IMO Guidelines on Life Cycle GHG Intensity of Marine Fuels

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1. INTRODUCTION

As part of efforts to reduce GHG emissions, the International Maritime Organization (IMO) has focused on improvement of the energy efficiency of individual ships from the viewpoint of satisfying both GHG reduction and economic development and has implemented EEDI (Energy Efficiency Design Index) as a fuel consumption regulation for ship design and SEEMP (Ship Energy Efficiency Management Plan) as a fuel consumption regulation for ship operation since 2013. Furthermore, the IMO adopted Initial IMO GHG Strategy to reduce the GHG emissions from international shipping in 2018. As short-term measures of the GHG Strategy, EEXI (Energy Efficiency Existing Ship Index) and CII (Carbon Intensity Indicator) rating have been also begun since 2023. At MEPC 80 held in July 2023, the GHG Strategy was revised and set an enhanced common ambition to reach net-zero GHG emissions from international shipping by or around, i.e. close to 2050. While the Initial IMO GHG Strategy focused on only GHG emissions from onboard ships, referred to as Tank-to-Wake, as shown in Fig. 1, the revised IMO GHG Strategy considers GHG emissions over the whole life cycle of the fuel used by a ship, referred to as Well-to-Wake. Since GHG emissions from onboard ships are allocated to international shipping, but GHG emitted onshore during the production and distribution of marine fuel are allocated to the country, GHG emission regulations in the IMO such as EEDI/EEXI, DCS and CII ratings have so far focused only on CO_2 emitted from ships. On the other hand, even next generation fuels such as ammonia and hydrogen, e.g. hydrogen produced using electricity generated from fossil fuels, have higher GHG emissions during electricity generation and therefore have higher GHG emissions than heavy fuel oil over their whole life cycle, as shown in Fig. 2. Therefore, in the revised IMO GHG Strategy, the GHG reduction target was also changed the GHG emissions from ships to the whole life cycle of the fuels. In the European Union (EU), the FuelEU Maritime Regulation on the life cycle GHG intensity of marine fuels will come into force in 2025. In addition, the International Civil Aviation Organization (ICAO) adopted a long-term decarbonization target of achieving carbon neutrality across the whole life cycle by 2050 at the 41st ICAO General Assembly. With the IMO changing its GHG reduction target from onboard emissions to whole life cycle emissions, for example, fossil-based LNG fuel will improve onboard emissions by about 18-26% compared to heavy fuel oil, but only by about 10-17% compared to heavy fuel oil over its whole life cycle due to the impact of liquefaction, and the benefits are significantly reduced. In addition, to achieve net-zero emissions over the whole life cycle, all ships need to use blue or green fuel, which is highly dependent on the availability of blue or green fuel.

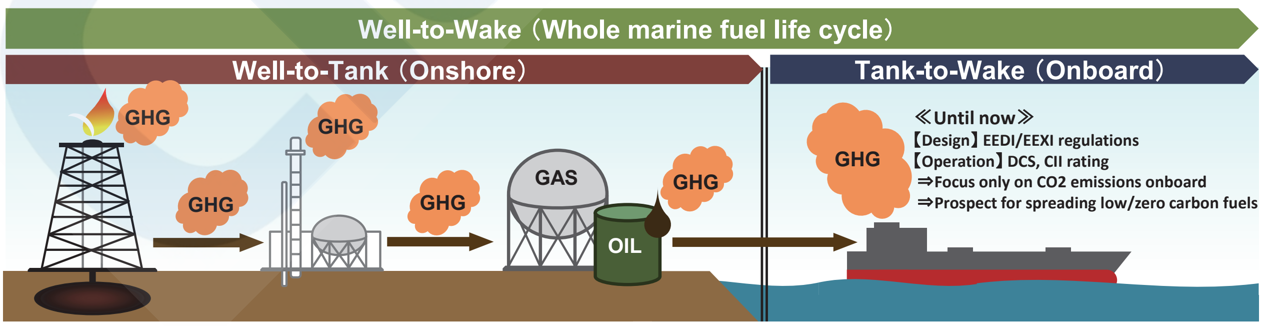

Fig. 1 Diagram of GHG emissions over the life cycle of marine fuels

With the reduction target in the revised IMO Strategy was changed from onboard emissions to the whole life cycle emissions reduction, IMO adopted the "GUIDELINES ON LIFE CYCLE GHG INTENSITY OF MARINE FUELS" [1] at MEPC 80 held in July 2023. On the other hand, as there were many issues in the Guidelines, a Correspondence Group (CG) on LCA of marine

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fuels was established, and discussions in the CG were made on the review of the data collection template for establishing default emission factors, examination of proposed default emission factors, carbon resulting from the LUC (Land-Use Change), methane leakage, credits from use of captured CO_2 as carbon stock to produce synthetic fuels, credits from onboard carbon capture and storage etc. At MEPC 81 held in March 2024, on the basis of the draft amendments [2] proposed by the CG, the amendments (the detailed evaluation method and quantification of parameters for GHG emissions from biofuel production, GHG intensity for electricity used during fuel production, evaluation method for onboard GHG emissions, etc.) to the Guidelines were made and adopted as the "2024 GUIDELINES ON LIFE CYCLE GHG INTENSITY OF MARINE FUELS" [3] (hereafter referred to as the "LCA Guidelines"). In this paper, the LCA Guidelines are explained with up-to-date information.

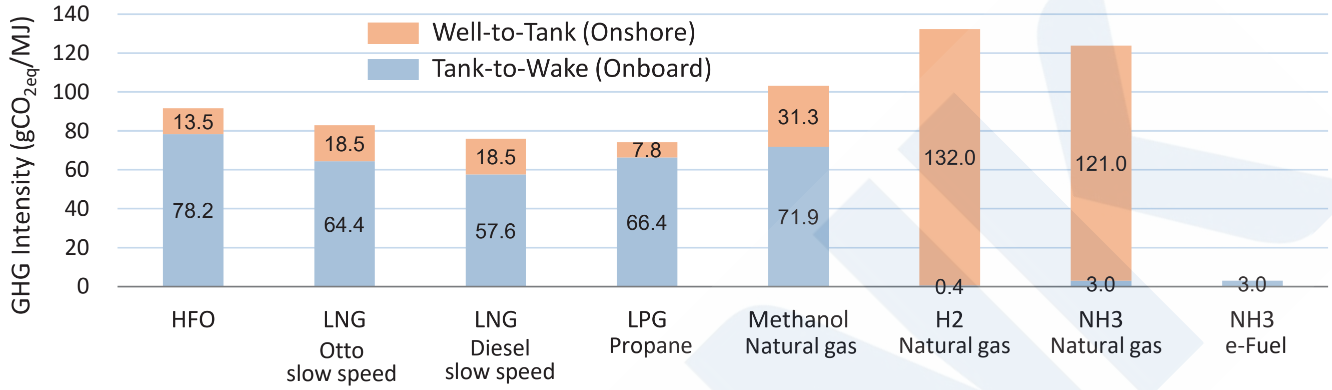

Fig. 2 Examples of GHG intensities of marine fuels [4]

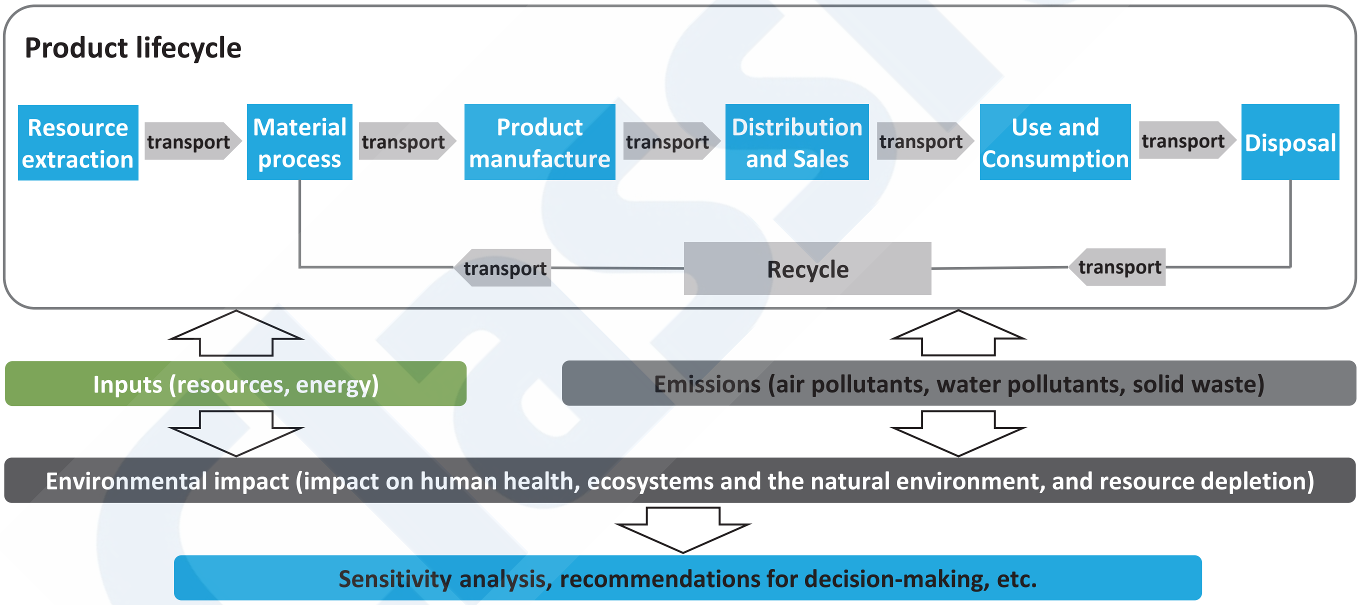

Fig. 3 Concept of Life Cycle Assessment (LCA) [5]

2. GUIDELINES ON LIFE CYCLE GHG INTENSITY OF MARINE FUELS

The LCA Guidelines consist of three main components: (i) a methodology for assessing GHG emissions throughout the whole life cycle of marine fuels from production to transport and onboard use; (ii) a theme/aspect of sustainable marine fuels on a life cycle basis (sustainability criteria); and (iii) verification and certification.

Life cycle assessment (LCA) is generally a method for quantitatively assessing the environmental impact of a product or service over its whole life cycle and has been standardized by the International Organization for Standardization (ISO). The details are as follows.

◇ LCA is a method that can provide scientific and objective evidence to support decision-making for environmental improvement, etc. by quantitatively grasping the amount of resource or energy input and the amount of various emissions at each stage in the whole life cycle of a product or service, from acquisition of feedstock to processing, distribution, use, disposal and recycling (inventory analysis), and further quantifying the various environmental impacts or impacts on resource or energy depletion that these have, etc. as much as possible (impact assessment).

◇ With the increase in the number of cases of life cycle assessment implementation, ISO decided that it would be desirable to establish a common basis for such assessments and standardized the assessment methodology. The methodology for conducting LCA is specified in ISO 14040:2006 and ISO 14044:2006, ISO 14040:2006 specifies the principles and framework for LCA and ISO 14044:2006 specifies the technical requirements and guidelines for LCA.

2.1 Assessment of GHG Emissions over Life Cycle of Marine Fuels

The LCA Guidelines define GHG emissions from feedstock extraction to processing, fuel production, transport and bunkering as Well-to-Tank, onboard GHG emissions as Tank-to-Wake, and GHG emissions over the whole life cycle as Well-to-Wake, as shown in Fig. 4. The GHG emissions over the whole life cycle are assessed by adding up the GHGs emitted in each process, and methane slip and N_2O are also considered. Furthermore, an assessment range (system boundary) is set according to the pathway, such as transport and storage of recovered CO_2, and the GHG intensity, i.e. the GHG emissions per unit of energy, is used to assess GHG emissions as shown in equation (1).

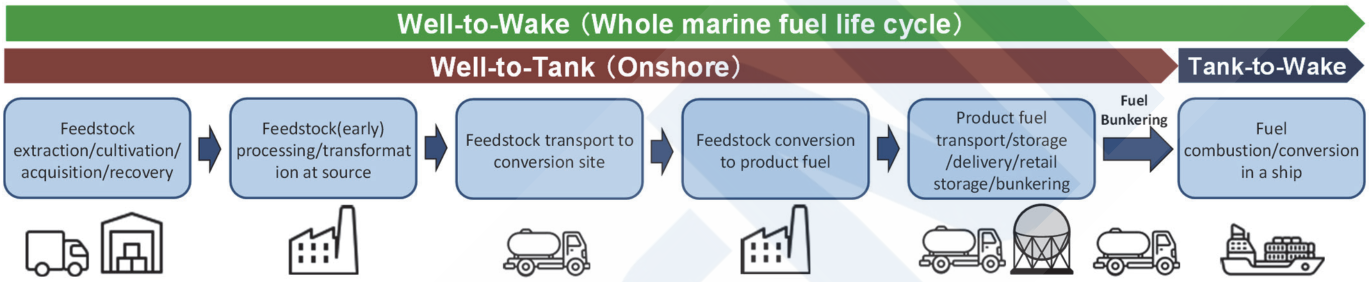

Fig. 4 An example of life cycle supply chains for marine fuels

$$GHG_{WtW} = GHG_{WtT} + GHG_{TtW} \quad (1)$$

GHG_{WtW}	$gCO_{2eq}/MJ_{(LCV)}$	GHG emissions per unit of energy over the whole life cycle of fuel from production to transport and onboard use
GHG_{WtT}	$gCO_{2eq}/MJ_{(LCV)}$	GHG emissions per unit of energy upstream of the fuel life cycle (e.g. extraction, processing, and transport of feedstock)
GHG_{TtW}	$gCO_{2eq}/MJ_{(LCV)}$	GHG emissions per unit of energy downstream of the fuel life cycle (onboard use)

2.2 Methods for Calculating GHG Intensity

In the LCA Guidelines, the GHG intensity of the Well-to-Tank, i.e. the GHG intensity on onshore, is calculated using equation (2), which calculates the GHG emitted from the extraction of feedstock to production, transport, and bunkering. However, emissions related to carbon stock changes caused by direct land-use change and soil carbon accumulation via improved agricultural management are assumed to be zero until a calculation method is established, and these cannot currently be considered. On the other hand, blue fuel with CCS can be considered, as the equation (2) considers CCS on onshore. Furthermore, GHG intensity of Tank-to-Wake, i.e. GHG intensity on board, is calculated using equation (3), which can also consider methane and N_2O emitted during fuel combustion, as well as methane leaked between the fuel tank and the engine. However, methane leaked between the fuel tank and the engine cannot currently be considered, as it is assumed to be zero until further technical work determines an appropriate factor. In onboard emissions, GHG reductions from biofuels can be considered, but synthetic fuels and onboard CCS cannot currently be considered, as their reductions are assumed to be zero until their treatment has been established.

$$GHG_{WtT} = e_{fecu} + e_l + e_p + e_{td} - e_{sca} - e_{ccs} \quad (2)$$

e_{fecu}	Emissions associated with the feedstock extraction/cultivation/acquisition/recovery	
e_l	Emissions (annualized emissions (over 20 years) from carbon stock changes caused by direct land-use change) **Pending further methodological guidance to be developed by the Organization, the value of parameter e_l should be set to zero.**	
e_p	Emissions associated with the feedstock processing and/or transformation at source and emissions associated with the conversion of the feedstock to the final fuel product, including electricity generation	
e_{td}	Emissions associated with the feedstock transport to conversion plant, and the emissions associated with the finished fuel transport and storage, local delivery, retail storage and bunkering	
e_{sca}	Emissions (annualized emission savings (over 20 years) from soil carbon accumulation via improved agricultural management) **Pending further methodological guidance to be developed by the Organization, the value of parameter e_{sca} should be set to zero.**	
e_{ccs}	Emissions credit from carbon capture and storage (e_{ccs}), that have not already been accounted for in e_p. This should properly account the avoided emissions through the capture and sequestration of emitted CO_2, related to the extraction, transport, processing and distribution of fuel (c_{sc}). From the above-mentioned emission credit, all the emissions resulting from the process of capturing (e_{cc}) and transporting (e_t) the CO_2 up to the final storage (including the emissions related to the injection, etc.) need to be deducted. This element should be calculated with the following formula: $e_{ccs} = c_{sc} - e_{cc} - e_t - e_{st} - e_x$	
	c_{sc}	Emissions credit equivalent to the net CO_2 captured and stored (long-term: 100 years)
	e_{cc}	Emissions associated with the process of capturing, compression and/or cooling and temporary storage of the CO_2
	e_t	Emissions associated with transport to a long-term storage site
	e_{st}	Any emissions associated with the process of storing (long-term: 100 years) the captured CO_2 (including fugitive emissions that may happen during long-term storage and/or the injection of CO_2 into the storage)
	e_x	Any additional emissions related to the CCS

$$GHG_{TtW} = \frac{1}{LCV}\left\{ \begin{aligned} &\left(\left(1-\frac{1}{100}\left(C_{slip\_ship}+C_{fug}\right)\right)\times\left(C_{fCO_2}\times GWP_{CO_2}+C_{fCH_4}\times GWP_{CH_4}+C_{fN_2O}\times GWP_{N_2O}\right)\right. \\ &\left. +\left(\frac{1}{100}\left(C_{slip\_ship}+C_{fug}\right)\times C_{sfx}\times GWP_{fuelx}\right)-S_{Fc}\times e_c-\left[S_{Fccu}\times e_{ccu}\right]-\left[e_{OCCS}\right]\right) \end{aligned} \right\} \quad (3)$$

C_{slip_ship}	Factor accounting for fuel (expressed in % of total fuel mass delivered to the ship) which escapes from the energy converter without being oxidized (including fuel that escapes from combustion chamber/oxidation process and from crankcase, as appropriate) $C_{slip\_ship} = C_{slip} * (1 - C_{fug}/100)$
C_{slip}	Factor accounting for fuel (expressed in % of total fuel mass consumed in the energy converter) which escapes from the energy converter without being oxidized (including fuel that escapes from combustion chamber/oxidation process and from crankcase, as appropriate)
C_{fug}	Factor accounting for the fuel (expressed in % of mass of the fuel delivered to the ship) which escapes between the tanks up to the energy converter which is leaked, vented or otherwise lost in the system **Pending further methodological guidance to be developed by the Organization to determine appropriate factor(s), the value of C_{fug} should be set to zero.**
C_{sfx}	Factor accounting for the share of GHG in the components of the fuel (expressed in g GHG/g fuel) Example: for LNG this value is 1
C_{fCO2}	CO_2 emission conversion factor (gCO_2/g fuel completely combusted) for emissions of the combustion and/or oxidation process of the fuel used by the ship
C_{fCH4}	CH_4 emission conversion factor (gCH_4/g fuel delivered to the ship) for emissions of the combustion and/or oxidation process of the fuel used by the ship For LNG/CNG fuel, the C_{slip_engine} is covering the role of C_{fCH4}, so C_{fCH4} is set to zero for these fuels.
C_{fN2O}	N_2O emission conversion factor (gN_2O/g fuel delivered to the ship) for emissions of the combustion and/or oxidation process of the fuel used by the ship
GWP_{CH4}	Global warming potential of CH_4 over 100 years (based on the fifth IPCC Assessment Report 5) : 28
GWP_{N2O}	Global warming potential of N_2O over 100 years (based on the fifth IPCC Assessment Report 5) : 265
GWP_{fuelx}	Global warming potential of GHG in the components of the fuel over 100 years (based on the fifth IPCC scientific Assessment Report)
LCV	Lower Calorific Value is the amount of heat that would be released by the complete combustion of a specified fuel
S_{Fc}	Carbon source factor to determine whether the emissions credits generated by biomass growth are accounted for in the calculation of the TtW value : 0 or 1
e_c	Emissions credits generated by biomass growth
S_{Fccu}	Carbon source factor to determine whether the emissions credits from the used captured CO_2 as carbon stock to produce synthetic fuels in the fuel production process are accounted for in the calculation of the TtW value : 0 or 1

e_{ccu}	Emission credits from the used captured CO_2 as carbon stock to produce synthetic fuels in the fuel production process and utilization (that was not accounted under e_{fecu} and e_p) **Pending further methodological guidance to be developed by the Organization, the value of the multiplication $S_{Fccu} \times e_{ccu}$ should be set to zero.**	
e_{occs}	Emission credit from carbon capture and storage (e_{occs}), where capture of CO_2 occurs onboard. This should properly account for the emissions avoided through the capture and sequestration of emitted CO_2, if CCS occurs on board. From the above-mentioned emission credit, all the emissions resulting from the process of capturing (e_{cc}), and transporting (e_t) the CO_2 up to the final storage (including the emissions related to the injection, etc.) need to be deducted. This element should be calculated with the following formula: **Pending further methodological guidance to be developed by the Organization, the value of e_{occs} should be set to zero.** $e_{occs} = c_{sc} - e_{cc} - e_t - e_{st} - e_x$	
	c_{sc}	Credit equivalent to the CO_2 captured and stored (long-term: 100 years)
	e_{cc}	Any emission associated with the process of capturing, compress and temporarily store on board the CO_2
	e_t	Emissions associated with transport to long-term storage site
	e_{st}	Any emission associated with the process of storing (long-term: 100 years) the captured CO_2 (including fugitive emissions that may happen during long-term storage and/or the injection of CO_2 into the storage)
	e_x	Any additional emission related to the CCS

2.3 Fuel Lifecycle Label (FLL)

The LCA Guidelines specify a technical tool called the Fuel Lifecycle Label, which collects and conveys the information relevant for the life cycle assessment of marine fuels and energy carriers (e.g. electricity for shore power) used for ship propulsion and power generation onboard and is used to assess the life cycle GHG emissions. The Fuel Lifecycle Label consists of five main parts, from Part A to Part E, as shown in Table 1.

Part A indicates information on fuel type, fuel pathway code, lower calorific value, fuel blend ratio and the WtT (upstream) GHG emission factor; Part B indicates information on reductions from biofuels and synthetic fuels; Part C indicates information on TtW (downstream) GHG emission factor from onboard emissions and engine type with and without consideration of biofuel and synthetic fuel reductions; Part D indicates the WtW GHG emission factor over the whole life cycle, and Part E indicates information on sustainability performance of the fuel.

Table 1 Fuel Lifecycle Label (FLL)

Part A-1	Part A-2	Part A-3	Part A-4	Part A-5
Fuel type (blend)	Fuel Pathway code	Lower Calorific Value (LCV, MJ/g)	Share in fuel blend ($\%MJ_{(LCV)}/MJ_{(LCV)}$)	WtT GHG emission factor (GWP100, $gCO_{2eq}/MJ_{(LCV)}$)

Part B-1	Part B-2
Emissions credits related to biogenic carbon source (e_c, in gCO_2 / g fuel based on GWP100)	Emissions credits related to source of captured carbon (e_{ccu}, in gCO_2 / g fuel based on GWP100)

Part C-1	Part C-2	Part C-3
TtW GHG intensity Value 1 (carbon source NOT taken into account): TtW GHG emission factor (GWP100, $gCO_{2eq}/MJ_{(LCV)}$)	TtW GHG intensity Value 2 (carbon source taken into account): TtW GHG emission factor (GWP100, $gCO_{2eq}/MJ_{(LCV)}$)	Energy Converter

Part D	Part E
WtW GHG emission factor (GWP100, $gCO_{2eq}/MJ_{(LCV)}$) Note: Part D = Part A-5 + Part C-2	Sustainability (Certification)

2.4 Fuel List with Fuel Pathway Codes

The LCA Guidelines classify fuel pathways according to the type of feedstock, origin, production method and energy used, with a total of 128 different fuel pathways specified. The representative fuels in the 128 different fuel pathways are shown in Table 2: Heavy Fuel Oil, LPG, LNG, Methanol, Hydrogen, Ammonia, Electricity and Wind propulsion.

Table 2 Examples of fuel list with fuel pathway codes

Order	Group	Fuel type	Feedstock structure		Conversion/Production process		Fuel Pathway Code
			Feedstock Type	Nature/Carbon Source	Process Type	Energy used in the process	
1	HFO (VLSFO)	Heavy Fuel Oil (ISO 8217 Grades RME, RMG and RMK, 0.10 < S ≤ 0.50%)	Crude Oil	Fossil	Standard refinery process	Grid mix electricity	HFO(VLSFO)_f_SR_gm
11	LPG	Liquefied Petroleum Gas (Propane)	Crude Oil	Fossil	Standard refinery process and liquefaction	Grid mix electricity	LPG(Propane)_f_SR_gm
31	LNG	Liquefied Natural Gas (Methane)	Natural Gas	Fossil	Standard LNG production including liquefaction	Grid mix electricity	LNG_f_SLP_gm
35	LNG	Liquefied Natural Gas (Methane)	$CO_2 + H_2$	CO_2: Fossil Point Source Carbon Capture H_2: Fossil Steam Methane Reformation	Methanation and liquefaction	Grid mix electricity	LNG_fCO2_fH2_M_gm
90	Methanol	Methanol	2nd and 3rd Gen. feedstock	Biogenic	Gasification of Biomass and Methanol Synthesis	Grid mix electricity	MeOH_b_G_MS_gm
110	Hydrogen	Hydrogen	Water + Electricity	Renewable	Dedicated Photovoltaic and/or Wind and/or other Electrolysis and liquefaction	Renewable electricity	LH2_EL_r_Liquefied
120	Ammonia	Ammonia	$N_2 + H_2$	N_2: separated with renewable electricity H_2: produced from renewable electricity	Haber Bosch process	Grid mix electricity	NH3_rN2_rH2_HB_gm
126	Electricity	Electricity		Fossil/Renewable	-	Grid mix electricity	Electricity_gm
128	Wind propulsion						

Table 3 Initial default emission factors per fuel pathway code

Order	Fuel type	Fuel Pathway Code	WtT GHG intensity (gCO_{2eq}/MJ)	LCV (MJ/g)	Energy Converter	C_f CO_2 (gCO_2/g fuel)	C_f CH_4 (gCH_4/g fuel)	C_f N_2O (gN_2O/g fuel)	C_{slip}/C_{fug} (mass %)	e_c (gCO_{2eq}/g fuel)	TtW GHG intensity (gCO_2eq/MJ)	NOTE
1	Heavy Fuel Oil (ISO 8217 Grades RME, RMG and RMK, 0.10 < S ≤ 0.50%)	HFO(VLSFO)_f_SR_gm (Fossil)	16.8	0.0402	ALL Internal Combustion Engines (ICEs)	3.114	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
2	Heavy Fuel Oil (ISO 8217 Grades RME, RMG and RMK exceeding 0.50% S)	HFO(HSHFO)_f_SR_gm (Fossil)	14.1	0.0402	ALL ICEs	3.114	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
3	Light Fuel Oil (ISO 8217 Grades RMA, RMB and RMD maximum 0.10% S)	LFO(ULSFO)_f_SR_gm (Fossil)		0.0412	ALL ICEs	3.151	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
4	Light Fuel Oil (ISO 8217 Grades RMA, RMB and RMD, 0.10 < S ≤ 0.50%)	LFO(VLSFO)_f_SR_gm (Fossil)		0.0412	ALL ICEs	3.151	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
5	Marine Diesel/Gas Oil (ISO 8217 Grades DMX, DMA, DMZ and DMB maximum 0.10 % S)	MDO/MGO(ULSFO)_f_SR_gm (Fossil)	17.7	0.0427	ALL ICEs	3.206	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
6	Marine Diesel/Gas Oil (ISO 8217 Grades DMX, DMA, DMZ and DMB, 0.10 < S ≤ 0.50%)	MDO/MGO(VLSFO)_f_SR_gm (Fossil)		0.0427	ALL ICEs	3.206	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
11	LPG (Propane)	LPG(Propane)_f_SR_gm (Fossil)		0.0463	ALL ICEs	3.000	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
21	LPG (Butane)	LPG(Butane)_f_SR_gm (Fossil)		0.0457	ALL ICEs	3.030	0.00005	0.00018				Resolution MEPC.364(79) Fourth IMO GHG study
31	LNG (Methane)	LNG_f_SLP_gm (Fossil)		0.0480	LNG Otto (dual fuel medium speed)	2.750	0	0.00011	**3.5**/-			Resolution MEPC.364(79) Fourth IMO GHG study
					LNG Otto (dual fuel slow speed)				**1.7**/-			

					LNG Diesel (dual fuel slow speed)				**0.15**/-			
					LBSI (Lean-Burn Spark-Ignited)				**2.6**/-			
					Steam Turbines and boilers				**0.01**/-			
33	LNG (Methane)	LNG_b_AD_gm (Biogenic)			LNG Otto (dual fuel medium speed)	2.750						
					LNG Otto (dual fuel slow speed)							
					LNG Diesel (dual fuel slow speed)							
					LBSI (Lean-Burn Spark-Ignited)							
					Steam Turbines and boilers							
62	Diesel (FAME)	FAME_b_TRE_gm_2ndgen (2nd Gen. feedstock)	**20.8**	0.0372	ALL ICEs							
77	Renewable Diesel (HVO)	HVO_b_HD_gm_2ndgen (2nd Gen. feedstock)	**14.9**	0.0440	ALL ICEs							
105	Hydrogen	H2_f_SMR_CCS_gm (Fossil)		0.1200	ALL ICEs	0						
					Fuel cell							
121	Ammonia	NH3_rN2_fH2_HB_gm (Renewal, Fossil)		0.0186	ALL ICEs	0						
					Fuel cell							

2.5 Provisions for Default and Actual Values

As the actual calculation/measurement of GHG intensities and various coefficients requires considerable time and effort, the LCA Guidelines allow the use of default values, which are set on the basis of representative and conservative assumptions. To establish the default values, GHG intensities and various coefficients are determined for each emission source for at least three different representative emission sources, and the upper (conservative) limit of these values is adopted as the default value. If a better value than the default value is desired, the actual value obtained according to the methodology specified in the LCA Guidelines may be used, subject to third-party certification. On the other hand, in the case of pure fossil fuels, actual values of GHG intensity are not permitted, so only default values are to be used. There are 128 different fuel pathways in the LCA Guidelines, but for fuels whose fuel pathways are not included in the LCA Guidelines, the actual values can be used if detailed information on the pathway is submitted, and third-party certification is obtained. Few default values have yet been established, and Table 3 shows the Well-to-Tank, i.e. upstream GHG intensities in red, but only five in total for fossil-based heavy fuel oil and biofuels, FAME and HVO. Furthermore, default values for methane slip have been established for different types of LNG engines, such as Otto cycle and high-pressure types, as shown in Table 3, but not yet for methane leaking from the fuel tank into the LNG engine or for N_2O generated by ammonia engines.

2.6 Sustainability Criteria for Marine Fuels

For marine fuels, sustainability also needs to be considered and the LCA Guidelines set out ten environmental themes or aspects, which are listed below. However, specific verification criteria have not been defined and will be discussed in the future. In addition, as a sustainable marine fuel, the LCA Guidelines specify lower GHG emissions than conventional marine fuels on a life cycle basis, but the ICAO CORSIA for international aviation requires a 10% reduction in GHG intensity compared to the reference fuel, while the EU Renewable Energy Directive (RED III) requires a 70% reduction (Renewable Fuels of Non-Biological Origin, Recycled Carbon Fuels) in GHG intensity compared to the reference fuel, which may become more stringent in the future.

1. GHG: Sustainable marine fuels generate lower GHG emissions than conventional marine fuels (energy-based weighted average of liquid petroleum products on 3 specific years of DCS data) on a life cycle basis.
2. Carbon source: Sustainable marine fuels do not increase GHG intensity from the use of fossil energy sources and the permanence of captured and stored carbon is ensured while also avoiding double counting across economic sectors.
3. Source of electricity/energy: Sustainable marine fuels requiring significant electricity input during WtT phase and electricity delivered directly to ships are produced by using electricity/energy from renewable, nuclear or biogenic sources, which are additional to current or long-standing demand levels, or by using surplus electricity during off-peak hours.

4. Carbon stock – direct land use change (DLUC): Sustainable marine fuels are not made from biomass obtained from land with high carbon stock; production of sustainable marine fuels minimizes emissions resulting from Direct Land Use Change.
5. Carbon stock – indirect land use change (ILUC): Cultivation of feedstock of sustainable marine fuels minimizes inducing negative changes in the use or management of land which occurs outside the product system being assessed.
6. Water: Production of sustainable marine fuels maintain or enhance water quality and availability.
7. Air: Production of sustainable marine fuels minimizes negative impacts on air quality.
8. Soil: Production of sustainable marine fuels maintain or enhance soil health.
9. Waste and chemicals: Production of sustainable marine fuels maintain or enhance responsible management of waste and use of chemicals.
10. Conservation: Production of sustainable marine fuels maintain or enhance biodiversity and ecosystems, or conservation services.

2.7 Verification and Certification

The LCA Guidelines specify that the Fuel Lifecycle Label (FLL) needs to be verified and certified by a third party, taking into account further guidance to be developed by the IMO.

- ◇ The verification and certification of Part A, Part B, Part C and Part E of the FLL may be carried out separately by different verification bodies. The verification and certification of Part D of the FLL needs to be based on the verified Part A, Part B and Part C.
- ◇ As long as Part A-1 to Part A-4 and Part C-3 of the FLL have been duly verified, the default emission factors contained in these guidelines can be consequently applied without further verification.
- ◇ In the case where lower emission factors are claimed compared to the default emission factors, the actual emission factors can be used only after the verification and certification by a third party, taking into account further guidance.

On the other hand, the LCA Guidelines specify that the verification and certification of individual parts of the FLL will use relevant certification schemes/standards recognized by the Committee, taking into account guidance to be developed by the IMO. The list of recognized certification schemes/standards will be publicly available and kept under review. In addition, it is specified that proposals to recognize international certification schemes/standards are submitted to the MEPC for consideration, and the framework, criteria and procedures leading to the recognition of certification schemes are implemented uniformly to guarantee the quality, reliability, and robustness of the IMO framework as a whole and to ensure a level playing field among certification schemes. However, as the LCA Guidelines do not specify details, guidance on certification schemes and third-party certification need to be developed in the future.

3. TERMS OF REFERENCE TO GESAMP WORKING GROUP ON LIFE CYCLE GHG INTENSITY OF MARINE FUELS

As mentioned above, there are still many issues in the LCA Guidelines, such as default values and certification methods, and as expertise is needed to resolve these issues, it was agreed at MEPC 81 held in March 2024 to newly establish a GESAMP working group on life cycle GHG intensity of marine fuels (GESAMP-LCA WG) under GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) and a Terms of Reference for the work was developed. The GESAMP-LCA WG is a group of experts to provide the best possible scientific and technical assessment of issues related to the implementation of the LCA Guidelines, and the Terms of Reference are as follows.

- ■ Methodological refinement of the emission quantification in the LCA Guidelines, with a view to ensuring the integrity of all information provided:
  - ✓ scientific review of the LCA methodology;
  - ✓ scientific review of the WtT GHG default emission factors of fuel production pathways and technologies;
  - ✓ scientific review of the TtW GHG default emission factors of fuel usage and onboard technologies (explicitly mentioning OCCS boundaries); and
  - ✓ sample calculations on LCA and reflecting the output into the existing FLL.
- ■ Sustainability themes/aspects:
  - ✓ refine and further explore indicators and metrics under the sustainability themes/aspects in the LCA Guidelines; and

- ✓ approaches to ILUC risk classification.
- ■ Methodological requirements of the LCA Guidelines with regard to certification:
  - ✓ provide external experience and further information for the development and/or identification of possible requirements for fuel pathway certification, including WtT and TtW actual values.

Note : GESAMP (the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) is independent group of experts set up already in 1969. It is currently co-sponsored by 10 UN agencies with an interest or mandate relating to the marine environment, and IMO provides the secretariat. Currently, GESAMP has nine active working groups, and the experts are all there as independent experts in their individual capacity. GESAMP working groups include, for example GESAMP WG 1 on the evaluation of hazardous substances carried by ship, and the working group on Review of applications for "active substances" to be used in ballast water management system (WG 34). To ensure independence, GESAMP selects the best expert for the task with maximum attention to gender and geographical balance. The author was one of the three coordinators of the Correspondence Group on LCA of marine fuels established at MEPC 80 held in July 2023, and was also selected as one of the 12 experts of the GESAMP-LCA WG.

4. NEW TERMS OF REFERENCE TO CORRESPONDENCE GROUP ON LCA OF MARINE FUELS

As the sustainability criteria for marine fuels does not specify other social and economic sustainability themes/aspects of marine fuels such as Land and Water Use Rights, Local and Social Development, Human and Labor Rights, Food Security etc., it was agreed at MEPC 81 held in March 2024 that the CG on LCA of marine fuels would consider them as new terms of reference and submit a report to MEPC 83 to be held in April 2025.

5. TERMS OF REFERENCE TO NEW CORRESPONDENCE GROUP ON MEASUREMENT AND VERIFICATION OF NON-CO_2 GHG EMISSIONS AND ONBOARD CARBON CAPTURE

At MEPC 81 held in March 2024, it was agreed to establish a new "Correspondence Group on measurement and verification of non-CO_2 GHG emissions and onboard carbon capture", separate from the GESAMP-LCA WG and the CG on LCA of marine fuels, because further studies are needed on onboard emissions of methane (CH_4) and N_2O as well as onboard CCS when the LCA Guidelines are revised. The Terms of Reference are as follows.

- ■ With regard to tank-to-wake CH_4 and N_2O emissions:
  - ✓ consider how to develop a framework for the measurement and verification of actual tank-to-wake CH_4 and N_2O emission factors and C_{slip} value for energy converters;
  - ✓ consider how to develop a methodological framework for associated certification issues, in support of the application of the LCA Guidelines;
  - ✓ identify the relevant gaps in existing instruments, and propose recommendations, with a view to developing necessary regulatory or recommendatory instruments;
- ■ With regard to onboard carbon capture:
  - ✓ further consider issues related to onboard carbon capture, and develop a work plan on the development of a regulatory framework for the use of onboard carbon capture systems with the exception of matters related to accounting of CO_2 captured on board ships; and
- ■ With regard to reporting to the Committee:
  - ✓ submit a written report to MEPC 83 to be held in April 2025.

6. CONCLUDING REMARKS

The LCA Guidelines will be further discussed in the GESAMP-LCA WG, the CG on LCA of marine fuels and the CG on measurement and verification of non-CO_2 GHG emissions and onboard carbon capture. As one of the members of the GESAMP-LCA WG, the author would be happy to continue contributing to the study. In particular, as a certification expert, the author would be happy to contribute to the development of Guidance on certification schemes/third-party verification for marine fuels.

REFERENCES

1) IMO: GUIDELINES ON LIFE CYCLE GHG INTENSITY OF MARINE FUELS (LCA GUIDELINES), IMO RESOLUTION MEPC.376(80)
2) Brazil, Japan and EC: Report of the Correspondence Group on the Further Development of the LCA Framework, IMO MEPC 81/7/4, 2024
3) IMO: 2024 GUIDELINES ON LIFE CYCLE GHG INTENSITY OF MARINE FUELS (2024 LCA GUIDELINES), IMO RESOLUTION MEPC.391(81)
4) EU: FuelEU Maritime, Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC (Text with EEA relevance)
5) Ministry of the Environment, Government of Japan: LCA guidelines for greenhouse gas reductions in the hydrogen supply chain Ver. 2.1, 2020