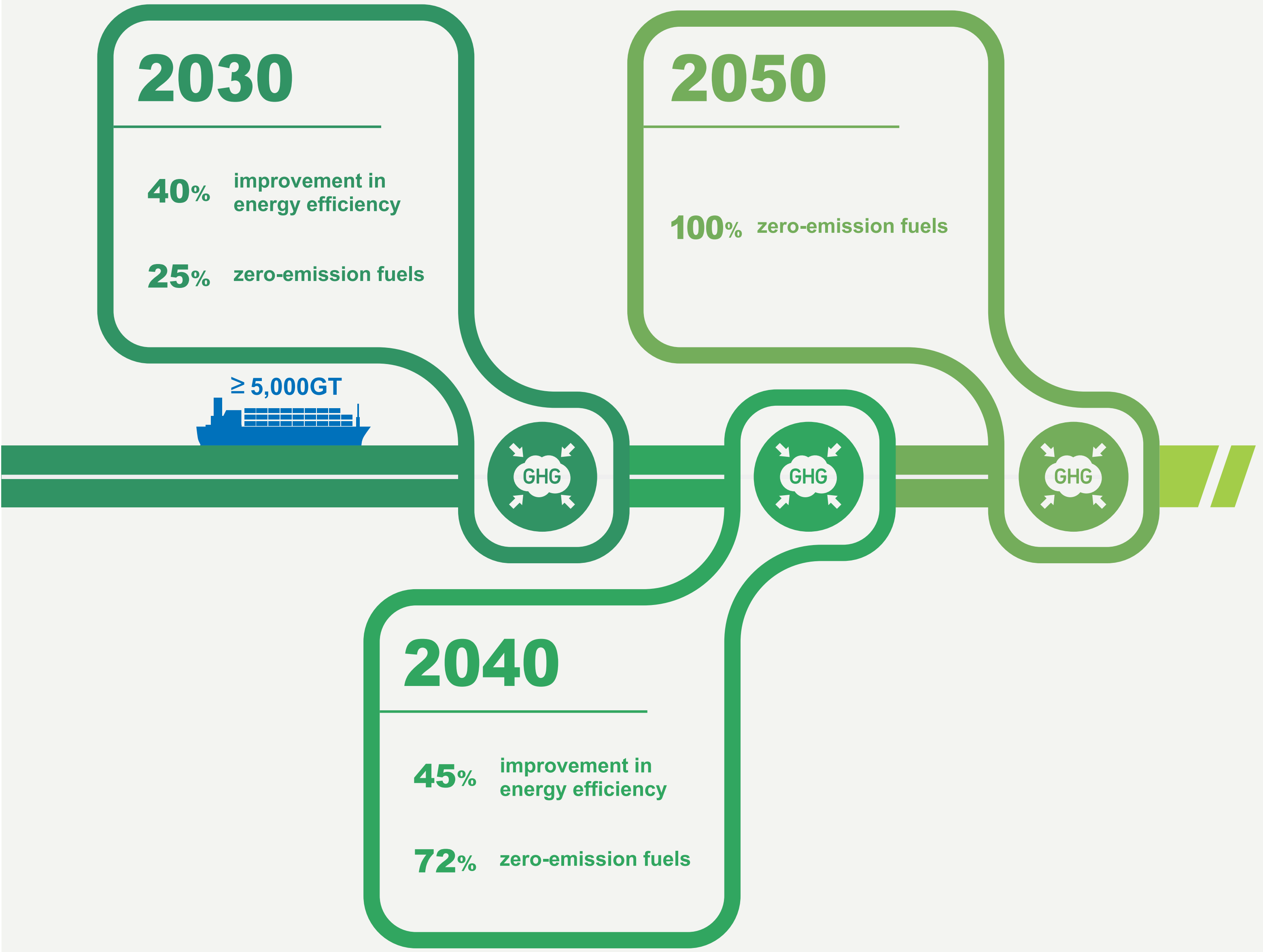
CHARTING THE FUTURE

ClassNK

Pathway to Zero-Emission in International Shipping

— Understanding the 2023 IMO GHG Strategy —

[English]



Executive summary

In July 2023, the IMO adopted the "2023 IMO Strategy on Reduction of GHG Emissions from Ships" (2023 IMO GHG Strategy). This updated strategy builds upon the initial strategy adopted back in 2018, now incorporating a net-zero GHG emission goal to be achieved by or around 2050. The 2023 IMO GHG Strategy sets the following numerical targets for reducing GHG emissions from international shipping, as well as indicative checkpoints for achieving these reductions. Notably, these targets and indicative checkpoints must consider the entire life cycle GHG emissions associated with the fuels used by ships.

◆Targets to be achieved by the measures (rules) developed by the IMO

- ✓ Net-zero GHG emissions by or around 2050
- ✓ 5% to 10% uptake of zero GHG emission fuels, etc. by 2030
- ✓ 40% reduction in CO_2 emissions (per transport work) by 2030 (compared to 2008)

◆Indicative checkpoints to achieve net-zero GHG emissions target

- ✓ 20% to 30% reduction in GHG emissions by 2030 (compared to 2008)
- ✓ 70% to 80% reduction in GHG emissions by 2040 (compared to 2008)

What is the significance of the numerical targets outlined in the 2023 IMO GHG Strategy?

Nippon Kaiji Kyokai (ClassNK) has conducted estimations[1] to promote understanding of the 2023 IMO GHG Strategy. These estimations pertain to the minimum 20% and 70% reductions in GHG emissions compared to 2008, which are set as indicative checkpoints for 2030 and 2040, respectively, in international shipping. The estimations involve determining the allowable "GHG emissions" and the required "introduction amount of zero-emission fuels and ships" for international shipping to achieve these indicative checkpoints. The summarized results are as follows.

◆Allowable GHG emissions for international shipping in 2030/2040

Table 1 outlines the allowable GHG emissions for international shipping to achieve the indicative checkpoints for 2030/2040.

The allowable GHG emissions for international shipping in 2030/2040 will be 585 million tons and 219 million tons, respectively. This represents a reduction of about 27% and 73% compared to the latest 2021 level of 798 million tons. Note that these GHG emissions are estimated based on the life cycle GHG emissions of the fuels used by ships.

[1] Estimations were made for ships of 5,000 gross tonnage and above engaged in international voyages (ships subject to IMO DCS).

Table 1 - Annual life cycle GHG emissions allowed for international shipping to achieve the indicative checkpoints

(Unit: million tons CO_{2eq})

GHG emissions	2008 (Base year)	2021 (Latest)	2030 indicative checkpoint (20% reduction from 2008)	2040 indicative checkpoint (70% reduction from 2008)
Life cycle GHG emissions (WtW[2])	**731**	**798**	**585**	**219**
(Breakdown) GHG emissions (WtT[3])	110	122	88	33
GHG emissions (TtW[4])	621	676	497	186

(Source: ClassNK estimations)

◆Introduction amount of zero-emission fuels and zero-emission ships required to achieve the indicative checkpoints

Table 2 outlines the introduction amount of zero-emission fuels and zero-emission ships required to achieve the indicative checkpoints for 2030/2040.

To achieve the indicative checkpoints for 2030/2040, approximately 25%/72% of the fuels[5] used in international shipping, respectively, must be zero-emission fuels. This necessitates the procurement of methanol and ammonia, etc., particularly those derived from green hydrogen, at a scale matching the current production levels across all sectors by 2030 and surpassing them by 2040.

To secure zero-emission ships capable of using this volume of zero-emission fuels, it will be necessary to introduce 85 million GT[6] of zero-emission ships annually over the four-year period from 2027 to 2030 through a combination of newbuildings and retrofits of existing ships. Subsequently, to secure the zero-emission ships required to achieve the indicative checkpoint for 2040, an annual introduction of 77 million GT of zero-emission ships will be essential during the ten-year period from 2031 to 2040, involving both newbuildings and retrofits of existing ships.

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2 GHG emissions throughout the life cycle of fuel production, transportation, storage, and onboard use, from “Well” to “Wake”.
3 GHG emissions from fuel production, transportation, and storage, from “Well” to “Tank”.
4 GHG emissions from onboard use of fuel, from “Tank” to “Wake”.
5 Energy consumption basis.
6 The world’s current annual newbuilding deliveries are about 60 million GT per year.

Table 2 – Introduction amount of zero-emission fuels and zero-emission ships required to achieve the indicative checkpoints

		2030 indicative checkpoint achieved (25% zero-emission fuel)	2040 indicative checkpoint achieved (72% zero-emission fuel)	Current production scale for all sectors
Introduction amount of zero-emission fuels	For Methanol	106 mil. tons	311 mil. tons	106 mil. tons/year (of which zero-emission fuels account for less than 1% of the total)
	For Ammonia	114 mil. tons	333 mil. tons	183 mil. tons/year (of which zero-emission fuels account for less than 1% of the total)
Introduction amount of zero-emission ships	- 2026 (Orderbook)	Newbuildings 12 mil. GT	←	-
	2027 - 2030	Newbuildings & Retrofits 85 mil. GT/year	←	
	2031 - 2040	-	Newbuildings & Retrofits 77 mil. GT/year	-
	Total amount	352 mil. GT	1,122 mil. GT	-
Life cycle GHG emissions (WtW)		580 mil. tons CO_{2eq} (20.7% reduction from 2008)	214 mil. tons CO_{2eq} (70.7% reduction from 2008)	-

(Source: ClassNK estimations)

Given that 25% introduction of zero-emission fuels is required to achieve the indicative checkpoint for 2030, achieving only a 5% to 10% introduction of zero-emission fuels, as outlined in the 2023 IMO GHG Strategy, would make it challenging to achieve the indicative checkpoint for 2030.

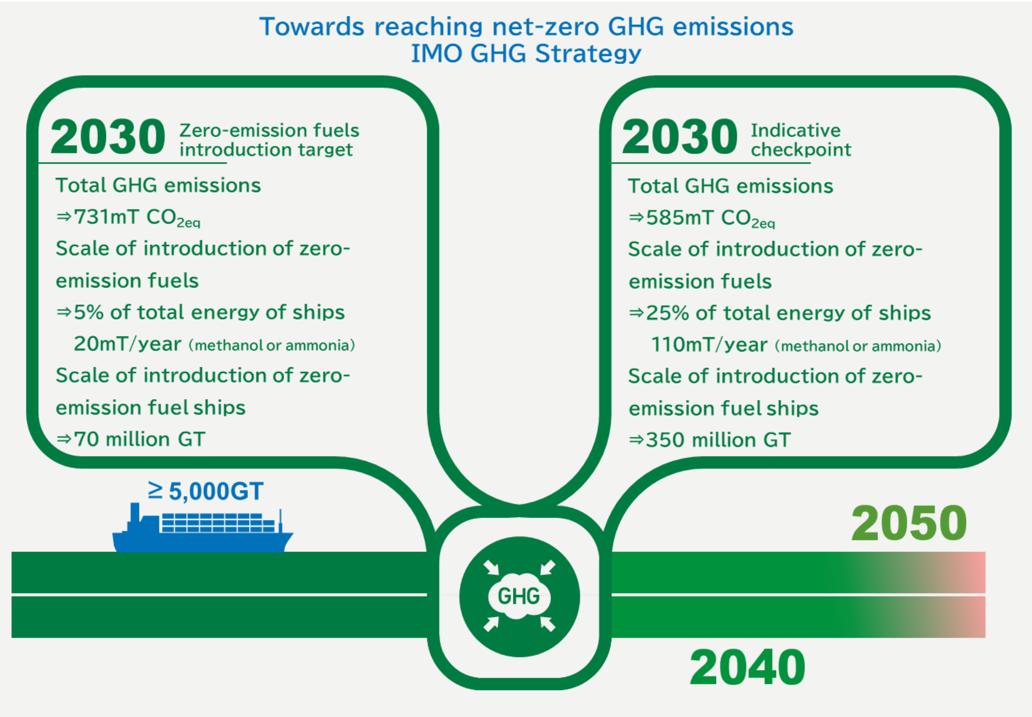
To achieve the indicative checkpoint for 2030, it's imperative to promptly introduce zero-emission ships. Nonetheless, even if the indicative checkpoint for 2030 is not achieved, an annual introduction of 80 million GT of zero-emission ships over the 14-year period from 2027 to 2040 will still be necessary to achieve the indicative checkpoint.

Achieving the numerical targets of the 2023 IMO GHG Strategy

In order to achieve the numerical targets outlined in the 2023 IMO GHG Strategy, a substantial amount of zero-emission fuels will need to be secured in international shipping. At the same time, given the current scale of zero-emission fuel production, the fuel production and distribution sector will need to accelerate investments, including in carbon-free hydrogen and electricity, more rapidly than with previous efforts in decarbonization. The early introduction of a regulatory framework, including effective carbon pricing, is essential to facilitate these investment decisions.

Concerning the newbuildings and retrofits of zero-emission ships, it is unlikely that there will be a significant shortage of newbuildings and retrofits capacity to achieve the numerical targets as long as a certain amount of ships are built and retrofitted each year. In the future, it will be essential to secure newbuildings and retrofits capacity in line with the pace of development of the zero-emission fuel production and distribution infrastructure.

The time remaining until 2030, which is the immediate target and checkpoint, is extremely limited. Achieving the zero-emission goal as outlined in the 2023 IMO GHG Strategy necessitates a collective and urgent effort from all stakeholders, including international organizations, national governments, the maritime industry, the energy sector, shippers, and the financial sector.



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Abbreviations

AER	Annual Efficiency Ratio
CH_4	Methane
CII	Carbon Intensity Indicator
CO_2	Carbon Dioxide
CO_{2eq}	Carbon Dioxide equivalents
DCS	Data Collection System
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
EJ	Exajoule
EU	European Union
GHG	Greenhouse gas
GT	Gross Tonnage
GWP	Global Warming Potential
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MJ	Megajoule
N_2O	Nitrous Oxide
TtW	Tank-to-Wake
WtT	Well-to-Tank
WtW	Well-to-Wake

Introduction

2023 IMO GHG Strategy

In July 2023, the IMO adopted the 2023 IMO GHG Strategy, which revises the initial strategy adopted in 2018 and includes a target of net-zero GHG emissions by or around 2050. The 2023 IMO GHG Strategy includes a "Vision," "Levels of ambition," and "Indicative checkpoints" for reducing GHG emissions from international shipping, as well as GHG reduction measures.

◆Vision

The IMO remains committed to reducing GHG emissions from international shipping and, as a matter of urgency, aims to phase them out as soon as possible, while promoting, in the context of this Strategy, a just and equitable transition.

◆Levels of ambition

1. carbon intensity of the ship to decline through further improvement of the energy efficiency for new ships
    - to review with the aim of strengthening the energy efficiency design requirements for ships
2. carbon intensity of international shipping to decline
    - to reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, compared to 2008
3. uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources to increase
    - uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources to represent at least 5%, striving for 10%, of the energy used by international shipping by 2030
4. GHG emissions from international shipping to reach net zero
    - to peak GHG emissions from international shipping as soon as possible and to reach net-zero GHG emissions by or around, i.e., close to, 2050, taking into account different national circumstances, whilst pursuing efforts towards phasing them out as called for in the Vision consistent with the long-term temperature goal set out in Article 2 of the Paris Agreement

Indicative checkpoints

1. to reduce the total annual GHG emissions from international shipping by at least 20%, striving for 30%, by 2030, compared to 2008
2. to reduce the total annual GHG emissions from international shipping by at least 70%, striving for 80%, by 2040, compared to 2008

Table 3 - 2023 IMO GHG Strategy

		Initial Strategy (2018) (Tank-to-Wake)	Revised Strategy (2023) (Well-to-Wake: Life cycle)
Vision		Phase out GHG emissions as soon as possible in this century.	Phase out GHG emissions as soon as possible.
Levels of ambition	Total annual GHG emissions (compared to 2008)	At least 50% reduction by 2050	At least 20% (striving for 30%) reduction by 2030 (Indicative checkpoint) At least 70% (striving for 80%) reduction by 2040 (Indicative checkpoint) Reach net-zero GHG emissions by or around, i.e. close to 2050
	Uptake of zero or near-zero GHG emissions technologies, fuels, energy sources		At least 5% (striving for 10%) by 2030
	Carbon intensity improvement (CO_2 emissions per transport work) (compared to 2008)	At least 40% reduction by 2030 At least 70% reduction by 2050	At least 40% reduction by 2030

(Source: Prepared by ClassNK)

Mid-term GHG reduction measures

It was agreed at the IMO that the basket of candidate mid-term measures, which consist of both technical and economic elements, will be further developed under a proposed timeline. Specifically, regarding the candidate measures such as year-by-year enhancements of reduction of annual GHG emission intensity (GFS, GHG Fuel Standard), payments on the basis of GHG emission amount (Levy) and a combination of implementing both levy for using fossil fuels and rebate for using zero-emission fuels (Feebate), it was agreed to further conduct a comprehensive impact assessment on the combination of technical and economic elements of the respective basket of measures, followed by the finalization of measures based on the assessment results. Furthermore, the timeline specifying adoption of specific mid-term measures by 2025 followed by entry into force by 2027 has been incorporated into the 2023 IMO GHG Strategy.

What is the significance of the numerical targets outlined in the 2023 IMO GHG Strategy?

While the 2023 IMO GHG Strategy has been adopted, there is currently no consensus within the maritime industry regarding what it signifies for international shipping, i.e., **"What are the allowable GHG emissions for international shipping to achieve the numerical targets outlined in the 2023 IMO GHG Strategy, and to what extent would the introduction of zero-emission fuels and zero-emission ships in international shipping be sufficient to achieve the numerical targets?"**

ClassNK has therefore estimated the amount of allowable GHG emissions, zero-emission fuels and zero-emission ships that would be required to achieve a minimum 20% reduction in GHG emissions in 2030 and a minimum 70% reduction in GHG emissions in 2040 compared to 2008, which are considered to be the indicative checkpoints for achieving net-zero GHG emissions in 2050.

The purpose of this document is to visualize the actions required by the 2023 IMO GHG Strategy in numerical form and to promote understanding of the strategy, thereby stimulating broad discussion among industry stakeholders and contributing to accelerating efforts to achieve zero emissions from international shipping. We hope that this document will help all stakeholders involved in shipping to consider future initiatives toward the realization of zero emissions from international shipping.

Methodology

This document visualizes the "GHG emissions" allowed for international shipping and the "introduction amount of zero-emission fuels and zero-emission ships" required to achieve the indicative checkpoints for 2030/2040 using the following methods.

◆Method for estimating GHG emissions

Estimated GHG emissions in 2008 based on the latest fuel consumption of ships in 2021, considering the increase in marine transport volume and improvement in energy efficiency of ships, and calculated the (A) GHG emissions required to achieve the indicative checkpoints for 2030/2040.

◆Method for estimating the introduction amount of zero-emission fuels/ships

1. Estimated the energy consumption of ships in 2030/2040 based on the latest (B) Energy consumption of ships in 2021 and taking into account the projected increase in (C) Marine transport volume and improvement in (D) Energy efficiency of ships.

   Energy consumption of ships in 2021 × Rate of increase in marine transport volume × Rate of improvement in energy efficiency of ships
   = Energy consumption of ships in 2030/2040

2. Compared the GHG emissions estimated based on the fuel mix, including conventional fuels and zero-emission fuels, to meet the energy consumption of ships in 2030/2040, and the (E) Fuel's GHG intensity, with the allowable GHG emissions to achieve the indicative checkpoints.

   Energy consumption of ships in 2030/2040 × Σ(each fuel's "share x GHG intensity")
   ≤ Allowable GHG emissions to achieve the indicative checkpoints for 2030/2040

3. Estimated the required introduction amount of zero-emission fuels and zero-emission ships for the scenarios that match item 2.

The scope of ships and GHG emissions in the estimation was defined as follows.

◆Scope of ships

Ships of 5,000 GT and above engaged in international voyages (ships subject to IMO DCS[7]).

◆Scope of GHG emissions

GHG emissions across the entire life cycle, from manufacturing, transportation, and storage to onboard use, for the fuels used by ships (WtW emissions).

[7] IMO's fuel consumption data collection system (commenced in 2019).

(A) GHG emissions

GHG emissions allowed for international shipping to achieve the indicative checkpoints for 2030/2040

In the 2023 IMO GHG Strategy, indicative checkpoints for 2030/2040 are set with 2008 as the base year. However, there are currently no agreed figures within the IMO for the annual life cycle GHG emissions at the 2008 baseline or the annual life cycle GHG emissions required to achieve the indicative checkpoints (these are expected to be discussed within the IMO in the future). Therefore, in order to visualize the actions called for by the 2023 IMO GHG Strategy, we estimated the annual life cycle GHG emissions in 2008, the latest ones in 2021, and the ones allowed for international shipping in 2030/2040. The results are as shown in **Table 4.**

Table 4 - Annual life cycle GHG emissions allowed for international shipping to achieve the indicative checkpoints

(Unit: million tons CO_{2eq})

GHG emissions	2008 (Base year)	2021 (Latest)	2030 indicative checkpoint (20% reduction from 2008)	2040 indicative checkpoint (70% reduction from 2008)
Life cycle GHG emissions (WtW)	**731**	**798**	**585**	**219**
(Breakdown) GHG emissions (WtT)	110	122	88	33
GHG emissions (TtW)	621	676	497	186

(Source: ClassNK estimations)

(Notes)

- GHG emissions include CO_2 emissions, CH_4 emissions, and N_2O emissions.
- The emission factors and methane slip for LNG fuel are based on the emission factors and methane slip rate (1.7%) specified in the EU's FuelEU Maritime Regulations[8].
- The GWP for CO_2/CH_4/N_2O is based on the GWP100 values from the IPCC Fifth Assessment Report (AR5) (CO_2: 1, CH_4: 28, N_2O: 265).

◆GHG emissions in 2008

Energy consumption of ships in 2008 was estimated by dividing the energy consumption of ships in 2021 by the "rate of increase in marine transport volume" from 2008 to 2021 (+40%: estimated value) and the "rate of improvement in energy efficiency of ships" (-22%: estimated value). Based on the estimated energy consumption of ships in 2008, GHG emissions in 2008 were calculated considering the fuel mix in 2008 [9], resulting in 731 million tons CO_{2eq}.

[8] 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

[9] Refer to Third IMO GHG Study 2014, Table 3.

◆GHG emissions in 2021

GHG emissions in 2021 were calculated based on the latest 2021 fuel consumption of ships published by the IMO (aggregated IMO DCS data: **Table 5**)[10], resulting in 798 million tons CO_{2eq}.

Based on the GHG emissions of 731 million tons in 2008, the GHG emissions allowed for international shipping in 2030/2040 would be 585 million tons and 219 million tons, respectively. This implies that reductions of approximately 27% and 73% would be required compared to the current level of 798 million tons in 2021.

Table 5 – Fuel consumption of ships in 2021 (aggregated IMO DCS data)

(Unit: tons)

Fuel type	Fuel consumption
Diesel Gas/Oil (MDO/MGO)	25,732,999
Ethanol	4,849
Heavy Fuel Oil (HFO)	109,169,447
Light Fuel Oil (LFO)	64,479,128
Liquefied Natural Gas (LNG)	12,623,121
Liquefied Petroleum Gas (LPG) - Butane	2,028
Liquefied Petroleum Gas (LPG) - Propane	34,973
Methanol	13,031
Other	170,501

(Source: Prepared by ClassNK based on MEPC 79/6/1)

[10] MEPC 79/6/1

(B) Energy consumption of ships in 2021

The energy consumption of ships in 2021, as shown in **Table 6**, was calculated based on the latest 2021 fuel consumption of ships published by the IMO (aggregated IMO DCS data)[11], resulting in a total of 8.79 EJ.

Energy consumption of ships in 2021 *× Rate of increase in marine transport volume*
8.79 EJ
× Rate of improvement in energy efficiency of ships
= Energy consumption of ships in 2030/2040

Table 6 – Fuel and energy consumption of ships in 2021

Fuel type	Fuel consumption [ton]	Energy consumption [EJ]
Diesel Gas/Oil (MDO/MGO)	25,732,999	1.10
Ethanol	4,849	-
Heavy Fuel Oil (HFO)	109,169,447	4.42
Light Fuel Oil (LFO)	64,479,128	2.64
Liquefied Natural Gas (LNG)	12,623,121	0.62
Liquefied Petroleum Gas (LPG) - Butane	2,028	0.0001
Liquefied Petroleum Gas (LPG) - Propane	34,973	0.002
Methanol	13,031	0.0003
Other	170,501	-

Total 8.79

(Source: ClassNK estimations)

(Notes)

- Due to rounding, the breakdown and the total do not match.

[11] The lower calorific values are based on the lower calorific values specified in the EU's FuelEU Maritime Regulations.

(C) Marine transport volume

Marine transport volume has a significant impact on achieving the indicative checkpoints. As global trade expands, an increase in marine transport volume (ton-miles) leads to higher GHG emissions if conventional fuels are continually used and increases the difficulty of achieving the indicative checkpoints.

Marine transport volume is derived from the marine transport volume scenarios presented in the Fourth IMO GHG Study 2020. The base case assumes a 25% increase from 2021 to 2030 and a 39% increase from 2021 to 2040[12].

Energy consumption of ships in 2021 × Rate of increase in marine transport volume
+25%/+39%
× Rate of improvement in energy efficiency of ships
= Energy consumption of ships in 2030/2040

Table 7 - Projected marine transport volume

(Unit: billion ton-miles)

Scenario	2008	2018	2021	2030	2040	2050
Base case[13] (compared to 2021)	42,000	59,000	59,000	74,000 (+25%)	82,000 (+39%)	89,500 (+52%)
High case[14] (compared to 2021)	42,000	59,000	59,000	88,000 (+49%)	109,000 (+85%)	126,000 (+114%)
Low case[15] (compared to 2021)	42,000	59,000	59,000	67,000 (+14%)	76,000 (+29%)	82,000 (+39%)

(Source: ClassNK estimations)

Table 8 - 12 main scenarios for marine transport volume (ton-miles)

Scenario	2018	2020	2025	2030	2035	2040	2045	2050
SSP1_RCP19_G	59,230	62,325	66,513	70,718	74,748	78,894	83,850	88,222
SSP1_RCP60_G	59,230	62,658	71,758	79,580	86,313	92,376	98,000	102,981
SSP2_RCP19_G	59,230	62,616	67,206	71,907	75,242	78,475	80,895	84,206
SSP2_RCP60_G	59,230	62,619	72,318	80,691	87,696	94,013	99,853	105,388
SSP3_RCP34_G	59,230	61,733	68,249	73,563	75,337	77,171	80,097	82,728
SSP3_RCP60_G	59,230	61,733	68,844	74,810	78,730	82,325	85,366	88,107
SSP4_RCP26_G	59,230	62,331	68,305	72,744	76,570	79,750	82,162	84,157
SSP4_RCP60_G	59,230	62,331	70,864	77,742	82,722	87,030	90,479	93,472
SSP5_RCP19_G	59,230	63,289	74,133	85,008	89,869	95,049	97,299	100,620
SSP5_RCP60_G	59,230	63,289	75,973	88,207	98,646	108,584	117,920	126,971
OECD_RCP26_G	59,230	57,679	62,826	67,471	71,613	75,799	79,073	82,464
OECD_RCP45_G	59,230	57,692	64,656	70,875	76,384	81,766	86,549	91,204

(Source: Fourth IMO GHG Study 2020, Table 36)

12 Estimated results for scenarios other than the base case are provided in the Appendix.
13 Based on the 12 scenarios listed in Table 8, an average increase in marine transport volume is assumed.
14 The case with the largest increase in marine transport volume among the 12 scenarios listed in Table 8.
15 The case with the smallest increase in marine transport volume among the 12 scenarios listed in Table 8.

(D) Energy efficiency of ships

The energy efficiency of ships has a significant impact on achieving the indicative checkpoints. Improved energy efficiency in each ship leads to reduced fuel consumption, resulting in decreased GHG emissions and contributing to the achievement of the indicative checkpoints.

In the 2023 IMO GHG Strategy, the following carbon intensity improvement target is outlined.

- to reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, compared to 2008

Energy efficiency of ships was assumed to improve by 23%[16] from 2021 to 2030 and by 30%[17] from 2021 to 2040, assuming the achievement of the carbon intensity improvement targets.

Energy consumption of ships in 2021 × Rate of increase in marine transport volume
× Rate of improvement in energy efficiency of ships
-23%/-30%
= Energy consumption of ships in 2030/2040

Table 9 – Carbon intensity through 2018

Year	EEOI (gCO_2/t/nm)				AER (gCO_2/dwt/nm)				DIST ($kgCO_2$/nm)				TIME (tCO_2/hr)			
	Vessel-based		Voyage-based		Vessel-based		Voyage-based		Vessel-based		Voyage-based		Vessel-based		Voyage-based	
	Value	Change	Value	Change	Value	Change	Value	Change	Value	Change	Value	Change	Value	Change	Value	Change
2008	17.10	–	15.16	–	8.08	–	7.40	–	306.46	–	350.36	–	3.64	–	4.38	–
2012	13.16	-23.1%	12.19	-19.6%	7.06	-12.7%	6.61	-10.7%	362.65	18.3%	387.01	10.5%	4.32	18.6%	4.74	8.1%
2013	12.87	-24.7%	11.83	-22.0%	6.89	-14.8%	6.40	-13.5%	357.73	16.7%	380.68	8.7%	4.18	14.6%	4.57	4.1%
2014	12.34	-27.9%	11.29	-25.6%	6.71	-16.9%	6.20	-16.1%	360.44	17.6%	382.09	9.1%	4.17	14.4%	4.54	3.5%
2015	12.33	-27.9%	11.30	-25.5%	6.64	-17.8%	6.15	-16.9%	366.56	19.6%	388.62	10.9%	4.25	16.6%	4.64	5.7%
2016	12.22	-28.6%	11.21	-26.1%	6.58	-18.6%	6.09	-17.7%	373.46	21.9%	397.05	13.3%	4.35	19.3%	4.77	8.7%
2017	11.87	-30.6%	10.88	-28.2%	6.43	-20.4%	5.96	-19.5%	370.97	21.0%	399.38	14.0%	4.31	18.2%	4.79	9.2%
2018	11.67	-31.8%	10.70	-29.4%	6.31	-22.0%	5.84	-21.0%	376.81	23.0%	401.91	14.7%	4.34	19.1%	4.79	9.2%

(Source: Fourth IMO GHG Study 2020, Table 2)

Starting from 2023, the IMO has initiated the CII regulations. With the implementation of these regulations, it is anticipated that efforts to improve actual energy efficiency will be made by each ship with the goal of maintaining or improving their CII rating. This system, in conjunction with the design-based energy efficiency regulations such as the EEDI and EEXI regulations, contributes to further improving the energy efficiency of ships.

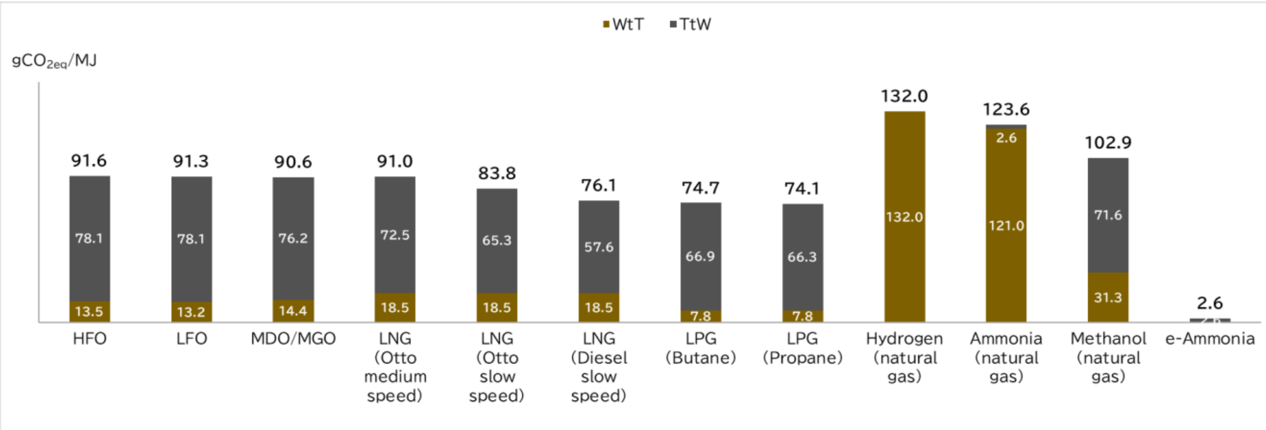
16 Equivalent to a 40% improvement compared to 2008 (AER basis).
17 Equivalent to a 45% improvement compared to 2008 (AER basis).

(E) Fuel's GHG intensity

What is fuel's GHG intensity?

Fuel's GHG intensity refers to the GHG emissions per unit of energy for a fuel. When evaluating GHG intensity over the entire life cycle (WtW), the sum of the GHG intensity at WtT and at TtW is the GHG intensity at WtW.

The GHG intensities of typical fuels are as shown in **Figure 1**, and GHG intensities can be calculated based on emission factors specified for each fuel type and production pathway.



(Source: Prepared by ClassNK based on the emissions factors listed in the FuelEU Maritime Regulations, etc.)

Figure 1 - GHG intensity by fuel type

When evaluating GHG intensity over the entire life cycle (WtW), it should be noted that fuels like hydrogen, ammonia, and methanol derived from natural gas may have GHG intensity higher than conventional fuels.

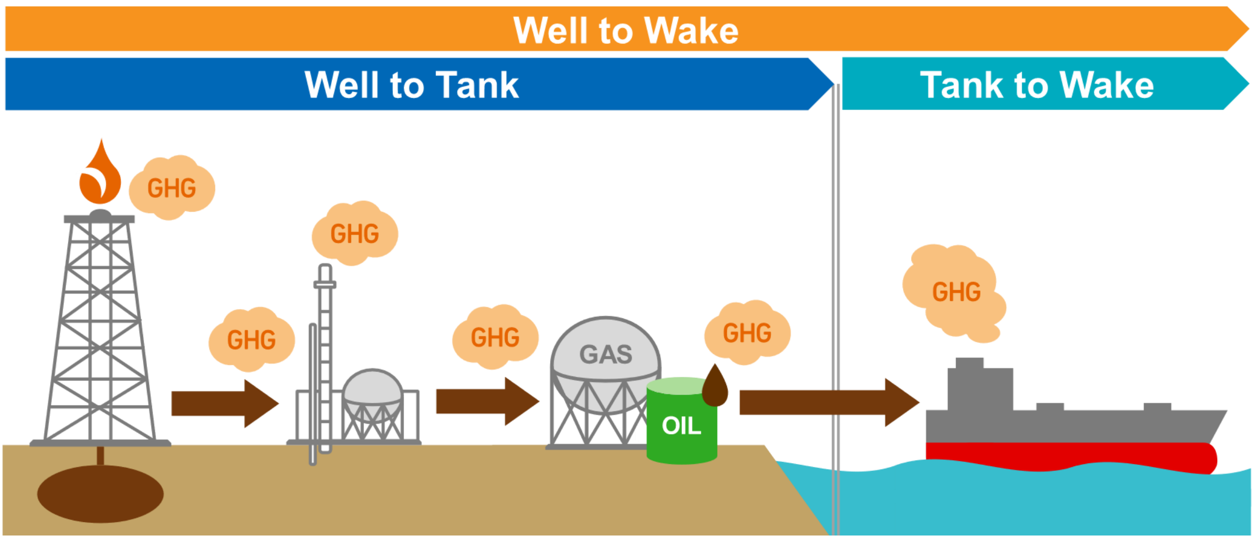


Figure 2 – Concept of a fuel's life cycle GHG emissions

Table 10 - Lower calorific value, emission factor, and slip rate by fuel type[18]

Fuel type	LCV [MJ/g]	$CO_{2eq\ WtT}$ [gCO_{2eq}/MJ]	$CO_{2eq\ WtT}$ [gCO_{2eq}/gFuel]	$CO_{2eq\ TtW}$ [gCO_{2eq}/MJ]	$CO_{2eq\ TtW}$ [gCO_{2eq}/gFuel]	Slip rate [%]
HFO	0.0405	13.5	0.547	78.1	3.163	0.0
LFO	0.041	13.2	0.541	78.1	3.200	0.0
MDO/MGO	0.0427	14.4	0.615	76.2	3.255	0.0
LNG (Otto medium speed)	0.0491	18.5	0.908	56.6	2.779	3.1
LNG (Otto slow speed)	0.0491	18.5	0.908	56.6	2.779	1.7
LNG (Diesel slow speed)	0.0491	18.5	0.908	56.6	2.779	0.2
LPG (Butane)	0.046	7.8	0.359	66.9	3.079	0.0
LPG (Propane)	0.046	7.8	0.359	66.3	3.049	0.0
Hydrogen (Natural gas)	0.12	132.0	15.840	0.0	0.000	0.0
Ammonia (Natural gas)	0.0186	121.0	2.251	2.6	0.049	0.0
Methanol (Natural gas)	0.0199	31.3	0.623	71.6	1.424	0.0
e-Ammonia	0.0186	0.0	0.000	2.6	0.049	0.0

(Source: Prepared by ClassNK based on FuelEU Maritime Regulations)

[18] 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

Scenarios for achieving the fuel introduction target for 2030

Based on the energy consumption of ships in 2021 and taking into account the increase in marine transport volume and the improvement in energy efficiency of ships, the estimated energy consumption of ships in 2030 was 8.47EJ.

Energy consumption of ships in 2021 × Rate of increase in marine transport volume
8.79 EJ *+25%*
× Rate of improvement in energy efficiency of ships
-23%
= Energy consumption of ships in 2030
8.47 EJ

The allowable GHG emissions required to achieve the indicative checkpoints can be calculated based on the energy consumption of ships and by considering the fuel mix (each fuel's share), including conventional fuels and zero-emission fuels.

Energy consumption of ships in 2030 × Σ(each fuel's "share × GHG intensity")
8.47 EJ
≤ Annual GHG emissions to achieve the indicative checkpoint for 2030
585 million tons CO_{2eq}

Note that the 2023 IMO GHG Strategy sets the following targets for the introduction of zero-emission fuels, etc.

- uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources to represent at least 5%, striving for 10%, of the energy used by international shipping by 2030

Therefore, we first examined scenarios for achieving the zero-emission fuel introduction target for 2030 (minimum 5% introduction)[19].

[19] While the targets for introduction vary from zero or near-zero GHG emission technologies, fuels, and/or energy sources, this document focuses solely on the calculation of the introduction for zero-emission fuels.

What is required to achieve the zero-emission fuel introduction target for 2030?

The fuel mix as of 2030 in this scenario is as shown in **Table 11.**

Table 11 - Fuel mix (case of achieving the zero-emission fuel introduction target for 2030)

	Fuel oil	LNG	Zero-emission fuel	Total amount
Ship energy consumption	7.20 EJ (85%)	0.85 EJ (10%)	0.42 EJ (5%)	8.47 EJ (100%)

(Source: ClassNK estimations)

(Notes)
- The energy consumption-based share of LNG fuel is assumed to increase to 10% in 2030, taking into account the actual share in 2021 (7%) and the orderbook for LNG-fueled ships as of September 2023.

The amount of zero-emission fuels required to achieve a 5% share on an energy consumption basis is as shown in **Table 12.** To achieve the zero-emission fuel introduction target for 2030, an annual volume of 21 million tons of methanol or 23 million tons of ammonia will be necessary as of 2030. These methanol and ammonia sources should be derived from green hydrogen, etc., that result in zero-emission fuels throughout their life cycle. It's worth noting that the most of currently produced methanol (primarily used for chemicals) and ammonia (mainly for fertilizers) are derived from natural gas and may result in higher GHG emissions throughout their life cycle compared to conventional fuels, making them unsuitable as zero-emission fuels for international shipping.

Table 12 – Introduction amount of zero-emission fuels (case of achieving the zero-emission fuel introduction target for 2030)

Fuel type	2030 introduction amount of zero-emission fuels (5% zero-emission fuel)	Current production scale for all sectors
For Methanol	21 mil. tons	106 mil. tons/year (of which zero-emission fuels account for less than 1% of the total)
For Ammonia	23 mil. tons	183 mil. tons/year (of which zero-emission fuels account for less than 1% of the total)

(Source: ClassNK estimations)

If the amount of zero-emission fuels required to achieve the zero-emission fuel introduction target for 2030 is secured, the corresponding amount of zero-emission ships needed to use these fuels is as shown in **Table 13**, requiring a fleet of 72 million GT in 2030[20]. Taking into account the 12 million GT of methanol-fueled ships remaining on orderbook as of September 2023, an additional 15 million GT of newbuildings per year will be required over the four-year

[20] Annual energy consumption is assumed to be 6,000 MJ/GT.

period from 2027 to 2030. This is equivalent to a quarter of the world's current annual newbuilding deliveries.

Table 13 – Introduction amount of zero-emission ships (case of achieving the zero-emission fuel introduction target for 2030)

	2021	- 2026	2027 - 2030 introduction amount of zero-emission ships	2030
Zero-emission ships	Existing ships 0.75 mil. GT	Newbuildings 12 mil. GT	Newbuildings **60 mil. GT (15 mil. GT/year)**	72 mil. GT
Entire fleet	1,250 mil. GT	1,330 mil. GT	-	1,430 mil. GT

(Source: ClassNK estimations)

(Notes)

- Until delivery in 2026, figures are based on the orderbook as of September 2023.

The GHG emissions from international shipping in 2030, based on the fuel mix in this scenario, are as shown in **Table 14.** In the case of achieving the zero-emission fuel introduction target for 2030, the GHG emissions in 2030 amount to 731 million tons. This exceeds the allowable GHG emissions of 585 million tons for international shipping to achieve the indicative checkpoint for 2030 (minimum 20% reduction compared to 2008). In other words, achieving the zero-emission fuel introduction target for 2030 alone makes it difficult to achieve the indicative checkpoint for 2030.

Table 14 - Annual life cycle GHG emissions in 2030 (case of achieving the zero-emission fuel introduction target for 2030)

	Fuel oil	LNG	Zero-emission fuel	Total amount
Ship energy consumption	7.20 EJ (85%)	0.85 EJ (10%)	0.42 EJ (5%)	8.47 EJ (100%)
Life cycle GHG emissions (WtW)	659 mil. tons CO_{2eq}	71 mil. tons CO_{2eq}	1 mil. tons CO_{2eq} (Methanol/Ammonia)	**731 mil. tons CO_{2eq}** (0% reduction from 2008)
Indicative checkpoint for 2030	-	-	-	**585 mil. tons CO_{2eq}**

(Source: ClassNK estimations)

(Notes)

- The GHG intensity (WtW) of fuel oil is assumed to be 91.6 gCO_{2eq}/MJ, equivalent to HFO.
- The GHG intensity (WtW) of LNG is assumed to be 83.8 gCO_{2eq}/MJ.
- The GHG intensity (WtW) of zero-emission fuel is assumed to be 2.6 gCO_{2eq}/MJ.

Scenario for achieving the indicative checkpoint for 2030

Next, we examined a scenario for achieving the indicative checkpoint for 2030 (minimum 20% reduction compared to 2008).

Energy consumption of ships in 2030 × Σ(each fuel's "share x GHG intensity")

8.47 EJ

≤ Allowable GHG emissions to achieve the indicative checkpoint for 2030

585 million tons CO_{2eq}

The fuel mix as of 2030 in this scenario is as shown in **Table 15.**

Table 15 - Fuel mix (case of achieving the indicative checkpoint for 2030)

	Fuel oil	LNG	Zero-emission fuel	Total amount
Ship energy consumption	5.50 EJ (65%)	0.85 EJ (10%)	2.12 EJ (25%)	8.47 EJ (100%)
Life cycle GHG emissions (WtW)	504 mil. tons CO_{2eq}	71 mil. tons CO_{2eq}	5 mil. tons CO_{2eq}	580 mil. tons CO_{2eq} (20.6% reduction from 2008)
Indicative checkpoint for 2030	-	-	-	585 mil. tons CO_{2eq}

(Source: ClassNK estimations)

(Notes)

- The GHG intensity (WtW) of fuel oil is assumed to be 91.6 gCO_{2eq}/MJ, equivalent to HFO.
- The GHG intensity (WtW) of LNG is assumed to be 83.8 gCO_{2eq}/MJ.
- The GHG intensity (WtW) of zero-emission fuel is assumed to be 2.6 gCO_{2eq}/MJ.

By introducing 25% zero-emission fuels on an energy consumption basis, the 2030 GHG emission reduction target (minimum 20% reduction compared to 2008) can be achieved.

The amount of zero-emission fuels required to achieve a 25% share of the energy consumption base is as shown in **Table 16.** 106 million tons of methanol or 114 million tons of ammonia per year will be needed in 2030 to achieve the indicative checkpoint for 2030.

Table 16 – Introduction amount of zero-emission fuels (case of achieving the indicative checkpoint for 2030)

Fuel type	2030 introduction amount of zero-emission fuels (25% zero-emission fuel)	Current production scale for all sectors
for Methanol	106 mil. tons	106 mil. tons/year (less than 1% of which is zero-emission fuel)
for Ammonia	114 mil. tons	183 mil. tons/year (less than 1% of which is zero-emission fuel)

(Source: ClassNK estimations)

If the amount of zero-emission fuels required to achieve the indicative checkpoint for 2030 is secured, the corresponding amount of zero-emission ships needed to use these fuels is as shown in **Table 17**, requiring a fleet of 352 million GT in 2030[21]. Taking into account the 12 million GT of methanol-fueled ships remaining on orderbook as of September 2023, an additional 85 million GT of newbuildings and retrofits of existing ships per year will be required over the four-year period from 2027 to 2030.

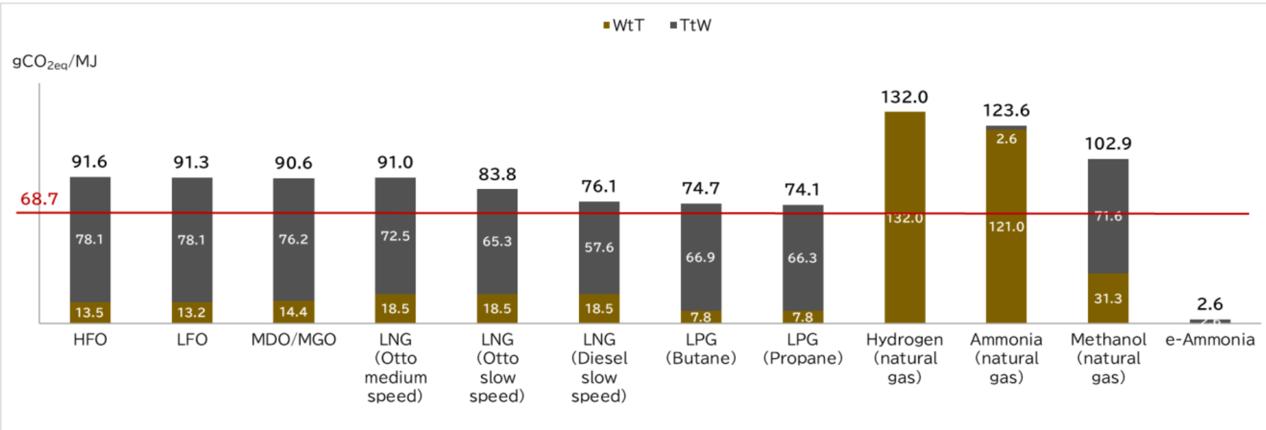
Table 17 – Introduction amount of zero-emission ships (case of achieving the indicative checkpoint for 2030)

	2021	- 2026	2027 – 2030 introduction amount of zero-emission ships	2030
Zero-emission ships	Existing ships 0.75 mil. GT	Newbuildings 12 mil. GT	Newbuildings and Retrofits **340 mil. GT** **(85 mil. GT/year)**	352 mil. GT
Entire fleet	1,250 mil. GT	1,330 mil. GT	-	1,430 mil. GT

(Source: ClassNK estimations)

(Notes)
- Until delivery in 2026, figures are based on the orderbook as of September 2023.

Reference) The average value of the fuel's GHG intensity (WtW) for the entire international shipping fleet required in the case of achieving the indicative checkpoint for 2030 is 68.7 gCO_{2eq}/MJ. This is an unachievable level even if the entire fleet were to use LNG fuel[22].



(Source: Prepared by ClassNK)

Figure 3 – Fuel's GHG intensity (WtW) to achieve the indicative checkpoint for 2030 (minimum 20% reduction compared to 2008)

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[21] Annual energy consumption is assumed to be 6,000 MJ/GT.

[22] The average fuel GHG intensity (WtW) for all fleets using LNG (Diesel slow speed) is 76.1 gCO_{2eq}/MJ, which is more than 68.7 gCO_{2eq}/MJ. This is similarly difficult to achieve even if methane slip measures are implemented.

Scenario for achieving the indicative checkpoint for 2030 (Reference: For biodiesel)

Biodiesel can also play a role in achieving the indicative checkpoint for 2030. Biodiesel is a drop-in fuel that can be used in conventional fuel main engines, and a GHG reduction effect has been recognized by the IMO for biodiesel that meets certain conditions.

Therefore, we considered a scenario in which the indicative checkpoint for 2030 (minimum 20% reduction compared to 2008) is achieved not with zero-emission fuels but with biodiesel.

The fuel mix as of 2030 in this scenario is as shown in **Table 18.**

Table 18 - Fuel mix (case of achieving the indicative checkpoint for 2030)

	Fuel oil	LNG	Biodiesel	Total amount
Ship energy consumption	5.16 EJ (61%)	0.85 EJ (10%)	2.46 EJ (29%)	8.47 EJ (100%)
Life cycle GHG emissions (WtW)	473 mil. tons CO_{2eq}	71 mil. tons CO_{2eq}	37 mil. tons CO_{2eq}	581 mil. tons CO_{2eq} (20.5% reduction from 2008)
Indicative checkpoint for 2030	-	-	-	585 mil. tons CO_{2eq}

(Source: ClassNK estimations)

(Notes)
- The GHG intensity (WtW) of fuel oil is assumed to be 91.6 gCO_{2eq}/MJ, equivalent to HFO.
- The GHG intensity (WtW) of LNG is assumed to be 83.8 gCO_{2eq}/MJ.
- The GHG intensity (WtW) of biodiesel is assumed to be 15.0 gCO_{2eq}/MJ, equivalent to that derived from waste cooking oil.

By introducing 29% biodiesel (B-100) on an energy consumption basis, the 2030 GHG emission reduction target (minimum 20% reduction compared to 2008) can be achieved.

The amount of biodiesel required to achieve a 29% share on an energy consumption basis is as shown in **Table 19.** 66 million tons of biodiesel per year will be needed in 2030 to achieve the indicative checkpoint for 2030. The biodiesel currently produced for all sectors is mainly used for automobile fuel, and further expansion of production is essential for use in international shipping.

Table 19 – Introduction amount of biodiesel (case of achieving the indicative checkpoint for 2030)

Fuel type	2030 introduction amount of biodiesel (29% biodiesel)	Current production scale for all sectors
For Biodiesel	66 million tons	42 million tons/year

(Source: ClassNK estimations)

Scenario for achieving the indicative checkpoint for 2040

Based on the energy consumption of ships in 2021 and taking into account the increase in marine transport volume and the improvement in energy efficiency of ships, the estimated energy consumption of ships in 2040 was 8.60EJ.

Energy consumption of ships in 2021 × Rate of increase in marine transport volume
8.79 EJ *+39%*
× Rate of improvement in energy efficiency of ships
-30%
= Energy consumption of ships in 2030
8.60 EJ

Next, we examined a scenario for achieving the indicative checkpoint for 2040 (minimum 70% reduction compared to 2008).

Energy consumption of ships in 2040 × Σ(each fuel's "share × GHG intensity")
8.60 EJ
≤ Allowable GHG emissions to achieve the indicative checkpoint for 2040
219 million tons CO_{2eq}

The fuel mix as of 2040 in this scenario is as shown in **Table 20.**

Table 20 - Fuel mix (case of achieving the indicative checkpoint for 2040)

	Fuel oil	LNG	Zero-emission fuel	Total amount
Ship energy consumption	1.55 EJ (18%)	0.86 EJ (10%)	6.19 EJ (72%)	8.60 EJ (100%)
Life cycle GHG emissions (WtW)	142 mil. tons CO_{2eq}	72 mil. tons CO_{2eq}	0 mil. tons CO_{2eq}	214 mil. tons CO_{2eq} (70.7% reduction from 2008)
Indicative checkpoint for 2040	-	-	-	219 mil. tons CO_{2eq}

(Source: ClassNK estimations)

(Notes)
- The GHG intensity (WtW) of fuel oil is assumed to be 91.6 gCO_{2eq}/MJ, equivalent to HFO.
- The GHG intensity (WtW) of LNG is assumed to be 83.8 gCO_{2eq}/MJ.
- The GHG intensity (WtW) of zero-emission fuel is assumed to be 0 gCO_{2eq}/MJ.

By introducing 72% zero-emission fuels on an energy consumption basis, the indicative checkpoint for 2040 (minimum 70% reduction compared to 2008) can be achieved.

The amount of zero-emission fuels required to achieve a 72% share of an energy consumption basis is as shown in **Table 21.** 311 million tons of methanol or 333 million tons of ammonia per year will be needed in 2040 to achieve the indicative checkpoint for 2040.

Table 21 – Introduction amount of zero-emission fuels (case of achieving the indicative checkpoint for 2040)

Fuel type	2040 introduction amount of zero-emission fuels (72% zero-emission fuel)	Current production scale for all sectors
For Methanol	311 mil. tons	106 mil. tons/year (less than 1% of which is zero-emission fuel)
For Ammonia	333 mil. tons	183 mil. tons/year (less than 1% of which is zero-emission fuel)

(Source: ClassNK estimations)

If the amount of zero-emission fuels required to achieve the indicative checkpoint for 2040 is secured, the corresponding amount of zero-emission ships needed to use these fuels is as shown in **Table 22**, requiring a fleet of 1,122 million GT in 2040[23]. Assuming that zero-emission ships are deployed at a level that achieves the indicative checkpoint by 2030, 77 million GT of zero-emission ships per year will be required over the 10-year period of 2031-2040. If the indicative checkpoint for 2030 is not achieved, it will be necessary to introduce 80 million GT of zero-emission ships per year from 2027 to 2040. However, if the use of e-methane, etc. in existing LNG-fueled ships expands by 2040, the required amount of zero-emission ships will decrease.

Table 22 – Introduction amount of zero-emission ships (case of achieving the indicative checkpoint for 2040)

	2030	2031 - 2040 introduction amount of zero-emission ships	2040
Zero-emission ships	352 mil. GT	Newbuildings and Retrofits **770 mil. GT (77 mil. GT/year)**	1,122 mil. GT
Entire fleet	1,430 mil. GT	-	1,550 mil. GT

(Source: ClassNK estimations)

23 Annual energy consumption is assumed to be 5,500 MJ/GT.

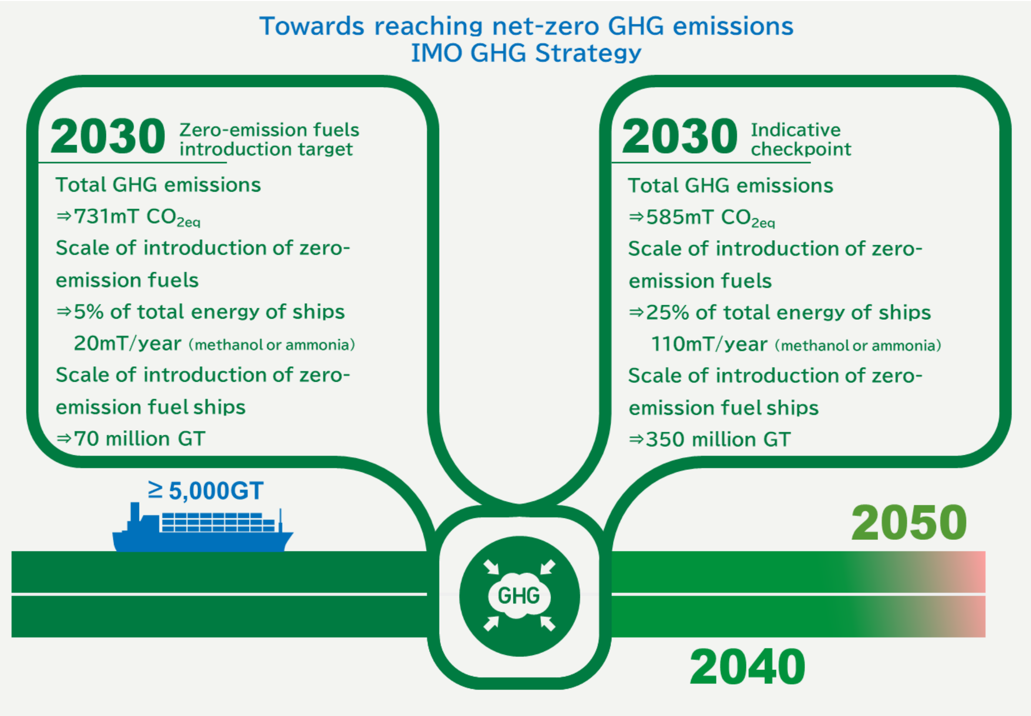
Discussion: achieving the numerical targets of the 2023 IMO GHG Strategy

In order to promote understanding of the 2023 IMO GHG Strategy, we examined the meaning of the numerical targets in this strategy, and found that it is necessary to secure a significant amount of zero-emission fuels in international shipping in the future to achieve the numerical targets. As for methanol and ammonia, which are candidates for zero-emission fuels, most of them are currently “non-zero emission fuels” derived from natural gas, and there are virtually no production that can make them zero-emission fuels over their entire life cycle. Therefore, the production and distribution sectors of fuels will need to accelerate investments, including in carbon-free hydrogen and electricity, more rapidly than with previous efforts in decarbonization. The early introduction of a regulatory framework, including effective carbon pricing, is essential to facilitate these investment decisions.

Concerning the newbuildings and retrofits of zero-emission ships, it is unlikely that there will be a significant shortage of newbuildings and retrofits capacity to achieve the numerical targets as long as a certain amount of ships are built and retrofitted each year. On the other hand, considering that the mainstay of zero-emission fuels in international shipping is yet to be determined at this point, and the possibility that multiple zero-emission fuels will be used in the future according to the type, size, and route of ships, it will be essential to secure newbuildings and retrofits capacity in line with the pace of development of the various zero-emission fuel production and distribution infrastructure.

The time remaining until 2030, which is the immediate target and checkpoint, is extremely limited. Achieving the zero-emission goal as outlined in the 2023 IMO GHG Strategy necessitates a collective and urgent effort from all stakeholders, including international organizations, national governments, the maritime industry, the energy sector, shippers, and the financial sector.

We hope that this document will promote understanding of the 2023 IMO GHG Strategy and stimulate a broad discussion among industry stakeholders, thereby helping all stakeholders involved in shipping to consider future initiatives toward the realization of zero emissions from international shipping.


Towards reaching net-zero GHG emissions
IMO GHG Strategy
2030 Zero-emission fuels introduction target
Total GHG emissions
⇒731mT CO_{2eq}
Scale of introduction of zero-emission fuels
⇒5% of total energy of ships
20mT/year (methanol or ammonia)
Scale of introduction of zero-emission fuel ships
⇒70 million GT
2030 Indicative checkpoint
Total GHG emissions
⇒585mT CO_{2eq}
Scale of introduction of zero-emission fuels
⇒25% of total energy of ships
110mT/year (methanol or ammonia)
Scale of introduction of zero-emission fuel ships
⇒350 million GT
≥ 5,000GT
GHG
2050
2040

Appendix

GHG emissions

(Unit: million tons CO_{2eq})

GHG emissions	2008 (Base year)	2021 (Latest)	2030 indicative checkpoint (20% reduction from 2008)	2030 indicative checkpoint (30% reduction from 2008)	2040 indicative checkpoint (70% reduction from 2008)	2040 indicative checkpoint (80% reduction from 2008)
Life cycle GHG emissions (WtW)	**731**	**798**	**585**	**512**	**219**	**146**
(Breakdown) GHG emissions (WtT) GHG emissions (TtW)	110 621	122 676	88 497	77 435	33 186	22 124

(Source: ClassNK estimations)

Marine transport volume

(Unit: billion ton-miles)

Scenario	2008	2018	2021	2030	2040	2050
Base case (compared to 2021)	42,000	59,000	59,000	74,000 (+25%)	82,000 (+39%)	89,500 (+52%)
High case (compared to 2021)	42,000	59,000	59,000	88,000 (+49%)	109,000 (+85%)	126,000 (+114%)
Low case (compared to 2021)	42,000	59,000	59,000	67,000 (+14%)	76,000 (+29%)	82,000 (+39%)

(Source: ClassNK estimations)

Example scenarios to achieve the indicative checkpoint for 2030 (20% reduction compared to 2008)

GHG emissions (WtW) (compared to 2021)	Marine transport volume (compared to 2021)		Ship energy efficiency (compared to 2021)	Fuel mix (as of 2030)	
-27%	Base case	+25%	-17%	Fuel oil	58%
				LNG	10%
				Zero-emission fuel	32%
			-23%	Fuel oil	65%
				LNG	10%
				Zero-emission fuel	25%
			-30%	Fuel oil	72%
				LNG	10%
				Zero-emission fuel	18%
	High case	+49%	-17%	Fuel oil	48%
				LNG	10%
				Zero-emission fuel	42%
			-23%	Fuel oil	53%
				LNG	10%
				Zero-emission fuel	37%
			-30%	Fuel oil	59%
				LNG	10%
				Zero-emission fuel	31%
	Low case	+14%	-17%	Fuel oil	67%
				LNG	10%
				Zero-emission fuel	23%
			-23%	Fuel oil	73%
				LNG	10%
				Zero-emission fuel	17%
			-30%	Fuel oil	81%
				LNG	10%
				Zero-emission fuel	9%

Scenarios analyzed in this document

(Source: ClassNK estimations)

Example scenarios for achieving the indicative checkpoint for 2030 (20% reduction compared to 2008) (for Biodiesel)

GHG emissions (WtW) (compared to 2021)	Marine transport volume (compared to 2021)		Ship energy efficiency (compared to 2021)	Fuel mix (as of 2030)	
-27%	Base case	+25%	-17%	Fuel oil	53%
				LNG	10%
				Biodiesel	37%
			-23%	Fuel oil	61%
				LNG	10%
				Biodiesel	29%
			-30%	Fuel oil	70%
				LNG	10%
				Biodiesel	20%
	High case	+49%	-17%	Fuel oil	41%
				LNG	10%
				Biodiesel	49%
			-23%	Fuel oil	47%
				LNG	10%
				Biodiesel	43%
			-30%	Fuel oil	54%
				LNG	10%
				Biodiesel	36%
	Low case	+14%	-17%	Fuel oil	63%
				LNG	10%
				Biodiesel	27%
			-23%	Fuel oil	71%
				LNG	10%
				Biodiesel	19%
			-30%	Fuel oil	80%
				LNG	10%
				Biodiesel	10%

Scenarios analyzed in this document

(Source: ClassNK estimations)

Example scenarios for achieving the indicative checkpoint for 2030 (30% reduction compared to 2008)

GHG emissions (WtW) (compared to 2021)	Marine transport volume (compared to 2021)		Ship energy efficiency (compared to 2021)	Fuel mix (as of 2030)	
-36%	Base case	+25%	-17%	Fuel oil	50%
				LNG	10%
				Zero-emission fuel	40%
			-23%	Fuel oil	56%
				LNG	10%
				Zero-emission fuel	34%
			-30%	Fuel oil	62%
				LNG	10%
				Zero-emission fuel	28%
	High case	+49%	-17%	Fuel oil	40%
				LNG	10%
				Zero-emission fuel	50%
			-23%	Fuel oil	45%
				LNG	10%
				Zero-emission fuel	45%
			-30%	Fuel oil	50%
				LNG	10%
				Zero-emission fuel	40%
	Low case	+14%	-17%	Fuel oil	57%
				LNG	10%
				Zero-emission fuel	33%
			-23%	Fuel oil	62%
				LNG	10%
				Zero-emission fuel	28%
			-30%	Fuel oil	69%
				LNG	10%
				Zero-emission fuel	21%

(Source: ClassNK estimations)

Example scenarios for achieving the indicative checkpoint for 2030 (30% reduction compared to 2008) (for Biodiesel)

GHG emissions (WtW) (compared to 2021)	Marine transport volume (compared to 2021)		Ship energy efficiency (compared to 2021)	Fuel mix (as of 2030)	
-36%	Base case	+25%	-17%	Fuel oil	44%
				LNG	10%
				Biodiesel	46%
			-23%	Fuel oil	50%
				LNG	10%
				Biodiesel	40%
			-30%	Fuel oil	57%
				LNG	10%
				Biodiesel	33%
	High case	+49%	-17%	Fuel oil	32%
				LNG	10%
				Biodiesel	58%
			-23%	Fuel oil	37%
				LNG	10%
				Biodiesel	53%
			-30%	Fuel oil	43%
				LNG	10%
				Biodiesel	47%
	Low case	+14%	-17%	Fuel oil	51%
				LNG	10%
				Biodiesel	39%
			-23%	Fuel oil	58%
				LNG	10%
				Biodiesel	32%
			-30%	Fuel oil	66%
				LNG	10%
				Biodiesel	24%

(Source: ClassNK estimations)

Example scenarios for achieving the indicative checkpoint for 2040 (70% reduction compared to 2008)

GHG emissions (WtW) (compared to 2021)	Marine transport volume (compared to 2021)		Ship energy efficiency (compared to 2021)	Fuel mix (as of 2040)	
-73%	Base case	+39%	-23%	Fuel oil	16%
				LNG	10%
				Zero-emission fuel	74%
			-30%	Fuel oil	18%
				LNG	10%
				Zero-emission fuel	72%
			-36%	Fuel oil	21%
				LNG	10%
				Zero-emission fuel	69%
	High case	+85%	-23%	Fuel oil	10%
				LNG	10%
				Zero-emission fuel	80%
			-30%	Fuel oil	11%
				LNG	10%
				Zero-emission fuel	79%
			-36%	Fuel oil	13%
				LNG	10%
				Zero-emission fuel	77%
	Low case	+29%	-23%	Fuel oil	18%
				LNG	10%
				Zero-emission fuel	72%
			-30%	Fuel oil	20%
				LNG	10%
				Zero-emission fuel	70%
			-36%	Fuel oil	23%
				LNG	10%
				Zero-emission fuel	67%

Scenarios analyzed in this document

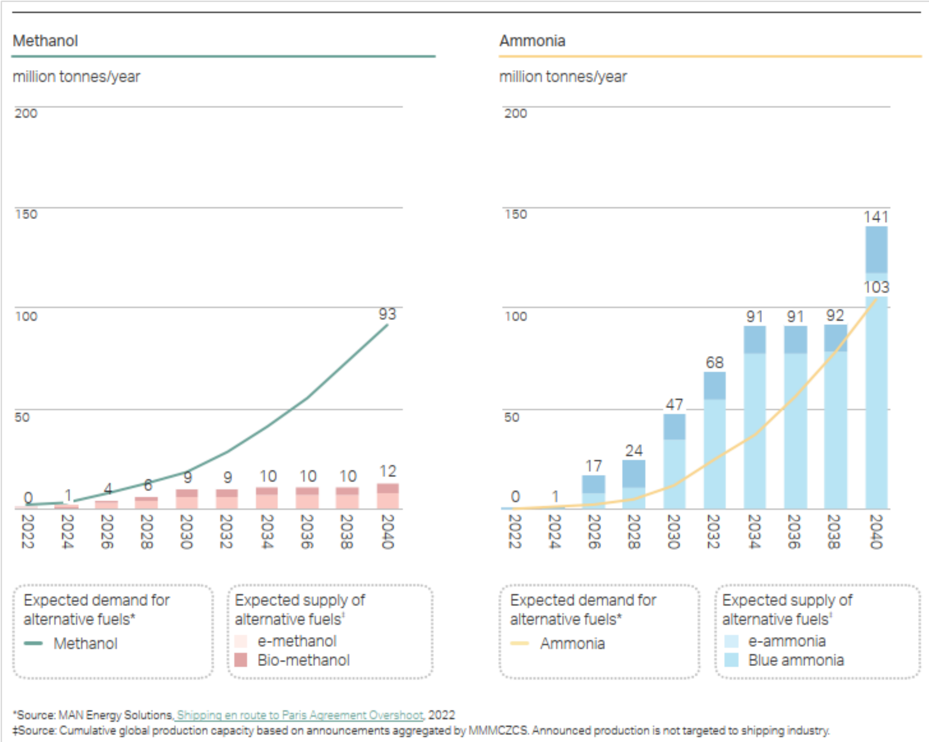
(Source: ClassNK estimations)

Example scenario for achieving the indicative checkpoint for 2040 (80% reduction compared to 2008)

GHG emissions (WtW) (compared to 2021)	Marine transport volume (compared to 2021)		Ship energy efficiency (compared to 2021)	Fuel mix (as of 2040)	
-82%	Base case	+39%	-23%	Fuel oil	7%
				LNG	10%
				Zero-emission fuel	83%
			-30%	Fuel oil	9%
				LNG	10%
				Zero-emission fuel	81%
			-36%	Fuel oil	11%
				LNG	10%
				Zero-emission fuel	79%
	High case	+85%	-23%	Fuel oil	3%
				LNG	10%
				Zero-emission fuel	87%
			-30%	Fuel oil	4%
				LNG	10%
				Zero-emission fuel	86%
			-36%	Fuel oil	6%
				LNG	10%
				Zero-emission fuel	84%
	Low case	+29%	-23%	Fuel oil	9%
				LNG	10%
				Zero-emission fuel	81%
			-30%	Fuel oil	10%
				LNG	10%
				Zero-emission fuel	80%
			-36%	Fuel oil	12%
				LNG	10%
				Zero-emission fuel	78%

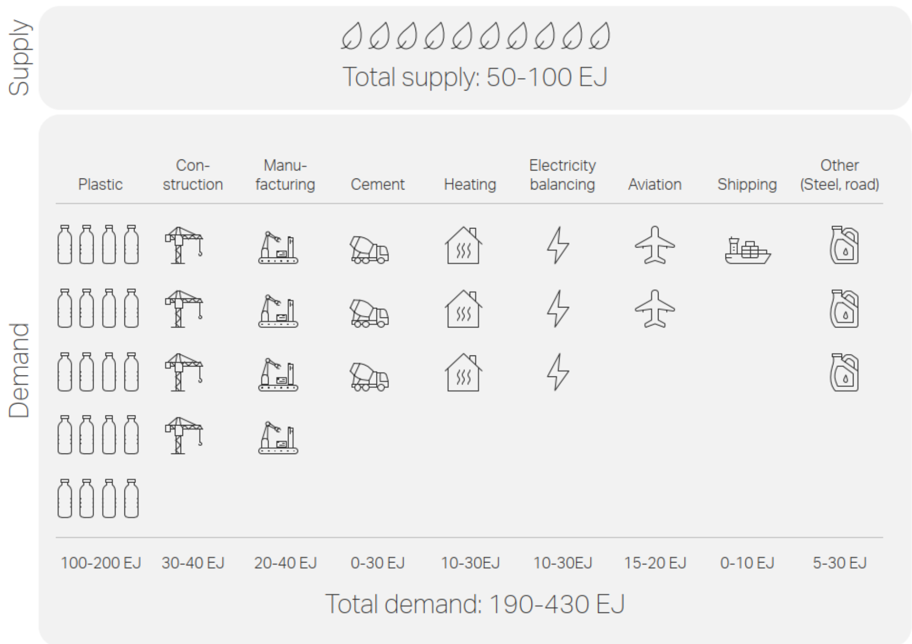
(Source: ClassNK estimations)

Expected additional supply of methanol and ammonia



(Source: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping[24])

Expected supply and demand of biomass as feedstock for biodiesel



(Source: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping)

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[24] ClassNK participates in this center as a Mission Ambassador.

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