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# KR Decarbonization Magazine

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# IMO MEPC 83: Approval of the Net-Zero Framework and the Maritime Industry's Response

At the 83rd session of the IMO Marine Environment Protection Committee (MEPC 83) held in April, the Net-Zero Framework—an amendment to MARPOL Annex VI—was officially approved as the mid-term measure to achieve net-zero greenhouse gas (GHG) emissions from international shipping by 2050. Although the decision was made by vote rather than unanimous consensus due to stark differences among member states, it represents an unprecedented and powerful measure in maritime history, requiring shipowners to pay GHG contributions based on their emissions. The symbolic and practical implications of this step are significant.

The industry has long anticipated the implementation of these mid-term measures and has undertaken extensive analysis and preparation. Now that the measures have been clarified and formally approved, the time has come to develop and implement concrete response strategies. This issue has been designed as a practical resource for industry stakeholders to revisit and reference as needed during the implementation process. The lead article of this issue provides a detailed explanation of the key elements and background of the mid-term measures—particularly the Base Target and Direct Compliance Target for reducing GHG fuel intensity. It also presents a cost analysis and introduces strategic options using biofuels as a case study for shipowners to consider.

Alongside fuel transitions, one of the most pressing areas of interest for shipowners is Energy-Saving Devices (ESDs). When appropriately installed and tailored to a vessel's characteristics, ESDs can deliver significant fuel savings, improve CII ratings, and reduce carbon costs—greatly shortening payback periods. For shipowners, it is advisable to prioritize devices with verified cost-effectiveness, while higher-cost devices should be assessed objectively based on the specific environmental conditions of their trading routes. KR has accumulated 80 years of global wave, wind, and current data and provides objective, transparent performance evaluations on behalf of clients.

In this issue's interview, we speak with an expert from Hanwha Power Systems to discuss the growing relevance of ammonia-fueled gas turbine technology in light of the newly approved mid-term measures. This technology offers various advantages, such as compact size, eliminating the need for pilot fuel, minimizing ammonia slip, and maintaining negative pressure within the system for enhanced safety. At the same time, challenges such as relatively low efficiency and the need for specialized crew training remain. The interview explores how these challenges can be addressed and will be of great interest to readers considering next-generation propulsion solutions.

The Regulatory Updates section provides a comprehensive overview of the approved mid-term measures. In addition, the CII reduction rate for 2030 has now been confirmed. There is encouraging news that long-standing criticism from shipowners regarding the inclusion of fuel consumption during port waiting times and idle periods in CII calculations has been acknowledged. A regulatory revision is now being promoted to exclude such emissions from the CII framework.

In Inside KR, we share news on the Approval in Principle (AiP) granted for a tank vacuum system, a core technology for liquefied hydrogen carriers. We also highlight the addition of ammonia bunkering simulation functions to KR's Alternative Fuel Simulation Center—following LNG and methanol—and the election of Mr. Yuntae Kim, Executive Vice President of KR's Technical Division, as Chair of the Tanker Structure Co-operative Forum (TSCF).

The approval of the IMO Net-Zero Framework marks a historic turning point for the maritime sector. With much of the regulatory uncertainty now resolved, it is time for each company to establish specific decarbonization strategies for its fleet and put them into action. In celebration of its 65th anniversary, KR is launching a new decarbonization platform to actively support shipping companies in this endeavor.

In a time of rapid change, no launch can ever be perfectly prepared. However, we can no longer afford to delay. Now is the time to embark on the journey of decarbonization and move toward implementation. Only those shipping companies that respond proactively to this transformation will lead the industry in the coming era of disruption.

With centuries of experience behind it, we believe that the global maritime industry will overcome the formidable challenge of GHG regulation with wisdom and resilience.

**SONG Kanghyun**

Head of KR Decarbonization · Ship R&D Center

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# Insights

## Insights 1

IMO Net-Zero Framework:
A New Paradigm for the Shipping Industry

## Insights 2

Response to Global Greenhouse Gas Emission Regulations:
Strategic Choices and Future Prospects of Ship Energy-Saving Technologies

# IMO Net-Zero Framework: A New Paradigm for the Shipping Industry

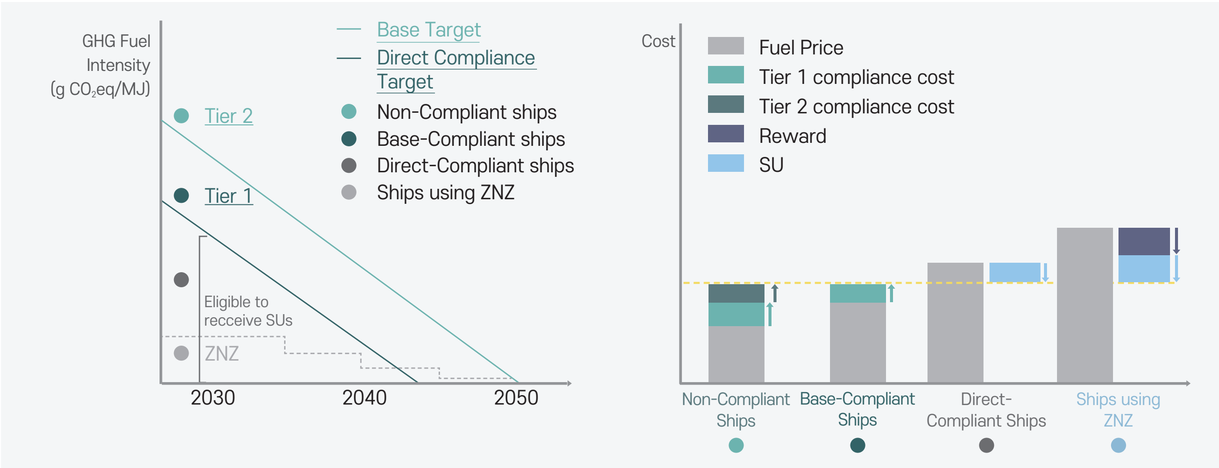
**HA Seungman** Principal Surveyor of KR Machinery Rule Development Team

The international shipping industry is at a critical juncture as it faces mounting pressure to address climate change and transition to a low-carbon future. The adoption of mid-term GHG reduction measures — including a GHG pricing mechanism — at the 83rd session of the International Maritime Organization's Marine Environment Protection Committee (MEPC 83) in April has helped resolve a significant portion of the regulatory uncertainty that has long delayed new ship orders and hindered the selection of alternative fuels.

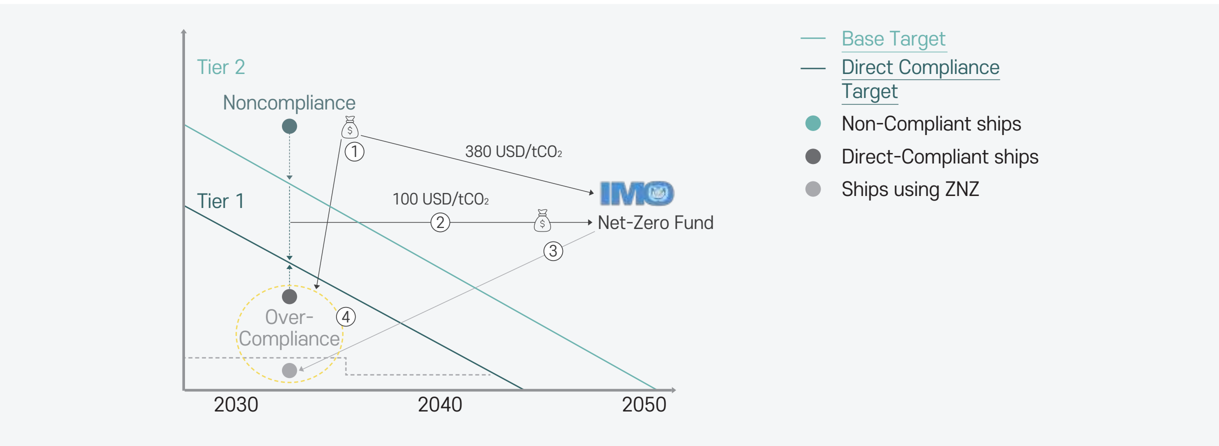
These measures are set to enter into force in 2027 and will be fully implemented starting in 2028, applying to large ocean-going ships over 5,000 gross tonnage. This marks a critical milestone as the regulations will be enforced based on GHG Fuel Intensity ($gCO_2eq/MJ$), fundamentally changing the landscape for international shipping.

Notably, this new framework represents a significant departure from the traditional Single-Target Approach, introducing a Two-Tier Approach consisting of a Base Target and a Direct Compliance Target. This structure not only focuses on reducing GHG emissions but also creates a direct financial incentive for emission reductions, rewarding ships that achieve ambitious targets while imposing penalties or taxes on those that fall short.

Conceptual Diagram of the IMO Net-Zero Framework (left) and Correlation Between Fuel Prices and Compensation (right)




Operational Mechanism of the IMO Net-Zero Framework




## ① Base Target

· Ships that exceed the Base Target should either pay USD 380 per tonne of excess $CO_2$eq(Tier 2 RU*price) or purchase Surplus Units (SUs**) at market prices to offset their emissions and comply with the Base Target.

*RU(Remedial Unit) : A non-transferable unit (t$CO_2$eq) that may be obtained through the IMO Registry when a ship fails to meet the Base Target.

**SU(Surplus Unit) : A transferable unit (t$CO_2$eq) granted to ships that exceed their Direct Compliance Target.

## ② Direct Compliance Target

· For emissions that fall between the Base Target and the Direct Compliance Target, a lower fee of USD 100 per tonne of excess CO2 (Tier 1 RU price) is imposed. This amount is allocated to the IMO Net-Zero Fund and is considered as meeting the Direct Compliance Target.

### ③ Utilization of the IMO Net-Zero Fund

· The revenues collected from items ① and ② above are pooled into the IMO Net-Zero Fund. This fund is used for a variety of purposes, including rewarding Zero or Near-Zero (ZNZ) fuels and supporting just transition initiatives in developing countries.

### ④ Incentive Structure

· Ships that meet the Direct Compliance Target can gain additional economic benefits by selling their surplus units (SUs) at market prices to ships that exceed the Base Target.

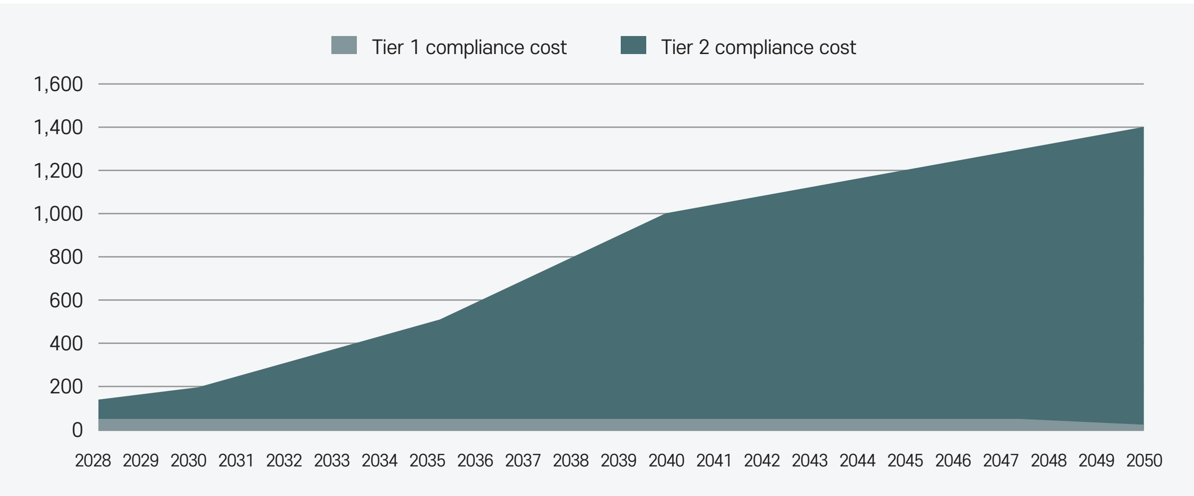
· Vessels using Zero or Near-Zero (ZNZ) fuels can receive additional rewards, providing further economic incentives for deeper decarbonization efforts.

This framework highlights that the focus of GHG regulations is no longer limited to fuel choice alone but now includes the overall energy efficiency of the ship itself as a critical component. Notably, under the stricter targets, ships will be required to reduce their GHG fuel intensity by 43% by 2035 and by 65% by 2040, reflecting increasingly ambitious reduction goals.

This shift represents a fundamental change for the maritime industry, requiring rapid and significant fleet renewal and innovative fleet management strategies to meet these aggressive decarbonization targets.

As illustrated in the figure below, ships that continue to use Very Low Sulfur Fuel Oil (VLSFO), which is considered, in this analysis, to have a GHG Fuel Intensity (GFI) of 95.5 $gCO_2eq/MJ$, are likely to face substantial compliance costs. By 2028, these costs are projected to reach maximum USD 140 per tonne of fuel, and by 2050, they could exceed USD 1,400 per tonne.

The term "maximum" refers to the upper bound of potential costs incurred when a ship fails to meet its GHG reduction targets, requiring the purchase of Remedial Units (RUs) at the Tier 2 price of USD 380 per tonne of $CO_2eq$, or alternatively, the equivalent market price of Surplus Units (SUs), also assumed to be USD 380per tonne.



Additionally, even when using the same Heavy Fuel Oil (HFO), significant differences in energy efficiency exist between older and newer vessels, leading to substantial variations in compliance costs. According to the IMO's mid-term measures impact assessment, ships built after 2025 are, on average, 25-32% more fuel-efficient than those built before 2015, resulting in proportionately lower annual GHG emissions.

This efficiency gap is reflected in the compliance calculations outlined in the Regulation 36 amendment of the IMO Net-Zero Framework, as approved at MEPC 83:

Annual Compliance Balance =
(Required Annual GHG Intensity - Attained Annual GHG Intensity) × Total Energy Used

The Annual Compliance Balance is a critical metric that measures how far a vessel deviates from its regulatory target, expressed in tonnes of $CO_2$eq.

As it is based on the ship's annual energy use — calculated as the product of fuel consumption and its lower heating value (LHV) — the higher the energy consumption, the greater the resulting compliance cost.

This is because the final compliance cost is determined by multiplying the $CO_2$eq. amount calculated from the annual Compliance Balance by either USD 380/tonne $CO_2$eq, USD 100/tonne $CO_2$eq, or the prevailing price of Surplus Units (SUs) per tonne of $CO_2$eq.

This means that simply choosing low-carbon fuels is not sufficient for compliance. Ships should also optimize their overall energy efficiency to minimize both short-term fuel costs and long-term regulatory compliance expenses. In other words, both reducing the attained GHG intensity through the use of Zero or Near-Zero emission fuels and improving vessel design are essential not only for immediate cost savings, but also for maintaining long-term competitiveness under regulatory compliance costs.

## The Needs for Familiarization with Marginal Abatement Costs (MAC)

The IMO Net-Zero Framework requires not only emission reductions but also strategic decision-making on the most cost-effective pathways to regulatory compliance. A critical concept in this process is the Marginal Abatement Cost (MAC), which represents the cost of reducing one additional tonne of $CO_2$eq through a specific mitigation measure. It serves as a key economic indicator for evaluating the viability of different fuels and technologies in meeting the required GHG reduction targets.

Under the current IMO framework, the cost of compliance varies depending on the GHG intensity of the fuel used:

- **Tier 1:** 100 USD per tonne of $CO_2$eq
- **Tier 2:** 380 USD per tonne of $CO_2$eq
- **Surplus Unit (SU) Prices:** Expected to fluctuate within this range, depending on evolving market conditions and the supply-demand balance

However, it remains uncertain whether these regulatory costs are sufficient to encourage widespread adoption of Zero or Near-Zero (ZNZ) fuels, such as e-fuels, given their higher production costs.

According to a 2022 study by MIT, the Marginal Abatement Cost (MAC) of replacing fossil fuels with renewable e-fuels ranged from USD 599 to 1,520 per tonne of $CO_2$eq as of 2020. However, the study projected that with active investment and technological advancement by governments and industry, this cost could decline to USD 57 to 557 per tonne of $CO_2$eq by 2050. However, this remains higher than the regulatory costs under both Tier 1 and Tier 2, suggesting that a transition to e-fuels may not be economically viable based on current compliance cost levels alone.

The IMO's Net-Zero Framework was adopted through a two-tier approach as a result of compromise among Member States amid diverse proposals and competing interests. This structure requires continuous monitoring of the impact these regulatory costs have on the global shipping market. In particular, shipping companies should carefully assess whether the carbon price or financial rewards set by the IMO adequately compensate for the Marginal Abatement Costs (MAC) associated with different fuel types. Additionally, the evolving dynamics of the fuel supply market will play a critical role in shaping these strategic decisions.

Ultimately, the relevant stakeholders such as shipping companies should make strategic choices about whether it is more cost-effective to switch to alternative fuels or simply pay the associated compliance costs. To make this decision, several scenarios should be carefully considered:

- Meeting the Base Target: If a ship fails to meet the Base Target, it will be subject to both Tier 1 (USD 100/t$CO_2$eq) and Tier 2 (USD 380/t$CO_2$eq) compliance costs. Alternatively, ships may choose to meet the Base Target to avoid paying the higher Tier 2 price.
- Exceeding the Direct Compliance Target: Ships that can achieve or surpass the Direct Compliance Target may be able to avoid both Tier 1 and Tier 2 charges entirely. Alternatively, they may choose to exceed these targets further, potentially earning additional financial rewards or surplus units (SUs) that can be sold on the market.

## Case Study : Bio Fuel

The following table provides an example of whether it is more advantageous to meet the Base Target or the Direct Compliance Target when using biofuels. This analysis was conducted based on fuel prices in Singapore as of April 2025 and the GHG intensity of Used Cooking Oil Methyl Ester (UCOME), as shown in the table below. VLSFO is included as a typical fossil fuel benchmark, while B30 and B100 represent alternative biofuels with different blending ratios.

| Fuel type | Price (USD/ton) | LHV (MJ/ton) | Attained GFI (g$CO_2$eq/MJ) |
|---|---|---|---|
| VLSFO | 481 | 40200 | 95.5 |
| B30 | 740 | 39390 | 70.63 |
| B100 | 1143 | 37500 | 8.3 |

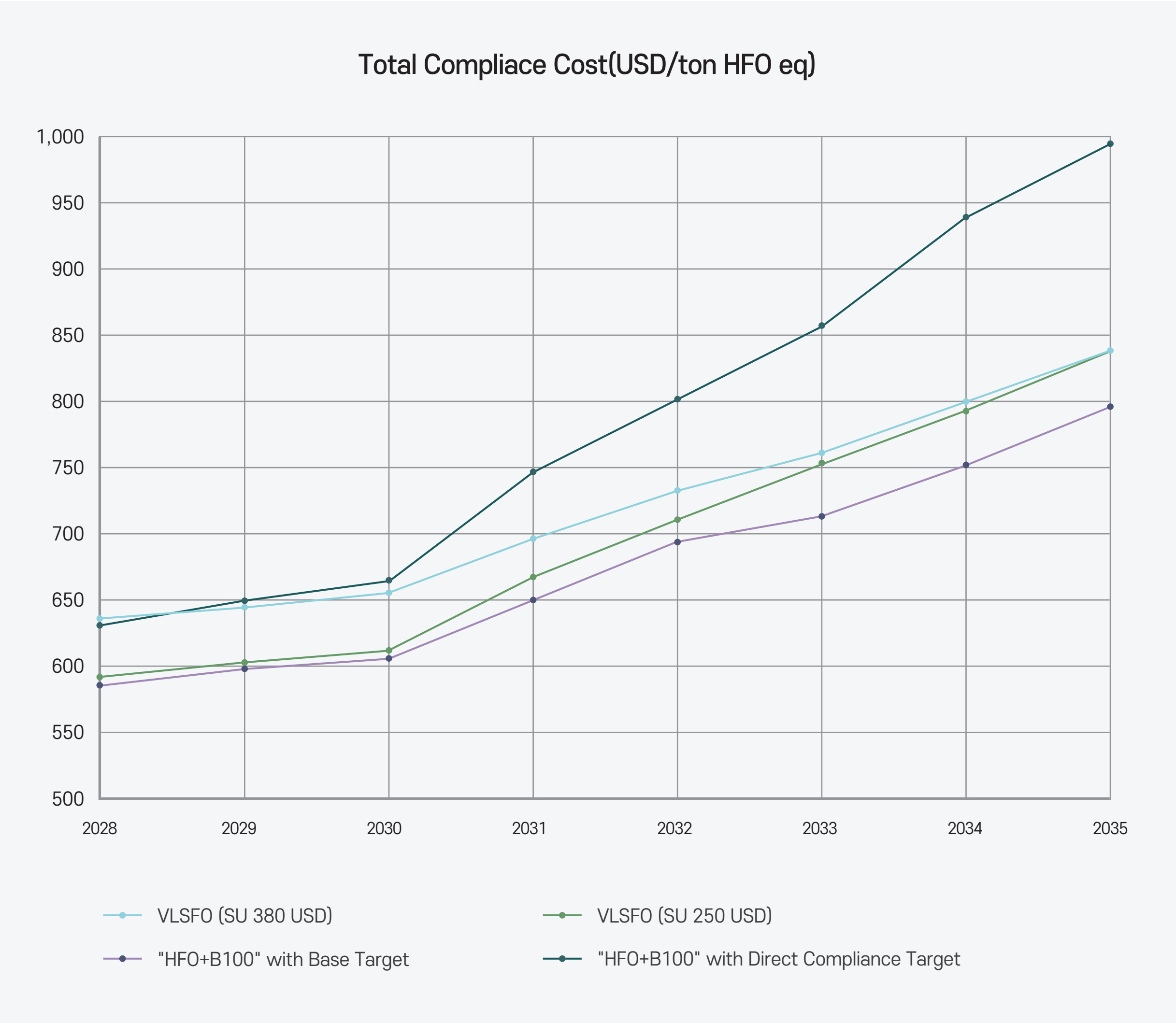
The Marginal Abatement Cost (MAC), which represents the cost of reducing one additional tonne of $CO_2$ eq, is calculated based on the following formula:

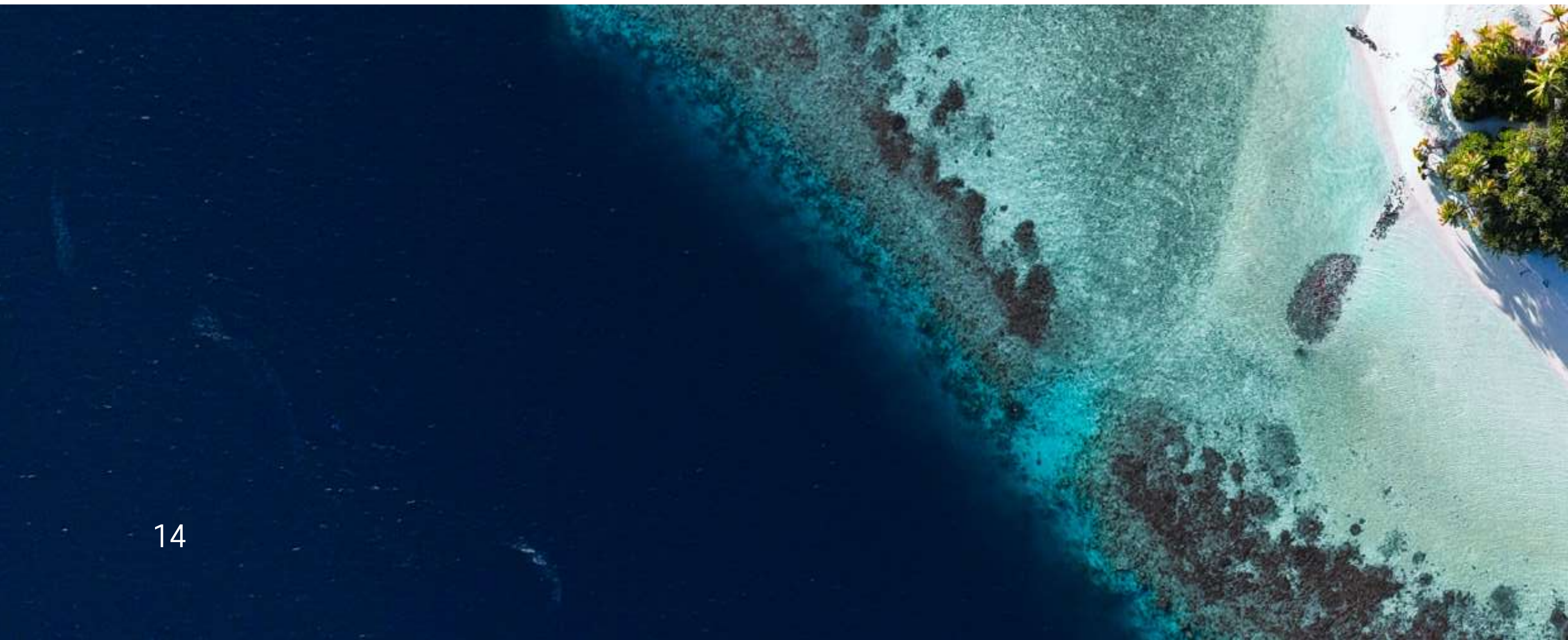
MAC=GHG Emission Reduction / Fuel Price Difference

Applying this formula, the MAC for each fuel type is as follows:

- **B100:** 212 USD/t$CO_2$eq
- **B30:** 274 USD/t$CO_2$eq

Since the MAC for B100 is lower than that for B30, this analysis will use B100 as the primary example to illustrate the economic viability of meeting compliance targets.



## Cost Analysis Results

- The MAC for B100 is 212 USD/t$CO_2$eq, which can be more economical than paying the Tier 2 compliance cost of 380 USD/t$CO_2$eq However, in the Tier 1 range, where the compliance cost is 100 USD/t$CO_2$eq, the cost advantage of B100 may be limited, highlighting the importance of careful strategic planning.
- In the absence of SU trading benefits and IMO rewards for ZNZ fuels, the scenario in which the Base Target is met using "HFO + B100" (purple) may be more favorable than the scenario in which the Direct Compliance Target is met using the same "HFO + B100" combination (blue). (Note: This comparison does not take into account any ZNZ fuel rewards.)
- The total compliance cost, including fuel costs, can vary significantly depending on the market price of SUs. For example, if the SU price is USD 250 (red) versus USD 380 (blue), the overall cost structure changes. In general, vessels that exceed the Base Target are likely to choose to buy carbon credits at lower market prices (e.g., USD 250) rather than pay the maximum 380 USD/t$CO_2$eq compliance fee.

However, it is important to note that this analysis does not yet account for potential rewards for Zero or Near-Zero (ZNZ) fuels, which the IMO is expected to finalize by March 1, 2027. The level of these rewards could significantly impact the cost-effectiveness of exceeding the Direct Compliance Target, making it a critical factor in future compliance strategies.

## Need for Comprehensive Response Strategies and Long-Term R&D Planning

The IMO's Net-Zero Framework represents more than a regulatory mechanism; it marks a critical turning point that demands a structural transformation of the shipping industry. The dual-target system—comprising the Base Target and the more ambitious Direct Compliance Target—goes beyond simple emission reduction. It compels long-term competitiveness through investments in new technologies and fuel transitions. The framework is designed to enhance vessel energy efficiency and promote the shift toward fuels with lower GHG intensity.

In response, shipping companies should establish comprehensive strategies that consider not only short-term cost burdens but also the evolving long-term regulatory landscape. In addition to the IMO's mid-term measures, the proliferation of regional regulations—such as the EU's FuelEU Maritime and Emissions Trading System (ETS)—further intensifies compliance pressures. Moreover, individual countries are increasingly likely to introduce similar domestic legislation. Within this multi-layered regulatory environment, older, fuel-intensive vessels face a heightened risk of being phased out of the market.

To ensure long-term sustainability, shipping companies should develop mid- to long-term plans that strategically integrate key elements: securing the supply of sustainable and renewable fuels, expanding the adoption of green technologies, establishing digital-based systems to monitor vessel-specific GHG intensity, and formulating financial strategies grounded in these efforts.

# Response to Global Greenhouse Gas Emission Regulations:

## Strategic Choices and Future Prospects of Ship Energy-Saving Technologies

**PARK Hyunsuk** Senior Surveyor of KR Green Ship Technology Team

Current climate change is progressing much more rapidly than previously predicted by the international community, affecting various industries worldwide. The maritime industry, in particular, is undergoing significant changes to meet the growing societal demand for decarbonization. As a result, international regulations on greenhouse gas emissions and air pollutants are tightening, with active discussions focused on the development of eco-friendly ship design technologies, the establishment of integrated digital platforms to enhance operational efficiency, and the use of alternative eco-friendly fuels.

Recently, the International Maritime Organization (IMO) announced a firm target to achieve 'Net-Zero' greenhouse gas emissions by 2050 for the international shipping sector. This sets an important benchmark for the sustainable development of the shipping industry and indicates that international carbon emission regulations will likely become even stricter in the future. These changes provide shipping companies with the opportunity to reconsider their existing operational practices and adopt new technologies.

Additionally, as part of the outcome of the 83rd MEPC session in April 2025, the IMO adopted the 'Greenhouse Gas Fuel Intensity (GHG Fuel Intensity, GFI)' regulation as a mid-term measure for greenhouse gas reduction. This provides shipping companies with the opportunity to devise swift and effective responses. At the same time, there is a deep focus on introducing energy-saving technologies that improve actual fuel efficiency during operation. While there is an extensive range of vessel energy-saving technologies currently in development, the practical response strategies to regulatory frameworks like EEDI (applicable to new ships) and EEXI (applicable to existing ships), enforced by the MEPC for international navigational vessels, remain quite limited. These technologies are outlined in MEPC.1/Circ.896, and shipping companies need to consider various constraints when applying them to their fleets.

This article aims to provide useful information that can help shipping companies strategically adopt energy-saving technologies to achieve successful outcomes. It will present valuable insights from various perspectives, including the types of energy-saving technologies, energy-saving mechanisms, the effectiveness of responding to greenhouse gas regulations through technology application, and future economic viability projections.

## Categorization of Energy-Saving Technologies under MEPC

At its 77th session in November 2021, the MEPC approved the 2021 Guidelines ("2021 Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of the attained EEDI and EEXI") for the calculation and verification of the attained values for EEDI/EEXI. Consequently, the MEPC distributed document MEPC.1/Circ.896 to the administrations of member states, industry stakeholders, relevant shipping organizations, shipping companies, and other interested parties.

Categories of Energy Efficiency Technologies according to MEPC.1/Circ.896

<table>
<tr><th colspan="5">Innovative Energy Efficiency Technologies</th></tr>
<tr><th colspan="3">Reduction of Main Engine Power</th><th colspan="2">Reduction of Auxiliary Power</th></tr>
<tr><th>Category A</th><th>Category B-1</th><th>Category B-2</th><th>Category C-1</th><th>Category C-2</th></tr>
<tr><td rowspan="2">Cannot be separated from overall performance of the vessel</td><td colspan="2">Can be treated separately from the overall performance of the vessel</td><td>Effective at All Time</td><td>Depending on Ambient Environment</td></tr>
<tr><td>$f_{eff} = 1$</td><td>$f_{eff} < 1$</td><td>$f_{eff} = 1$</td><td>$f_{eff} < 1$</td></tr>
<tr><td>· Low Friction Coating<br>· Bare Optimization<br>· Rudder Resistance<br>· Propeller Design</td><td>Hull Air Lubrication System<br>(Air Cavity Via Air Injection to Reduce Ship Resistance)<br>(can be Switched Off)</td><td>Wind Assistance<br>(Sails, Flettner-Rotors, Kites))</td><td>Waste Heat Recovery System<br>(Exhaust Gas Heat Recovery and Conversion to Electric Power)</td><td>Photovoltaic Cells</td></tr>
</table>

The major roles of the innovative energy-saving technologies categorized under MEPC.1/Circ.896 for the calculation of EEDI/EEXI are summarized as follows:

· Category A: Technologies that shift the power-speed curve, altering the combination of propulsion power ($P_P$) and reference speed ($V_{ref}$)
-This category primarily includes Propulsion Improvement Devices (PID), which achieve energy savings mainly through flow control. It also encompasses technologies that directly reduce viscous resistance, such as fins, low-friction coatings, and air resistance reduction techniques through superstructure optimization

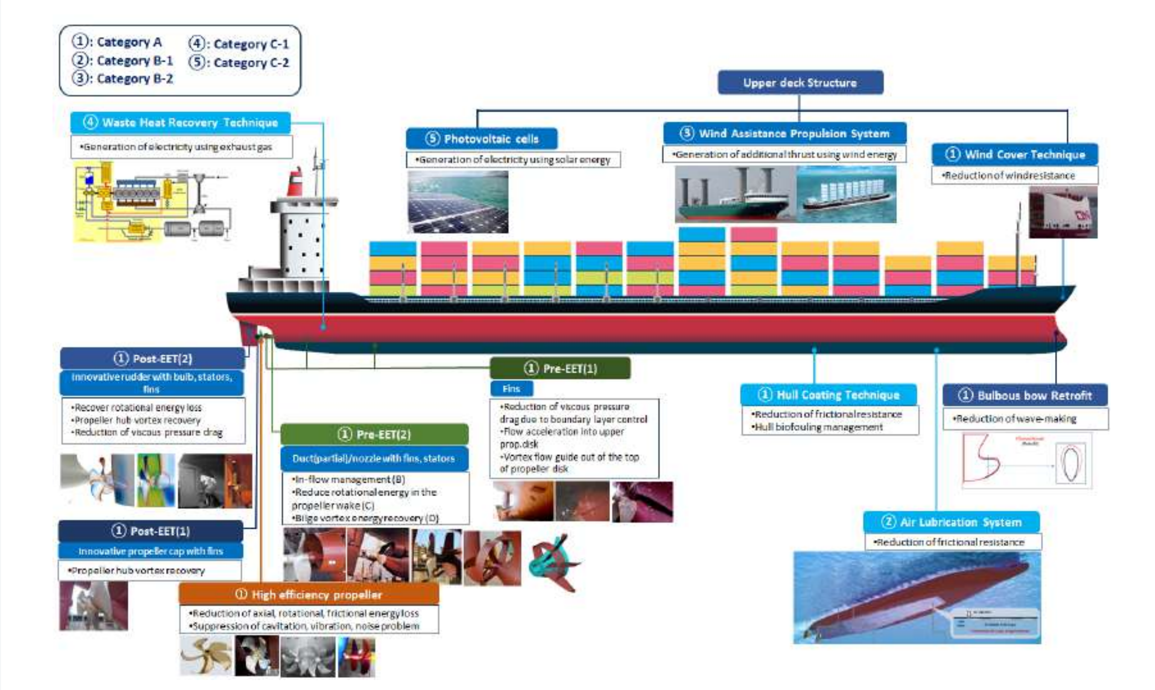
· Category B: Technologies that reduce $P_P$ at a fixed $V_{ref}$ without generating electricity
-Category B-1: Technologies that can be used regardless of weather conditions during vessel operation, with an availability factor ($f_{eff}$) set at 1.0 (applicable at all times)

-Category B-2: Technologies that can only be utilized at maximum output under limited wind conditions, with the availability factor ($f_{eff}$) applied at less than 1.0 (weather-dependent)

· Category C: Technologies that generate electricity, reducing energy consumption from auxiliary engines, with the reduced energy being calculated independently.
-Category C-1: Technologies that can be used regardless of weather conditions during vessel operation, with an availability factor ($f_{eff}$) set at 1.0 (applicable at all times)
-Category C-2: Technologies that can only be utilized at maximum output under limited conditions (e.g., sunlight), with the availability factor ($f_{eff}$) applied at less than 1.0 (weather-dependent)

Energy-saving technologies classified as PID (Propulsion Improvement Device) in Category A can be further categorized based on their installation location. They can be classified into: energy-saving technologies installed forward of the propeller (Pre-EET), high-efficiency propellers, and energy-saving technologies installed aft of the propeller (Post-EET).

The Principal Concepts and Mechanisms of Representative Energy Efficiency Technologies as Categorized in MEPC.1/Circ.896




## Energy-Saving Technologies and EEDI/EEXI

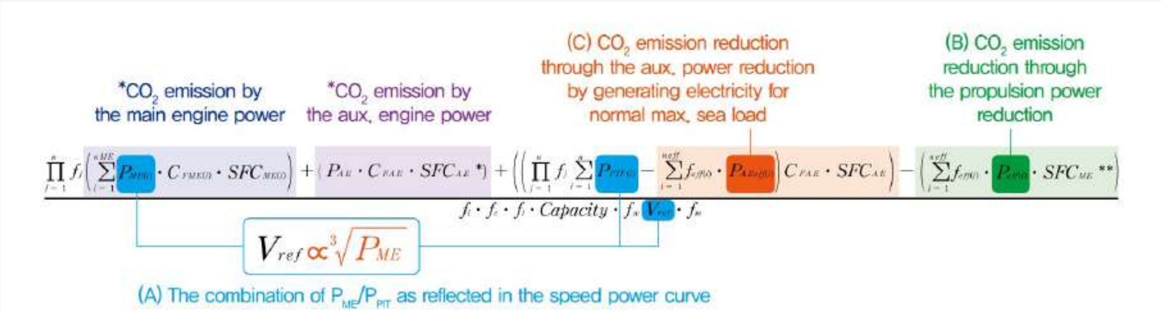
The IMO agreed to distribute MEPC.1/Circ.815 ("2021 Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of the attained EEDI") through the MEPC 65th session (2013).

Subsequently, prior to the enforcement of the Energy Efficiency Existing Ship Index (EEXI), which became effective on January 1, 2023, as a short-term measure to reduce greenhouse gas emissions from existing vessels, the International Maritime Organization (IMO) amended MEPC.1/Circ.815 during the 77th session of the Marine Environment Protection Committee (MEPC 77th, 2021) to include provisions related to EEXI. Additionally, IMO distributed MEPC.1/Circ.896 ("2021 Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of the Attained Energy Efficiency Design Index (EEDI) and EEXI") to member states and stakeholders to facilitate implementation.

For the EEDI, to apply energy-saving technologies and obtain approval from a Recognized Organization (RO), the guidelines of IACS Procedural Requirement No.38-Rev.4 must be followed. This requirement details the procedures for all activities in which the classification society is involved during the inspection and certification of EEDI, as per the regulations 5, 6, 7, 8, and 9 of MARPOL Annex

VI. Conversely, it is important to note that the application of EEXI is governed differently by Resolution MEPC.335(76), MEPC.350(78), MEPC.351(78), IACS Recommendation No.172-Rev.1 (revised in April 2024), and IACS Recommendation No.173.

EEDI/EEXI Calculation Formula Referred to Resolution MEPC.333(76)

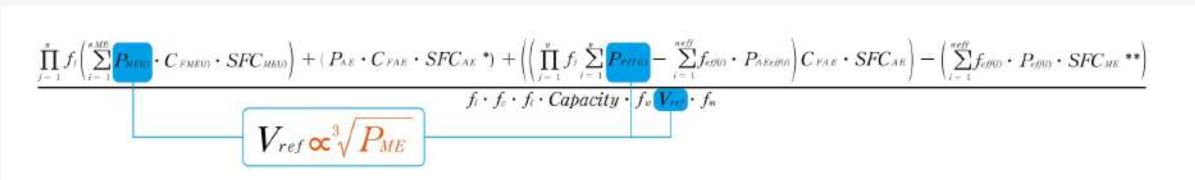



## Considerations for the Adoption of Category A Technologies

· **Impact on EEDI/EEXI**

Energy-saving technologies falling under Category A primarily refer to those that reduce the vessel's resistance or improve propulsion efficiency, thereby increasing the reference speed ($V_{ref}$) from the power ($P_{ME}$) set by EEDI/EEXI regulations.

These technologies theoretically reduce the actual fuel consumption based on the power reduction derived from model tests, sea trials, or Computational Fluid Dynamics (CFD). However, the calculation of the attained EEDI/EEXI is based on a predefined formula that incorporates power ($P_{ME}$) and the increased reference speed ($V_{ref}$). As a result, the power reduction effect of energy-saving technologies is not directly reflected in the improvements of the attained EEDI/EEXI, which is a limitation. Generally, the reference speed ($V_{ref}$) is approximated to be proportional to the cube root of power. For example, if Category A energy-saving technologies are applied to reduce the brake power by 5% on a vessel, the theoretical improvement effect on the attained EEDI/EEXI may be calculated to be approximately 1.7%.

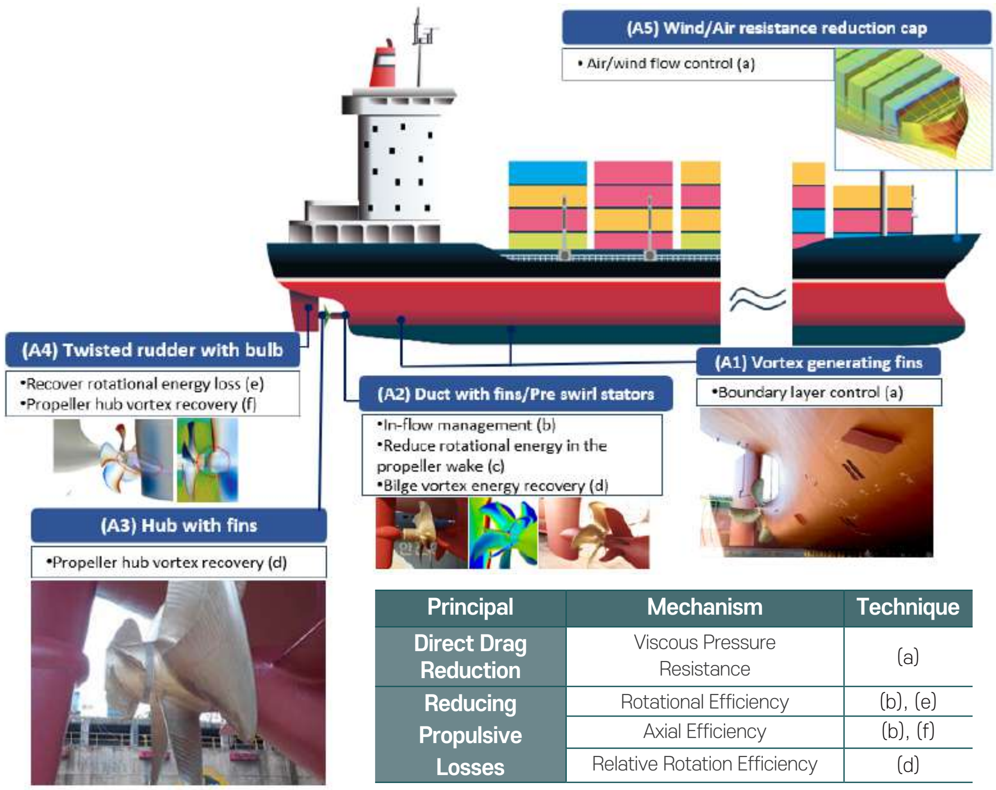



※The Combination of $P_{ME}/P_{PTI}$ as Reflected in the Speed Power Curve

### · Technical/Economic Considerations

The figure below briefly illustrates the principles and energy-saving mechanisms of the representative Propulsion Improvement Device (PID) energy-saving technologies that shipping companies most commonly selected during recent voluntary re-verifications of EEXI.

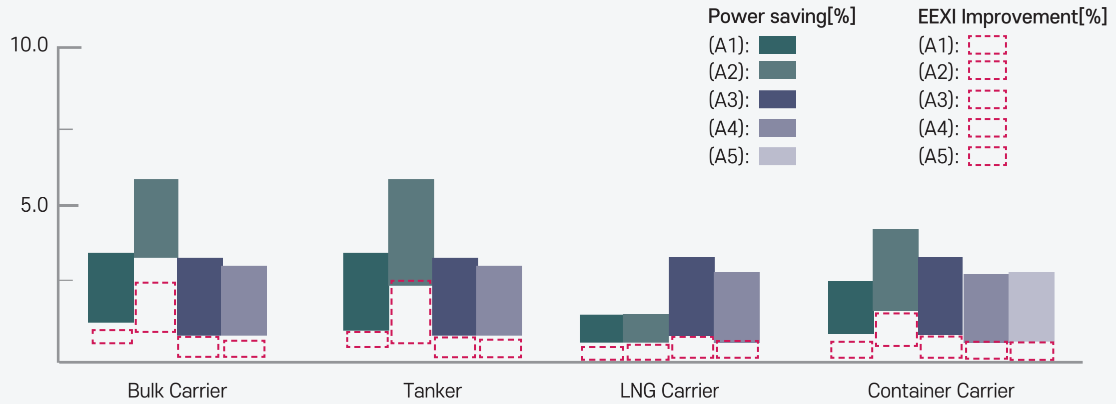
The Principal Concepts and Mechanisms of Representative PID-type Energy-Saving Technologies




| Principal | Mechanism | Technique |
|---|---|---|
| Direct Drag Reduction | Viscous Pressure Resistance | (a) |
| Reducing Propulsive Losses | Rotational Efficiency | (b), (e) |
| | Axial Efficiency | (b), (f) |
| | Relative Rotation Efficiency | (d) |

Notably, the technologies most commonly selected by shipping companies during recent retrofits for various vessel types, including Bulk Carriers, Tankers, LNG Carriers, and Container Carriers, are as follows: (A1) Vortex Generating Fins, (A2) Duct with Fins/Pre-swirling Stators, (A3) Hub with Fins, (A4) Twisted Rudder with Bulb, and (A5) Wind/Air Resistance Reduction Cap (primarily applied to Container Carriers).

The anticipated approximate power savings (%), EEXI improvement (%), CAPEX (USD), and retrofit duration (from design to installation) for each individual technology are estimated and illustrated in the following figure. Furthermore, the projected overall power reduction and EEXI enhancement when integrating the energy efficiency technologies corresponding to (A1) + (A2) + (A3) + (A4) across four representative vessels are also depicted.

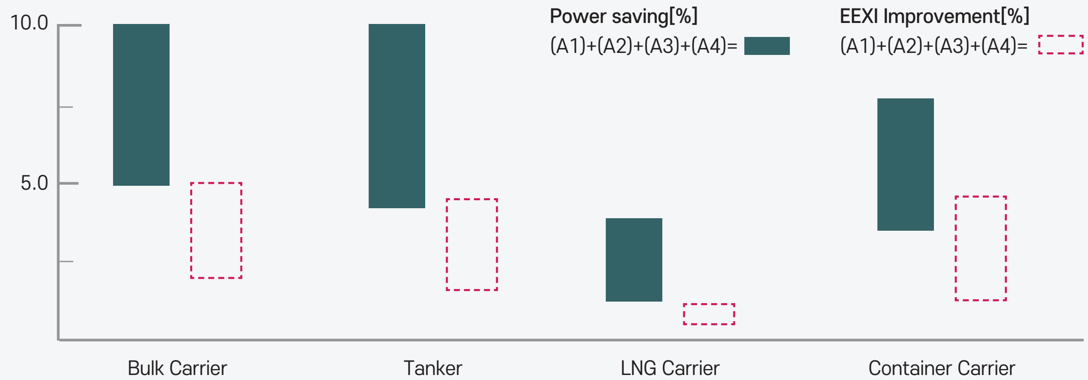



**CAPEX(Design~Installation)** [unit: USD]

- (A1): 0.5 ~1.0M
- (A2): 0.5~1.0M
- (A3): 0.05~0.1M
- (A4): 0.7~1.2M
- (A5): 1.0~2.0M

**Retrofit Period(Design~Installation)** [unit: Month]

- (A1): 6.5~8.0(Design: 2.0~3.0)
- (A2): 8.0~11.5(Design: 2.5~3.0)
- (A3): 4.3~5.5(Design: 0.5~1.0)
- (A4): 4.0~6.5(Design: 1.0~1.5)
- (A5): 4.5~7.0(Design: 3.0~3.5)




It is important to recognize that the specific numerical values are inherently variable, depending on the actual ship speed-power curve characteristics and the manufacturer of the energy-saving technologies. Analysis of the trend indicates that lower-speed, fuller vessels tend to realize greater power savings from energy efficiency measures, while, conversely, the effects diminish for high-speed, slender, and longer ships.

# Considerations for the Adoption of Category B Technologies

· **Impact on EEDI/EEXI**

Energy-saving technologies that fall under Category B are positioned as independent terms on the far-right side of the numerator in the EEDI/EEXI calculation formula, as can be observed below.

The technology serves to reduce the vessel's fuel consumption based on the following principles and energy-saving mechanisms.

**The Independent Term Influenced by Energy-Saving Technologies of the Category B in the EEDI/EEXI Formula**

$$\frac{\prod_{j=1}^{n} f_j \left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}{}^{*}\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{n} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot SFC_{ME}{}^{**}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref} \cdot f_m}$$

**Energy Saving Method of Category B**

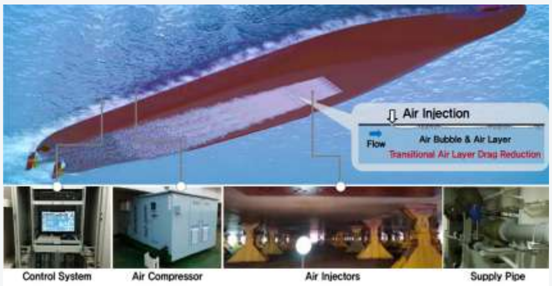
| Category | Principal | Mechanism | Technique | Methodology |
|---|---|---|---|---|
| B-1 | Direct Drag Reduction | Frictional Resistance | Reduce Shear Force | · Air Lubrication System |
| B-2 | Use of Renewable Energy | Wind Energy | Additional Thrust | · Flettner Rotor<br>· Sails<br>· Kite |

In contrast to energy-saving technologies categorized under Category A, the reductions in main engine power attributable to the air lubrication system (B-1) and wind-assisted propulsion system (B-2), as specified in the guidelines of MEPC.1/Circ.896, can be directly integrated into the respective separate components in the numerator of the EEDI/EEXI calculation. This method ensures that the estimated reduction in main engine power accurately corresponds to the actual improvement in EEDI/EEXI, thereby providing a precise representation of these technologies' effectiveness.

The air lubrication system (B-1) is typically applied to vessels with a flat hull bottom and low draft (e.g., large container ships, LNG carriers). This is advantageous as the flat bottom helps maintain an air lubrication layer formed by fine air bubbles injected from the compressor at high pressure. Additionally, a lower draft allows for a reduction in the capacity of the air compressor, leading to greater net fuel savings (the figure representing fuel savings from the main engine due to the air lubrication system is calculated excluding the fuel consumption of the auxiliary engine that drives the air lubrication system).

Wind-assisted propulsion systems (B-2), such as Flettner Rotors and Sails, utilize wind energy as a renewable resource to achieve energy savings. These systems are primarily applied to vessels with simple superstructure geometries and smaller surface areas, such as bulk carriers and tankers. They function by converting aerodynamic forces from the wind into auxiliary propulsion, thereby reducing fuel consumption of the main engine. The anticipated fuel savings from main engine reductions through both B-1 and B-2 systems are approximately 5–9%. As a result, these systems are garnering attention as an effective and prominent strategy within the current newbuilding market for meeting EEDI Phase III requirements.

SAVER Air, B-1*



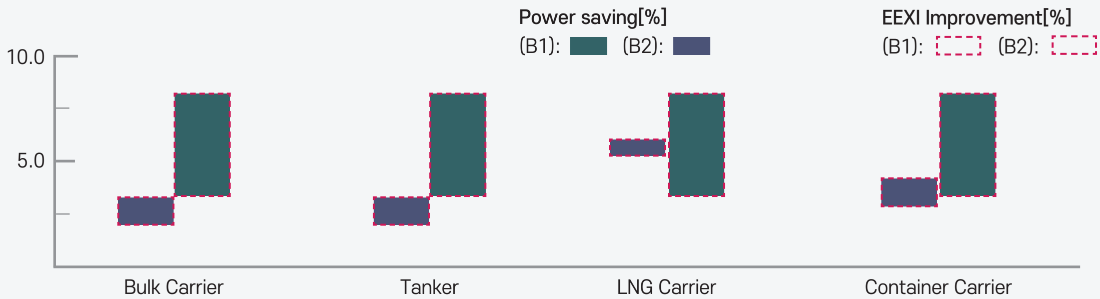

*2024 Responding to IMO GHG Regulations: A Selection Guide to Ship Energy Efficiency Technologies, KR-RND-DECB-INF-007

Flettner rotor, B-2*

*2024 Responding to IMO GHG Regulations: A Selection Guide to Ship Energy Efficiency Technologies, KR-RND-DECB-INF-007

### · Technical/Economic Considerations

For vessel types such as bulk carriers, tankers, LNG carriers, and container carriers, the approximate expected power savings (%), EEDI/EEXI improvement effects (%), CAPEX (USD), and retrofit duration (from design to installation) when applying the Air Lubrication System (B1) and Flettner Rotor(s) (B2) technologies have been assessed, as these technologies have been frequently selected by shipping companies in recent newbuilding or retrofit projects. However, it is important to note that specific figures may vary based on actual operating conditions and the manufacturers involved.




**CAPEX(Design~Installation)** [unit: USD]
- (B1): 3.5~4.0M
- (B2): 3.0~6.0M

**Retrofit Period(Design~Installation)** [unit: Month]
- (B1): 10.0~13.0(Design: 3.5~4.5)
- (B2): 12.0~15.0(Design: 4.5~6.0)

## Considerations for the Adoption of Category C Technologies

Energy-saving technologies in Category C refer to innovative systems capable of generating electricity, which the vessel's generators are responsible for supplying. In the EEDI/EEXI calculation formula.

These technologies are represented as independent terms in the numerator and serve to reduce the vessel's fuel consumption based on the following principles and energy-saving mechanisms.

### The Independent Term Influenced by Energy-Saving Technologies of the Category C in the EEDI/EEXI Formula

$$\frac{\prod_{j=1}^{n} f_j\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}{}^{*}\right) + \left(\left(\prod_{j=1}^{n} f_j \sum_{i=1}^{n} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot SFC_{ME}{}^{**}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref} \cdot f_m}$$

### Energy saving method of Category C

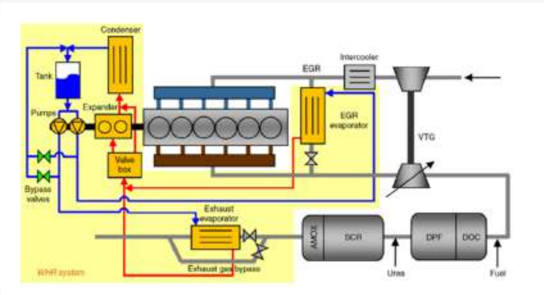
| Category | Principal | Mechanism | Technique | Methodology |
|---|---|---|---|---|
| C-1 | Waste Heat Recovery | Exhaust Gas | Electricity Generation | · Waste Heat Recovery System |
| C-2 | Use of Renewable Energy | Solar Energy | Electricity Generation | · Photovoltaic Panels |

Energy-saving technologies that fall under Category C can calculate their power generation based on the guidelines of MEPC.1/Circ.896 and apply this to a separate term in the numerator of the EEDI/EEXI calculation formula, effectively converting it into the power reduction from the auxiliary engine. This provides the advantage of directly reflecting the power-saving effects in the improvements of EEDI/EEXI, similar to the technologies in Category B.

The waste heat recovery system (C-1) and solar cells (C-2) are known to have significantly high capital expenditures (CAPEX), with the market indicating that the CAPEX for the waste heat recovery system accounts for approximately 10% of the newbuilding costs. However, both C-1 and C-2 have seen very few applications on large vessels, leading some stakeholders to raise concerns about economic viability and operational safety issues.

Despite these challenges, technologies within Category C hold significant potential to enhance the overall energy efficiency of vessel operations. As the shipbuilding industry continues to evolve and regulatory pressures for decarbonization from the IMO increase, advancements in waste heat recovery and solar technology could provide substantial long-term savings for shipping companies. Furthermore, ongoing research and development efforts may address current limitations, ultimately improving both the operational feasibility and economic justification for broader adoption in the maritime sector.

Schematic Diagram of WHR System, C-1*




Photovoltaic Cells, C-2

*R.Leloup,K.Roncin,M.Behrel,G.Bles,J.-B.Leroux,C.Jochum,Y.Parlier, 2015, A continuous and analytical modeling for kites as auxiliary propulsion devoted to merchant ships, including fuel saving estimation, Renewable Energy Volume 86, February 2016, Pages 483-496

## Energy-Saving Technologies and CII

The Carbon Intensity Indicator (CII) is a short-term measure implemented by the IMO to reduce greenhouse gas emissions from existing ships, complementing the EEXI as a technical measure. Following the approval of amendments to MARPOL Annex VI at MEPC 75th session, the final amendments including technical guidelines were adopted at MEPC 76th session, establishing both EEXI and CII as mandatory requirements effective from January 1, 2023.

The technical guidelines and key considerations established to facilitate the effective implementation of CII, adopted during the 76th and 78th sessions of the MEPC, are summarized as follows:

- Resolution MEPC.336(76)
  CII Reference Lines Guidelines(G1) →
  Application and calculation methods for individual vessels' attained CII (AER or cgDIST)
- Resolution MEPC.337(76)
  CII Reference Lines Guidelines(G2) →
  Methods for establishing reference line calculations and reference line calculations by vessel type

· **Resolution MEPC.338(76)**
CII Reduction Factor Guidelines (G3) →
Methods for determining CII reduction factors and reduction rates for 2023~2030

· **Resolution MEPC.339(76)**
CII Rating Guidelines (G4) → Methods for assigning CII ratings to existing vessels

· **Resolution MEPC.355(78)**
CII Correction Factors and Voyage Adjustments for CII Calculations Guidelines(G5) →
Methods for applying specific correction factors (such as cargo retention, handling systems, etc.) and voyage exclusions (navigating in ice-covered areas, severe sea conditions, or long-term anchorage for safety reasons) in the determination of the attained CII.

These technical guidelines are set to be revised after decisions or agreements reached at the MEPC 83rd session, with most revisions expected to take place after 2026.

· Determined CII reduction rates for 2027~2030 through the MEPC 83rd session

| Year | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|
| Reduction Rate Compared to 2019 (%) | 13.625 | 16.25 | 18.875 | 21.5 |

· Fuel consumption during port waiting time and idle time is usually incurred regardless of the owner's intent, so it has been agreed to exclude the fuel consumption used while at anchor from the calculation of the attained CII and the CII reference lines.

· It has been agreed to further discuss the review of IMO DCS data, the review of CII indicator units (the scope of fuel consumption excluding anchoring, port waiting, and docking), the recalculation of reference lines (amendment of Guidelines G2), and the potential for amendments to other IMO documents in the second phase review to be conducted after 2026.

### · CII Calculation and Rating Assessment

**Calculation of Attained CII**

It is predicted that the timing for implementing the agreed amendments related to CII through the MEPC 83rd session (2025) will be reflected after the second phase review to be conducted after 2026, with revisions to G1-G5 guidelines. However, to date, the attained CII has been calculated based on the guidelines established by MEPC 76th session (2021) and the existing IMO DCS data collection format. The calculation formula is as follows:

$$attained\ CII_{ship} = \frac{\sum(FC_j \times C_{fj})}{Capacity \times total\ Distance\ travelled}$$

Here,

$j$ : Fuel type

$FC_j$ : Annual fuel consumption per fuel type

$C_{fj}$ : Conversion factor for each type of fuel consumption to be converted to $CO_2$ emissions

Capacity : Gross tonnage[1)] or Deadweight [2)]

1) Cruise passenger ships, Ro-Ro cargo ships(vehicle carriers) and Ro-Ro passenger ships,

2) Bulk carriers, Tankers, Container ships, Gas carriers, LNG carriers, Ro-Ro cargo ships, General cargo ships, Refrigerated cargo carrier and Combination carriers

When calculating the attained CII using the vessel's capacity based on deadweight (DWT), it is referred to as AER. When calculated using gross tonnage (GT), it is referred to as cgDIST.

**Calculation of Required Annual Operational CII**

To calculate the required annual operational CII, the reference CII for the target vessel must be calculated first, and the formula for determining the reference CII is as follows:

$$CII_{ref} = aCapacity^{-c}$$

Here, “a” and “c” are parameters derived from the attained CII and the capacities of individual vessels based on the IMO DCS statistics data collected in 2019, with values categorized by vessel type and size as follows:

**Parameters for Deriving Baseline by Ship Type**

| Ship Type | | Capacity | a | c |
|---|---|---|---|---|
| Bulk Carrier | 279,000 DWT and above | 279,000 | 4745 | 0.622 |
| | Less than 279,000 DWT | DWT | 4745 | 0.622 |
| Gas Carrier | 65,000 DWT and above | DWT | 14405X10$^{7}$ | 2.071 |
| | Less than 65,000 DWT | DWT | 8104 | 0.639 |
| Tanker | | DWT | 5247 | 0.610 |
| Container Ship | | DWT | 1984 | 0.489 |
| General Cargo Ship | 20,000 DWT and above | DWT | 31948 | 0.792 |
| | Less than 20,000 DWT | DWT | 588 | 0.389 |
| Refrigerated Cargo Carrier | | DWT | 4600 | 0.557 |
| Combination Carrier | | DWT | 40853 | 0.812 |
| LNG Carrier | 100,000 and above | DWT | 9.827 | 0.000 |
| | 65,000 DWT and above, but Less than 100,000 DWT | DWT | 14479X10$^{10}$ | 2.673 |
| | Less than 65,000 DWT | 65,000 | 14479X10$^{10}$ | 2.673 |
| Ro-RO Cargo Ship (Vehicle carrier) | 57,700 GT and above | 57,700 | 3627 | 0.590 |
| | 30,000 GT and above, but Less than 57,700 GT | GT | 3627 | 0.590 |
| | Less than 30,000GT | GT | 330 | 0.329 |
| Ro-Ro Cargo Ship | | GT | 1967 | 0.485 |
| Ro-Ro Passenger Ship | Ro-Ro Passenger Ship | GT | 2023 | 0.460 |
| | High-Speed craft designed to SLAS Chapter X | GT | 4196 | 0.460 |
| Cruise Passenger Ship | | GT | 930 | 0.383 |

Once the reference CII is determined, the required annual operational CII is calculated by finally incorporating the reduction rate (G3) as follows:

$$Required\ annual\ operational\ CII = \left(1 - \frac{Z}{100}\right) CII_{ref}$$

"Z" is the annual CII reduction factor compared to the 2019 baseline, applied uniformly to all vessels regardless of type and size. The finally confirmed reduction rates for the period from 2023 to 2030 at the MEPC 83rd session are as follows:

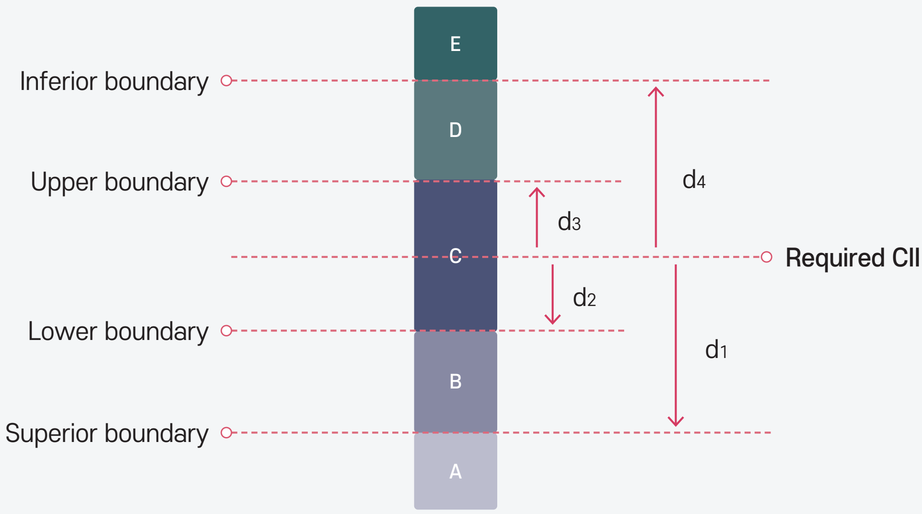
Confirmed reduction rate compared to the 2019 baseline

| Year | '23 | '24 | '25 | '26 | '27 | '28 | '29 | '30 |
|---|---|---|---|---|---|---|---|---|
| Reduction Rate Compared To 2019 | 5.00% | 7.00% | 9.00% | 11.00% | 13.625% | 16.25% | 18.875% | 21.50% |

Determination of CII Ratings

CII ratings range from A to E, with a total of five categories, and the boundary for each rating is determined based on the required CII as follows:

Boundary and calculation method for deriving CII rating




$$superior\ boundary = exp(d_1) \times required\ CII$$
$$lower\ boundary = exp(d_2) \times required\ CII$$
$$lower\ boundary = exp(d_3) \times required\ CII$$
$$inferior\ boundary = exp(d_4) \times required\ CII$$

"exp(dx)" represents the exponent of the dd vector, indicating the direction and distance from the required CII, with the values categorized by vessel type and size as follows:

'dd' vectors by ship type for calculation of CII rating

| Ship Type | | Capacity | dd vectors | | | |
|---|---|---|---|---|---|---|
| | | | exp($d_1$) | exp($d_2$) | exp($d_3$) | exp($d_4$) |
| Bulk Carrier | | DWT | 0.86 | 0.94 | 1.06 | 1.18 |
| Gas Carrier | 65,000 DWT and above | DWT | 0.81 | 0.91 | 1.12 | 1.44 |
| | Less than 65,000 DWT | | 0.85 | 0.95 | 1.06 | 1.25 |
| Tanker | | DWT | 0.82 | 0.93 | 1.08 | 1.28 |
| Container Ship | | DWT | 0.83 | 0.94 | 1.07 | 1.19 |
| General Cargo Ship | | DWT | 0.83 | 0.94 | 1.06 | 1.19 |
| Refrigerated Cargo Ship | | DWT | 0.78 | 0.91 | 1.07 | 1.20 |
| Combination Carrier | | DWT | 0.87 | 0.96 | 1.06 | 1.14 |
| LNG Carrier | 100,000 DWT and above | DWT | 0.89 | 0.98 | 1.06 | 1.13 |
| | Less than 100,000 DWT | | 0.78 | 0.92 | 1.10 | 1.37 |
| Ro-Ro Cargo Ship (veghicle carrier) | | GT | 0.86 | 0.94 | 1.06 | 1.16 |
| Ro-Ro Cargo Ship | | DWT | 0.66 | 0.90 | 1.11 | 1.37 |
| Ro-Ro Passenger Ship | | GT | 0.72 | 0.90 | 1.12 | 1.41 |
| Cruise Passenger Ship | | GT | 0.87 | 0.95 | 1.06 | 1.16 |

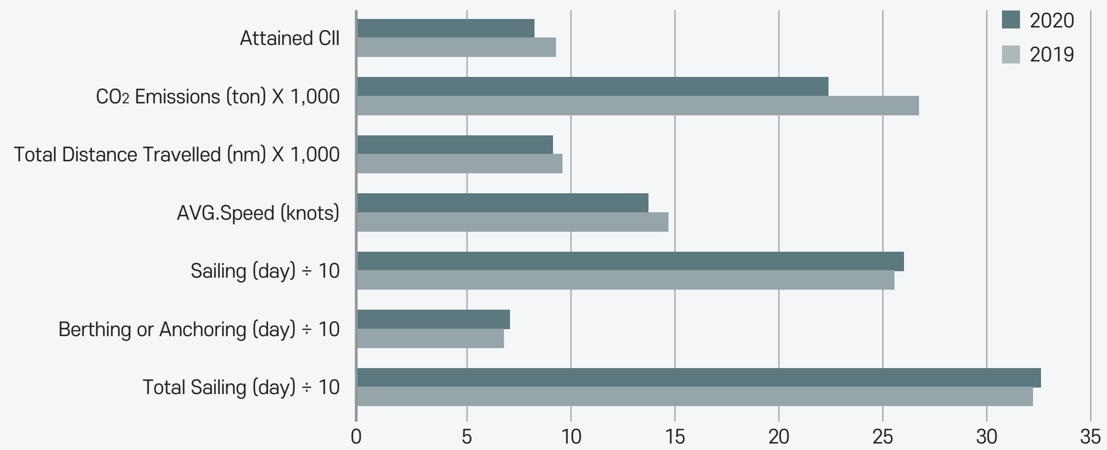
### · Limitations of Energy Savings Technology: A Comprehensive Approach is Needed for CII Improvement

Recently, shipping companies have adopted slow steaming strategies based on engine power (or shaft power) limitations as the most practical and cost-effective means of complying with the EEXI and CII regulations for existing vessels. The figure below presents two years of recorded IMO DCS data collected from the same vessel (with the same EEXI) operating on identical routes, illustrating the effectiveness of slow steaming in enhancing the attained CII.

However, limiting engine power (or shaft power) faces several challenges, including reduced speed under charter agreements, a consequent decrease in competitiveness in the charter market, and inherent limitations that may not be sustainable in light of the anticipated strengthening of international greenhouse gas emission regulations. Therefore, shipping companies may consider adopting energy-saving technologies as a cost-effective short-term alternative, serving as another technical measure to address international greenhouse gas emission regulations.

Historical cases of EEDI/EEXI approval demonstrate that energy-saving technologies can directly reduce a vessel's resistance and

**Comparison of 2 Years of Voyage Data for the Same Vessel**




| Year | Total Sailing (day) | Berthing or Anchoring (day) | Sailing (day) | Avg. Speed (knots) | Total Distance Travelled (mm) | $CO_2$ Emissions (ton) | Attained CII |
|---|---|---|---|---|---|---|---|
| 2019 | 325 | 71 | 254 | 14.78 | 94,820 | 26,310 | 9.66 |
| 2020 | 329 | 72 | 257 | 13.80 | 91,470 | 22,780 | 8.59 |
| Difference(%) | +1.2 | +1.4 | +1.2 | -6.6 | -3.5 | -13.5 | -11.1 |

propulsion losses through various methods, including simple appendage-type devices or more complex electric control systems. Additionally, these technologies can leverage renewable energy sources like wind to generate additional thrust, thereby decreasing the vessel's fuel consumption ($CO_2$ emissions) and garnering attention as effective responses to technical regulations such as EEDI/EEXI.

In contrast, CII is determined based on various data collected from the actual annual operations of existing vessels, unlike EEDI/EEXI. To improve the attained values and ratings of CII, it is necessary to integrate optimal operational strategies and appropriate maintenance methods alongside design-oriented responses like energy-saving technologies. Therefore, a comprehensive effort is required to minimize fuel consumption ($CO_2$ emissions) as measured and reported within the IMO DCS framework by utilizing all these approaches.

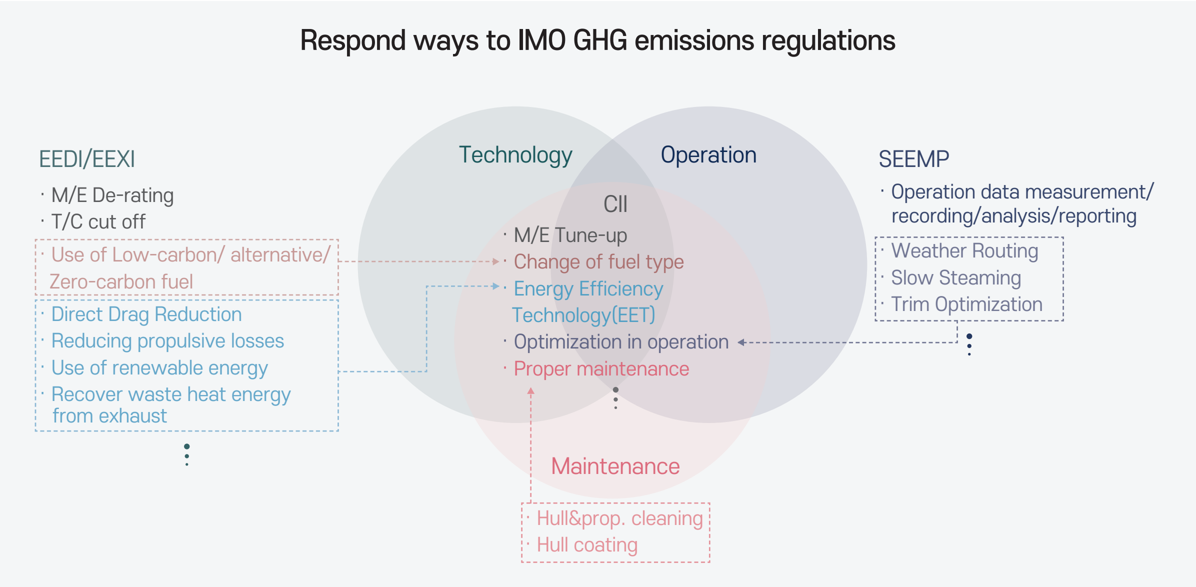
**Representative Fuel Saving Method in Ship Operation**

| Principal | Mechanism | Technique | Methodology |
|---|---|---|---|
| Operation | Optimization in Operation | ICT | Weather Routing |
| | | | Slow Steaming |
| | Aging | Maintenance | Docking |
| | | | Roughness Treatment |

For example, as illustrated in the previous figure, even when the same energy-saving technology is implemented and the vessel has attained the same EEXI, it can be observed that the attained CII significantly decreased in 2020 compared to 2019. The primary reason is that while the number of operational days and mooring periods were similar in both periods, the total operational distance in 2020 was reduced by approximately 3.5% due to slow steaming, while the total fuel consumption ($CO_2$ emissions) decreased by about 6.6%.

As shown in this case, to reduce the fuel consumption ($CO_2$ emissions) measured within the IMO DCS framework, a thorough analysis of the vessel's historical operational pattern data must precede. Additionally, effective data analysis requires systematic collection of external environmental data, including the vessel's mechanical operating state, weather, and sea state. This underscores the necessity for a comprehensive measurement and monitoring system (smart platform) capable of managing this data.

Such a measurement system must be able to record real-time changes in the mechanical states of the vessel, including environmental factors that significantly affect the vessel's resistance characteristics, such as wind, waves, and currents during actual operations, as well as parameters like draft, trim, main engine output, RPM, and speed. Based on this information, shipping companies will be able to accurately diagnose the necessary measures to improve the targeted CII rating (e.g., operational aspects, design-oriented aspects like the introduction of energy -saving technologies, and maintenance aspects), which will be an indispensable prerequisite for establishing customized CII response strategies.





## The Role of Energy-Saving Technologies in Response to Greenhouse Gas Fuel Intensity (GFI)

One of the critical issues in the international community's response to greenhouse gas regulations is the transition from fossil fuels to low carbon fuels for shipping. This transition to low carbon fuels is expected to gain momentum after the implementation of the IMO's mid-term measures in 2027.

The GFI regulation, which is a key component of the IMO's mid-term measures aimed at reducing greenhouse gases and approved during the 83rd MEPC session (April 2025), is set to be newly added to the MARPOL Annex VI amendment. It is scheduled to be adopted during the special session of the MEPC set for October 2025 and will enter into force internationally on March 1, 2027. Additionally, the MEPC 83 session agreed to hold an Inter-Session Working Group (ISWG) meeting immediately after the special session and just before the 84th MEPC session to develop various guidelines to support the implementation of the IMO's mid-term measures (including calculation guidelines for attained GFI determination, compliance measures, and guidelines for compensating ships using Zero or Near-Zero fuels or technologies).

The main elements* of the Greenhouse Gas Fuel Intensity (GFI) regulation are outlined below:

* KR IMO News Flash (MEPC 83)

| | |
|---|---|
| **\| Regulations \|** **Applicability** | ▸ New chapter 5 of MARPOL Annex VI (IMO GHG mid-term measures) shall apply to all ships of 5,000 gross tonnage and above, same as the current IMO DCS reporting framework |
| **\| Regulations \|** **Application date of GHG Fuel Intensity, GFI** | ▸ While IMO mid-term measures will enter into force on 1 March 2027, given that the attained GFI could only be calculated using data from the full preceding calendar year (1 January to 31 December), all applicable ships shall collect GFI data starting from 1 January 2028 and report the relevant data to the Administration or RO for GFI verification in early 2029 |

**| Regulations |**
**Attained GFI Calculation Methodology**

Calculation of GFI based on Well-to-Wake(WtW) GHG emissions of marine fuels

▶ The formula below calculates the average GHG intensity of all energy and fuels used by a ship. It multiplies the GHG intensity (EI) of each energy source by the energy used (Energy), sums the results, and divides by the total energy consumption (Energytotal) to obtain the attained GFI value. A lower value indicates more environmentally friendly energy usage

$$\mathrm{GFI}_{\mathrm{attained}} = \frac{\sum_{j=1}^{J} \mathrm{EI}_j \times \mathrm{Energy}_j}{\mathrm{Energy}_{\mathrm{total}}}$$

**| Regulations |**
**Target Annual GHG Fuel Intensity**

▶ Target GHG fuel intensity (GFI) starts at 93.3 $gCO_2eq/MJ$, representing the average GFI of international shipping in the year 2008

▶ Target annual GFI consists of two tiers: a Base Target annual GFI (Base Target) and Direct Compliance Target annual GFI (Direct Compliance Target)

▶ Base Targets and Direct Compliance Targets are as follows:

| Year | Reduction Rate for Base Target(%) | Reduction Rate for Direct Compliance Target(%) |
|---|---|---|
| 2028 | 4.0 | 17.0 |
| 2029 | 6.0 | 19.0 |
| 2030 | 8.0 | 21.0 |
| 2031 | 12.4 | 25.4 |
| 2032 | 16.8 | 29.8 |
| 2033 | 21.2 | 34.2 |
| 2034 | 25.6 | 38.6 |
| 2035 | 30.0 | 43.0 |

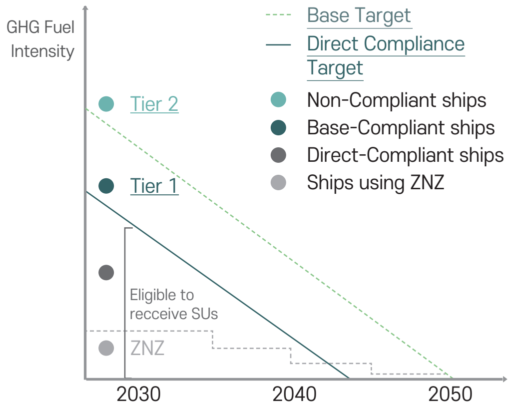
▶ The determined Basic Targets and Direct Targets are utilized for the classification of "Tier 1" and "Tier 2" based on the GHG emissions from individual ships, as mentioned in the "Compliance Approaches" section as below

▶ While the Basic Targets and Direct Targets for the years 2036 to 2040 will be determined by 1 January 2032, Basic Target for the year 2040 shall be set at 65%

**| Regulations |**
**Compliance Approaches**

▸ To comply with the GFI requirements, ships may trade GHG emissions among themselves. Ships that are unable to meet the GFI target may offset their excess emissions by purchasing Surplus Units from ships using low-emission fuels or by purchasing Remedial Units at a predetermined price through a registry

▸ The following approaches are provided to comply with the GFI requirements:




- Ships with an attained GFI falling within Tier I must offset their emissions exceeding the Direct Target by purchasing Remedial Units (USD 100 per GHG tonne) from the registry. In this case, purchasing Surplus Units from ships using low-emission fuels is impossible.

- Ships with an attained GFI falling within Tier II must offset their emissions exceeding the Base Target by purchasing, in addition to the Tier I amount, Surplus Units at market price from ships using low-GHG fuels or by purchasing Remedial Units (USD 380 per GHG tonne) from the registry.

- Ships using low-GHG fuels (where attained GFI falls outside Tier I and Tier II) will generate Surplus Units and sell them to ships that fail to meet the Base Target, thereby creating a revenue-generating opportunity.
  In addition, ships employing Zero or Near-Zero GHG fuels and technologies are eligible for incentive benefits.

**| Regulations |**
**Uptake of Zero or Near-Zero GHG Emission Technologies, Fuels and Energy Sources**

▸ Zero or Near-Zero GHG emission technologies, fuels and/or energy sources should meet the following criteria, and ships utilizing such fuels and technologies with GHG emissions below the specified thresholds may qualify for incentives.

| Year | Until 2034 | From 2035 onward |
|---|---|---|
| WtW GFI ($gCO_2eq/MJ$) | 19.0 | 14.0 |

▸ The details of ZNZ energy sources and technologies, along with the corresponding compensation amounts, will be reviewed every five years and shall comply with the requirements set forth in the guidelines to be developed in the future.

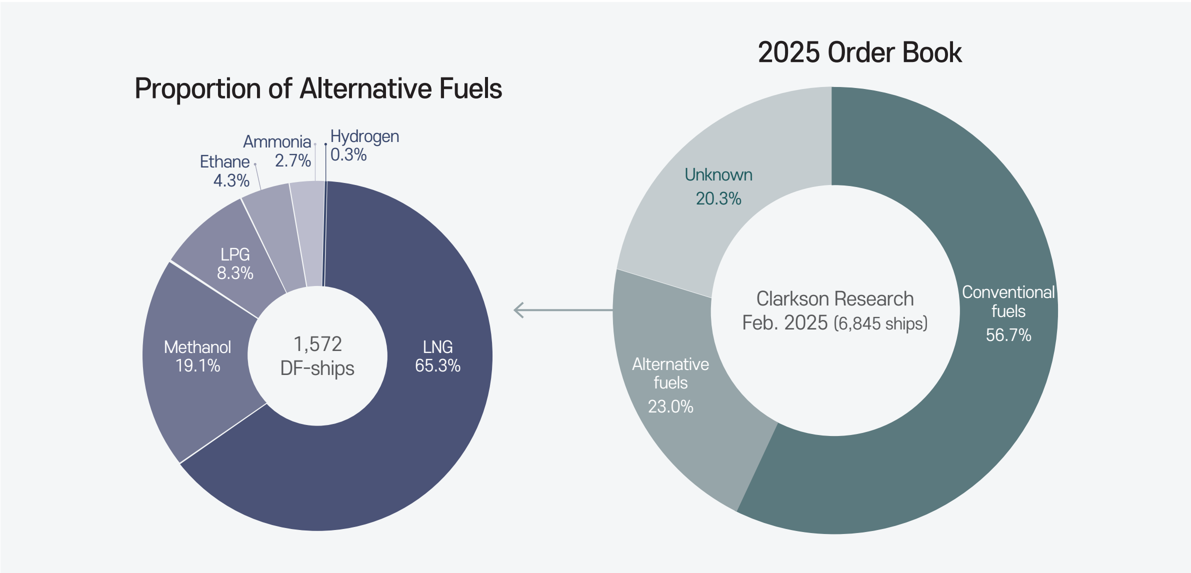
**| Regulations |**
**Disbursement of Revenue**

▸ The fund generated from the IMO mid-term measures will be utilized for various purposes, including providing incentives for alternative-fuel ships, developing infrastructure for alternative fuel supply in developing country ports, supporting GHG-vulnerable countries such as small island developing states (SIDS) and administrative expenses, etc.

### · Future Impact of Energy-Saving Technologies: Increase vs. Decrease

To predict the future impact of energy-saving technologies (mainly payback time predictions), the representative fuel types considered include HFO, LNG, LPG, Bio-Diesel, Bio-Methanol, and e-Ammonia, based on the 2025 Clarkson Research order book* for dual-fuel vessels as of February 2025.

* Clarkson Research Feb. 2025.



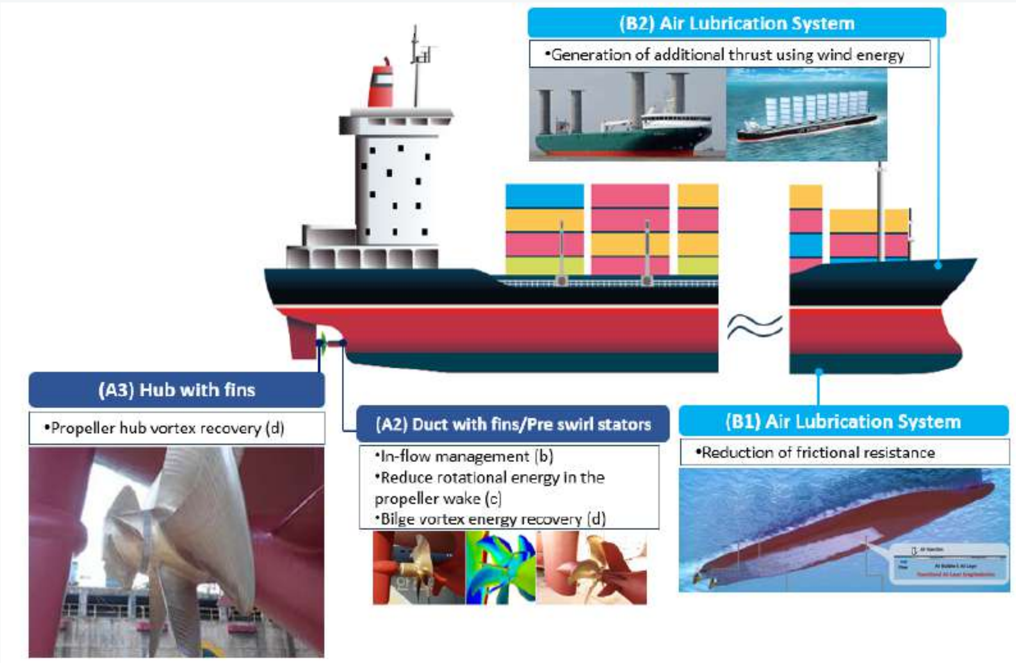

Prior to the recent finalization of IMO's GFI regulation, shipping companies generally believed that operational expenditure (OPEX) would increase proportionally with the price of bunkered fuels, especially when using expensive, low carbon fuels. They also theorized that deploying energy-saving technologies would result in the shortest payback period for capital expenditure (CAPEX) when operating with the most costly fuels.

However, when considering IMO's mid-term greenhouse gas (GHG) reduction measure, specifically the GHG Fuel Intensity (GFI), forecasts of the annual 'net OPEX' defined as the sum of annual fuel costs and GFI compliance costs, or minus the revenue from selling surplus units achieved by exceeding the annual GFI reduction targets along with various analysis results that incorporate these assumptions, generally challenged this previously held view among shipping companies.

The assumptions used to predict the timing of investment cost recovery (payback time) related to the adoption of energy-saving technologies are outlined as follows:

- HFO (HSHFO) consumption assumed at 12,820 MT annually (515,364,000 MJ), operating on non-EU routes.
- OPEX forecasts by fuel type are based on the Clarkson Research order book* for dual-fuel vessels released in 2025.

  * Clarkson Research Feb. 2025.
- GFI cost calculations: reflecting results from the 83rd MEPC.
- Information on 'Initial Default Emission Factors per Fuel Pathway Code' necessary for GFI calculations of fuel types not included in the 2024 IMO LCA Guideline is referenced from FuelEU Maritime.
- OPEX considers only annual fuel consumption (fuel costs) and GFI impact.
- Types of energy-saving technologies applied: (A2)+(A3), (B1), (B2)
- Types of vessels to which energy-saving technologies ((A2)+(A3), (B1), (B2)) are applied: Bulk Carrier, Tanker, LNG Carrier, Container Carrier.

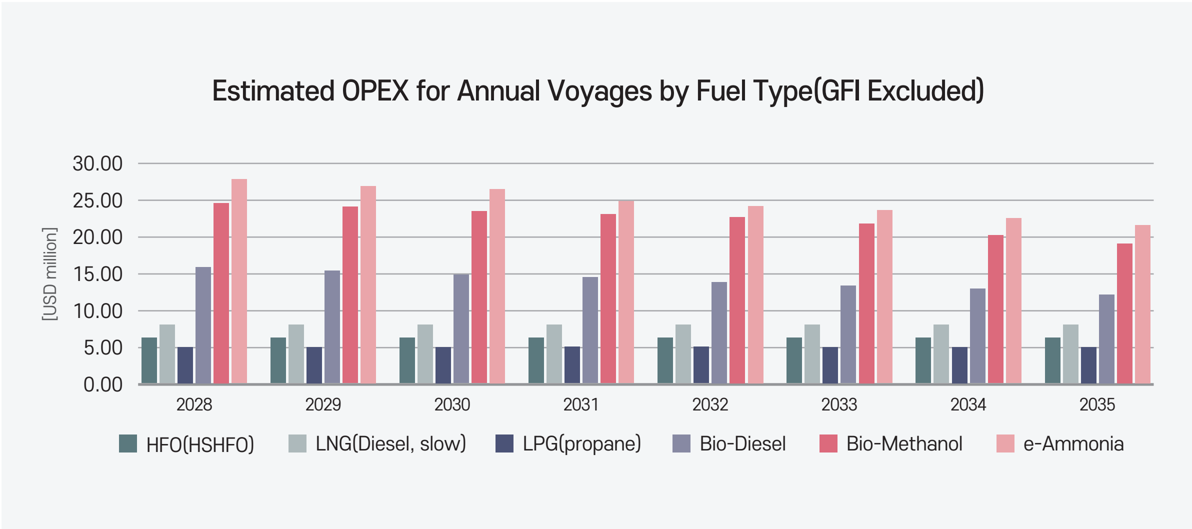



- 'Energy-saving technologies' CAPEX is as follows (to be implemented in 2027):

| Technology | CAPEX (USD) | Remark |
|---|---|---|
| (A2) Duct with Fins/Pre-swirl Stators + (A3) Hub with Fins (Category A) | 0.90 M | Installation in 2027 |
| (B1) Air Lubrication System (Category B-1) | 3.75 M | |
| (B2) Wind Assisted Propulsion System (Category B-2) | 5.00 M | |



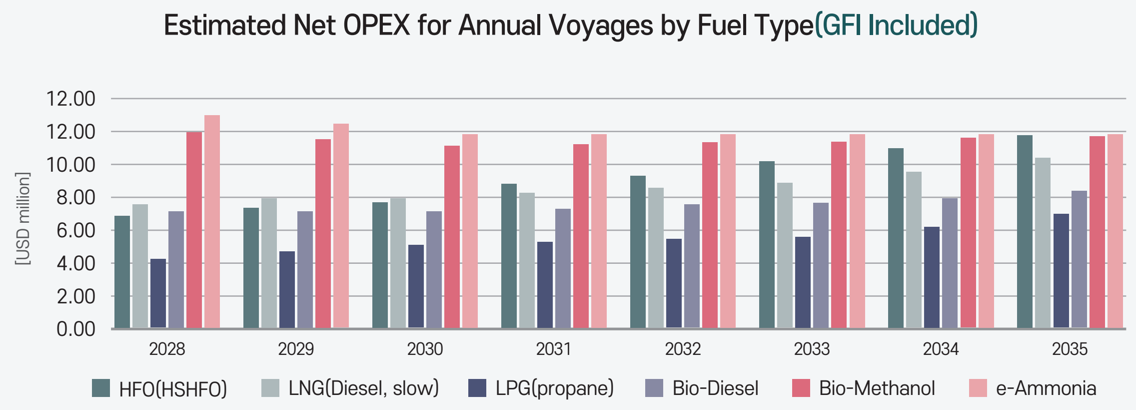
The figure below illustrates the annual OPEX predictions by fuel type based on the forecasted bunker prices of fuels, excluding the consideration of GFI(GHG Fuel Intensity).

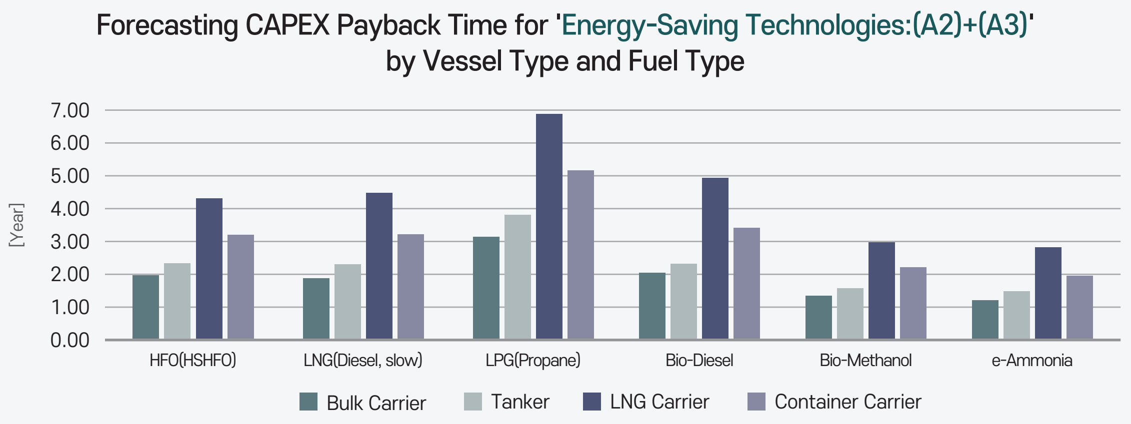



As illustrated in the figure above, when ships use eco-friendly fuels, bunker costs are expected to be higher due to increased production and supply expenses, primarily resulting from a lack of infrastructure. Consequently, the annual operational expenditure (OPEX) considering only fuel costs for vessels using eco-friendly fuels tends to be approximately 4 to 5 times higher than that for vessels using fossil fuels. However, with the enforcement of GFI regulations, the annual 'net OPEX' (as defined in the previous paragraph) including fuel-specific GFI compliance costs—is expected to vary significantly depending on the type of fuel used. Accordingly, 'net OPEX' for each fuel type was forecasted under the GFI regulation.

The subsequent figures show that over time, the 'net OPEX' of both fossil and eco-friendly fuels gradually converges. This can be interpreted as, while the costs for fossil fuels increase over time due to stricter GFI annual reduction rates, the revenue from selling surplus units arising from exceeding GFI direct compliance targets for eco-friendly fuels substantially offsets the initial (2028) differences in 'net OPEX' between the two fuel types.

In the following results, the GFI compliance costs for fossil fuels are calculated in accordance with GFI regulations, assuming surplus units are sold at a market price of $380 per tonne.



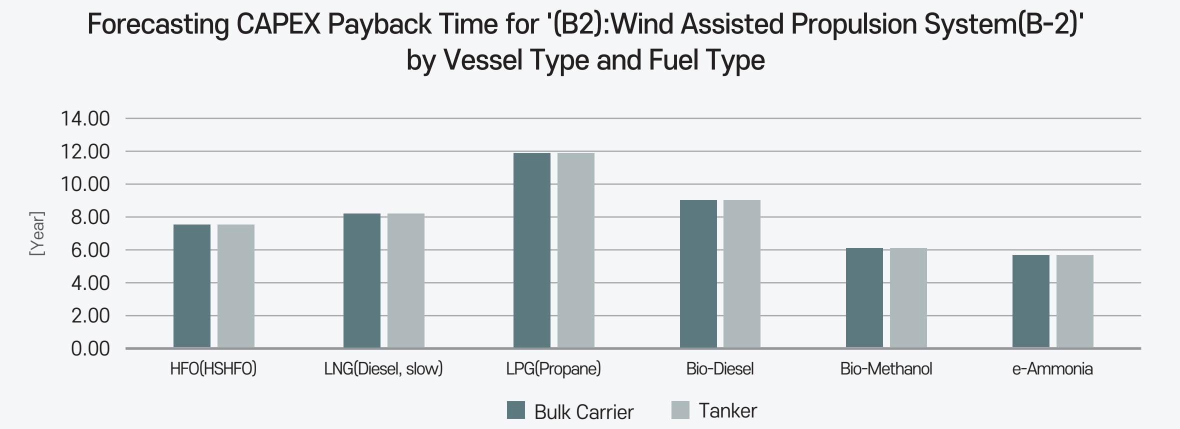

Assuming that the energy-saving combination of '(A2) + (A3)' under Category A is installed by 2027, the previously determined four representative vessel types were analyzed to forecast the payback period of CAPEX for '(A2) + (A3)' based on different fuel types. The results are summarized as follows:

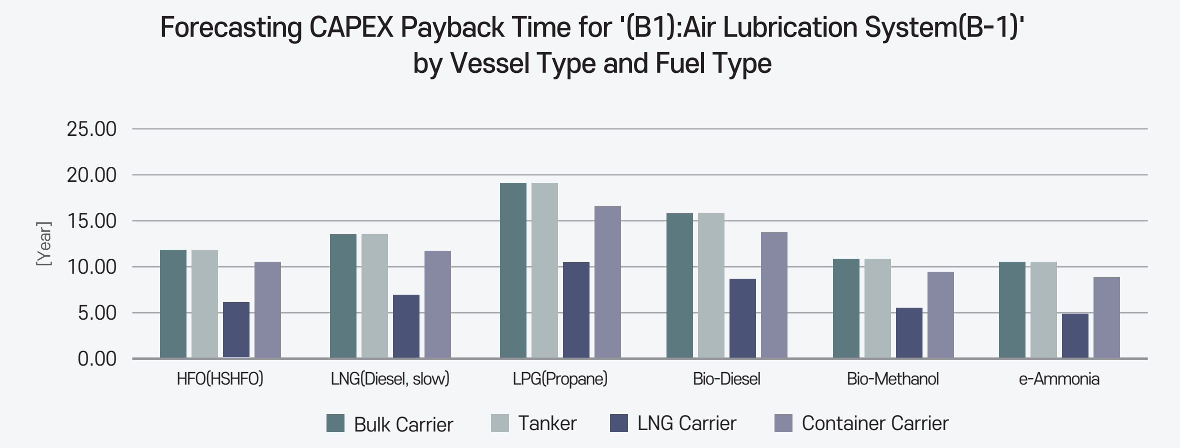
First, the energy-saving performance of '(A2) + (A3)' was found to be similarly effective in both bulk carriers and tankers, with container carriers and LNG carriers following in effectiveness.

Second, based on the predicted 'net OPEX' for each fuel type, the payback period for CAPEX on '(A2) + (A3)' was estimated. Notably, on bulk carriers using e-Ammonia considered a future eco-friendly fuel with the highest bunker cost the payback period is projected to be approximately one year around 2028.

An additional noteworthy finding is that even for bulk carriers and tankers powered by fossil fuels, the CAPEX payback period for '(A2) + (A3)' remains relatively short, at approximately two to three years. Other vessel types also exhibited payback periods of up to approximately four to seven years, which can be considered relatively short.

These results suggest promising prospects for shipowners considering the adoption of '(A2) + (A3)' energy-saving technologies in the near future, especially given the favorable payback periods.




Assuming that energy-saving technologies corresponding to Category B, namely (B1) and (B2), will be installed by 2027, the analysis results for the expected CAPEX payback periods specifically for (B1) and (B2) when applied to the four previously selected ship types are as follows:

First, the energy-saving performance of (B1) was found to be the best in LNG carriers among the considered ship types, followed by container ships, bulk carriers, and tankers.

Second, the energy-saving performance of (B2) was found to be similar for both bulk carriers and tankers. This analysis was conducted by focusing solely on these two ship types from the four considered earlier. The reason is that (B2) is typically installed on the upper deck, which requires sufficient space on the upper deck of the target ship type to achieve a satisfactory energy-saving effect. This is because greater space reduces interaction between superstructures, thereby enhancing the technical and economic feasibility of the installation.

Third, based on the previously predicted six types of fuel-specific annual "net OPEX" (bunker cost + GFI cost), the CAPEX payback period of (B1) was predicted to be the shortest at about five years for LNG carriers using e-Ammonia, which are eco-friendly fuels and have the highest bunker cost.

Fourth, the CAPEX payback period for (B2) was expected to be relatively short, approximately 5.8 years, and this was nearly the same for both bulk carriers and tankers using e-Ammonia. This estimate was based on the assumption that, for (B2), the CAPEX is approximately 1.3 times higher than that of (B1), while the energy-saving effect is predicted to be about 1.2 times greater.

An additional noteworthy point is that the CAPEX payback period for (B1), which demonstrated the greatest energy-saving effect in LNG carriers, shows only a minimal difference when compared to using eco-friendly fuels (Bio-Methanol, e-Ammonia) and fossil fuels (HFO, LNG). This trend primarily arises because, after around 2033, the reduction target rates under GFI regulations increase significantly. Meanwhile, the expected 'net OPEX' for fossil fuels is projected to be high due to rising GFI compliance costs, whereas the 'net OPEX' for eco-friendly fuels is anticipated to be lower slightly thanks to consistent revenue from surplus unit sales in the shipping market and decreasing future production and bunker costs. Additionally, the gap in CAPEX payback periods of (B1) between fossil and eco-friendly fuels is expected to narrow over time as stricter reduction targets are enforced for both the 'Basic' and 'Direct Compliance' targets within the GFI regulation. A similar trend is projected for (B2), despite its CAPEX being 1.3 times higher than that of (B1).

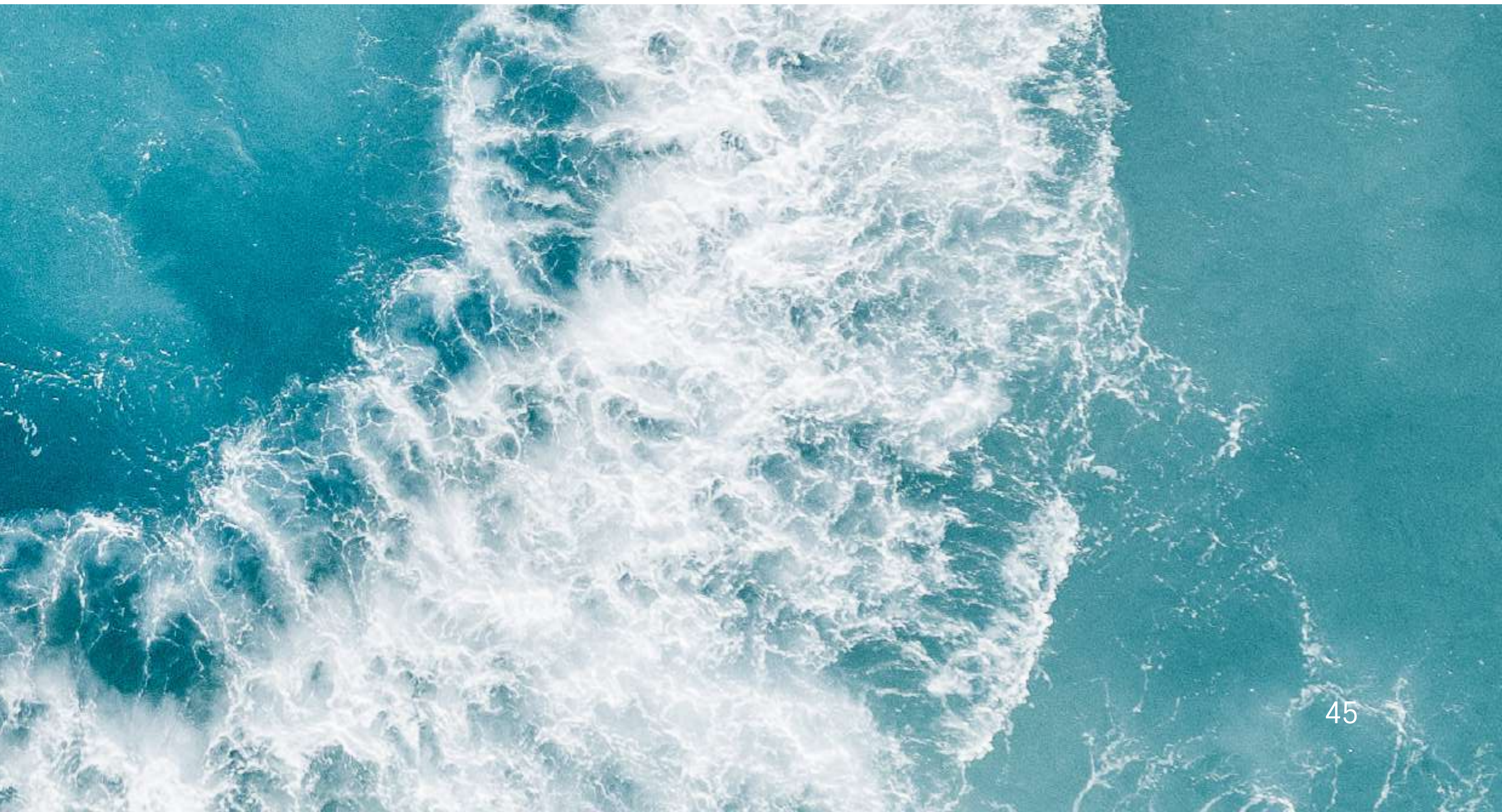
However, the predictions of CAPEX payback periods for each ship type, concerning energy-saving technologies categorized as (A) and (B) according to MEPC.1/Circ.896 based on the previously forecasted 'net OPEX' of eco-friendly fuels require careful analysis for the following two reasons:

- First, the '2024 IMO LCA Guidelines' have not yet established the 'Initial Default Emission Factors' per Fuel Pathway Code, which are required for calculating GFI for fuels such as Bio-Diesel, Bio-Methanol, and e-Ammonia. As a result, the 'Initial Default Emission Factors' for the eco-friendly fuels considered in previous analyses have been referenced from FuelEU Maritime. Since these figures are determined by the EU, their applicability to the calculation of the IMO GHG fuel intensity (GFI attained) has not been verified.
- Second, the market selling price for the 'Surplus Units' generated from using Bio-Diesel, Bio-Methanol, and e-Ammonia which was set at $380 per tonne according to GFI regulations in previous analyses is likely to rise further. This directly affects the calculation of the 'net OPEX' for eco-friendly fuels and has a significant impact on the projected CAPEX payback time for the energy-saving technologies previously considered.

Additionally, the methodology for projecting the payback period of capital expenditures (CAPEX) associated with deploying energy-saving technologies—considering various eco-friendly fuels—should be approached with caution until the '2024 IMO Lifecycle Assessment (LCA) Guidelines' are revised to include 'Initial Default Emission Factors per Fuel Pathway Category' for a range of eco-friendly fuel types, which are essential for accurately calculating the attained GFI.

In conclusion, as GFI was adopted as a mid-term measure to regulate greenhouse gas emissions by IMO at MEPC 83rd session (April 2025), the adoption of the energy-saving technologies discussed earlier will continue to serve as one of the key supporting strategies for shipping companies to meet both short- and mid-term IMO GHG regulations. This is particularly relevant given the current dominance of fossil fuels in the shipping industry sector. Moreover, energy-saving technologies are expected to play a crucial role during the transition from fossil fuels to eco-friendly fuels, aiding in the achievement of IMO's intermediate targets for 2030/2040 and ultimately facilitating full decarbonization by 2050.

Meanwhile, many experts caution that, even if the maritime sector makes significant progress toward adopting eco-friendly fuels by 2040, fuel prices are likely to remain high due to ongoing infrastructural development and production cost challenges. As a result, energy-saving technologies that can directly reduce fuel consumption during ship operations are expected to gain continued market attention.



# Interview

## Drawing a Carbon-Neutral Future: Hanwha Power Systems' Ammonia Gas Turbine

Semi Kim, Green GT Development Team Leader
at Hanwha Power Systems

# Drawing a Carbon-Neutral Future:
## Hanwha Power Systems' Ammonia Gas Turbine

**Semi Kim**, Green GT Development Team Leader
at Hanwha Power Systems

**The mid-term GHG reduction measures were decided at the 83rd MEPC meeting. While various fuel options are being discussed, the possibility of using multiple alternative fuels in parallel is being raised due to supply uncertainties. In this context, how do you assess the importance of ammonia fuel?**

The mid-term GHG reduction measures agreed upon at the 83rd MEPC session mark a major turning point in accelerating the decarbonization of international shipping. The position of LNG, once considered a relatively eco-friendly fuel, is weakening, while demand for alternative fuels such as bio-fuels, methanol, ammonia, and hydrogen is expected to increase rapidly and gradually replace traditional fossil fuels. As a result, investments in stable production and supply of alternative fuels, securing price competitiveness, and developing related equipment and systems will be accelerated. Among these alternative fuels, ammonia stands out as a fuel with significant advantages in terms of production, transport, storage, and infrastructure. While its inherent toxicity and corrosiveness pose safety challenges, if these can be overcome through technological development and thorough validation, ammonia, as a carbon-free fuel, could achieve complete decarbonization. Additionally, its compatibility with existing production infrastructure and supply chains, along with its relative ease of storage and transport, positions it as a strong candidate not just as an interim fuel but as a fundamental solution for Zero or Near-Zero (ZNZ).

**There is significant industry interest in Hanwha Power Systems' development of ammonia gas turbines. Could you briefly introduce the background or motivation for starting this project and the progress made so far?**

Hanwha Power Systems, in collaboration with Hanwha Impact, successfully completed a hydrogen demonstration on an 80 MW mid-to-large-scale gas turbine in 2023 as part of our 100% hydrogen capable combustion system development program. While exploring sustainable and eco-friendly solutions not only for land-based power generation but also for the marine and offshore sectors, we decided to leverage the capabilities of our affiliates to initiate the development of an ammonia gas turbine with for electric propulsion in ships. Ammonia gas turbines offer several notable advantages as follows: they do not require a single drop of pilot oil during normal operation; they demonstrate excellent fuel flexibility, supporting both 100% ammonia and 100% natural gas (NG) combustion, and ammonia-NG co-firing in various ratios; they produce almost no methane slip, ammonia slip, or $N_2O$ emissions, and can meet Tier III NOx standards for large low-speed engines without the need to install the Selective Catalytic Reduction (SCR) systems; their compact footprint allows ammonia fuel to be stored without sacrificing cargo space; and they are designed with built-in enclosures in depression and ventilation systems to address safety concerns related to ammonia fuel. We believe this technology could be revolutionary in the maritime sector, which has traditionally been dominated by internal combustion engines. Moreover, we are expanding development to target other markets such as land-based power plants and offshore platforms.

To this end, Hanwha Power Systems and Hanwha Ocean signed a joint development agreement with Baker Hughes, an energy technology company, to develop a new small-size turbine for ammonia applications in February of this year.

PSM – Hanwha Power Systems sister company based in Florida, USA - is developing the ammonia combustor, and they successfully completed a second ammonia full pressure test in March of this year.

" Hanwha Power Systems is currently focusing on developing marine gas turbine packages and establishing a dedicated testing facility, with the goal of completing full engine test with ammonia by the end of 2027 and delivering it to shipyards. "

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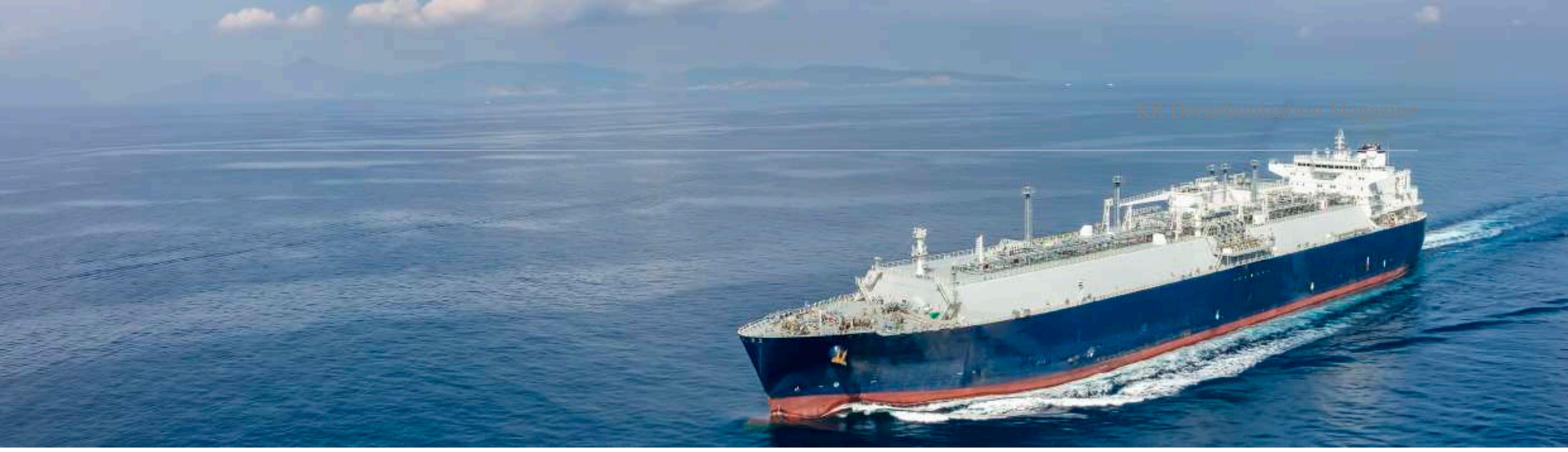
## For which types of vessels is the ammonia gas turbine expected to be most competitive?

When we began developing the ammonia gas turbine in early 2023, our primary target was LNG carriers of 174,000 cubic meters or larger. Since the turbine is being developed to allow both full ammonia and full NG combustion—as well as co-firing at any desired ratio—it can economically utilize Boil-Off Gas (BOG) from the LNG cargo tanks as fuel. At the same time, blending with ammonia allows the vessel to comply with increasingly stringent environmental regulations, avoiding penalties and potentially earning compliance incentives.

However, we've recently seen significant interest from container carriers as well. Large container ships require high power output for both propulsion and onboard electricity, making them eager for fundamental solutions that use alternative fuels compliant with environmental regulations. Unlike LNG carriers, however, container ships require additional installations to use LNG fuel and face complications in bunkering, leading many operators to prefer fuel oil (FO) for start-up or supplementary fuel. In response, we are now considering a derivative version of the ammonia gas turbine that can start and co-fire with FO instead of NG. This diversification of start-up and co-firing fuels could make ammonia gas turbines applicable to a broader range of vessels, including container ships, Very Large Ammonia Carriers (VLACs), and Very Large Crude Carriers (VLCCs). If FO is replaced with bio-diesel or similar fuels, a fully carbon-free operation—from start-up to full power—can be achieved.

We also believe there's economic feasibility in retrofitting relatively new vessels with ammonia gas turbines, and we are conducting various reviews to explore this possibility.



### How do you assess the market potential and economic viability of ammonia gas turbines?

If there were no environmental regulations, it would be difficult for any vessel or engine using alternative fuels to secure an economic advantage over Heavy Fuel Oil (HFO) and conventional internal combustion engines. However, the mid-term GHG reduction measures adopted at MEPC 83 have sent a clear message to the market. Unlike previous regulations like the EU ETS and FuelEU Maritime that were limited to the EU, the IMO has now established a foundation for regulations applicable to ships worldwide. This shift means that environmental compliance costs must now be factored into any genuine assessment of economic viability. Furthermore, the incentive scheme for ZNZ fuels, to be agreed upon in 2027, is expected to serve as an effective driver to accelerate the transition to carbon-free fuels like ammonia.

If infrastructure for ammonia fuel production and bunkering continues to develop rapidly and related safety concerns are sufficiently addressed within this paradigm shift, shipowners' perceptions will evolve, leading to ammonia gas turbines being well positioned as a highly competitive emerging technology.

### There are concerns about the harmful effects of ammonia on human health, making safety a critical issue when used as marine fuel. How is Hanwha Power Systems addressing these safety concerns?

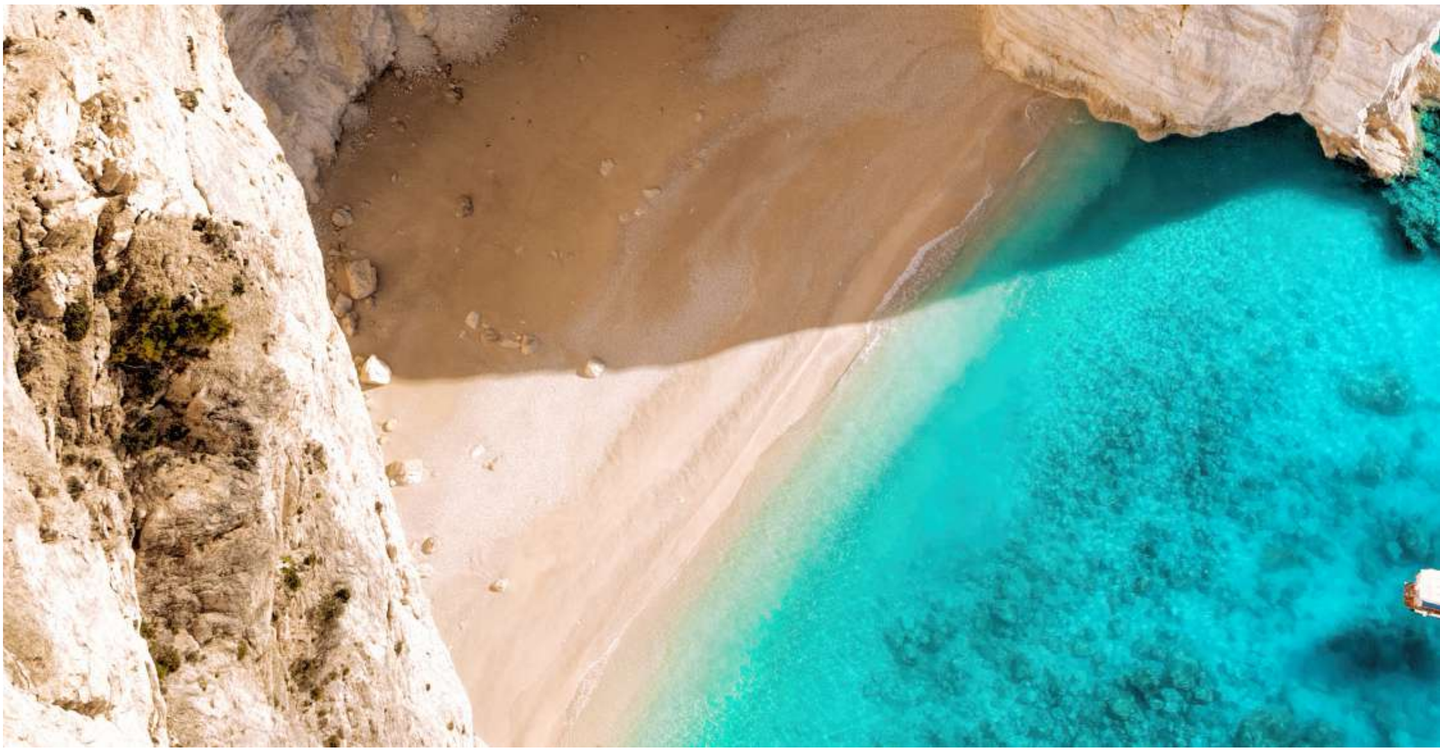
Ironically, safety concerns about ammonia fuel are one of the reasons we are developing ammonia gas turbines —gas turbines offer an inherently safer system for utilization of ammonia fuel. As previously mentioned, the compact footprint of a gas turbine allows it to be installed within its own enclosure, equipped with a dedicated ventilation system that maintains negative pressure inside the enclosure at all times. To help shipowners understand this setup more intuitively, we often describe it as a "double engine room"—an engine room within the engine room.

In addition, we are incorporating high-performance sensors for leak detection and implementing multiple layers of protective systems. The fuel storage and transfer lines are designed with doublewalled piping, automatic shut-off valves, and emergency ventilation systems. We are also strictly complying with the IMO's International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) and International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). At the same time, we are conducting scenario-based risk analyses to ensure safe ship operations and to protect crew members.

**While ammonia combustion can reduce GHG emissions, there are also concerns about exhaust gas issues such as ammonia slip. Could you elaborate on the environmental advantages of this gas turbine technology?**

Methane slip and ammonia slip from propulsion and power generation systems are critical environmental or safety concerns. In the case of engines, additional devices are often required to manage methane slip, and ammonia slip poses significant safety risks, requiring careful handling. Gas turbines, however, operate through continuous rotational motion and combustion, which inherently reduces the likelihood of incomplete fuel combustion.

" As a result, methane and ammonia slips are negligible. In the second combustion test conducted this past March, we confirmed that both methane and ammonia slips were virtually undetectable even without any additional after-treatment systems. "



There is a general perception that gas turbines are less thermally efficient than internal combustion engines. Given this, there may be concerns about fuel efficiency when using ammonia. What strategies or technical solutions is Hanwha Power Systems implementing to address this?

Gas turbines do typically have lower thermal efficiency in independent operations compared to internal combustion engines. However, when configured as part of a Combined Cycle System—paired with waste heat recovery technologies like steam turbines or supercritical $CO_2$ ($sCO_2$) cycles—the overall system efficiency can be significantly improved. While their efficiency may not exceed that of low-speed engines which are currently dominant in the market, ammonia gas turbines are expected to offer higher efficiency than medium-speed generator engines. Hanwha Power Systems, in collaboration with Baker Hughes and PSM, is continuously working to further improve gas turbine efficiency. We are optimizing the overall system, including waste heat recovery units and fuel supply systems, to enhance performance from a holistic perspective.

Moreover, since gas turbines are used in conjunction with electric propulsion systems, they can be operated in optimal combinations with fuel cells and batteries. This allows us to overcome the relative efficiency disadvantage of the turbine itself by designing a highly efficient and more integrated overall system.

**Ammonia is being recognized as a key fuel for decarbonization, and in the future, it will likely face competition from internal combustion engines and fuel cells that also use ammonia. What is your outlook on the competitiveness and market positioning of ammonia gas turbines?**

As mentioned earlier, ammonia gas turbines offer several distinct advantages over ammonia engines. These include the ability to operate without pilot oil, enabling fully carbon-free operation, superior fuel flexibility with the capability to co-fire with NG, a compact footprint that simplifies the installation of ammonia fuel tanks, and the use of enclosed systems that mitigate safety concerns related to ammonia handling. Additionally, they produce minimal noise and vibration, and they do not require exhaust after-treatment systems like Selective Catalytic Reduction (SCR) to reduce NOx levels below the IMO Tier III standard. Unlike fuel cells, ammonia gas turbines do not need to crack ammonia into hydrogen, which is a very energy intensive process, as they can use ammonia directly as fuel. Their power output is also sufficient to serve as a main propulsion system, giving them a clear advantage over fuel cells. If ammonia becomes the dominant alternative fuel, ammonia gas turbines are expected to secure a strong competitive edge in the market.

**Despite the many strengths of ammonia gas turbines, what are some of the challenges that still need to be overcome?**

While the advantages are significant, there are two key challenges that still need to be addressed.

The first challenge to be tackled is the stable supply and global bunkering infrastructure for blue or green ammonia. This is expected to accelerate over time, and we believe that as the related technologies mature, price competitiveness will also improve. To help complete the entire value chain from upstream to downstream, we are actively building networks and engaging in discussions with various partners.

The second challenge is the relative unfamiliarity of ammonia fuel and gas turbine systems among shipowners and crew. To address this, we plan to provide comprehensive manuals and intensive training programs to ensure safe operation and maintenance. We are working with Baker Hughes and Hanwha Ocean to prepare these effective methods.

KR Decarbonization Magazine

# Regulatory Updates

**| IMO Regulatory Trends |**

MEPC 83 Key Highlights

## | IMO Regulatory Trends |

# MEPC 83 Key Highlights

## Approval of the amendments to MARPOL Annex VI on IMO mid-term measures to reduce GHG emissions from international shipping

The draft amendments to MARPOL Annex VI, setting forth the implementation measures for the IMO's mid-term measures aimed at achieving the target of "Net-Zero GHG emissions from international shipping by 2050" as established in the "2023 IMO Strategy on Reduction of Greenhouse Gas Emissions from Ships" (Resolution MEPC.377(80)) adopted at the 80th session of the MEPC have been approved.

Due to sharp divisions among member States, unanimous agreement could not be reached. Accordingly, at the request of a specific Member State, the measures were approved through a voting process, and they include the following key elements:

▶ IMO GHG mid-term measures shall apply to all ships of 5,000 GT and above, and all applicable ships shall collect GFI data starting from 1 January 2028 and report the relevant data to the Administration for GFI verification in early 2029. It was agreed that expanding the application of the measures to ships of 400 GT and above would be decided through further deliberations in the future.

▶ The GHG reduction pathway for international shipping will be structured based on a dual-target approach (base target and direct compliance target), with levies on individual ships' emissions imposed under a grading scheme. Ships that fail to meet the Direct Target (Tier 1) due to the use of high GHG emission fuels must offset their emissions exceeding the Direct Target by paying the cost of purchasing Remedial Units (RUs) (USD 100 per GHG tonne) into the IMO Net-Zero Fund.

▶ However, ships that fail to meet the Base Target (Tier 2) must offset their emissions exceeding the Base Target by purchasing, in addition to the Tier I amount, Surplus Units (SUs) (at market price) from ships using low-GHG fuels or by paying the cost of purchasing Remedial Units (RUs) (USD 380 per GHG tonne) into the IMO Net-Zero Fund. The cost of the aforementioned remedial units will remain valid only until 2030, and the price applicable from 2031 onward will be subject to revision through a separate review to be conducted by 1 January 2028. However, in accordance with the principle of no backsliding, it is anticipated that the price will be increased.

▶ Ships using Zero or Near-Zero GHG fuels and technologies can receive incentives to compensate for the capital expenditure put into new building construction and the price gap between alternative fuels and fossil fuels. The exact scope of beneficiaries eligible for incentives, as well as the detailed pricing, will be determined through the future development of separate technical guidelines or equivalent instruments.

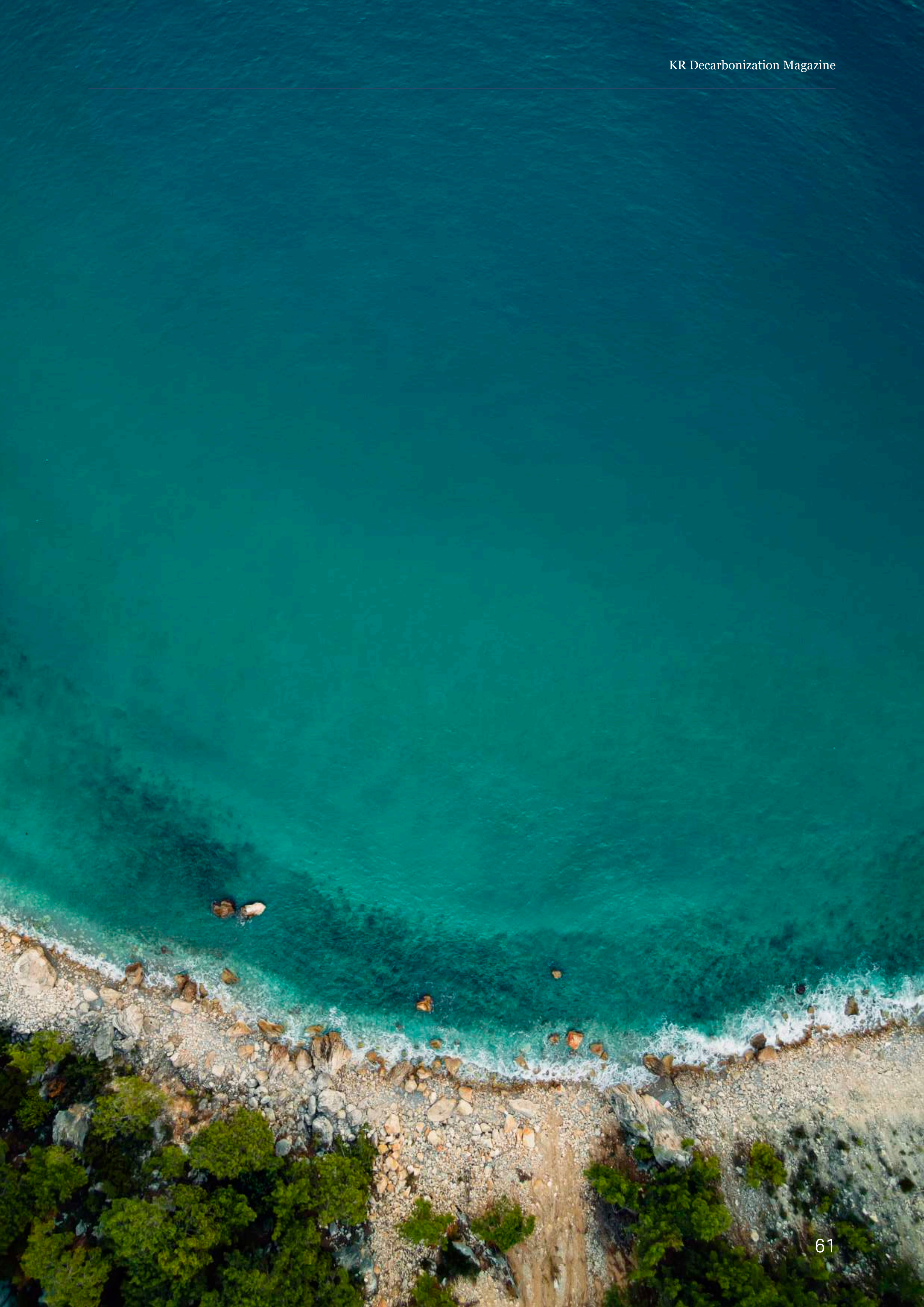
## Review of Short-Term Measures

### (CII, Carbon Intensity Indicator)

· The CII reduction rate for the years 2027 to 2030 has been determined as follows:

| Year | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|
| Z-factor (%) | 13.625 | 16.25 | 18.875 | 21.5 |

· Considering that the fuel consumption occurring during port waiting time and idle time is mostly incidental and beyond the shipowners' control and cannot be considered as transport work based on the ship's movement, it has been agreed that the relevant fuel consumption occurring should be excluded from the Attained CII calculation and the CII reference line. Thus, further discussion on reviewing IMO DCS data, examining CII metric (defining the scope of fuel consumption excluding anchoring, port waiting, and berthing), recalculating the reference lines (amending Guidelines G2), and assessing the possibility of amending other IMO instruments will take place in Phase 2, which will be implemented beyond 2026.



# Inside KR

# INSIDE KR

## KR Grants World's First AIP to HD KSOE for Pioneering Large-Scale Liquid Hydrogen Tank Vacuum System

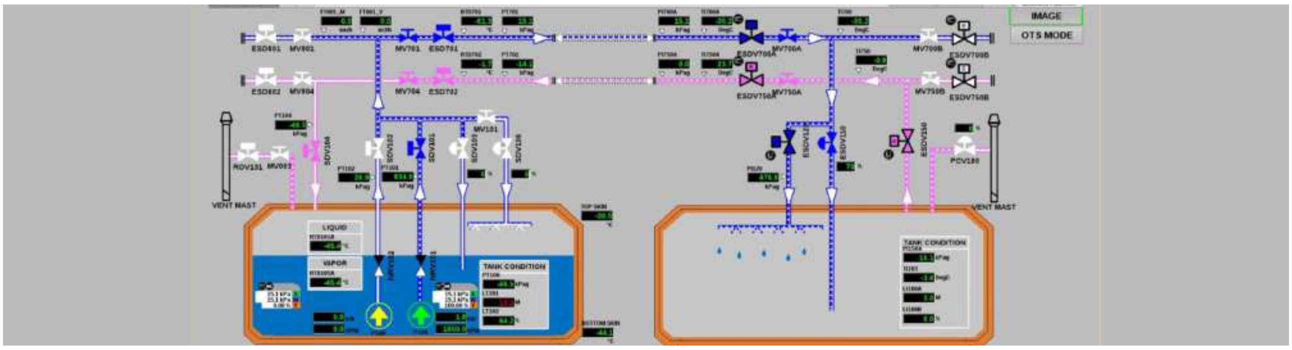

KR has awarded the world's first Approval in Principle (AiP) to HD KSOE for its breakthrough vacuum-insulated large-scale liquid hydrogen tank system, marking a significant advancement in clean energy transportation technology. The AiP follows the successful completion of validation tests, demonstrating the system's feasibility and innovative design.

HD KSOE has independently developed a vacuum-insulated liquid hydrogen tank system that addresses key challenges by introducing cutting-edge solutions. This innovative system dramatically reduces the time required to create a vacuum in large tanks, shortening the process from several months to just a few days.

KR evaluated the system's compliance with domestic and international standards, confirming its effectiveness and stability and granting the AiP as a result.

KIM Daeheon, Executive Vice President of KR's R&D Division, commented: "This AiP reflects HD KSOE's technological excellence and highlights the promising potential of the hydrogen industry. KR remains committed to supporting the safety and technological progress of this vital sector."

Operator training simulator in KR LSC




Ammonia Bunkering Status Display Screen (Monitoring System)

# KR Expands Technical Services with New Ammonia Bunkering Simulation System

KR and Trans Gas Solution Co., Ltd. have launched an “Ammonia bunkering simulation system” at the LNG Fueled & Bunkering Simulation Center (KR LSC) located at its Busan headquarters.

KR launched the KR LSC in 2020, providing training on LNG fuel supply and bunkering systems, risk analysis, and related technical services. In January 2024, the center expanded its capabilities with the addition of a methanol bunkering simulation system.

The newly developed ammonia bunkering simulation system is based on 17 designs of ammonia fuel supply and bunkering systems, drafted by TGS and reviewed by KR, ensuring objectivity and reliability. With this expansion, KR has further extended its technical services beyond LNG and methanol to include ammonia, offering tailored commissioning, operational optimization, and comprehensive risk assessments for bunkering systems.

# KR Executive Vice President KIM Yeontae Elected as TSCF Chairman

KIM Yeontae, Executive Vice President of KR Technical Division, has been elected Chairman of the Tanker Structure Co-operative Forum (TSCF) the during the TSCF Steering Committee meeting held in Seoul from February 12-13, 2025. His term as Chairman will run for two years, from February 2025 to February 2027.

Established in 1983, TSCF is an international forum committed to advancing maritime safety through improvements in tanker structural integrity. Its members include oil majors including BP and Shell, shipowners such as Stena Rederi, Teekay, and MOL, as well as leading classification societies.

Mr. Kim, who joined KR in 1989, is a technical specialist with extensive experience in plan approval, field surveys, international standards development, and business management. Since 2020, he has led KR Technical Division, overseeing plan approval and rule development.

Commenting on his appointment as TSCF Chairman, Mr. Kim stated, "This recognition reflects KR's enduring contributions to tanker safety in the global maritime industry. I will strive to further strengthen TSCF's role while facilitating the adoption of its key initiatives and technical advancements throughout the Korean maritime sector."


# KR Specialists Appointed as Expert Committee Members of the Presidential Advisory Council on Science and Technology

JANG Hwasup, General Manager of the KR AI Convergence Center, and ROH Gilltae, Principal Surveyor of the KR Alternative Fuel Technology Research Team, have been appointed as members of the Expert Committee under the Presidential Advisory Council on Science and Technology (PACST). Both appointments are for a two-year term ending January 2027.

The Expert Committee plays a crucial role in reviewing government R&D investment directions, developing technology investment strategies, evaluating budgets, and providing expert consultation on various research and development policies.

JANG Hwasup has been with the KR Research Division since 2010, where he has directed numerous digital technology developments including autonomous ship navigation and AI convergence solutions. In recognition of his contributions to regulatory innovation for autonomous ship technology, he received the presidential commendation in 2023.

ROH Gilltae, who also joined KR in 2010, has led the development of green ship technologies, particularly in hydrogen and fuel cell power systems on board ships. His achievements have been recognized with the Busan Metropolitan City Clean Energy Award in 2020 and a commendation from the Minister of Trade, Industry and Energy in 2023.

KR expects that these appointments will provide significant opportunities to contribute to national science and technology advancement and research development policies. KR remains committed to leading innovation in the maritime industry through autonomous shipping, green ship technologies, and sustainable maritime industry development.

In keeping with our passion for the protection of the natural environment, KR offers survey and certification services for renewable energies, including wind and ocean power. KR is continuously working on new and innovative green ship technologies to reduce emissions and fuel usage, using these advances to enable our customers to meet their environmental goals.

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