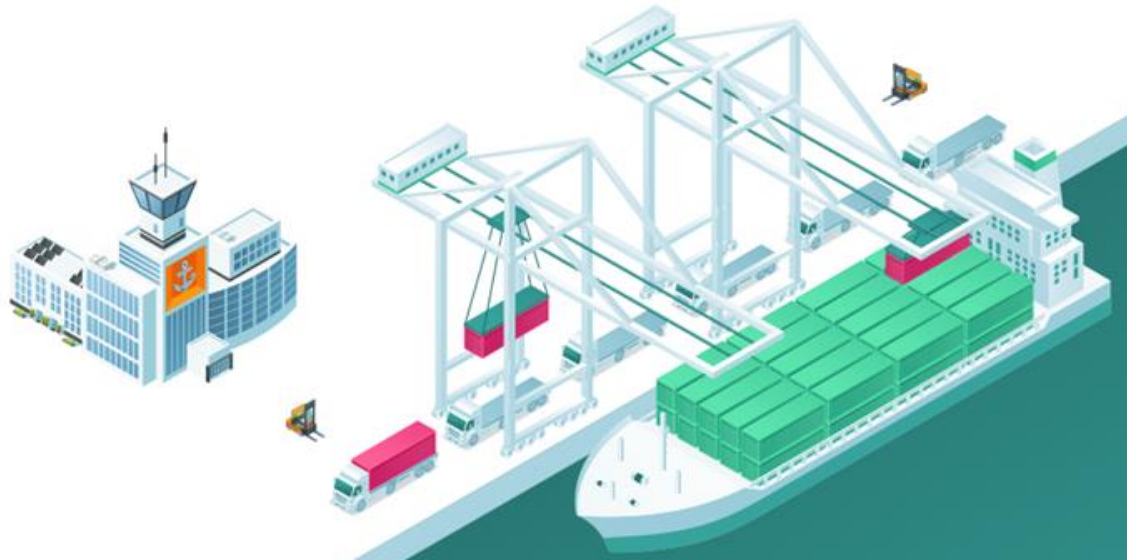
Navigating biofuel utilization in shipping sector:
Global regulations and Technological challenges



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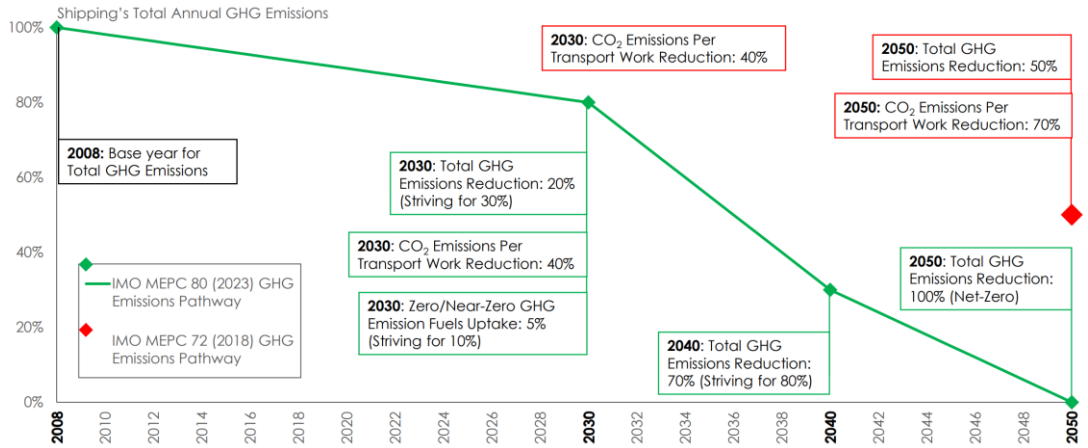
Introduction

1. Global(IMO) GHG regulations
2. Local(EU) GHG regulations
3. Precautions when using biofuel

Global(IMO) GHG regulation

IMO GHG Strategy(through MEPC 80th session)

- GHG emissions to reach net zero by (close to) 2050
  - Indicative checkpoints:
    - Reduce GHG emissions by at least 20% by 2030
    - Reduce GHG emissions by at least 70% by 2040
- Zero/near zero tech./fuel/energy source uptake at least 5% by 2030 (striving for 10%)
- Agreement of a plan to develop and finalize mid-term GHG emissions reduction measures



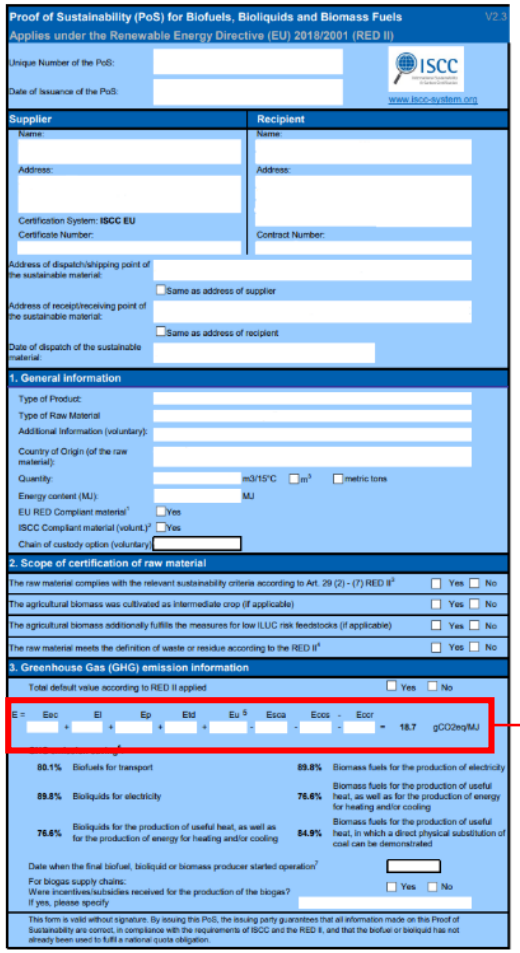
Source: Clarksons Research, September 2023, Fuelling Transition: Tracking the economic impact of emission reductions and fuel changes.

- Approval of interim guidance on biofuels (MEPC.1/Circ.905)
  - Pending the development of the comprehensive method to account for well-to-wake GHG emissions

1. Satisfies the Sustainability Criteria according to the international certification system
2. Reduction of more than 65% compared to 94 gCO_{2eq}/MJ of WTW GHG emissions of MGO fuel
   (i.e. achieving an emissions intensity not exceeding 33 gCO_{2eq}/MJ)
3. $CF_{biofuel}$: Certified value multiplied by its LCV
   (For blends, the CF should be based on the weighted average of the CF for the respective amount of fuels by energy)
4. In any case, CF value of biofuel: >0
   ($CF_{uncertified\ biofuel} = CF_{fossil\ fuel}$)
5. Interim guidance revoked upon greenhouse gas methodology implementation via LCA guidelines.

Global(IMO) GHG regulation

Confirmation of conversion factor of biofuel and its blends


Proof of Sustainability (PoS) for Biofuels, Bioliquids and Biomass Fuels
Applies under the Renewable Energy Directive (EU) 2018/2001 (RED II)

Unique Number of the PoS:
Date of Issuance of the PoS:

Supplier / Recipient

1. General information
2. Scope of certification of raw material
3. Greenhouse Gas (GHG) emission information

E = Eec + El + Ep + Etd + Eu 5 - Esca - Eccs - Eccr = 18.7 gCO2eq/MJ

1. Confirmation of whether or not the sustainability criteria are met through an international certification scheme

ISCC RSB

2. Confirmation of the WtW GHG intensity value

E =	Eec	+	El	+	Ep	+	Etd	+	Eu 5	-	Esca	-	Eccs	-	Eccr	=		
					20.0		6.48										26.48	gCO2eq/MJ

3. Check the calorific value of the biofuel, 0.0375 MJ/g*

* EU RED II Annex III, FAME's value

4.1 Determination of CO_2 conversion factor of biofuel

$$CF_{B100} = E(gCO_{2eq}/MJ) \times LHV\ (MJ/g)$$
$$= 26.48(gCO_{2eq}/MJ) \times 0.0375\ (MJ/g)$$
$$= 0.993$$

4.2. CF Calculation of Biofuel Blends (70% HFO + 30% Biofuel)

Fuels	Blending Ratio	CF	Fuel cons.(ton)	LCV(MJ/kg)
HFO	70%	3.114	6515.3	40.2
Biofuel	30%	0.993	2792.3	37.5

$$CF_{B30} = \frac{LCV_{HFO} \times Cons._{HFO} \times CF_{HFO} + LCV_{Bio} \times Cons._{bio} \times CF_{biO}}{Energy_{HFO} + Energy_{Bio}}$$
$$= \frac{Energy_{HFO} \times CF_{HFO} + Energy_{Bio} \times CF_{biO}}{Energy_{HFO} + Energy_{Bio}} = 2.508$$

Local(EU) GHG regulation

EU ETS

- Applied ships: Ships with 5,000 GT from 2024
  (Inclusion of 400-5,000 GT to be evaluated in 2025)
- GHG emissions: CO_2 from 2024
  (Include CH_4 and N_2O in EU ETS from 2026)
- $CO_{2(e)}$ calculation method: Tank to wake
- Voyages: 100% of intra-EU voyages
  50% of extra(in/out)-voyages

EU ETS	2024	2025	2026
CO2 cost from 2020 base levels (tank to wake)	40%	70%	100%

- Biofuel certified under EU RED's criteria
  : CO_2 considered zero

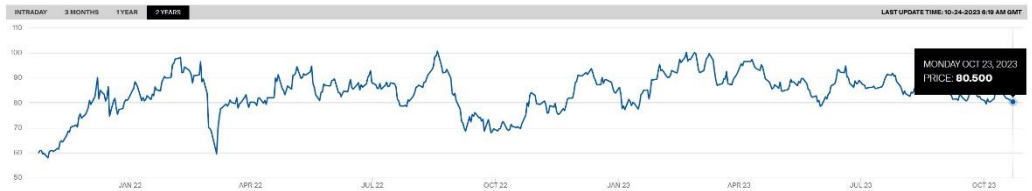


Image source: www.ice.com

FuelEU Maritime

- Applied ships: Same as EU ETS
- GHG emissions: CO_2, CH_4, N_2O
- CO_{2e} calculation method:
  Well to wake (whole life cycle)
- Voyages: Same as EU ETS

Year	GHG Intensity Limit (gCO_{2eq}/MJ)
Reference	91.16
From 2025	89.34(-2%)
From 2030	85.69(-6%)
From 2035	77.94(-14.5%)
From 2040	62.90(-31%)
From 2045	34.64(-62%)
From 2050	18.23(-80%)

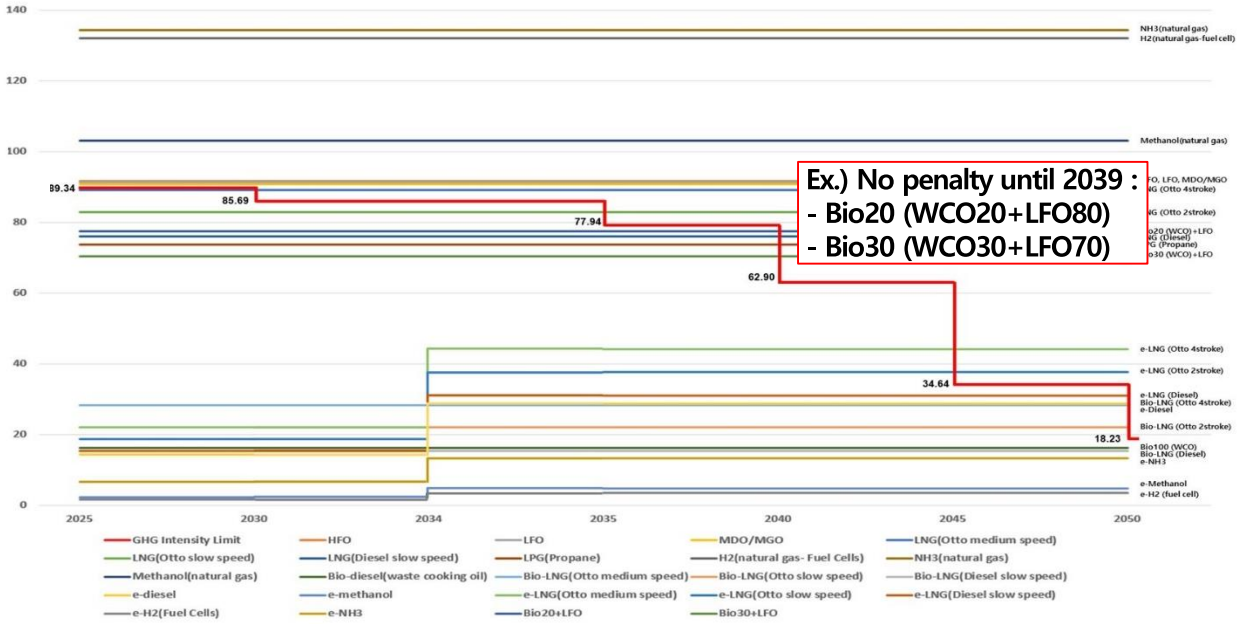
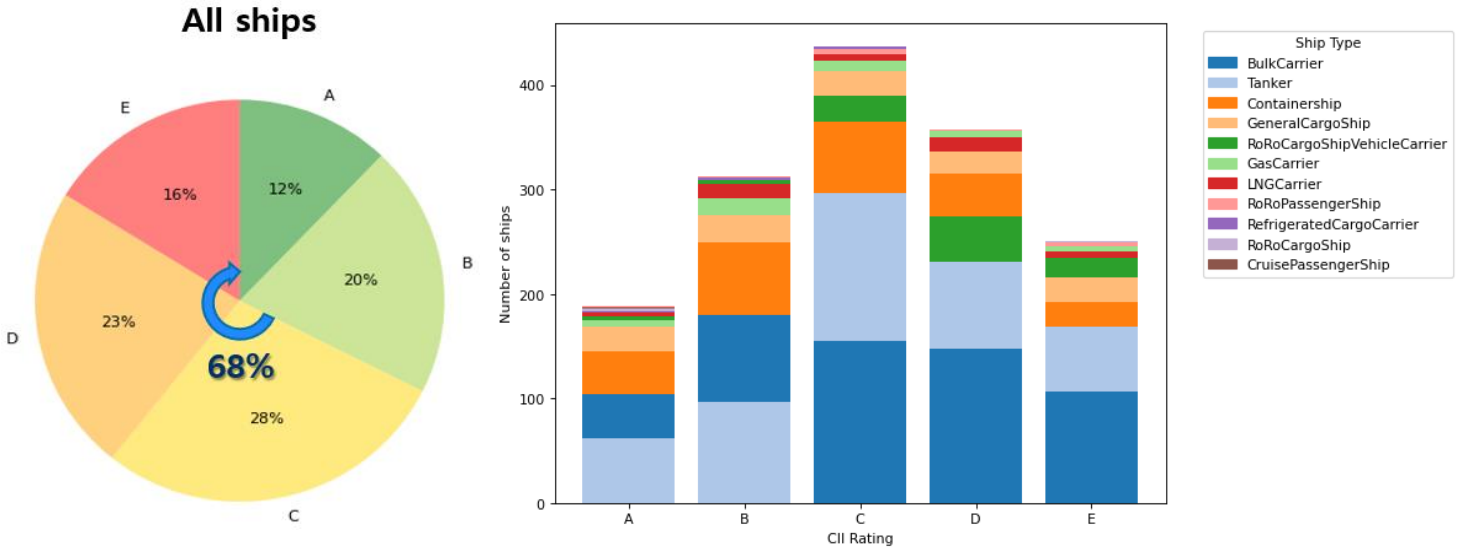
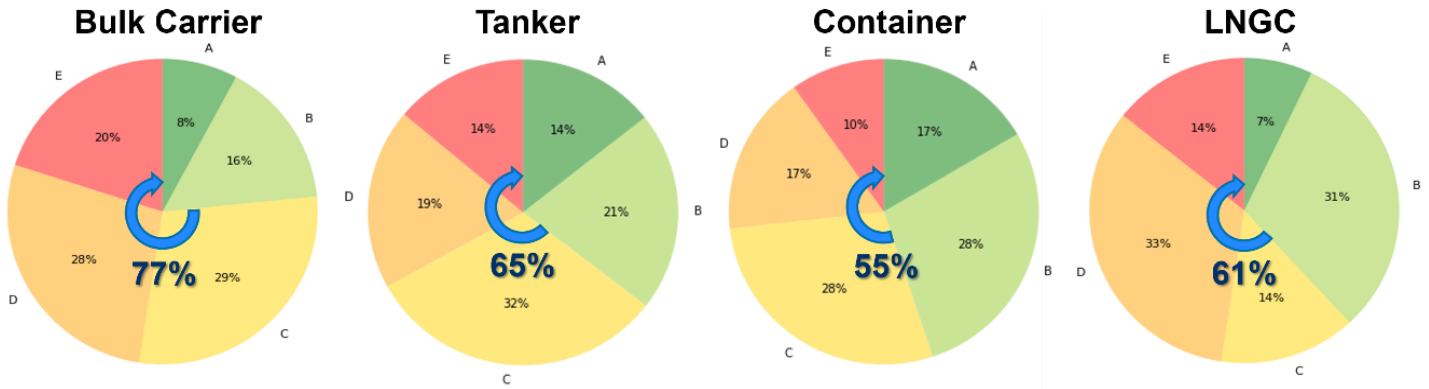


Image source: Jinhyung KIM, KR Green Ship Technology Team

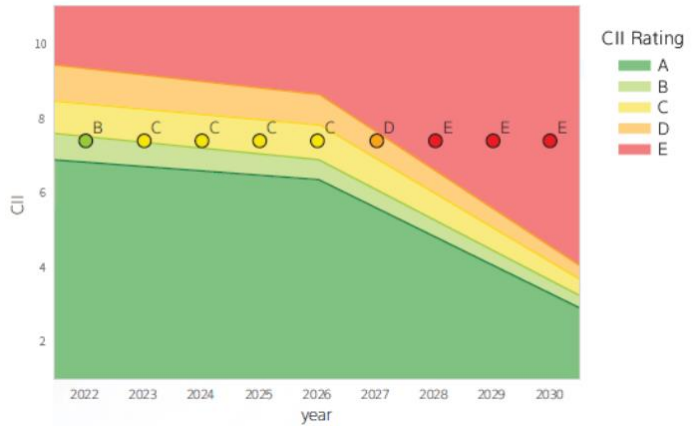
Analysis of CII rating

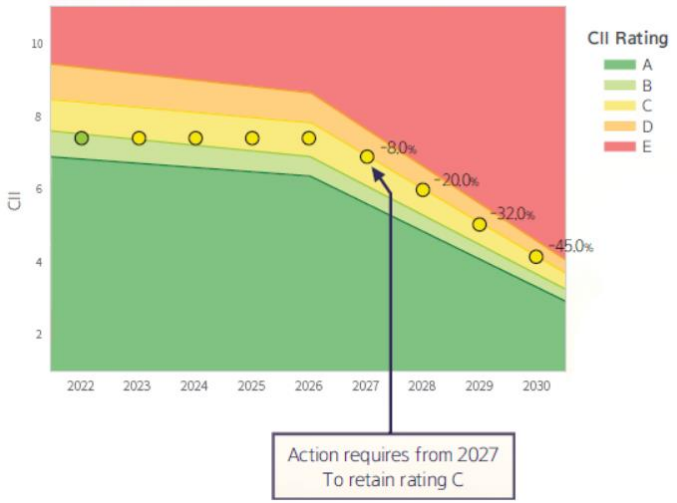
CII Rating status(abt. 2,000 vessels) and improvement Methods





✓ Need for improvement in CII ratings





Source: Donggi KIM(KR Green Ship Technology Team), KR Decarbonization Magazine, Vol. 04, Autumn 2023

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Biofuel as an alternative marine fuel

1. Alternative marine fuel
2. Characteristics of biofuel for ships
3. Precautions when using biofuel
4. Case study

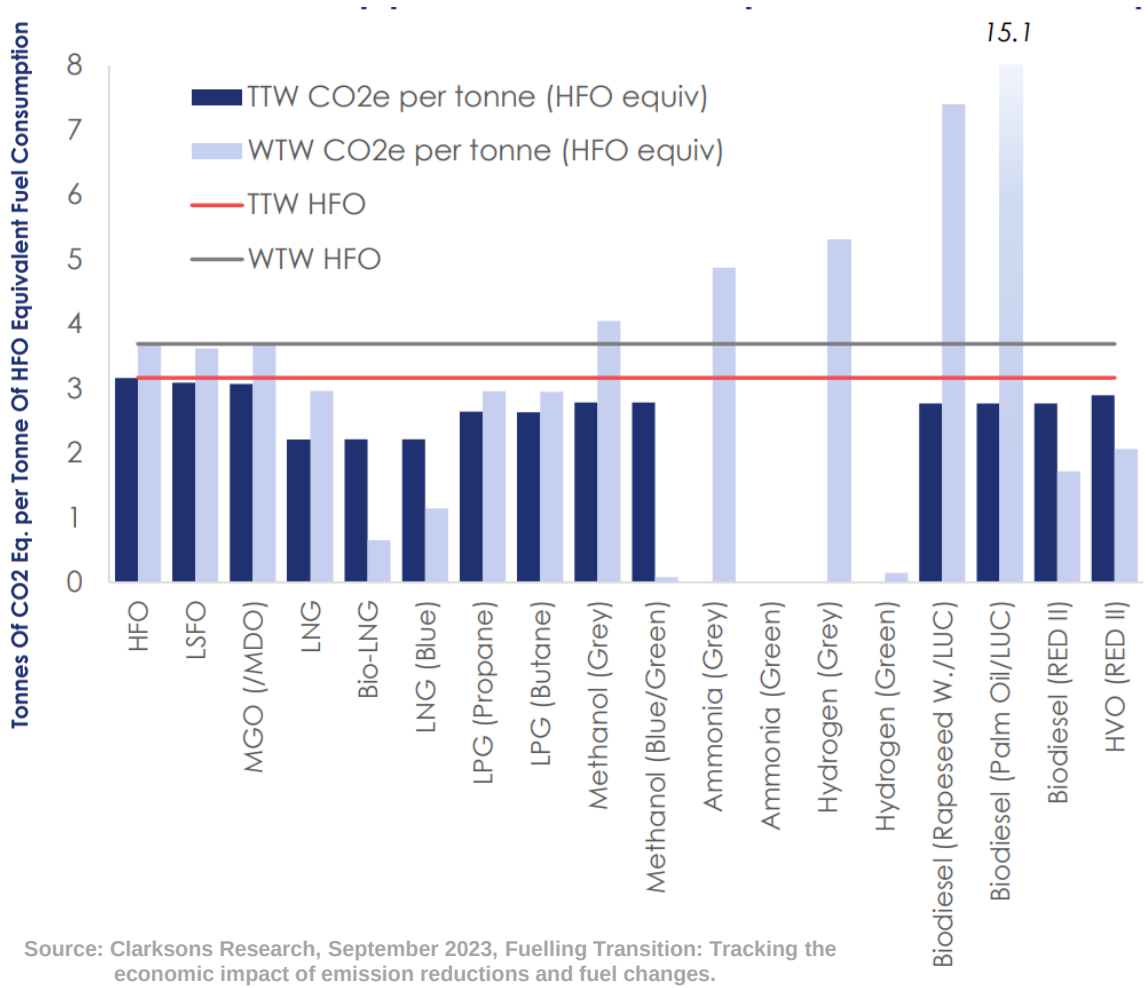
Alternative marine fuels

Potential of various GHG reduction methods for achieving net zero targets

- Technical measures: up to 75% reduction
- Operational measures: up to 50% reduction
- Alternative fuel application: up to 100% reduction
  - ➢ Biofuel(FAME, HVO, FT-diesel): A 'drop-in fuel' suitable for ICE, addressing short/mid-term regulatory compliance

Source: IMO action to reduce greenhouse gas emissions from international shipping, IMO

- Comparison of lifecycle GHG emissions by alternative fuels



Source: Clarksons Research, September 2023, Fuelling Transition: Tracking the economic impact of emission reductions and fuel changes.

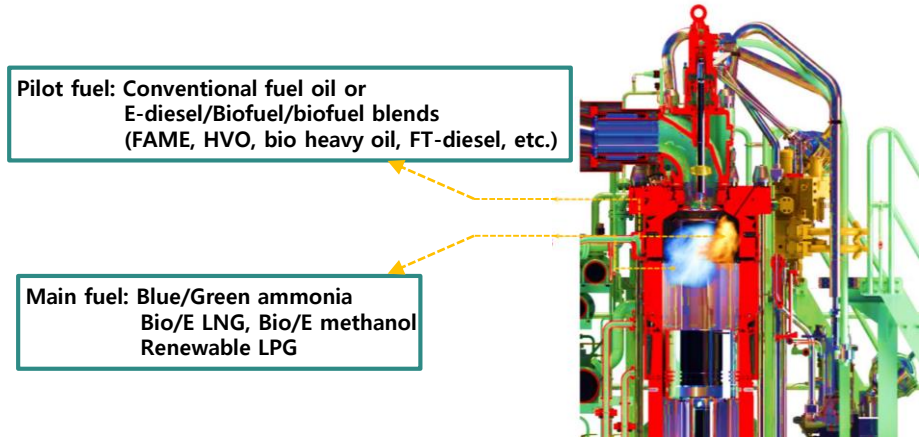
Alternative marine fuels

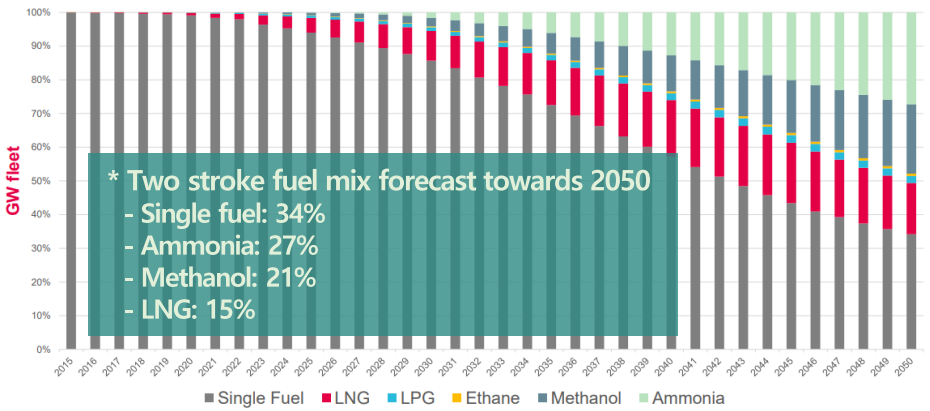
Alternative fuels applicable to ship (only ICE)

From a WtW(Well to wake) perspective, to achieve net zero goal,

- Grey Ammonia → Blue/Green Ammonia
- Grey LNG → Bio/E LNG
- Grey Methanol → Bio/E Methanol
- Grey LPG → r(enewable) LPG
- HFO/MDO/MGO → E diesel, Biofuel(FAME, HVO, FT-diesel, etc.)

Ship type	Operational mode
Existing ship (Mono fuel engine)	Only diesel mode - Conventional fuel oil - E-diesel - Biofuel or biofuel blends (FAME, HVO, Bio heavy oil, FT-diesel, etc.)
Existing ship or new building ship (Dual fuel engine)	Diesel mode - Conventional fuel oil - E-diesel - Biofuel or biofuel blends (FAME, HVO, bio heavy oil, FT-diesel, etc.) Gas mode - Main fuel: Ammonia, LNG, LPG, Methanol - Pilot fuel: Conventional fuel oil or Biofuel/biofuel blends (FAME, HVO, bio heavy oil, FT-diesel, etc.)





Source: MAN Energy Solutions, sept., 2023, MAN B&W ammonia engine development

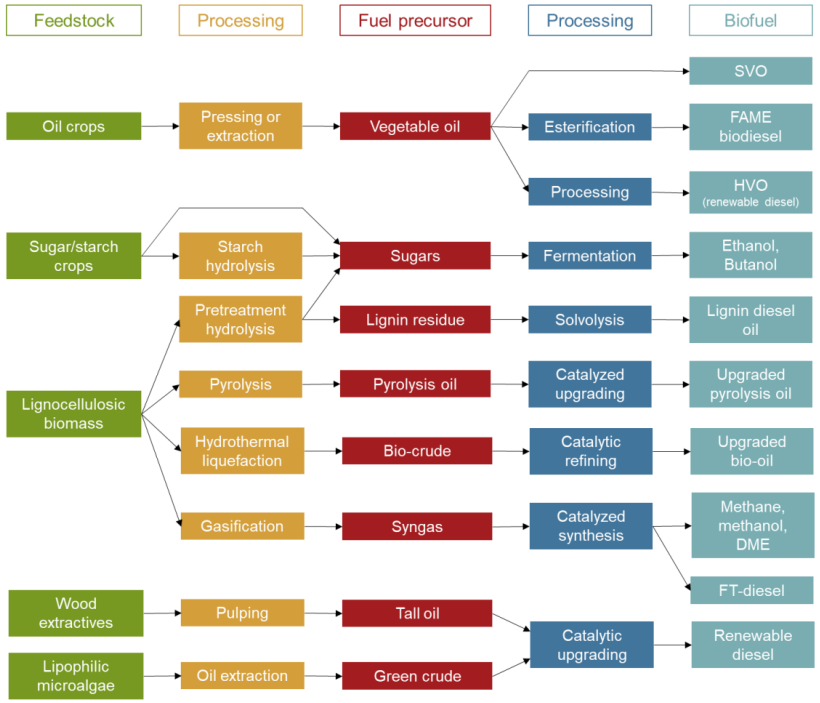
Characteristics of biofuel for ships

Representative biofuels for shipping sector

Definition of biofuel (Cambridge Business English Dictionary)

- A fuel that is made from living things or their waste and is less harmful to the environment than other types of fuel

Feedstock conversion routes to marine biofuels



Source: IEA bioenergy, June, 2021, Progress towards biofuels for marine shipping

Process pathway and TRL of biofuels

Fossil fuel replaced	Type of biofuel	Process pathway and Technology Readiness Level(TRL)				Feedstock
		Process step 1	TRL	Process step 2	TRL	
LNG	Bio-methane	Anaerobic digestion	9	Upgrade	9	Agricultural residue, sewage sludge, food waste
	Synthetic natural gas	Anaerobic digestion	9	Methane synthesis from CO_2		
Methanol	Bio-methanol	Anaerobic digestion to methane	9	Synthesis	9	Agricultural residue, sewage sludge, food waste
		Gasification of biomass	7			Lignocellulosic biomass
Residuals & distillate (e.g., HFO, VLSFO, MGO)	FAME	Trans-esterification	9	-	-	Waste fats, oils, greases(FOG), vegetable oils (palm, soy)
	HVO	Hydro-processing	9	-	-	
Residuals (e.g., HFO, VLSFO)	Fast pyrolysis (FP) bio-oil	Pyrolysis	8-9	Upgrade	6	Lignocellulosic biomass, forestry/agricultural Residue
	Hydrothermal liquefaction (HTL) bio-oil	Hydrothermal liquefaction	6	Upgrade		Lignocellulosic biomass, forestry/agricultural Residue, wet waste

* FT-diesel: Process step(FT synthesis). TRL(6/8),
Bio heavy oil: Byproducts of the biodiesel manufacturing process(feedstock)

Source: Maersk Mc-Kinney Moller Center, 2023, Using bio-diesel onboard vessels

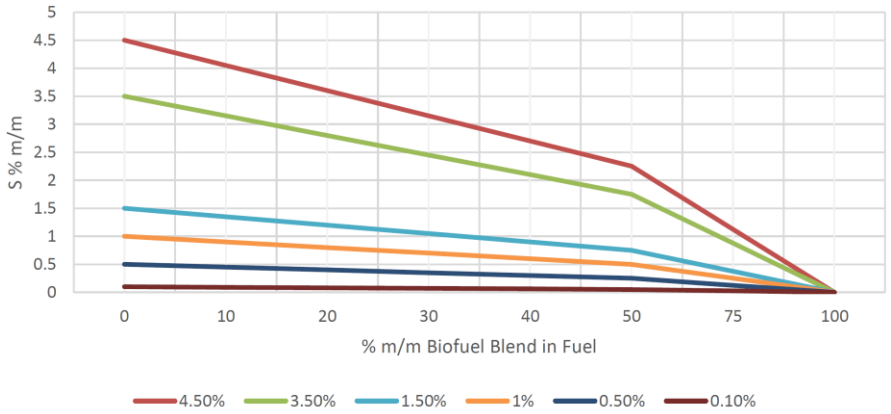
Characteristics of biofuel for ships

Air pollutants from ICE using biofuel

Approval UI regard to biofuel (MEPC.1/Cir.795/Rev. 6)

- Biofuel blends(≤30% by volume)
  - Treated as conventional petroleum-derived fuels (No special NOx emission trials or evaluations)
- Biofuel blends(>30% by volume)
  - If the NOx critical components and operational values align with the engine's Technical File, then there's no need for NOx emission trials.
  - If needed, verify engine's NOx emissions meet MARPOL Annex VI and NTC 2008 using specified fuel.

SOx emission: Closed to zero (in case of neat biofuel)



Source: Alfalaval, 2021, Marine biofuels

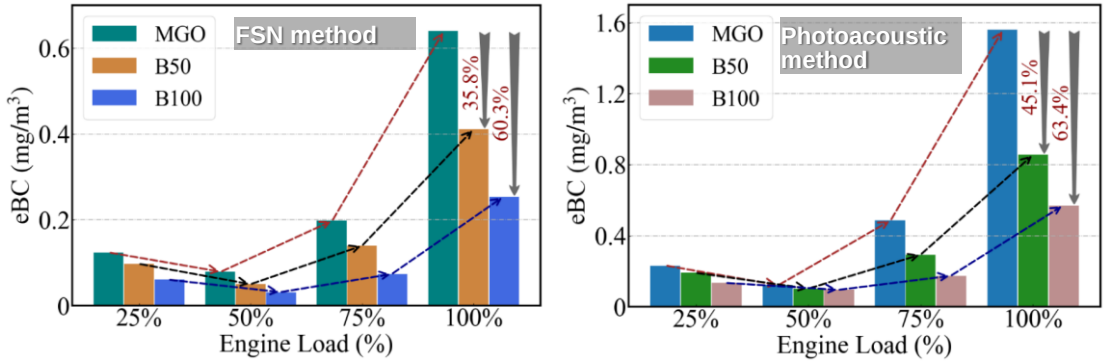
NOx emission trend of biofuels

Fuel type	NOx emission	
	Decrease	Increase
FAME	-	10-20%[a)]
HVO	0-20%[b)]	-
FT-diesel	0-20%[b)]	-

Source[a)] : Kai Juoperi(Wartsila), June 23, 2021, Use of biofuels marine applications, CIMAC tech talks

Source[b)] : ICCT, 2020, The potential of liquid biofuels in reducing ship emissions, Working paper 2020-21

BC emission: decrease with the application of biofuel



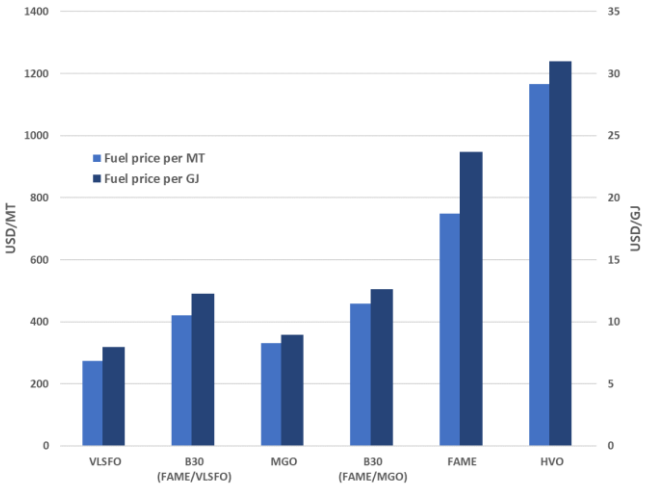
Source: IMO PPR 10/Inf.4, January 30, 2023, Black carbon emission measurement results of a marine low speed diesel engine using biofuel.

Characteristics of biofuel for ships

Biofuel price forecast

Comparison of the biofuel price

- Alfalaval report(2021) [a)]
  - FAME: approx. 2.6 times compared MGO
  - HVO: approx. 3.5 times compared MGO
- ICCT report [b)]
  - FAME: 1.3 to 2.2 times compared MGO
  - HVO: 1.5 to 2.4 times compared MGO
  - FT diesel: 1.5 to 4.1 times compared MGO
- MMMC report [c)]
  - Bio oils: In 2030 and 2050, approx. 2.0 times compared to LSFO



Source[a)] : Alfalaval, 2021, Marine biofuels

Fuel	Feedstock	Estimated production cost (USD/GJ)	Price multiple
FAME	Vegetable oil, waste FOGs	20 to 35	1.3 to 2.2
HVO	Vegetable oil, waste FOGs	24 to 39	1.5 to 2.4
FT diesel	Lignocellu-losic biomass	24 to 66	1.5 to 4.1

* Based on MGO price 16 USD/MJ

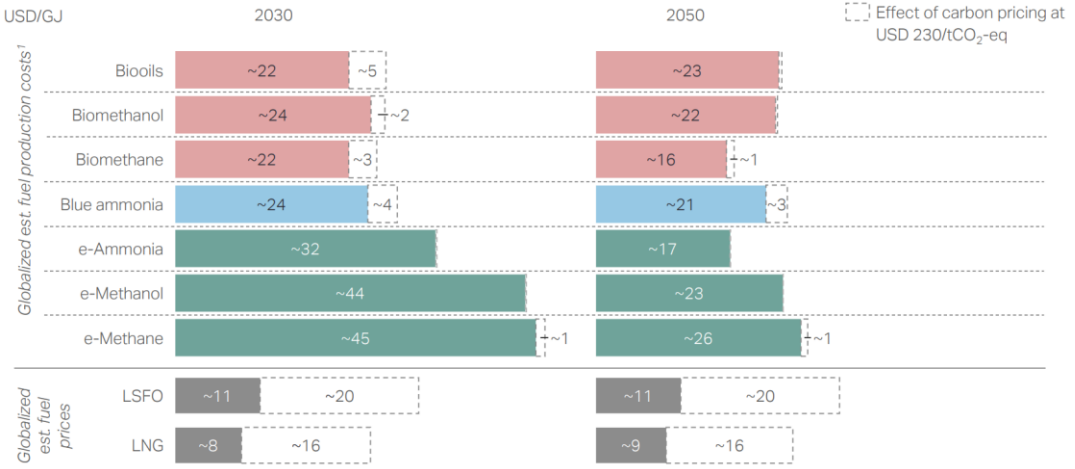
Source[b)] : ICCT, 2020, The potential of liquid biofuels in reducing ship emissions, Working paper 2020-21

Analysis of the biofuel price

- Biofuel price: FAME < HVO < FT-diesel
- According to the MMMC report, while the price of bio-oil is expected to remain stable, it is reasonable to predict that the price will increase due to competition for biomass with other industries.

Sectors		2022	2030	2034	2050
Biofuels share by sector	Road	5%	11%	12%	3%
	Shipping	0%	8%	13%	19%
	Aviation	0%	10%	22%	33%

Source: International Energy Agency, 2023 update, Net zero roadmap – A Global Pathway to Keep the 1.5℃ Goal in Reach



Source[c)] : Maersk MC-Kinney Moller Center, October 2021, Industry Transition Strategy

Precautions when using biofuel

Potential issues from biofuel (FAME) use and corresponding solutions

Oxidation and storage stability

- Lower oxidation stability with higher oxygen content→ more prone to degrade over time
  → the formation of acidic products (possibility of accelerating formation due to increase in water content)
  → 1. Affects the fuel compatibility,
  2. increase sludge build-up potentially clogging filters, separators and injectors
  3. Corrosion of the fuel system's components lead to damage of fuel pumps, piston rings and injectors
- Expansion of fuel storage period through additives (cost & rare usage)
- Proper tank coating / frequent tank cleaning / more frequent bunkering

Microbial growth

- Water affinity of biofuels → Risk of microbial growth (microbial require moisture to grow and reproduce)
- The most effective way for reducing microbial growth: control of water content
- Draining of fuel tanks more often and frequent water level checks
- Increase sampling frequency of biofuel blends in tanks
- Addition of biocides is not recommended due to environmental and health concerns.

Deleterious materials

- Presence of deleterious materials (unreacted feedstocks and by-products) in biofuels
  Glycerin, as a by-product in transesterification process, can react intermediates
  → Clogged injector and form deposits on valves, pistons, and injector nozzles
- The biodiesel should not contain Free-fatty acid, methanol, glycerin, or glyceride.

Precautions when using biofuel

International standards for marine biofuels

International standards related to biofuels

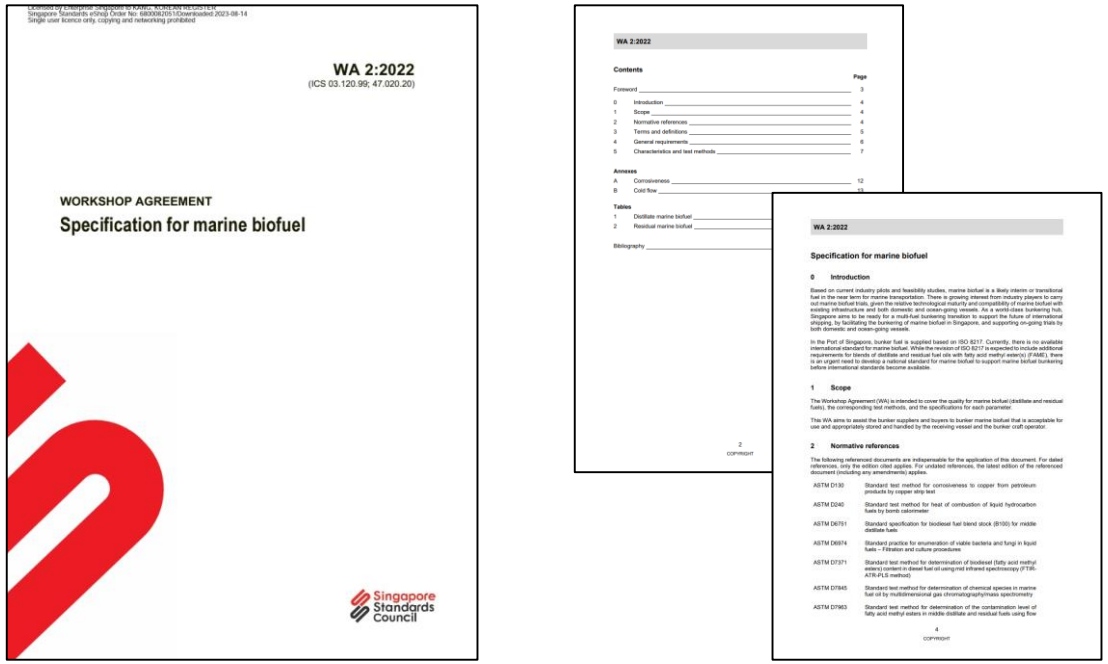
- ISO 8217: allows up to only 7.0 v/v % FAME in distillate (DF grades) marine fuel
- HVO quality unspecified in marine fuel standards (EN15940: standard for automotive paraffinic diesel fuels)

Properties	FAME (EN 14214)		HVO (EN15940)	
	Min.	Max.	Min.	Max.
Cetane number	51	-	70	
Density @ 15℃ [kg/m3]	860	900	765	800
Flashpoint [℃]	101	-	55.1	-
Viscosity @ 40℃ [mm2/s]	3.5	5.0	2.0	4.5
Lubricity [㎛]			-	400
Aromatics [% (m/m)]			-	1.1
C residue on 10% distillation residue [% (m/m)]			-	0.1
Sulphated ash content [% (m/m)]	-	0.02	-	0,001
Water content [% (m/m)]	-	0.05	-	0.02
Total contamination [mg/kg]	-	24	-	24
Oxidation stability @ 110℃ [h]	8.0	-	-	25
Acid value [mg KOH/g]	-	0.5	-	0.01
Cloud point [℃]			-	-10(summer) -32(winter)

Source: Alfalaval, 2021, Marine biofuels

WA 2: 2022: Development of a national(Singapore) standard for marine biofuel to support marine biofuel bunkering

- As a quality standard for biofuel blends, it contains up to 50 volume % or mass % FAME
- FAME for blending: Compliant with EN 14214 or ASTM D6751



Source: Singapore Standards Council, WA 2:2022 Specification for marine biofuel

Case study

CII rating improvement with biofuels

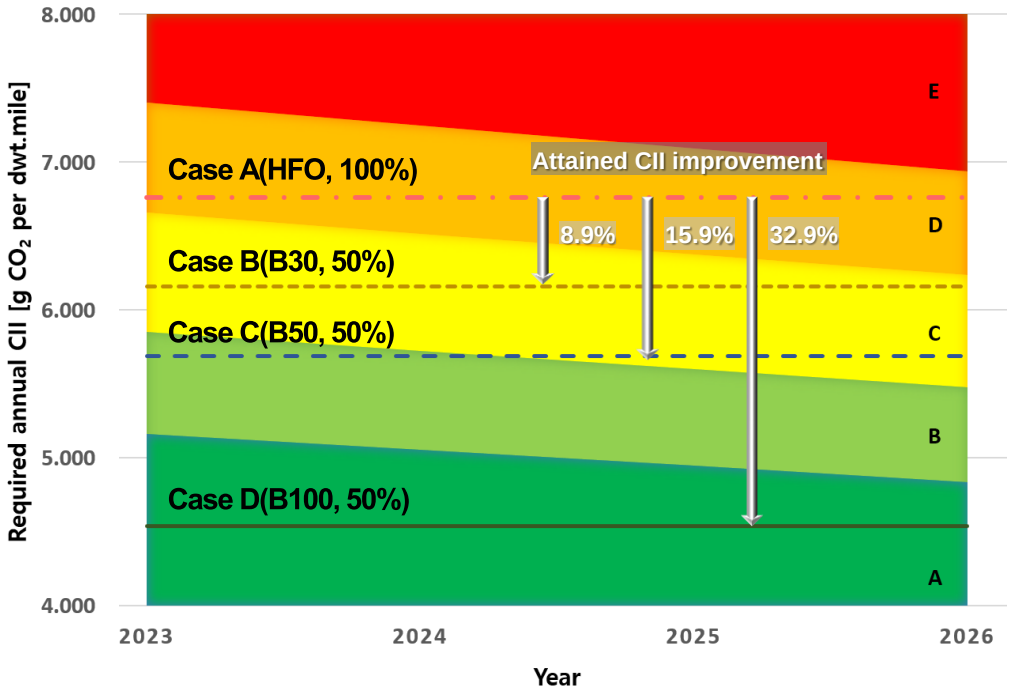
Vessel type	Vessel information	Fuel type
Container (10,000 teu)	- Deadweight: 120,000 tons - Gross tonnage: 114,200 tons - Distance travelled: 70,000 nautical mile - Fuel consumption (HFO): 18,240 M/T	- Case A: HFO 100% (Base) - Case B: B30(HFO 70 m/m% mixed with Biofuel 30 m/m%) - Case C: B50(HFO 50 m/m% mixed with Biofuel 50 m/m%) - Case D: Biofuel 100%

* Assumptions
1) same travelling distance and route with fuels
2) In the case of biofuels and mixed fuels, 50% of the fuel is substituted based on the mass of HFO

Photo of biofuel blends bunkering
Source: https://bunkermarket.com, Sept. 18, 2023

Photo of PCTC vessel completing biofuel blends test
Source: https://www.vesselfinder.com

Fuel type	CO_2 [tons]	Attained CII [gCO_2/dwt.mile]
Case A (HFO, 100%)	56799.4	6.762
Case B (B30. 50%)	51745.1	6.160
Case C (B50, 50%)	47778.4	5.688
Case D (B100, 50%)	38107.9	4.537



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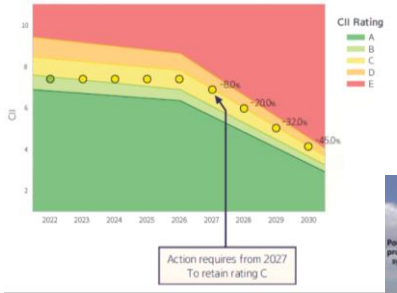
Summary and Suggetion

Summary & Suggestion

(사)해양산업통합클러스터

Step 1. Checking the current status of your vessel under GHG regulations

- Confirm the moment of regulatory non-compliance
- Verify the annual GHG reduction rate to be achieved

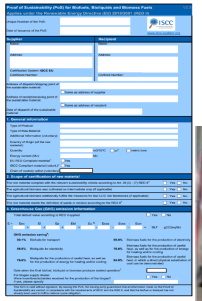


Step 2. Review of GHG reduction measure implementation strategies

- Verify the GHG reduction characteristics for various measures or combinations of measures of the ship, concurrently analyze economic feasibility

Step 3. (If) Applying biofuels as a regulatory response measure

- Selection of biofuel supplier: Review WtW GHG intensity, LCV, fuel quality, Verify technical and operational issues with the engine maker/equipment manufacturers of the respective ship, etc.

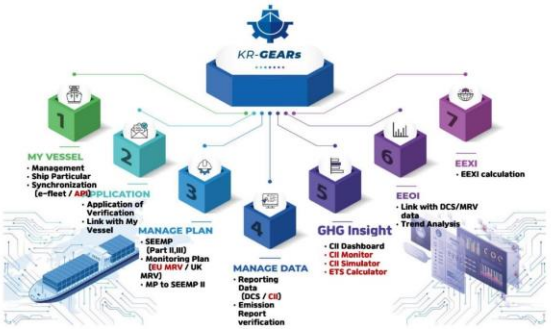


Step 4. Bunkering and operation of biofuels

- Upon first use, consume the fuel as quickly as possible
- Identifying and resolving issues → Considering increasing quantity and/or usage duration

Step 5. Verifying GHG reduction characteristics for the last year

- Comparative analysis between predicted and actual GHG (Greenhouse Gas) emissions
- Move to Step 1



Appendix I - Pilot project for marine biofuel

◆ Promotion of the marine biofuel pilot project underway

✓ Pilot project (Sep., 2023 ~ Dec., 2024) overview

- Project lead: Ministry of Trade, Industry and Energy & Ministry of Oceans and Fisheries
  KPetro(Korea Petroleum Quality and Distribution Authority)
- Participating shipping companies: HMM, H-LINE, HYUNDAI GLOVIS, SINOKOR
- Ship and navigation route(as of October 24th), mainly B30(HFO 70% + Biodiesel 30%)

  1. HYUNDAI TACOMA(HMM)
     - Route: ROK(9/15) – Singapore – Brazil – India – Singapore – ROK
  2. SILVER RAY(HYUNDAI GLOVIS)
     - Route: ROK (9/16) – Western United States – ROK
  3. HL SUCCESS(H-LINE SHIPPING)
     - Route: ROK (10/9) – Australia – ROK
- Plan: 1. Establishment of criteria for the use of biofuels in ships under domestic law
  2. Confirmation of biofuel quality characteristics
     - Land-based test: Verification of performance and environmental impact
     - Sea trial: Confirmation of stability and durability
  3. Establishment of biofuel quality and performance evaluation criteria (Revision of public notice)

Appendix II - Abbreviations and Acronyms

BC: Black carbon
(블랙카본)

CF: Conversion Factor
(변환 계수)

EN: European Standards

EU ETS: EU Emission Trading System
(EU 배출권 거래제)

FAME: Fatty Acid Methyl Esters
(지방산 메틸 에스테르)

FOGs: Waste fats, Oils, Greases

FP bio-oil: Fast Pyrosis bio-oil
(급속 열분해 바이오 연료)

FT-diesel: Fischer Tropsch diesel
(피셔 트롭쉬 디젤)

GHG: Greenhouse Gas

HTL bio-oil: Hydrothermal Liquefaction bio oil
(열수 액화 바이오 연료)

HVO: Hydrotreated vegetable oil
(수소 처리 식물성 연료)

ICE: Internal Combustion Engine
(내연기관)

LCV: Lower Calorific Value
(저위발열량)

TtW: Tank to Wake

UI: Unified Interpretation
(규정 통일해석)

WTW: Well to Wake

Thanks

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