ClassNK Alternative Fuels Insight

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Issuance of ClassNK Alternative Fuels Insight

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- Amidst the pressing need for society-wide reduction of GHG emissions, it is anticipated that GHG emission regulations in international shipping, spearheaded by organizations like the IMO and the EU, will be further strengthened. Consequently, we are entering an era where GHG emissions from ships become a cost factor. In such a business environment, strategically reducing GHG emissions from ships is crucial. This necessitates not only further energy efficiency improvements but also the essential adoption of alternative fuels with lower environmental impacts.
- On the other hand, there is a wide range of alternative fuels available for use in ships. When adopting alternative fuels, it is crucial to select the appropriate fuel based on factors such as the ship type, size, and route. Therefore, it is essential to not only consider technical aspects but also to grasp the overall trend of alternative fuels, including factors such as fuel availability and cost projections.
- The "ClassNK Alternative Fuels Insight," issued by ClassNK, aims to support your future fuel selection. We hope that the ClassNK Alternative Fuels Insight will be a helpful resource in your efforts to reduce GHG emissions.

Four Steps for Introducing Alternative Fuels

Step 1 Understanding regulations → **Step 2** Understanding trends → **Step 3** Understanding alternative fuels → **Step 4** Understanding costs

A Snapshot of the Current State of Energy Transition in International Shipping

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Demand side

In service:

37,000 ships[*1]

Conventional fuel ships: 36,000 ships (97%)

Alternative fuel ships:[*2] **1,000 ships (3%)**

A transition of 36,000 ships to alternative fuels is necessary. (Alternative fuel ships can use zero-emission fuels.)

*1 5,000 gross tonnage and above (as of the end of December 2023, adjusted for fractions)

*2 LNG-fueled LNG carriers are included.

Fuel consumption:

220 mil. tons/year[*3]

Conventional fuel oil 207 mil. tons (94%)

Alternative fuel 13 mil. tons[*4] **(6%)**

The required amount for a full transition to zero-emission fuels would be...

For methanol	440 mil. tons/year
For ammonia	470 mil. tons/year
For hydrogen	70 mil. tons/year

*3 The annual fuel consumption for ships engaged in international voyages with 5,000 gross tonnage and above (abt. 30,000 ships subject to IMO DCS) in 2022 (conventional fuel oil equivalent)

*4 Conventional fuel oil equivalent (of which 99% is LNG fuel.)

Supply side

Shipyard

Newbuildings:

1,300 ships[*5]

Conventional fuel ships: 1,100 ships (85%)

Alternative fuel ships: 200 ships (15%)

*5 5,000 gross tonnage and above (2023, adjusted for fractions)

Green fuel producers

- ✓ **Methanol 0.5 mil. tons/year**[*6]
- ✓ **Ammonia 4.6 mil. tons/year**[*6]
- ✓ **Hydrogen 1.5 mil. tons/year**[*6]

*6 Operational, construction, FID (for all sectors)

Other sectors

- ✓ **Methanol**
  Chemical, etc.
- ✓ **Ammonia**
  Electricity, Agriculture, Chemical, etc.
- ✓ **Hydrogen**
  Electricity, Automobile, Steel, etc.

Much of the green fuels and green chemicals produced are expected to be directed towards demand from other sectors.

While biofuels contribute to GHG emission reductions, there are constraints on the resource availability of biomass, which serves as their raw material. Moreover, demand for biomass competes across sectors.

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— Step 1

Understanding regulations

When considering the adoption of alternative fuels, understanding the GHG-related regulations that are expected to be strengthened in the future is crucial above all else. In this section, we will introduce the GHG-related regulations of the IMO and the EU, which will play a central role in GHG emission reduction measures in international shipping moving forward.

Key Takeaways

- ✓ Successive regulations promoting the use of zero or low-emission fuels are being introduced in international shipping.
- ✓ The IMO is to implement the "mid-term measures," while the EU has "EU-ETS for Shipping" and "FuelEU Maritime" playing central roles.
- ✓ The additional costs that ships will incur due to these regulations depend on their specific provisions. However, it’s conceivable that these costs could eventually reach levels equivalent to annual fuel costs.
- ✓ Since the scope of emissions targeted and the anticipated costs vary between each regulation, it is crucial to thoroughly understand the details of each regulation in order to minimize regulatory costs across the fleet.
- ✓ ClassNK provides information to support understanding of these regulations.

Understanding regulations

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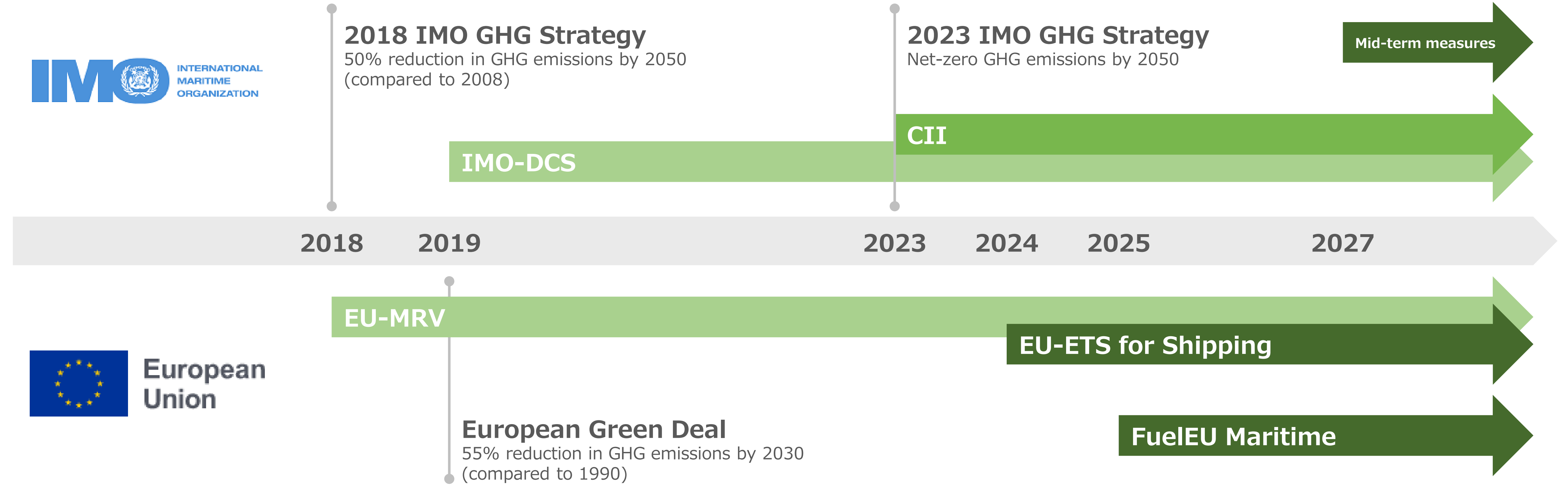
Carbon pricing

In order to further reduce GHG emissions from ships, successive regulations promoting the use of zero- and low-emission fuels are being introduced in international shipping. The IMO is currently discussing a new regulatory framework for mid-term measures, aiming for implementation in 2027. In Europe, the European Union Emissions Trading System (EU-ETS), a carbon pricing mechanism, has been expanded to include the maritime sector since 2024. In 2025, FuelEU Maritime will be introduced to drive the decarbonization of shipping fuels. With these regulations in place, GHG emissions from ships will become a cost factor, making it crucial for the future of maritime business to strategically reduce GHG emissions from ships.

Introduction schedule of GHG-related regulations*

*Only operational GHG-related regulations are listed here.



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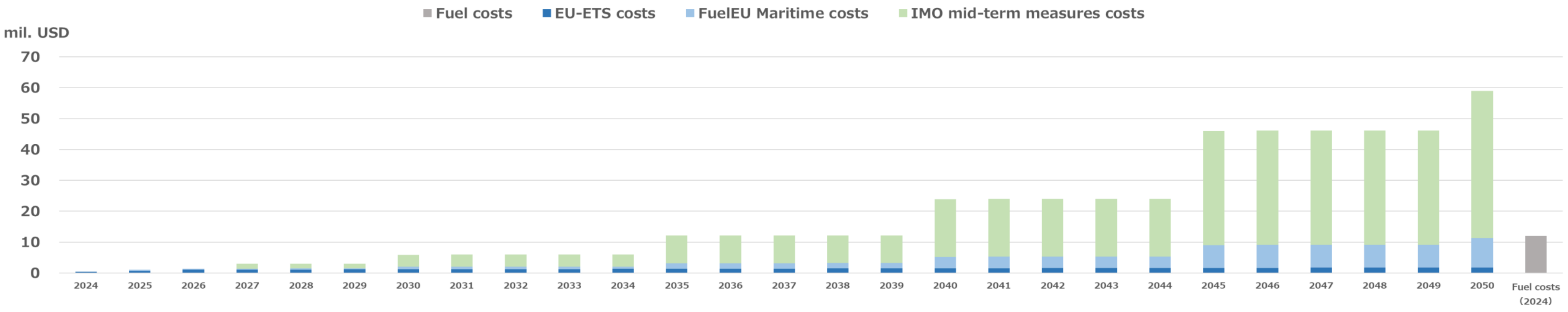
Increase in the cost of GHG emissions

The regulations set by the IMO and the EU are aimed at promoting the transition to zero- or low-emission fuels. Therefore, it is anticipated that the costs associated with regulatory compliance (GHG emission costs) will gradually increase. Understanding the extent to which GHG emission costs will affect the fleet in the future is the first step in considering the adoption of alternative fuels.

Image of increasing GHG emission costs (Continuing to use conventional fuel oil: e.g. 14,000 TEU containership)



- The figure above illustrates the annual increase in GHG emission costs if a 14,000 TEU containership continues to use conventional fuel oil.
- Depending on the specifics of the IMO's planned mid-term measures*, there is a possibility that the annual GHG emission costs may surpass fuel costs sooner rather than later.

  *The figure assumes the introduction of GHG intensity regulations on a Well-to-Wake basis as part of the mid-term measures in 2027.
- Especially noteworthy is the difference between the EU regulations (EU-ETS and FuelEU Maritime), which only regulate GHG emissions from EU-related voyages, and the IMO regulations, which cover GHG emissions from all voyages. Consequently, the introduction of the IMO regulations (mid-term measures) is expected to have a significantly larger impact on the burden of GHG emission costs.

Detailed cost simulations are provided in Step 4. ➡

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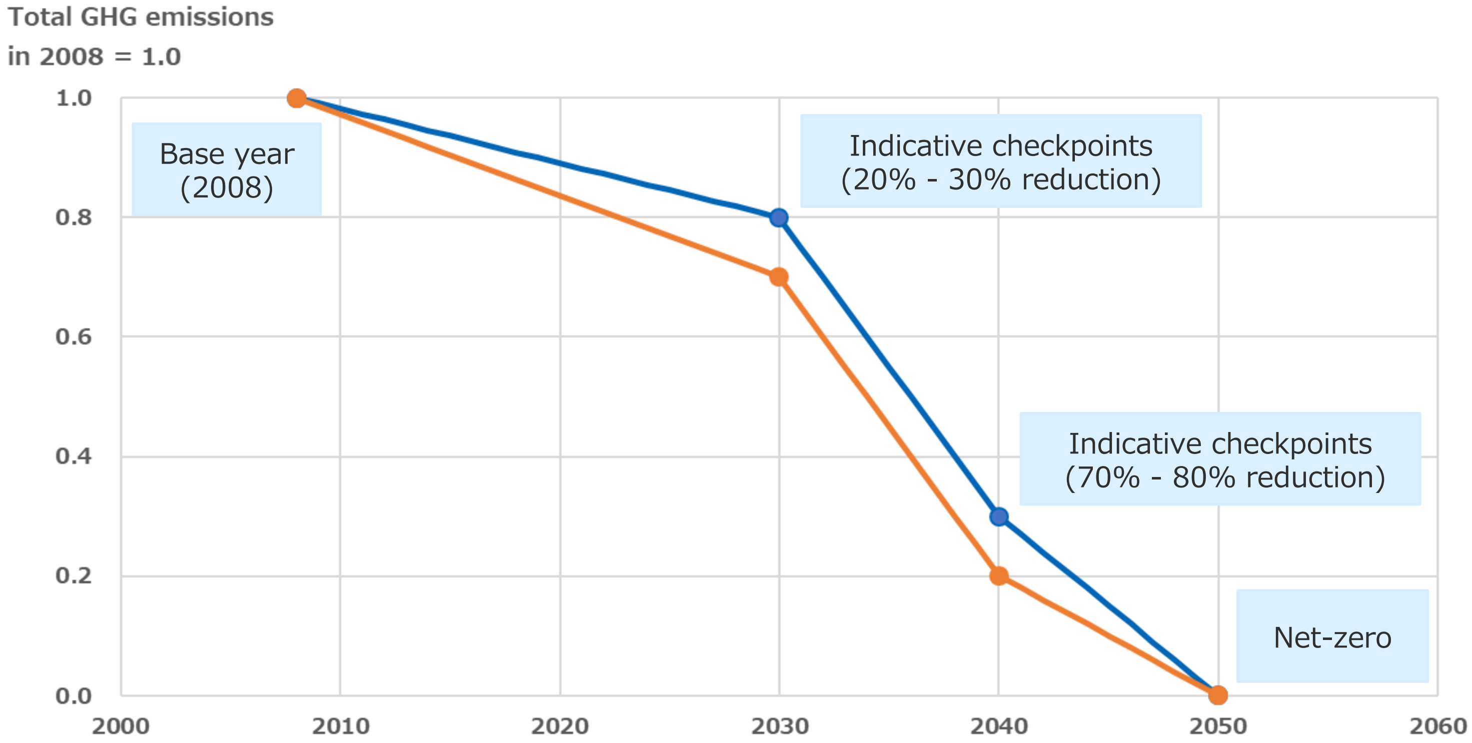
IMO GHG Strategy

In July 2023, the IMO revised its initial strategy on the reduction of GHG emissions from ships and adopted the "2023 IMO GHG Strategy," which includes the goal of achieving net-zero GHG emissions by or around 2050. Serving as the foundation for future discussions on reducing GHG emissions from international shipping, understanding this strategy is crucial for the shipping industry. ClassNK has published a white paper titled "Pathway to Zero-Emission in International Shipping - Understanding the 2023 IMO GHG Strategy -" to facilitate understanding of this strategy.

IMO GHG reduction goal



White Paper "Pathway to Zero-Emission in International Shipping - Understanding the 2023 IMO GHG Strategy -"

(English)

IMO mid-term measures

Currently, the IMO is engaged in discussions to introduce new regulations (mid-term measures) aimed at promoting the use of zero- and low-emission fuels. Scheduled to be finalized in 2025 and enforced in 2027, these mid-term measures will have a significant impact on the maritime industry. It is important for stakeholders in the shipping business to closely monitor the progress and discussions at the IMO regarding these regulations.

The outline of the mid-term measures proposed to the IMO* (As of March 2024, MEPC 81)

*The mid-term measures are expected to be finalized by combining the contents of these proposals.

	Schemes	Proposed by	Summary
Technical elements	**GFS** (Greenhouse Gas Fuel Standard)	EU member states, EC	• Gradual reduction of fuel's GHG intensity (gCO_{2eq}/MJ) on a Well-to-Wake (WtW) basis • Flexibility mechanisms* for regulatory compliance are included. *Transfer of excess compliance from ships that achieve regulatory limits to those that do not meet them *Considering compliance with regulations through payment of contributions to the IMO
Technical elements	**IMSF&F** (International Maritime Sustainable Fuels and Fund)	China, Brazil, Norway, UAE, Argentina, South Africa, Uruguay	• Gradual reduction of fuel's GHG intensity (gCO_{2eq}/MJ) on a Tank-to-Wake (TtW) basis • Flexibility mechanisms for regulatory compliance* and preferential treatment for relaxation of regulatory limits for certain routes in developing countries recognized to be adversely affected by this regulation *Transfer emission allowance of excess compliance from ships that achieve regulatory limits to those that do not meet them & Considering compliance with regulations through payment of contributions to the IMO
Economic elements	**Feebate** ※Fee and rebate	Japan	• Levying based on GHG emissions (WtW basis or TtW basis) • Refunds for ships using zero-emission fuels on a WtW basis, without excluding support for developing countries
Economic elements	**Feebate**	ICS, Bahamas, Liberia	• Levying based on GHG emissions (TtW basis) • Refunds for ships using zero-emission fuels on a WtW basis, also used for supporting developing countries
Economic elements	**GHG Levy** (Universal Mandatory Greenhouse Gas Levy)	Island countries (9 countries)	• Levying based on GHG emissions (WtW basis) • Levy is USD150/ton GHG, increasing every five years. • The revenue from the levy is primarily utilized for supporting developing countries.
Economic elements	**Unnamed** [New proposal]	Canada	• Levying based on GHG emissions (TtW basis) • Levy is USD90/ton GHG, increasing every year. • The revenue from the levy is utilized through a fund approved by the IMO.
Economic elements	**Green Balance Mechanism** [New proposal]	WSC	• Levying on ships that fail to meet the GHG fuel intensity threshold • Refunds are provided to ships that exceed a certain percentage of the GHG fuel intensity threshold.

European regional regulations

In Europe, the implementation of the European Union Emissions Trading System (EU-ETS) in the maritime sector began in 2024, and in 2025, FuelEU Maritime will be introduced. When assigning ships to European routes, it is essential to accurately understand the contents of these regulations in order to minimize regulatory compliance costs as much as possible. ClassNK has issued "FAQs on the EU-ETS for Shipping" and "FAQs on the FuelEU Maritime," each explaining the overview of the regulations and the essential preparations for compliance in a Q&A format specific to European regional regulations.

FAQs to understand EU's GHG-related regulations

FAQs on the EU-ETS for Shipping (Edition 2.1)

(English)

FAQs on the FuelEU Maritime (1st Edition)

(English)

— Step 2

Understanding trends

When considering the adoption of alternative fuels, it is important to understand the trends and future prospects of these options. Demand-side trends also influence the fuel supply side. In this section, we will introduce the adoption trends of alternative fuels, including their utilization across different ship types and sizes.

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Key Takeaways

- ✓ ClassNK has compiled data on the trends in the adoption of alternative fuels in shipping.
- ✓ The data includes ships with a gross tonnage of 5,000 and above, which are also subject to IMO DCS and CII (these ships are likely to be subject to IMO's mid-term measures). Additionally, LNG carriers have been excluded from the data on alternative fuel ships to provide a more accurate representation of the adoption status in ship types other than LNG carriers.
- ✓ The number of alternative fuel ships is steadily increasing, and it is projected that by 2026, the number of alternative fuel ships excluding LNG carriers will exceed 1,000.
- ✓ While there is a noticeable trend in orders for methanol fueled ships, LNG fueled ships still dominate the orderbook for alternative fuel ships.
- ✓ When categorized by ship type, the adoption rate of alternative fuel ships in bulk carriers and product/chemical tankers appears relatively lower compared to other ship types. Nevertheless, there is evidence of alternative fuel ships being adopted across all ship types, including large and small to medium-sized vessels. This suggests that ongoing efforts are being made to address design challenges associated with the utilization of alternative fuels.

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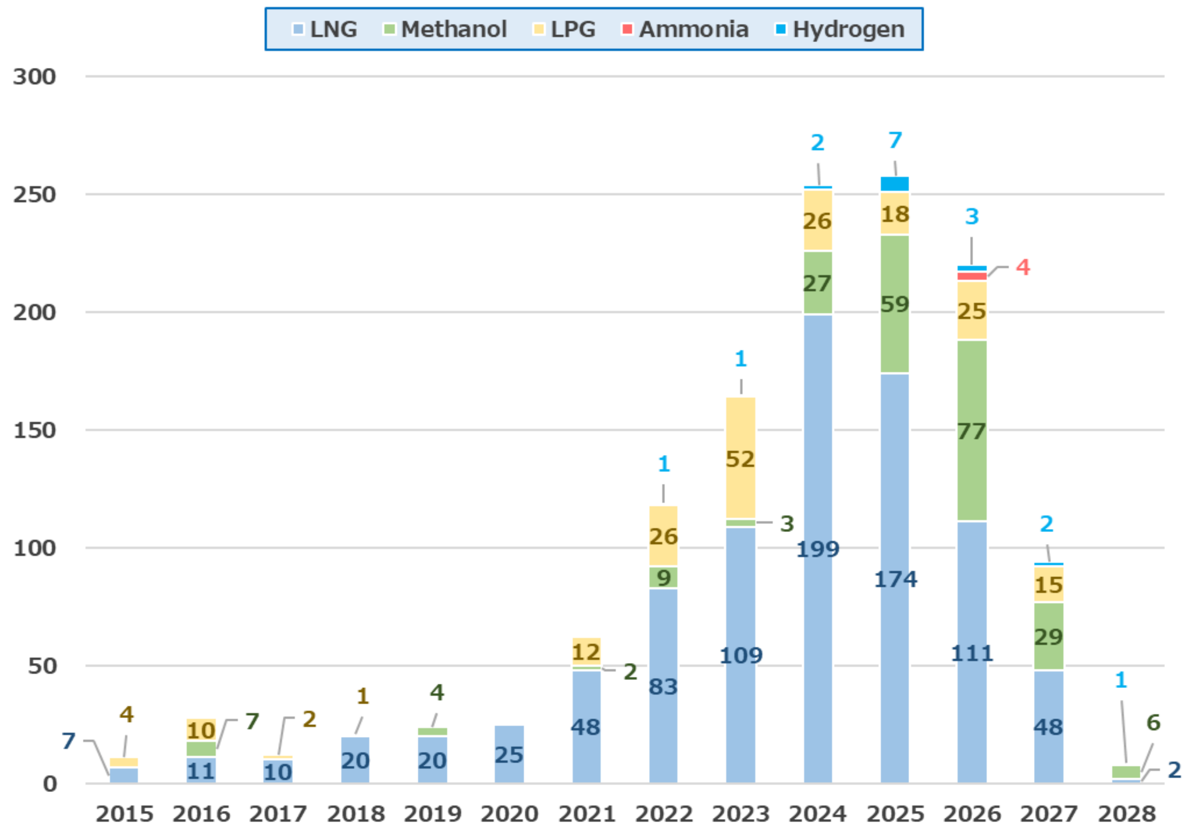
Trends in alternative fuel ships

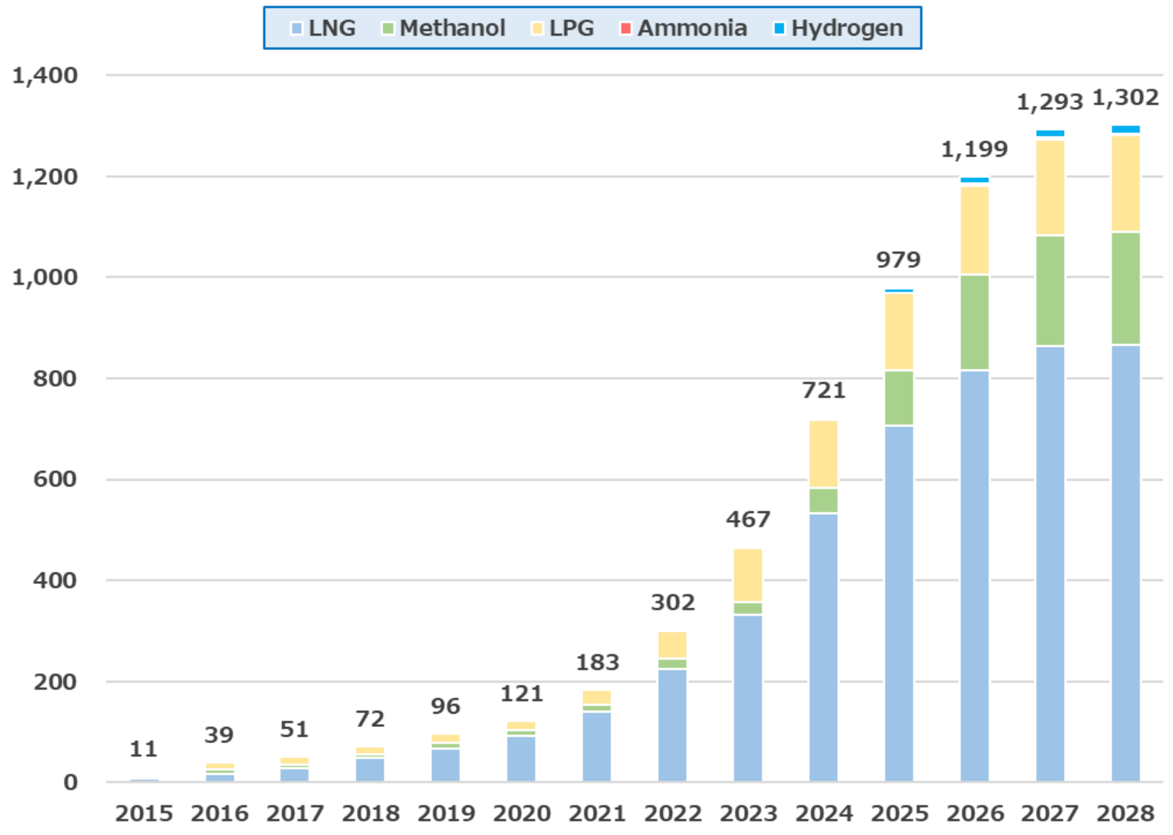
"Newbuilding" alternative fuel ship trend



- ✓ As of the end of December 2023 (Orderbook after 2024)
- ✓ 5,000 gross tonnage and above
- ✓ LNG carriers are not included in LNG fueled ships.

"In service" alternative fuel ship trend*

*Cumulative number of ships delivered since 2015, without considering scrapping

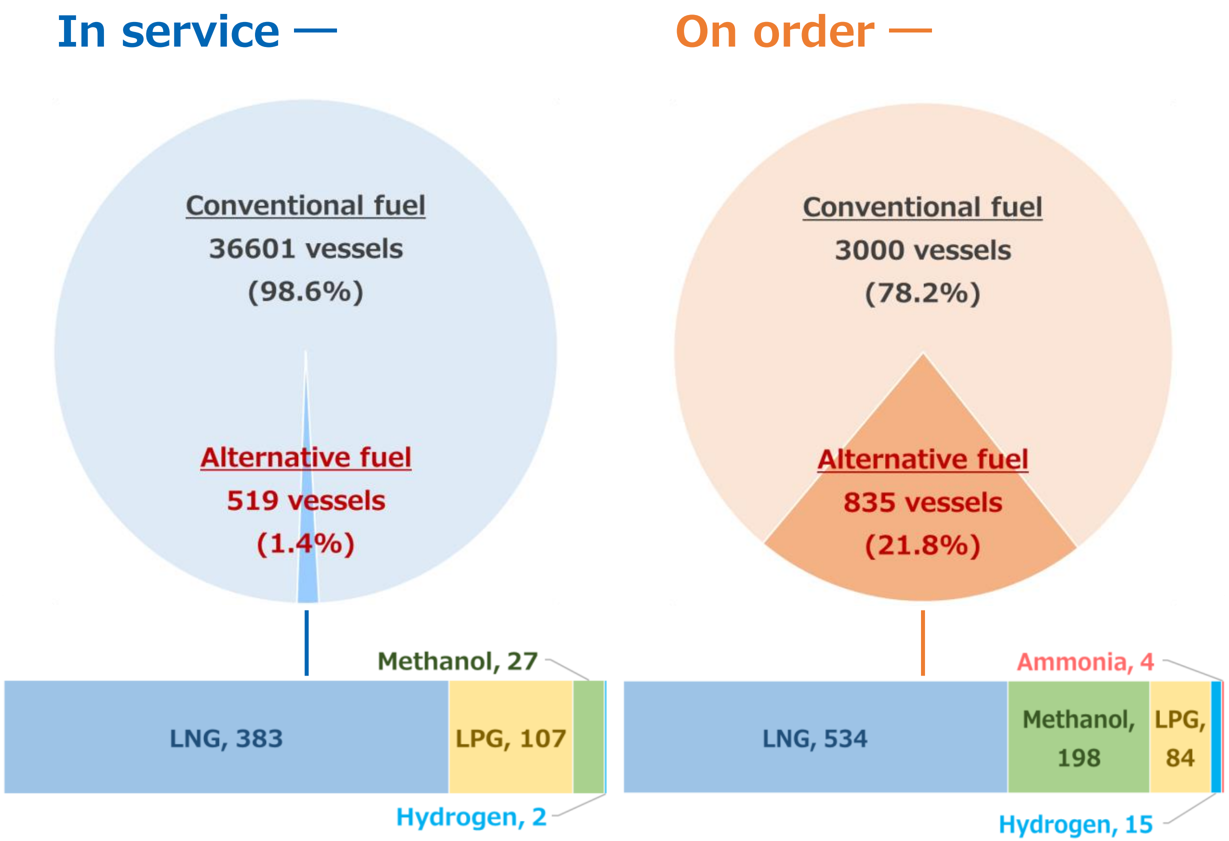


- ✓ As of the end of December 2023 (Orderbook is included after 2024.)
- ✓ 5,000 gross tonnage and above
- ✓ LNG carriers are not included in LNG fueled ships.

Source: The figures and tables presented in this section are created by ClassNK based on data from Clarkson Research Services Limited.

Trends in alternative fuel ships

Share of alternative fuel ships



- ✓ As of the end of December 2023
- ✓ 5,000 gross tonnage and above
- ✓ LNG carriers are not included in LNG fueled ships.

Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	429 vessels (1.2%)	519 vessels (1.4%)
Total GT	26,539,215 GT (1.8%)	33,461,484 GT (2.2%)

During the past six months, there has been an increase of 90 vessels totaling 7.0 million GT. This growth can be attributed to the successive deliveries of LNG fueled containerships, bulk carriers, and LPG fueled LPG carriers, leading to an increase in alternative fuel ships.

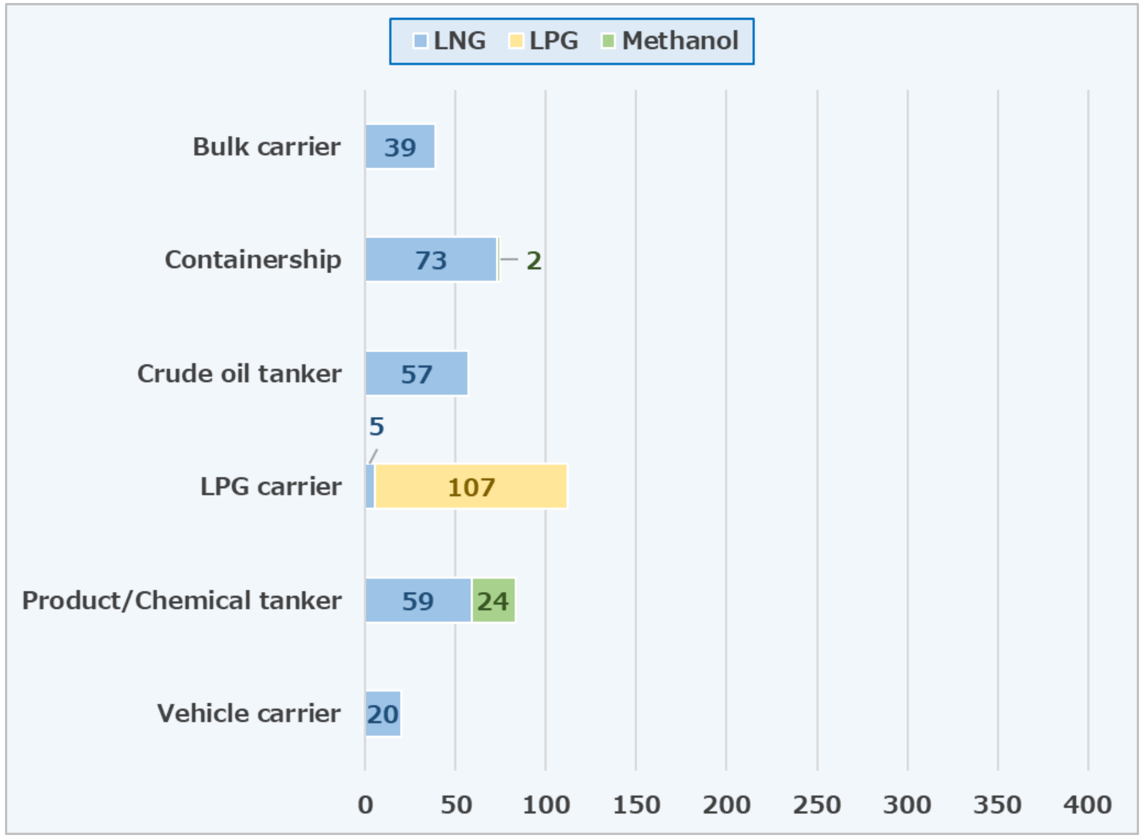
On order —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	722 vessels (21.2%)	835 vessels (21.8%)
Total GT	58,698,042 GT (30.1%)	61,732,161 GT (30.9%)

During the past six months, there has been an increase of 113 vessels totaling 3.0 million GT. Particularly notable is the high number of orders for methanol fueled ships spanning various ship types, notably 16,000 TEU- containerships, bulk carriers, vehicle carriers, and product/chemical tankers.

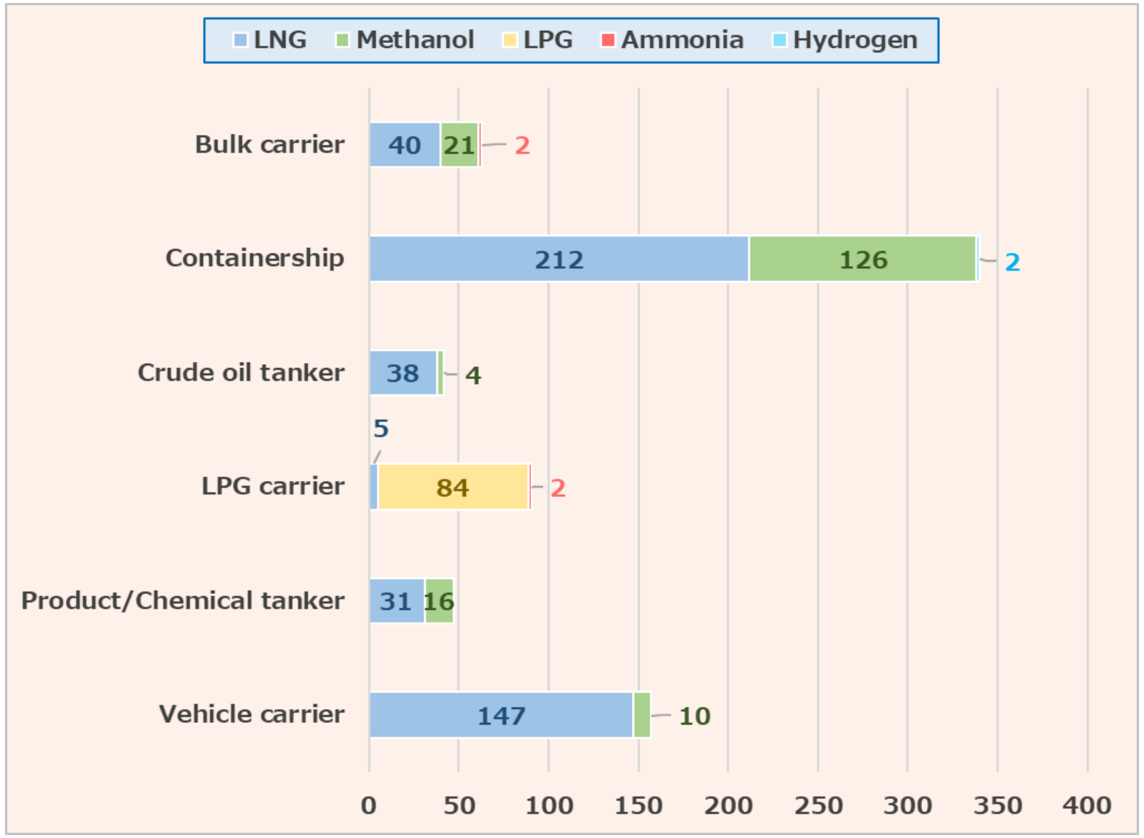
Trends in alternative fuel ships (by ship type)

In service —



- ✓ As of the end of December 2023
- ✓ 5,000 gross tonnage and above
- ➢ **With the exception of LPG carriers and product/chemical tankers, which include methanol carriers, LNG fueled ships constitute the majority in the adoption of alternative fuels.**

On order —

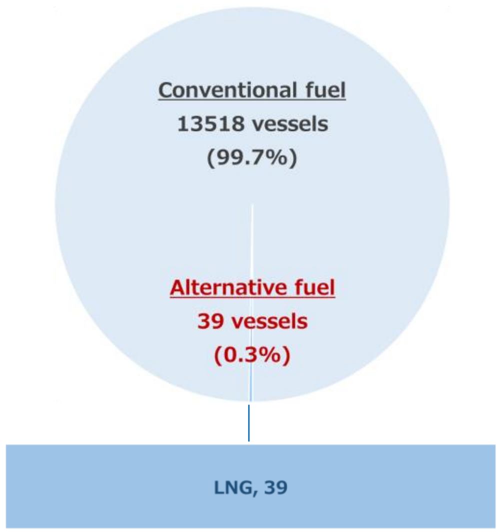


- ✓ As of the end of December 2023
- ✓ 5,000 gross tonnage and above
- ➢ **Adoption of methanol fueled ships is expanding, especially among containerships. Additionally, orders for ammonia fueled ships have been observed in some ship types.**

Trends in alternative fuel ships (by ship type)

Bulk carriers

In service —



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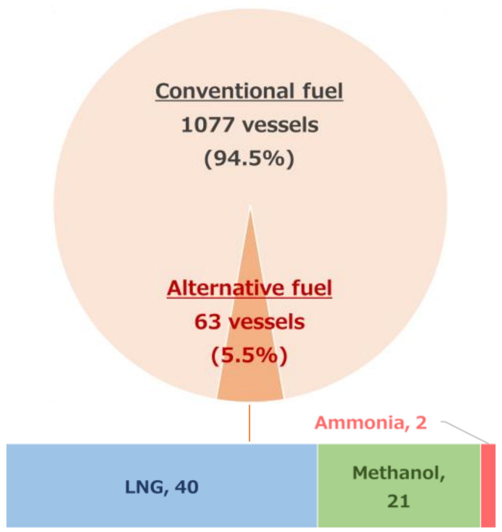

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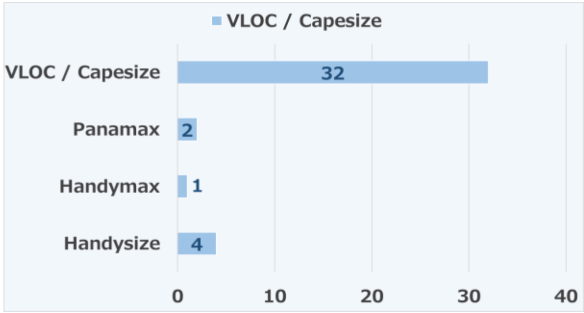

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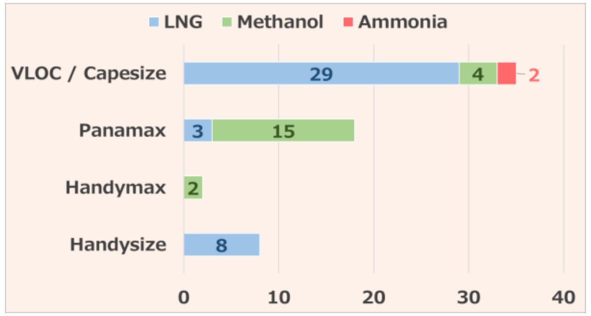

Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	29 vessels (0.2%)	39 vessels (0.3%)
Total GT	2,831,602 GT (0.5%)	3,622,799 GT (0.7%)

During the past six months, there was an increase of 10 vessels, totaling 0.8 million GT. By ship size, more than half of the increase is accounted for by VLOC/Capesize, indicating that, in line with previous trends, alternative fuel ships are often adopted in larger sizes. It's worth noting all deliveries were LNG fueled ships.

On order —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	50 vessels (5.0%)	63 vessels (5.5%)
Total GT	3,635,838 GT (9.0%)	4,926,559 GT (10.3%)

During the past six months, there was an increase of 13 vessels, totaling 1.3 million GT. By ship size, VLOC/Capesize and Panamax accounted for the majority. By fuel type, methanol fueled ships were the most common. Additionally, orders for ammonia fueled ships were observed in the VLOC/Capesize category.

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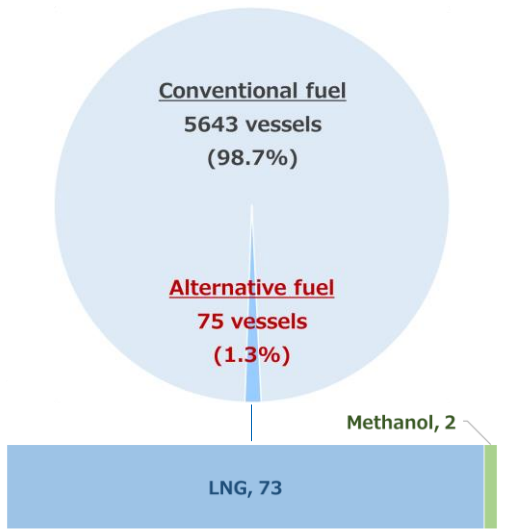
Trends in alternative fuel ships (by ship type)

Containerships

In service —



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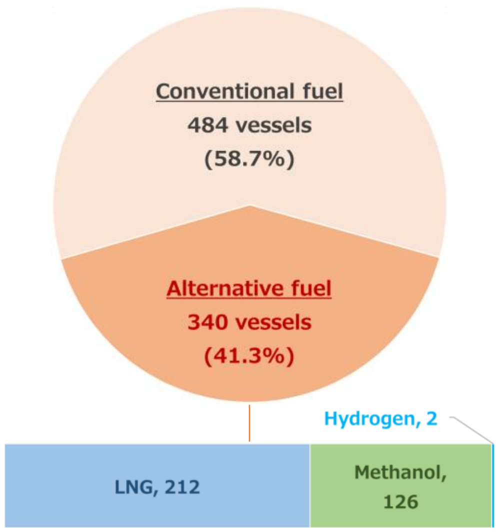

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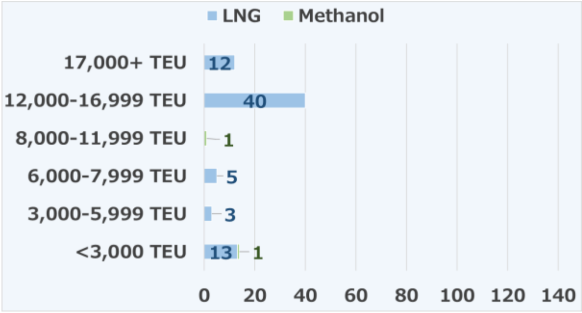

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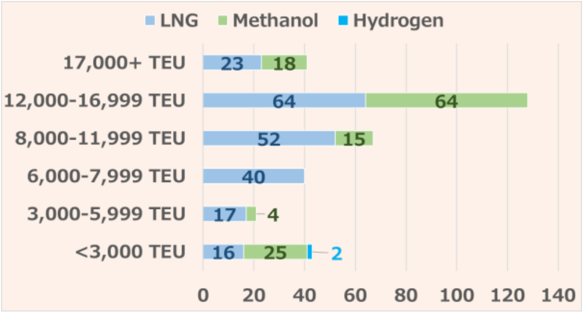

Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	55 vessels (1.0%)	75 vessels (1.3%)
Total GT	7,349,369 GT (2.6%)	9,683,956 GT (3.3%)

During the past six months, there was an increase of 20 vessels, totaling 2.4 million GT. By ship size, the majority of deliveries were of the 15,000 TEU, with some 7,000 TEU and 23,500 TEU. By fuel type, the majority were LNG fueled ships, although there were also deliveries of methanol fueled ships.

On order —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	300 vessels (33.9%)	340 vessels (41.3%)
Total GT	34,360,667 GT (48.7%)	38,028,991 GT (56.5%)

During the past six months, there was an increase of 40 vessels, totaling 3.6 million GT. By ship size, around 16,000 TEU accounted for half of the deliveries. By fuel type, methanol fueled ships accounted for more than half. There is an expanding trend in the adoption of methanol fueled ships.

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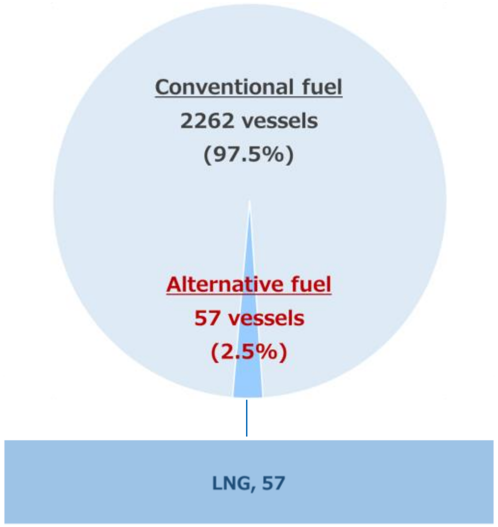
Trends in alternative fuel ships (by ship type)

Crude oil tankers

In service —



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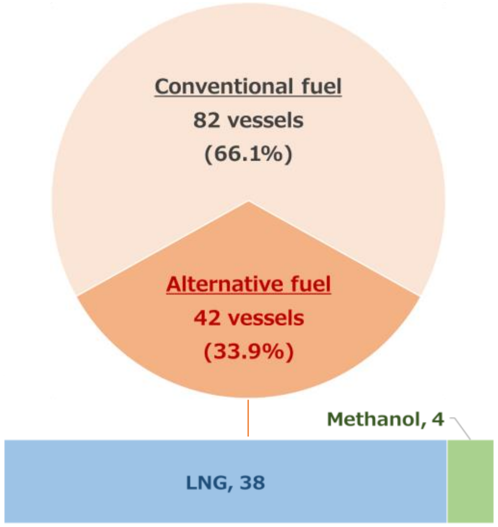

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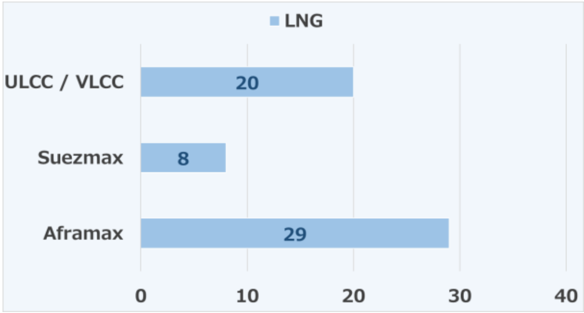

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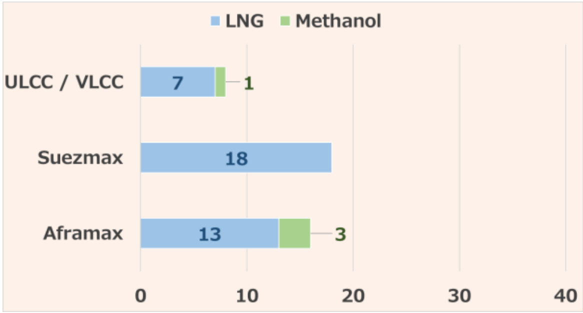


Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	48 vessels (2.1%)	57 vessels (2.5%)
Total GT	4,725,855 GT (1.9%)	5,775,831 GT (2.4%)

During the past six months, there was an increase of 9 vessels, totaling 1.1 million GT. By ship size, ULCC/VLCC accounted for more than half, with the remaining being Aframax (all LNG fueled). It is noteworthy that there were no confirmed deliveries of alternative fuel ships in the Suezmax during this period.

On order —

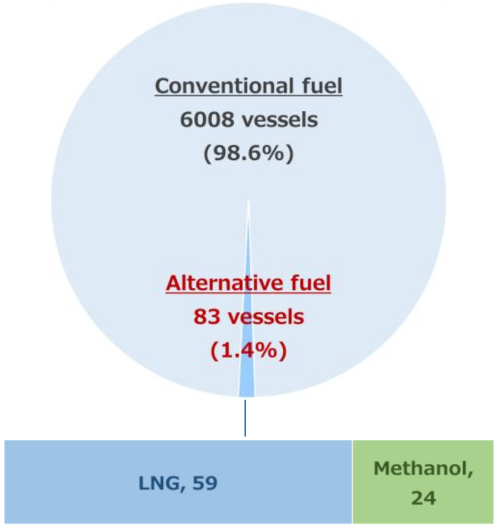
	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	37 vessels (44.0%)	42 vessels (33.9%)
Total GT	3,303,019 GT (48.4%)	3,736,624 GT (33.6%)

During the past six months, there was an increase of 5 vessels, totaling 0.4 million GT. By ship size, Suezmax, which had been lagging behind in the adoption of alternative fuels, were the most ordered, followed by ULCC/VLCC. By fuel type, LNG fueled ships were the most ordered, followed by methanol fueled ships.

Trends in alternative fuel ships (by ship type)

Product/Chemical tankers

In service —



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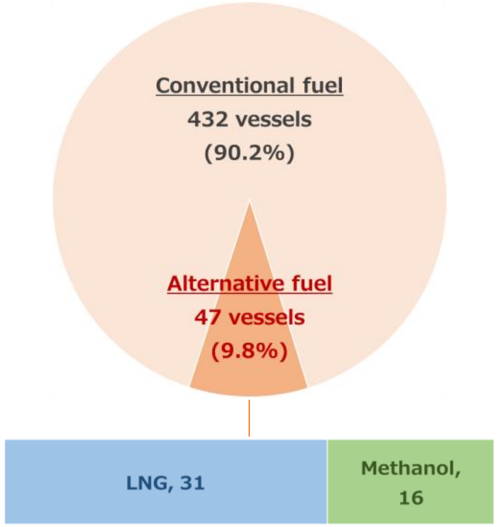

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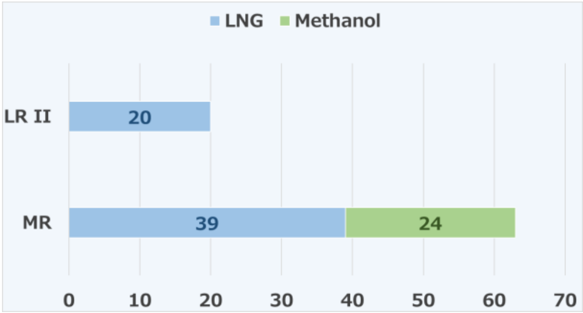

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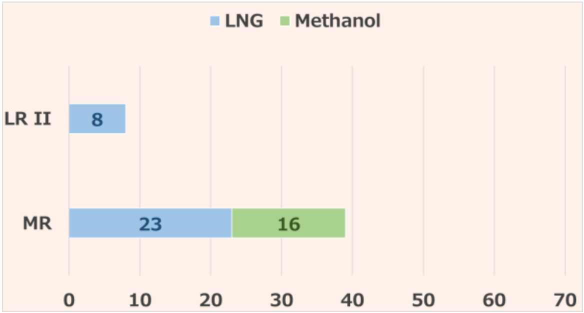

Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	74 vessels (1.2%)	83 vessels (1.4%)
Total GT	2,213,494 GT (1.6%)	2,596,463 GT (1.8%)

During the past six months, there was an increase of 9 vessels, totaling 0.4 million GT. By ship size, LRII and MR each accounted for half of the deliveries, while there was no increase in LRI during this period. By fuel type, LNG fueled ships dominated, although there were also a few deliveries of methanol fueled ships.

On order —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	41 vessels (11.4%)	47 vessels (9.8%)
Total GT	1,212,658 GT (10.5%)	1,280,079 GT (8.3%)

During the past six months, there was an increase of 6 vessels, totaling 0.1 million GT. By ship size, there were more orders for MR. By fuel type, the majority were methanol fueled ships.

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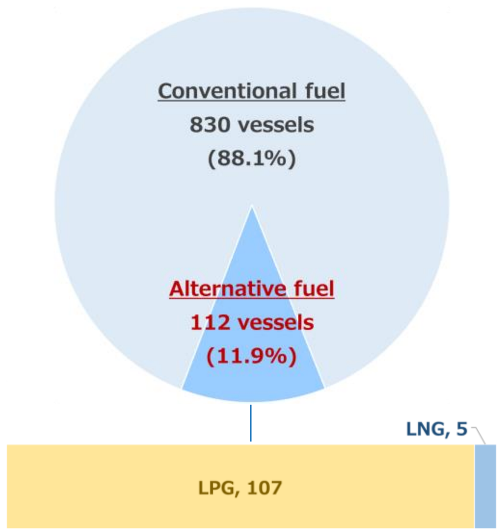
Trends in alternative fuel ships (by ship type)

LPG carriers

In service —



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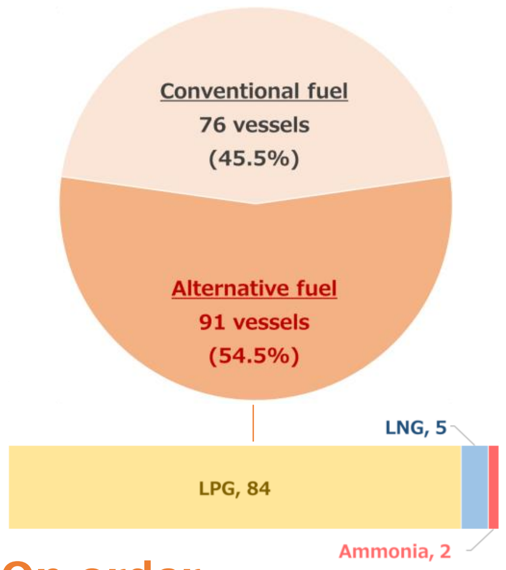

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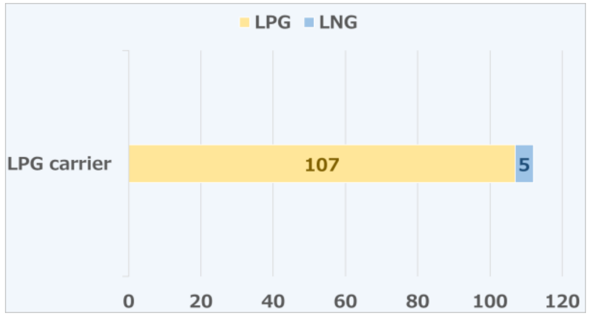

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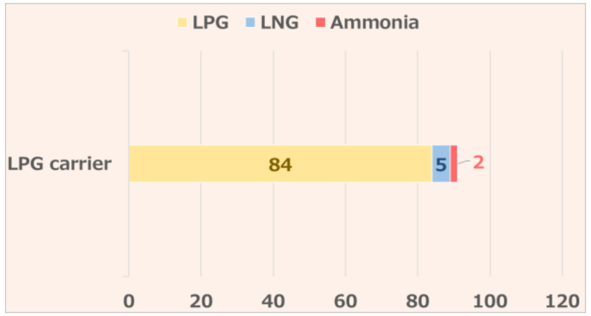

Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	85 vessels (9.4%)	112 vessels (11.9%)
Total GT	3,560,569 GT (13.5%)	4,834,491 GT (17.4%)

During the past six months, there was an increase of 27 vessels, totaling 1.2 million GT. By ship size, VLGC (over 80,000m³) were predominant. All vessels were LPG fueled ships, and no deliveries other than LPG fueled ships were confirmed.

On order —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	87 vessels (67.4%)	91 vessels (54.5%)
Total GT	3,959,686 GT (72.4%)	3,781,639 GT (55.8%)

During the past six months, there was an increase of 4 vessels and a decrease of 0.2 million GT. By ship size, similar to those in service, VLGC (over 80,000 m³) accounted for more than half. All vessels were LPG fueled ships, with one being an ammonia fueled ready ship.

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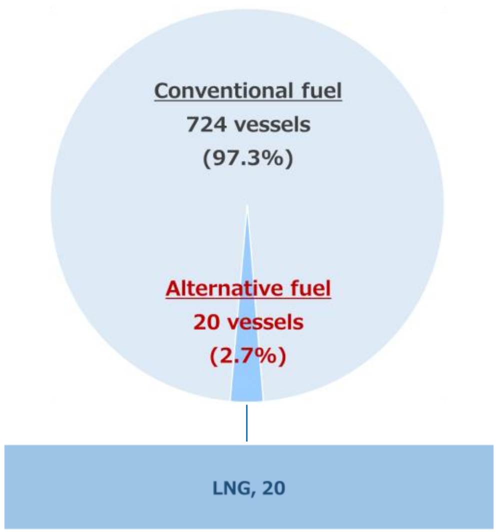
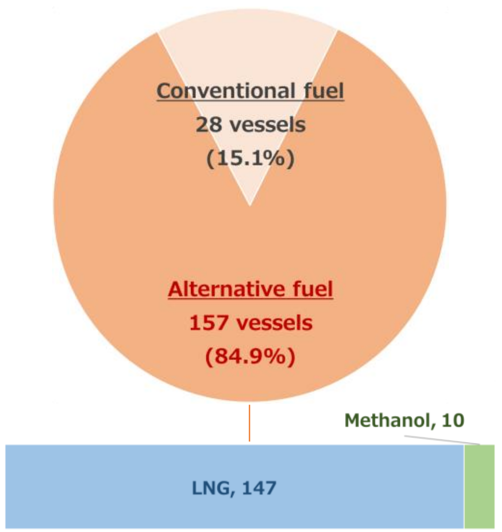
Trends in alternative fuel ships (by ship type)

Vehicle carriers

In service —



On order —



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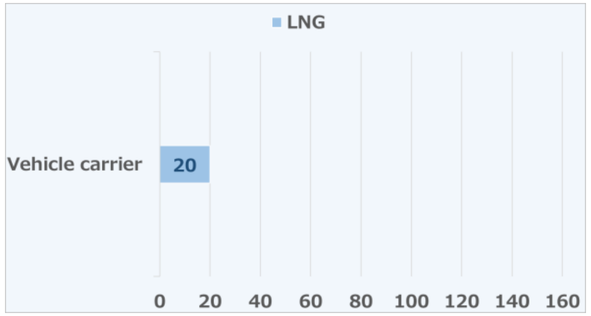
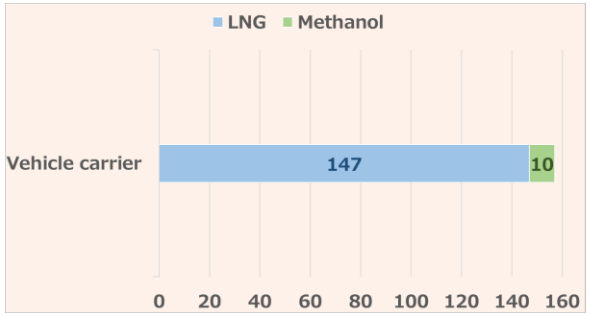


On order —



Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	13 vessels (1.8%)	20 vessels (2.7%)
Total GT	771,559 GT (2.0%)	1,275,216 GT (3.3%)

During the past six months, there was an increase of 7 vessels and 0.5 million GT. All vessels had a size of around 7,000 cars, and they were all LNG fueled ships.

On order —

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	126 vessels (84.0%)	157 vessels (84.9%)
Total GT	7,491,129 GT (80.0%)	9,978,269 GT (82.5%)

During the past six months, there was an increase of 31 vessels totaling 2.5 million GT. The most common size was around 10,000 cars, although orders were seen across a wide range of sizes from 4,000 cars to 10,000 cars. By fuel type, LNG fueled ships predominated, but there were also a few orders for methanol fueled ships.

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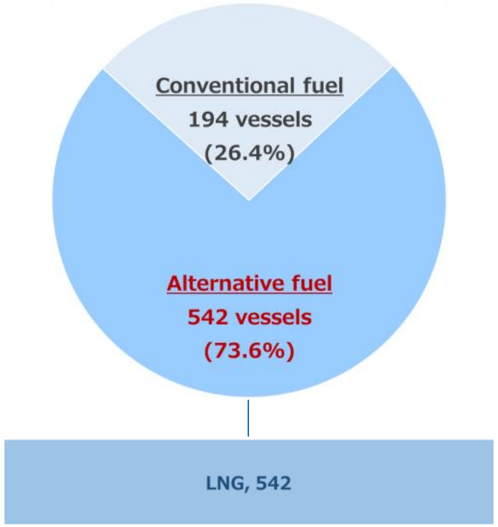
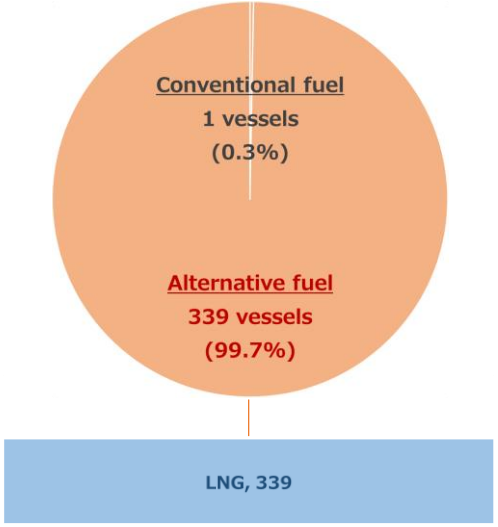
Trends in alternative fuel ships (by ship type)

LNG carriers (for reference)

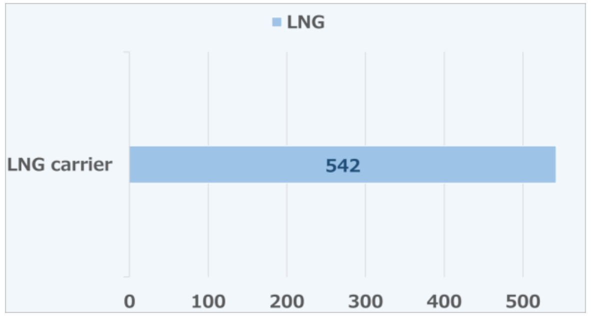
In service



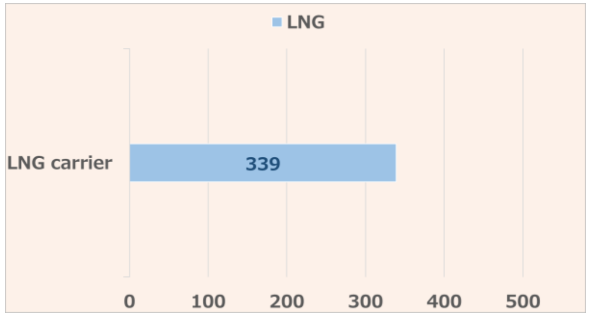
On order



In service



On order



Details of alternative fuel ships (Jun. 2023 → Dec. 2023)

In service

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	515 vessels (72.5%)	542 vessels (73.6%)
Total GT	53,642,631 GT (72.0%)	56,307,657 GT (73.0%)

During the past six months, there was an increase of 27 vessels totaling 2.7 million GT. All of these vessels were LNG fueled ships, and there were no confirmations of deliveries of other alternative fuel ships.

On order

	As of Jun. 30, 2023	As of Dec. 31, 2023
Number of vessels	328 vessels (99.7%)	339 vessels (99.7%)
Total GT	35,434,449 GT (100.0%)	36,855,375 GT (99.9%)

During the past six months, there was an increase of 11 vessels totaling 1.5 million GT. All of these vessels were LNG fueled ships. Similar to those in service, there were no confirmations of adoption for other alternative fuel ships.

— Step 3

Understanding alternative fuels

When considering the adoption of alternative fuels, it is important to understand the characteristics of each fuel, such as their properties and GHG emissions, and to grasp factors like cost and projected supply. In this section, we will outline the attributes of various alternative fuels envisaged for use in international shipping, providing insights into their costs, supply prospects, and other relevant factors.

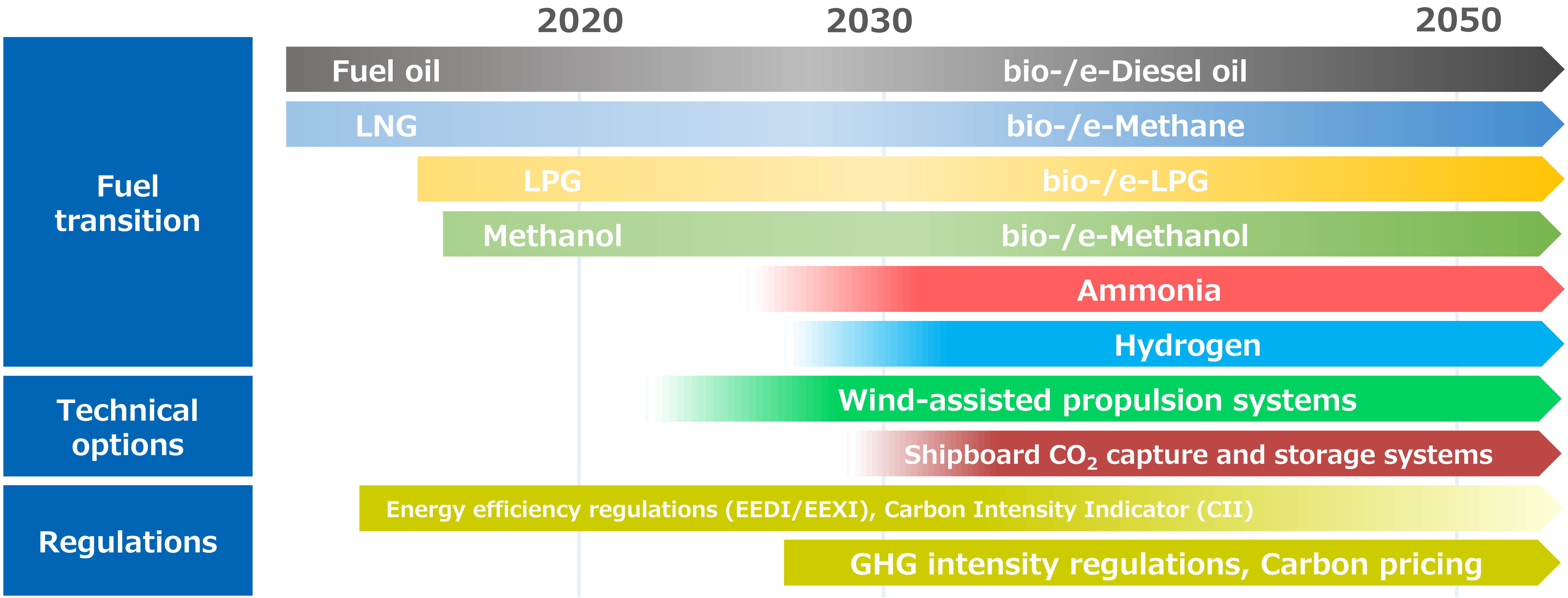
Key Takeaways

- ✓ Each alternative fuel envisaged for use in international shipping has the potential to become zero-emission or carbon-neutral fuel.
- ✓ Due to differences in calorific value, alternative fuels require larger fuel tank capacities compared to conventional fuel oil, potentially resulting in reduced distance covered with the same fuel tank capacity. Therefore, comprehensive fleet-wide consideration, including planned routes, is necessary when adopting alternative fuel ships.
- ✓ The GHG emissions of each alternative fuel differ significantly not only during combustion but also throughout their lifecycle. Therefore, it is important to fully understand the scope of GHG emissions targeted by regulations and to weigh the pros and cons of each fuel under regulation.
- ✓ The cost of zero-emission or carbon-neutral fuels is generally considered to be lower for biomass-derived fuels than for green hydrogen-derived fuels. However, biomass-derived fuels face supply constraints, requiring careful attention to their availability.
- ✓ ClassNK has conducted surveys on the production volumes of zero-emission or carbon-neutral fuels. Considering the demand for these fuels in international shipping, current production volumes are vastly insufficient, necessitating rapid expansion of production scale.

Fuel transition, technological options, and regulations in international shipping

Various alternative fuels are envisioned for use in shipping, and it remains uncertain which fuel will become predominant. Depending on the manufacturing method, each fuel has the potential to become zero-emission or carbon-neutral throughout its lifecycle, and it is essential to consider the manufacturing technology trends, cost projections, and supply trends of each fuel when selecting fuels.

Timeline for fuel transition, etc.



Fuel properties - 1

As alternative fuels vary significantly in energy density (per weight and volume) depending on the fuel type, the required fuel amount and necessary fuel tank capacity can differ greatly compared to conventional fuel oil. Accurately understanding the physical properties of each fuel is the first step in considering the adoption of alternative fuels.

List of fuel properties (Overview)

Fuel type	HFO	LNG (Methane)	LPG		Methanol	Ammonia	Hydrogen
			Propane	Butane			
TtW CO_2 emission [HFO = 1]	1	0.73	0.85	0.86	0.90	0	0
TtW GHG emission [HFO = 1]	1	0.82	0.85	0.86	0.92	0.04	0.01
Required to obtain the same amount of energy Fuel ton [HFO = 1]	1	0.84	0.87	0.88	2.02	2.16	0.34
In liquid form Fuel tank capacity [HFO = 1]	1	1.89	1.69	1.41	2.47	3.07	4.63
Flammability (Lower Explosive Limit)	0.7 vol%	5.0 vol%	2.1 vol%	1.8 vol%	6.0 vol%	15.0 vol%	4.0 vol%
Toxicity (TLV-TWA*)	-	-	-		200 ppm	25 ppm	-
Cyrogenic (Boiling point)	- (Liquid at normal temp.)	-161℃	-42℃	-0.5℃	- (Liquid at normal temp.)	-33℃	-253℃

*TLV-TWA: Threshold Limit Value Time Weighted Average

Source: CO_2 emission and GHG emission are calculated by ClassNK based on emission factors specified in the FuelEU Maritime regulation.

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Fuel properties - 2

Here, we focus on the environmental aspects as we introduce the characteristics of each fuel.

List of fuel properties (Environment-related)

Fuel type	HFO	LNG (Methane)	LPG		Methanol	Ammonia	Hydrogen
			Propane	Butane			
TtW CO_2 emission [HFO = 1]	1	0.73	0.85	0.86	0.90	0	0
TtW GHG emission [HFO = 1]	1	0.82	0.85	0.86	0.92	0.04	0.01
Emissions	✓ NOx ✓ SOx ✓ PM	✓ NOx ✓ Methane slip	✓ NOx		✓ NOx ✓ Methanol slip ✓ Formaldehyde	✓ NOx ✓ Ammonia slip ✓ N_2O	✓ NOx ✓ Hydrogen slip

Source: CO_2 emission and GHG emission are calculated by ClassNK based on emission factors specified in the FuelEU Maritime regulation.

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Fuel properties - 3

Here, we focus on the design aspects as we introduce the characteristics of each fuel.

List of fuel properties (Design-related)

Fuel type	HFO	LNG (Methane)	LPG		Methanol	Ammonia	Hydrogen
			Propane	Butane			
In liquid form Energy density per unit volume [HFO = 1]	1	1.89	1.69	1.41	2.47	3.07	4.63
Liquid density [ton/m³]	0.96	0.42	0.5	0.6	0.79	0.68	0.07
Liquefaction temp. (Boiling point)	-	-161℃	-42℃	-0.5℃	65℃	-33℃	-253℃
Lower calorific value [MJ/kg]	40.5	49.1	46.0	46.0	19.9	18.6	120.0
Engine type (2 stroke)	Diesel	Diesel/ Otto	Diesel		Diesel	Diesel	Diesel
Engine type (4 stroke)	Diesel	Otto	-		Diesel	Diesel/ Otto	Otto
Onboard storage methods	Gravity tank	Type A/B/C Membrane	Type A/B/C		Gravity tank	Type A/B/C Membrane	Low-temp. (Type C, Membrane) High pressure (Type 1/2/3/4)

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Fuel properties - 4

Here, we focus on the safety aspects as we introduce the characteristics of each fuel.

List of fuel properties (Safety-related)

Fuel type	HFO	LNG (Methane)	LPG		Methanol	Ammonia	Hydrogen
			Propane	Butane			
Flammability [Vol%]	0.7 - 5	5 - 15	2.1 – 9.5	1.8 – 8.4	6 - 50	15 – 33.6	4 - 75
Flash point	>60℃	-187.7℃	-104℃	-60℃	9℃	132℃	-
Ignition point	>400℃	537℃	450℃	365℃	440℃	630℃	560℃
Minimum ignition energy	-	0.3 mJ	0.26 mJ	0.26 mJ	0.14 mJ	680 mJ	0.017 mJ
Toxicity [ppm] (ACGIH, TWA-TLV*1)	-	-	-		200	25	-
Toxicity [ppm] (ACGIH, TWA-STEL*2)	-	-	-	1000	250	35	-

*1 Toxicity criteria established by American Conference of Governmental Industrial Hygienist (ACGIH). TLV-TWA (Threshold Limit Value Time Weighted Average) represents the concentration that is believed not to cause adverse health effects to workers who are repeatedly exposed to it during an average workday of 8 hours or a workweek of 40 hours.
*2 Toxicity criteria established by American Conference of Governmental Industrial Hygienist (ACGIH). TLV-STEL (Threshold Limit Value Short Term Exposure Limit) represents the concentration that is believed not to cause adverse health effects to workers if exposed continuously for 15 minutes, provided that their daily exposure does not exceed the TLV-TWA.

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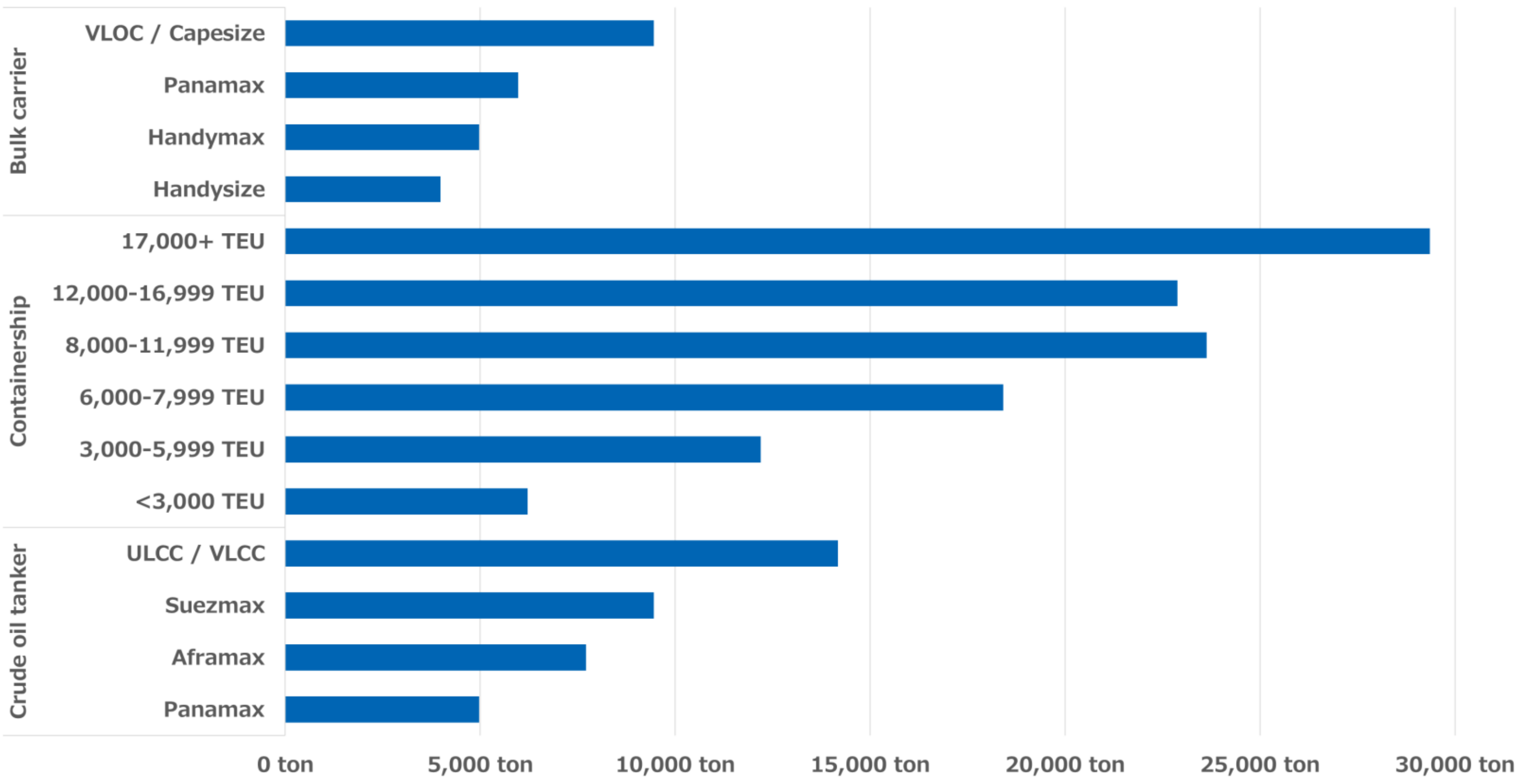
Understanding fuel consumption - 1

Alternative fuels have different calorific values compared to conventional fuel oil, resulting in changes in the required fuel volume (in tons) when transitioning to alternative fuels. It is important to understand the estimated required fuel volume for each fuel type depending on the ship type and size when considering the adoption of alternative fuels.

Image of annual fuel consumption (For conventional fuel oil: HFO) — Bulk carrier、Containership、Crude oil tanker



Required amount of fuel when transitioning to alternative fuels (tons) [Relative to conventional fuel oil]

LNG	0.84 times
LPG	0.87 times
Methanol	2.02 times
Ammonia	2.16 times
Hydrogen	0.34 times

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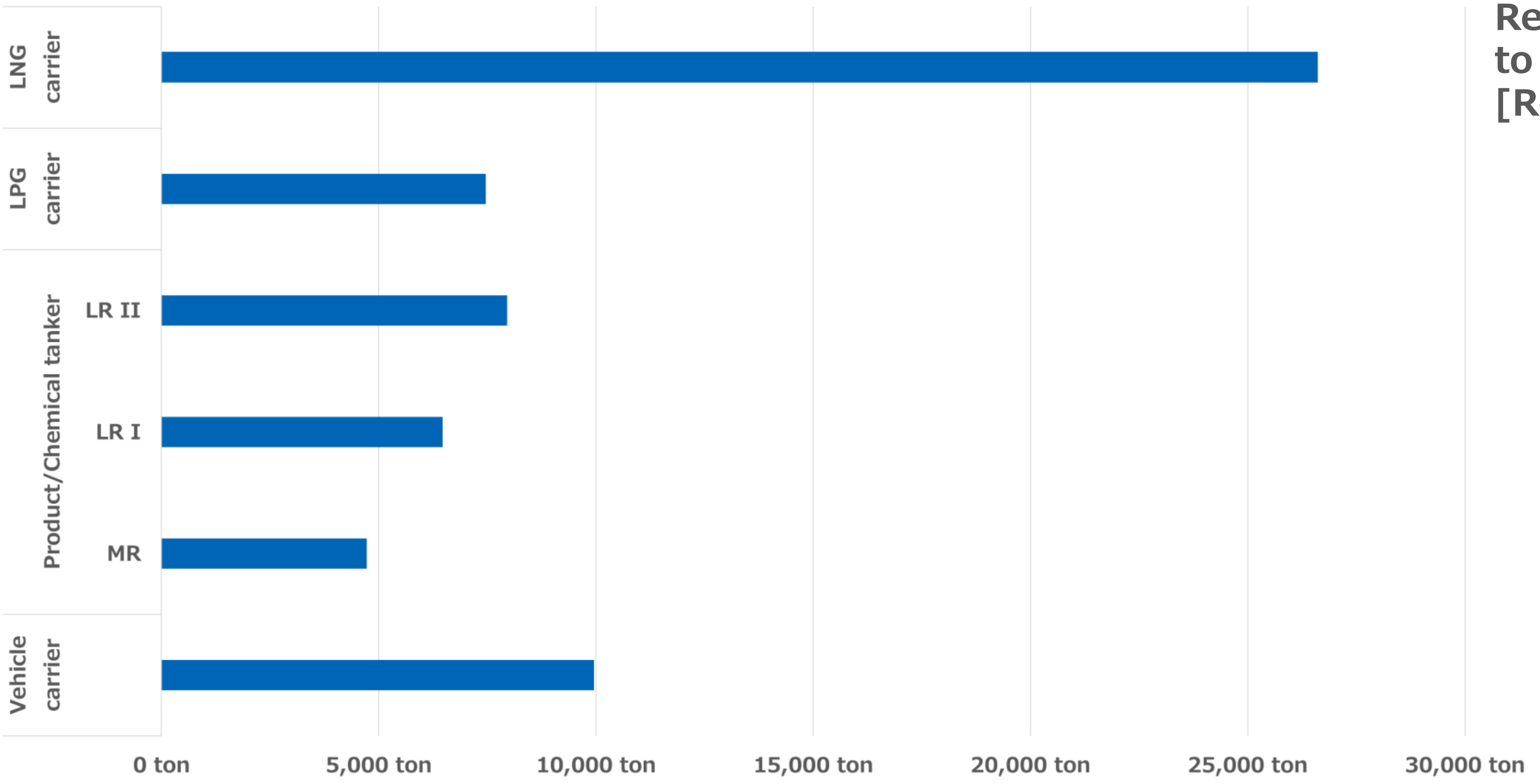
Understanding fuel consumption - 2

Alternative fuels have different calorific values compared to conventional fuel oil, resulting in changes in the required fuel volume (in tons) when transitioning to alternative fuels. It is important to understand the estimated required fuel volume for each fuel type depending on the ship type and size when considering the adoption of alternative fuels.

Image of annual fuel consumption (For conventional fuel oil: HFO) — LNG carrier、LPG carrier、Product/Chemical tanker、Vehicle carrier



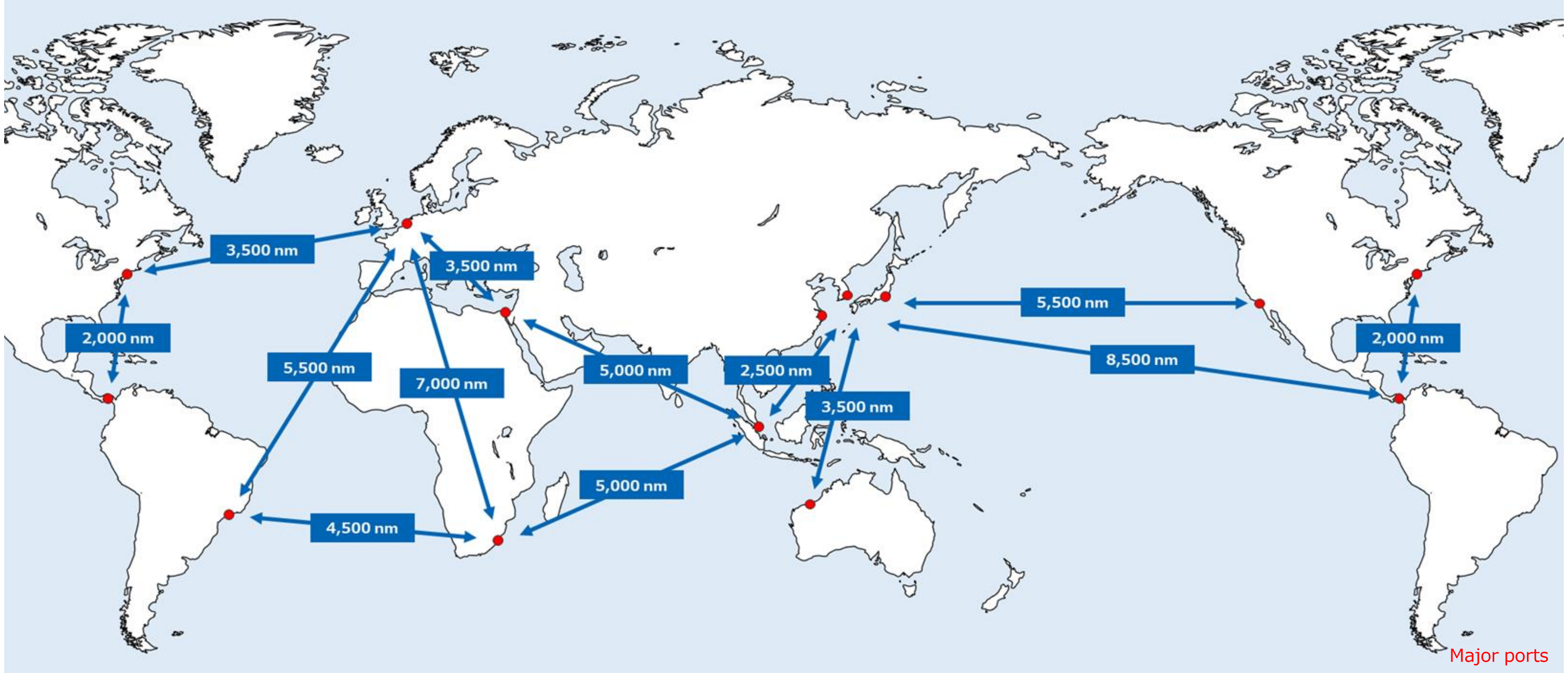
Required amount of fuel when transitioning to alternative fuels (tons) [Relative to conventional fuel oil]

LNG	0.84 times
LPG	0.87 times
Methanol	2.02 times
Ammonia	2.16 times
Hydrogen	0.34 times

Route selection

Alternative fuel ships cover shorter distances and require different fuel amounts (in tons) compared to conventional fuel ships, even with the same fuel tank capacity. When considering the adoption of alternative fuel ships, it is important to select routes considering the type of fuel and bunkering locations.

Voyage distance on major routes



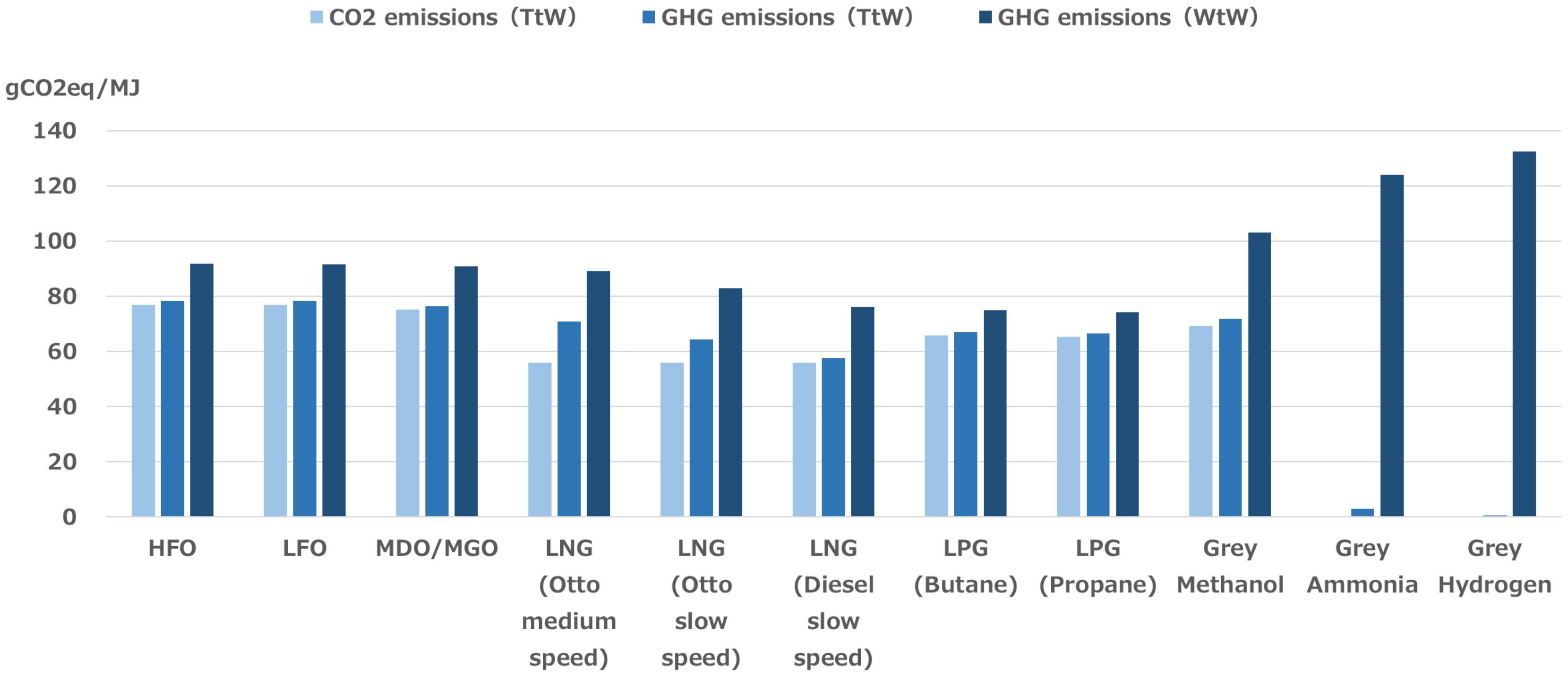
The amount of fuel required for a 206,000 DWT bulk carrier to sail one way (laden) from Japan to Australia over a distance of 3,500 nm.

- Fuel oil :500 tons
- LNG :420 tons
- LPG :435 tons
- Methanol :1,010 tons
- Ammonia :1,080 tons
- Hydrogen :170 tons

"CO_2 emissions (TtW)" vs. "GHG emissions (TtW)" vs. "GHG emissions (WtW)"

The scope of emissions targeted by regulations varies, including "CO_2 or GHG" and "Tank-to-Wake or Well-to-Wake." To minimize regulatory compliance costs, it is important to understand the default values of emission factors in each regulation and the differences in emissions for each fuel. (TtW: Tank-to-Wake, WtW: Well-to-Wake)

Emissions per unit of energy



Source: Calculated by ClassNK based on emission factors specified in the FuelEU Maritime regulation

Emissions targeted by each regulation

The emissions targeted by regulations within the IMO and the EU include the following:

- ✓ CII :**CO_2 (TtW)**
- ✓ EU-ETS (2026-) :**GHG (TtW)**
- ✓ FuelEU Maritime :**GHG (WtW)**
- ✓ IMO mid-term measures :**To be determined**

Most emission cost-competitive fuel

The fuel with the lowest emissions in each emission scope is as follows* (excluding zero-emission/carbon-neutral fuels):

- ✓ For CO_2 (TtW) :**LNG**
- ✓ For GHG (TtW) :**LNG**
- ✓ For GHG (WtW) :**LPG**

*When compared using the emission factors specified in the FuelEU Maritime regulation

Comparison of CII ratings resulting from fuel transition

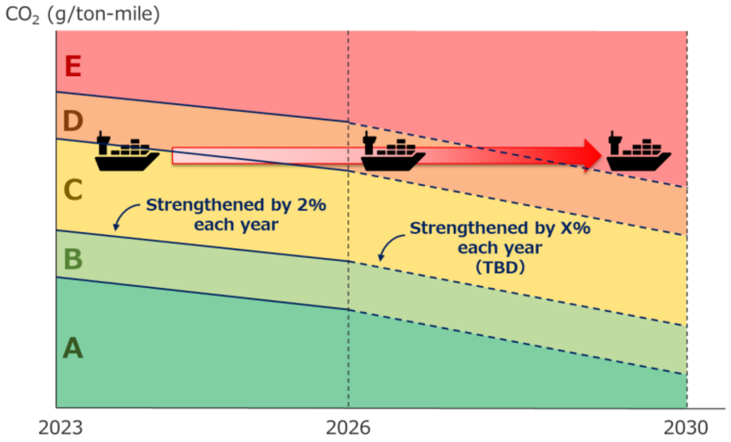
The adoption of alternative fuels is also highly effective in improving CII ratings. Here, we present a comparison of CII ratings for a handymax-sized bulk carrier transitioning from a conventional fuel ship to either a methanol or LNG fueled ship. (CII: Carbon Intensity Indicators)

Comparison of CII ratings (Conventional fuel oil ship vs. Methanol fueled ship vs. LNG fueled ship: e.g. Handymax bulk carrier)

Fuel type	CII ratings 2023 (5%)	2024 (7%)	2025 (9%)	2026 (11%)	After 2027 (TBD)
Conventional fuel oil	C	C	D	D	-
Methanol [10% CO_2 reduction compared to conventional fuel oil]	B	C	C	C	-
LNG [27% CO_2 reduction compared to conventional fuel oil]	A	A	B	B	-

The reduction rate (compared to 2019) from the CII reference line in setting the required CII is provided in parentheses.

Image of CII rating transition



- Based on the average energy efficiency performance in 2022, the CII rating for a handymax-sized bulk carrier (using conventional fuel oil) would be **C** as of 2023, and it will follow the trends as indicated in the table (without assuming energy efficiency improvements).
- If it transitions from conventional fuel oil to methanol, the CII rating would improve from **C** to **B** as of 2023 (without assuming fuel efficiency improvements).
- If it transitions from conventional fuel oil to LNG, the CII rating would improve from **C** to **A** as of 2023 (without assuming fuel efficiency improvements).

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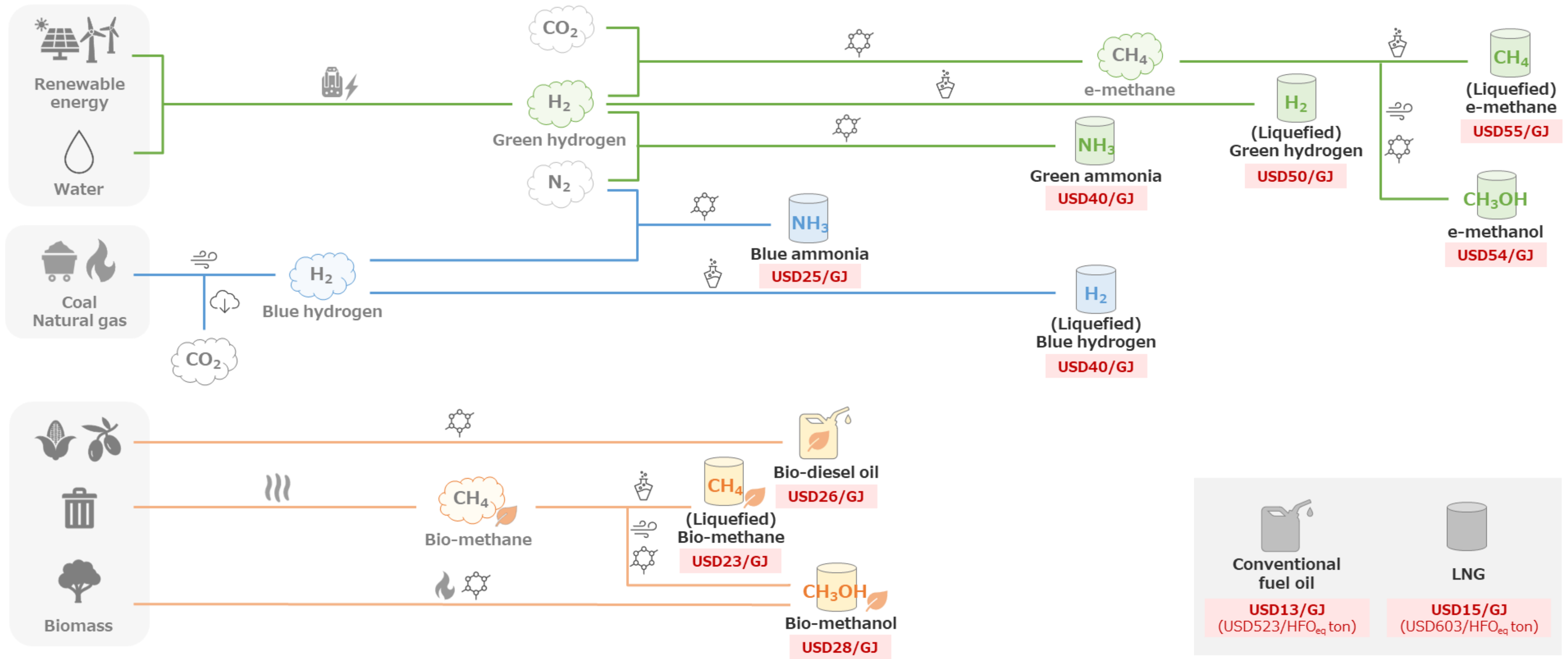
Alternative fuel costs

Alternative fuels available for ships vary widely, but the cost of each alternative fuel is expected to be 1.5 to 4 times higher than that of conventional fuel oil by 2030. While the cost gap between conventional fuel oil and alternative fuels is expected to narrow in the future as production expands and regulations are introduced, price trends based on supply and demand remain uncertain. Therefore, when considering the adoption of alternative fuels, it is crucial to assess the trend of fuel costs.

Production pathways and costs of alternative fuels (The costs are projected as of 2030.)



Share of alternative fuels

Alternative fuels such as LNG, LPG, and methanol account for only 6% of the annual fuel consumption of the world fleet, which is 220 million tons (as of 2022). With an expected increase in orders for alternative fuel ships, this proportion is expected to increase. Therefore, further expansion of production capacity is essential to meet the growing demand for alternative fuels in the future.

Fuel Consumption of ships subject to the IMO DCS (5,000 gross tonnage and above engaged in international voyages) [Unit: ton]

	Heavy Fuel Oil (HFO)	Light Fuel Oil (LFO)	Diesel/Gas Oil (MDO/MGO)	LNG	LPG (Propane)	LPG (Butane)	Methanol	Ethanol	Other	Total (HFO eq)
2019 (27,221 ships) (1.19 bn GT)	171,428,136	6,930,061	24,125,110	10,482,742	6,202	1,182	29,551	149	67,660	216,763,596
2020 (27,723 ships) (1.22 bn GT)	101,268,542	64,171,708	25,500,000	11,974,761	16,622	1,562	77,631	0	92,807	208,572,760
2021 (28,171 ships) (1.25 bn GT)	109,169,447	64,479,128	25,732,999	12,623,121	34,973	2,028	13,031	4,849	170,501	217,710,495
2022 (28,834 ships) (1.29 bn GT)	116,576,283	57,077,835	28,285,802	10,950,408	88,774	16,673	35,523	10,890	226,739	218,339,992

If we aim to replace all 220 million tons of Heavy Fuel Oil (HFO) with alternative fuels...

- **HFO eq 220 mil. tons** ▶ **For all methanol** **440 mil. tons of methanol needed** (Current global production volume for all sectors: 106 mil. tons/year*)
- **HFO eq 220 mil. tons** ▶ **For all ammonia** **470 mil. tons of ammonia needed** (Current global production volume for all sectors: 183 mil. tons/year*)
- **HFO eq 220 mil. tons** ▶ **For all hydrogen** **70 mil. tons of hydrogen needed** (Current global production volume for all sectors: 94 mil. tons/year*)

*Approximately 99% of the production volume is derived from grey hydrogen.

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Amount of renewable energy electricity required for green hydrogen production

Expanding the production of green hydrogen, which serves as the raw material for green ammonia and green methanol, requires an increase in the adoption of renewable energy. Here, we introduce an estimate of the renewable energy electricity capacity needed for green hydrogen production.

Amount of renewable energy electricity required for green hydrogen production

Annual fuel consumption in international shipping*1

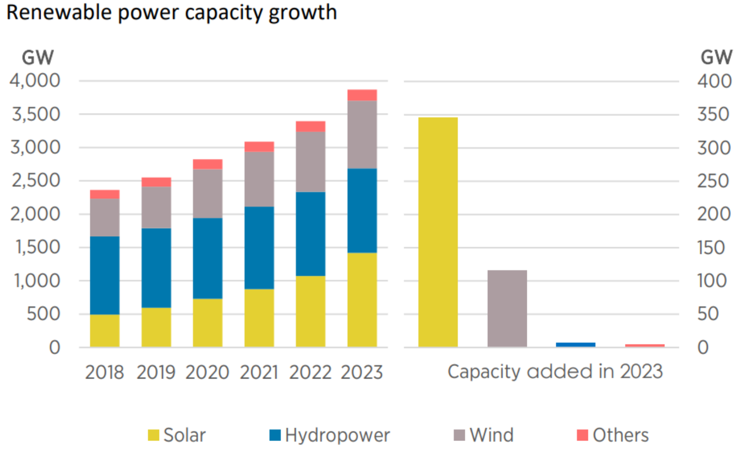
*1Subject to ships 5,000 gross tonnage and above engaged in international voyages

HFO eq 220 mil. tons

Methanol eq	Ammonia eq	Hydrogen eq
440 mil. tons	**470 mil. tons**	**70 mil. tons**
Required Hydrogen 84 mil. tons	**Required Hydrogen** 85 mil. tons	
Required renewable energy electricity capacity*2 **530 GW** x 365 days of operation	**Required renewable energy electricity capacity***2 **540 GW** x 365 days of operation	**Required renewable energy electricity capacity***2 **450 GW** x 365 days of operation

*2The calculated power consumption is based on 5.0 kWh per Nm^3-H_2.

Trend of global renewable energy capacity



Source: IRENA (2024), Renewable capacity statistics 2024, International Renewable Energy Agency, Abu Dhabi. (Highlights)

➢ Renewable energy capacity is increasing, but currently, most of it is used directly as electricity. For the decarbonization of international shipping, the key point moving forward will be finding ways to introduce and expand the use of renewable energy for green hydrogen production purposes.

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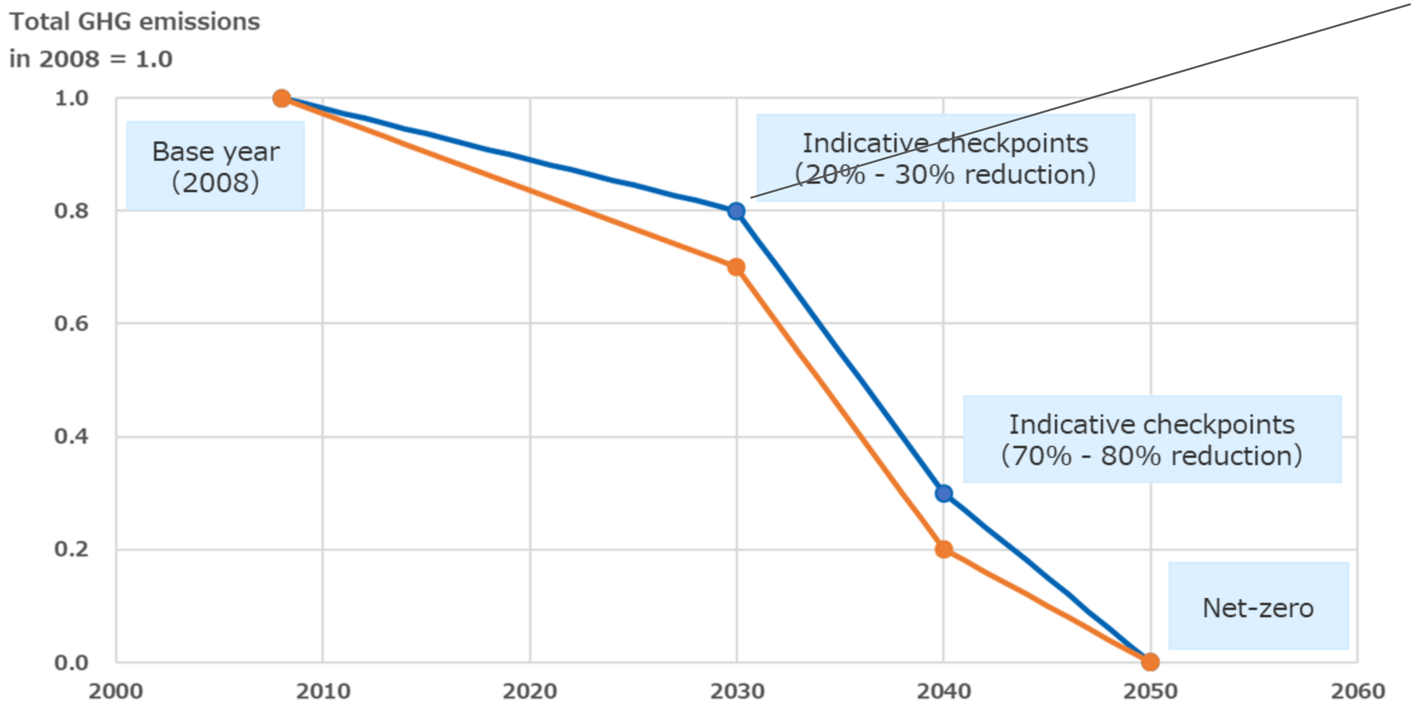
Zero-emission fuels and zero-emission ships required for international shipping

The "2023 IMO GHG Strategy" has set new GHG reduction targets, and international shipping will now chart a course towards achieving net-zero GHG emissions by or around 2050. Here, we introduce the volume of zero-emission fuels and zero-emission ships needed along this pathway.

Introduction volume of zero-emission ships/fuels needed to achieve the 2030 indicative checkpoint in the IMO's GHG reduction goal



Introduction volume of zero-emission ships/fuels needed to achieve the 2030 indicative checkpoint (Well-to-Wake)*:

*Calculations for ships of 5,000 gross tonnage and above engaged in international voyages (ships subject to IMO DCS)

✓ Zero-emission fuels

25% of the fuel used in international shipping to be zero-emission fuel (as of 2030)

- For all green methanol :106 million tons
- For all green ammonia :114 million tons

✓ Zero-emission ships

Zero-emission ships needed to consume the above fuel volume (as of 2030)

- 352 million gross tonnage

Please refer to the ClassNK-issued white paper titled "Pathway to Zero-Emission in International Shipping - Understanding the 2023 IMO GHG Strategy" for more details.

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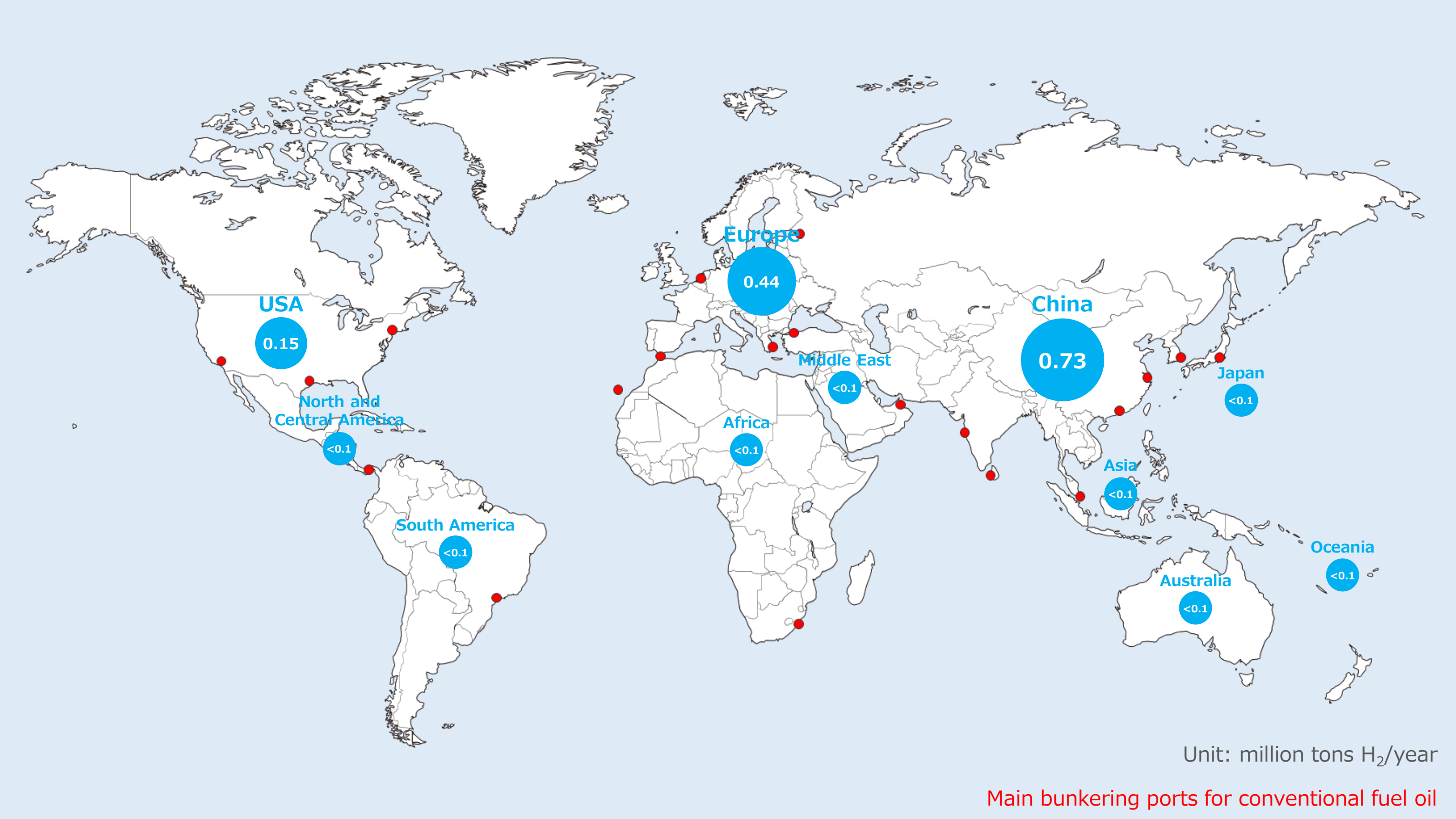
Alternative fuel production projects - 1 (Green hydrogen)

Understanding the projected supply of each fuel is essential when adopting alternative fuels. Here, we present the production scale (including planned production) of green hydrogen. Hydrogen can be used not only directly as marine fuel but also as a raw material for ammonia and methanol. Please note that production projects are not limited to the shipping sector.

Distribution of green hydrogen production projects (Operational/Construction/FID, for all sectors, as of October 2023)



Country/ Region	Number of projects	Annual production capacity (total)
China	32	732,049 tons H_2/year
Europe	223	447,093
USA	29	155,849
Australia	26	61,687
North and Central America	16	40,462
Asia	26	12,493
South America	15	4,381
Japan	16	2,150
Africa	2	1,286
Middle East	4	239
Oceania	1	195
Total	**390**	**1,457,884**

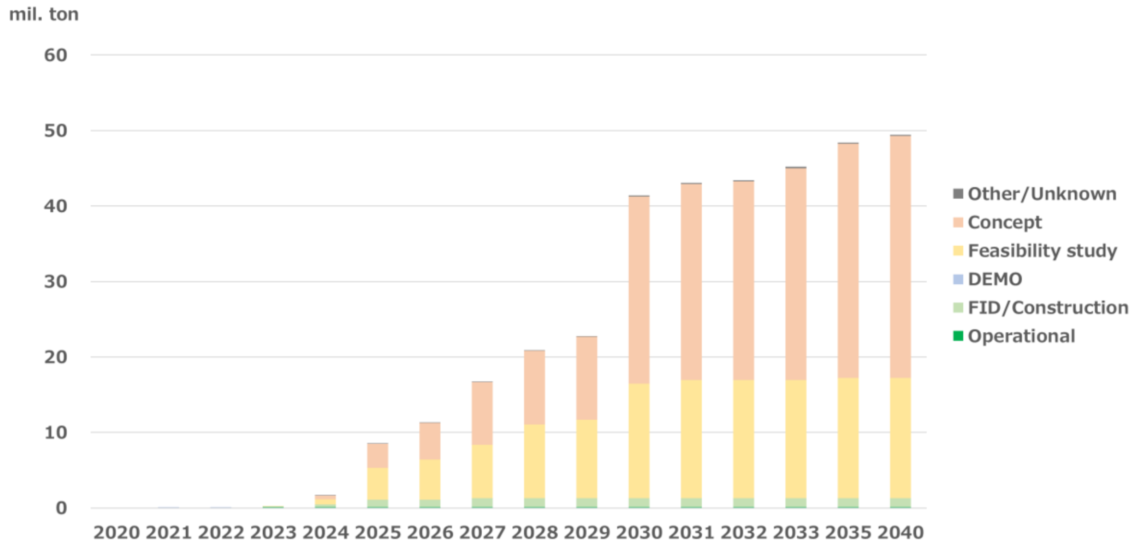
Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

Alternative fuel production projects - 1 (Green hydrogen)

The majority of green hydrogen projects slated to commence production by 2040 are still in the feasibility study or conceptual stages and have not reached the final investment decision. It is necessary to continue monitoring the progress of these projects to assess the expected production volume in the future.

Projected production capacity of green hydrogen (for all sectors, as of October 2023)

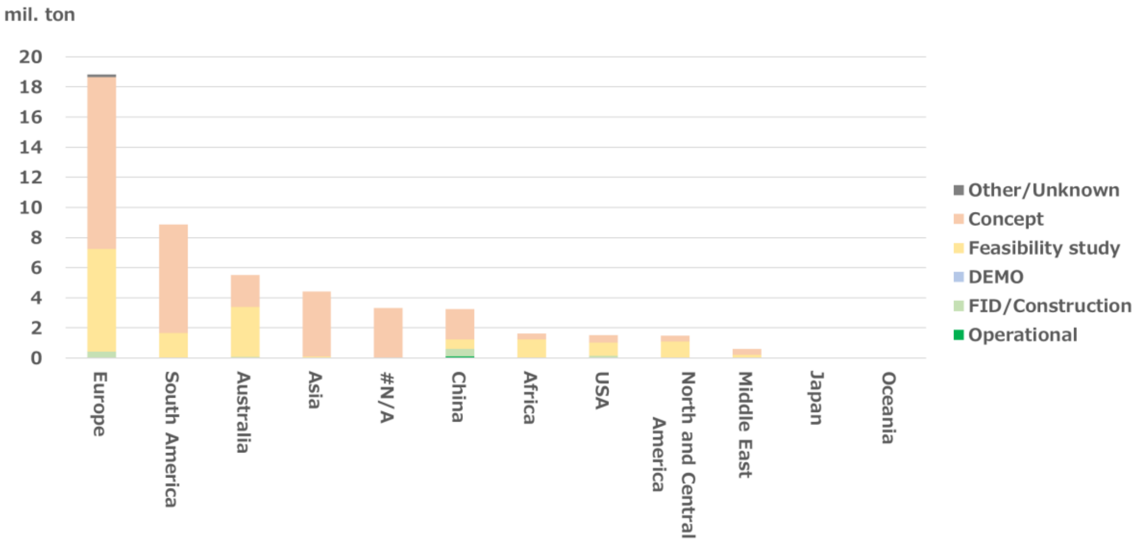
Projected production capacity by year



➢ The green hydrogen production capacity is expected to increase rapidly after 2030, but most of the projects are still in the feasibility study or conceptual stages.

Projected production capacity by country (as of 2040*)

*After 2040, there are no projects planned.



➢ Many of the green hydrogen projects slated to start production by 2040 are located in Europe, followed by South America and Australia, which are considered suitable locations for green hydrogen production.

Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

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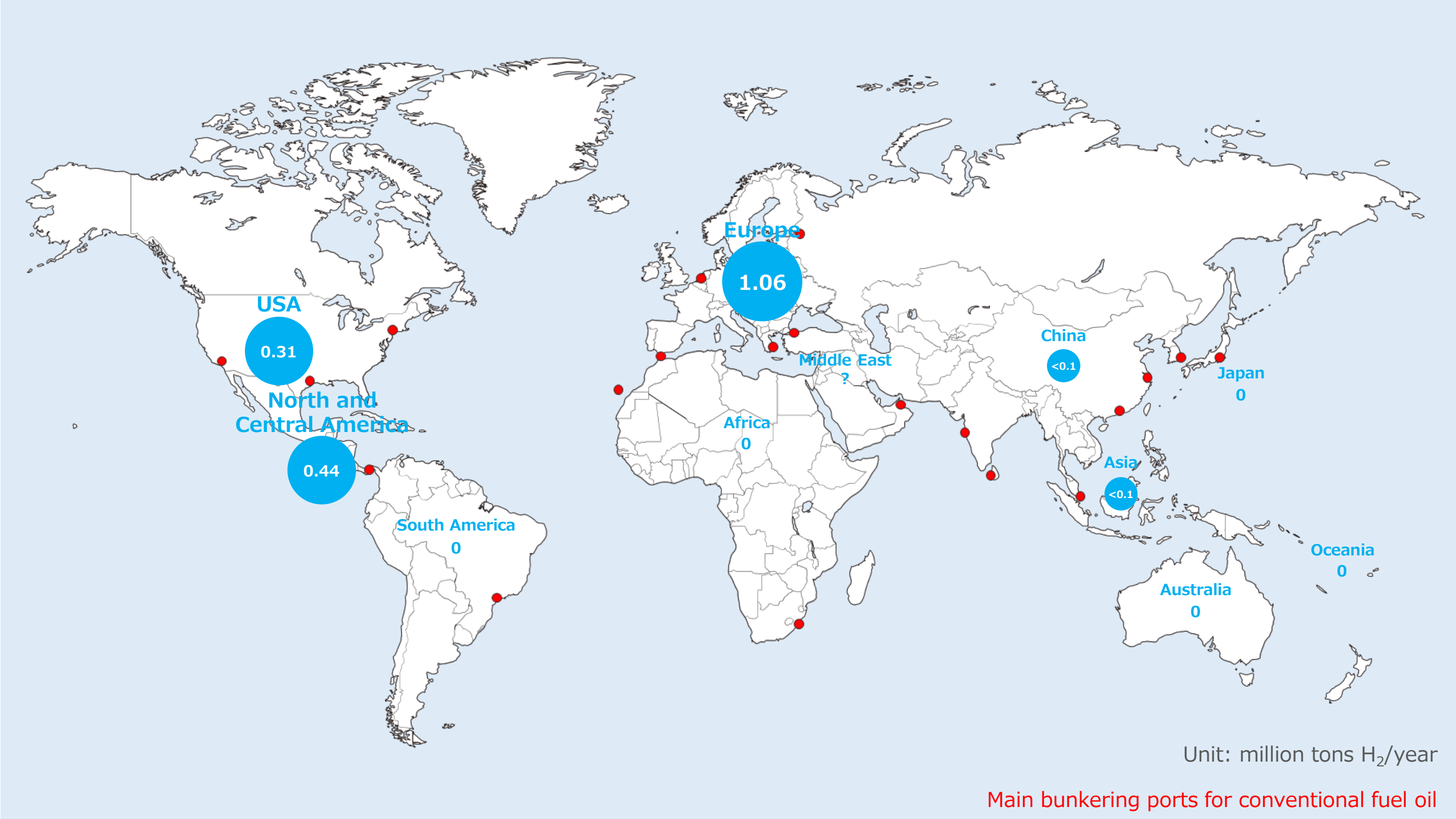
Alternative fuel production projects - 2 (Blue hydrogen)

Here we introduce the production scale of blue hydrogen (including planned production). Hydrogen can be used not only directly as marine fuel but also as a raw material for ammonia and methanol. Please note that production projects are not limited to the shipping sector.

Distribution of blue hydrogen production projects (Operational/Construction/FID, for all sectors, as of October 2023)



Country/ Region	Number of projects	Annual production capacity (total)
Europe	4	1,060,151 tons H_2/year
North and Central America	4	440,000
USA	3	316,155
China	2	54,575
Asia	1	1,825
Middle East	1	?
Total	**15**	**1,872,706**

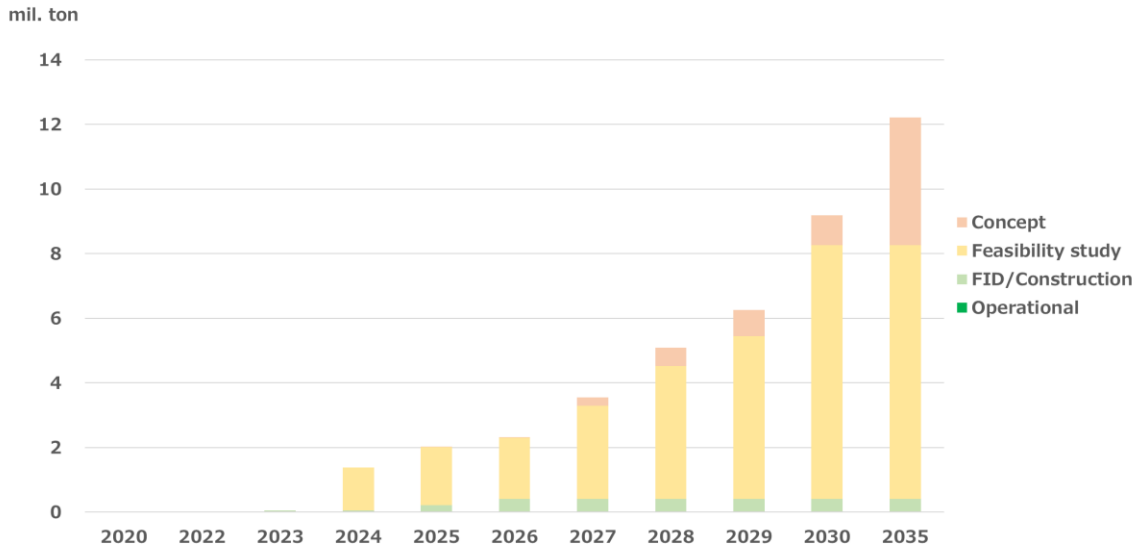
Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

Alternative fuel production projects - 2 (Blue hydrogen)

The majority of blue hydrogen projects slated to commence production by 2035 are still in the feasibility study or conceptual stages and have not reached the final investment decision. It is necessary to continue monitoring the progress of these projects to assess the expected production volume in the future.

Projected production capacity of blue hydrogen (for all sectors, as of October 2023)

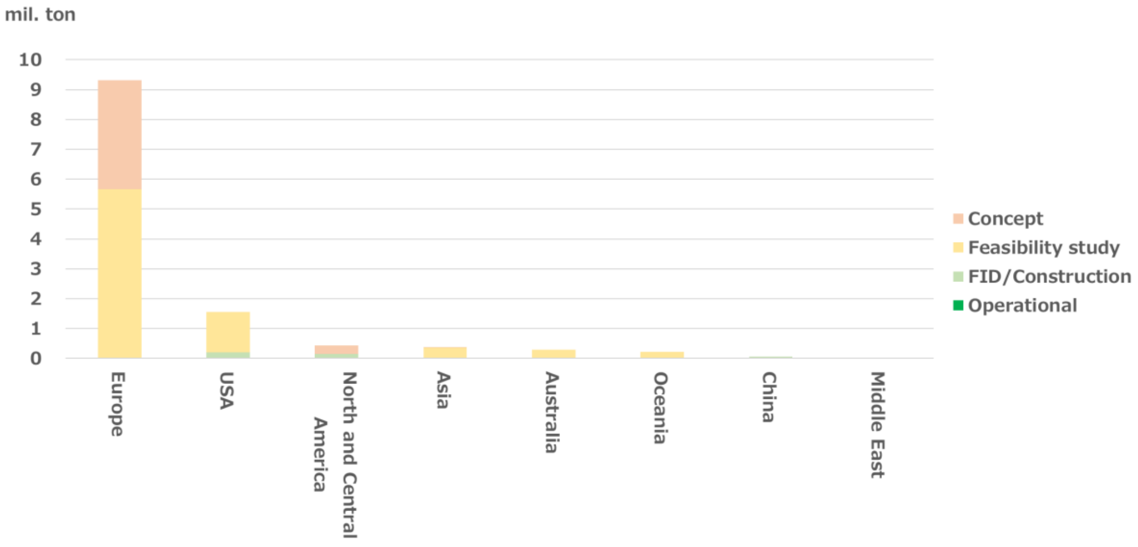
Projected production capacity by year



➢ The blue hydrogen production capacity is expected to increase in the latter half of the 2020s, but most of the projects are still in the feasibility study or conceptual stages.

Projected production capacity by country (as of 2035*)

*After 2035, there are no projects planned.



➢ Most of the blue hydrogen projects slated to start production by 2035 are located in Europe.

Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

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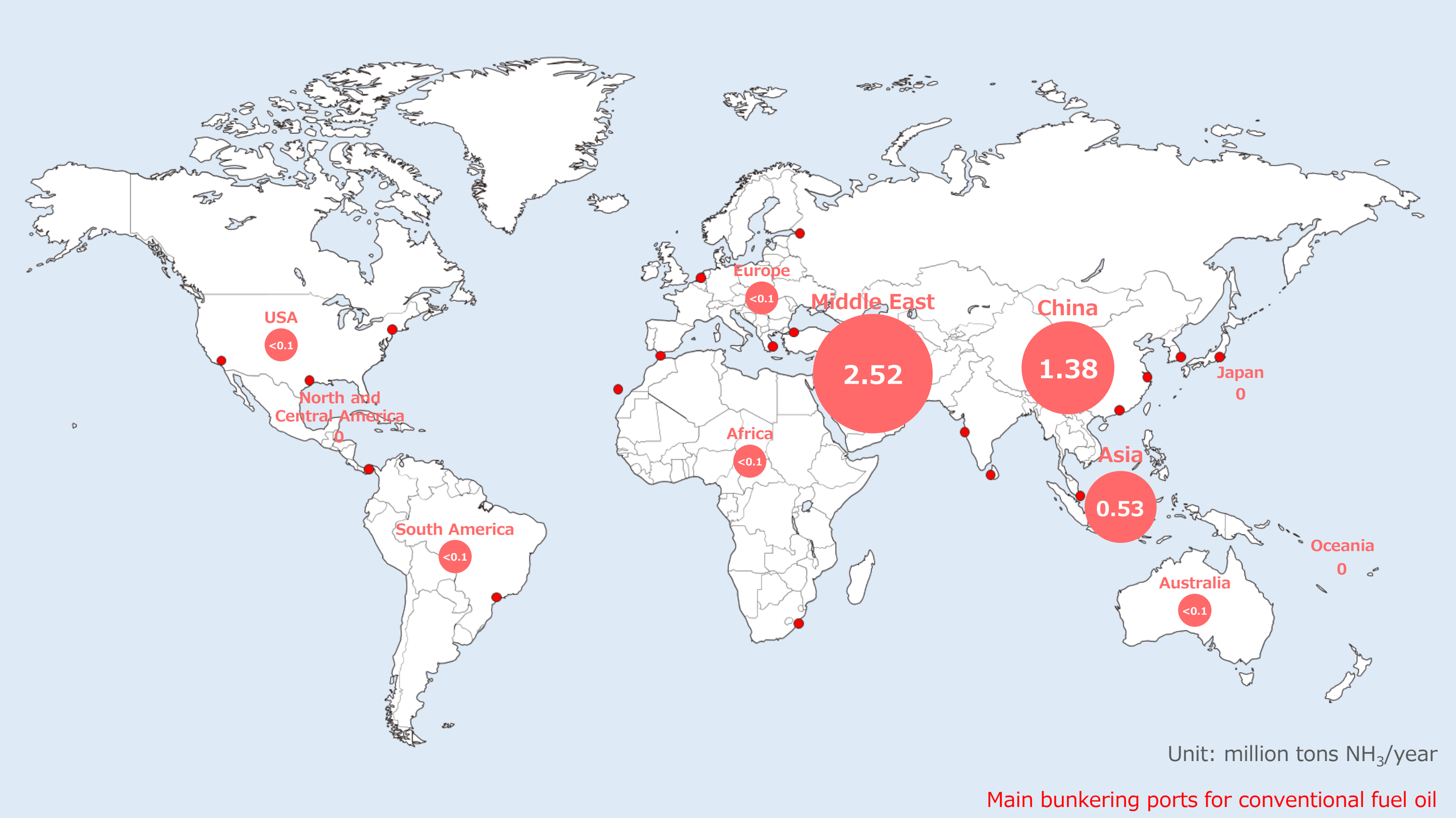
Alternative fuel production projects - 3 (Green ammonia)

Here we introduce the production scale of green ammonia (including planned production). Ammonia is expected to be used not only directly as marine fuel but also as a hydrogen carrier. Please note that production projects are not limited to the shipping sector.

Distribution of green ammonia production projects (Operational/Construction/FID, for all sectors, as of October 2023)



Country/ Region	Number of projects	Annual production capacity (total)
Middle East	3	2,523,652 tons NH_3/year
China	11	1,385,574
Asia	3	535,113
South America	3	82,168
Europe	4	46,880
USA	1	18,824
Australia	1	9,621
Africa	2	481
Total	**28**	**4,602,313**

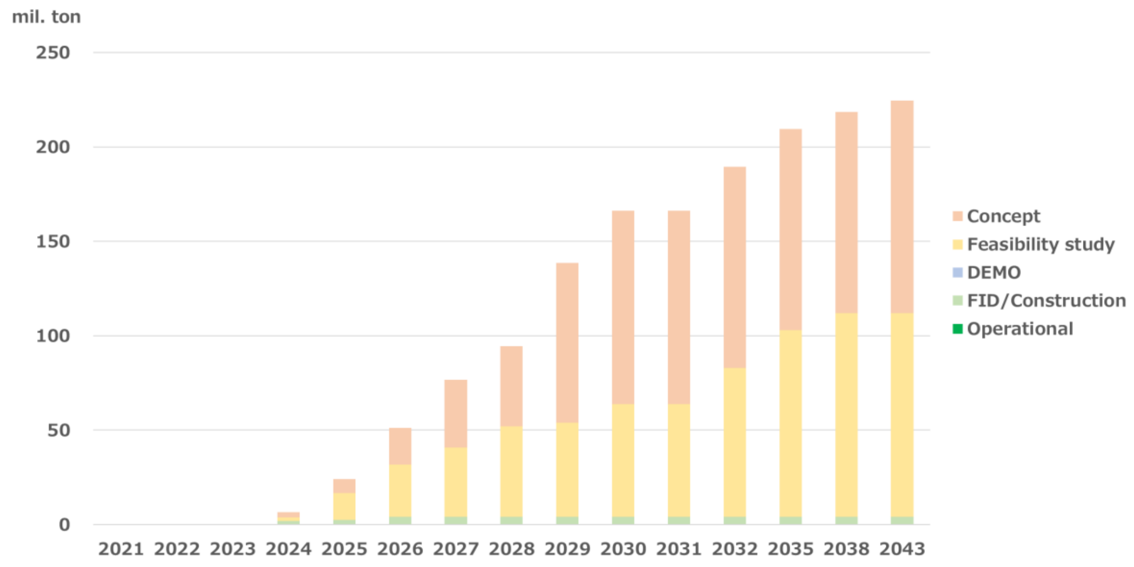
Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

Alternative fuel production projects - 3 (Green ammonia)

The majority of green ammonia projects slated to commence production by 2043 are still in the feasibility study or conceptual stages and have not reached the final investment decision. It is necessary to continue monitoring the progress of these projects to assess the expected production volume in the future.

Projected production capacity of green ammonia (for all sectors, as of October 2023)

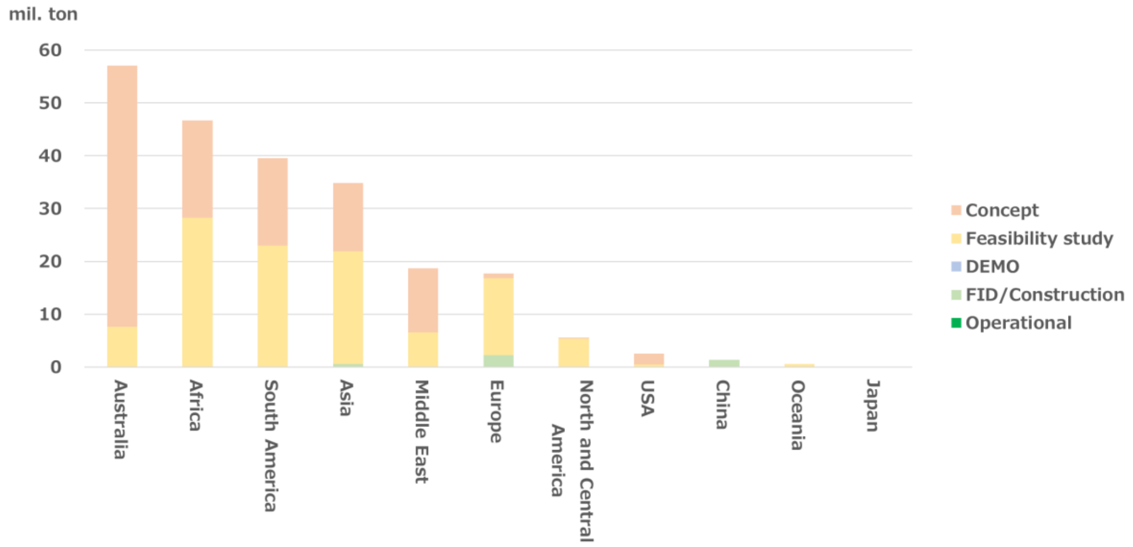
Projected production capacity by year



➢ The green ammonia production capacity is expected to increase gradually, but most of the projects are still in the feasibility study or conceptual stages.

Projected production capacity by country (as of 2043*)

*After 2043, there are no projects planned.



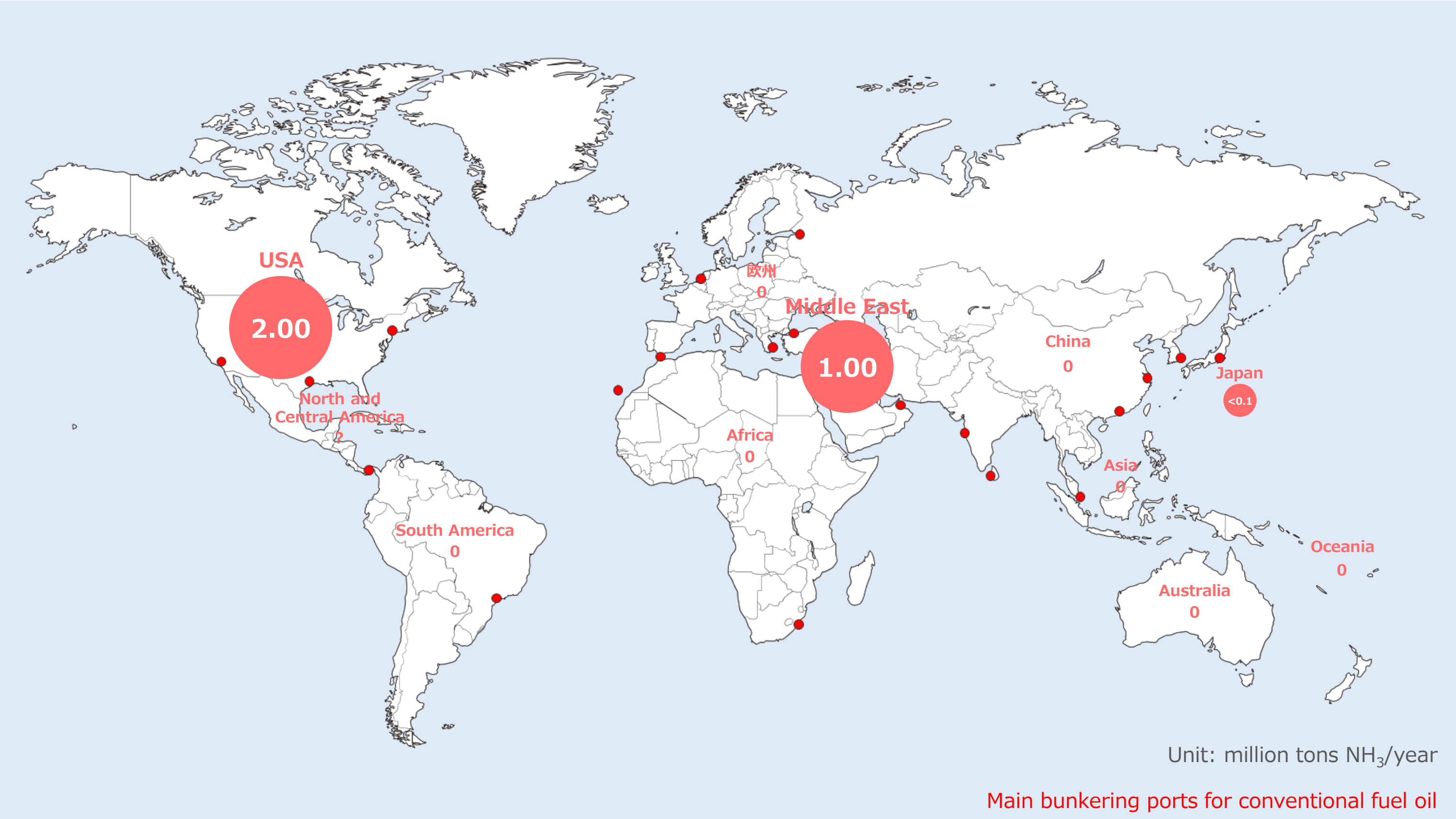
➢ Many of the green ammonia projects slated to start production by 2043 are located in Australia, Africa, South America, and Asia.

Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

Alternative fuel production projects - 4 (Blue ammonia)

Here we introduce the production scale of blue ammonia (including planned production). Ammonia is expected to be used not only directly as marine fuel but also as a hydrogen carrier. Please note that production projects are not limited to the shipping sector.

Distribution of blue ammonia production projects (Operational/Construction/FID, for all sectors, as of October 2023)



Country/ Region	Number of projects	Annual production capacity (total)
USA	5	2,000,000 tons NH_3/year
Middle East	1	1,000,000
Japan	1	3,887
North and Central America	1	?
Total	**8**	**3,003,888**

Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

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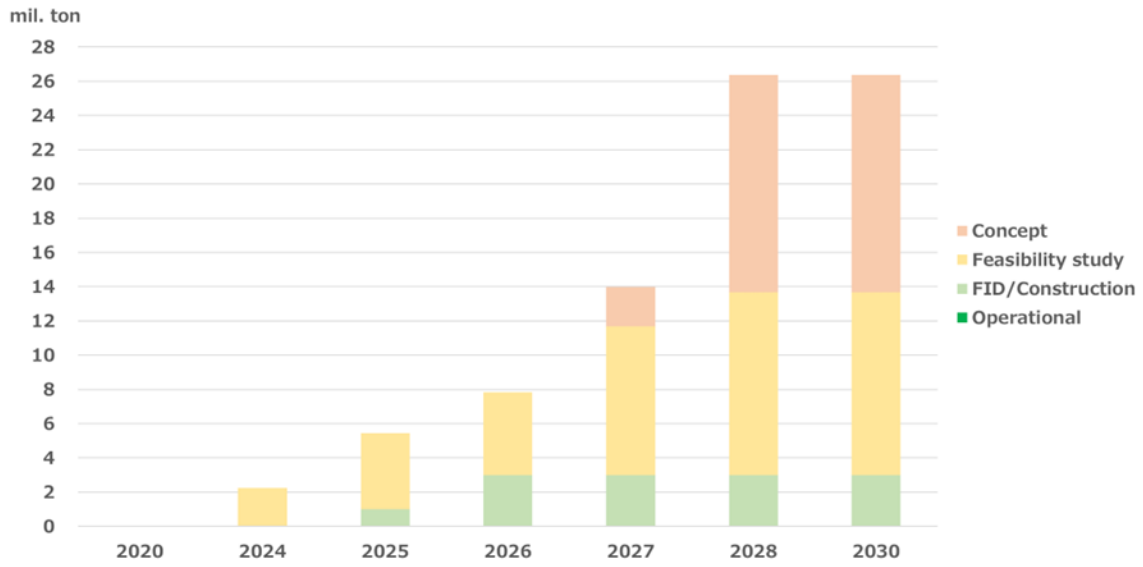
Alternative fuel production projects - 4 (Blue ammonia)

The majority of blue ammonia projects slated to commence production by 2030 are still in the feasibility study or conceptual stages and have not reached the final investment decision. It is necessary to continue monitoring the progress of these projects to assess the expected production volume in the future.

Projected production capacity of blue ammonia (for all sectors, as of October 2023)

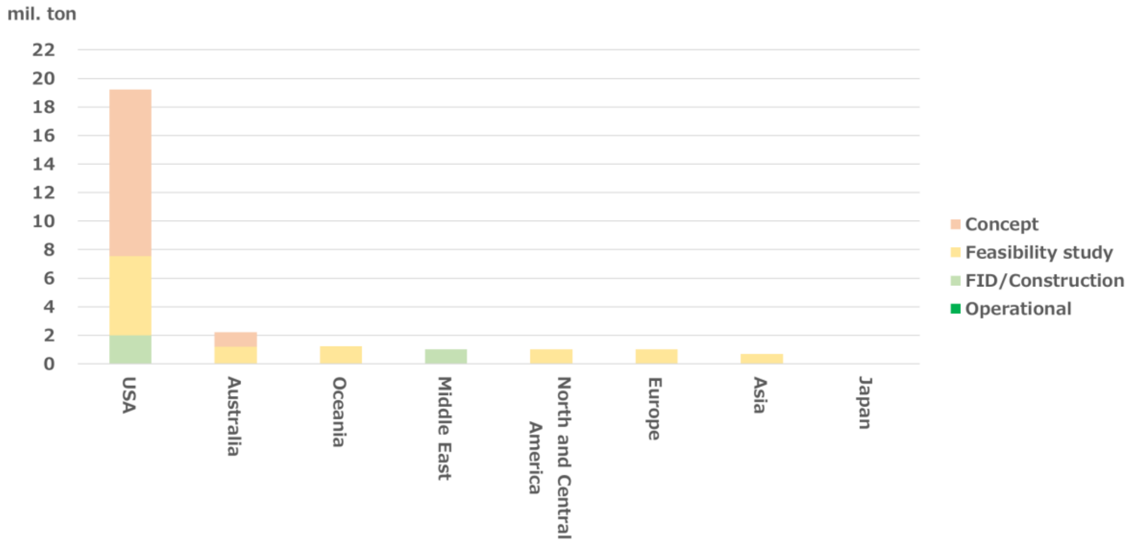
Projected production capacity by year



- The blue ammonia production capacity is expected to increase gradually, but most of the projects are still in the feasibility study or conceptual stages.

Projected production capacity by country (as of 2030*)

*After 2030, there are no projects planned.



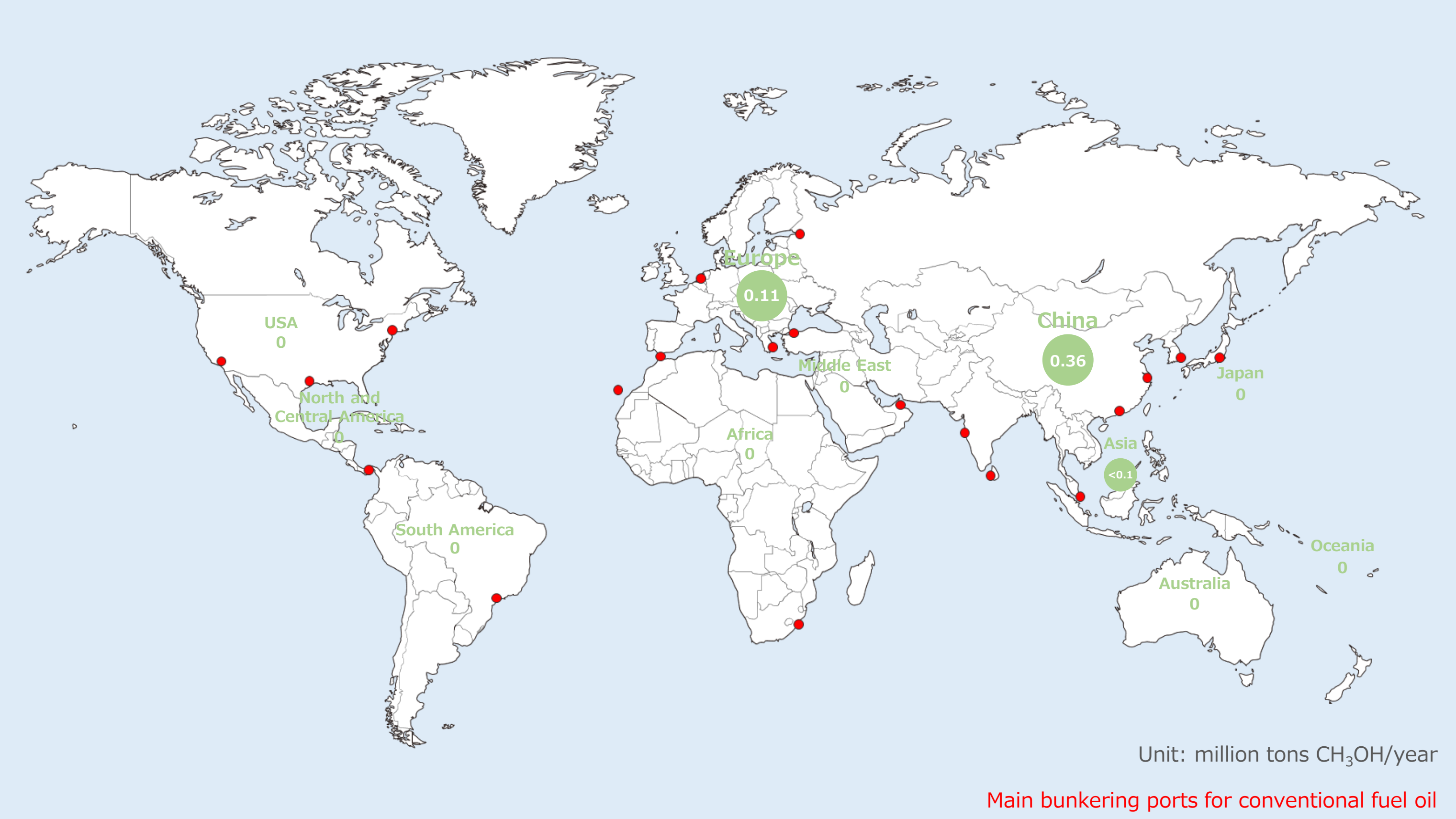
- Most of the blue ammonia projects slated to start production by 2030 are located in the USA.

Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

Alternative fuel production projects - 5 (Green methanol)

Here we introduce the production scale of green methanol (including planned production). Methanol is not only used directly as marine fuel but also required for the production of biodiesel such as FAME (Fatty Acid Methyl Ester). Please note that production projects are not limited to the shipping sector.

Distribution of green methanol production projects (Operational/Construction/FID, for all sectors, as of October 2023)



Country/ Region	Number of projects	Annual production capacity (total)
China	3	365,867 tons CH_3OH/year
Europe	9	119,675
Asia	1	3,918
Total	**13**	**489,461**

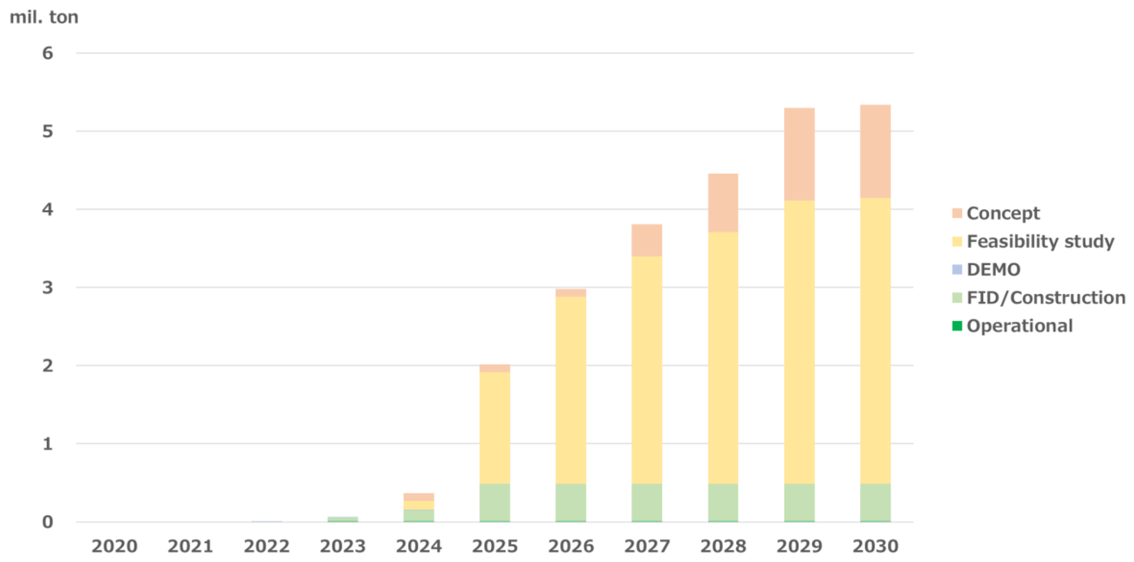
Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

Alternative fuel production projects - 5 (Green methanol)

The majority of green methanol projects slated to commence production by 2030 are still in the feasibility study or conceptual stages and have not reached the final investment decision. It is necessary to continue monitoring the progress of these projects to assess the expected production volume in the future.

Projected production capacity of green methanol (for all sectors, as of October 2023)

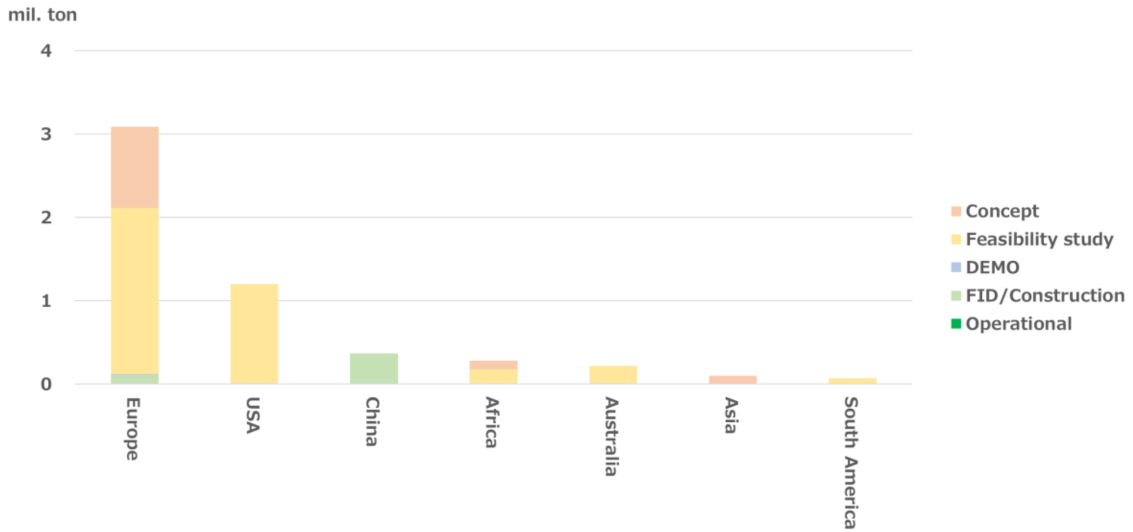
Projected production capacity by year



- ➢ The green methanol production capacity is expected to increase gradually, but most of the projects are still in the feasibility study or conceptual stages.

Projected production capacity by country (as of 2030*)

*After 2030, there are no projects planned.



- ➢ Many of the green methanol projects slated to start production by 2030 are located in Europe and the USA.

Source: Prepared by ClassNK based on IEA (2023), Hydrogen Production Projects Database

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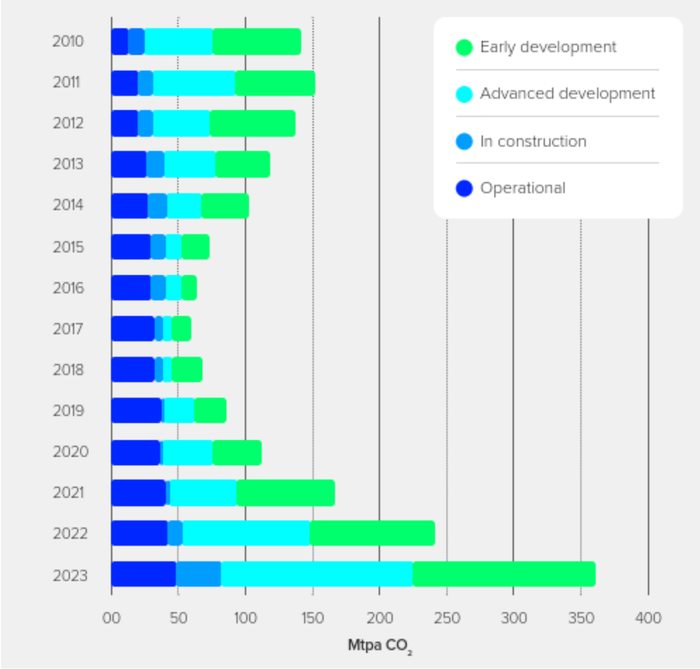
CCS projects

To reduce GHG emissions from ships, not only the use of alternative fuels, but also the utilization of onboard CCS (Carbon Capture and Storage) are effective measures. In the utilization of onboard CCS, it is important to consider where the captured CO_2 will be offloaded and stored. Here, we introduce the trends and distribution of CCS facility development.

Development trends and distribution of CCS facilities

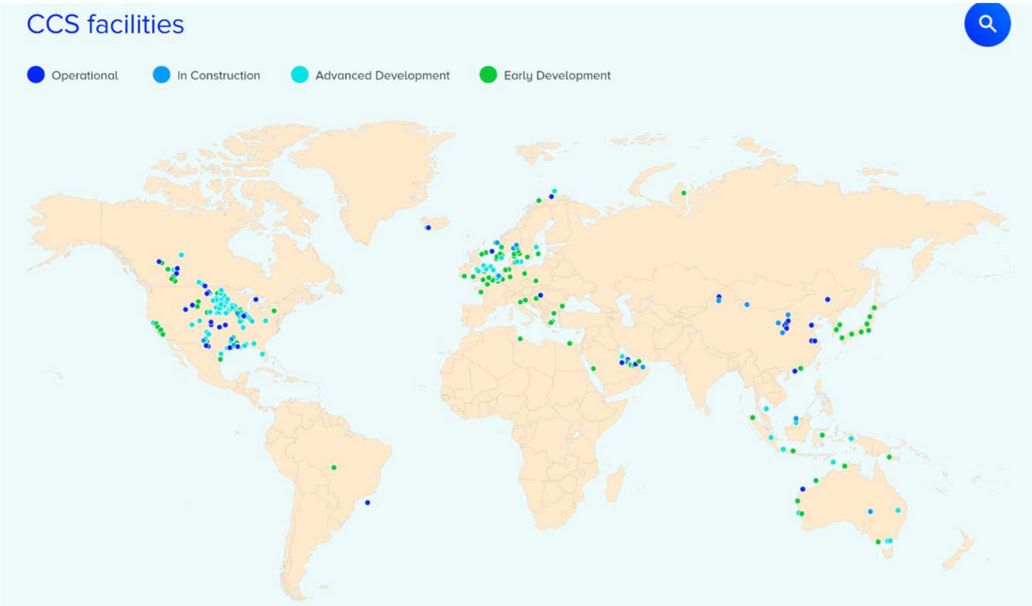
Development trends of CCS facilities



- There were approximately 49 million tons[*1] of CO_2 storage worldwide in 2023.

[*1]Equivalent to emissions from about 16 million tons of heavy fuel oil

Distribution of CCS facilities



- As of 2023, operational facilities[*2] are concentrated in the United States, but construction and development are progressing in various regions worldwide, including Europe.

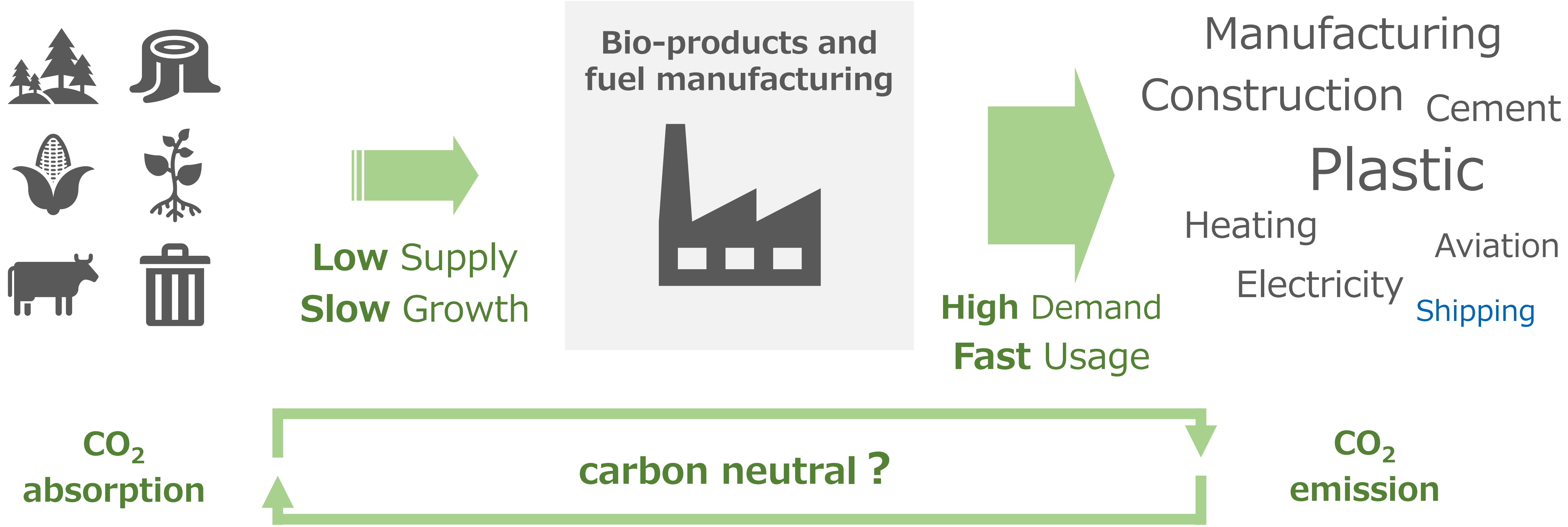
[*2]Most of these are CO_2 storage facilities aimed at enhanced oil recovery.

Source: Global CCS Institute, 2023. The Global Status of CCS: 2023. Australia.

Feasibility of biofuel supply

Biofuels are considered carbon-neutral fuels over their entire lifecycle because the plants used as their raw materials absorb CO_2 from the atmosphere during their growth. Additionally, they attract attention as drop-in fuels that can be used without extensive modification of existing engines. However, biofuels face constraints due to the limited availability of biomass resources, and competition for these resources with other sectors highlights the importance of ensuring stable procurement.

The gap between "supply and demand" and "growth time and usage time"



Use of biofuels

Reducing GHG emissions from ships is important, and the use of biofuels stands out as a significant option. However, it's crucial to fully understand the considerations associated with their use and to identify in advance the types of biofuels acknowledged for their CO_2 reduction effects under regulations.

Two steps to using biofuels

1. **Understand safety precautions**

   Biofuels vary widely in their characteristics depending on the feedstock and production methods. When using them, it's essential to understand the features of each fuel, any precautions for use, and potential issues that may arise. ClassNK provides support for the use of biofuels through information in the "Technical Guide for Using Biofuels."

2. **Make arrangements to use recognized biofuels for CO_2 reduction**

   Biofuels that are recognized for their CO_2 reduction effects may vary depending on regulations. When arranging to use biofuels, please ensure beforehand whether the biofuels meet the requirements of the regulations.

Technical Guide for
Using Biofuels (Edition 1.1)
April 2024

This technical guide can be accessed from the "Guidelines" menu on the ClassNK website's My Page after logging in.
https://www.classnk.or.jp/account/en/Rules_Guidance/ssl/guidelines.aspx

Image of
Proof of Sustainability

Regulation	Requirements for recognizing CO_2 reduction effects	CO_2 reduction effect	Required documents (Arrangement by fuel supplier)
IMO (CII)	・Satisfaction of "sustainability criteria" in international certification schemes (such as ISCC, RSB, etc.) ・GHG intensity (Well-to-Wake) not exceeding 33 gCO_{2eq}/MJ	Depends on the CO_2 conversion factor calculated based on the GHG intensity and lower calorific value of the biofuel in question	Proof of Sustainability or equivalent documents
EU (EU-ETS)	Satisfaction of "sustainability criteria" and "GHG emission reduction criteria" in the Renewable Energy Directive	The CO_2 emissions are reduced to zero.	Proof of Sustainability or equivalent documents

Regulatory trends

The IMO has been actively developing rules and guidelines for various alternative fuels, including zero- and low-emission fuels. Here, we introduce the rules and guidelines of the IMO regarding each alternative fuel, as well as the corresponding rules and guidelines provided by ClassNK.

Rules and guidelines concerning alternative fuels

Alternative fuels/ Related technologies	IMO Rules/Guidelines	ClassNK Rules/Guidelines
LNG	IGF Code	Rules for the Survey and Construction of Steel Ships / Guidance Part GF SHIPS USING LOW-FLASHPOINT FUELS
Methanol	Interim Guidelines for the Safety of Ships Using Methyl / Ethyl alcohol as Fuel (MSC.1/Circ.1621)	Guidelines for Ships Using Alternative Fuels (Edition 2.1) Part A Guidelines for Ships Using Methyl/Ethyl Alcohol as Fuels Part B Guidelines for Ships Using LPG as Fuel Part C Guidelines for Ships Using Ammonia as Fuel Annex 1 Alternative Fuel Ready
LPG	Interim Guidelines for the Safety of Ships Using LPG Fuels (MSC.1/Circ. 1666)	
Ammonia	Under development (The finalization is scheduled for September 2024 at CCC10.)	
Hydrogen	Under development (The finalization is scheduled for September 2024 at CCC10.)	Under development
Fuel Cell	Interim Guidelines for the Safety of Ships Using Fuel Cell Power Installations (MSC.1/Circ.1647)	Guidelines for Fuel Cell Power Systems On Board Ships [Second Edition]

Existing rule | Existing guidelines | Guidelines under development

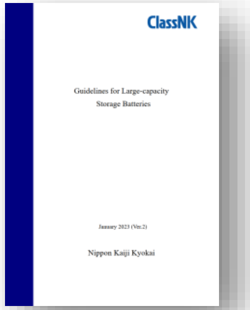
ClassNK's guidelines

ClassNK provides technical support for various aspects, such as issuing Approval in Principle and retrofitting alternative fuel ships, through the issuance of various guidelines. When considering the adoption of alternative fuel ships, we encourage you to make use of these guidelines.

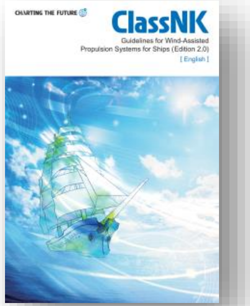
ClassNK List of alternative fuel-related guidelines

Guidelines for Technology Qualification
March 2022

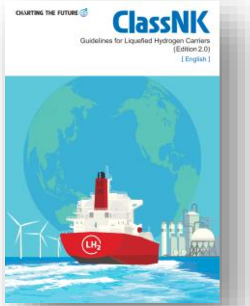
Guidelines for Approval in Principle and General Design Approval
March 2022



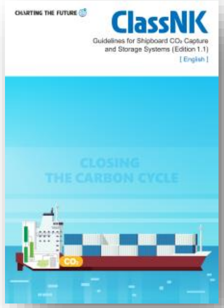
Guidelines for Large-capacity Storage Batteries
January 2023
updated



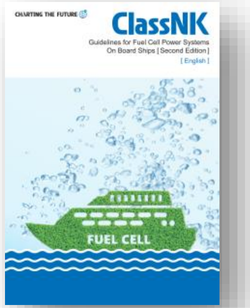
Guidelines for Wind-Assisted Propulsion Systems for Ships
April 2023
updated



Guidelines for Liquefied Hydrogen Carriers
August 2023
updated

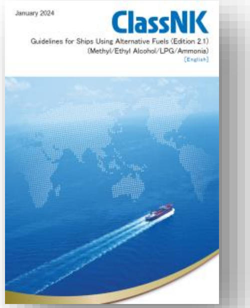


Guidelines for Shipboard CO_2 Capture and Storage Systems
June 2023
updated



Guidelines for Fuel Cell Power Systems On Board Ships
September 2023
updated

Technical Guide for Using Biofuels
April 2024
updated



Guidelines for Ships Using Alternative Fuels
January 2024
updated

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https://www.classnk.or.jp/account/en/rules_guidance/ssl/login.aspx

— Step 4

Understanding costs

When considering the adoption of alternative fuels, understanding the total cost for each fuel is paramount. In this section, we will introduce the cost factors to consider during fuel transition and discuss the cost simulation conducted by ClassNK.

Understanding costs

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Key Takeaways

- ✓ The main costs associated with the adoption of alternative fuel ships are shipbuilding costs, fuel costs, and regulatory costs.
- ✓ Regulatory costs to comply with IMO and EU regulations depend on the GHG emissions resulting from fuel use. To understand regulatory costs, it's necessary to grasp each ship's GHG emissions, including the potential for reduction through fuel transition.
- ✓ It's worth noting that EU regulations (EU-ETS for Shipping and FuelEU Maritime) target GHG emissions in EU-related voyages, while IMO regulations (mid-term measures) may cover GHG emissions in all voyages. Consequently, the regulatory cost burden may be relatively higher, requiring attention.
- ✓ ClassNK is prepared to conduct cost simulations for fuel transition. As soon as the contents of IMO regulations (mid-term measures) are finalized in 2025, ClassNK will provide calculation services for cost simulations.

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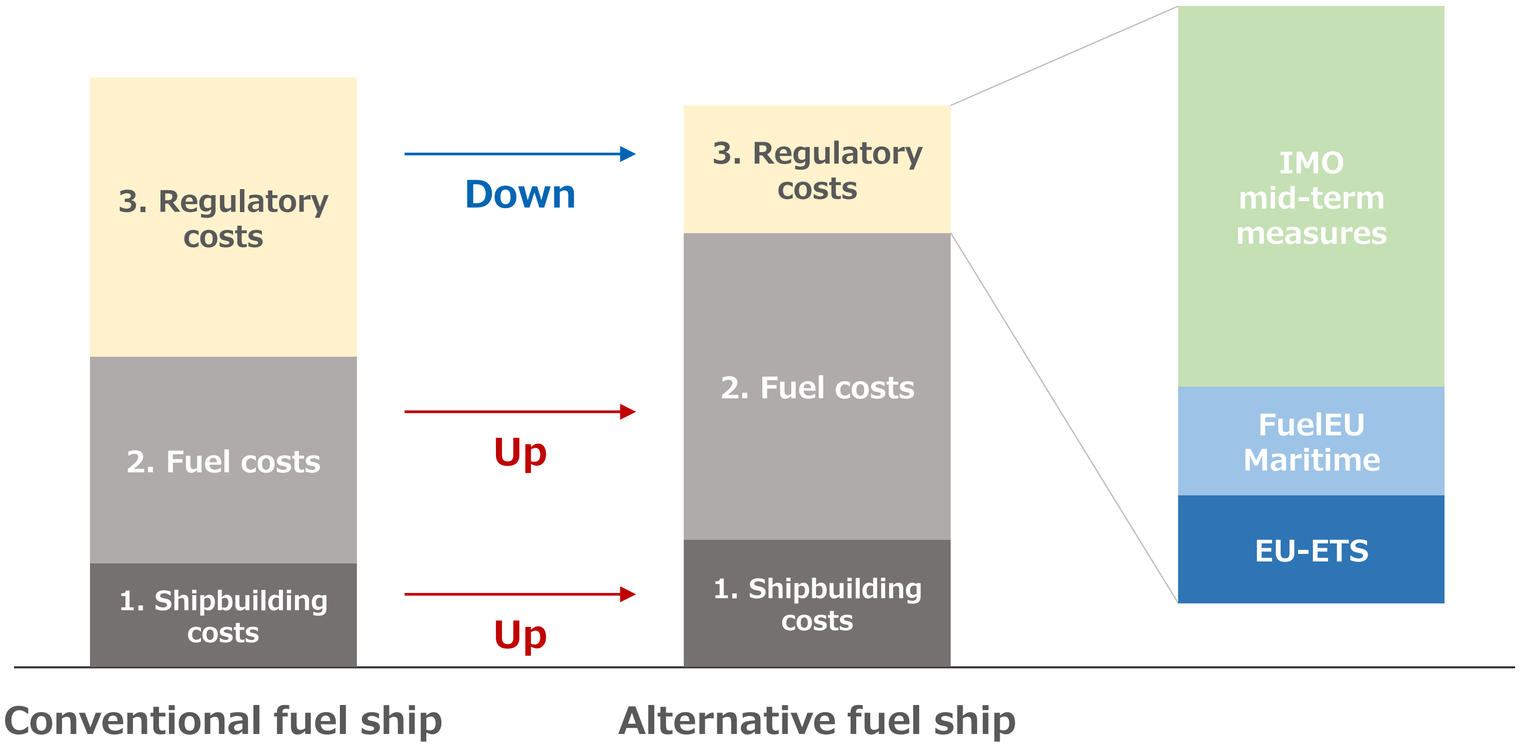
Uncertain factors in costs (1. Shipbuilding costs, 2. Fuel costs, 3. Regulatory costs)

When considering the adoption of alternative fuels, it's crucial to understand the total costs associated with each fuel option for comparison. Among the various cost factors, shipbuilding costs, fuel costs, and regulatory costs stand out as significant components. It's essential to forecast how these costs will change in the future and make the right fuel selections at the appropriate timing, as this will determine the competitive advantage in the maritime business going forward.

Image of primary costs

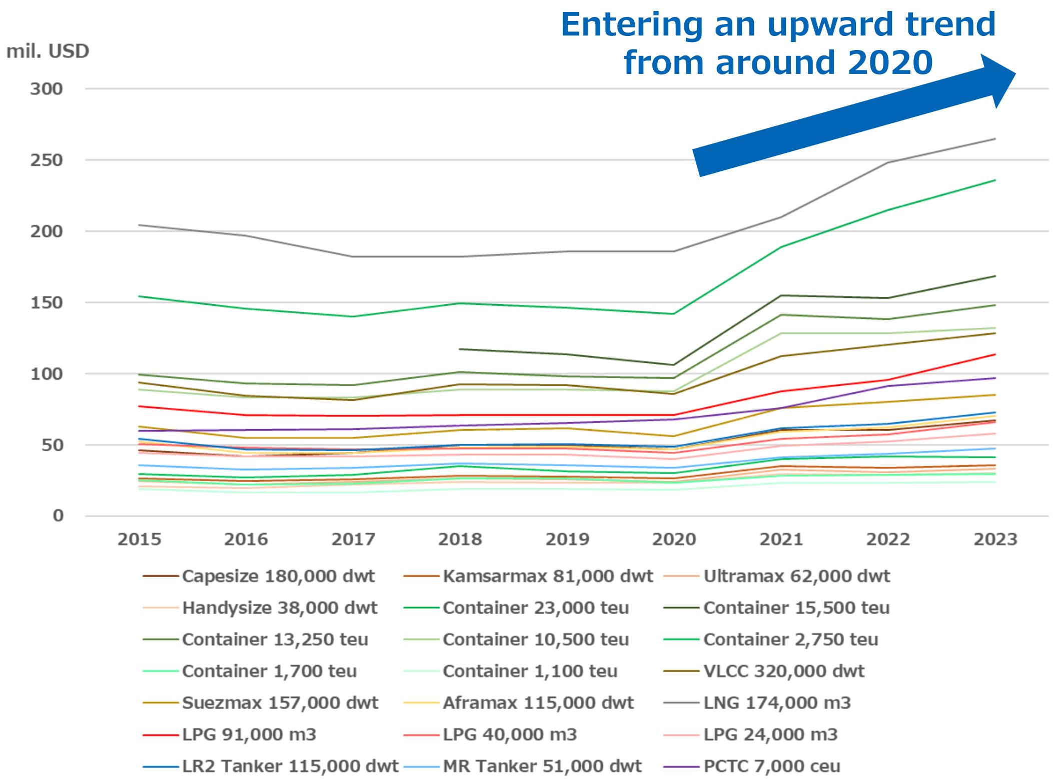


- ✓ The adoption of alternative fuel ships is expected to result in increased shipbuilding costs and fuel costs compared to conventional fuel ships, while regulatory costs are anticipated to decrease.
- ✓ The primary factors contributing to regulatory costs are the EU's EU-ETS and FuelEU Maritime, as well as IMO's mid-term measures.
- ✓ While EU regulations target GHG emissions in EU-related voyages, IMO regulations are likely to cover GHG emissions in all voyages, potentially leading to relatively higher regulatory cost burdens.

Uncertain factors in costs (1. Shipbuilding costs)

The shipbuilding cost of alternative fuel ships, which require different fuel tanks and fuel supply systems, is expected to be higher than that of conventional fuel ships. The outlook for shipbuilding costs until 2050 is uncertain due to significant fluctuations in steel prices, but it's important to invest based on a long-term assessment of ship pricing levels.

The historical trend of shipbuilding costs (ship prices) and the shipbuilding costs of alternative fuel ships



Source: Prepared by ClassNK based on data from Clarkson Research Services Limited

Shipbuilding costs of alternative fuel ships (relative to conventional fuel ships)

LNG	+19%
LPG	+19%
Methanol	+11%
Ammonia	+19%

✓ The shipbuilding cost of alternative fuel ships is typically 10% to 20% higher compared to conventional fuel ships, depending on the ship types and sizes.

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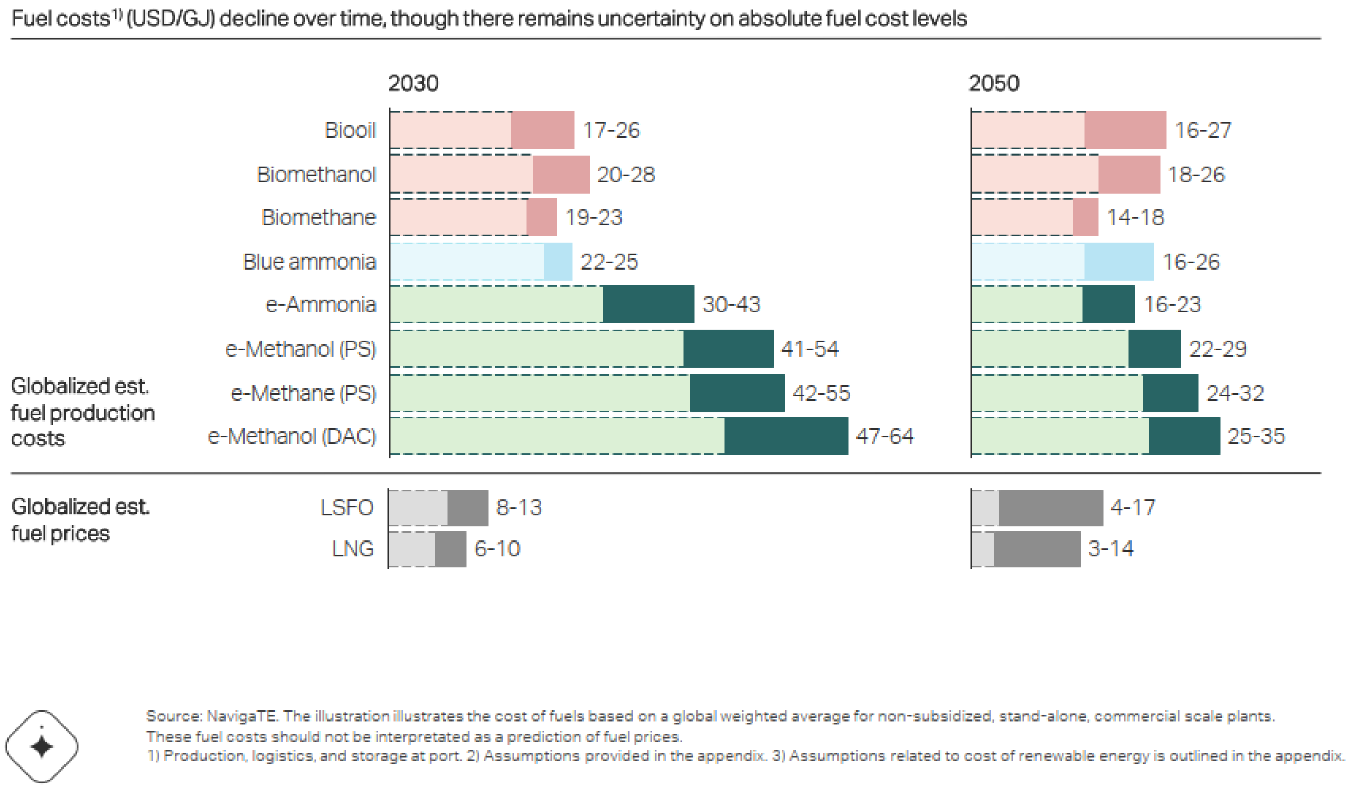
Uncertain factors in costs (2. Fuel costs)

There is a wide range of alternative fuels available for use in ships, but it is anticipated that the cost of each alternative fuel will be higher than conventional fuel oil. However, with the expected expansion of production and the introduction of regulations in the future, the cost gap between alternative fuels and conventional fuel oil is expected to narrow. When considering the adoption of alternative fuels, it is crucial to closely monitor the trends in fuel costs.

Image of fuel costs



Source: Maersk Mc-Kinney Moller Center for Zero Carbon Shipping (2021), Position Paper Fuel Option Scenarios

- ✓ Alternative fuels can be broadly categorized into "biomass-derived fuels" and "e-fuels produced from green hydrogen and captured CO_2."
- ✓ The main cost factor for "biomass-derived fuels" is the price of biomass itself. The price of biomass is influenced by factors such as the availability of biomass resources and the demand trends in other sectors.
- ✓ For "e-fuels produced from green hydrogen and captured CO_2," the main cost factor is the price of green hydrogen. The price of green hydrogen is influenced by the costs of renewable energy and electrolysis equipment.
- ✓ It is possible that the cost of alternative fuels will remain higher than that of conventional fuel oil even by the year 2050.

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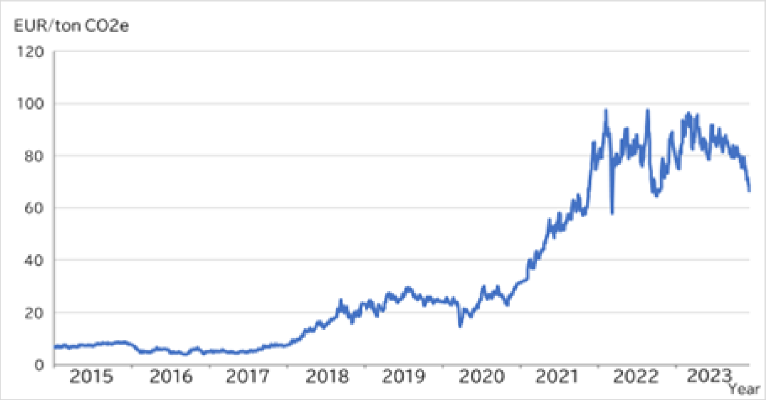
Uncertain factors in costs (3. Regulatory costs)

In the future, a series of regulations encouraging the use of zero and low-emission fuels will be introduced in international shipping. In Europe, the European Union Emissions Trading System (EU-ETS) is expanding to the maritime sector from 2024, and the FuelEU Maritime is set to be introduced in 2025. Meanwhile, the IMO is discussing a new regulatory framework (mid-term measures) for implementation in 2027. Each regulation entails uncertainties in the resulting costs, necessitating caution in total cost estimations.

The three major GHG regulations in international shipping going forward

1. **EU-ETS (2024 -)**
   - ✓ It requires the surrender of emission allowances corresponding to the targeted GHG emissions.
   - ✓ Emission allowances must be procured through the market, and their prices fluctuate daily based on supply-demand balances, etc.
   - ✓ The fluctuating prices of emission allowances are a major uncertain factor in EU-ETS costs.
2. **FuelEU Maritime (2025 -)**
   - ✓ It sets limits for the GHG intensity of fuels (GHG emissions per unit of energy) and requires ships exceeding these limits to pay penalties.
   - ✓ The total amount of penalties is determined by the "degree of excess over the limit" and the "amount of energy consumed."
   - ✓ Flexibility mechanisms (banking, borrowing, pooling) are available to avoid penalties, and the adept use of these flexibility mechanisms affects the costs of FuelEU Maritime.
3. **IMO mid-term measures (Scheduled for 2027 -)**
   - ✓ The contents of the regulation itself are not determined (the regulation details are expected to be finalized in 2025).

Transition of the price of allowances at the European Energy Exchange (EEX)

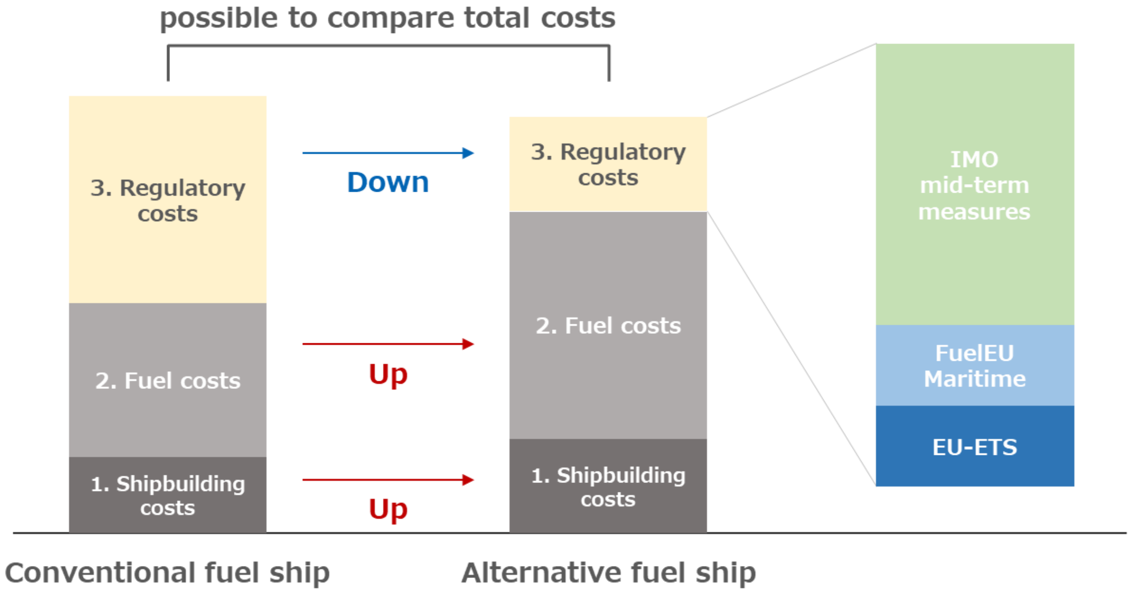


Source: Prepared by ClassNK, based on the emission allowance price data publicly available from the EEX

Conducting cost simulation

ClassNK conducts cost simulations with the aim of supporting your future fuel selections, particularly regarding the transition (replacement) of conventional fuel ships to alternative fuel ships. Here, we provide an overview of the cost simulation process.

Overview of cost simulation



- ✓ Calculate while focusing solely on the major components of costs, namely shipbuilding costs, fuel costs, and regulatory costs, which constitute the majority of the total costs.
- ✓ Compare the total costs of adopting conventional fuel ships with those of alternative fuel ships for ships of the same type and size.
- ✓ Calculated the expected fuel costs and regulatory costs based on the fuel type and fuel consumption. Assumptions regarding fuel costs and regulatory costs can be set as follows:

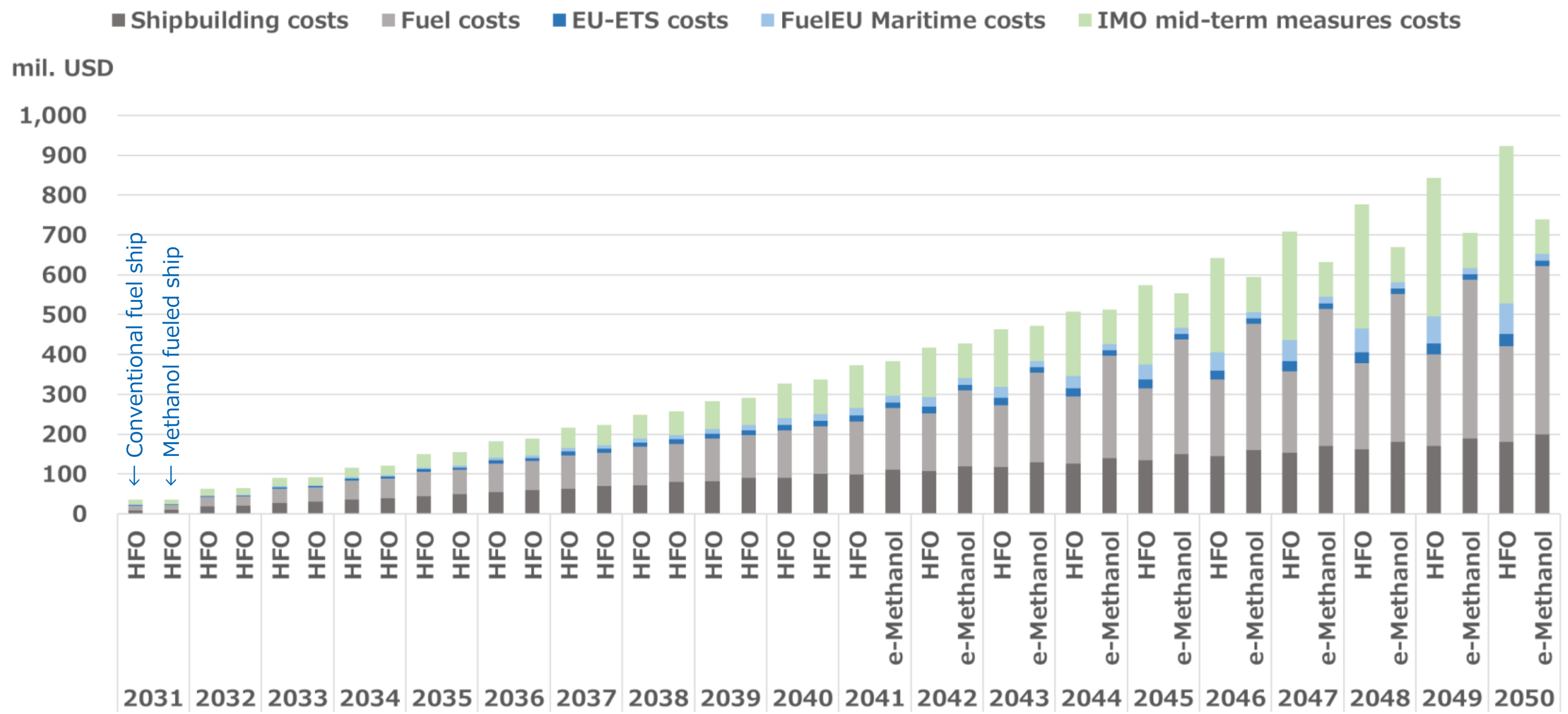
> • Gradual transition case (Regulatory costs: **low**, Zero-emission fuel costs: **high**)
> A case assuming a gradual transition to decarbonization in shipping. GHG emission regulations are lenient, and the cost decrease of zero-emission fuels progresses gradually.
> • Stepwise transition case (Regulatory costs: **middle**, Zero-emission fuel costs: **middle**)
> A case that falls between the "gradual transition case" and the "rapid transition case."
> • Rapid transition case (Regulatory costs: **high**, Zero-emission fuel costs: **low**)
> A case assuming a rapid transition to decarbonization in shipping. GHG emission regulations are stringent, and the cost decrease of zero-emission fuels progresses rapidly.

- ✓ Once the contents of the IMO's mid-term measures are finalized (scheduled for 2025), more accurate calculations will be possible. ClassNK plans to provide cost simulation calculation services in response to this.

Cost simulation example

When adopting alternative fuel ships, it's important to consider fuel costs and regulatory costs while aiming for a timely transition to zero-emission fuels. Here, we present a comparison of total costs between adopting conventional fuel ships and methanol fueled ships in a stepwise transition case, using a 14,000 TEU containership as an example.

Cost simulation example (Conventional fuel ship vs. Methanol fueled ship 14,000 TEU containership: Stepwise transition case)



<Assumption>

- ✓ Delivery in 2031
- ✓ The shipbuilding cost is accumulated annually over a 20-year period.

<How to read the graph>

- ✓ The bar graph on the left side:
  The cumulative cost if a conventional fuel ship is adopted. (Fuel selection limited to HFO only)
- ✓ The bar graph on the right side:
  The cumulative cost if a methanol fueled ship is adopted. (Fuel selection options include HFO or e-Methanol)

<Cost simulation results>

- ➢ For the methanol fueled ship, from 2041 onwards, choosing e-Methanol would be cost-effective ("e-Methanol fuel cost" < "HFO fuel cost + regulatory cost").
- ➢ The cumulative cost of a methanol fueled ship will fall below that of a conventional fuel ship in 2045.

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(Reference) Assumptions for cost simulation example

The assumptions for the cost simulation example for a 14,000 TEU containership are as follows:

The items in blue represent the main uncertainties in costs.

Category			Unit	2024 (ref.)	2031	2050	Comments
Base	**Newbuilding price** (Methanol fueled ship)		-	-	-	-	USD 199,800,000 (Conventional fuel ship+11%)
Base	**Fuel consumption** (HFO)		ton	-	23,000	23,000	Same energy consumption in methanol fueled ship
Base	**Fuel price** (HFO)		USD/ton	522.6 (=13.0 USD/GJ)	522.6	522.6	
Base	**Fuel price** (e-Methanol)	Gradual transition case	USD/ton	1,233.8 (=62.0 USD/GJ)	1,061.1	592.2	2.0% decrease each year compared to 2024
Base	**Fuel price** (e-Methanol)	Stepwise transition case[*1]	USD/ton	1,233.8 (=62.0 USD/GJ)	1,043.8	528.1	2.2% decrease each year compared to 2024
Base	**Fuel price** (e-Methanol)	Rapid transition case	USD/ton	1,233.8 (=62.0 USD/GJ)	1,026.5	463.9	2.4% decrease each year compared to 2024
EU regulations-related	**Emissions subject to EU reg.** (% in total emissions)		%	20	20	20	
EU regulations-related	**EU-ETS allowance price**	Gradual transition case	USD/tonCO_{2eq}	70.0	74.9	88.2	1% increase each year compared to 2024
EU regulations-related	**EU-ETS allowance price**	Stepwise transition case[*1]	USD/tonCO_{2eq}	70.0	84.7	124.6	3% increase each year compared to 2024
EU regulations-related	**EU-ETS allowance price**	Rapid transition case	USD/tonCO_{2eq}	70.0	94.5	161.0	5% increase each year compared to 2024
EU regulations-related	**FuelEU Maritime costs**		-	As per the reg. (2025)	As per the reg.	As per the reg.	HFO's GHG intensity (gCO_{2eq}/MJ) is 91.7. e-Methanol's GHG intensity is 0.0.
IMO regulation-related	**Emissions subject to IMO reg.** (% in total emissions)		%	100	100	100	
IMO regulation-related	**IMO mid-term measures costs**[*2]		-	The same contents as FuelEU Maritime (2027)	The same contents as FuelEU Maritime	The same contents as FuelEU Maritime	HFO's GHG intensity (gCO_{2eq}/MJ) is 91.7. e-Methanol's GHG intensity is 0.0.

[*1]The cost simulation example in the previous slide was calculated under the "stepwise transition case."

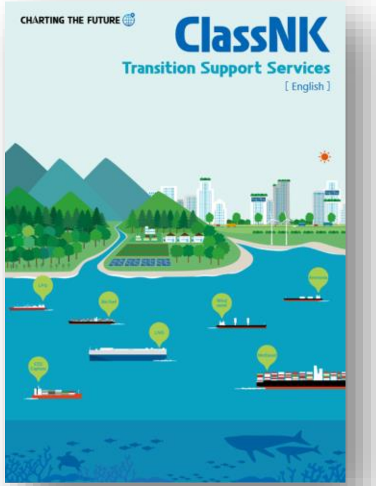
[*2]The IMO's mid-term measures are aligned with FuelEU Maritime, and the emissions targeted by the regulations cover emissions in all voyages.

ClassNK’s support

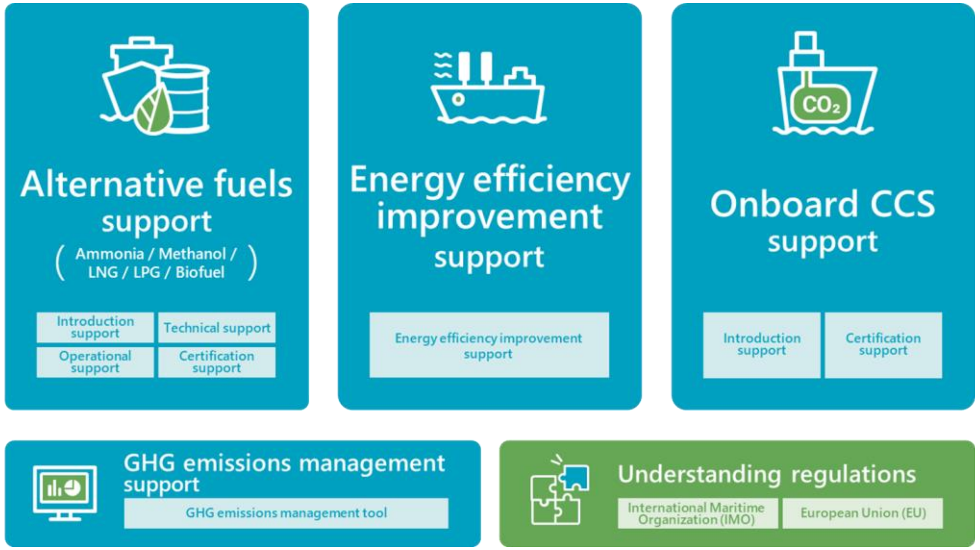
Towards net-zero GHG emissions by 2050

The international shipping industry is expected to undergo a significant fuel transition period toward achieving net-zero GHG emissions by or around 2050. However, the infrastructure for supplying zero-emission fuels is currently underdeveloped. Therefore, in the meantime, it is necessary to transition to zero emissions while utilizing various GHG emission reduction measures. ClassNK has launched the "ClassNK Transition Support Services" to provide comprehensive support for seamless transitions to zero emissions for our clients by leveraging insights gained from activities such as issuing Approval in Principle (AiP) for alternative fuel ships, participating in demonstration projects for energy efficiency improvement technologies and onboard CCS, and verifying GHG emissions. We encourage you to take advantage of our "ClassNK Transition Support Services" for your efforts to reduce GHG emissions from ships.

ClassNK Transition Support Services



(English)



For inquiries regarding ClassNK Transition Support Services in general, please contact us at the following:

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ClassNK Alternative Fuels Insight will continue to be updated according to the alternative fuel trends in international shipping. For more detailed information about the contents of this document or for any feedback or requests, please contact us.

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THANK YOU