SFO°C
Solutions for Our Climate

° Issue Brief

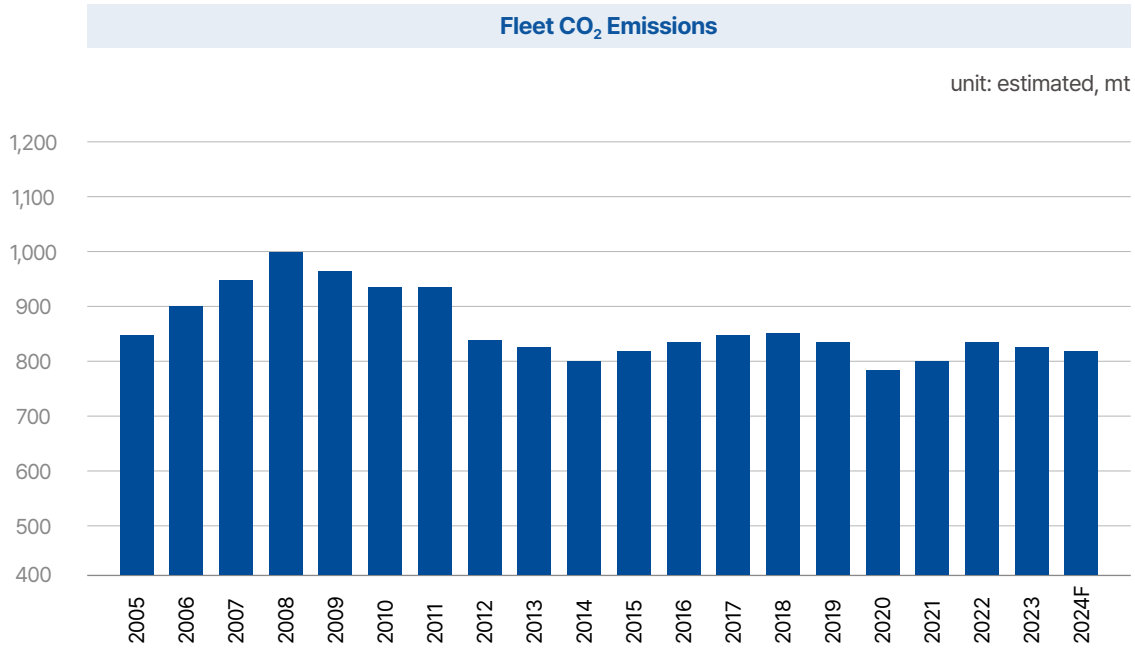
Limitations of LNG in Shipping Decarbonization

Why LNG-powered Vessels are Killing the Planet

01 Introduction: The Need for Net Zero in International Shipping

Countries with significant greenhouse gas (GHG) emissions, such as South Korea, established reduction targets for each industry sector and developed regulations and policies to shift away from fossil fuels, aiming for net zero by 2050. Reduction policies are being established for the transportation sector, which accounts for about 25% of global GHG emissions. International shipping, responsible for around 3% of the world's GHG emissions, is subject to increasingly stringent emission reduction targets.

[Table 1] Fleet CO_2 Emissions by Year



Source: Clarksons Research, 2024

The International Maritime Organization (IMO) is the primary agency responsible for regulating GHG emissions from international shipping. In July 2023, the IMO adopted an enhanced 2050 net zero strategy and set "interim targets" for regulating air pollutants and GHG emissions from vessels. The interim targets aim to reduce annual GHG emissions from international shipping by at least 20% (striving for 30%) by 2030 and at least 70% (striving for 80%) by 2040, compared to 2008 levels. To achieve these interim targets, "mid-term measures"[1] will be implemented starting in 2027, with regulations finalized and agreed upon by 2024. As a result, global shipping corporations are obligated to achieve net zero compared to 2008, making the transition to carbon-free shipping fuels inevitable.

The maritime shipping industry is adopting liquefied natural gas (LNG) as a transitional fuel to replace conventional petroleum-based fuels in response to the enhanced IMO targets. Additionally, LNG has been classified as an environment-friendly shipping fuel, leading to significant investments in the development of related technologies and facilities within the global shipping industry. However, as a fossil fuel, LNG has limitations in achieving substantial GHG reductions. While the combustion of LNG reduces air pollutants, it still emits about 80% of the carbon dioxide compared to conventional shipping fuels during operation, indicating that it is not a fundamental solution. The prolonged use of LNG fuel in the shipping sector could accelerate climate warming.

In this brief, we analyze the global GHG regulations for vessels, the order status of LNG-powered vessels, and South Korea's policies supporting LNG fuels. Additionally, we examine the issues associated with LNG as a shipping fuel and provide policy recommendations.

1 'The "mid-term measures" include a target-based fuel standard to gradually regulate the GHG intensity of shipping fuels and an economic component based on a price mechanism. Discussions and issues regarding the development of the "mid-term measures" will be addressed at the MEPC 82 (Marine Environment Protection Committee) in September 2024. Key issues include incorporating Well-to-Wake emissions into the target-based fuel standards and introducing a global pricing mechanism.

02 Characteristics and Current Status of LNG-powered Vessels Order

In response to the IMO's 2020 regulations on ship emissions, maritime shipping companies have transitioned from using traditional high-sulfur fuel oil (HSFO) to very low-sulfur fuel oil (VLSFO) and marine gas oil (MGO). As VLSFO and MGO are petroleum-based heavy fuel oils compatible with existing ship engines, the primary difference being increased fuel costs, this transition has allowed shipping companies to switch fuels without significant burden. On the other hand, some global shipping companies are considering LNG as an alternative fuel for their vessels. Although LNG is more expensive and requires longer shipbuilding times compared to petroleum-based fuels, it can reduce carbon dioxide emissions by at least 20% compared to heavy fuel oil on a "Tank-to-Wake"[2] basis; additionally, it can reduce sulfur oxide emissions by about 95%, nitrogen oxide emissions by over 90%, and particulate matter (PM), which causes fine dust, by 95%. Therefore, LNG-powered vessels can reduce air pollutants compared to conventional heavy fuel oil.

Orders for LNG-powered vessels are increasing naturally due to growing interest in LNG fuel as an alternative to conventional petroleum-based fuels. According to Clarksons Research,[3] as illustrated in [Table 2], as of March 2024, out of 109,000 vessels exceeding 100 GT, there are 1,070 LNG-powered vessels in operation, making up 1% of the total fleets. There are 556 LNG-powered vessels, excluding LNG carriers, indicating a higher number of LNG-powered vessels in operation than other alternative fuel ships, like methanol-powered vessels. Notably, most electric-powered ships on order are small vessels due to battery capacity limitations, which suggests a prevalence of large LNG-powered vessels.

[Table 2] Alternative Fuel Ships in Operation

	Alternative Fuel Type				
	LNG	Methanol	LPG	Battery Fitted	Other Alt. Fuel
Fleet, No.	1,070	29	114	506	150
% Fleet No.	1.0	0.0	0.1	0.5	0.1
% Fleet GT	**5.5**	**0.1**	**0.3**	**0.3**	**0.4**

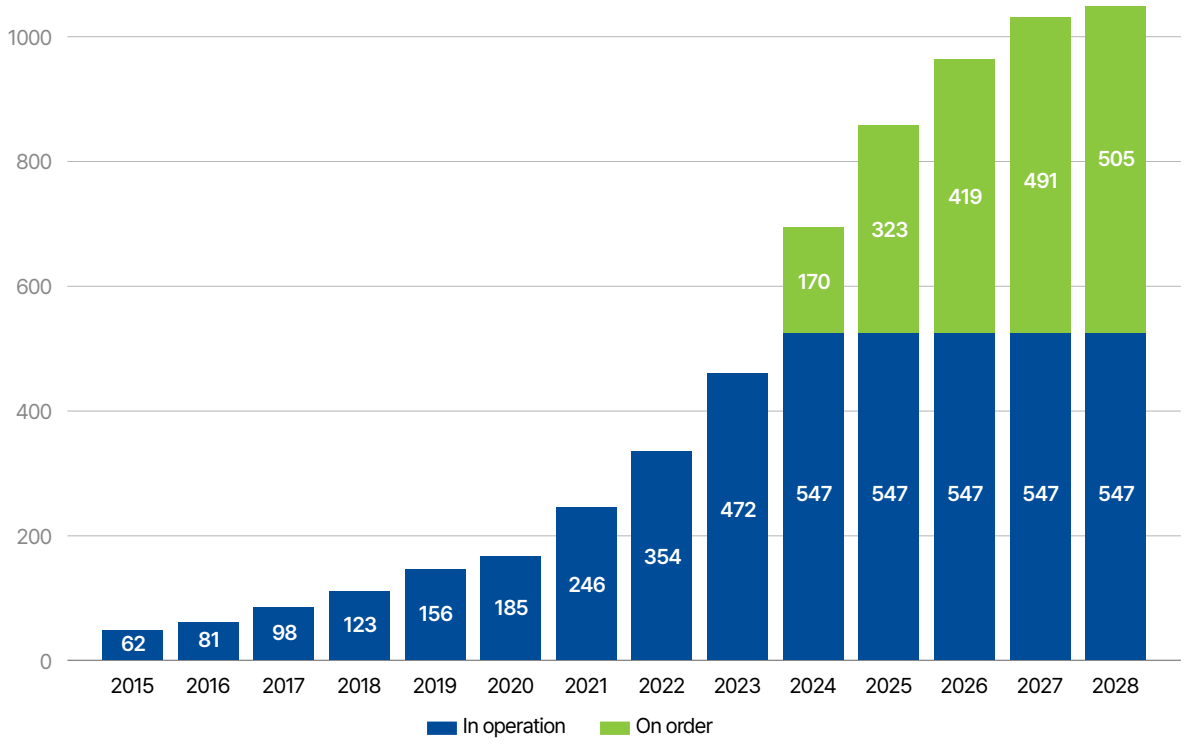
Source: Clarksons Research, 2024

2 Tank-to-Wake (TtW) is a method of assessing GHG emissions that only considers the emissions released during the fuel consumption phase, excluding emissions generated during the fuel production and transportation processes. For a detailed explanation, please refer to page 12 of this brief.

3 Clarksons Research is a British shipbuilding and shipping market analysis agency. The data referenced here is based on its World Fleet Register.

According to Det Norske Veritas (DNV), the Norwegian classification society, there were 472 LNG-powered vessels (excluding carriers) worldwide in 2023. This represents an approximate 284% increase compared to 2018 when the IMO announced its regulations on carbon emissions in international shipping. By 2028, one year after the IMO's "mid-term measures" are implemented, there are expected to be 1,052 LNG-powered vessels (547 in operation and 505 on order), an increase of about 120% compared to 2023. The increase in LNG-powered vessels is projected to boost the share of LNG in global shipping fuel consumption. Although estimates vary among research organizations, the annual consumption of LNG for bunkering is projected to rise from 3.7 million tons in 2023 to 7.4 million tons in 2025 and exceed 10 million tons by 2027.[i] These figures are based on the confirmed fleet volumes to date, and the actual LNG demand in the shipping sector may vary.

[Table 3] LNG-powered vessels in Operation and Order books

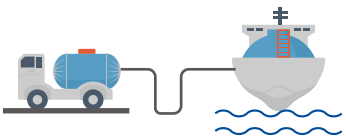
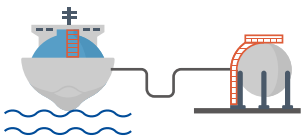
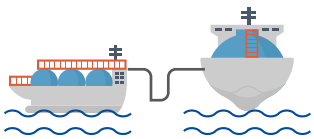


Source: Korea LNG Bunkering Industry Association, 2024 (Raw Data: DNV)

LNG Bunkering Explained

There are three types of LNG bunkering technologies used to supply LNG fuel to vessels: Truck-to-Ship (TTS), Ship-to-Ship (STS), and Port-to-Ship (PTS). The TTS method is the most commonly used because it is operationally flexible, does not require extensive infrastructure, and requires relatively low upfront investment. In recent years, the demand for larger LNG-powered vessels has increased, leading to a corresponding growth in the demand for STS and PTS bunkering, which can handle larger volumes. LNG bunkering is conducted extensively in Europe, North America, and East Asia, with Europe accounting for 44% of the global LNG bunkering fleet in operation.[ii]

[Table 4] Difference Between Three Types of LNG Bunkering

	TTS	PTS	STS
			
Bunkering Method	LNG is supplied using flexible hoses with personnel or cranes, etc., while docked	LNG is supplied at docks equipped with LNG terminals or small LNG storage tanks	LNG is supplied by mooring alongside an LNG bunkering ship with a pier or fender in between
Bunkering Capacity and Flow Rates	Capacity: 50~100 m^3 Flow rate: 40~60 m^3/h	Capacity: 500~20,000 m^3 Flow rate: 1,000~2,000 m^3/h	Capacity: 100~6,500 m^3 Flow rate: 500~1,000 m^3/h
Pros	- Operational flexibility - Relative ease of meeting safety requirements - Capability to vary supply within a specific range	- Ability to provide the fastest and large volume supply - Suitability for piers with long-term stable bunkering demand	- Suitability as the most appropriate method for LNG bunkering - Lack of interruptions to hoisting or cargo operations, allowing simultaneous operations - Faster delivery of larger amounts of fuel compared to TTS
Cons	- Limited capacity and delivery speed of trucks - Restrictions on docks and roads	- Difficulty in accessing the dock from an operational perspective - Challenges in ensuring accessibility to large LNG terminals - Difficulty in obtaining small LNG storage tank without prior arrangements	- High upfront investment costs associated with designing, building, and operating LNG bunkering vessels - Significant impact on the lifecycle of specific LNG bunkering business - Requirement of stability and accident impact assessments in highly uncertain waters - Heavy influence by the conditions of the dock and various LNG-powered vessels

Source: Understanding LNG Bunkering and Practices, 2022

03 Problems of LNG in the Shipping Sector

1) Environmental Issues

The IMO has announced its plan to assess emissions from a lifecycle assessment perspective, considering the entire process from fuel production to the final use on ships.[iii] If the "Well-to-Wake (WtW)" standard is adopted, shipping companies must consider LNG's entire life cycle emissions. In LNG-powered vessels, emissions occur not only from the combustion of LNG during operations, which releases boil-off gas (BOG) into the atmosphere but also from methane slip, where unburned methane leaks from the engine. Considering that LNG is mainly methane, the WtW emissions of LNG could be higher than anticipated due to methane's high Global Warming Potential (GWP).[4] Methane, the second most potent climate-warming pollutant after carbon dioxide, raises the earth's temperature by approximately 0.5°C and contributes to 30% of global warming.[iv]

[Table 5] Lifecycle Assessment and WtW/TtW

Well-to-Wake Emissions					
"Lifecycle" emissions from marine fuels(the sum of Well-to-Tank(WTT) and Well-to-Wake(TTW). i.e. including emissions from every stage of the lifecycle of a fuel; from extraction/production to combustion/usage onboard					
Well-to-Tank Emissions					**Tank-to-Wake Emissions**
"Upstream" emissions from marine fuels: WTT emissions includes all GHG emissions released into the atmosphere from:					"Downstream" GHG emissions from marine fuels i.e. the emissions that are generated by combustion / conversion / usage of marine fuel once onboard the vessel
Feedstock / Exfraction / Cultivation / Acquisiyion / Recovery	**Feedstock (early) Processing / Transformalion at source**	**Feedstock transport to conversion site**	**Feedstock conversion to product fuel**	**Product fuel Transport / Starage / Delivery / Retail / Starage / Bunkering**	

Source: Clarksons Research, 2024

4 The Global Warming Potential (GWP) represents the impact each GHG has on global warming compared to the impact of carbon dioxide, which is set as 1. For example, the GWP of methane over 100 years is 29 times that of carbon dioxide, and over 20 years, its GWP can be up to 92 times higher (IPCC, 2021).

A report by the World Bank (2021) analyzes the role of LNG in contributing to net zero in the shipping sector and highlights the high WtW emissions of LNG fuel as a limitation. The report concludes that the theoretical benefits of LNG-powered vessels are diminished and offset because methane is emitted at all stages of the LNG lifecycle, from production to transport, storage, and combustion. For LNG to effectively contribute to decarbonizing the shipping sector as a shipping fuel, methane slip from ship engines and methane leakage in upstream LNG supply chains must be significantly reduced.

The International Council on Clean Transportation (ICCT), a US-based environmental organization, measured methane slip from LNG-powered vessels sailing off the coasts of the Netherlands, Denmark, Belgium, and Australia to understand the methane slip from their engines during operation and while docked.[v] The findings revealed that LNG-powered vessels generate methane slip during operation and while docked and unloading cargo. The average methane slip from common types of LNG engines (LPDF 4-stroke) was measured at 6.4%, higher than the EU standard of 3.1% and the IMO standard of 3.5%. The ICCT concluded that when including methane leaks from the extraction and production processes of LNG, the total WtW GHG emissions of LNG are estimated to be 120% higher than those of marine diesel oil (MDO).

2) Marketability Issues

High methane emissions from LNG-powered vessels exacerbate the climate crisis and burden shipping companies economically. Starting in 2027, the IMO will require shipping companies to pay a levy per unit of GHG emissions from the shipping fuel they use as a new reduction regulation to achieve net zero by 2050. In the EU, the EU ETS is extended to the shipping sector beginning in 2024, requiring maritime shippers to purchase carbon credits based on the WtW GHG intensity of each fuel, as stipulated in FuelEU Maritime.[5] The introduction of the WtW standard, based on a life cycle assessment in regulating GHG emissions from vessels, will reduce the economic merits of LNG-powered vessels since the WtW emissions of LNG, including methane slip and leakage, will increase.

5 FuelEU Maritime is part of Europe's Fit for 55 Package, which sets new regulations for the use of renewable or low-carbon fuels in maritime transport, aiming to gradually create large-scale production and demand

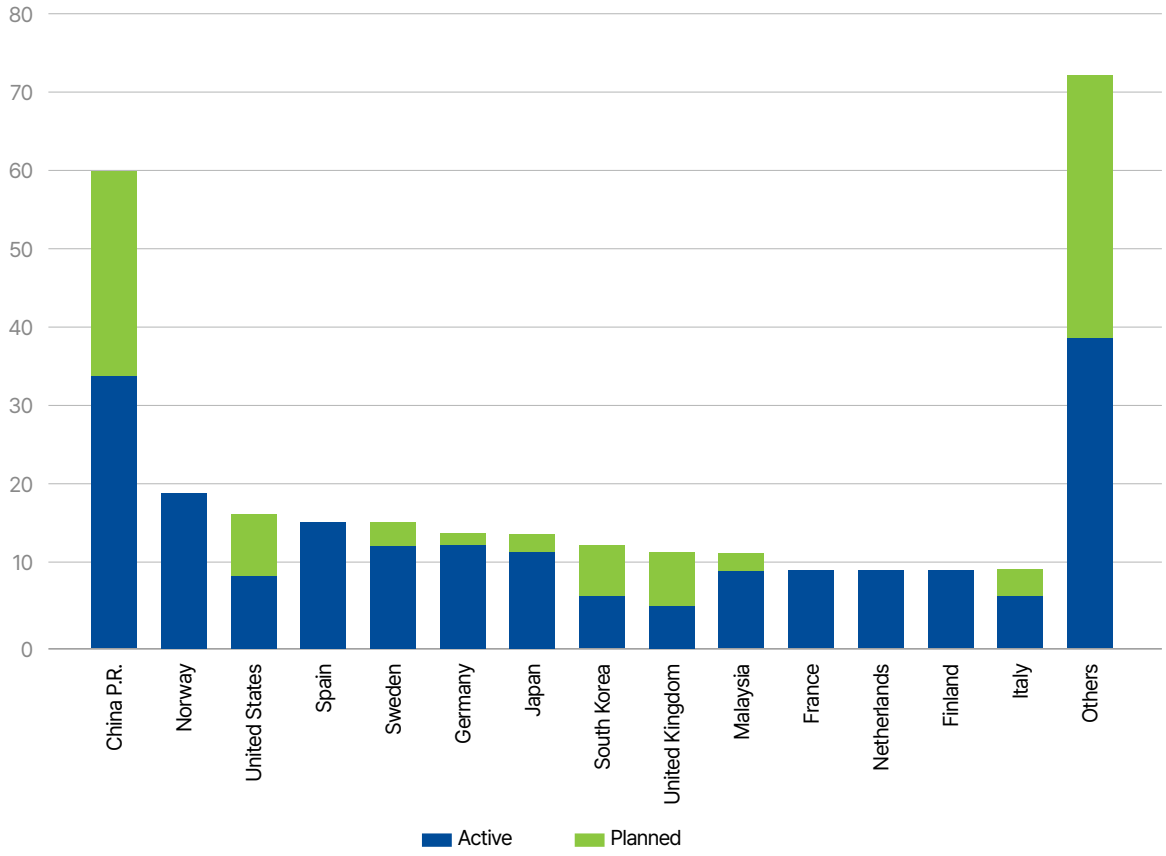
A) Limitation on the Size of South Korea's Bunkering Market

South Korea's LNG bunkering market in 2024 is estimated at around 60,000 tons, which is relatively insignificant in the global LNG bunkering market. Korea LNG Bunkering Co., Ltd. (KOLB), a wholly-owned subsidiary of Korea Gas Corporation (KOGAS), sold approximately 40,000 tons of LNG bunker fuel in 2023. Most of this was used for LNG vessel commissioning, with an estimated 6,000 tons for actual operations.[vi] KOLB provides 70 to 80 percent of the country's LNG bunkering, with POSCO International and SK Gas also in the bunkering business. Industry insiders believe that low bunkering demand is likely to continue in the short term and that a sharp increase in domestic LNG bunker fuel demand is unlikely. In contrast, the Port of Singapore, which had the lowest performance among the top three bunkering ports in 2023, recorded approximately 110,000 tons that year. In January this year, Singapore reached a five-month high with 10,400 tons of LNG bunkering volume,[vii] a figure that is about 20 times South Korea's LNG bunkering performance in 2023.

China is a more significant threat to the domestic LNG bunkering market than Singapore, where a stable market and infrastructure are already established. Hai Gan Wei Lai (海港未来), with a tank capacity of 20,000m³, services the Port of Shanghai. Hai Yang Shi You (海洋石油) 301, with a capacity of 30,000m³, covers other outer ports, while Xinao Putuo Hao (新奥普陀), with a capacity of 8,500m³, services the eastern coastal region of China. Together, they provide a formidable volume of LNG bunkering services in their regions.[viii] Additionally, Hai Yang Shi You (海洋石油) 302, with a capacity of 12,000m³, is expected to be deployed this year.[ix] According to Clarksons Research, while China's LNG bunkering capacity still lags behind major ports like Rotterdam and Singapore, its aggressive deployment of large-capacity LNG bunkering ships enables many ports to offer LNG bunkering services. This positions China to emerge as a major LNG bunkering nation.

[Table 6] Ports Offering LNG Bunkering Services by Country

***Planned includes ports with LNG bunkering projects that are currently proposed, under construction and in MOU statuses**



Source: Clarksons Research, 2024

Under these circumstances, South Korea's aggressive expansion of the LNG bunkering business, driven by optimism for mid- to long-term growth, contradicts the purpose of using LNG as a shipping fuel. As a transitional fuel, LNG is intended to reduce GHG emissions gradually, yet it still emits 80% of the carbon dioxide of heavy fuel oil. Ignoring this and relying on LNG, a fossil fuel, will make substantial GHG reductions impossible.

As South Korea is just beginning to transition to eco-friendly fleets, achieving net zero by 2025 necessitates caution against biased investment by companies and the government solely in constructing LNG bunkering infrastructure, which requires tremendous upfront capital. LNG bunkering facilities cannot be shared with alternative fuels such as methanol, ammonia, and hydrogen, emerging as significant alternative fuels. Therefore, investing in LNG bunkering infrastructure will inevitably extend the lifespan of LNG, a fossil fuel. Additionally, newly constructed fossil fuel facilities post-2025 are expected to struggle to meet their 25–30-year lifespan due to tightened environmental regulations, exposing them to the significant risk of becoming stranded assets. The potential decline in LNG prices due to reduced international fossil fuel demand should also be considered.

04 South Korea's Policies for Shipping Decarbonization

The South Korean government has also announced support policies and research & development plans to align with the regulation on GHG emissions from international shipping. While the ultimate goal is to transition to carbon-free fuels, the current focus of South Korea's fleet transition and port infrastructure development is regrettably on LNG, a commercially viable technology at present. This focus stems from the *Act on the Promotion of the Development and Distribution of Environment-Friendly Ships* (the Green Ship Act), which has been in effect since January 2020 and defines LNG-powered vessels as "environment-friendly ships." The *Green Ship Act* (*2020*) classifies ships using seven specific environment-friendly energy sources as "environment-friendly ships" as specified in the *Rules on Standards and Certification of Environment-Friendly Ships*. Therefore, we will examine the policy proposals related to the green transition of the shipping sector, with a particular focus on support for LNG fuel.

The Green Ship Act (2020)

Article 2 (Definitions), Paragraph 3

3. "Environment-friendly ship" refers to ships that fall under any of the following:

A. A ship designed using technologies that can reduce marine pollution or increase ship energy efficiency in compliance with the standards set jointly by the Ministry of Trade, Industry and Energy (MOTIE) and the Ministry of Oceans and Fisheries (MOF) (hereinafter referred to as the "Joint Ordinances");

B. A ship that uses environment-friendly energy sources, as determined by the Joint Ordinances, such as liquefied natural gas (LNG), as its power source;

C. An electric-powered ship that uses electricity from an electric power source;

D. A hybrid ship that uses a combination of gasoline, diesel, liquefied petroleum gas (LPG), natural gas, or other fuels and electricity (including electricity from an electric power source), as determined by the Joint Ordinances, as its power source;

E. A fuel cell-powered ship that uses electricity generated from hydrogen, etc., as its power source

Rules on Standards and Certification of Environment-Friendly Ships

Article 3 (Environment-Friendly Energy)

In Article 2, Subparagraph 3, Item B of the Act, "environment-friendly energy sources, as determined by the Joint Ordinances, such as liquefied natural gas" means energy that falls under any of the following:

1. Liquefied Natural Gas (LNG)
2. Compressed Natural Gas (CNG)
3. Liquefied Petroleum Gas (LPG)
4. Methanol
5. Hydrogen
6. Ammonia
7. Any other energy recognized by the Minister of Trade, Industry and Energy and the Minister of Oceans and Fisheries as necessary for the creation of a clean marine environment

① *Strategy for International Shipping Decarbonization*

In February 2023, the South Korean government announced the *Strategy for International Shipping Decarbonization*, extending its commitment to realizing net zero by 2050 to the international shipping sector. This strategy includes plans to reduce GHG emissions through the eco-friendly transformation of the shipping industry. According to the United Nations Framework Convention on Climate Change (UNFCCC), emissions from international shipping are classified as international bunkering in the GHG inventory reports of various countries, including South Korea. They are reported as the memo item, excluding them from aggregating total national inventory emissions. As a result, these emissions[6] have often been overlooked as they have not been included in Nationally Determined Contributions (NDCs) of GHG reduction targets. In alignment with the expansion of decarbonization regulations to include the international shipping sector, the Ministry of Oceans and Fisheries (MOF) and other relevant agencies have announced the Strategy for International Shipping Decarbonization, with the ambitious goal of making South Korea the world's leading eco-friendly shipping nation.

To realize the 2050 decarbonization of international shipping, the MOF aims to reduce GHG emissions by 60% (17 million tons) by 2030, 80% (22 million tons) by 2040, and 100% (28 million tons) by 2050 compared to 2008 levels. Of the 867 national flag vessels of 5,000 GT or above subject to IMO regulations, 118 vessels will be converted to carbon-free ships by 2030, 606 vessels by 2040, and all 867 vessels by 2050.

6 According to GHG emissions from international bunkering in the National GHG Inventory Report, the GHG emissions from international shipping in 2008 were 28,081,000 tCO_2eq. For reference, GHG emissions from international shipping in 2021 were 33,708,000 tCO_2eq.

[Table 7] Details of Vessels of 5,000 GT or Above for Green Conversion

(Subject to Conversion) Out of 1,162 oceangoing vessels, 867 oceangoing vessels* of 5,000GT or above are subject to conversion.

Total (vessels)	Container Ships	General Cargo Ships	Oil/ Chemical Tankers	Car Carriers	Crude Oil Tankers	Ore Carriers	LNG Carriers	Coal/Steel Carriers
867	174	299	176	61	72	46	29	10

Source: Strategy for International Shipping Decarbonization, 2023

In addition, South Korea is responding to the European Union's Emissions Trading Scheme (EU-ETS). By 2030, 26 out of the 44 (60%) regular container ships operating on European and American routes will be converted to LNG-methanol dual-fuel vessels[7] as a priority. According to the MOF, although LNG and methanol-powered vessels are not carbon-free, the priority will likely be on using e-methanol and LNG due to the current limitations in technology and supply. E-methanol is a clean methanol produced by synthesizing green hydrogen, generated through renewable energy, with CO^2. It is not yet commercialized as LNG in South Korea due to the shortage of renewable energy and high production costs.

According to estimates by the MOF, the cost of transitioning to greener fleets[8] will be KRW 7.6772 trillion (USD 5.54B) by 2030 and KRW 70.5557 trillion (USD 50.9B) by 2050. These estimates are based on expected orders of new ships when existing ships reach 25 years of age and are replaced at 28 years. The cost of building new conventional ships is estimated to be KRW 5.8575 trillion (USD 4.23B) in 2030, making the conversion to greener fleets approximately 31% more expensive. Therefore, the government estimate of the conversion cost to green ships by 2030 is KRW 1.8197 trillion (USD 1.31B).

7 A dual-fuel vessel is equipped with dual-fuel (DF) engines that can power two or more fuel types. LNG DF ships are specifically designed to run on LNG, primarily MGO or LSFO.

8 The unit costs of green ships, as the MOF applies, are based on the average unit costs by ship types from previous studies conducted by the Korea Institute of Energy Research and the Korea Shipowners' Association. The costs are as follows: KRW 220 billion (USD 158M) for large methanol carriers, KRW 170 billion (USD 122M) for series container carriers, and KRW 44 billion (USD 31M) for container carriers.

To alleviate the financial burden of the increased costs, the MOF is implementing policies and financial support measures to encourage timely investment by shipping companies. These measures include expanding government subsidies for fleet conversion and enlarging the new shipbuilding support program. This program is jointly funded by the Korea Ocean Business Corporation, the Korea Development Bank, the Export-Import Bank of Korea, and the Korea Asset Management Corporation, committed to securing up to KRW 4.5 trillion (USD 3.25B) in public funds. Additionally, green finance support will be provided for the construction and operation of eco-friendly ships, offering interest rate reduction benefits of 0.9-3.4% on ship loans.

As mentioned, LNG is classified as an environmentally friendly energy under the *Green Ship Act (2020)*. Consequently, LNG dual-fuel (DF) ships and other LNG-powered vessels, which are the most commonly ordered domestically, also benefit from these policy supports.

② *2024 Greenship-K Development and Distribution Implementation Plan*

Since 2021, the Ministry of Trade, Industry, and Energy (MOTIE) has announced annual development implementation plans following the *Green Ship Act (2020)*. Based on Clarksons's analysis, the MOTIE projects that carbon-free fuel propulsion will be commercially available by 2030 and account for 67% of global fleets by 2050. Despite this shift, long-term support for developing LNG-powered vessels and related equipment remains a part of their plans. For instance, KRW 4.293 billion (USD 3.1M) has been allocated in the 2024 budget to support the localization and commercialization of essential technologies and equipment for LNG-powered vessels.

Similarly, the MOF has also been announcing annual distribution implementation plans since 2021 following the *Green Ship Act (2020)*. According to the *1st Framework Plan for the Development and Distribution of Green Ships* (2021-2030), the MOF aims to convert 528 vessels (388 public and 140 private) to eco-friendly vessels by 2030. This represents the initial conversion of 15% of the 3,542 targeted ships. The government-led conversion of public vessels to green ships will primarily focus on hybrid[9] and LNG-powered vessels. Vessels over 200 tons will be constructed as LNG-powered vessels, while those under 200 tons will be built as electric or hybrid vessels. In cases where building green ships is not feasible, scrubbers or other emission-reduction devices will be installed.

9 A hybrid propulsion vessel is a vessel that utilizes power from a diesel engine or generator, along with energy stored in batteries, either in direct or parallel configuration, to drive a propulsion motor.

③ *Plan to Build Supply Chains for Green Shipping fuel*

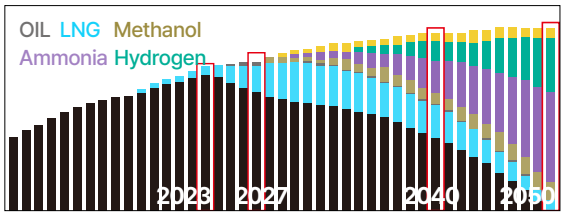
The conversion of national flagships and public vessels to green ships will increase demand for alternative fuels such as LNG and methanol, as stipulated in the *Green Ship Act (2020)*. Recognizing that the establishment of alternative fuel supply chains is directly tied to the competitiveness of ports and the maintenance of shipping routes during the decarbonization transition, the MOF announced support policies in November 2023 to build supply networks for eco-friendly ship fuels at domestic trade ports. The goals are to increase the share of alternative fuel supplies to 30% by 2030, expand the proportion of alternative fuel-powered container ships entering domestic ports to 20%, and secure a storage capacity of 1 million tons for alternative fuels at ports.

According to [Table 8], the domestic supply of ship fuel for international voyage vessels was 13.4 million tons in 2022, with the current share of green ship fuels being 0%. However, the MOF plans to expand this to 1.34 million tons (10%) by 2027 and 4.02 million tons (30%) by 2030. To preemptively meet at least 25% of domestic demand through the public sector's supplies by 2027, the targets include supplying up to 600,000 tons of LNG and 230,000 tons of methanol.

[Table 8] Demand Forecast for Domestic Ship Fuel

2027 Demand Forecast of Domestic Ship Fuel	
OIL	10.4 million tons (77.6%)
LNG	2.4 million tons (18.9%)
Methanol	230,000 tons (1.8%)

*Clarksons Research (Q3 2022), etc.

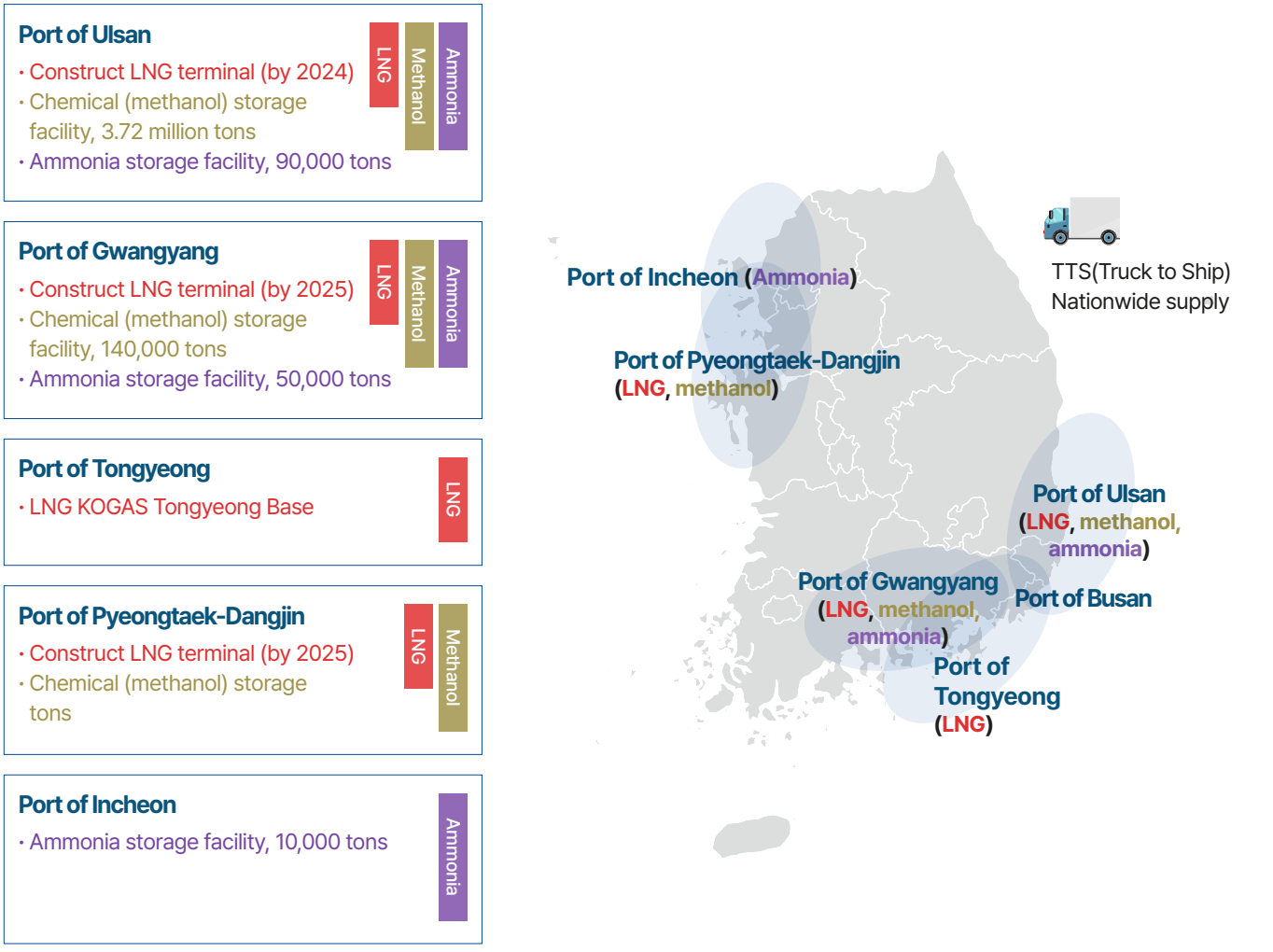


Source: Plan to Build Supply Chains for Green Shipping fuel, 2023

Compared to Europe, which proactively began constructing LNG bunkering infrastructure around 2016, South Korea's LNG bunkering infrastructure facilities and supply chain are still in the early stages. There is only one dedicated LNG bunkering vessel in South Korea and one supply port, the Port of Tongyeong, indicating an insufficient establishment of shipping fuel-specific supply chains. To alleviate the burdens of high upfront investment and demand uncertainty risks for port authorities when building bunkering vessels, the MOF plans to build an 18,000-square-meter LNG bunkering vessel by 2027 through the Ulsan Port Authority in partnership with the private sector. South Korea has two LNG bunkering vessels—one dedicated vessel and one registered as a dual-use coastal LNG cargo vessel. The government aims to increase the number of dedicated LNG bunkering vessels by seven, bringing the total to eight by 2030.

Region-specific plans are being formulated to develop LNG bunkering infrastructure at ports to meet the increasing demand for LNG-powered vessels. In the East and South Sea regions, the KOGAS terminal in the Port of Tongyeong, which is currently operational, along with terminals currently under development in the Port of Ulsan and the Port of Gwangyang, will address the demand in these regions, including that from the Port of Busan. Although the demand in the West Sea region remains uncertain, the LNG terminal developed at the Port of Pyeongtaek-Dangjin is expected to serve ports like the Port of Incheon. The East Sea region anticipates the arrival and departure of small to medium-sized LNG-powered vessels, which are expected to be accommodated through TTS (Truck-to-Ship) to meet the bunkering demand. The government envisions a fuel bunkering plan centered on LNG, as illustrated in Figure 1 below.

[Figure 1] Government-led Development of Infrastructure for LNG Bunkering Ports



Source: Plan to Build Supply Chains for Green Shipping fuel, 2023

05 Implications and Policy Recommendations

Due to the small number of LNG-powered vessels in operation, LNG currently accounts for a trivial share of the shipping sector's fuel demand. Nonetheless, the expansion of LNG-powered vessels and facilities should be approached with caution, as there are significantly more orders for LNG-powered vessels than those using alternative fuels. In estimating the cost of transitioning to greener fleets, the MOF assumed that new ships would be ordered when existing ships reach 25 years of age and are replaced at 28 years. Even with a lifespan of at least 25 years for future LNG-powered vessels, we would still rely on fossil fuels as we approach 2050, the year we have committed to achieving net zero. The prolonged use of LNG as a shipping fuel will hinder progress towards achieving net zero in international shipping by 2050. South Korea, which has declared its ambition to become a green shipping powerhouse in the net zero era, has paradoxically not yet established a specific timeline for phasing out LNG fuel and transitioning to carbon-free fuels. This brief proposes three policy recommendations for the early phase-out of fossil fuels in the shipping sector.

A) Establish a Timeline for Phasing Out LNG, CNG, and LPG in the *Green Ship Act (2020)*

The MOF has estimated an investment of approximately KRW 7.6 trillion (USD 5.48B) for converting fleets to greener alternatives by 2030, with about KRW 1.8 trillion (USD 1.3B) being the additional cost for this transition. While the MOF's support for deploying green ships is positive and helps ease the burden on shipping companies, it is essential to examine the types of alternative fuels eligible for government support and their actual environmental benefits. As per Clarksons Research, there are currently 57 alternative fuel vessels on order in South Korea, with 46 of these being LNG-powered vessels. This imbalance, with LNG-powered vessels accounting for about 80% of the orders, underscores the need for a more diverse approach to greener fleets rather than a heavy concentration on LNG due to government benefits and support.

South Korea's policies heavily support and subsidize LNG because gaseous fuels such as LNG, CNG, and LPG are currently classified as environment-friendly energy sources. Therefore, rather than investing in developing carbon-free fuel technologies or ships to achieve net zero, shipping companies opt for LNG as a relatively easier path. However, LNG is a fossil fuel that can only reduce GHG emissions by 20% compared to conventional heavy fuel oil and should ultimately be phased out based on the lifecycle assessment. In South Korea, the Ministry of Environment has included shipping-related green economic activities in the Korean Green Taxonomy.[10] It recognizes the construction and introduction of green ships, which is defined somewhat broadly in South Korea, for a limited period until 2030. These measures prevent green financing from being funneled solely to the transition sector. If South Korea genuinely wishes to become a climate model leading the international shipping sector in the net zero era, the MOF must establish a clear timeline for categorizing fossil fuels like LNG, CNG, and LPG as green fuels. This would ensure that the phase-out of these fossil fuels happens well before 2030.

10 The Green Taxonomy establishes criteria for determining which economic activities are classified as green to prevent corporate greenwashing. The Korean Green Taxonomy recognizes a broader scope than the criteria selected in the EU Taxonomy by defining not only green activities but also transition activities.

B) Increase Support for Renewable Energy to Ensure E-Fuels

Finding sustainable, affordable, and readily available alternative fuels is a significant challenge for the shipping industry. In exploring various alternative fuels, one area that has received less attention from the MOF but should always be prioritized is expanding renewable energy. Fuel produced using electricity derived from renewable energy sources such as solar and wind can significantly reduce GHG emissions from a WtW perspective. In the shipping sector, electricity generated from renewables can be used for fuel and alternative maritime power (AMP), which provides electricity to ships in port, thereby contributing to carbon reduction in ports. Since the international shipping sector is not the only industry that relies on renewable electricity to decarbonize, support for the large-scale capacity expansion of renewable energy installations is essential.

South Korean government needs to seriously consider expanding renewable energy for fueling ships in the decarbonization of the shipping sector. Studies indicate that by 2050, most renewable energy facilities will be primarily supplied by wind and solar power.[xi] South Korea has favorable geographical advantages for offshore wind power development, being surrounded by the sea on three sides. However, South Korea has no suitable backwater ports for large-scale offshore wind farms.[xii] If the government actively intervenes to create hinterlands dedicated to offshore wind power, it will not only expand the total amount of renewable energy available for fuel production but also revitalize the local economy by forming related industry clusters.[11]

In the era of climate crisis, renewable energy is an essential source for the maritime shipping and shipbuilding industries and various other sectors. Until carbon-free fuels are fully commercialized and available, the shipping industry should focus on synthetic fuels (e-fuels) generated from renewable energy to achieve substantial emission reductions rather than relying on fossil fuels and investing in carbon capture technologies. Given the importance of renewable energy and the role of ports in offshore wind power generation, the MOF, which aims to achieve net zero in international shipping by 2050, should actively support securing renewable energy and creating hinterland ports and complexes as part of its net zero strategy.

11 In the case of the Danish port of Esbjerg, the government's proactive response to the growing demand for offshore wind has naturally resulted in the formation of a supply chain and cluster of related industrial facilities, leading to job creation and establishing the port as a leading hinterland port and complex for offshore wind farms (Solutions for Our Climate, 2024).

C) Increase Support for Investment and Development of Carbon-Free Fuels

The GHG reduction targets set by many countries that have ratified the Paris Agreement were created in response to the climate crisis. The IMO's 2023 revised strategy and the MOF's Strategy for International Shipping Decarbonization by 2050 similarly declare a commitment to a sustainable and ecologically sound future by regulating ship and port emissions in the high-emitting shipping industry. To achieve these goals, transitioning away from fossil fuels is not just a choice, but an urgent necessity. The continued use of fossil fuels relies on imperfect technologies and alternatives, such as carbon capture, which ultimately discourages the aggressive investment required to research and support the development of carbon-free technologies that we must embrace. The shipping industry's excessive expansion of LNG-powered vessels and bunkering facilities could lead to a long-term extension of the lifespan of fossil fuels. This outcome is neither environment-friendly nor economically viable.

The demand for zero-carbon ships, driven by increasingly stringent environmental regulations, such as those on the calculation of fuel's WtW emissions, is already slowly shifting the paradigm of alternative fuel ship orders in developed countries. Methanol, the leading transitional fuel, can be produced through a renewable-based synthetic process using green hydrogen and carbon dioxide, making it a low-carbon fuel with almost zero emissions. Unlike LNG, methanol remains liquid at room temperature, which is advantageous as it allows the use of liquid fuel-based infrastructure similar to heavy fuel oil. The potential of methanol as a transitional fuel is promising, with a total of 23 alternative-fueled ships ordered in April 2024, of which 12 were methanol-powered vessels. This was followed by seven LNG-powered vessels and four ammonia-powered vessels.

The alternative fuel shipping paradigm is in flux, and international shipping lines, primarily in developed countries, are preparing for a gradual phase-out of fossil fuels. However, South Korea has been slow to join the early trend of green fleet transitions and is only now focusing on expanding the LNG-powered vessels and bunkering market. This raises concerns about long-term dependence on LNG fuel, with only 26 years remaining until 2050. Considering that the lifespan of an LNG-powered carrier is at least 20 years, LNG-powered vessels currently on order and expected to be delivered in the late 2020s will still be in service as 2050 approaches. Given the longer lifespan and higher fuel requirements of larger ships, there is an urgent need for increased government support for developing and distributing non-LNG transitional fuels. The role of government support in this transition cannot be overstated. Policy changes are not just important, they are crucial for the future of sustainable shipping.

06 Conclusion

LNG appears to be an easy path to GHG emissions reductions due to its relative commercialization. However, as a fossil fuel, LNG can only reduce GHG emissions by about 20% compared to heavy fuel oil on a voyage basis. LNG's GHG emissions will increase under the lifecycle assessment, which will soon be implemented in many international regulations. Furthermore, competition for LNG is fierce, with many countries already investing heavily to expand their LNG markets. Additionally, to achieve net zero by 2050, it will be difficult to use fossil fuel facilities for more than 20 years, exposing the risk of these becoming stranded assets.

Given these challenges, government-led analysis of LNG fuel emissions based on WtW standards is essential. The environmental and economic characteristics of LNG must be closely scrutinized to respond to increasingly stringent environmental regulations and contribute to achieving net zero in the shipping sector. To this end, as discussed above, the MOF should **1) specify the timeline for the phase-out of fossil fuels such as LNG, CNG, and LPG before 2030 within the Green Ship Act; 2) secure renewable-based marine synthetic fuels by implementing increased renewable energy support policies; and 3) expand support for investment and development of carbon-free fuels that will ultimately be a way forward**

In a follow-up study, Solutions for Our Climate will examine the sustainability of bridge shipping fuels, including LNG, and compare the MOF's decarbonization strategy with the IMO's 2050 net zero strategy. This comparison will derive modeling results on the year-by-year energy mix needed for the South Korean shipping sector to achieve net zero, providing insights and recommendations for the MOF's policy decisions.

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Limitations of LNG in Shipping Decarbonization – Why LNG-powered Vessels are Killing the Planet

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Solutions for Our Climate (SFOC) is an independent nonprofit organization that works to accelerate global greenhouse gas emissions reduction and energy transition. SFOC leverages research, litigation, community organizing, and strategic communications to deliver practical climate solutions and build movements for change.