PACIFIC ENVIRONMENT

NATIONAL KOREA MARITIME & OCEAN UNIVERSITY

GSTL Green Ship Technology Laboratory

REPUBLIC OF KOREA COUNTRY REPORT
EXECUTIVE SUMMARY AND POLICY RECOMMENDATION



Policy Analysis Report on Decarbonization Transition in Republic of Korea's Shipbuilding and Shipping Industries



Contents

CHAPTER Ⅰ Introduction

CHAPTER Ⅱ Geen Ship Fuel Transition Policy

CHAPTER Ⅲ Financial Policy for Green Fuel Transition

CHAPTER Ⅳ Analysis of Target Routes & ESG Management

CHAPTER Ⅴ Results of TCO Modeling Study

CHAPTER Ⅵ Recommendations for Green Fuel Transition

Q&A

Background, Methodology

IMO GHG Strategy & Mid-term Measures

- **2050 Net Zero Ambition:** Mandates steep reduction in GHG Fuel Intensity (GFI) and Zero or Near-Zero (ZNZ) fuel adoption.
- **Technical + Economic Measures (NZF):** Dual-tier Regulation Units (RU1 / RU2 penalties) alongside Surplus Units (SU) trading and ZNZ rewards.
- **Current Impasse:** Political uncertainties (e.g. US Administration opposition) delaying NZF adoption, generating high strategic risks for lines.

Regional Regulations (EU-ETS & FuelEU Maritime)

- **EU-ETS(fr. 2024):** Phase-in carbon allowance purchases required for EU-calling voyages.
- **FuelEU Maritime(fr. 2025):** Strict Well-to-Wake (WtW) GHG intensity limits with high penalty rates (€2,400/t VLSFOeq).

NATIONAL KOREA MARITIME & OCEAN UNIVERSITY

UCL

RMI ENERGY. TRANSFORMED.

Research Conducted by: KMOU GSTL / UCL / RMI

2.89%

GLOBAL CO_2 SHARE FROM MARITIME SHIPPING (1.06B ton)

TCO modeling considering Regulatory Delay

- Multiple highly probable implementation scenarios at present are established and compared for governments and shipowners.
- Key representative routes linked to Korea's main trade and raw material supply chains.
- TCO modeling is performed for each route based on distance, voyage days, cargo, ports of call, vessel size, and GHG emissions.

Key Findings: Regulatory Delay Cost

- Delayed Fleet Renewal (2029 vs. 2032 Deliv.): +33% to +97% Higher Lifetime TCO
- Modeling Clarification:
  - A vessel built in 2032 under a Delayed IMO scenario exhibits essentially the same TCO as a vessel built in 2032 under the IMO As-Is scenario.
  - The observed +33% to +97% TCO increase reflects the inherent cost premiums of delaying investment decisions from 2029 to 2032—driven by capital cost inflation, projected fuel price escalation, and entering into significantly tighter GFI reduction baselines at the year of delivery.

Background, Methodology

TCO(Total Cost of Ownership) Analysis

- **The present value of the total costs incurred over the vessel's lifetime**
- Net Present Value (NPV) is a financial evaluation concept used to compare future cash flows on a consistent present-value basis. In vessel lifecycle analysis, future cash flows—including **initial capital expenditure (CAPEX), fuel costs, operation and maintenance costs, and regulatory compliance costs**—are discounted to their value at a specified base date.

NPV(Net Present Value)

- **Time Value of Money:** KRW 1 million today is worth more than the same amount received in the future. NPV applies a discount rate (cost of capital) to future cash flows, converting them into present values to enable consistent and accurate comparison.
- **Value Creation:** NPV > 0 indicates that the investment creates economic value, whereas NPV < 0 indicates that the investment results in a loss in value.
- I**nvestment Decision Criterion:** When comparing multiple investment alternatives, projects with NPV > 0 are considered economically viable. All else being equal, the alternative with the highest NPV is generally preferred.

WACC(Weighted Average Cost of Capital)

- The weighted average required return on equity and debt, based on their respective shares in the capital structure.
- **Represents the minimum average return required by shareholders and lenders when a company raises capital for investment.**
- **Used as a discount rate reflecting the opportunity cost of capital in investment appraisal.**

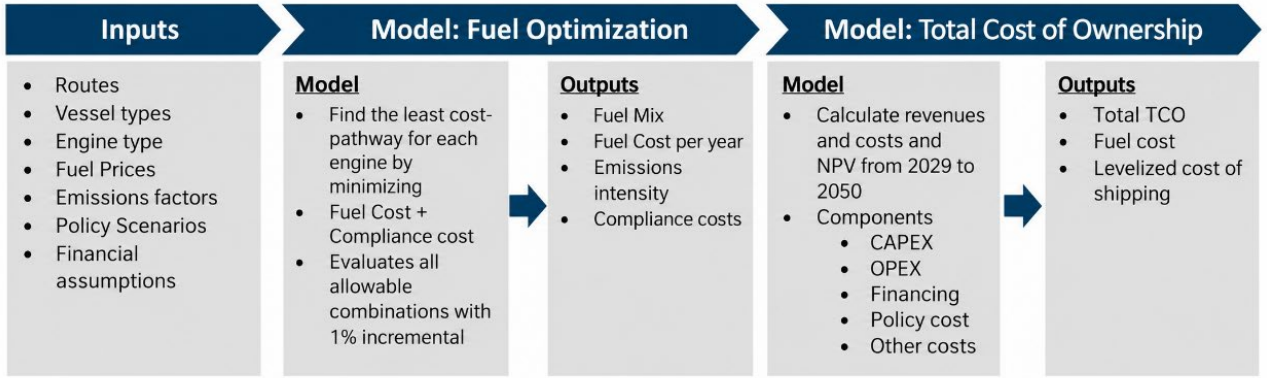
$$NPV = \sum_{t=0}^{n} \frac{C_{Ft}}{(1+WACC)^t} - C_0$$

- C_{Ft} ; Future Cash Flow at Time t (Inflows − Outflows)
- $WACC$; Weighted Average Cost of Capital(%)
- C_0 ; Initial Investment Cost

$$WACC = (E/V) * K_e + (D/V) * K_d * (1 - T_c)$$

- E (Equity): Market Value of Equity
- D (Debt): Market Value of Debt
- V : Total Capital Value $(V = E + D)$
- Ke : Cost of Equity(Expected Return req. by Shareholder)
- Kd : Cost of Debt(Borrowing Interest Rate)
- Tc : Corporate Tax Rate

Overview of TCO Modeling



ROK Policy Framework; Greenship-K(2021~2030)

2030 Greenship-K Master Plan

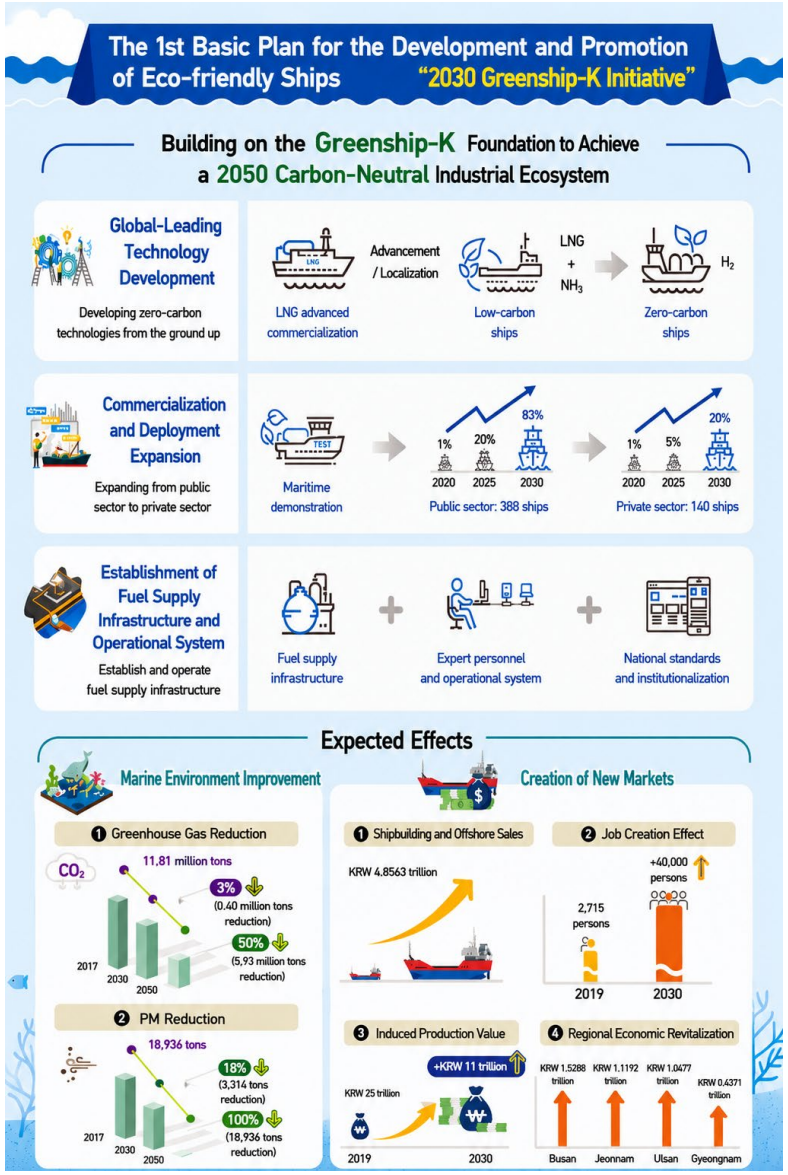
- **GHG reduction Tech. target:** 70% reduction Tech. in GHG emissions by 2030 (40% by 2025).
- **Fleet Conversion Goal:** 15% vessels(528(388+140) vessels out of 3,542 target fleet) by 2030.
- **Public Sector Leadership:** 388 public vessels out of 467 leading early adoption (LNG, Hybrid, All-Electric).
- **Private Sector Diffusion:** Subsidies and credit guarantees targeting 140 (out of 3,075) commercial ocean-going & coastal vessels).
- **Eco-Friendly Equipment:** Target 90% localization rate for green ship equipment by 2030.

Fuel Supply & Port Infrastructure

- **LNG Bunkering Capacity:** LNG bunkering scale from 350k tons('20) to 700K('25)/ 1.4M tons by 2030.
- **Alternative Maritime Power(AMP):** Expand shore power berths from 21('20) to 174('25)/248('30) units.
- **Green Fuel Hubs:** Designating Ulsan ports as regional Green Methanol & LNG bunkering hubs.

Gap Identified

Current annual budgets (~KRW 222.3B/year for 81 vessels, 2025) and direct subsidies cover **less than 11%** (KRW 5.5 Trillion) of total ROK fleet conversion requirements (KRW 49-55 Trillion), necessitating private finance mobilization.



ROK Policy Framework; The 2nd Greenship-K(2026~2035)

The 2nd Basic Plan for the Development and Deployment of Eco-Friendly Ships (2026–2035), announced in August 2026

- The 2nd Basic Plan for Eco-Friendly Ships (2026–2035) is a joint mid- to long-term strategy by the Ministry of Trade and Industry and the Ministry of Oceans and Fisheries, aimed at accelerating the commercialization and deployment of eco-friendly ships and fostering the joint growth of Korea's shipbuilding and shipping industries.
- **Vision: "Greenship-K 2035: Advancing Super-Gap Shipbuilding and Climate-Friendly Green Shipping"** With shipbuilding and shipping as the two key policy pillars, the Plan aims to strengthen the competitiveness of the eco-friendly ship industry while accelerating the shipping sector's transition toward carbon neutrality.

Policy Goals

- **Shipbuilding:** Aim to become a global leader in advanced eco-friendly shipbuilding through super-gap technologies, targeting a 25% share of the global shipbuilding market and 50% of the zero-carbon ship market by 2035. Expand Korea's existing LNG-based competitiveness into next-generation green technologies, including zero-carbon fuels such as hydrogen and ammonia, as well as electric and hybrid propulsion.
- **Shipping:** Aim to establish Korea as a leading green shipping nation through the transition to a carbon-neutral fleet, targeting:
  - 61% GHG reduction by 2035 vs. 2008 for the Korean ocean-going fleet
  - 20.2% GHG reduction by 2035 vs. 2018 under the national NDC shipping target
- **Integrated Policy Approach:** Link green ship technology development and commercialization, clean fuel supply infrastructure, and fleet transition to simultaneously strengthen the future competitiveness of Korea's shipbuilding industry and achieve substantial GHG reductions in shipping.

Vision	Greenship–K 2035, Advancing Super–Gap Shipbuilding and Climate–Friendly Green Shipping
Policy Goal	(Shipbuilding) Lead in Advanced Green ship building with Super-Gap Technologies (25% of Global Shipbuilding / 50% of Zero-Carbon Ship Market) (Shipping)Lead Green Shipping with a Carbon-Neutral Fleet (61% GHG Reduction by 2035 vs. 2008 – Korean Ocean-Going Fleet) (20.2% GHG Reduction by 2035 vs. 2018 – NDC Shipping Target)

5 Key Strategy	13 Key Implementation Tasks
1. R&D for Advanced Low-Carbon Ships	Secure Super-Gap Tech. for Zero-Carbon Fuelled Ships Advance Ship Technologies through Localization of Multi-Fuel Equipment Secure Core Technologies for Carbon-Neutral and Green Energy Caniers
2. Commercialization Support for New Tech.	Onshore and Offshore Testing for Core Technology Validation Enhanced Commercialization Support for Domestic Technologies
3. Expansion of Green Fuel Supply Infrastructure	Expand Low-Carbon Fuel Supply Infrastructure Establish Zero-Carbon Fuel Supply Infrastructure
4. Promotion of Eco-Friendly ship Deployment	Expand Eco-Friendly Ship Deployment in Domestic Shipping Expand Eco-Friendly Ship Deployment in International Shipping Advance Eco-Friendly Ship Conversion in the Public Sector
5. Develop. of Green Shipping & Shipbuilding Ecosystem	Create Favourable Investment Conditions for Green Shipping Establish a Training System for Safe Operations and Skilled Personnel Establish a Full-Lifecycle Carbon Emissions Management System

Green Shipping Corridor

ROK-US Transpacific Corridor

- **Target Routes:** Busan(CNTR)/Ulsan(PCTC) ↔ USWC (Seattle, Tacoma).
- **Vessel Scope:** 13,000 TEU Container Vessels (HMM) & PCTC (GLOVIS).
- **Fuel Pathway:** Green Methanol deployment target by 2027.

Note: Draft Enforcement Decree and Enforcement Rules are currently under legislative notice as of September 2026, ahead of the Special Act on Supporting Green Shipping Corridors, scheduled to take effect in April 2027.

ROK-Australia Raw Material Corridor(MOU)

- **Target Routes:** Australia ↔ ROK
- **ROK–Australia Partnership:** Started a joint pre-feasibility study to establish a z ero-emission Green Shipping Corridor(Feb. 2025)
- **Roadmap:** Deployment target by 2029

Corridor Advantage: Fixed shuttle routes (COA) allow fuel bunkering infrastructure to be built at just two end ports, drastically lowering infrastructure risk.

< 2027 Operation Target, Co-operation for Trans-Pasific ROK-US Green Shipping Corridor Establishment >

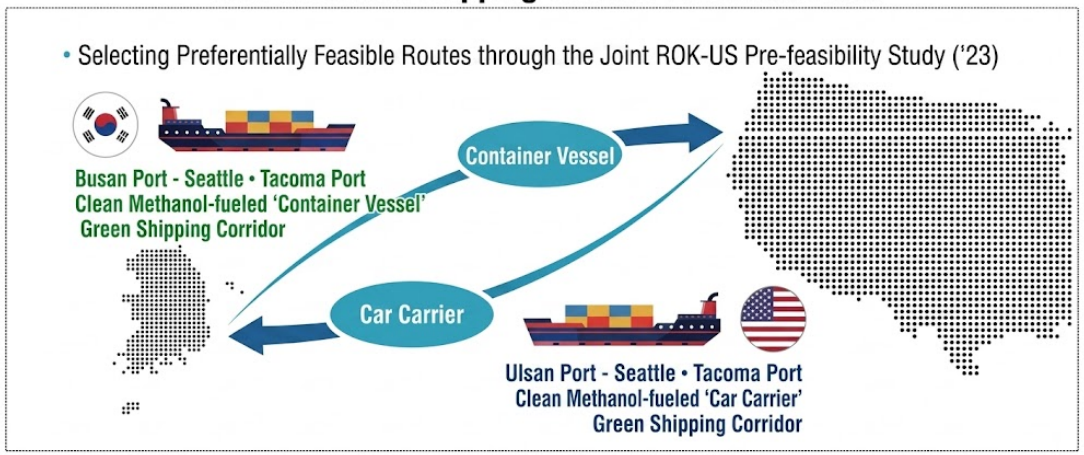




Photo ; 180K LNGDF BC (ROK-Australia) by Greenship-K program / POSCO Chartered

ROK Financial Policy

Policy Support Program	Scale (KRW)	Key Mechanism & Objective	Target Fleet Scope
Maritime Management Safety Net	Abt. 3.0 Trillion	Crisis response fund, special support for mid-small carriers	SME Carriers
Management Stability and Vitality Injection	Abt. 3.5 Trillion	Support for Eco-friendly Newbuilding, Public Shipowner Business, Bunkering Infrastructure Fund, etc.	Mixed
Eco-friendly Ship Newbuilding Support Package	Abt. 5.5 Trillion	Focus on Eco-friendly Newbuilding	Ocean-going Newbuilds
Cumulative Policy Support Size	**Abt. 6.5 Trillion**	Combined ROK Government & KOBC Financial Interventions (Sum of the 2022 measure and the 2024 Additional measure)	Nationwide Fleet

Note: Each figure is based on the data compilation method of public materials from the Ministry of Oceans and Fisheries and Policy Briefing, and classification by policy objective and classification by announcement timing may be intermingled.

KOBC Financial Programs

- **Co-Investment Program:** Joint equity/debenture investment with KDB (excl. containers).
- **Global Low-Carbon Vessel Subsidy:** Direct government grant integration via K OMSA green certification(For new builing) .
- **Retrofit Interest Subsidies:** Interest gap support & guarantees for ESTs (Shaft Gen, EPL, etc.).

Demand vs. Supply Gap

Replacing 605 aging/CII D-E vessels by 2030 requires **KRW 49-55 Trillion**.

Current policy funding covers ~10-11%. Government funds must act as catalytic first-loss capital to leverage private institutional capital.

Structural Financial Handicap; ROK Vs. Japan WACC

Empirical financial parameter analysis reveals that ROK shipping lines shows a relative capital cost disadvantage compared to Japanese company, dictating completely different green investment pathways.

Financial Parameter	Korea (ROK)	Japan (JPN)	Disparity / Impact Analysis
Weighted Average Cost of Capital (WACC)	**9.40%**	**4.30%**	**ROK 5.10% Higher** (Increases annual debt service)
Cost of Debt (Kd)	5.33%	1.35%	ROK interest rates & risk premiums higher
Cost of Equity (Ke)	11.27%	6.00%	High equity hurdle rate limits long-term CAPEX payoff
Target Internal Rate of Return (IRR)	13.25%	10.00%	Higher investment hurdle rate for ROK green newbuilds
Tax Depreciation Schedule	10-yr Declining (25.9%)	15-yr Straight-line	ROK tax structure favors early CAPEX tax shield

Strategic Consequence of WACC Gap: High WACC makes ROK lines averse to high initial CAPEX with FuelEX(Direct Ammonia/Methanol newbuilds). ROK lines rationally prefer Fossil base fuel(**LNG DF) Newbuilding or Retrofit Pathways (Deferring Initial CAPEX)**, whereas Japanese lines (WACC 4.3%) can afford direct Ammonia/Methanol newbuilds.

Note ; Parts originating from interest rate and currency differentials are difficult to improve through domestic financial policies alone.

Note ; WACC levels in China and the United States are approximately 5% and 7%, respectively, both lower than the domestic financing WACC in Korea.

GREEN VESSEL CERTIFICATION & SUBSIDY

Certification Tier & Subsidy Rates (2025) / KOBC

Ship price	Grade 1	Grade 2	Grade 3
<20B KRW	30%	29%	28%
20B-30B KRW	20%	18%	16%
≥30B KRW	10%	8%	6%

⚠ Large Vessel Disincentive: Ocean-going vessels (>30B KRW) receive ≤10% subsidy, which is insufficient to cover the Green CAPEX premium.

Policy Restructuring Directives

- **Subsidy Calculation Framework:** Expand beyond vessel price to comprehensi vely incorporate projected GHG reduction
- **Differentiated Support Strategies by Carrier Size:** Customized based on carrier scale and operation type—providing long-term financing and newbuild support for major carriers, while focusing on retrofits, guarantees, and interest subsidies for small-to-medium carriers



CHEONGHWA 2nd (LNG DF, PORT CLEANGIN / ULSAN)



ECONURI(LNG DF,PORT PATROL/ INCHEON)



13k TEU LNGDF Container (HMM)



10k CEU LNGDF PCTC (HYUNDAI GLOVIS)

STRATEGIC PROFILE OF ROK CORE TRADE ROUTE

USWC Container

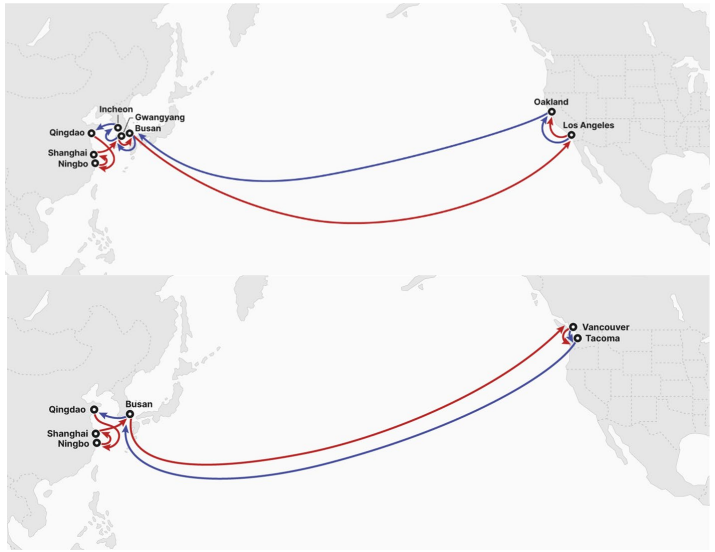
- **Fleet:** 13k-15k TEU Neo-Panamax (HMM, SM Line).
- **Volume & Emissions:** >30% of ROK container volume; **20.59M tCO_2/yr**.
- **Operation:** 15.2 knots, 11-13 days to US West C oast.
- **Fuel Readiness:** High; LNG STS bunkering active in Long Beach, Green Methanol trial 2027.

USWC PCTC (Car Carrier)

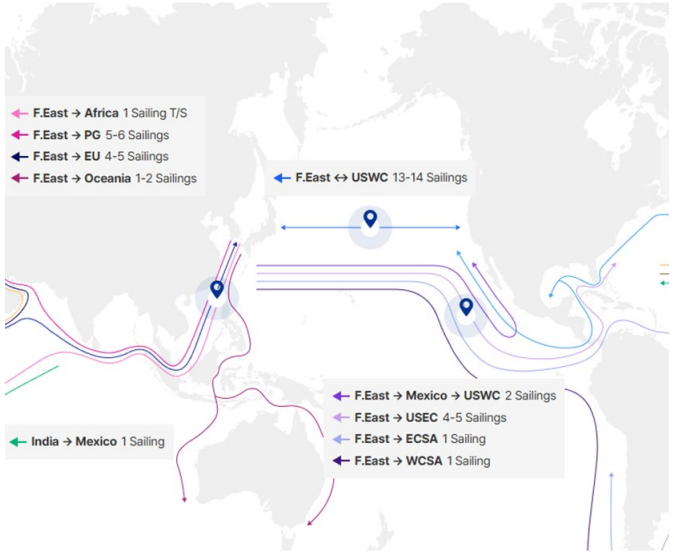
- **Fleet:** 7,000-10,800 CEU PCTC (GLOVIS, EUKOR, H-Line).
- **Volume & Emissions:** ~180 voyages/yr; **0.80M tCO_2/yr**.
- **Operation:** 15.4 knots, tri-angular routing to min imize ballast.
- **Fuel Readiness:** High PCTC orderbook for LNG DF & Ammonia-Ready PCTC; Scope 3 pressure from automakers.

Australia Bulk

- **Fleet:** 180k-210k DWT Capesize/Newcastlemax.
- **Volume & Emissions:** ~70% ROK iron ore import (50M+ tons/yr); **1.20M tCO_2/yr**.
- **Shuttle Operation:** 28-32 dedicated vessels, 30-35 day roundtrip.
- **Fuel Readiness:** Ideal for Green Ammonia Corrid or (Fortescue-POSCO partnership).



HMM PS6(Pacific South Express) / PN3(Pacific Northwest Express) Route



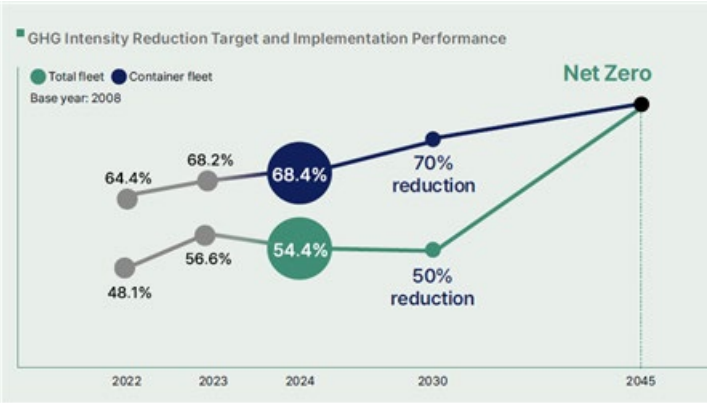
HYUNDAI GLOVISS FAR EAST – USWC Route



ROK-Australia iron ore route

ESG & FLEET DECARBONIZATION BENCHMARKING

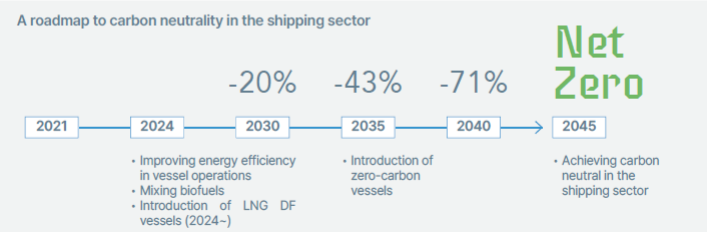
Company	Target Year	Primary Fuel Strategy	Newbuild & Fleet Orderbook	Digital & ESG Innovation
HMM	2045 Net-Zero	LNG DF, Methanol DF, Bio-fuel (Mass Balance)	9 x 9k TEU Methanol DF, 12 x 13k TEU LNG DF (Total 21 Green DF) + 2 x 7.7K LNG DF Charte r	Fleet Operation Center, Green Sailing Service for Scope 3
HYUNDAI GLOVIS	2045 Net-Zero	LNG DF, B100 Bio-fuel, Ammonia/ Methanol Ready	20 x LNG DF PCTC by 2028 (incl. 6 x 10,800 CEU Ammonia-Ready)	AI Autonomous Navigation, ESI Port Participation (62 ships)
EUKOR / W.Wilhelmsen	2040 Net-Zero	Methanol DF, Ammonia Ready, Bio-fuel B100	14 x Shaper-Class PCTC (9,300-12,100 CEU Methanol/Ammonia Ready)	Wind Propulsion (Tirranna), Digital Emission Bank, Shadow Carbo n Price ($70.7/t)
Pan Ocean	2050 Net-Zero	LNG Carriers, Bio-fuel, Future Ammonia/CCUS	Total 12, 174k LNG Carriers & 18k LNG Bunkering vessels ($2.09B)	Fleet Operation e-Center, OceanWise AI Carbon Prediction, ALS/PBCF retrofits



GHG Reduction Target, HMM 2025 ESG REPORT

Carbon neutrality implementation plan in the shipping sector

- Established a carbon neutrality target for 2045, five years ahead of the IMO's 2050 decarbonization goal for international shipping
  - Short term : Improving energy efficiency in vessel operations, Mixing biofuels, Introducing LNG DF vessels
  - Mid- to long-term : Transitioning to zero-carbon fuels such as electro-synthetic fuel, ammonia, and hydrogen



GHG Reduction Target, HYUNDAI GLOVIS 2025 ESG REPORT

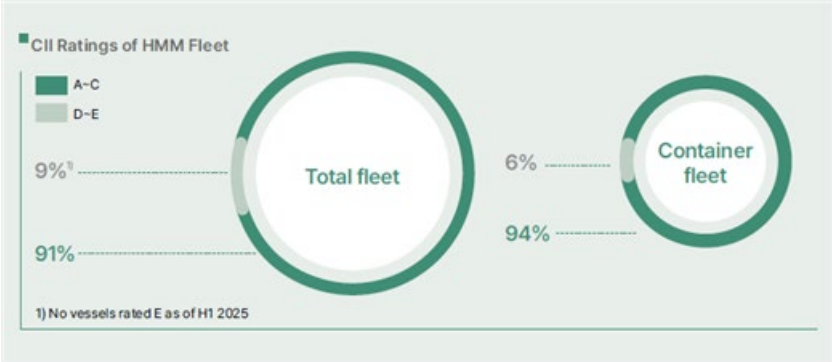
Science-based climate targets	Target scope	2022 Baseline value	2030 Target	2030 Target value	2035 Target	2035 Target value	2040 Target	2040 Target value
Reduce absolute scope 1 GHG emissions from logistics operations	Scope 1	28,299	42 %	16,143	66 %	9,621	90.0 %	2,830
Reduce intensity scope 1 and 3 (Well-to-wake) GHG emissions from shipping operations	Scope 1+3	5,264,144	40 %	3,159,975	79 %	1,082,437	96.4 %	188,545
Reduce intensity scope 1 and 3 (Well-to-wake) GHG emissions from shipping operations per tonne nautical mile	Scope 1+3	66.55	44 %	37.28	82 %	12.33	97.1 %	1.95
Increase active annual sourcing of renewable electricity	Scope 2	7 %	100 %	0	N/A	N/A	N/A	N/A
Reduce remaining absolute scope 3 GHG emissions	Scope 3	204,022	N/A	N/A	46 %	109,797	90 %	20,372

GHG Reduction Target base don SBTi, EUKOR / W.Wilhelmsen

ESG & FLEET DECARBONIZATION BENCHMARKING

Company	Carbon Emission Management Framework	Low-Carbon Services for Cargo Owners	ESG & Regulatory Participation
HMM	EEDI, EEXI, EEOI, and CII; Preparing for future WtW GHG Intensity regulations	Operating Green Sailing Service; Utilizing Bio-fuel reductions for cargo owners' Scope 3 reduction	Achieved CDP Climate Change A- rating; Established ESG disclosure & regulatory compliance framework
HYUNDAI GLOVIS	Advanced MRV, CII management, and establishing foundation for GFI compliance	Expanding supply chain carbon management and customer support services	CDP Climate Change Leadership A, participating in TCFD and ESI
EUKOR / W.Wilhelmsen	Managing per-vessel emissions based on EE OI, CII, and Digital Emission Bank	Operating Reduced Carbon Service; Providing reduction based on ISCC-EU certified Bio-fuel	SBTi-verified targets, Internal Carbon Pricing, Sustainable Finance, participating in First Movers Coalition
Pan Ocean	Advanced management of Scope 1–3 emissions, IMO DCS, EU MRV, and EEOI	Focused on operational efficiency and ESG disclosure rather than explicit services	Achieved CDP Climate Change B rating; Operating ESG Committee & ESG Task Force

Common Industry Directions: (1) Dual-Fuel newbuildings, (2) AI digital route optimization, (3) Energy Saving Technologies (EST) retrofits, and (4) Providing Scope 3 carbon certificates to charterers.



CII Fleet management, HMM 2025 ESG REPORT



EST(WAPS) , HMM 2025



EPLO(Engine Part load Optimization), GLOVIS / EUKOR, 2025

TCO RESEARCH: MODELING FRAMEWORK & SCENARIOS

To evaluate the Lifetime TCO (2029-2050 NPV), three distinct global regulatory scenarios were modeled in partnership with UCL and RMI.

Scenario 1: IMO As-Is

ADOPTION 2026 / START 2029

- IMO NZF GFI trajectory enforced as planned.
- RU1 ($100/t) & Tier 2 RU2 ($380/t to 1.1 x Bio-MGO cost).
- SU trading & ZNZ rewards active globally.

Scenario 2: Delayed IMO

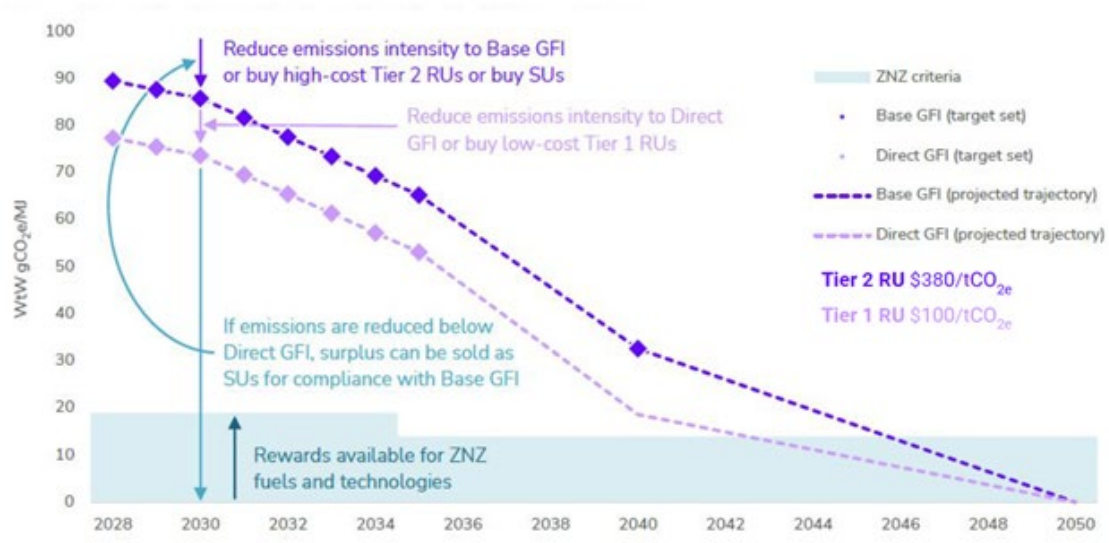
ADOPTION 2029 / START 2032

- Political impasse delays NZF start by 3 years.
- Vessels enter straight into steeper 2032 GFI reduction targets.
- Higher cumulative penalty exposure for fossil ships.

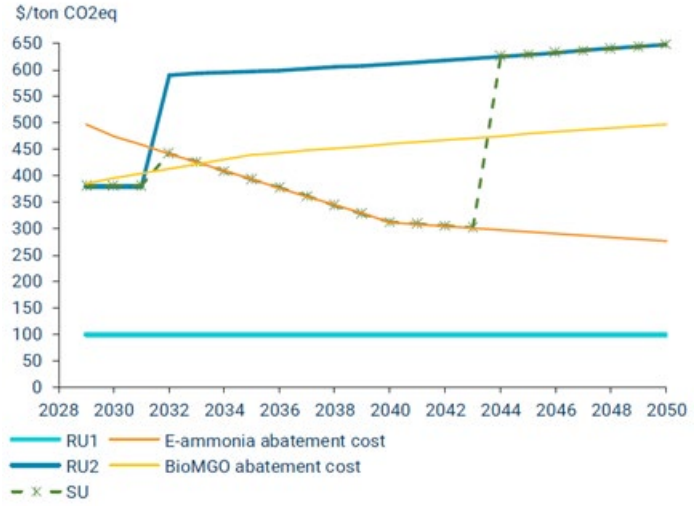
Scenario 3: EU-ETS / FuelEU

REGIONAL POLICY ONLY

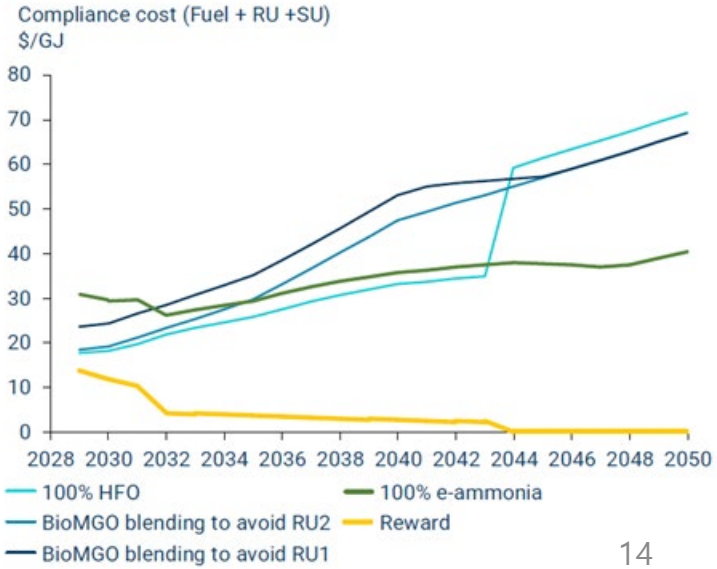
- Global IMO NZF fails completely.
- FuelEU Maritime WtW limits & EU-ETS GHG price apply on EU voyages (100% EEA / 50% sco pe out of EEA).
- Bio-MGO favored over e-fuels.



IMO GHG Reduction projection



RU Penalty and SU price settings



ZNZ Reward Level settings

TCO RESULT: CONTAINER, PCTC & ORE CARRIER

Ship Type & Route	Conventional (LSFO)	LNG Dual Fuel	LNG to NH_3 Retrofit	Ammonia DF	Methanol DF
ROK-USWC Container (13k TEU)	+38.98%	+23.29%	-3.81%	-21.01%	-28.12%
ROK-USWC PCTC (7.5k CEU)	+33.43%	+19.56%	-4.16%	-20.50%	-25.80%
ROK-Australia Ore Carrier (180k DWT)	+36.32%	+19.47%	-3.93%	-20.84%	-26.27%

*Note: Percentages reflect TCO change vs Baseline No-Policy under Scenario 1 (IMO As-Is).

Percentage change in TCO relative to no-policy baselines

Largest increase in TCO relative to baseline ← → Largest reduction in TCO relative to baseline

	Conventional		LNG DF	
	IMO as it is	Delayed IMO	IMO as it is	Delayed IMO
Container				
Korea - US West	38.98%	54.16%	23.29%	33.98%
Nagoya - Los Angeles	75.89%	97.58%	50.25%	66.84%
Nagoya - Shanghai	64.76%	82.99%	39.26%	54.71%
PCTC				
Korea - US West	33.43%	46.37%	19.56%	28.53%
Kobe - Mid East	57.54%	73.60%	36.63%	51.51%
Nagoya - Zeebrugge	48.71%	61.09%	30.02%	42.96%
Bulk Carrier				
Korea - Newcastle	36.32%	50.47%	19.47%	28.38%
Nagoya-Pot Walcott	57.65%	74.15%	36.32%	50.68%
Nagoya - Sept-Iles	45.36%	57.92%	27.12%	39.78%

	LNG to NH3 Retrofit		Ammonia DF		Methanol DF	
	IMO as it is	Delayed IMO	IMO as it is	Delayed IMO	IMO as it is	Delayed IMO
Container						
Korea - US West	-3.81%	3.11%	-21.01%	-12.13%	-28.12%	-22.37%
Nagoya - Los Angeles	-3.58%	5.32%	-17.76%	-7.55%	-22.83%	-15.45%
Nagoya - Shanghai	-6.75%	4.78%	-16.19%	-6.93%	-21.14%	-14.27%
PCTC						
Korea - US West	-4.16%	1.87%	-20.50%	-11.91%	-25.80%	-20.58%
Kobe - Mid East	-4.23%	4.54%	-15.66%	-6.92%	-20.36%	-13.73%
Nagoya - Zeebrugge	-3.83%	1.16%	-14.39%	-9.83%	-18.80%	-13.47%
Bulk Carrier						
Korea - Newcastle	-3.93%	2.17%	-20.84%	-12.32%	-26.27%	-20.78%
Nagoya-Pot Walcott	-3.61%	4.52%	-15.34%	-6.58%	-20.11%	-13.52%
Nagoya - Sept-Iles	-3.22%	3.97%	-13.97%	-6.53%	-18.09%	-12.20%

TCO Comparison based on relative NPV change for each fuel case

Key Findings: Regulatory Delay Cost

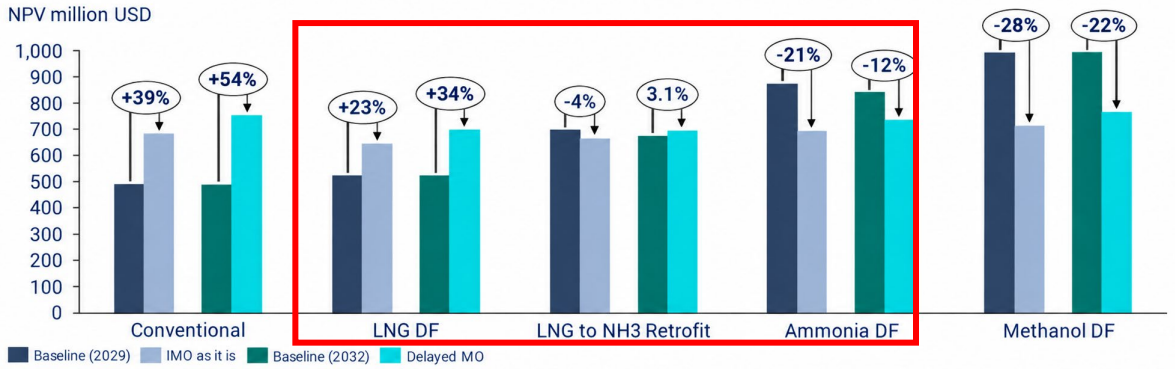
- Postponing Fleet Renewal (2029 vs. 2032 Delivery): +33% to +97% Higher Lifetime TCO
- Modeling Clarification:
  - A vessel built in 2032 under a Delayed IMO scenario exhibits essentially the same TCO as a vessel built in 2032 under the IMO As-Is scenario.
  - The observed +33% to +97% TCO increase reflects the inherent cost premiums of delaying investment decisions from 2029 to 2032—driven by capital cost inflation, projected fuel price escalation, and entering into significantly tighter GFI reduction b aselines at the year of delivery.
- Policy Takeaway:
  - Regulatory delays at the IMO level do not alleviate compliance costs. Postponing fleet renewal exposes shipowners to steeper GFI thresholds upon delivery without the benefit of early-action rewards, strongly reinforcing the need for proactive fleet planning.

Delayed IMO Policy ; +33% to +97% Higher Lifetime TCO for Fossil Fleet

TCO RESULT: CONTAINER & PCTC

ROK-USWC Container (13k TEU)

Total cost of ownership by type of engine

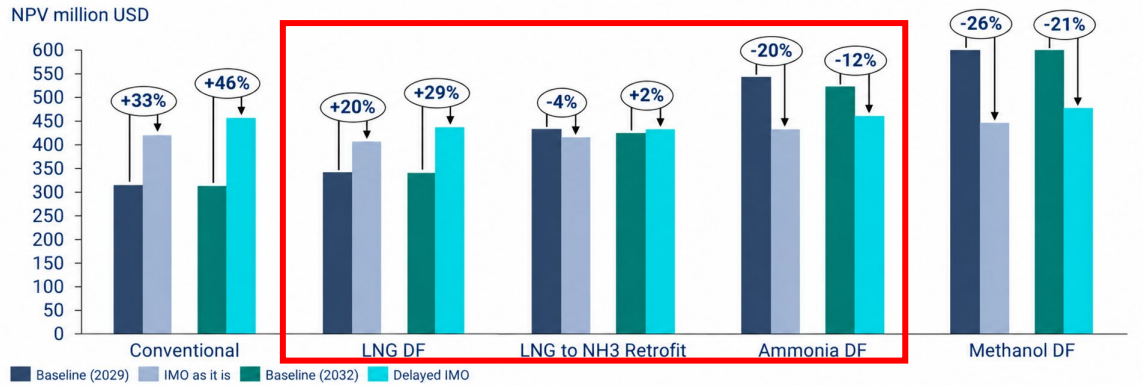


Breakdown of engine cost, NPV million USD

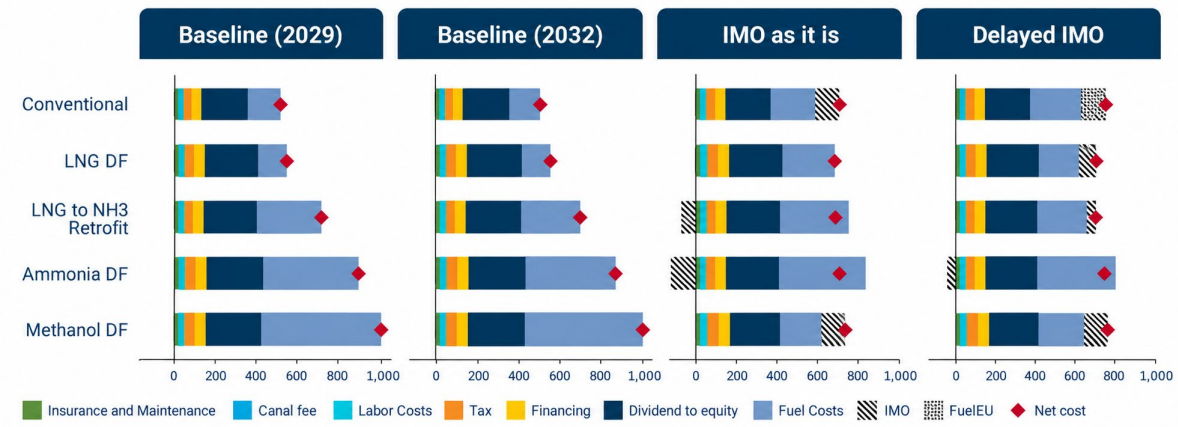


ROK-USWC PCTC (7.5k CEU)

Total cost of ownership by type of engine



Breakdown of engine cost, NPV million USD



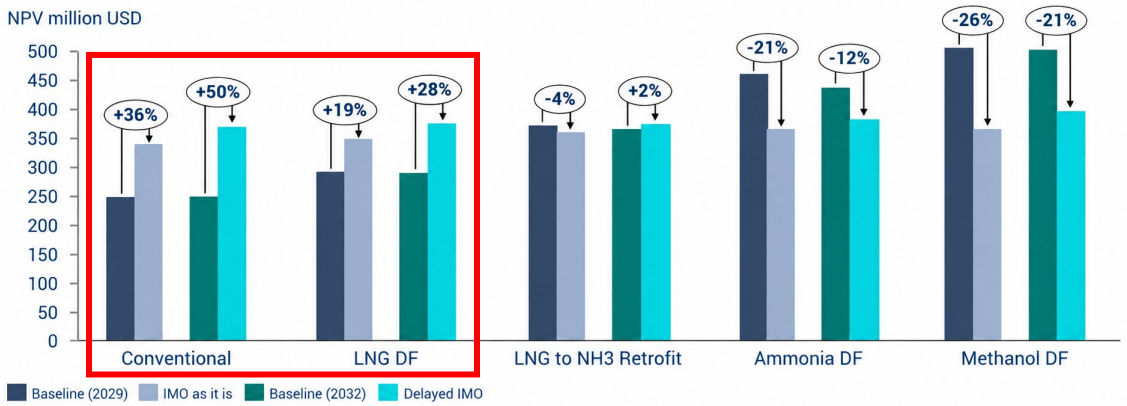
Container & PCTC TCO Dynamics

High fuel consumption makes ZNZ rewards and penalty avoidance the dominant driver. Ammonia DF & LNG-to-Ammonia retrofits provide strong lifetime TCO savings.

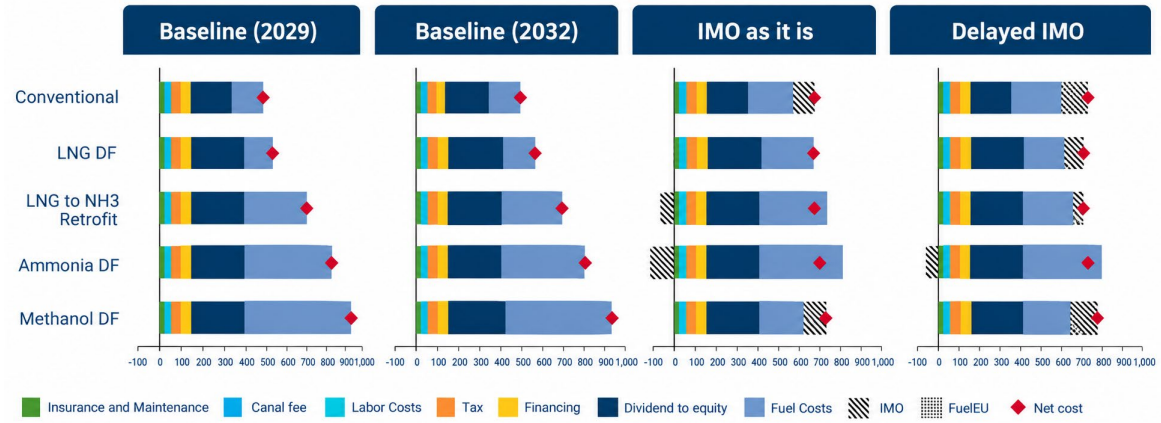
TCO RESULT: ORE CARRIER

ROK-Australia Ore Carrier (180k DWT)

Total cost of ownership by type of engine



Breakdown of engine cost, NPV million USD



TCO Comparison based on absolute NPV change for each fuel case

Percentage change in TCO relative to the lowest-TCO engine option for the respective shipping route

The highest-TCO engine option ← → The lowest-TCO engine option

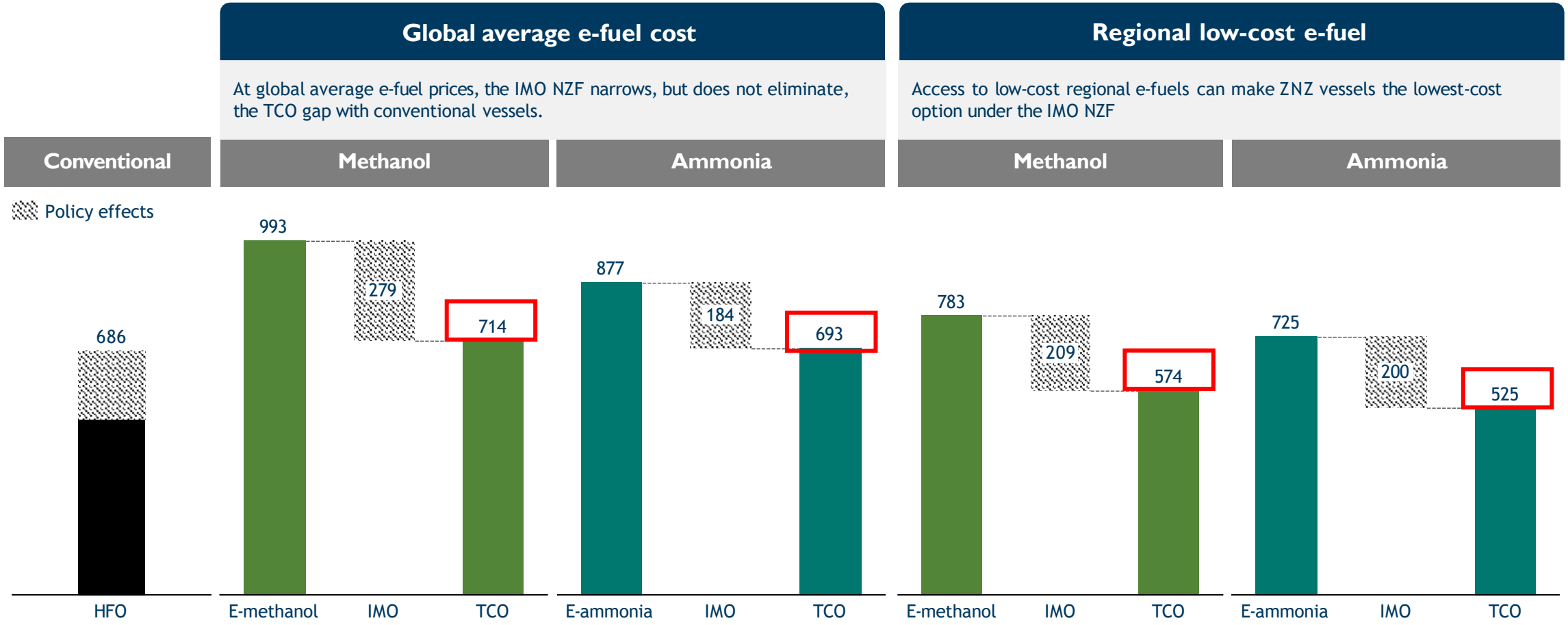
IMO as it is-Baseline blending	Conventional	LNG DF	LNG to NH3	Ammonia DF	Methanol DF
Korea-US west Container	10.21%	3.59%	0.00%	3.42%	18.58%
Korea-US west PCTC	7.62%	3.85%	0.00%	3.89%	17.24%
Korea-Newcastle Bulk Carrier	2.13%	4.19%	0.42%	0.00%	12.06%
Nagoya-Los Angeles Container	39.06%	21.55%	0.30%	0.00%	17.91%
Nagoya-Shanghai Container	34.22%	20.66%	2.88%	0.00%	15.37%
Nagoya-Pot Walcott Bulk Carrier	33.53%	19.16%	0.96%	0.00%	15.21%
Nagoya-Sept-Iles Bulk Carrier	29.44%	17.00%	1.39%	0.00%	12.79%
Kobe-Mid East PCPT	35.41%	19.35%	1.31%	0.00%	15.67%
Nagoya-Zeebrugge PCPT	31.63%	17.62%	1.47%	0.00%	13.83%

IMO as it is-Optimal blending	Conventional	LNG DF	LNG to NH3	Ammonia DF	Methanol DF
Korea-US west Container	6.12%	0.00%	3.34%	7.21%	10.52%
Korea-US west2 PCTC	3.11%	0.00%	2.18%	6.18%	9.42%
Korea-Newcastle Bulk Carrier	0.00%	3.02%	5.60%	4.92%	7.09%
Nagoya-Los Angeles Container	16.27%	0.00%	2.21%	4.40%	13.18%
Nagoya-Shanghai Container	13.23%	0.00%	3.72%	3.72%	11.86%
Nagoya-Pot Walcott Bulk Carrier	14.30%	0.00%	2.26%	4.04%	12.56%
Nagoya-Sept-Iles Bulk Carrier	13.21%	0.00%	2.37%	3.41%	11.50%
Kobe-Mid East PCPT	16.39%	0.00%	2.23%	4.27%	13.64%
Nagoya-Zeebrugge PCPT	14.69%	0.00%	2.25%	3.82%	12.45%

⚠ Ore Carrier Anomaly

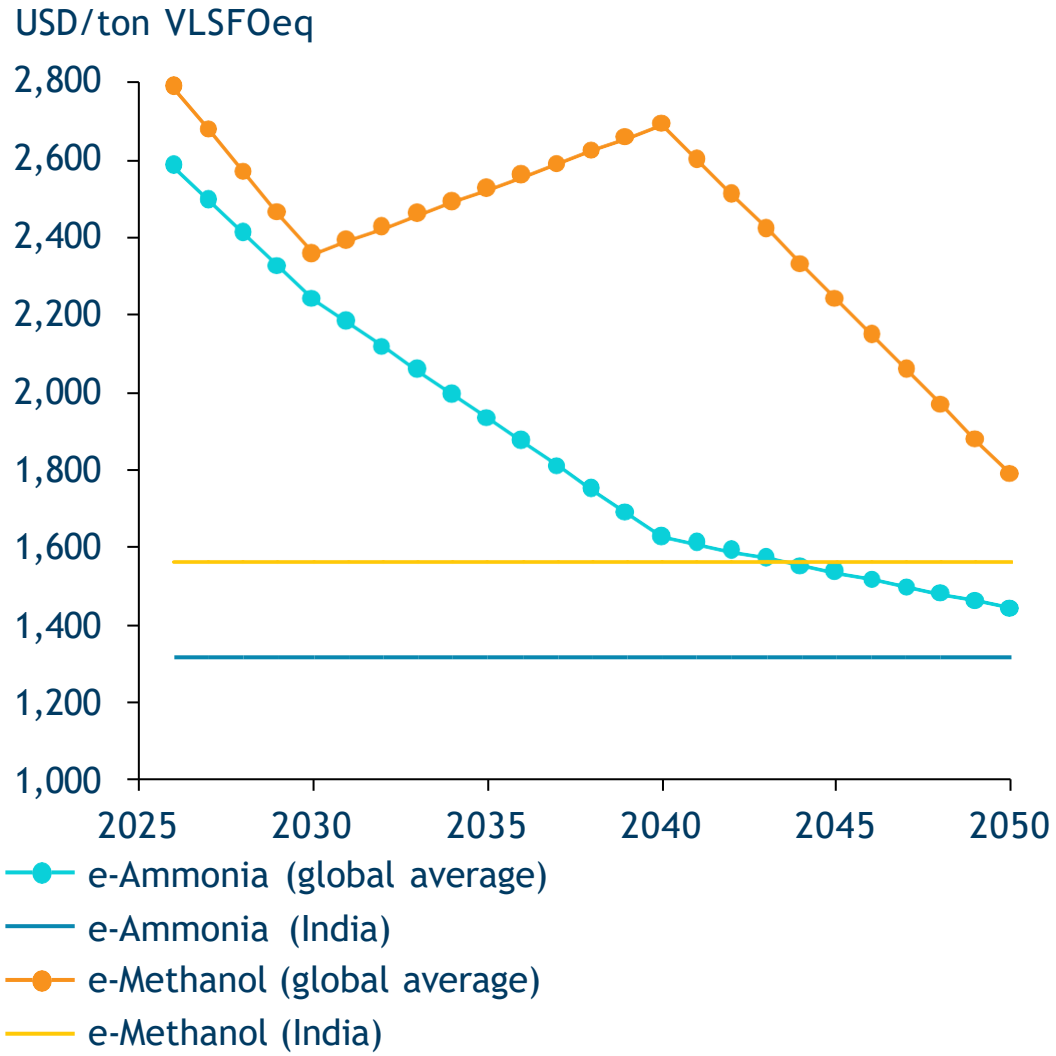
Capesize Bulk carriers have low base ship prices. The high CAPEX premium for DF engines heavily disincentivizes newbuild DF unless subsidized or backed by long-term COAs.

TCO RESULT: Regional Low-Cost e-Fuels(ROK-USWC Container)



Note: Regional cases use molecule-specific production costs rather than a uniform discount to global averages. The GFI target and SU, RU and reward prices remain unchanged, but total policy value varies because fuel prices change the optimal fuel mix and resulting unit volumes. Hatched bars therefore combine direct IMO NZF support and fuel-optimization effects. Ammonia remains lower-TCO in both cases; low-cost regional supply makes both ZNZ pathways competitive. Korea–US West container route shown. **Source:** RMI analysis.

TCO RESULT: Regional Low-Cost e-Fuels(ROK-USWC Container)



Lower-cost e-fuel supply from India is assumed in sensitivity cases to represent a situation in which Republic of Korea and Japan can access e-fuels at prices significantly below the global average. This allows the analysis to assess how the IMO policy affects vessel TCO under such conditions

- e-Ammonia at $32/GJ, approximately $600/ton based on India's record-low green ammonia (e-ammonia) prices discovered in Solar Energy Corporation of India (SECI) auctions, ranging from $580[1] to $641[2] per ton
- e-Methanol at $38/GJ, approximately $750/ton, based on e-methanol project developers quoting FOB India prices in the range of $725 to $1,250 per ton[3]

1. https://fuelcellsworks.com/2025/08/15/clean-energy/jakson-green-wins-india-s-sixth-green-ammonia-tender-with-record-low-50-75-0-58-kg-bid
2. https://ammoniaenergy.org/articles/acme-641-per-ton-for-renewable-ammonia-in-india/
3. https://www.spglobal.com/energy/en/news-research/latest-news/energy-transition/051426-indias-emethanol-push-for-shipping-hobbled-bybio-co2-crunch-price-gap

Shipping company's Operational Fuel Mix Pathway & Practical Constraints

Shipping company's expected approach

Phase 1: 2029 - 2035

Initial compliance via SUs:

- Lines blend low-percentage Bio-MGO or purchase inexpensive SUs from early zero-emission ships.
- LNG DF vessels maximize fossil LNG usage due to low cost.

Phase 2: 2035 - 2043

Bio-LNG & Bio-MGO Drop-in Blending:

- Bio-LNG drop-in becomes the most cost-effective pathway for existing LNG DF fleets.
- 70-100% WtW carbon reduction credited under IMO GFI.

Phase 3: Post-2044

Mandatory e-Fuel Transition:

- SU supply ceases. Steep RU2 penalties force 100% transition to e-Ammonia or e-Methanol.

Bio-LNG Drop-In Value: Chemical identity with fossil LNG allows immediate drop-in without engine modification.
Utilizing ROK domestic biogas infrastructure with Chain of Custody (CoC) certification avoids IMO penalties at lowest CAPEX.

Critical Bottlenecks & Uncertainties

Biofuel Supply Crunch: Recent marine biofuel shortfalls in Rotterdam highlight severe supply bottlenecks created by national renewable mandates.

Multi-Sector Competition: Aviation (SAF) and heavy industry compete for the same sustainable biomass feedstocks, driving up future bio-MGO prices.

SU Market Liquidity: If fewer vessels adopt ZNZ early, SU supply will be scarce, spiking SU market prices well above baseline assumptions.

WACC IMPACT: WHY ROK & JAPAN CHOICES DIVERGE

ROK Situation (WACC 9.4%)

- **High Discount Rate:** Heavily discounts future fuel savings in NPV terms.
- **CAPEX / High fuel price Penalty:** High interest burden makes direct Ammonia /Methanol newbuilding & operation(high upfront CAPEX & FuelEX) financially unviable without subsidies.
- **Optimal ROK Choice: LNG DF Newbuild or LNG-to-Ammonia Retrofit** (Defers CAPEX, leverages immediate cheaper fossil LNG).

Japan Situation (WACC 4.3%)

- **Low Discount Rate:** Future 20-year fuel cost savings fully reflected in NPV.
- **CAPEX Tolerance:** Low debt cost (1.35%) enables direct newbuilding of expens ive Ammonia/Methanol DF vessels.
- **Optimal JPN Choice: Direct Ammonia / Methanol DF Newbuilding**.

Core Insight for ROK Policy: To make ROK lines competitive in green newbuilding, policy MUST lower ROK's Cost of Debt (5.33%) and Equity Risk Premium via government guarantees, bridging the 5.1%p WACC gap with Japan.

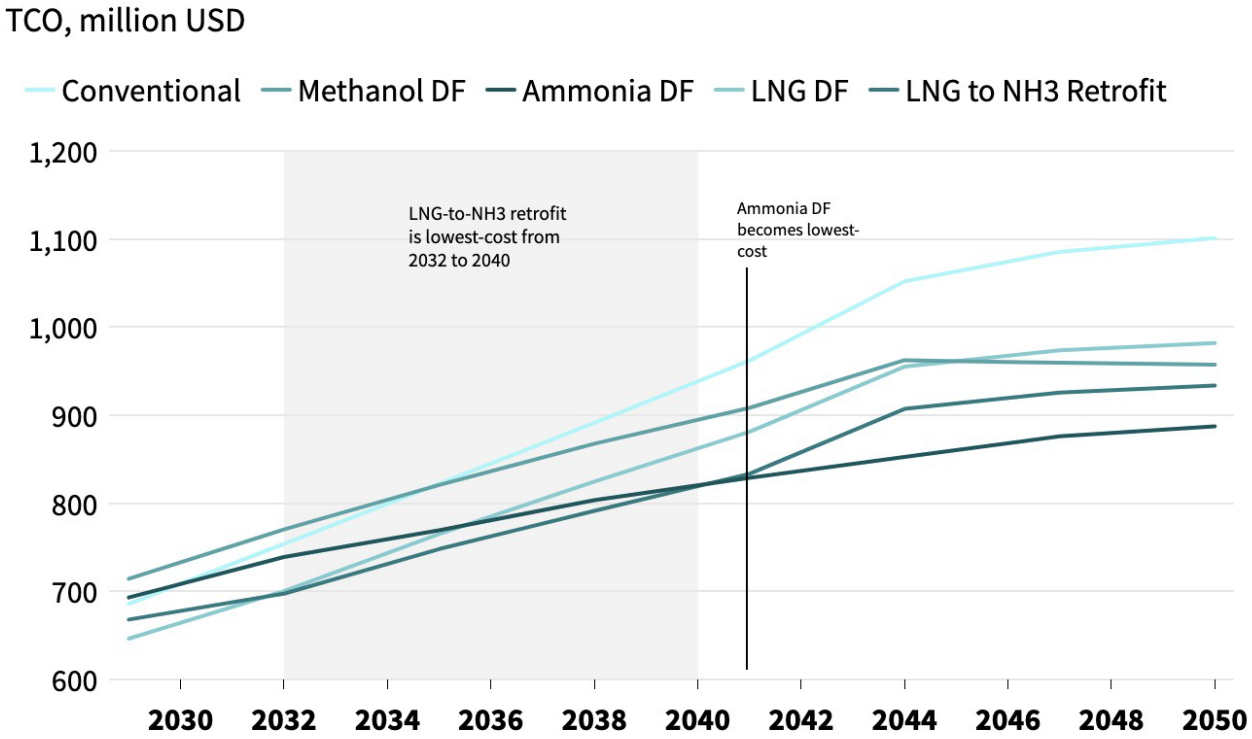


TCO RESULT: ROK-USWC container

The combination of higher capital costs, higher WACC, and accelerated depreciation shifts the cost-optimal transition to ammonia to a later point in time

Korea–USWC container shows the least-cost pathway shifting from LNG DF in 2029, to LNG-to-NH3 retrofit from 2032–2038, and to ammonia DF from 2041 onward

Korea-US West Container, 2029-2050 build years



The Korean archetype financing assumptions result in a later transition than the Japanese example

LNG DF is lowest-cost in 2029 at $646m, before LNG-to-NH3 retrofit becomes the least-cost pathway from 2032 through 2038. Ammonia DF does not become lowest-cost until 2041, indicating a longer period where retrofit-ready assets remain economically relevant.

Retrofit readiness has a wider investment window

The Korea–US West route shows that retrofit-ready strategies can bridge much of the 2030s, reducing the urgency to transition from LNG.

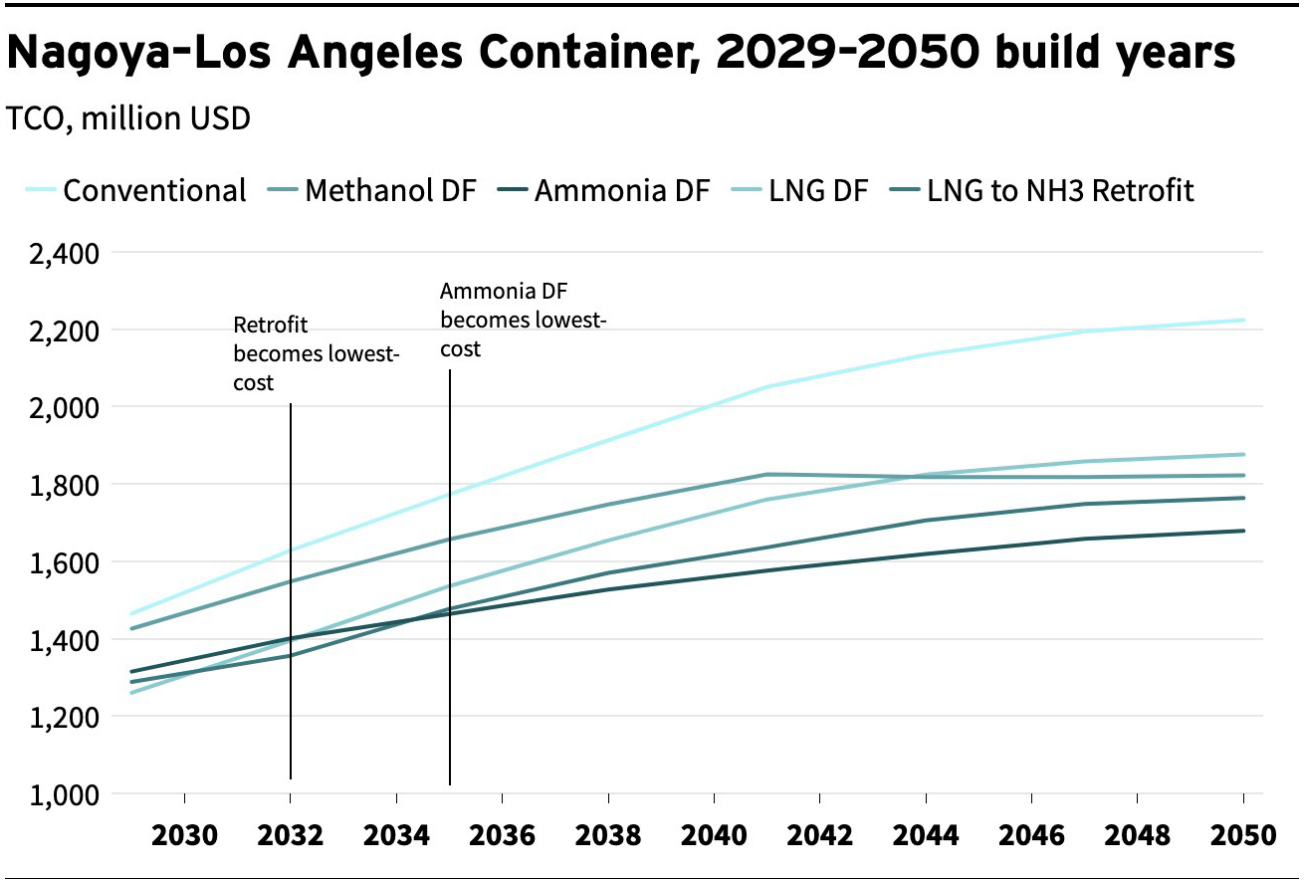
Implications for Republic of Korea

Republic of Korea's representative container route supports a staged investment pathway under the IMO NZF, with near-term flexibility with LNG, retrofit readiness through the 2030s, and lower-GHG newbuilds from the early 2040s such as ammonia and methanol.

TCO RESULT: JAPAN-USWC container

During early years, LNG to ammonia retrofit is the lowest-cost compliance pathway under the IMO NZF framework; the lowest-cost option gradually shifts to newbuilt ammonia engines over time

Nagoya–Los Angeles Container shows the least-cost pathway shifting from LNG DF in 2029, to LNG-to-NH3 retrofit in 2032, and to ammonia DF from 2035 onward



Japanese archetype financing assumptions cause least-cost pathway to change quickly after 2029

LNG DF is lowest-cost pathway after 2029, for a short period. LNG-to-NH3 retrofit becomes the lowest-cost in 2032, with then ammonia DF becoming lowest-cost from 2035 onward.

Retrofit creates a short transition window

The retrofit pathway has value in the early 2030s because it preserves near-term flexibility while delaying part of the compliance cost. By 2035, however, the economics shift toward ammonia DF.

Implications for Japan

For the representative Japan container route, the transition-ready window is relatively short. Vessel strategies that rely on near-term flexibility need a credible path to lower-GHG operation by the mid-2030s to remain cost-competitive.

Summary of TCO modeling

IMO NZF creates a consistent pathway signal across routes, reducing the burden of transitioning to ZNZ fuels while incr easing the cost of incumbent fossil fuel pathways.

% change versus each route-pathway's own no-IMO baseline

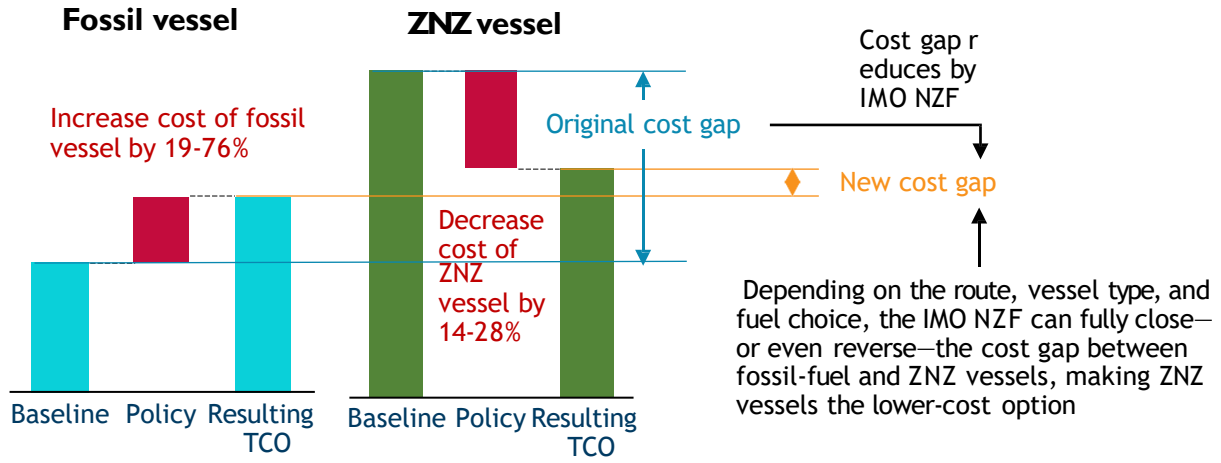
2029 newbuilds under IMO NZF adopted in 2026 with first GFI year in 2029

Country	Segment	Route	Conventional	LNG DF	LNG to NH3 Retrofit	Ammonia DF	Methanol DF
●	Container	Nagoya - Los Angeles	76	50	−4	−18	−23
●	Container	Nagoya - Shanghai	65	39	−7	−16	−21
●	PCTC	Kobe - Mid East	58	37	−4	−16	−20
●	PCTC	Nagoya - Zeebrugge	49	30	−4	−14	−19
●	Bulk Carrier	Nagoya - Port Walcott	58	36	−4	−15	−20
●	Bulk Carrier	Nagoya - Sept-Iles	45	27	−3	−14	−18
🇰🇷	Container	S. Korea - US West	39	23	−4	−21	−28
🇰🇷	PCTC	S. Korea - US West	33	20	−4	−20	−26
🇰🇷	Bulk Carrier	S. Korea - Newcastle	36	19	−4	−21	−26

−28% 76%

Note: Each cell compares the same route and vessel pathway against its own no-IMO ba seline; negative values mean the pathway becomes cheaper under IMO 2026, positive va lues mean it becomes more expensive. TCO for vessels built in 2029; IMO NZF adopted in 2026 with 2029 as first compliance/payment year. LNG-to-NH_3 Retrofit refers to a ve ssel that is initially built as an LNG dual-fuel vessel and retrofitted to an ammonia dual-fu el vessel in Year 5 during its first special survey.

Similar impacts are observed across all routes, regardless of route characteristics



IMO NZF improves economics of lower-GHG alternative pathways by providing SU revenue and ZNZ reward

- Ammonia DF and methanol DF show consistent TCO reductions across routes, with ammonia at -14% to -21% and methanol at -18% to -28% versus no-IMO baselines, reinforcing that NZF changes pathway economics more than route fundamentals.
- Cost reductions reflect both policy support and optimized fuel use. Methanol dual fuel benefits most, relying on lower-cost SUs until they become scarce in 2044 before switching to e-methanol. Ammonia dual fuel uses e-ammonia throughout, resulting in a smaller optimization benefit.
- LNG-to-NH3 retrofit remains close to neutral across routes, at roughly -3% to -7%.

Fossil-intensive newbuilds face higher costs, with varying magnitudes across cases

- Conventional vessels show the largest TCO increase (+33% to +76%), while LNG dual-fuel vessels increase by +19% to +50% because of their lower emissions.
- The exact cost impact varies by financing structure, vessel type, and route, but the overall direction of the policy signal is consistent.

Summary of TCO modeling

Adoption of the IMO NZF will reward Republic of Korea and Japan fuel and vessel strategies that reduce early compliance exposure while enabling credible long- term transition pathways

1 IMO Net Zero Framework provides a framework that promotes shipping sector's energy transition

- The Surplus Unit and Reward mechanisms reduce the effective cost of adopting ZNZ fuels.
- The Remedial Unit mechanism increases the cost of fossil fuel pathways, strengthening the economic incentive to decarbonize

2 All routes studied— regardless of their characteristics — are affected similarly by the IMO Net Zero Framework

- The primary drivers of total TCOs are fuel and engine choice, financing structure, and policy effect.
- Route characteristics, including distance, vessel type, and ship size, do not materially change the impact of NZF.

3 Different financing structure shapes how shipowners can respond to the IMO Net Zero Framework and influence ve ssel investment decisions

- Higher financing costs increase the value of near-term cash flows, making early compliance benefits more influential.
- Accelerated depreciation offsets higher CAPEX by bringing forward tax benefits and incentivizing early-year (potentially higher GHG pathway) cash flow.
- Lower financing costs reduce the discount on future savings, improving the modeled economics of higher-CAPEX, lower-GHG pathways.
- Government action to improve access to lower-cost capital can help the private sector place greater value on long-term investment benefits

4 Ammonia, LNG, and their hybrid pathways are likely to represent the least-cost options for 2029 newbuilt vessels under the IMO Net Zero Framework, with the optimal pathway gradually shifting toward newbuild ammonia vessels over time

- Ammonia, LNG-to-ammonia retrofit, and LNG vessels represent the lowest-TCO options under IMO NZF,
- depending on assumptions and timing.
- LNG may offer a near-term cost advantage, largely enabled by access to low-cost SUs, but the advanta ge is expected to shift toward LNG-to-ammonia retrofit and eventually newbuild ammonia vessels.
- The timing of technology cross-over varies depending on financing structures - which can be on average higher cost in some countries and lower cost in others. Higher financing costs, a stronger emphasis on near-term cash flows, and aggressive accelerated depreciation policies to offset high CAPEX may delay the transition from LNG to ammonia vessels.
- LNG-to-ammonia retrofit may be a viable pathway for some shipowners and markets, but is unlike ly to become an industry-wide solution due to operational and scalability barriers

5 Regional low-cost e-fuel supply can make e-fuel vessels economically attractive under the IMO Net Zero Framework

- Some countries can already produce e-fuels at sufficiently low costs to make e-fuel vessels economically attractive under IMO NZF, with the potential to achieve lower lifetime TCO than conventional vessels.
- Countries able to produce or access low-cost regional e-fuels can capitalize on IMO NZF by accelerating ZNZ fuel production and vessel deployment, unlocking economies of scale, improving cost competitiveness, and positioning themselves as leaders in the energy transition.

6 Regional policy is insufficient for energy transition

- FuelEU and ETS can create early biofuel demand on EU-exposed routes, but their impact is limited to the regulated share of energy demand under the route's scope
- Due to less stringent GFI targets and limited regulatory scope, FuelEU drives only limited ZNZ fuel demand. Thus, BioMGO and bio-LNG are preferred compliance options, while e-fuels become competitive only after significant reductions in abatement costs.

Summary of TCO modeling

Financing structures are a key driver that shapes investment decisions under the IMO Net-Zero Framework

Financing conditions create diff erent investment incentives un der the same IMO NZF

- Financing conditions, including cost of capital, debt structure, tax treatment, and depreciation, shape vessel investment decisions under the IMO NZF.
- Higher financing costs increase the value of near-term cash flows, making early compliance revenues (SUs and ZNZ Rewards) and avoided fossil fuel penalties (RUs) more valuable in today's terms(Present Value).
- Lower financing costs reduce the penalty on future cash flows, supporting earlier investment in higher-CAPEX, lower-GHG vessel pathways.
- Accelerated depreciation can partially offset higher CAPEX by bringing tax benefits forward and improving early-year cash flow, particularly in jurisdictions with meaningful corporate tax rates

Modeled Republic of Korea archetype: Stronger preference for early cash flow

- **Parameters:** WACC 9.4%, Cost of debt 5.33%, Cost of equity 11.27%, Tax rate 26.4%, Tax depreciation 10-yr DB @ 25.9%/yr
- Higher financing costs increase the value of near-term returns, favoring strategies that generate earlier cash flow benefits.
- Accelerated depreciation and its corresponding tax benefits can partially offset higher CAPEX options, reducing the disadvantage of higher upfront investment.
- As a result, retrofit strategies remain competitive for longer before lower-GHG newbuilds become economically competitive.

Modeled Japan archetype: Lower cost of capital enables earlier transition

- **Parameters :** WACC 4.3%, Cost of debt 1.35%, Cost of equity 6%, Tax rate 29.74%, Tax depreciation 15-yr straight line
- When the investment decision is based on modeled TCO, a lower WACC reduces the discount applied to future fuel-cost savings, making higher-CAPEX non- conven tional vessel pathways appear more economically attractive over the invest ment horizon. more important.
- Lower-GHG newbuilds become economically attractive earlier than under higher-cost financing structures.

Policy implication

- **The same IMO policy signal may lead to different investment pathways across markets.** Financing conditions such as cost of capital, tax treatment, and access to financing can significantly influence technology adoption decisions.
- **Complementary financing measures can unlock zero and near-zero emission investments.** Financing support, risk-sharing mechanisms, favorable tax schedule, and targeted incentives can improve the business case for higher-CAPEX zero and near-zero emission v essels.
- **Governments can strengthen the effectiveness of IMO policies by improving financing conditions.** Collaboration between policymakers and financial institutions can reduce financing barriers and better align investment decisi ons with maritime decarbonization goals.

RECOMMENDATIONS FOR ROK GOVERNMENT

"Green Priority Berthing" System

- **Zero-Wait Port Access:** Guarantee immediate, zero-wait port berthing for green fuel or verified carbon-reduction ships.
- **Green Pass Issuance:** Issue "Green Pass" to vessels exceeding IMO baseline to bypass port congestion queues.
- **Economic Value:** Shorter port turnaround increases fleet utilization (more voyages/yr) and eliminates costly demurrage for charterers.
- **Benchmarking CARB :** Align with California CARB rules to grant AMP usage exemptions for alternative-fueled ships.

Package-Style Port Incentives

- Broaden port facility fee waivers (entry/exit, berthing fees) for Grade 1-2 green vessels.
- Set competitive, subsidized utility rates for Alternative Marine Power (AMP) usa ge.

Bio-LNG Supply Chain & CoC

- Foster regional biogas production & establish Chain of Custody (CoC) certification for Bio-LNG bunkering. (Book & Claim Considerable)



RECOMMENDATIONS FOR FINANCIAL INSTITUTIONS

Pay-As-You-Save (PAYS) Financing

- **Consortium Structure:** Policy banks (KOBC, KDB) + ESCOs fund 100% upfront CAPEX for Energy Saving Technologies (WAPS, ALS, PTO etc.).
- **Repayment via Savings:** Shipping lines repay debt solely through verified fuel savings & avoided carbon penalties (EU-ETS, IMO NZF).
- **"No Save, No Pay" Protection:** Mandate performance guarantee insurance to shield carriers from equipment underperformance.

Subsidized WACC & Future Fuel Loans

- **WACC Reduction:** Lower ROK cost of debt (5.33%) & guarantee premiums for Future Fuel Ready fleets to bridge the 5.1% gap(WACC 9.4%) with Japan (4.3%).
- **Poseidon Principles Alignment:** Grant higher Loan-to-Value (LTV) ratios for vessels with verified conversion flexibility, lowering stranded asset risks.
- **Joint Procurement Platform:** Launch eco-equipment joint procurement to cut unit prices by 10-20% for mid-sized lines.

	Republic of Korea	Japan
Financing structure	WACC **9.4%**, Cost of debt **5.33%**, Cost of equity **11.27%**, Tax depreciation **10-yr DB @ 25.9%/yr**	WACC **4.3%**, Cost of debt **1.35%**, Cost of equity **6%**, Tax depreciation **15-yr straight line**
CAPEX premium impact	↑ High —Favors CAPEX deferral (retrofit pathway)	↓ Low —direct non-conventional build is more affordable
Value of ZNZ rewards & SU revenues	↑ High —near-term benefits receive more weight	↓ Lower —early benefits are less decisive in NPV
Value of long-term fuel cost reduction	↓ Lower —future fuel costs discounted more heavily	↑ High —full present-value weight on 20-year fuel exposure
Conclusions	Increases financing costs but heavily discounts future fuel expenditures, giving greater relative importance to near-term IMO incentives and have early tax benefits from the depreciation schedule.	Reduces financing costs but gives greater importance to lifetime fuel expenditures.

Improve the legal framework

- **Adoption of advanced financing mechanisms;** Including the enhancement of ship financing markets strengthened guarantee schemes and expanded tax credits.

RECOMMENDATIONS FOR CARGO OWNERS & CHARTERERS

Green Charterparty & Carbon Sharing

- **Contractual Value Sharing:** Standardize BIMCO green clauses to contractually split financial gains from eco-investments.
- **Gain Sharing:** Share saved EU-ETS expenditures, FuelEU compliance surplus, an d IMO NZF Surplus Unit (SU) market revenues between Owner & Charterer.
- **RightShip(Ex.) GHG Benchmarking:** Mirror global charterers (BHP, Rio Tinto) b y adopting RightShip GHG ratings (A-G) to exclude inefficient tonnage from bids.

Logistics Data & Co-loading Policies

- **Consignor Collaboration:** Power utilities (KEPCO subsidiaries) & steelmakers (P OSCO/Hyundai) consolidate import itineraries for coal & iron ore.
- **Co-Loading Platform:** State-supported logistics platform to centralize cargo all ocation and drastically cut ballast (empty) voyages.
- **Antitrust Clean-Team Safeguards:** Mandate neutral trustee (KOBC) anonymization, limiting shared data to historical volumes to ensure FTC antitrust compliance.



RECOMMENDATIONS FOR SHIPPING COMPANY

Newbuilding with e-fuel

- **Long-term Compliance Cost & Penalty Insulation**: Eliminating lifetime exposure t o steep IMO NZF Tier 2 penalties ($380/tCO₂eq) and FuelEU Maritime fines, while s ecuring early Net-Zero Fund (ZNZ) rewards that offset upfront capital investments over the vessel lifecycle.
- **Longitudinal TCO Advantage & Future-Proofing**: Time-series lifecycle modeling d emonstrates that scalable green fuel vessels (e-Ammonia/e-Methanol) achieve predictable, lower lifetime operating costs post-2035 compared to fossil/bio-blended fleets facing escalating carbon taxes and biomass supply shortages
- **Synergy with Green Corridors & Off-take Deals**: Fixed shuttle trade routes (e.g., ROK–USWC Methanol Container/PCTC and ROK–Australia e-Ammonia Bulker corridors) enable long-term regional fuel off-take agreements, unlocking competitive fuel pricing and eliminating global bunkering infrastructure risks.
- **Scope 3 Decarbonization & Charterer Premium**: Direct zero-emission newbuilds meet stringent ESG and Scope 3 mandates from global makers securing long-term charterparty premiums and safeguarding against vessel devaluation / early asset stranding





"Practical DF Ready" & Standardized Machinery

- **Practical Ready Design:** Pre-incorporating structural foundations, pipe trunks, and hazardous zoning into standardized fleet designs, while utilizing "Slim Accommodation" and "Aft Parallel Body" forms to secure large alternative fuel tank spaces without losing cargo capacity.
- **Machinery/Power Ready :** Ordering engines under DF specifications (shop-tes ted with gas components safely preserved ashore) and integrating Shaft Gener ators (PTO) early to avoid insufficient electric power generation during future e-fuel or OCCS conversions
- **Lifecycle & Conversion optimization :** Pre-sizing redundant fuel transfer piping to streamline supply chains, significantly shortening shipyard off-hire and conversion lead times while mitigating stranded asset risks

EST "Seat / Space / Utility Ready"

- **WAPS Structural Seats:** Pre-weld deck stiffeners & foundations for Rotor Sails during newbuild → enables rapid, low-cost yard installation later.
- **ESS Battery & Fuel Cell Utility:** Pre-route cooling trunks, high-voltage cableways, and reserve switchboard breaker slots.
- **Safety Readiness:** Pre-install isolation blind flanges in central cooling loops, ga s venting ducts, and A-60 fire-rated bulkheads.

Thanks for joining us!

Questions?

PACIFIC ENVIRONMENT

국립 한국해양대학교 NATIONAL KOREA MARITIME & OCEAN UNIVERSITY

GSTL Green Ship Technology Laboratory