CLEANER SEAS: MITIGATING MARITIME EMISSIONS

Insights and perspectives

JULY 2025

asean Ports and Logistics 2025
Reshaping the Transport Logistics Sector in Creating a Path to Global Economic Recovery

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Cleaner Seas – what does it take?

Recent trends in maritime decarbonization **01**

Decarbonization **pathways** **02**

Roadmap for decarbonization **03**

Concrete actions to take **04**

Source: Arthur D. Little

1 DECARBONIZATION TRENDS IN MARITIME

Green topics remain top priorities for the maritime sector, currently a significant contributor to global CO_2 emissions

Top 5 issues in Maritime industry

Decarbonization of Shipping	01
New Environmental Regulation	02
Geopolitical tension	03
Workforce & skill shortages	04
Fuel price increases	05

2 of top **5** maritime issues are related to **Green topics**

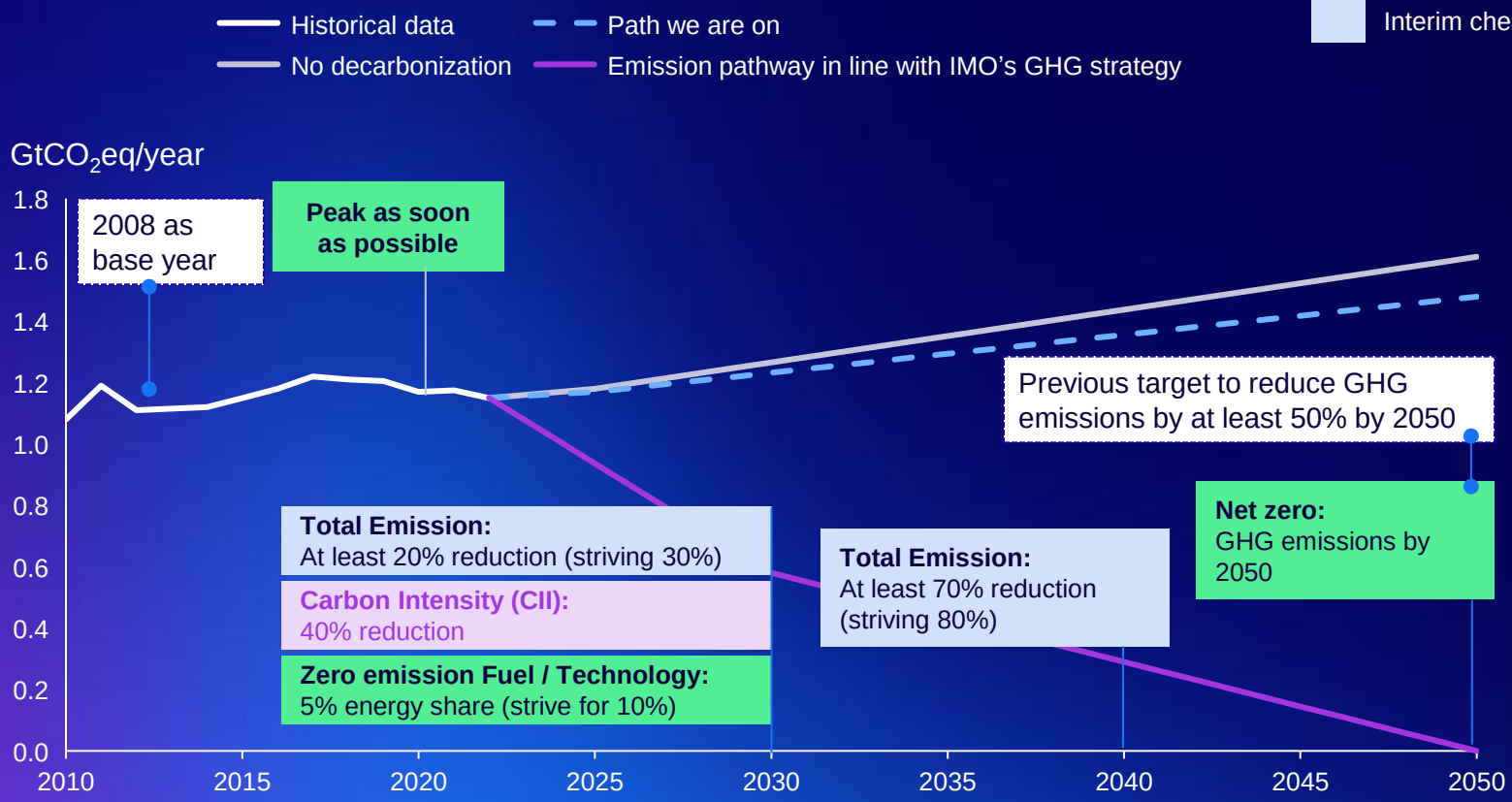
Global CO_2 emission by Maritime

Maritime contributes **3%** of total GHG emission, which will continuously increase due to growing global demand if no counter measures are made

Source: Global Maritime Issues Monitor 2022, Fourth IMO GHG Study 2020

The path we are on is falling short of meeting the interim and net zero target by 2050

Addressing GHG Emissions in Shipping: IMO Targets



In April 2025, IMO approved **net-zero regulations** for global shipping

The regulation will set mandatory **marine fuel standards and GHG emission pricing** for shipping

New regulations to be formally adopted in Oct 2025 and will become mandatory in 2027

Source: Decarbonising maritime transport: The EU perspective (European Parliament), Mærsk Mc-Kinney Møller Center, Arthur D. Little analysis

Regulations are coming into effect sooner and with direct financial penalties

Maritime regulations	Penalty type	Target
IMO CII	**Indirect penalty: Rating system** **Poor rating** for high CII ships which discourages collaborations (e.g., financial institutions, port authorities)	Reduction in **Carbon Intensity Indicator**: Baseline: 2008; >40% by 2030; Net Zero by 2050
EU-ETS	**Direct penalty: ETS allowances per ton** of CO_2 exceeding target allowance level (ETS allowances based on market price)	Applicability of **ETS on CO_2 emissions**: 20% (2023), 40% (2024), 70% (2025), 100% (2026)
Fuel EU Maritime	**Direct penalty: EUR 623 /ton CO_2e Penalty** per ton of CO_2 exceeding target level	Reduction in **Carbon Intensity Indicator**: Baseline: 2020; 2% by 2025; 20% by 2035; 80% by 2050

Source: Secondary resources, Arthur D. Little analysis

2 PATHWAYS TO MARITIME DECARBONIZATION

Decarbonization pathways the maritime industry can consider

Stop emissions

Alternative fuels

Producing and adopting low and zero carbon fuels for shipping

E.g., LNG, methanol, ammonia

Reduce emissions

Carbon management

Compensating or offsetting carbon usage through various mechanisms

E.g., internal carbon pricing, carbon offset, carbon calculator, onboard CCS

Operational efficiency

Improving efficiency of operations by optimizing existing assets

E.g., slow steaming, vessel size modification, automation, digital tools

Ecosystem partnership

Collaboration and coordination between stakeholders to promote maritime decarbonization

E.g., Zero-emission shipping mission, green shipping corridors

Source: Arthur D. Little analysis

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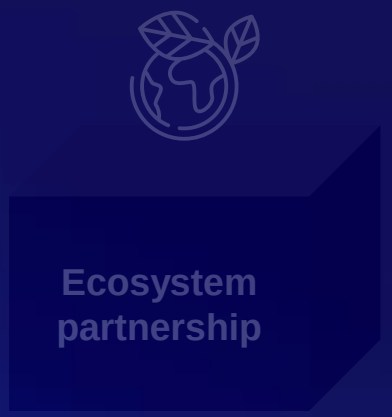

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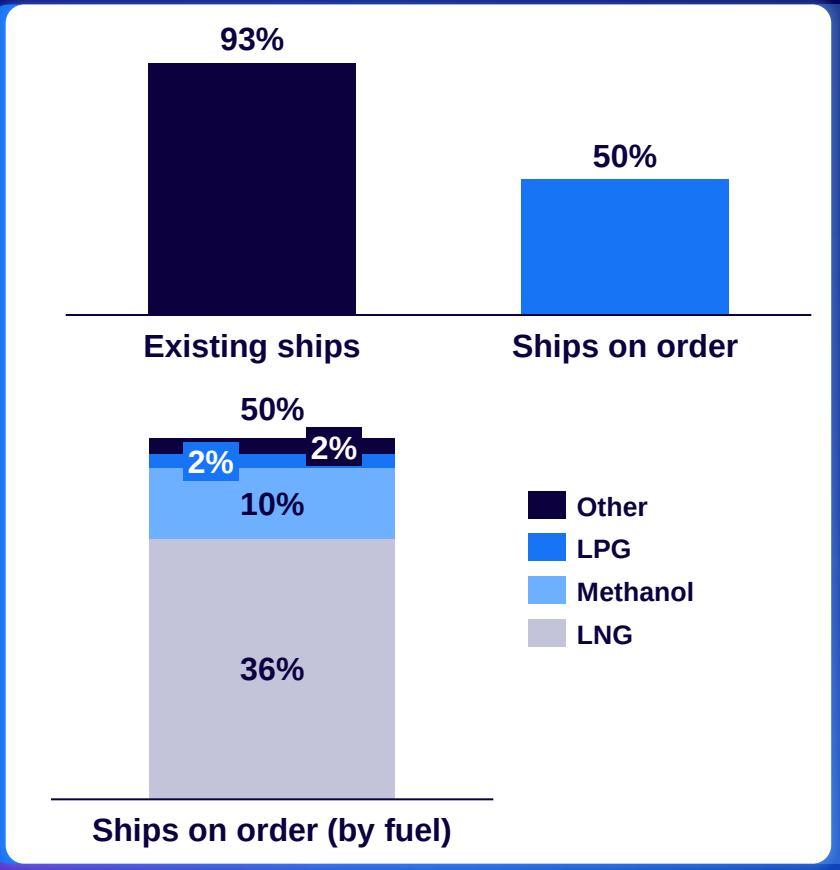
Source: Arthur D. Little analysis

Carriers and ports have made significant investments especially in LNG & Methanol

Ships by Gross Tonnage[2]



- **93%** of existing ships by Gross tonnage use **conventional fuel** but
- Approx **50%** of the new ships on order[1] by Gross tonnage are for **alternative fuel**

- **46%** of ships on order by Gross tonnage are for LNG and Methanol
- LNG is the preferred alternative fuel (832 ships on order[1])
- Most of the ships ordered are dual fuel vessels

- Increasing number of Ports offering LNG & Methanol bunkering
- **201** ports offering **LNG bunkering** in 2024 expected to grow to 258 in 2026
- **10** ports offering **Methanol bunkering**, 11 developing & 122 offering storage

Note: 1- As of June 24, 2 - Gross tonnage (GT) is a measure of a ship's overall internal volume, used to assess its size for regulatory and commercial purposes
Source: DNV & various other sources, Arthur D. Little analysis

Development of e-fuels in early phase, transition fuels such as biofuels being considered

Alternative fuels assessment: Summary

Less Promising — Most promising

			TODAY	TOMORROW
Blue fuels	Conventional fuels	Blue methanol	**Support fuel** Mainly due to inability to meet alternative fuel regulatory requirement, share decrease expected	
		Blue ammonia		
		Blue hydrogen		
Green fuels	Biofuels	Bio diesel / HVO	**Support fuel** Mainly due to supply constraints, share decrease expected	
		Bio methane		
		Bio methanol		
	E-fuels	E-methane (SNG)	**Most promising fuel in the long run** Decline in production costs, potential for decarbonization will drive commercialization and increase in market share	
		E-methanol		
		E-diesel		
		Green hydrogen		

Note: 1) Decarbonization benefit based on the approximate percentage of carbon emission reduction in comparison to crude oil / HFO (heavy fuel oil) ; Will vary slightly depending on feedstock and production process used

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Source: Arthur D. Little analysis

Internal carbon pricing - incentive for emissions reduction and low-carbon solutions

Common types of carbon pricing

Regulation-driven

IMO CII

EU-ETS

Fuel EU Maritime

Emission trading system

Market place imposed by a (supra)national organization, on which emitters can trade GHG emission units to meet their targets

Carbon tax

Direct price set on GHG emissions by **defining a tax rate per tonne of emitted CO_2eq**

Offset mechanism

Designation of GHG emission reductions (included in registry) from program-based activities, which can be sold to other parties

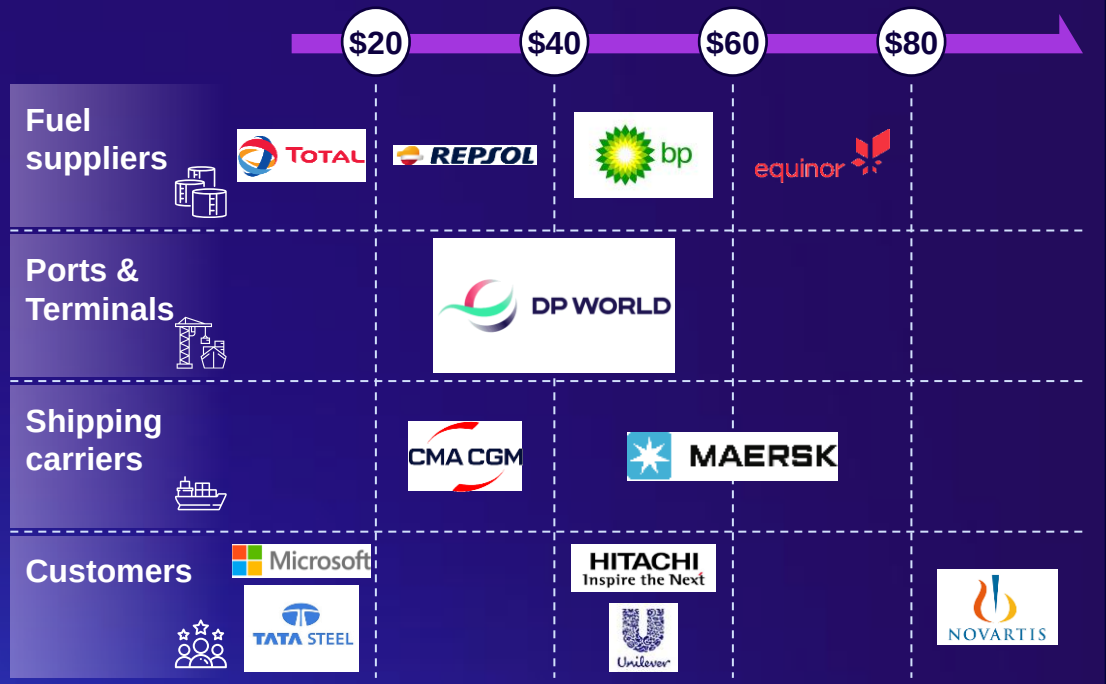
Voluntary

Internal carbon pricing (ICP)

Voluntary effort by companies to put an **internal price on the GHG emissions** they are producing and to **incentivize reductions** in those emissions

Internal Carbon Pricing (ICP)

Companies adopted ICPs to **manage risks**, promote **energy efficiency** and identify new opportunities with the aim of **low-carbon investment**



Source: Secondary research, Arthur D. Little anlaysis

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Source: Arthur D. Little analysis

Slow steaming and larger vessels a viable short to mid-term solution

Operations improvement at sea

	SLOW STEAMING	LARGE VESSELS
MAERSK	• **2010:** Introduced during recession to absorb capacity, lower cost and emissions • **2018:** Against adopting global legislation to regulate speed limits to reduce CO_2 emissions	• Order book capacity 1.4X of vessel in operations
CMA CGM	• **2009:** Slow steaming used to reduce cost • **2014:** Ships sail at 16-18 knots to cut emissions • **2019:** CMA and French govt. supports slow-steaming to be mandatory	• Order book capacity 2X of vessel in operations
COSCO SHIPPING	• **2010:** COSCO extent their slow steaming regime on Asia-Europe and Mediterranean trades	• Order book capacity 3X of vessel in operations
Hapag-Lloyd	• **2019:** Believes further reduction in speeds requires carriers to invest to meet capacity and schedule requirements; may even lead to increased total emissions if not managed well	• Order book capacity 2.8X of vessel in operations

Besides emissions reduction, other factors are considered when using slow steaming such as customer needs, berth availability; For use of large vessels, considerations include port infrastructure, physical route restrictions, etc..

Source: Expert interviews, secondary sources, Arthur D. Little analysis

Digitalization & Sustainable Design Case Study: Singapore

Green ports initiatives – Singapore

World's **largest automated** terminal by 2040 consolidated into Existing container terminals

Existing port terminals

Jurong Port

Rooftop solar
- 9.65MW solar installed on warehouse rooftops
- Powers port operations with excess supplied to national grid

Smart Multi-Energy
- **AI-driven** port energy grid control system
- Supports energy efficiency and CO_2 footprint reduction

Green berths
- Berths constructed using **recycled berths and yards' materials**

Keppel Terminal

Electric vehicles
- **Electrified** cranes and ground vehicles
- Will be world's largest fleet of **automated guided vehicles**

Tuas port project

Key features

Full automation
- **Fully electric** guided vehicles and harbor craft
- **Unmanned vehicles** e.g., automated yard cranes, drones, data analytics and driverless trucks for port transports to be deployed

Full integration
- **Consolidated handling facilities**
- Reduced inter-terminal hauling operations and emissions
- Annual container processing capacity of 65m TEUs vs. existing 50m TEU capacity

Green design
- Completely **greenfield site construction**
- Designed with **innovation and sustainability** as key features

Green construction
- **>50% reused and recycled materials** utilized in land reclamation work
- Relocation of sensitive coral colonies residing in project site

Source: Secondary research, Arthur D. Little analysis

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Source: Arthur D. Little analysis

Green corridors help drive rapid deployment of zero-emission shipping

NON-EXHAUSTIVE	Rotterdam and Gothenburg	European Green Corridors	Halifax and Hamburg	Rotterdam and Singapore
Locations	• Port of Rotterdam (Netherlands) and Gothenburg (Sweden)	• Port of Hamburg (Germany), Gdynia (Poland), Roenne (Denmark), Rotterdam (Netherlands), Tallinn (Estonia)	• Ports of Halifax (Canada) and Hamburg (Germany)	• Ports of Rotterdam (Netherlands) and Singapore
Date announced	• Oct 2022	• Mar 2022	• Sep 2022	• Aug 2022
Purpose	• To realize more sustainable shipping and promote the use of **alternative fuels in support of the Paris Agreement**	• To reduce CO_2 emissions for ocean shipping by **60% by 2030** and become **carbon neutral by 2050**	• Bunkering / export of **green hydrogen** and derivatives • Ease of business between Germany and Canada	• Realize **first sustainable vessels** sailing on route by 2027
Details / Measures	• Setting up **e-methanol value chain** at the Port of Gothenburg	• Conduct feasibility study on **potential routes, vessel types, fuel types, regulation, etc**	• Develop necessary **port infrastructure for hydrogen logistics**	• Bring together shippers, fuel suppliers to work on **fuel transition, develop maritime efficiency**
Expected date of launch	• N/A	• N/A	• N/A	• 2027
Partners	• N/A	• N/A	• N/A	msc, CMA CGM, MAERSK, ONE

Implementing green corridors could put pressure on owners / operators who are hesitant to invest in green technologies, leading to rapid improvements in zero-emission shipping's economic, logistic and political feasibility

Source: News articles, Arthur D. Little analysis

3 MARITIME DECARBONIZATION ROADMAP

Decarbonization – a collective effort of policies, supply chain and digitalization

Key Trends	Fuel suppliers	Shipyards	Ports & Terminals	Shipping carriers	Customers	Government
Alternative fuels	• **Innovate** and **scale up production** of alternative fuels	• **Design** alternative fuel vessels	• **Develop / re-purpose existing infrastructure** to support uptake of alternative fuels	• **Commit to use and order** alternative fuels and vessels / dual-fuel vessels	• **Encourage** use of alternative fuels	• **Facilitate R&D,** Provide **incentives** and Mobilize **capital / funding**
Carbon management	• Explore use of **renewable energy sources**	• Design **fuel efficient** vessels • Adopt **digital tools** to consolidate company emission data and offer predictive analytics to optimize operations	• **Adopt energy savings solutions** to optimize energy-intensive equipment e.g., cranes • **Adopt digital tools** to optimize delivery and logistics	• Adopt **internal carbon pricing scheme** • Offer **low-carbon service offering** • Explore green tech. such as **onboard CCS**	• Adopt **carbon offset solutions**	• Introduce **internal carbon pricing scheme** • Provide **incentives** • Mobilize **capital / funding**
Operational efficiency	N/A (Not relevant to maritime decarbonization)			• Adopt **emissions-reduction protocols** e.g., slow steaming • Adopt **digital tools** e.g., fleet performance monitoring	N/A (Not relevant to maritime decarbonization)	• Develop **operational standards and guidelines / policies**
Ecosystem partnerships	• Participation in cross industry **maritime decarbonization initiatives** across all stakeholders e.g., creation of **Green Corridors** • Develop **common policies** for low-emission fuels					

Effective decarbonization in the maritime sector requires an ecosystem-wide approach that emphasizes the need for continuous alignment and collaboration among stakeholders across the entire value chain

Source: Arthur D. Little analysis

4 CONCRETE ACTIONS TO DECARBONIZATION

Concrete actions, interventions and strategies for maritime decarbonization

Maritime decarbonization requires collective action and convergence across Maritime and Energy, and beyond

01 Technology outlook and investment roadmap (asset management)

02 Partnership and ecosystem development support

03 Social Return on Investment (ROI) assessment

04 Transformation and organization support

05 Market Analysis / Alternative fuels assessment

06 Sustainability audit / Environmental, Social and Governance due diligence

07 Corporate and green strategy

Source: Arthur D. Little analysis

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