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From:	General Secretariat of the Council
To:	Permanent Representatives Committee (Part 1)
No. Cion doc.:	10585/21
No. prev. doc.:	10638/21
Subject:	Draft submission by Member States and the Commission to the 9th session of the International Maritime Organization's Intersessional Meeting of the Working Group on Reduction of GHG Emissions from Ships 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 - IMO/ISWG-GHG 9 (15 – 17 September 2021)

– *Endorsement*

I. INTRODUCTION

1. On 5 July 2021, the Commission transmitted to the Council a Staff Working Document containing a draft submission initially addressed to the 77th session of the International Maritime Organization's Marine Environment Protection Committee (MEPC 77) of the International Maritime Organization (IMO) 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.
2. It was subsequently clarified by the Commission that the above mentioned draft submission should be addressed to the 9th session of the IMO's Intersessional Meeting of the Working Group on Reduction of GHG Emissions from Ships (ISWG-GHG 9) which will be held on

15-17 September 2021. The deadline for transmitting the draft submission to the IMO Secretariat is 3 August 2021.

II. WORK WITHIN THE COUNCIL

3. The draft submission was presented by the Commission at an informal videoconference of the members of the Shipping Working Party on 2 July 2021, based on an informal advance copy. The submission was further examined at two informal videoconferences of the members of the working party on 7 and 15 July 2021. At that last meeting, in the light of delegations' additional comments and remarks, the Presidency made on-spot suggestions and proposed to prepare a revised compromise text of the submission, in view of reaching consensus. The revised compromise text, as reflected in the Annex to the present note, was further subject to an informal silence procedure. This latter was launched on 16 July 2021 and ended on 19 July 2021, at noon. No objections were raised.
4. The Commission holds the view that the substance of the draft Union submission falls under EU exclusive competence as it is largely covered by EU legislation. However, it is the understanding of the Shipping Working Party that the submission falls under exclusive Union competence only to the extent that its subject matter is covered by EU legislation. To the extent that the matters covered by the submission are not largely covered by EU legislation, the understanding is that the submission is made by the Member States under shared competence and that this submission should not be construed as exercising shared Union competence.¹
5. Furthermore, there is no agreement on who should submit the draft submission. The Commission maintains the view that the draft submission should be made by "the European Commission on behalf of the European Union", while the Member States consider that it should be made by the Member States and the European Commission.
6. Given the urgency and importance of the matter, it was agreed at working party level to propose to transmit the submission in the name of the Member States and the European Commission, while taking good note of the position of the Commission.

¹ Please note that this is currently a matter of dispute in Case C-161/20, *Commission v Council (Organisation maritime internationale)*.

III. CONCLUSION

7. In the light of the above, the Permanent Representatives Committee is invited to endorse the text of the draft submission in the annex, with a view to its transmission by the Presidency to the International Maritime Organization by 3 August 2021.
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INTERSESSIONAL MEETING OF THE
WORKING GROUP ON REDUCTION OF GHG
EMISSIONS FROM SHIPS
9th session
Agenda item 2

ISWG-GHG 9/XX/XX
2 August 2021
ENGLISH ONLY
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 Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark,
Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania,
Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain,
Sweden and the European Commission**

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 21

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 as 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

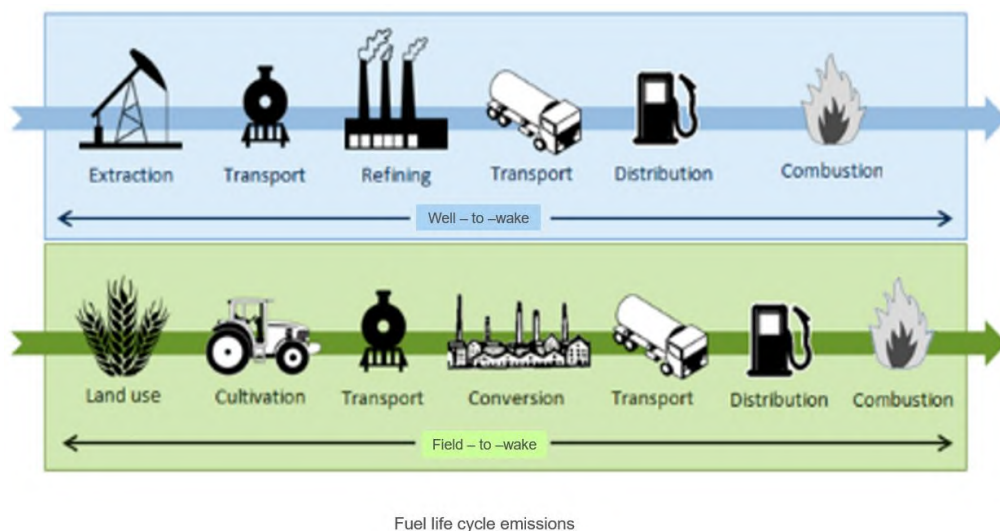
sustainable alternative low-carbon and zero-carbon fuels and thus the transition to net zero-GHG-emission ships. Net zero CO_{2eq} GHG emissions are the goal. Therefore, a methodology needs to be established on a well to wake basis. Shipping has to reach full decarbonisation as soon as possible to support 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 Member States of the European Union and the European Commission 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 Intergovernmental Panel on Climate Change (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/Well-to-Wake 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 considering that shipping accounts the emissions produced for the combustion of the fuel used but not for the production of these fuels. The figure below depicts two possible pathways for fossil and bio fuels life cycle.



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 In ISWG-GHG 7/5/8 Australia et al, proposed to introduce a fuel life cycle label (FLL) which broadly categorizes a fuel based on carbon source and other sustainability aspects and determines if the CO₂ emissions in a fuel labelling simplified LCA approach. Any approach based on a fuel labelling should rely on a solid internationally accepted methodology, in order to capture properly the numerous ways in which sustainable fuels can be produced. This submission provides such a method.

7 A LCA - WtW methodology is important to support the effective uptake of the most climate-friendly and sustainable alternative fuels, in the context of the discussion on mid- and long-term measures, for which this methodology is a pre-requisite. As such, the LCA on a WtW basis including sustainability criteria is a methodology independent from any measure. (Fig.2).

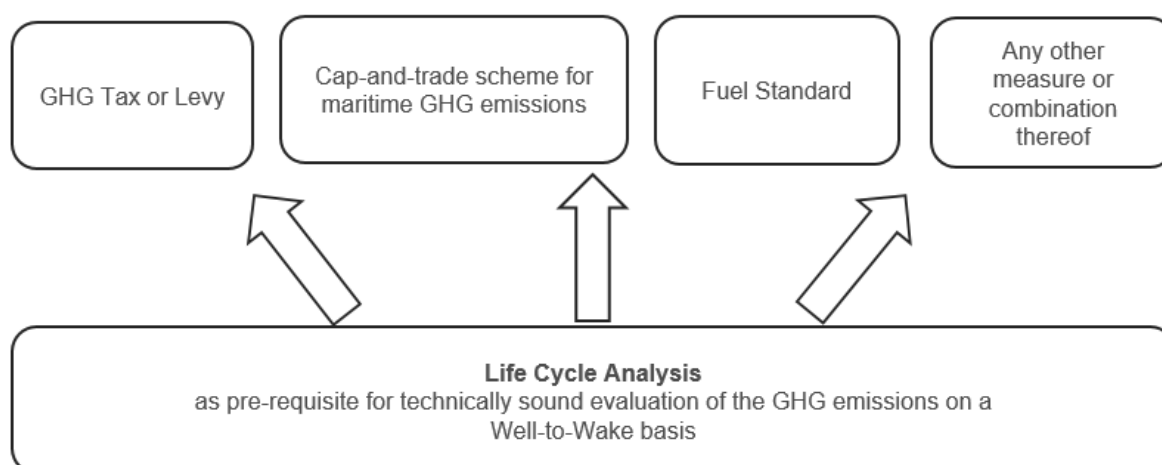


Fig. 2 LCA independent of the incentive scheme IMO will choose on

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

$$GHGe [gCO_{2eq}] = WtT (fuel \text{ and electricity}) + TtW (fuel \text{ consumed including fugitive emissions}) \quad (1)$$

LCA GHG emissions	Well to Tank	Tank to Wake
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<i>GHGe =</i>			<i>WtT (fuels and electricity) +</i>			<i>TtW(including fugitive emissions)</i>		
CO ₂	CH ₄	N ₂ O	CO ₂	CH ₄	N ₂ O	CO ₂	CH ₄	N ₂ O
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 II.

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

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

10 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;
- Consider the need of relevant certification schemes;
- Seek a consistent approach for all transport means

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

11 The methodology presented in Annex II as basis for discussion includes 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.

12 The methodology requires information on a limited number of factors, as further highlighted in Annex II. 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.

- 13 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 relevant GHG's (namely CO₂, CH₄, N₂O);
 - 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 II.

IMO instruments - Implications

14 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, by 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 (foreseen for 2023), should take into consideration the result of the technical evaluation, when setting the targets.

15 Collection and reporting of ship fuel oil consumption data (MARPOL Annex VI, Regulation 22A², 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.

16 The Bunker Delivery Note³ might be considered to include the following: 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 [gCO_{2eq}/MJ of fuel]. The certification scheme applied to the specific fuel pathway should also be specified on the BDN; in the absence of a certified value by a certification scheme, the agreed default value should be used.

17 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, in the co-sponsors opinion.

18 The NO_x Technical Code should be taken into consideration in relation to the Guidelines for verification and certification for the Tank-to-Wake part for ICE energy consumers, e.g. for taking into account fugitive emissions like methane slip within dedicated test cycles.

² Regulation 22A will become Regulation 27 after adoption of the latest MARPOL amendments

³ MARPOL Annex VI, Regulation 18 and Appendix V.

Proposed way forward

19 The LCA and the suggested methodology would require an expert debate and thorough technical review. The ISWG-GHG could consider establishing of a Correspondence Group, as appropriate.

20 Member States and organizations should be encouraged to include relevant experts in their delegations. The work could be taken-up in the ISWG-GHG by following the simple structure in Fig.7 and further develop it in a Correspondence Group. The work in Stream 1 (WtT) could address the development of core-LCA, sustainability criteria, accounting and reporting, as well as certification schemes.

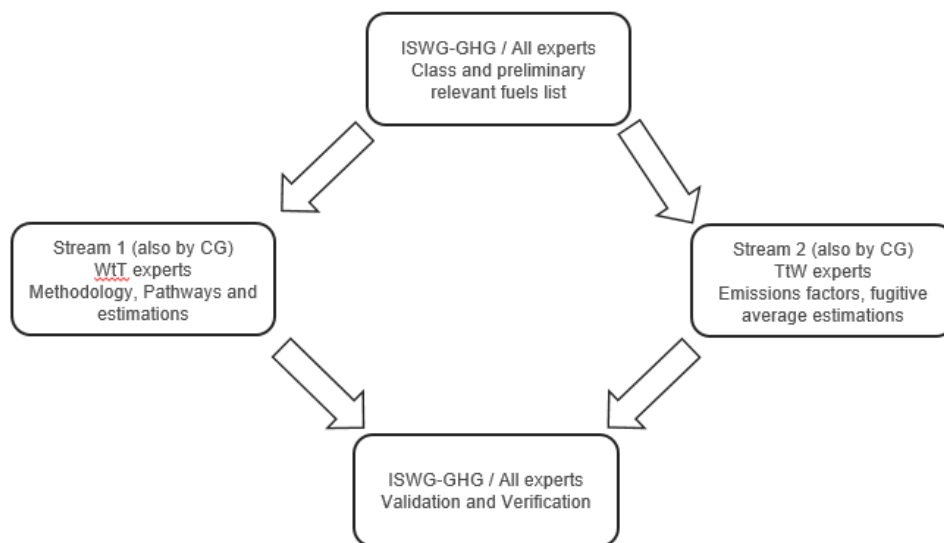


Fig.7 - Work-flow

The Guidelines may be prepared in two sessions of the ISWG-GHG.

Proposals

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

Action requested of the Working Group

22 The Group is invited to consider the information and proposals provided in this document, and take action, as appropriate.

Annex I

Further Considerations on the LCA Well-to-Wake methodology

1. 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 (such as aviation or road transport) have already and since long opted for a LCA approach for the evaluation of the GHG impact of their activities. As an example, at European level, the Renewable Energy Directive -RED/RED II-⁴ and the Fuel Quality Directive -FQD-⁵ 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.
2. 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) available at international level. Independent certification schemes for fuel pathway production will play a key function in the future. With this, the pre-defined default values need to be sufficiently high to allow a certification scheme can proof a benefit against the default. However, actual values may be difficult to control in such an international market and therefore may pose a higher risk of mistakes or even 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 ...'.
3. 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. This would even lead to incentivise a fuel that may – from a holistic life cycle perspective – not be sustainable at all, e.g. hydrogen produced by fossil basis.
4. 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 – c.f. box below para 12)
 - the uncertainty in the data (e.g. in case the fuel is not yet commercially produced)
5. 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

⁴ 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.

⁵ 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

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)⁶.

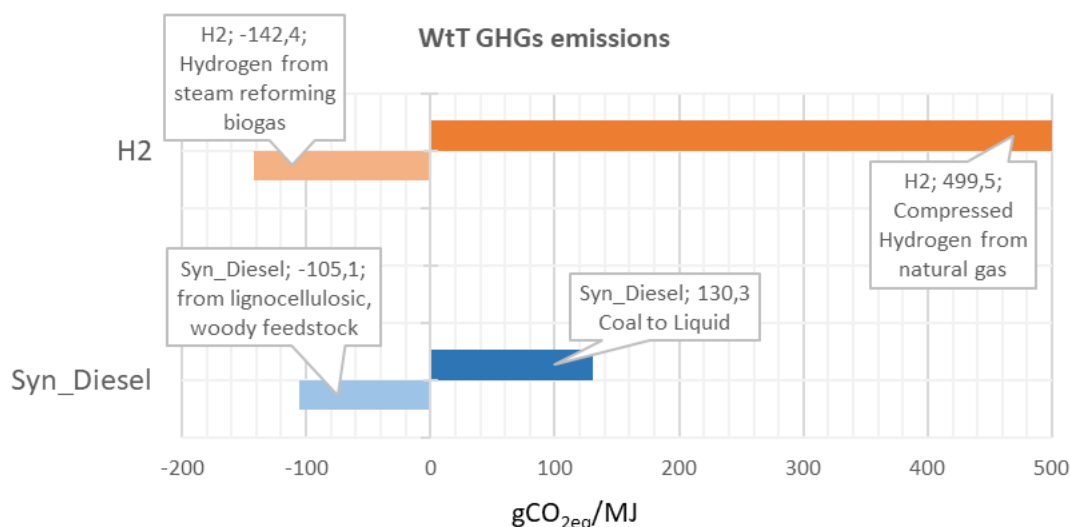


Fig.2 - Example - Well-to-Tank GHGs emissions for H2 and Syn_Diesel for certain pathways (derived from the JEC Study)

- As another example figures 3 and 4 below show some of the possible production pathways for methanol as fuel (in fig.3) and the range of its WtT emissions (in fig.4). In particular in fig.3 several production pathways for methanol are identified and breakdown in elementary steps. On the left of figure the feedstock are identified as inputs (Coal, Natural Gas, Waste Wood,, etc.); on the right of the figure each specific methanol is labelled by an acronym on the basis of the elementary steps the feedstock has been processed (KOME1, GPME1b, etc.). In fig.4, each specific methanol pathway (KOME1, GPME1b, etc.) is compared in terms of its CO_{2eq} emissions, where 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).

⁶ JEC Well-to-Tank Report v5 – EUR 30269 EN – Joint Research Centre of the European Commission

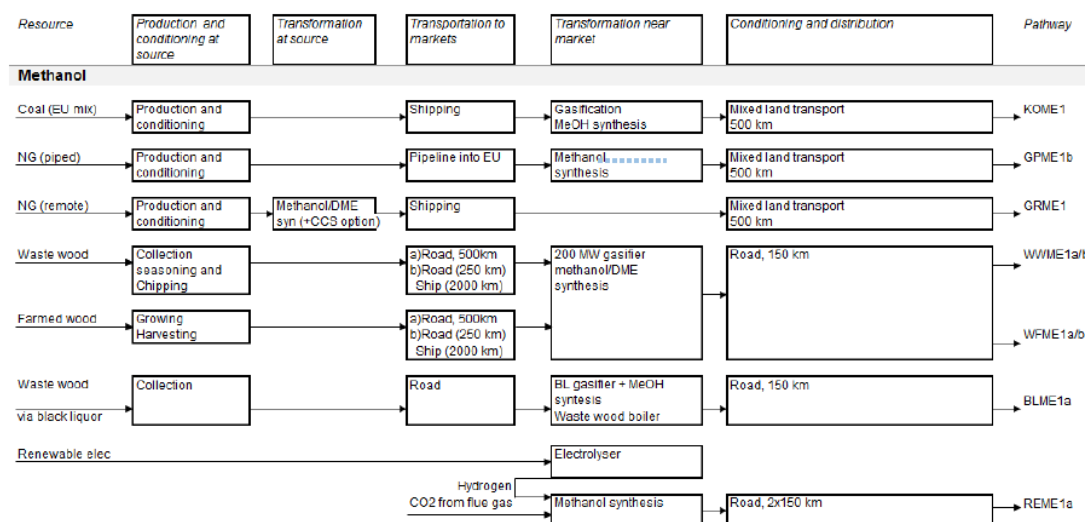


Fig. 3 - Example - Methanol WtT possible production pathways (pathways' codes on the right) - (derived from the JEC Study)

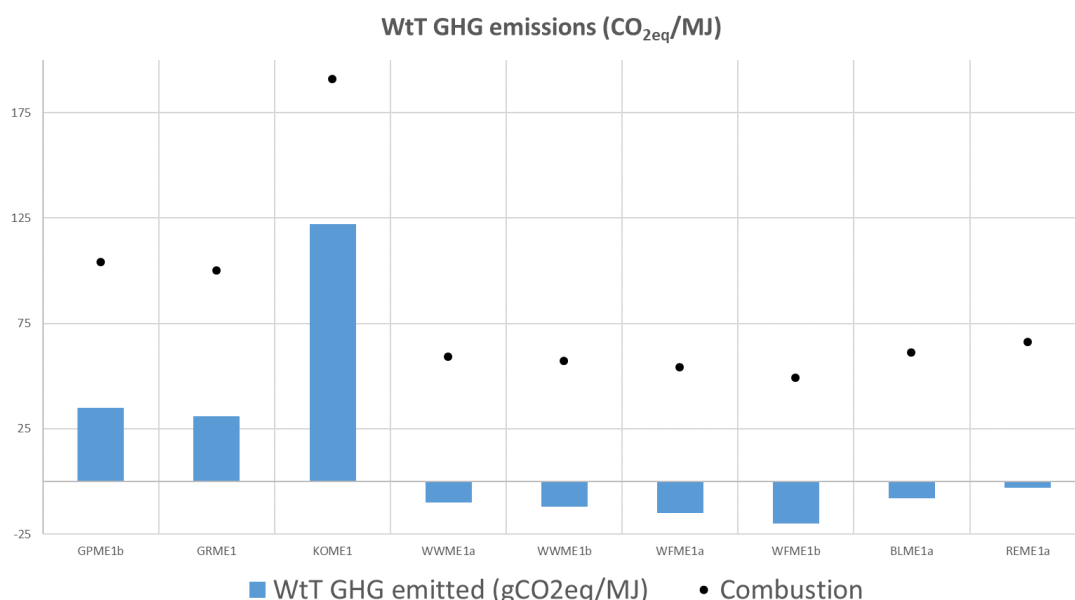


Fig. 4- Example - WtT GHGs emissions for the identified pathways for Methanol - (derived from the JEC Study)

- For the purpose of the WtW GHG emissions, gases with a greenhouse effect considered having relevant Global Warming Potential (GWP) are CO₂, CH₄ and N₂O. In line with existing provisions, defined in many other legislative acts for transport sector (such as REDII, FQD, ICAO/CORSIA, etc.), the GWP over 100 years is considered for the purpose of the maritime WtW⁷. 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 part⁸. 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 three GHGs mentioned above each multiplied by the IPCCG GWP100 AR5 multipliers as per the table below (and in Annex II). The GHG impact is then expressed in gCO_{2eq}/MJ for the purpose of easy comparisons with existing systems.

⁷ 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.

⁸ Black Carbon can be introduced in the methodology as the matter will be deemed mature.

GHG	GWP 100 – IPCC AR5
CO ₂	1
CH ₄	28
N ₂ O	265

Well-to-Tank Emissions

8. 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 handbook⁹) 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.
9. 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:
 - i. Goal and Scope Definition,
 - ii. Inventory Analysis,
 - iii. Impact Assessment with a common underlying interpretation layer. In each of these phases, choices are made to achieve a coherent and
 - iv. Consistent evaluation of the GHG emissions.
10. 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 A-LCA, 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. The attributional approach A-LCA, tends 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.
11. Other essential elements of the WtT GHG emissions evaluation should be considered;

⁹ <https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf>

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 co-products, deals with the accounting of co- and by-products generated along fuel production. Some preliminary definitions and principles are presented for discussion.

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](#)

12. In order to achieve coherent policies for decarbonization, the evaluation of fuel stream emissions and the methodology considered at international level should be consistent, as far as practicable, for all transport modes and with their implementation at national levels.
13. 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
14. 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.

15. 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.).
16. 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.
17. 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)
	LSFO
	VLSFO (0.5% sulphur limit)
	ULSFO(0.1% sulphur limit)
	LFO
	MDO/MGO
	LNG
	LPG
	Methane
	H2 (from natural gas / grey and blue)
	Methanol (from natural gas)
	Ethane
	NH ₃
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

18. When biofuels, biomass fuels, bioliquid fuels, and more in general for all fuels, produced from food and feed crops are used, specific sustainability principles and criteria have to be

adopted, such as criteria for land with high biodiversity value, high carbon stock and indirect land-use change (ILUC). On the basis of such sustainability criteria the WtT-GHG emissions figures for GHG emissions should be established and a minimum GHG reduction effect should be considered. 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. When food and feed crops are used to produce biofuels, for use in maritime transport, their use should be limited to strict sustainability criteria. All relevant sustainability criteria must also be defined for e-fuels.

19. 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 calculation of the GHG are available 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.
20. The methodology should also take into consideration the advent of the increasing introduction of battery packs 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 and is part of the overall energy consumption of a ship. 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) where the ship is being re-charged (via OPS).
21. 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.
22. 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 provided in the Bunker Delivery Note.
23. The proposed methodology (see Annex II, Table 1) suggests the use of default values for fossil 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 types of fuels can be subject to certification (see Annex II Table 2).

24. 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. Such certification schemes are already applied to other modes of transport.

25. These certification schemes are applicable to sustainable alternative fuels for the WtT part. For fossil fuels, the default values as presented in Annex II should be used, only after careful consideration so that they are consistently applied for the shipping industry allowing suitable benchmarking.
26. The IMO should consider certification schemes, to certify that the fuels¹⁰ fulfil the established principles and to provide data on CO_{2eq} emissions for the relevant fuel pathways in their WtT part.
27. The methodology should allow to include any new fuel or even a new fuel category at any point in time.

Tank-to-Wake Emissions

28. 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.
29. The same GHG emission types as with the upstream emissions (WtT) should be accounted for the downstream emissions (TtW), namely: CO₂, CH₄ and N₂O. 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.
30. 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 N₂O emissions should be also accounted.
31. 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 transfer on-board or by crankcase venting). 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 N₂O may be formed

¹⁰ All fuels, except fossil fuels for which the default values should be used.

(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.

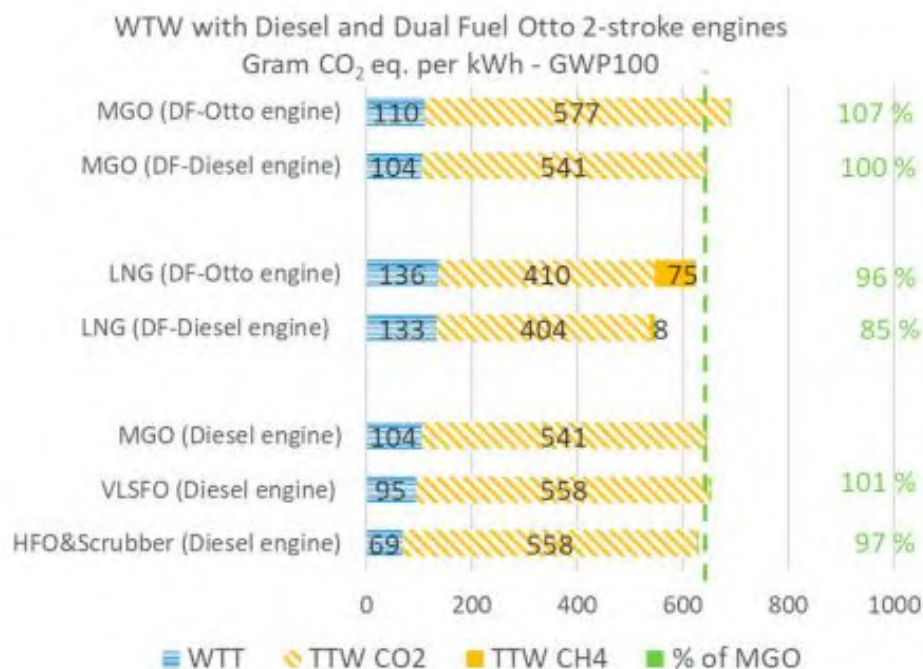


Fig. 6 - Examples of different WtW figures for different fuels and energy converter technology, Lindstad *et al.*

32. 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.
33. 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 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 CH₄ and N₂O. 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.
34. 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. N₂O emissions for ammonia.
35. The WtW methodology should be framed consistently with the precautionary principle and

stringent sustainability criteria. The increase of alternative low-carbon and zero carbon fuels may consider the limits of sustainable biomass available. This approach reflects and respects the full spectrum of sustainable fuel options.

Annex II

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 and it is based on the following notional formulation (see paragraph 15):

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

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

$GHG \text{ emission} =$	$\sum_i^{n \text{ fuel}} M_i \times CO_{2eq \text{ WtT},i} \times LCV_i + \sum_k^c E_k \times CO_{2eq \text{ electricity},k}$	$+ \sum_i^{n \text{ fuel}} \sum_j^{m \text{ consumer}} M_{ij} \times [(1 - C_{slip \ j}) \times (CO_{2eq \text{ TtW},i}) + (C_{slip \ j} \times GWP_{CH_4})]$
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:

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

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)
$CO_{2eq \text{ WtT},i}$	are the WtT GHG emissions in gCO _{2eq} /MJ for each specific fuel, calculated according an agreed methodology (such as RED II)
$CO_{2eq \text{ TtW},i}$	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 ₂ O
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.
$CO_{2eq\ electricity,k}$	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 may 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.

CO₂ credits generated for CO₂ 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, $\text{gCO}_{2\text{eq}}/\text{MJ}^{11}$ 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 [$\text{gCO}_{2\text{eq}}/\text{MJ}$] of the electricity taking into account regional differences where relevant.

Emissions associated with ship battery charging from power supply need will need to be considered.

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 certification schemes were used, the fuel pathway in BDN should include the reference to the certification scheme used, the upstream emissions in $\text{CO}_{2\text{eq}}$ [$\text{gCO}_{2\text{eq}}/\text{MJ}$], 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) [$\text{gCO}_2/\text{gFuel}$]¹
- LCV [MJ/g]

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

Preferably the BDN should also provide information about the Certification Scheme applied for the determination of the upstream emissions in $\text{CO}_{2\text{eq}}$ [$\text{gCO}_{2\text{eq}}/\text{MJ}$].

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

¹¹ Or it can be provided in kWh and transformed in MJ by multiplied by 3.6

- 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 (CO₂, CH₄ and N₂O) 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 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 (CO₂) 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 CH₄ and N₂O 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 CO₂ 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 CO₂ emissions factors should be established based on their carbon content.

CH₄ 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.

N₂O 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 H₂ 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, depending on the onboard handling and/or energy converter technology.

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).
Therefore, no values are contained in Column 7 for LNG internal combustion engines.

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).
It is however anticipated that this issue needs to be further discussed

Some conversions factors

For total combustion:

- 1 kg of a fuel with C% carbon emits: $1 \times C\% / 100 / 12 \times 44 = (0.0367 \times C\%)$ kg of CO₂;
- 1 MJ of a fuel with λ MJ/kg (LCV) and C% carbon emits: $1 / \lambda \times C\% / 100 / 12 \times 44 = (0.0367 / \lambda \times C\%)$ 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 [$\frac{MJ}{g}$]	CO _{2eq} WtT [$\frac{gCO_{2eq}}{MJ}$]	Energy Converter Class	C _{f CO₂} [$\frac{gCO_2}{gFuel}$]	C _{f CH₄} [$\frac{gCH_4}{gFuel}$]	C _{f N₂O} [$\frac{gN_2O}{gFuel}$]	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 Gas Turbine Steam Turbines and Boilers Aux Engines	3,114 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	-
	LSFO [better HFO>0,5]	0,0405	13,2, crude 13,7 blend Thinkstep	ALL ICEs	3,114	0,00005 TBM	0,00018 TBM	-

1	2	3	4	5	6	7	8	9
	WtT				TtW			
				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 2 nd GHG Study	ALL ICEs	3,114 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 2020 17,7 Sphera	LNG Otto (dual fuel medium speed)	2,75 MEPC245 (66) MRV Regulation	[0]	0,00011 TBM	3,1
				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 Butane 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	0,044	-20,7 RED II	ALL ICEs	3,115	0,00005 TBM	0,00018 TBM	-

1	2	3	4	5	6	7	8	9
	WtT			TtW				
	mix							
	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]	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 RES D1 (from RES)	ALL ICEs	3,206	0,00005 TBM	0,00018 TBM	-
	e-methanol EU electricity mix	0,0199	-67,1 RED REME1a (from RES)	All ICEs	1,375 MEPC245 (66) MRV Regulation	0,00005 TBM	0,00018 TBM	-
	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]	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 ₂ O	265

Table 2

Calculation Example(s)

The following examples show the application of Equation (1) and Equation (2), to specific cases.

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 $\left[\frac{MJ}{g}\right]$	$CO_{2eq\ WtT}$ $\left[\frac{gCO_{2eq}}{MJ}\right]$	Energy Converter Class	$C_{f\ CO_2}$ $\left[\frac{gCO_2}{gFuel}\right]$	$C_{f\ CH_4}$ $\left[\frac{gCH_4}{gFuel}\right]$	$C_{f\ N_2O}$ $\left[\frac{gN_2O}{gFuel}\right]$
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 = $5879,84 \times 10^6$ [g of LFO]
- 1226,26 Tons of MGO = $1226,26 \times 10^6$ [g of MGO]

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

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

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

- for LFO $13,2$ [gCO_{2eq}/MJ] \times 0,041 [LVC MJ/g] = $0,5412$ [$gCO_{2eq}/gFuel$]
- for MGO $14,3$ [gCO_{2eq}/MJ] \times 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 $5879,84 \times 10^6$ [g of LFO] \times $0,5412$ [$gCO_{2eq}/gFuel$] = $3182,16 \times 10^6$ [gCO_{2eq}]
- for MGO $1226,26 \times 10^6$ [g of MGO] \times $0,6148$ [$gCO_{2eq}/gFuel$] = $754,01 \times 10^6$ [gCO_{2eq}]

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

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

$$+ \sum_i^{n\ fuel} \sum_j^{m\ engine} M_{ij} \times [(1 - 0) \times (CO_{2eq,TtW}) + (0 \times GWP_{CH_4})]$$

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 $5879,84 \times 10^6$ [g of LFO] $\times 3,2001$ [gCO_{2eq}/gFuel] = $18816,0716 \times 10^6$ [gCO_{2eq}]

- for MGO $1226,26 \times 10^6$ [g of MGO] $\times 3,2551$ [gCO_{2eq}/gFuel] = $3991,599 \times 10^6$ [gCO_{2eq}]

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

- $18816,0716 \times 10^6$ [gCO_{2eq}] + $3991,599 \times 10^6$ [gCO_{2eq}] = $22\,807,67 \times 10^6$ [gCO_{2eq}]

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

WtT mass of CO _{2eq}	TtW mass of CO _{2eq}	WtW mass of CO _{2eq}
$3936,17 \times 10^6$ [gCO _{2eq}]	$22\,807,67 \times 10^6$ [gCO _{2eq}]	$26743,84 \times 10^6$ [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 $\left[\frac{gCO_{2eq}}{MJ}\right]$	Energy Converter Class	C _f CO ₂ $\left[\frac{gCO_2}{gFuel}\right]$	C _f CH ₄ $\left[\frac{gCH_4}{gFuel}\right]$	C _f N ₂ O $\left[\frac{gN_2O}{gFuel}\right]$	C _{slip} As % of the mass of the fuel used by the engine
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LFO ISO 8217 Grades RMA to RMD	0,041	13,2	ALL ICES	3,151 MEPC245 (66)	0,00005	0,00018	
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MGO ISO 8217 Grades DMX to DMB	0,0427	14,4	ALL ICES	3,206 MEPC245 (66)	0,00005	0,00018	
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LNG from fossil feedstock	0,0491	18,5	LNG Otto (dual fuel medium speed)	2,755 MEPC245 (66)	[0]	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 = $3884,24 \times 10^6$ [g of LFO]
- 5685,87 Tons of LNG = $5685,87 \times 10^6$ [g of LNG]
- 188,00 Tons of MDO = $188,00 \times 10^6$ [g of MDO]

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

- for LFO $13,2$ [gCO_{2eq}/MJ] $\times 0,041$ [LVC MJ/g] = $0,5412$ [gCO_{2eq}/gFuel]
- for LNG $18,5$ [gCO_{2eq}/MJ] $\times 0,0491$ [LVC MJ/g] = $0,90835$ [gCO_{2eq}/gFuel]
- for MDO $14,3$ [gCO_{2eq}/MJ] $\times 0,0427$ [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 $3884,24 \times 10^6$ [g of LFO] $\times 0,5412$ [gCO_{2eq}/gFuel] = $2102,15 \times 10^6$ [gCO_{2eq}]
- for LNG $5685,87 \times 10^6$ [g of LNG] $\times 0,90835$ [gCO_{2eq}/gFuel] = $5164,76 \times 10^6$ [gCO_{2eq}]
- for MDO $188,00 \times 10^6$ [g of MDO] $\times 0,6148$ [gCO_{2eq}/gFuel] = $115,58 \times 10^6$ [gCO_{2eq}]

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

$$- 2102,15 \times 10^6 \text{ [gCO}_{2eq}\text{]} + 5164,76 \times 10^6 \text{ [gCO}_{2eq}\text{]} + 115,58 \times 10^6 \text{ [gCO}_{2eq}\text{]} =$$

$$7382,4931 \times 10^6 \text{ [gCO}_{2eq}\text{]}$$

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:

$$\sum_i^{n \text{ fuel}} \sum_j^{m \text{ engine}} M_{ij} \times [(1 - 0) \times (CO_{2eq,TtW}) + (0 \times GWP_{CH_4})]$$

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

$$\sum_i^{n \text{ fuel}} \sum_j^{m \text{ engine}} M_{ij} \times [(1 - 0,2\%) \times (CO_{2eq,TtW}) + (0,2\% \times GWP_{CH_4})]$$

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

- for LNG $CO_{2eq,TtW} = 2,755 \times 1 + 0 \times 28 + 0,00011 \times 265 = 2,784$

hence:

$$5685,87 \times 10^6 (1 - 0,002) \times (2,784) + 5685,87 \times 10^6 (0,02 \times 28) = 16116,2119 \times 10^6 \text{ [gCO}_{2eq}\text{]}$$

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

$$- 12429,9564 \times 10^6 \text{ [gCO}_{2eq}\text{]} + 611,9588 \times 10^6 \text{ [gCO}_{2eq}\text{]} + 16116,2119 \times 10^6 \text{ [gCO}_{2eq}\text{]} =$$

$$29158,1271 \times 10^6 \text{ [gCO}_{2\text{eq}}]$$

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

WtT mass of CO _{2eq}	TtW 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 10⁶ [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 CH₄ term is set at zero; therefore CH₄ is only considered once within the 0,2% mass term as combination of all fugitive emissions and unburned CH₄.

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 (<u>certification scheme to be defined</u>).
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 (<u>existing certification scheme shall be used</u>).	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 (<u>certification scheme to be defined</u>).
Others (including electricity)	CO _{2eq} values as provided in Table 1 can be used, alternatively approved certification scheme can be used (<u>existing certification</u>	Emissions factors, default values can be used as provided in Table 1, alternatively Certified values by mean of

scheme shall be used).

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 III

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 IV

Possible ToRs for the ISWG-GHG

Using document ISWG-GHG 9/XX/XX 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 CO_{2eq})
9. Report to MEPC 79]
