renewable Fuels of Non-Biological Origin (RFNBO's: e-fuels, including hydrogen) compared to their fossil equivalent on a LCA basis.

7 Data collection for and calculation of LCA GHG emission reduction is covered by existing certification schemes and/or GHG calculation tools ("voluntary schemes"; 3rd party verification) some of which are recognised also by the European Commission specifically for demonstrating compliance with the GHG emission requirements in the RED/REDII and FQD. Rewarding higher GHG-reduction than the default value via actual values might lead to more GHG-reduction in the supply chain. However, actual values are difficult to control in such an international market and therefore have a higher risk of mistakes and fraud. If actual values are considered it is fundamental to take extra steps with regards to private and public supervision and transparency in the supply chain (via for example a Database as mentioned in the RED II). At international level, ICAO in Resolutions A39-2.18.i and in Resolution A40-18.24.d requested States to consolidate ICAO policies and practices adopting measures and 'recognizing existing approaches to assess the sustainability of all fuels in general, including those for use in aviation which should achieve net GHG emissions reduction on a life cycle basis …'.

8 If only downstream emissions—emissions related to fuel combustion on board the ship—were considered instead of life cycle GHG emissions, the GHG emissions induced by the use of different fuels and manufacturing technologies would not be sufficiently assessed and compared,

9 The determination of WTT GHG emissions always results in a range (which explains the ranges in the diagram presented here), depending on e.g.:

- the specific circumstances (feedstock used, characteristics of the process);
- the allocation method used (consequential, attributional or mixed)

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[9] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

[10] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions

- the uncertainty in the data (e.g. in case the fuel is not yet commercially produced)

10 The importance of taking into account the upstream emissions is illustrated by the example in Figure 2, which shows the range of Well-to-Tank (WtT) GHG emissions for Hydrogen and for Synthetic Diesel. Hydrogen derived from natural gas hits nearly 500 gCO_{2eq}/MJ while if derived from certain biogas pathways its emissions are negative (-142 gCO_{2eq}/MJ). Synthetic Diesel if derived from Coal hits 130 gCO_{2eq}/MJ while if derived from wood feedstock is negative (-105 gCO_{2eq}/MJ). Data presented (para 8-9) are based on data and parameters used in the JEC Study (version 5 January 2021)[11].

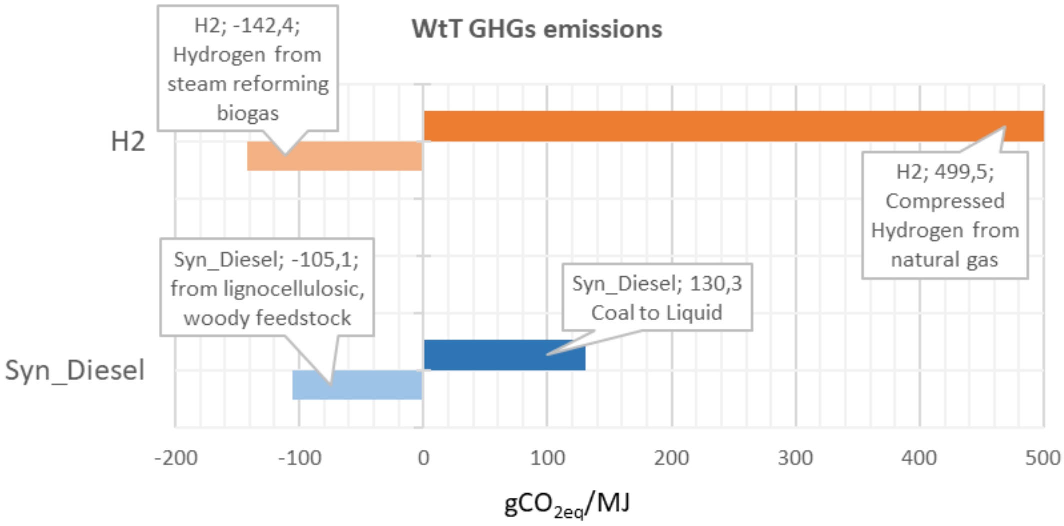

Fig.2 - Example - Well-to-Tank GHGs emissions for H2 and Syn_Diesel for certain pathways (derived from the JEC Study)

11 As another example Figures 3 and 4 below show some of the possible production pathways for Methanol as fuel and the range of its WtT emissions depending on the specific pathway (in Fig.4 blue rectangles represents WtT values and the black dots represent the value for full combustion). Although it might look a complex methodology, an LCA is well-established coded and straightforward procedure, which needs to be solidly anchored to an agreed definition of sustainable options (determining exclusion/eligibility).

[11] JEC Well-to-Tank Report v5 – EUR 30269 EN – Joint Research Centre of the European Commission

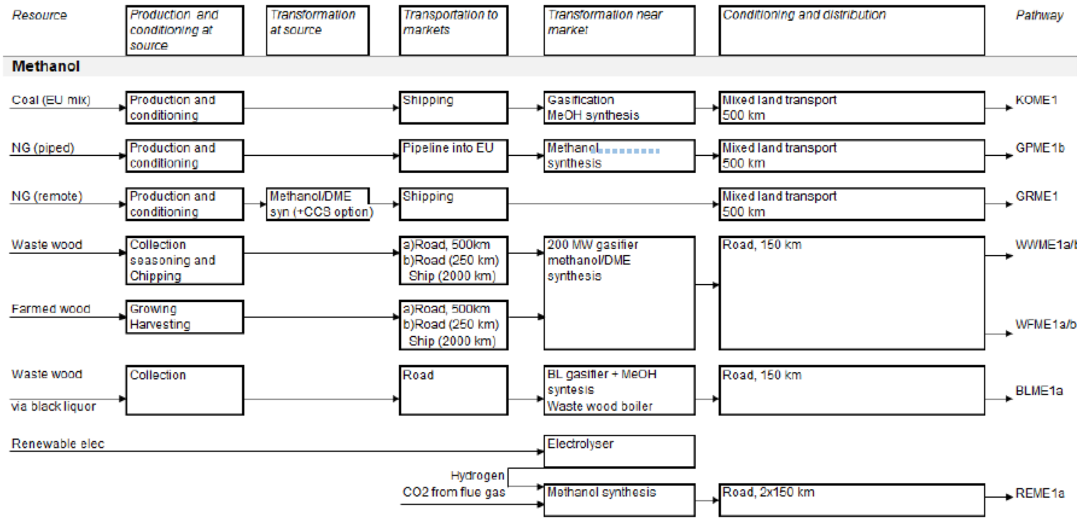

Fig. 3 - Example - Methanol WtT possible production pathways (pathways' codes on the right) - (derived from the JEC Study)

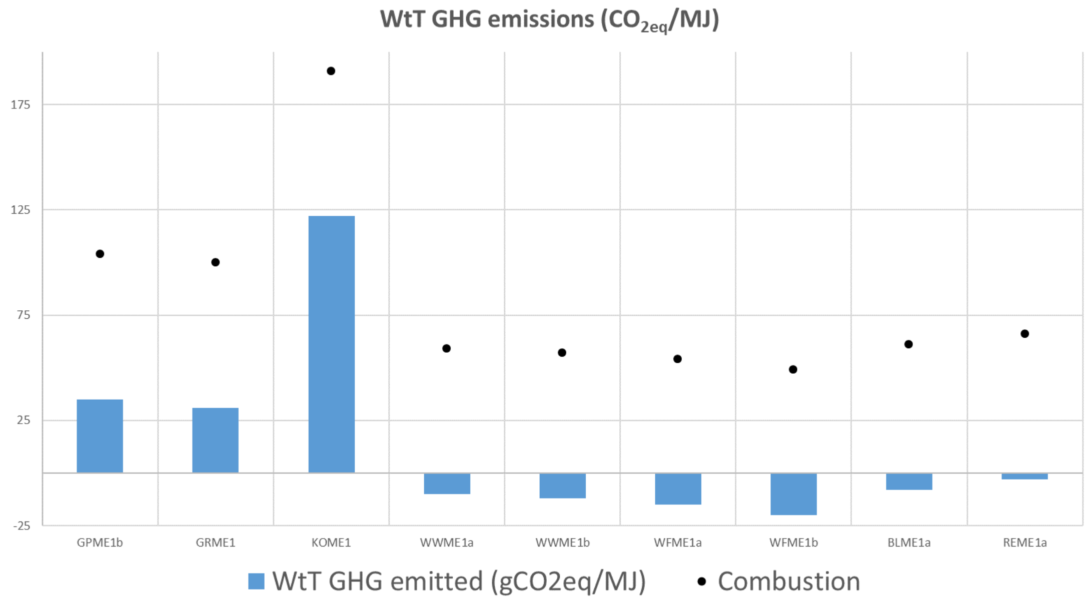

Fig. 4- Example - WtT GHGs emissions for the identified pathways for Methanol - (derived from the JEC Study)

12 From the discussion that took place at various occasions in the IMO, it appears clear as a WtW methodology is important to support the effective uptake of the most climate-friendly and sustainable alternative fuels, including from an environmental perspective, notably in the context of the adoption of mid- and long-term measures at IMO, for which this methodology can be used as a support tool. Whatever mid-term measure will be agreed by the Organization either a levy, GHG emissions cap or low-GHG fuel standards (or their combination), a LCA on a WtW basis and sustainability criteria is a relevant support tool (Fig. 5).

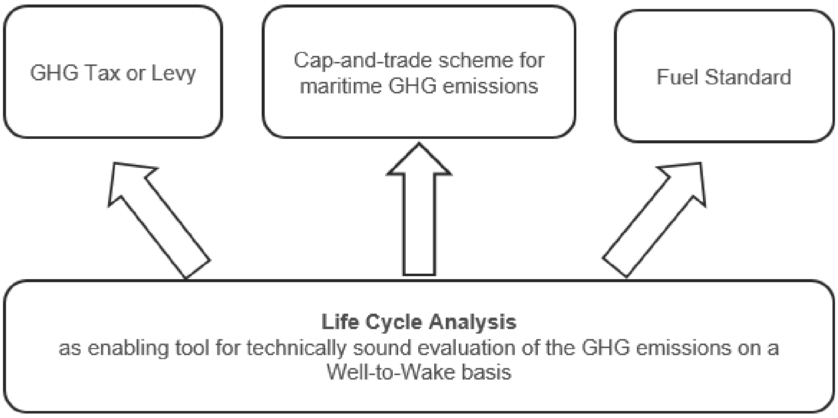

Fig. 5

13 Any future measure aiming at reducing GHG emissions from shipping will have to rely on agreed methodologies based on best technical knowledge and available data. As for several other IMO regulatory approaches on energy efficiency that were implemented in the past years (such as for the EEDI, DCS, etc, for which a solid base of data was required), also fuels life cycle GHG assessment will have to follow a similar process. A methodology should be agreed, assisting the Organization in its endeavour towards a measure to reduce GHG emissions in line with the IMO Initial Strategy, also stimulating the uptake of sustainable zero-emission fuels.

14 For the purpose of the WtW GHG emissions, gases with a greenhouse effect considered having relevant Global Warming Potential (GWP) are CO_2, CH_4 and N_2O. In line with existing provisions, defined in many other legislative acts for transport sector (i.e. REDII, FQD, ICAO/CORSIA, etc.), the GWP over 100 years is considered for the purpose of the maritime WtW[12]. The Black Carbon (BC), whilst certainly being an emission type with greenhouse effect, is not considered in this document due to the current scientific uncertainty related to its evaluation for both the WtT and TtW part[13]. However BC could be possibly considered in the future and the methodology in the Annex caters for this possibility. The so-called CO_{2eq} is therefore established as the sum of the 3 GHGs mentioned above each multiplied by the IPCCC GWP100 AR5 multipliers as per the table below. The GHG impact is then expressed in gCO_{2eq}/MJ for the purpose of easy comparisons with existing systems.

GHG	GWP 100 – IPCC AR5
CO_2	1
CH_4	28
N_2O	265

15 The total GHG emissions on LCA basis can hence be constructed by mean of the following conceptual model:

$$GHGe = WtT\ (energy\ carrier\ supply) + TtW(\ fuel\ use) \quad (1)$$

[12] GWP100 is also used in CORSIA, however GWP over 20 years should also be monitored. The GWP over 20 years might later be considered for the purpose of the maritime WtW.
[13] Black Carbon can be introduced in the methodology as the matter is deemed mature.

LCA GHG emissions	Well to Tank	Tank to Wake
$GHGe\ =$	$WtT\ (fuels\ and\ electricity) +$	$TtW(\ including\ fugitive\ emissions)$
CO_2 CH_4 N_2O	CO_2 CH_4 N_2O	CO_2 CH_4 N_2O
Total ship's GHG emissions that can be measured in [gCO_{2eq}/MJ]	WtT GHG energy carrier emissions: fuels, electricity that can be measured in [gCO_{2eq}/MJ]	TtW GHG emissions from fuel consumed and fugitive emissions that can be measured in [gCO_{2eq}/MJ]

The LCA GHG emissions are the sum of the WtT and the TtW emissions. WtT emissions, on top of the emissions from extraction, refining, processing, conversion, transport, conditioning and distribution, should to the extent possible also include the emissions from the production of the electricity delivered to the ship either as main fuel and/or for auxiliary services, while TtW should to the extent possible include fugitive emissions in addition to the emissions (see Section Tank-to-Well) from the main and auxiliary engines. The methodology is detailed in Annex I.

16 In the following, the WtT and TtW streams will be separately explained and analysed.

Well-to-Tank Emissions – What do we need?

17 Evaluation of fuels upstream emissions is a matter for which a vast literature exists and several methodologies and standards are already widely in use across sectors and geographical areas. LCA methodologies are in use in several sectors relying on a solid methodology (ISO 14040 series can be used as guideline, as well as ILCD handbook[14]) for sound GHG emissions evaluation. Based on this knowledge, the Organization should select the most appropriate methodologies and standards for the evaluation of the upstream emissions of the maritime sector, as discussed in the next paragraphs.

18 The LCA is a methodology whose unique characteristic is holistically following the fuel (in this case) from the raw material to its utilisation (in this case) on-board of ships, assessing the potential climate impact of its use, in comparison with standard fuels and technologies. General principles and methodology can be found in ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines and ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework, set the framework for the LCA, for the quantification of the environmental impact of products, processes and services in the supply chain. On this basis a specific LCA methodology can be tailored for its application to marine fuels. A generic LCA framework (ISO 14040:2006) consists of the following stages:

- Goal and Scope Definition,
- Inventory Analysis,

[14] https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf

- Impact Assessment with a common underlying interpretation layer. In each of these phases, choices are made to achieve a coherent and
- Consistent evaluation of the GHG emissions.

Furthermore the ISO 14083 standard under development, will establish a common methodology for the quantification and reporting of GHG emissions arising from the operations of transport chains of passengers and freight (this standard is expected to be finalised by the end of 2022).

19 Amongst the several choices that need to be made for the LCA methodology, the one between the attributional (A-LCA) and consequential (C-LCA) modelling (or also so-called marginal) is very relevant. The A-LCA is mostly applied on specific products or processes in a micro-economic modelling as it focuses on the specific supply chain and its products. The C-LCA is applied in macro-economic modelling as it aims at creating a generic supply chain that can reflect market, policy and consumer behaviour. A discussion should take place among the experts to help clarifying the mechanism for the allocation of the emissions in complex processes (such as those happening in refineries or in processes for alternative fuels production). The preference of the submitters is for the A-LCA, which provides for a simplified computation using stable inventories, and grants general validity across the temporal and spatial scales within the scope of the specific legal goal while C-LCA is more uncertain as it depends on designed scenarios. A-LCA is used in regulatory frameworks in different world regions. Current major legislative acts and initiatives (in the EU) are based on attributional approach A-LCA, as this tend to reduce uncertainties, especially when allocation is required. However, case by case, amendments, extensions for marginal consideration or consequential-thinking might be needed to capture the complexity of several feedstock-to-fuel pathways.

20 Other essential elements of the WtT GHG emissions evaluation should be considered; elements such as, but not limited to, fuel pathways description and system boundaries, available LCA Inventories, calculation method and co-products allocation criteria, sustainability criteria and thresholds defining restrictions and exclusions, presentation format, should be established. The element related with the accounting of the

Attributional LCA (A-LCA) aims to assess environmental impacts associated with all stages of a product's life from cradle to grave (i.e. from raw material extraction through materials processing, manufacture, distribution, use, etc.). Attributional modelling makes use of historical, fact-based, average and measurable data of known (or at least knowable) uncertainty and includes all the processes that are identified to relevantly contribute to the system being studied.

Advanced A-LCA looks beyond the immediate system boundaries by comparing multiple systems ('counterfactuals'). For instance, when assessing the potential environmental impacts of a bio-based commodity, it should be considered that the biomass feedstock and the land cover on which it is grown are limited resources. Therefore, multiple systems should be compared to partially integrate market-mediated effects to get a better picture of the potential risks associated with the bio-based commodity. Advanced A-LCA also takes into account additional GHG and environmental indicators.

Consequential LCA (C-LCA) identifies the consequences that a decision in the foreground system has for other processes and systems of the economy, both in the analysed system's background system and on other systems outside the boundaries. It models the studied system around these consequences. The consequential life cycle model is hence not reflecting the actual (or forecast) specific or average supply chain. Instead, it models a hypothetical, generic supply chain that is modelled according to market mechanisms, and potentially includes political interactions and consumer behaviour changes. Secondary consequences may counteract the primary consequences (then called 'rebound effects') or further enhance the preceding consequence.

Source: Bioeconomy Report 2016. JRC Scientific and Policy Report co-products, deals with the accounting of co- and by-products generated along fuel production. Some preliminary definitions and principles are discussed in the following for the purpose of showing a possible structure along which to organise the discussion.

21 A fuel pathway is identified for each fuel type and should include:
Feedstock extraction
Feedstock (early) processing/ transformation at source
Feedstock transport
Feedstock conversion to product fuel
Product fuel transport
Product fuel storage
Local delivery
Retail storage and dispensing

22 Resources are sources, supply, raw materials, primary energy source used for production of goods and utilities such as energy carriers (fuels and electricity). Resources can be either from a fossil origin, i.e. energy carriers produced from crude oil, coal or natural gas or from a biological origin (crops and residues), i.e. energy carriers like (biogas, bio-ethanol, biodiesel, hydro-treated vegetable oils (HVO). In the case of electricity, the origin can also be renewable other than bioenergy, e.g. wind or solar energy.

23 Early Processing embeds all the steps and operations needed for the extraction, capture or cultivation of the primary energy source; process includes basic transformation at source operations needed to make the resource transportable to the market place (e.g. drying, chemical/physical upgrade such gas-to-liquid, etc.).

24 Transportation, Processing and Distribution include transportation of the products in the fuel pathway to the place of transformation, conditioning (such as compression, cooling, etc.), distribution to the market place and eventual leakages.

25 Most relevant energy carriers (specific for maritime use) should be identified for the purpose of the evaluation of the upstream emissions (pathways). A possible classification is presented in the table below:

Fuel Class	Pathway name and Feedstock
Fossil	HFO 3.5%S (3.5% sulphur limit)
	FO 0.5%S (0.5% sulphur limit)
	FO 0.1%S (0.1% sulphur limit)
	LSFO
	ULSFO
	VLSFO
	LFO
	MDO/MGO
	LNG
	LPG
	Methane
	H2 (from natural gas / grey and blue)
	Methanol (from natural gas)
	Ethane
	NH_3

Fuel Class	Pathway name and Feedstock
Liquid biofuels	Bio-FA: Biodiesel fatty acids - Main products / wastes / feedstock mix
	Bio-FAME: Biodiesel fatty acid methyl esters - Main products / wastes / Feedstock mix
	Bio-oil: Biodiesel type oils - Main products / wastes / Feedstock mix
	HVO - Main products / wastes / Feedstock mix
	Bio-LNG - Main products / wastes / Feedstock mix
	Bio-Methanol and Bio-Ethanol
Gas biofuels	Bio-H_2 - Main products / wastes / Feedstock mix
	LBG: Biomethane - Main products / wastes / Feedstock mix
e- fuels	e-diesel - electricity mix (such as EU el. Mix or Nat el. Mix)
	e-methanol - electricity mix (such as EU el. Mix or Nat el. Mix)
	e-LNG - electricity mix (such as EU el. Mix or Nat el. Mix)
	e-H_2 - electricity mix (such as EU el. Mix or Nat el. Mix)
	e-NH_3 - electricity mix (such as EU el. Mix or Nat el. Mix)
Others	Electricity produced on purpose – such as EU electricity mix

26 For biofuels, biomass fuels, bioliquid fuels, and more in general for all fuels, produced from food and feed crops, specific sustainability principles and criteria have to be adopted, such as criteria and actual figures for land with high biodiversity value, high carbon stock and indirect land-use change (ILUC). IPCC land usage cover categories: forestland, grassland, wetlands, settlements, or other land, to cropland or perennial cropland should be used as basis to define feedstock production for which a direct land-use change occurred. However, food and feed crops used to produce biofuels, for use in maritime transport, should be limited to strict sustainable criteria. All relevant sustainability criteria must also be defined for e-fuels, in particular the additionally of renewable energies, water consumption, land use, nature conservation and socio-economic aspects.

27 The pathway of each relevant marine fuel needs to be detailed and the emissions of the fuels need to be calculated on the basis of the pathway. Specialisation of some pathways may be necessary with respect to the geographical area to take into account different efficiencies of the specific fuel’s pathway. The method applied, including the accounting of co- and by-products, should guarantee adequate accuracy. Several tools for the actual calculation of the GHG are available (such as Oil Production Greenhouse Gas Emissions Estimator (OPGEE), ICAO/FTG/CORSIA, REDII, JEC WTT5, etc.) and an average/best technically sound approach and values should be agreed by the experts. For petrol and diesel fuels the upstream emissions reduction are evaluated in accordance with ISO 14064-3, while the organisation verifying such emissions are accredited in accordance with ISO 14065 and ISO 14066. The responsibility of the fuel supplier should also be clearly defined.

28 The methodology should also take into consideration the advent of the increasing introduction of battery pack for the purpose of propulsion or anyway as a means to provide for energy to be consumed on board for uses other than propulsion. Clearly the chemical energy converted in this type of energy converter does not produce any relevant direct GHG emissions, however these battery packs are recharged by means of on-shore power supply (OPS) provided to the ship while at berth in ports ready for this service. The GHG emissions

generated to provide battery packs recharge should be accounted for, as well. These emissions are part of the WtT upstream GHG emissions part because generated electricity has – depending on its production pathway – a GHG impact. Thus, the electricity used in port for recharging purpose needs to be assessed and accounted for into the energy balance of a LCA approach. One of the possible ways to cater for such emissions is to refer to the National Electricity index (measured in CO_{2eq}/MJ or kWh).

29 The methodology is therefore capable of delivering default values for both the WtT and the TtW streams, as well as actual values processed by verification and certification schemes again for both WtT and TtW. Default values could incorporate conservative assumptions to cope with inevitable uncertainties linked to using averages at global scale.

30 Once the methodology will be agreed and the main fuel pathways established, together with their CO_{2eq} evaluation, the next step should be to link such upstream emissions to the downstream emitter (the ship). In the methodology presented in the Annex the approach is to evaluate the GHG impact on the basis of the type of the bunkered fuel and its quantity. The reason for this choice is found in the availability of the Bunker Delivery Note and the information it contains on the bunkered fuel. The information on the WtT emissions should be given in the Bunker Delivery Note.

31 Main steps for the WtT stream *in nuce*:

- Identify and agree on an LCA methodology for the estimation of the upstream emissions,
- Define and include either qualitatively or quantitatively in the methodology any relevant criteria for preserving the environmental integrity of such methodology, among others: direct and indirect land use, risk of harmful induced effects for feedstock displacement, minimum GHG saving criteria, biodiversity protection, risk of double counting/claiming, etc. ;
- For each fuel identify relevant production pathways, capturing geographical differences, and proposing options to reconcile them as relevant;
- Estimate the GHG emissions for each fuel pathway by applying the agreed methodology and present the output in gCO_{2eq}/gFuel, gCO_{2eq}/MJ;
- Propose relevant certification schemes.

Tank-to-Wake Emissions – What do we need?

32 The GHG emissions evaluation for the downstream TtW has to be developed in a consistent approach and methodology in respect to the upstream WtT GHG emissions evaluation. This shall not be confused with any of the other measures already in force or under discussion by the IMO such as CII, AER, EEDI, etc.

33 The same GHG emissions as with the upstream emissions (WtT) should be accounted for the downstream emissions (TtW), namely: CO_2, CH_4 and N_2O. These three gases, combined and weighted according to their Global Warming Potential (over 100 years – GWP100 and also monitored over 20 years), results in the CO_{2eq} GHG impact for the TtW downstream emissions.

34 For the TtW two main mechanisms of emissions should be accounted for:

(1) all fuel consumers (e.g. the combustion/partial-oxidation of the fuel when converted in the combustion chamber e.g. in the Internal Combustion Engine (ICE), turbine or in a boiler); and

(2) the so-called fugitive emissions. As well fuel cells in combination with onsite reformers would emit GHG emissions and are part of the TtW part and are captured by this approach. After treatment systems such as SCR that may cause N_2O emissions are also accounted.

Fugitive emissions account for that part of the fuel / substance (and its carbon) that did not reach or slipped unburned through the combustion chamber and leaked or vented other way (e.g., due to storage or transfer on-board). Fugitive emissions are relevant for only certain type of gaseous fuels and sometimes only in combination with their specific energy converters. Taking into account the status of technology, these emissions are considered relevant for example for LNG when converted in ICE, however, this might become relevant for future fuels like ammonia when possibly N_2O may be formed (that should be considered through its own emission factor). Figure 6 shows CO_{2eq} emissions per fuel and energy converter for both the WtT and the TtW.

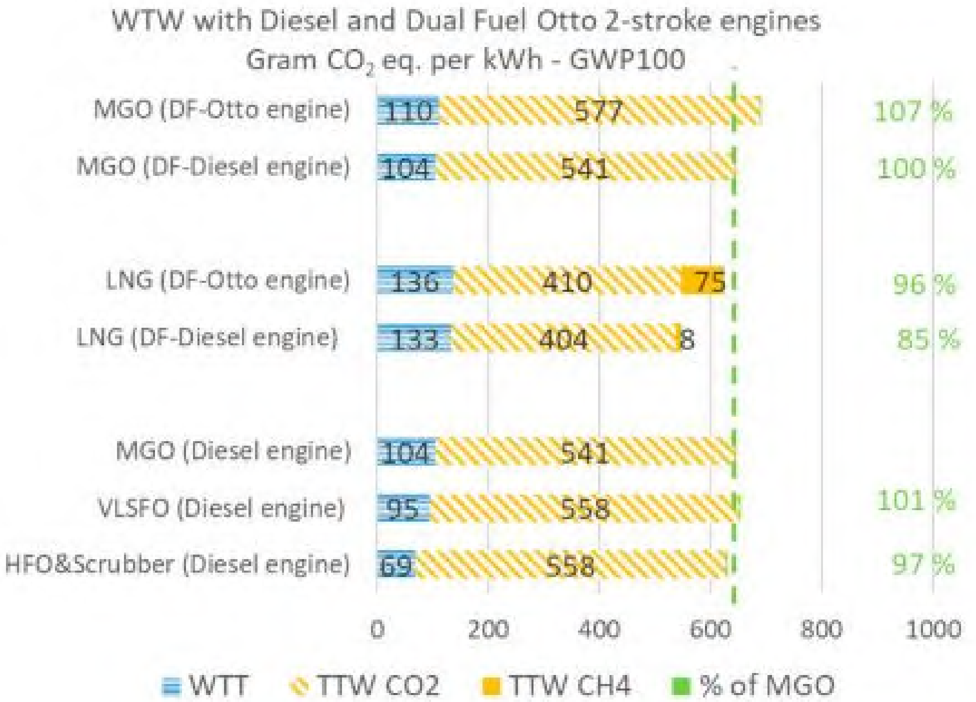

Fig. 6 - Examples of different WtW figures for different fuels and energy converter technology, Lindstad *et al.*

35 Other so-called zero-emissions propulsion technologies such as wind sails are ramping-up. These technologies, which should be dealt indeed in the TtW downstream part, are providing for propulsion power to the ship without generating any GHG. Focusing on wind, the characteristics of such type of propulsion are related to several factors during navigation, such as intensity, direction, sea state, actual ship speed, season, route, etc.. All these variables qualify this intermittent energy source and the direct evaluation of the average power delivered for propulsion becomes a monitoring challenge. Additionally, a wind assistant propulsion system would reduce the fuel consumption directly and thus a reporting of this technology is directly expressed in lower fuel usage and thus lower TtW emissions.

36 The methodology presented in the Annex as basis for discussion, accounts for all the elements discussed above, including three different GHG emissions, fugitive emissions

and battery recharge and it is prepared to take into account incentives for zero-emissions technologies such as wind propulsion or solar. The proposed methodology achieves all these objectives by introducing a **fuel-mass based approach**.

37 The methodology requires information on a limited number of factors, as further highlighted in the Annex. As it becomes evident from the technical structure of the methodology, one of its characteristics is that there is no need for the pre-knowledge of all factors, as they can be specified and/or updated as the technology evolves. The methodology can therefore be expanded and easily adapted to new technological developments as they occur by simply agreeing on the needed factors on the basis of the best knowledge.

38 Main steps for the TtW stream *in nuce*:

- For the relevant fuels and/or fuel category to identify and agree on the relevance of default emissions factors for the 3 relevant GHG´s;
- Establish main energy consumers classes/categories and default emissions factors in relation to the fuel in use;
- Establish the average amount of relevant fugitive emissions as % of the mass of the fuel used in relation to its energy consumer;
- Establish relevant conversion factors and Lower Calorific Value (LCV) of the fuel to present the result in gCO_{2eq}/MJ.

A draft preliminary structure table (Table 1) is presented in Annex I.

Further considerations

Well-to-Tank part

39 The proposed methodology (see Annex I, Table 1) suggests the use of default values for fossils fuels for the WtT established in such way to incorporate the overall uncertainties stemming from the averaging at global scale. Such default values for fossil fuels WtT shall not be subject to any certification scheme, as opposed to the actual values that for all other fuels instead can undergo to certification (see Annex I Table 2).

40 The methodology includes the use of default values for the relevant factors needed to calculate the GHG impact of fuels. However, performers who believe to do better than default values should be given the opportunity to demonstrate their real performances through the application of a certification scheme. In the domain of GHG certification there are several available and trustful certification schemes that can be used. Existing certification schemes such as those provided for International Sustainability and Carbon Certification (ISCC) (https://www.iscc-system.org/), Roundtable on Sustainable Biomaterials (RSB) (https://rsb.org/) and REDCert (https://www.redcert.org/en/), may serve as basis for calculation and verification of the WtT GHG emissions.

41 These certification schemes are applicable to sustainable alternative fuels for the WtT part. For fossil fuels, instead the default values as presented in Annex I should be used, only.

42 The IMO should adopt certification schemes, to certify that the fuels fulfil the established principles and to provide data on CO_{2eq} emissions for the relevant fuel pathways in their WtT part.

43 The methodology should allow to include a new fuel or even a new fuel category at any point in time.

Tank-to-Wake part

44 As for the Well-to-Tank part, the methodology includes some default values. Guidelines for verification and certification should be drawn-up so performers have the opportunity to demonstrate if they to do better than default values. It should be noted, that the TtW stream, besides being open to laboratory testing, may be opened also for continuous (online) monitoring in exhaust pipes for all GHGs provided that they can be measured sufficiently precisely and the right regulatory framework being set. Guidelines should, *inter-alia*, identify most appropriate methodologies to assess emissions factors for CH_4 and N_2O. For example for N2O experts should come together to review the available methodologies across the industry such as chromatographic techniques, optical techniques, et al., in relation to the specific needs (accuracy, availability, costs) for the specific case.

45 As mentioned within the WtT emissions; the methodology should allow to include a new fuel or even a new fuel category at any point of time. In the case of the TtW downstream emissions, any new combination of a fuel and an energy converter can be included in the methodology provided that the efficiency yields and emissions factors are known. Finally the same applies to all kinds of fugitive emissions being these methane slip or boil-off gases, provided that these can be quantified in average in relation to the mass of fuel used, e.g. N_2O emissions for ammonia.

46 Finally, it is worth to re-iterate the specific case of Biofuels and the need to compensate land use changes (direct or induced): the methodology should include adequate provisions to minimise the risk of negating net benefits by disregarding their possible indirect effects. However, the European Union strongly believes that any fuel for which production requires land to be subtracted to food or forestry or other environmental sensitive features lacks sustainability and this should be well reflected when defining the WtW boundaries. This approach allows this full spectrum and the European Union believes that such fuels should not be eligible for decarbonisation.

IMO instruments - Implications

47 MARPOL Annex VI has expanded the scope of the Convention from pollution and air pollutants to climate relevant greenhouse gases and therefore Annex VI is, in the structure of the Convention, the most suitable section in which life cycle assessment for fuels should be addressed. On the basis of the suggested approach and methodology, if adopted, the revised IMO GHG strategy (foresee in 2023), should take into consideration the result of the technical evaluation, when setting the targets.

48 Collection and reporting of ship fuel oil consumption data (MARPOL Annex VI, Regulation 22A, and Appendix IX (Data Collection)) and related guidelines may require to be revised after the completion of the work envisaged in this submission. Regulation 22A and Appendix IX, already foresee the collection of Fuel oil consumption, by fuel oil type in metric tonnes and methods used for collecting fuel oil consumption data. This Fuel oil consumption by fuel type will be used as input data in the suggested methodology.

49 Fuel oil quality and the Bunker Delivery Note (MARPOL Annex VI, Regulation 18 and Appendix V) should be amended by including in the BDN the specific fuel pathway, the lower calorific value (LCV) of the fuel in [MJ/g of Fuel] and the upstream WtT CO_{2eq} value in [gCO2eq/MJ] as certified by the application of one of the approved certification schemes.

50 Ship Energy Efficiency (MARPOL Annex VI, Regulation 20 and resolution MEPC 308 (73) as amended). No implications are foreseen for Regulation 20. For resolution MEPC 308 (73) as amended, the values of C_F for the relevant fuels should be considered. Two options are possible: (1) the list is left untouched and the table with the relevant values is integrated in the Guidelines, with the caveat that if resolution MEPC 308 (73) as amended, will be amended then also the Guidelines will need to be amended; (2) the table is expanded to include new relevant fuels and their factors. Option (1) is most preferred.

51 NO_x Technical Code should be taken into consideration in relation to the Guidelines for verification and certification for the methane slip of engines. E2/E3 test cycle can also be considered in the certification guidelines.

Method of Work

52 As it has become evident from the discussion, the LCA and the suggested methodology, would require an expert debate and thorough technical review that could be dealt within the remit of the ISWG-GHG under Agenda Item XX, with a view to deliver *Life cycle GHG Guidelines for maritime fuels and sustainability criteria for maritime fuels*. The ISWG-GHG should be tasked of organising the work also by mean of Correspondence Group, as appropriate.

53 The Committee should gather relevant experts to attend the next ISWG-GHG, and to participate to the work on the Guidelines. Attention is drawn to the fact that the expertise needed to effectively and efficiently progress on the discussion for the WtT and TtW streams should be gathered by the IMO Member States. While the expertise needed to address TtW is an expertise generally made available to the IMO, the one needed to address WtT should be sourced from other technical and scientific domains, but still generally available to the IMO Member States. The IMO Member States should try, to their best capabilities to ensure the presence of such experts at the ISWG-GHG next meetings. The work could be taken-up in the ISWG-GHG by following the simple structure in Fig.7 and further developed in Correspondence Groups. The work in Stream 1 (WtT) could be further structured with experts dedicated to the development of core-LCA, sustainability criteria, accounting and reporting, certification schemes.

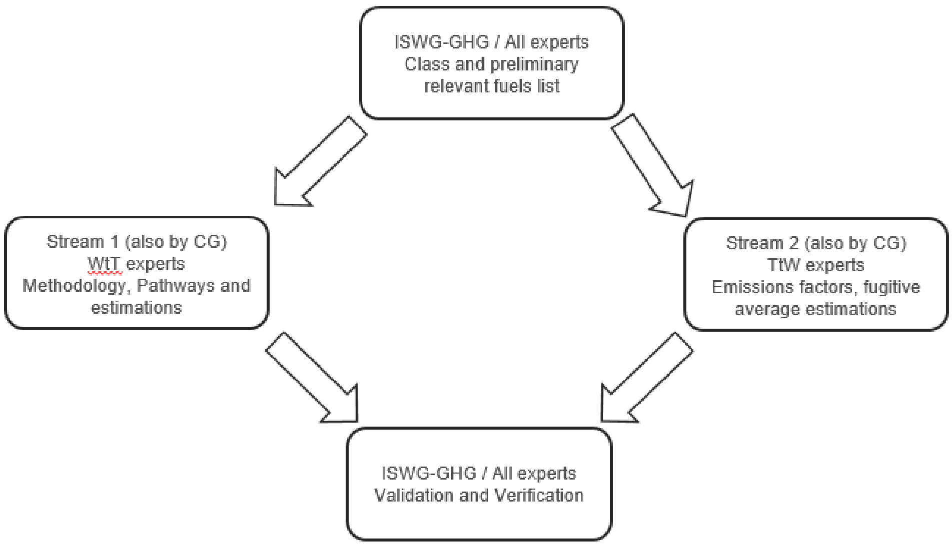

Fig.7 - Work-flow

54 The Guidelines should be prepared in 2 sessions of the ISWG-GHG, ready to be presented to the Committee for adoption.

Proposals

55 It is proposed to use as basis for discussion the methodology presented in this submission and more specifically in its Annex I, with a view to establish a life cycle approach for the evaluation of the GHG emissions from shipping.

Annex I

Maritime fuels GHG emissions evaluation by using Life Cycle Assessment (LCA) How the model works and what essential information is required

The calculation can be made over a reference period (such as 1 year) and it is based on the following notional formulation:

$$GHGe\ [gCO_{2eq}] = WtT\ (fuel\ and\ electricity) + TtW(\ including\ fugitive\ emissions)$$

And more specifically, for the purpose of actual calculation, on the following formulation derived from the previous equation:

$GHG\ emission\ =$	$\sum_{i}^{n\,fuel} M_i \times CO_{2eq\ WtT,i} \times LCV_i + \sum_{k}^{c} E_k \times CO_{2eq\ electricity,i}$	$+\sum_{i}^{n\,fuel} \sum_{j}^{m\,consumer} M_{ij} \times$	$(1 - C_{slip\,j}) \times (CO_{2eq,TtW})$	$+ (C_{slip\,j} \times GWP_{CH_4})\ ]$
GHG emissions in $[gCO_{2eq}]$ over the reference period	Well-to-Tank GHG emissions in $[gCO_{2eq}]$	Tank-to-Wake GHG in $[gCO_{2eq}]$		
Ship's GHG emissions	Well-to-Tank GHG emissions as summation of all fuels delivered to the ship, normalised respect to the total fuel delivered in the reference period. Electrical energy delivered to the ship at berth.	Summation over the fuel type and the prime mover consuming it	CO_{2eq} of the fuel combusted in the engine minus the % of the fuel that escapes combustion (fugitive, vented, leaked) in– see below	Fugitive emission of fuel that does not reach the combustion chamber – see below

Equation (1)

Where:

$$CO_{2eq,TtW,i} = \left(C_{f\,CO_2} \times GWP_{CO_2} + C_{f\,CH_4} \times GWP_{CH_4} + C_{f\,N_2O} \times GWP_{N_2O}\right)_i$$ **Equation (2)**

Note: Eq. (2) deals with combustion emissions factors and it is not related to slip. The emissions factors for CH4 and N2O are normally very small.

Term	Explanation
i	Index corresponding to the fuels (for each specific fuel pathway) delivered to the ship over a reference period.
j	Index corresponding to the different fuel consumers. Energy consumers considered are e.g. main engines and auxiliaries engines, boilers, waste incineration plants
k	Index corresponding to the connection points (c) where electricity was supplied per connection point
c	Index corresponding to the number of electrical charging points
m	Index corresponding to the number of energy consumers
M_{ij}	Is the mass of the specific fuel *i* oxidised in consumer *j* (in gFuel)
$CO_{2eq\,WtT,i}$	are the WtT GHG emissions in gCO_{2eq}/MJ for each specific fuel, calculated according an agreed methodology (such as RED II)
$CO_{2eq,TtW,i}$	Are the TtW GHG emissions for in gCO_{2eq}/gFuel for each specific fuel, when consumed on board by the fuel consumer *j*
$C_{f\,CO_2}$, $C_{f\,N_2O}$, $C_{f\,N_2O}$	Are the emissions factors in (*g of GHG/g of Fuel*)

LCV_i	Lower Calorific Value of the i^{th} fuel (considered in its own specific pathway) in MJ/g
$C_{slip\ j}$	Fuel slip in % of the mass of the fuel used by the energy converter j
$GWP_{CO_2}, GWP_{CH_4}, GWP_{N_2O}$	Is the GWP potential coefficient over 100 years for the relevant GHG gas CO_2, CH_4 and N_2O
E_k	Is the electricity delivered to the ship measured in MWh (and transformed in MJ). In this case the index k indicates the number of the ship's charging/connection points, if more than one.
$CO_{2eq\ electricity,i}$	Are the GHG emissions in CO_{2eq}/MJ associated to the electricity delivered to the ship at berth.

WtT Methodology

On the basis of the LCA methodology, upstream emissions for each fuel pathway should be evaluated and a default value in CO_{2eq} measured in [CO_{2eq}/MJ] should be used.
Such default values could be calculated on the basis of the methodology established in Directive (EU) 2018/2001, Annex V section C, whose main features, for easy reference are reported below:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

Where:

E	total emissions from the use of the fuel;
e_{ec}	emissions from the extraction or cultivation of raw materials
e_l	annualised emissions from carbon stock changes caused by land-use change (over 20 years)
e_p	emissions from processing
e_{td}	emissions from transport and distribution
e_u	emissions from the fuel in use
e_{sca}	emission savings from soil carbon accumulation via improved agricultural management
e_{ccs}	emission savings from CO_2 capture and geological storage
e_{ccr}	emission savings from CO_2 capture and replacement

In the proposed methodology the term e_u is set to zero and accounted in the TtW part.
CO_2 credits generated for CO_2 consumed by the plants are accounted in the upstream WtT, often resulting in a negative value.

On this basis values contained in Table 1, preliminary default factors are presented for certain relevant fuels pathways. The preliminary list of default factors can be expanded and re-evaluated as the need arises to further populate the list of fuel pathways or if there is evidence that a default value needs to be reviewed.

WtT GHG emissions default (or certified) values are then treated as specified in eq. (1) (by multiplying the gCO_{2eq}/MJ times the Lower Calorific Value of the fuel times its mass), to deliver an output in $gCO_{2eq.}$/gfuel (i.e. dimensionless to be added to the TtW part and can be multiplied by the fuel mass used by the ship)

Electricity
The methodology also accounts for the electricity delivered to the ship. The energy delivered from on-shore to the ship, for the purpose of being accumulated in chemical form for examples in batteries, can be seen as part of the WtT upstream emissions. Also for the electricity, as any other fuel/energy carrier fuel pathway, gCO_{2eq}/MJ[15] can be estimated by applying the same methodology as for any other fuel, while taking into consideration the specificity of its pathway.

It is necessary to establish default values for the WtT upstream emissions [gCO_{2eq}/MJ] of the electricity taking into account regional differences where relevant.

Default values could be replaced by actual values when certified under one of the accepted Certification Schemes.

Method of delivery
The methodology requires that the mass of the fuel bunkered by the ship is reported. The fuel bunkered should be accompanied by its pathway identification (see the upstream GHG emissions values in Table 1). If the operator opts for a certification scheme, the fuel pathway in BDN should include the reference to the certification scheme used, the upstream emissions in CO_{2eq} [gCO_{2eq}/MJ], the Lower Calorific Value of the fuel [MJ/g of fuel] and its carbon factor for the CO_2 downstream emissions [gCO_2/g of fuel].
The BDN should be complemented with at least the following information:

- product name
- fuel mass [t]
- fuel volume [m^3]
- density [kg/m^3]
- WtT GHG emission factor for CO_2 (carbon factor) [gCO_2/gFuel][1]
- LCV [MJ/g]

(1) separate certificates carrying the values of CO_{2eq} for the WtT part, related to the fuel production pathway should be made available.

The methodology could build up on the Data Collection System (DCS) as appropriate.

BDN Electricity

For the purposes of this methodology, relevant BDNs for electricity delivered to the ship should contain at least the following information:

- supplier: name, address, telephone, email, representative
- receiving ship: IMO number (MMSI), ship name, ship type, flag, ship representative
- port: name, location [(LOCODE), terminal/ berth]
- connection point: OPS-SSE connection point, connection point details
- connection time: date/time of commencement/finalisation
- energy supplied: power fraction allocated to supply point (if applicable) [kW], electricity consumption (kWh) for the billing period, peak power information (if available)
- metering

TtW
Methodology
The aim of the TtW methodology is to evaluate the amount of GHG (CO_2, CH_4 and N_2O) emitted by the ship (over a reference period, for example one year). The GHG emissions are generated on-board of the ship basically by 2 mechanisms: by combustion and by fugitive

[15] Or it can be provided in kWh and transformed in MJ by multiplied by 3.6

emissions. For future use of fuel cells with a reforming unit, also electro-chemical reaction forming GHGs can be taken into account by this TtW methodology.
During the combustion/oxidation of a fuel several compounds are generated including the 3 GHGs relevant for assessing the fuels climate impact. The actual GHG emissions caused by the use of a fuel on board depend both on the properties of the fuel and on the energy converter in which the fuel is consumed. While for the emission factor related to carbon (CO_2) it is regarded as if all carbon is oxidised, thus the molar ratio of carbon to oxygen multiplied with the carbon mass of the fuel provides the carbon factor for the specific fuel and solid references exist. For the emissions (or conversion) factors for CH_4 and N_2O within normal Diesel process combustion, or by any other energy converter, those factors are deemed to be small but in some cases cannot be disregarded (as for LNG), however, more consideration might be needed.

For the **CO_2 emissions** factors it is proposed to make use of resolution MEPC.245 (66) as amended for the fuels specified in the resolution. For all other fuels, other than those specified in resolution MEPC.245 (66) as amended, default CO_2 emissions factors should be established based on their carbon content.

CH_4 emissions factors for fossil fuels (such as HFO, MDO and LNG) are contained in the 4th and 3rd IMO GHG study. In particular this factor, which is relevant for methane and LNG fuels, should be established on the best available knowledge.

N_2O emissions for HFO, MDO and LNG are also contained in the 4th and 3rd IMO GHG study. This factor is believed to be relevant for certain type of fuels such as those on methane or for H_2 when consumed in ICE. For all other fuels this factor should be established on the best available knowledge (which includes being set to zero).

Fugitive emissions arising from fuels that do not reach the combustion chamber [or slip unburned through the combustion chamber] and are lost, leaked, vented, boiled-off in the system. The evaluation of such emissions is of complex nature because depending on the layout of the system, the actual load that the engine is operated on, mass consumed and other factors. Methane/LNG slip is considered to be most relevant fugitive emissions at the current technology state, in particular for 4-stroke dual fuel engines. The outcome should be that it can be expressed as % of fuel mass used.

The same type of treatment could be done for the boil off emissions or any other fugitive emissions.
It should be noted, that this TtW approach may be opened for continuous (online) monitoring in exhaust pipes for all GHG´s in case they can be measured sufficiently precise.
Combustion/Oxidation emissions and Fugitive emissions are then combined according to eq. (1) to deliver an output in g, kg or ton CO_{2eq}.
For fuels such as LNG for which the fugitive emissions (slip) are believed to be a relevant issue, the amount of fugitive emissions as presented in Table 1 is expressed in % of the mass of fuel used (Column 9). The values contained in Column 9 shall be used, in accordance with equation (1), in the calculation in place of the values of Column 7.

The values of C_{slip} in Table (1) are calculated at 50% of the engine load (E2/E3 test cycle can also be considered as method of reference in the certification guidelines).

Some conversions factors
For total combustion:
- 1 kg of a fuel with C% carbon emits: 1 x C% / 100 / 12 x 44 = (0.0367 x C%) kg of CO2;
- 1 MJ of a fuel with λ MJ/kg (LCV) and C% carbon emits: 1 / λ x C% / 100 / 12 x 44 = (0.0367 / λ x C%) kg of CO2;

- 1 KWh ((kg·m²·s⁻³) ·s) = 3,6 MJ (kg·m²·s⁻²)

Preliminary default factors

The Table below contains the information needed for the evaluation of the WtW GHG emissions as provided in Eq. (1)

In the table:

- TBM stands for To Be Measured
- N/A stands for Not Available
- The dash means not applicable

Table 1 – Preliminary default factors

1	2	3	4	5	6	7	8	9
	WtT			TtW				
Class	**Pathway name**	LCV $\left[\frac{MJ}{g}\right]$	$CO_{2eq\,WtT}$ $\left[\frac{gCO2eq}{MJ}\right]$	**Energy Converter Class**	$C_{f\,CO_2}$ $\left[\frac{gCO2}{gFuel}\right]$	$C_{f\,CH_4}$ $\left[\frac{gCH_4}{gFuel}\right]$	$C_{f\,N_2O}$ $\left[\frac{gN_2O}{gFuel}\right]$	C_{slip} As % of the mass of the fuel used by the engine
Fossil	HFO ISO 8217 Grades RME to RMK	0,0405	9,6 - 14,1 Sphera 2nd GHG Study	**ALL ICEs**	3,114 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	-
				Gas Turbine				
				Steam Turbines and Boilers				
				Aux Engines				
	LSFO [better HFO>0,5]	0,0405	13,2, crude 13,7 blend Thinkstep	**ALL ICEs**	3,114	0,00005 TBM	0,00018 TBM	-
				Gas Turbine				
				Steam Turbines and Boilers				
				Aux Engines				
	ULSFO	0,0405	13,2	ALL ICEs	3,114	0,00005 TBM	0,00018 TBM	-
	VLSFO	0,041	13,2 SINTEF 2020 14,0 Sphera 2nd GHG Study	ALL ICEs	3,206 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	-
	LFO ISO 8217 Grades RMA to RMD	0,041	13,2	ALL ICEs	3,151 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	-
	MDO MGO ISO 8217 Grades DMX to DMB	0,0427	14,9 Sphera	ALL ICEs	3,206 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	-
	LNG	0,0491	18,5 SINTEF	LNG Otto (dual fuel	2,75 MEPC245 (66)	0,0512 TBM	0,00011 TBM	3,1

1	2	3	4	5	6	7	8	9
	WtT			TtW				
			2020 17,7 Sphera	medium speed)	MRV Regulation			
				LNG Otto (dual fuel slow speed)				1,7
				LNG Diesel (dual fuel slow speed)				0.2
				LBSI				N/A
	LPG	0,046	7,8	All ICEs	3,03 Buthane 3,00 Propane MEPC245 (66) MRV Regulation	TBM	TBM	
	H2 (natural gas)	0,12	132 JEC	Fuel Cells	0	0	-	-
				ICE	0	0	TBM	
	Methanol (natural gas)	0,0199	31,3 RED II	All ICEs	1,375 MEPC245 (66) MRV Regulation	TBM	TBM	-
	Ethane							
	NH3 (natural gas)	0,0186	121	No engine	0	0	TBM	-
Liquid biofuels	Ethanol E100	0,0268	-33,2 RED sugarbeet	All ICEs	1,913 MEPC245 (66) MRV Regulation	TBM	TBM	-
	FAME							
	Bio-diesel Main products / wastes / feedstock mix /rapeseed	0,0372	115,1 Rapseed incl. LUC 306,7 Palm incl. LUC	ALL ICEs	2,834	0,00005 TBM	0,00018 TBM	-
	Bio-diesel Main products / wastes / Feedstock mix	0,0372	-26,1 RED II	ALL ICEs	2,834	0,00005 TBM	0,00018 TBM	-
	HVO Main products / wastes / Feedstock mix	0,044	-20,7 RED II	ALL ICEs	3,115	0,00005 TBM	0,00018 TBM	-
	Bio-LNG Main products / wastes / Feedstock mix	0,05	-38,9 RED II	LNG Otto (dual fuel medium speed)	2,755 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	3,1
				LNG Otto (dual fuel slow speed)				1,7
				LNG Diesel (dual fuels)				0.2
				LBSI				N/A
Gas biofuels	Bio-H2 Main products / wastes / Feedstock mix	0,12	N/A	Fuel Cells	0	0	0	-
				ICE	0	0	TBM	
e-fuels	e-diesel EU electricity mix	0,0427	-47,6 RED RESD1 (fromRES)	**ALL ICEs**	3,206	0,00005 TBM	0,00018 TBM	-
	e-methanol EU electricity	0,0199	-67,1 RED REME1a (fromRES)	All ICEs	1,375 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	-

1	2	3	4	5	6	7	8	9
	WtT			TtW				
	mix							
	e-LNG EU electricity mix	0,0491	-26,6 RED WFLG2 (from biomass gasification)	LNG Otto (dual fuel medium speed)	2,755 MEPC245 (66) MRV Regulation	0,0512 TBM	0,00011 TBM	3.1
				LNG Otto (dual fuel slow speed)				1,7
				LNG Diesel (dual fuels)				0.2
				LBSI				N/A
	e-H2 EU electricity mix	0,12	3,6 JEC	Fuel Cells	0	0	0	-
				ICE	0	0	TBM	
	e-NH3 EU electricity mix	0,0186	0 SINTEF 2020	No engine	0	N/A	TBM	N/A
Others	Electricity EU electricity mix	-	106,3 EU MIX 2020 72 EU MIX 2030	OPS	-	-	-	-

(*) Note for column 4: for the values in column 4, make mostly reference to RED II values without combustion for reference and testing.

Global Warming Potential over 100 years as per IPCC AR5:

GHG	GWP 100 – IPCC AR5
CO_2	1
CH_4	28
N_2O	265

Table 2

Calculation Example(s)

Example 1

A given ship, with an internal combustion engine (ICE), consumes over a year period the following quantities of two fuels:

LFO	5879,84 tons
MGO	1226,26 tons

From Table 1 we have the following values for the two fuels:

Pathway name	LCV $\left[\frac{MJ}{g}\right]$	$CO_{2eq\,WtT}$ $\left[\frac{gCO2eq}{MJ}\right]$	Energy Converter Class	$C_{f\,CO_2}$ $\left[\frac{gCO2}{gFuel}\right]$	$C_{f\,CH_4}$ $\left[\frac{gCH_4}{gFuel}\right]$	$C_{f\,N_2O}$ $\left[\frac{gN_2O}{gFuel}\right]$
LFO ISO 8217 Grades RMA to RMD	0,041	13,2	ALL ICEs	3,151 MEPC245 (66)	0,00005	0,00018
MGO ISO 8217 Grades DMX to DMB	0,0427	14,4	ALL ICEs	3,206 MEPC245 (66)	0,00005	0,00018

STEP 1 - For the WtT the following calculations are made:

- 5879,84 Tons of LFO = 5879,84 x 10^6 [g of LFO]
- 1226,26 Tons of MGO = 1226,26 x 10^6 [g of MGO]

The energy content of the two fuels delivered to the ship is then calculated as:

- 5879,84 x 10^6 [g of LFO] x 0,041 [LCV MJ/g] = 241,07 x 10^6 [MJ]
- 1226,26 x 10^6 [g of MGO] x 0,0427 [LCV MJ/g] = 52,36 x 10^6 [MJ]

The gCO_{2eq} per g of fuel is given for the two fuels by:

- for LFO 13,2 [gCO_{2eq}/MJ] x 0,041 [LVC MJ/g] = 0,5412 [gCO_{2eq}/gFuel]
- for MGO 14,3 [gCO_{2eq}/MJ] x 0,0427 [LVC MJ/g] = 0,6148 [gCO_{2eq}/gFuel]

The amount of g of CO_{2eq} associated to the mass of the two fuels delivered to the ship is:

- for LFO 5879,84 x 10^6 [g of LFO] x 0,5412 [gCO_{2eq}/gFuel] = 3182,16 x 10^6 [gCO_{2eq}]
- for MGO 1226,26 x 10^6 [g of MGO] x 0,6148 [gCO_{2eq}/gFuel] = 754,01 x 10^6 [gCO_{2eq}]

The total amount of gCO_{2eq} for the WtT is then:

- 3182,16 x 10^6 [gCO_{2eq}] + 754,01 x 10^6 [gCO_{2eq}] = 3936,17 x 10^6 [gCO_{2eq}]

STEP 2 - For the TtW the following calculations are made:

For this type of installation (ICE and liquid fossil fuel) the fugitive emissions are zero (i.e. C_{slip} is zero).
Therefore setting C_{slip} = 0, the TtW terms of Equation (1) are greatly simplified and reduces to:

$$+\sum_{i}^{\boldsymbol{n}\,fuel}\sum_{j}^{\boldsymbol{m}\,engine} M_{ij} \times [\quad (1-0)\times\left(CO_{2eq,TtW}\right) + \left(0 \times GWP_{CH_4}\right)]$$

hence, for the two fuels:

$$M_{LFO,ICE} \times CO_{2eq,TtW} + M_{MGO,ICE} \times CO_{2eq,TtW}$$

$CO_{2eq,TtW}$ is calculated as prescribed in Equation (2) making use of the C_f factors for the two fuels and of the GWP_{100} as in Table 2.
That for the two fuels becomes:

- for LFO $CO_{2eq,TtW} = 3{,}151 \times 1 + 0{,}00005 \times 28 + 0{,}00018 \times 265 = 3{,}2001$ [gCO_{2eq}/gFuel]
- for MGO $CO_{2eq,TtW} = 3{,}206 \times 1 + 0{,}00005 \times 28 + 0{,}00018 \times 265 = 3{,}2551$ [gCO_{2eq}/gFuel]

The amount of g of CO_{2eq} contained in the mass of the two fuels consumed by the ship is:

- for LFO 5879,84 x 10^6 [g of LFO] x 3,2001 [gCO_{2eq}/gFuel] = 18816,0716 x 10^6 [gCO_{2eq}]
- for MGO 1226,26 x 10^6 [g of MGO] x 3,2551 [gCO_{2eq}/gFuel] = 3991,599 x 10^6 [gCO_{2eq}]

The total amount of gCO_{2eq} for the TtW is then:

- 18816,0716 x 10^6 [gCO_{2eq}] + 3991,599 x 10^6 [gCO_{2eq}] = 2280,675 x 10^6 [gCO_{2eq}]

STEP 3 – Total amount of gCO_{2eq} emitted by the ship over the reference period:

WtT mass of CO_{2eq}	WtT mass of CO_{2eq}	WtW mass of CO_{2eq}
3936,17 x 10^6 [gCO_{2eq}]	2280,675 x 10^6 [gCO_{2eq}]	**26743,847 x 10^6 [gCO_{2eq}]**

Brief discussion: for this case, given the use of liquid fossil fuels (LFO and MGO) the default values in Table 1 for the emission factors are not dependent on the type of energy converters and therefore there is no need to know which amount of fuel was burned in which energy converter. However, it is worth to remark that for the TtW part of the calculation a verification and certification scheme (still to be draw-up) can still be used to eventually demonstrate better performances.

Example 2

A given ship, with a dual fuel diesel internal combustion engine (for LFO and LNG) and an internal combustion engine as auxiliary (for MDO), consumes over a year period the following quantities of three fuels:

LFO	3884,24
LNG (fossil origin)	5685,87
MDO	188

From Table 1 we have the following values for the three fuels:

Pathway name	LCV $\left[\frac{MJ}{g}\right]$	$CO_{2eq\,WtT}$ $\left[\frac{gCO2eq}{MJ}\right]$	Energy Converter Class	$C_{f\,CO_2}$ $\left[\frac{gCO2}{gFuel}\right]$	$C_{f\,CH_4}$ $\left[\frac{gCH_4}{gFuel}\right]$	$C_{f\,N_2O}$ $\left[\frac{gN_2O}{gFuel}\right]$	C_{slip} As % of the mass of the fuel used by the engine
LFO ISO 8217 Grades RMA to RMD	0,041	13,2	ALL ICEs	3,151 MEPC245 (66)	0,00005	0,00018	
MGO ISO 8217 Grades DMX to DMB	0,0427	14,4	ALL ICEs	3,206 MEPC245 (66)	0,00005	0,00018	
LNG from fossil feedstock	0,0491	18,5	LNG Otto (dual fuel medium speed)	2,755 MEPC245 (66)	0,0512 TBM	0,00011 TBM	3,1
			LNG Otto (dual fuel slow speed)				1,7
			LNG Diesel (dual fuel slow speed)				0,2

STEP 1 - For the WtT the following calculations are made:

- 3884,24 Tons of LFO = 3884,24 x 10^{6} [g of LFO]
- 5685,87 Tons of LNG = 5685,87 x 10^{6} [g of LNG]
- 188,00 Tons of MDO = 188,00 x 10^{6} [g of MDO]

The gCO_{2eq} per g of fuel is given for the two fuels by:

- for LFO 13,2 [gCO_{2eq}/MJ] x 0,041 [LVC MJ/g] = 0,5412 [gCO_{2eq}/gFuel]
- for LNG 18,5 [gCO_{2eq}/MJ] x 0,0491 [LVC MJ/g] = 0,90835 [gCO_{2eq}/gFuel]
- for MDO 14,3 [gCO_{2eq}/MJ] x 0,0427 [LVC MJ/g] = 0,6148 [gCO_{2eq}/gFuel]

The amount of g of CO_{2eq} associated to the mass of the two fuels delivered to the ship is:

- for LFO 3884,24 x 10^6 [g of LFO] x 0,5412 [gCO_{2eq}/gFuel] = 2102,15 x 10^6 [gCO_{2eq}]
- for LNG 5685,87 x 10^6 [g of LFO] x 0,90835 [gCO_{2eq}/gFuel] = 5164,76 x 10^6 [gCO_{2eq}]
- for MGO 188,00 x 10^6 [g of MGO] x 0,6148 [gCO_{2eq}/gFuel] = 115,58 x 10^6 [gCO_{2eq}]

The total amount of gCO_{2eq} for the WtT is then:

- 2102,15 x 10^6 [gCO_{2eq}] + 5164,76 x 10^6 [gCO_{2eq}] + 115,58 x 10^6 [gCO_{2eq}] =

7382,4931 x 10^6 [gCO_{2eq}]

STEP 2 - For the TtW the following calculations are made:

For the two liquid fossil fuel (LFO and MDO) the fugitive emissions are zero (i.e. C_{slip} is zero). Therefore setting C_{slip} = 0, the TtW terms of Equation (1) for LFO and MDO we have:

$$\sum_{i}^{\boldsymbol{n}\,fuel} \sum_{j}^{\boldsymbol{m}\,engine} M_{ij} \times [\quad (1-0) \times \left(CO_{2eq,TtW} \right) + \left(0 \times GWP_{CH_4} \right)]$$

hence, for the two fuels:

$$M_{LFO,ICE} \times CO_{2eq,TtW} + M_{MGO,ICE} \times CO_{2eq,TtW}$$

$CO_{2eq,TtW}$ is calculated as prescribed in Equation (2) making use of the C_f factors for the two fuels and of the GWP_{100} as in Table 2.

That for the two fuels becomes:

- for LFO $CO_{2eq,TtW} = 3{,}151 \times 1 + 0{,}00005 \times 28 + 0{,}00018 \times 265 = 3{,}2001$ [gCO_{2eq}/gFuel]
- for MGO $CO_{2eq,TtW} = 3{,}206 \times 1 + 0{,}00005 \times 28 + 0{,}00018 \times 265 = 3{,}2551$ [gCO_{2eq}/gFuel]

The amount of g of CO_{2eq} contained in the mass of the two fuels consumed by the ship is:

- for LFO 3884,24 x 10^6 [g of LFO] x 3,2001 [gCO_{2eq}/gFuel] = 12429,9564 x 10^6 [gCO_{2eq}]
- for MDO 188,00 x 10^6 [g of MDO] x 3,2551 [gCO_{2eq}/gFuel] = 611,9588 x 10^6 [gCO_{2eq}]

For LNG, because C_{slip} is not zero for this type of fuel/installation, the value of C_{slip} corresponding to the specific installation should be chosen. In this case because the energy converter is a diesel engine, from Table 1, Column 9 value of 0,2% in mass of fuel, is used. The TtW term of Equation (1) for LNG becomes:

$$\sum_{i}^{\boldsymbol{n}\,fuel} \sum_{j}^{\boldsymbol{m}\,engine} M_{ij} \times [\quad (1-0{,}2\%) \times \left(CO_{2eq,TtW} \right) + \left(0{,}2\% \times GWP_{CH_4} \right)]$$

where $CO_{2eq,TtW}$ for LNG is:

- for LNG $CO_{2eq,TtW}$ = 2,755x1 + 0x28 + 0,00011x265 = 2,784

hence:

5685,87 x 10^6 (1-0,002)x(2,784) + 5685,87 x 10^6 (0,02x28) = 16116,2119 x 10^6 [gCO_{2eq}]

The total amount of gCO_{2eq} for the TtW is then:

- 12429,9564 x 10^-6 [gCO_{2eq}] + 611,9588 x 10^-6 [gCO_{2eq}] +16116,2119 x 10^-6 [gCO_{2eq}] = 29158,1271 x 10^-6 [gCO_{2eq}]

STEP 3 – Total amount of gCO_{2eq} emitted by the ship over the reference period:

WtT mass of CO_{2eq}	WtT mass of CO_{2eq}	WtW mass of CO_{2eq}
7382,4931 x 10^-6 [gCO_{2eq}]	29158,1271 x 10^-6 [gCO_{2eq}]	**36540,6202 x 10^-6 [gCO_{2eq}]**

Brief discussion: for this case,
For the LFO and MDO the treatment is made as *per* in Example 1. For LNG because C_{slip} is not zero the value in Table 1 Column 9 for diesel engine is used. Value of Column 9 is used in this case in alternative to the one in Column 7. Indeed in the calculation of the LNG $CO_{2eq,TtW}$ the CH_4 term is set at zero; therefore CH_4 is only considered once within the 0,2% mass term as combination of all fugitive emissions and unburned CH_4.

Verification and Certification

The following table summarise the Verification and Certification needs and gaps.

Table 2 – Verification and Certification map

Fuel Class	WtT	TtW
Fossil	Default values shall be used as provided in Table 1.	MEPC245 (66) CO_2 carbon factors shall be used for fuels for which such factor is provided For all other emissions factors, default values can be used as provided in Table 1, alternatively Certified values by mean of laboratory testing or direct emissions measurements (certification scheme to be defined).
Sustainable Renewable Fuels (Bio Liquids, Bio Gases, e-Fuels)	CO_{2eq} values as provided in Table 1 can be used, alternatively approved certification scheme can be used (existing certification scheme shall be used).	Emissions factors, default values can be used as provided in Table 1 of this Regulation, alternatively Certified values by mean of laboratory testing or direct emissions measurements (certification scheme to be defined).
Others (including electricity)	CO_{2eq} values as provided in Table 1 can be used, alternatively	Emissions factors, default values can be used as provided in Table 1, alternatively

	approved certification scheme can be used (existing certification scheme shall be used).	Certified values by mean of laboratory testing or direct emissions measurements (certification scheme to be defined).

Blended fuels should be included in the certification schemes and relevant values determined in proportion of the mass of each fuel part of the blend.

Annex II

Possible Structure of the *Life cycle GHG Guidelines for maritime fuels*.

1. SCOPE

2. APPLICATION

3. DEFINITIONS

4. MODEL FOR THE CALCULATION OF WtW GHG EMISSIONS

5. WtT METHODOLOGY and EVALUATION OF UPSTREAM GHG EMISSIONS
    - 5.1 WtT Methodology
    - 5.2 [Preliminary] Fuels Pathways
    - 5.3 Sustainability Criteria
    - 5.4 Quantitative Evaluation

6. TtW METHODOLOGY and EVALUATION OF DOWNSTREAM GHG EMISSIONS
    - 6.1 TtW Methodology
    - 6.2 GHG emissions factors
    - 6.3 Fugitive emissions
    - 6.4 Quantitative Evaluation

7. CERTIFICATION
    - 7.1 WtT Certification Schemes (Which Certification Scheme for which Pathway)
    - 7.2 TtW Certification Methodology

8. DATA PRESENTATION FORMAT

9. CRITERIA FOR THE INCLUSION OF NEW FUELS OR NEW FUEL PATHWAY
    - 9.1 WtT (Ability to establish computable pathways)
    - 9.2 TtW (Ability to deliver emissions factors)

10. WORKOUT EXAMPLES

Appendix I – DEFAULT VALUES FOR RELEVANT QUANTITIES

Appendix II – LIST OF APPROVED CERTIFICATION SCHEMES

Annex III

Possible ToRs for the ISWG-GHG

Using document MEPC77/7/X as basis:

1. Identify main relevant fuels and their pathways (to establish their quantitative emissions),
2. Establish the methodology for the WtT estimation of CO_{2eq},
3. Establish the methodology for the TtW estimation of emissions factors and CO_{2eq},
4. Define sustainability criteria for fuels,
5. Review the default value for the relevant fuels for both WtT and TtW,
6. Define eligibility criteria for existing certification schemes for the WtT,
7. Develop draft Guidelines for verification and certification for TtW,
8. Develop draft Guidelines for the calculation of the overall emissions (in mass of $CO2_{eq}$)
9. Report to MEPC 79