

NAVIGATING MARITIME DECARBONIZATION IN AN ERA OF ENERGY UNCERTAINTY

Insights and perspectives

JULY 2026



ARTHUR D LITTLE



Cleaner Seas – what does it take?



Recent trends in maritime decarbonization

01



Decarbonization **pathways**

02



Roadmap for decarbonization

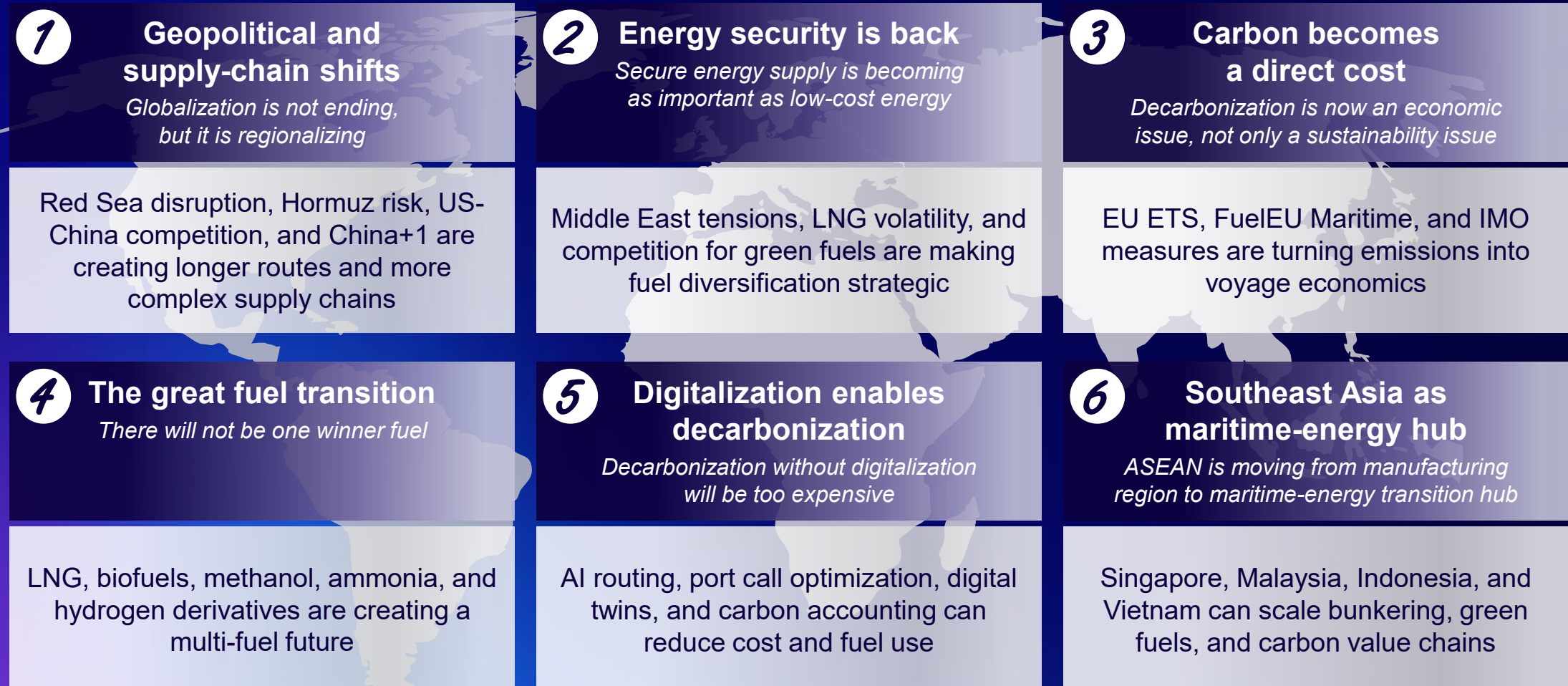
03



Concrete actions to take

04

Global shifts are making Southeast Asia a more strategic logistics hub



1 DECARBONIZATION TRENDS IN MARITIME

2026 context – Maritime decarbonization is now shaped by energy security, cost volatility and regulation

	Energy security	Cost volatility	Regulation & carbon cost
2026 Context			
Highlight	Middle East tensions and Strait of Hormuz risks are putting marine fuel supply security back on the board agenda	Red Sea disruption and Cape of Good Hope rerouting are increasing voyage distance, fuel burn and schedule uncertainty	Carbon regulation is turning emissions from a sustainability metric into a direct operating cost
Keywords	▪ Strait of Hormuz ▪ Middle East risk ▪ Fuel supply resilience	▪ Red Sea disruption ▪ Suez avoidance ▪ Longer voyages	▪ EU-ETS ▪ FuelEU Maritime ▪ IMO uncertainty ▪ Compliance cost

Green topics remain top priorities for the maritime sector, currently a significant contributor to global CO₂ emissions



Top 5 issues in Maritime industry



Decarbonization of Shipping

01



Energy security and fuel price volatility

02



New Environmental Regulation

03



Geopolitical tension

04



Workforce & skill shortages

05

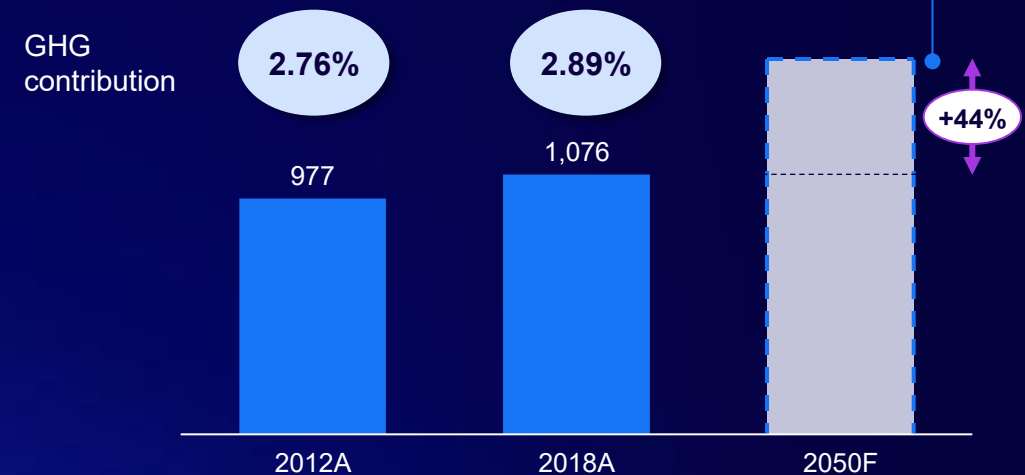
2 of top **5** maritime issues are related to **Green topics**



Global CO₂ emission by Maritime

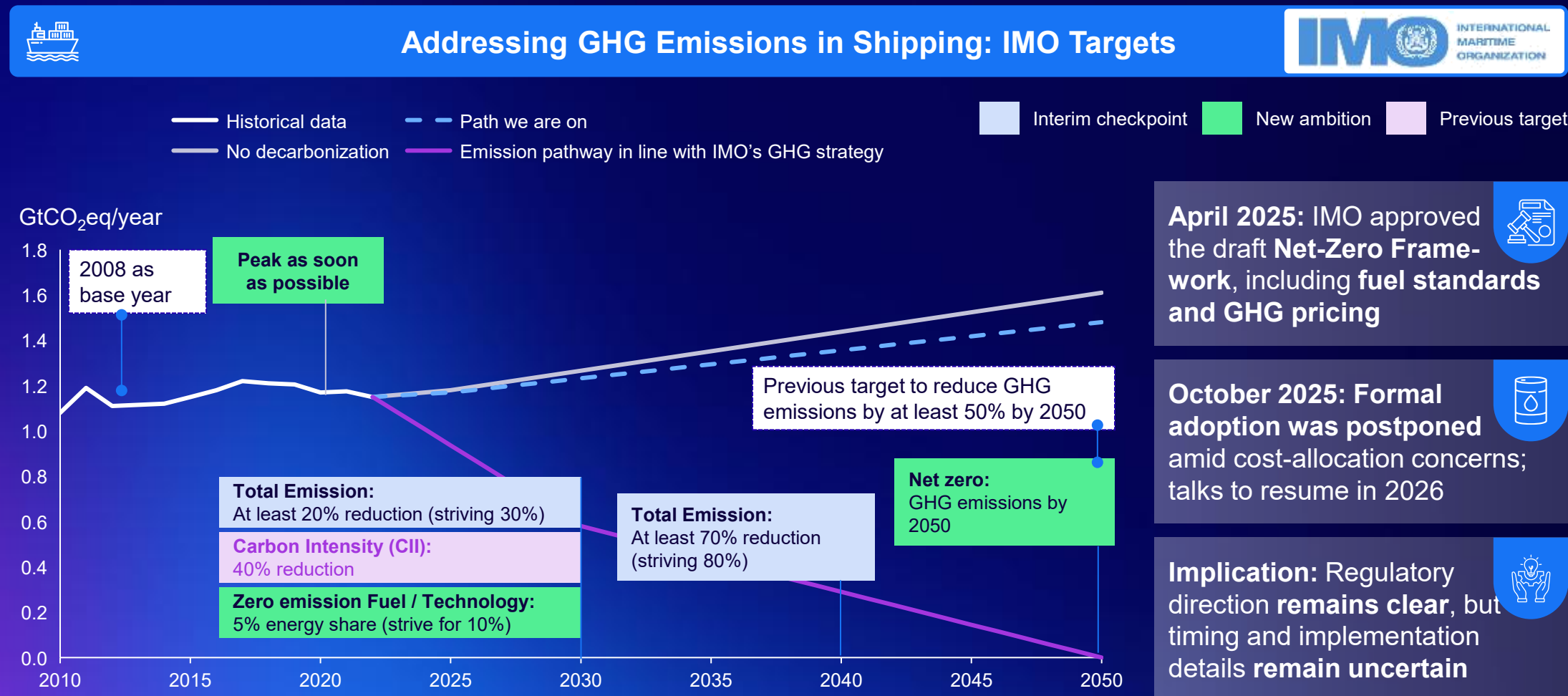
Units: Millions Metric Tonnes

Without additional measures, shipping emissions are projected to increase by +44% in 2050

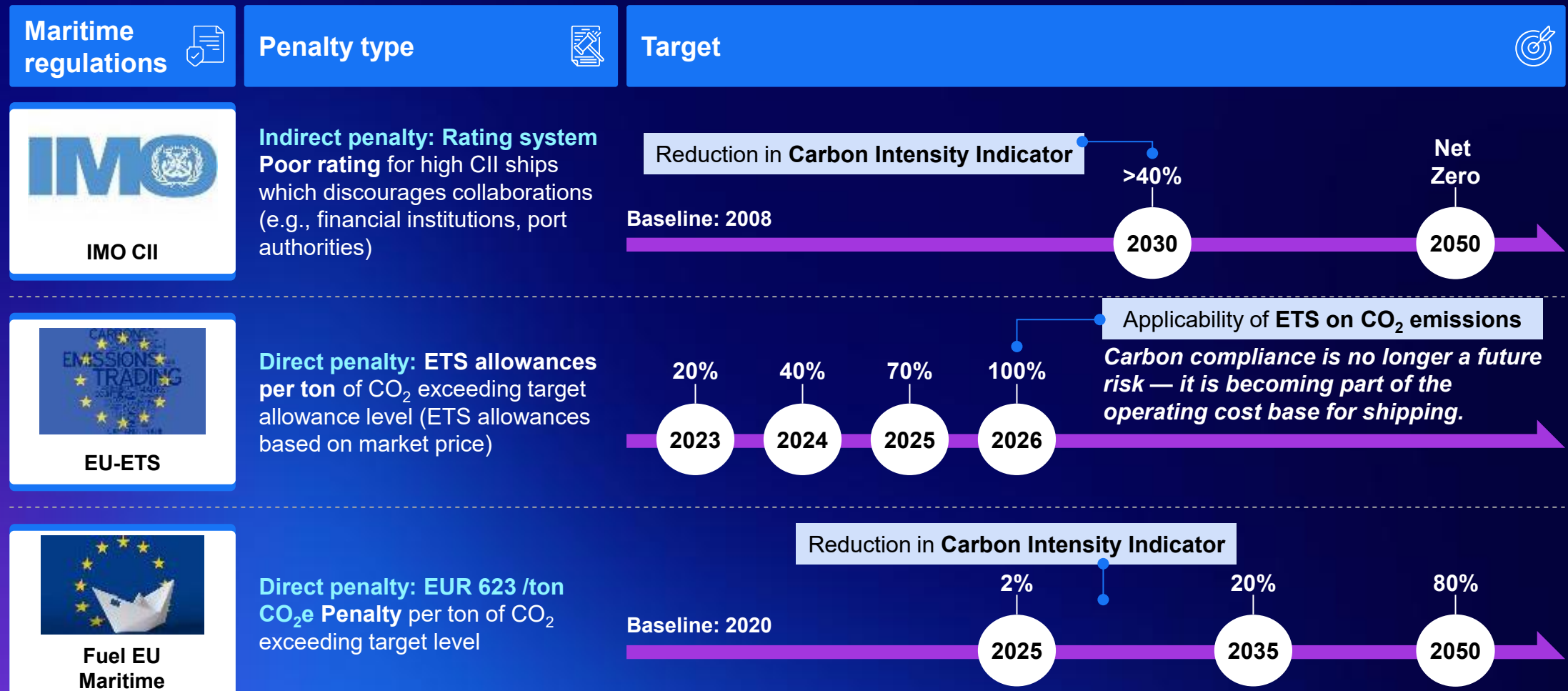


Maritime contributes **3%** of total GHG emission, which will continuously increase due to growing global demand if no counter measures are made

The ambition remains clear, but implementation uncertainty is rising

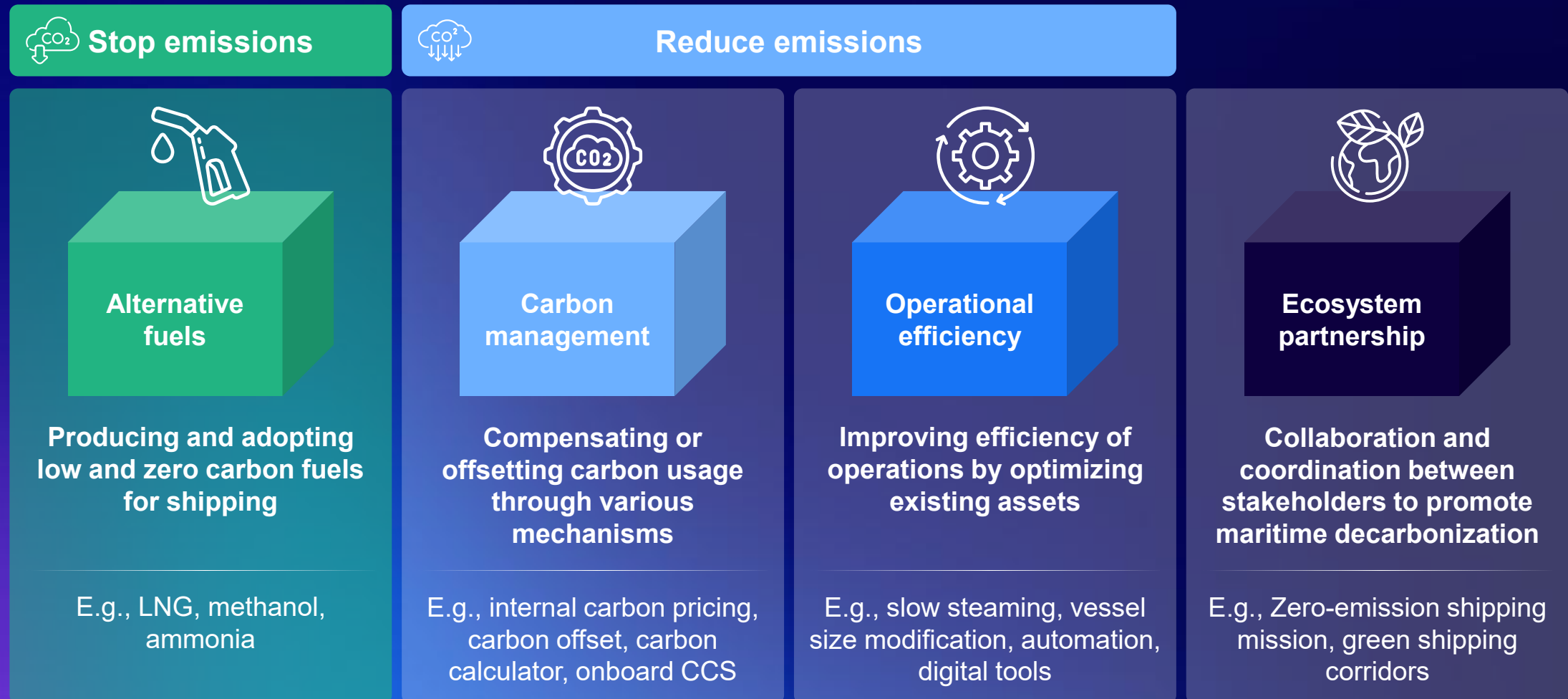


Regulations are coming into effect sooner and with **direct financial penalties**

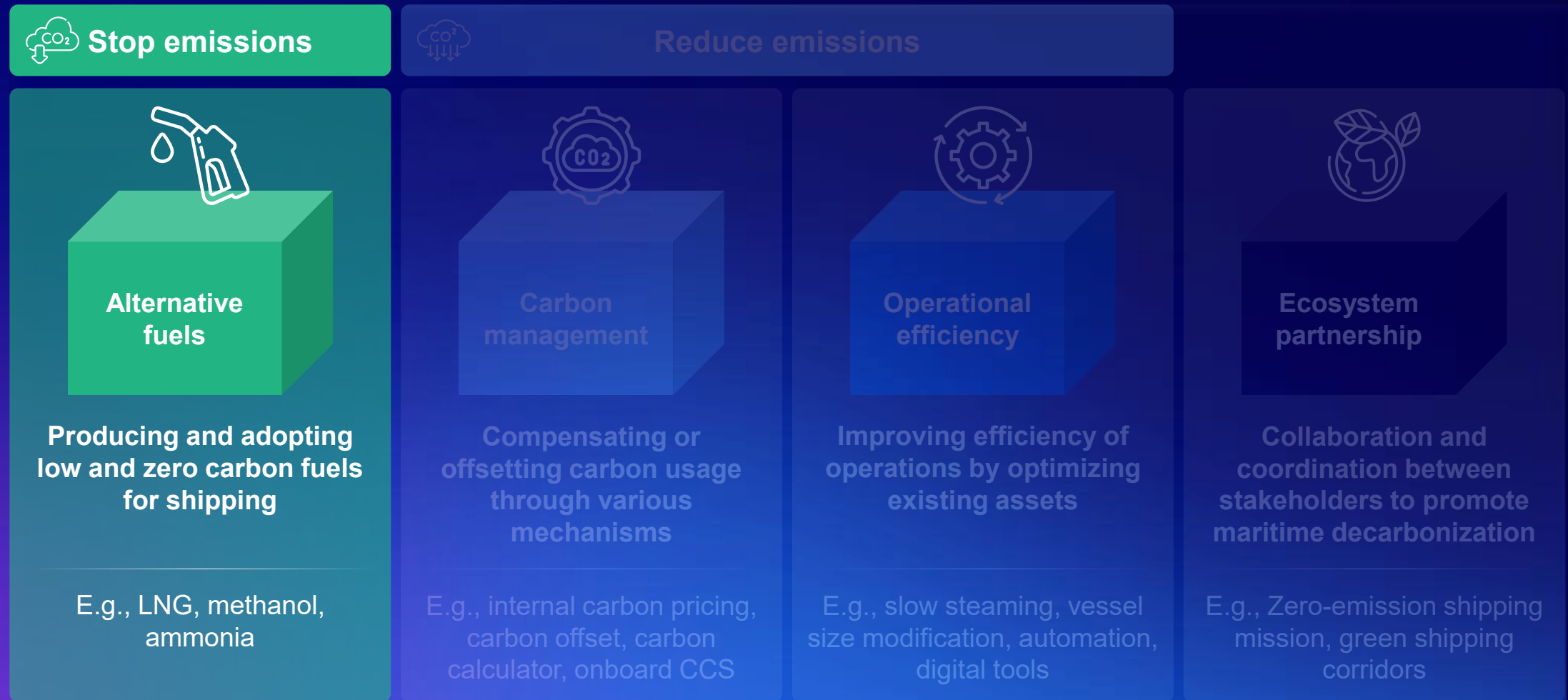


2 PATHWAYS TO MARITIME DECARBONIZATION

Decarbonization pathways the maritime industry can consider



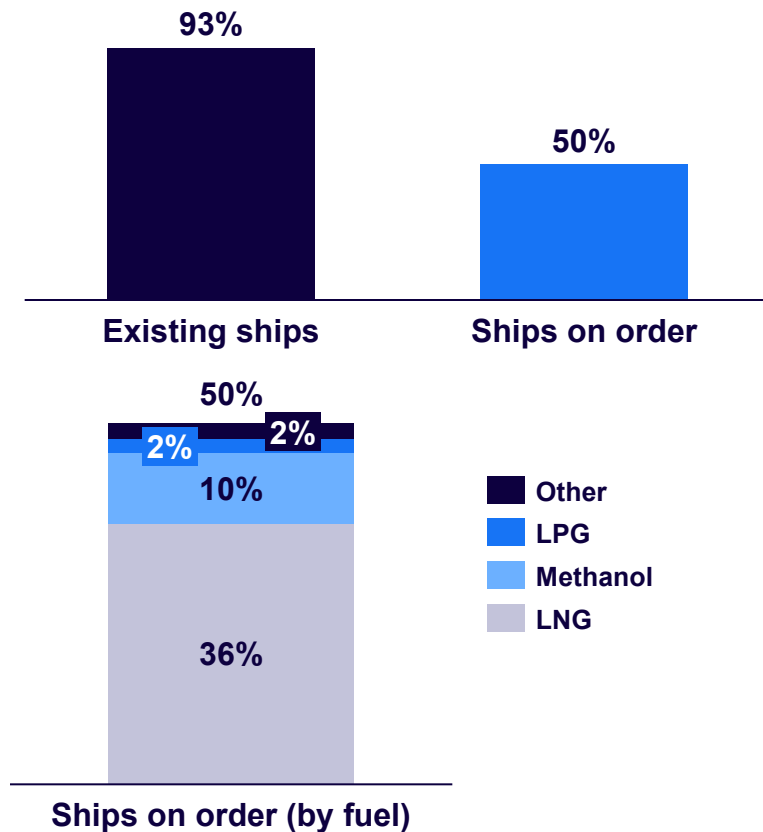
Decarbonization pathways the maritime industry can consider



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

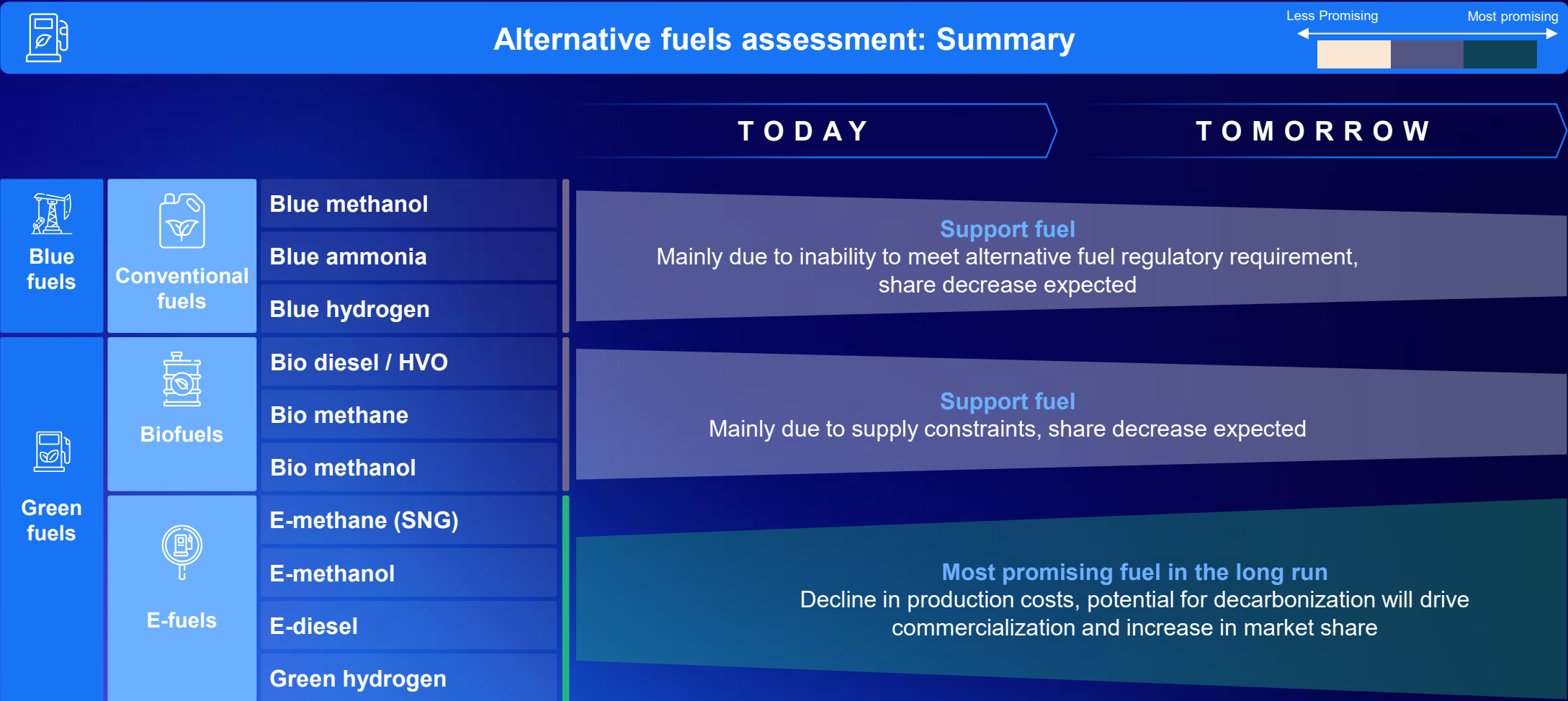


Ships by Gross Tonnage²



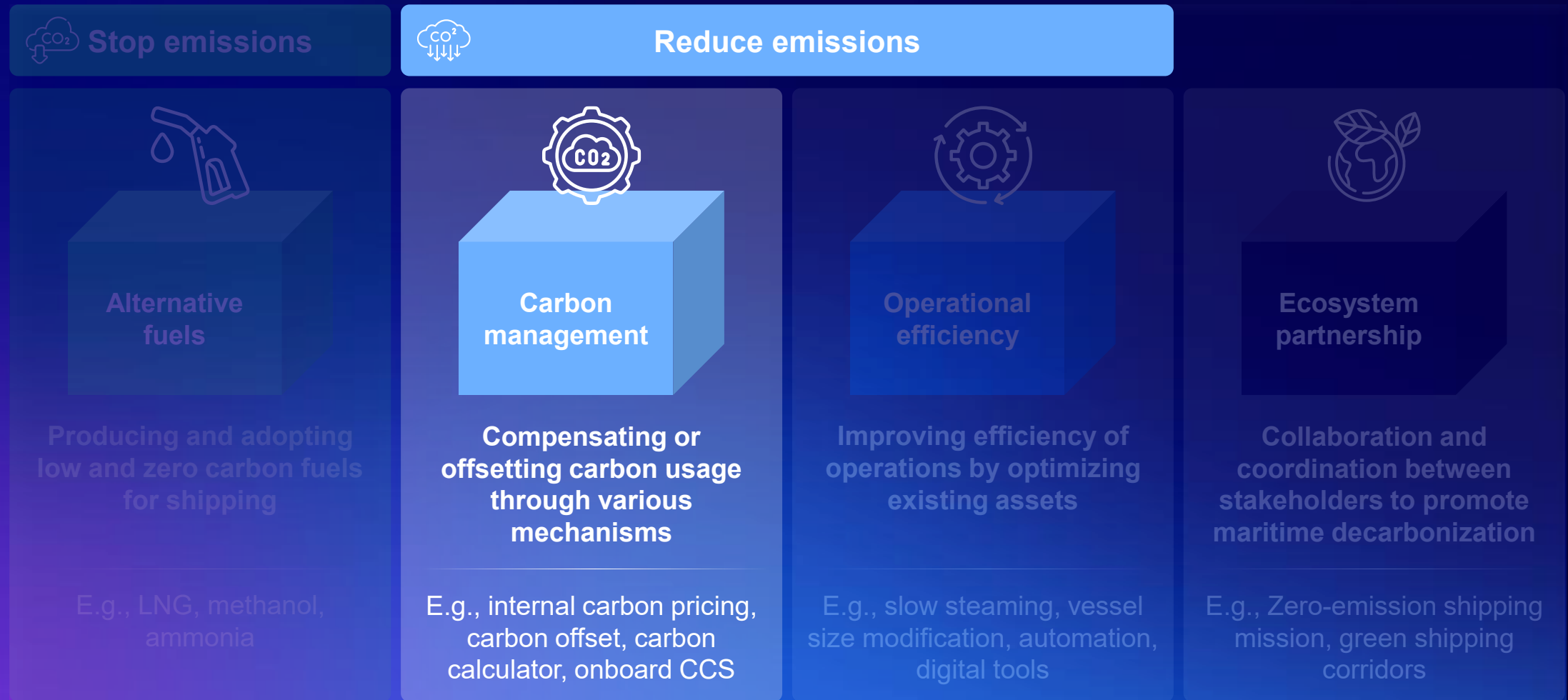
- **93%** of existing ships by Gross tonnage use **conventional fuel** but
- Approx **50%** of the new ships on order¹ by Gross tonnage are for **alternative fuel**
- **46%** of ships on order by Gross tonnage are for LNG and Methanol
- LNG is the preferred alternative fuel (832 ships on order¹)
- Most 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

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

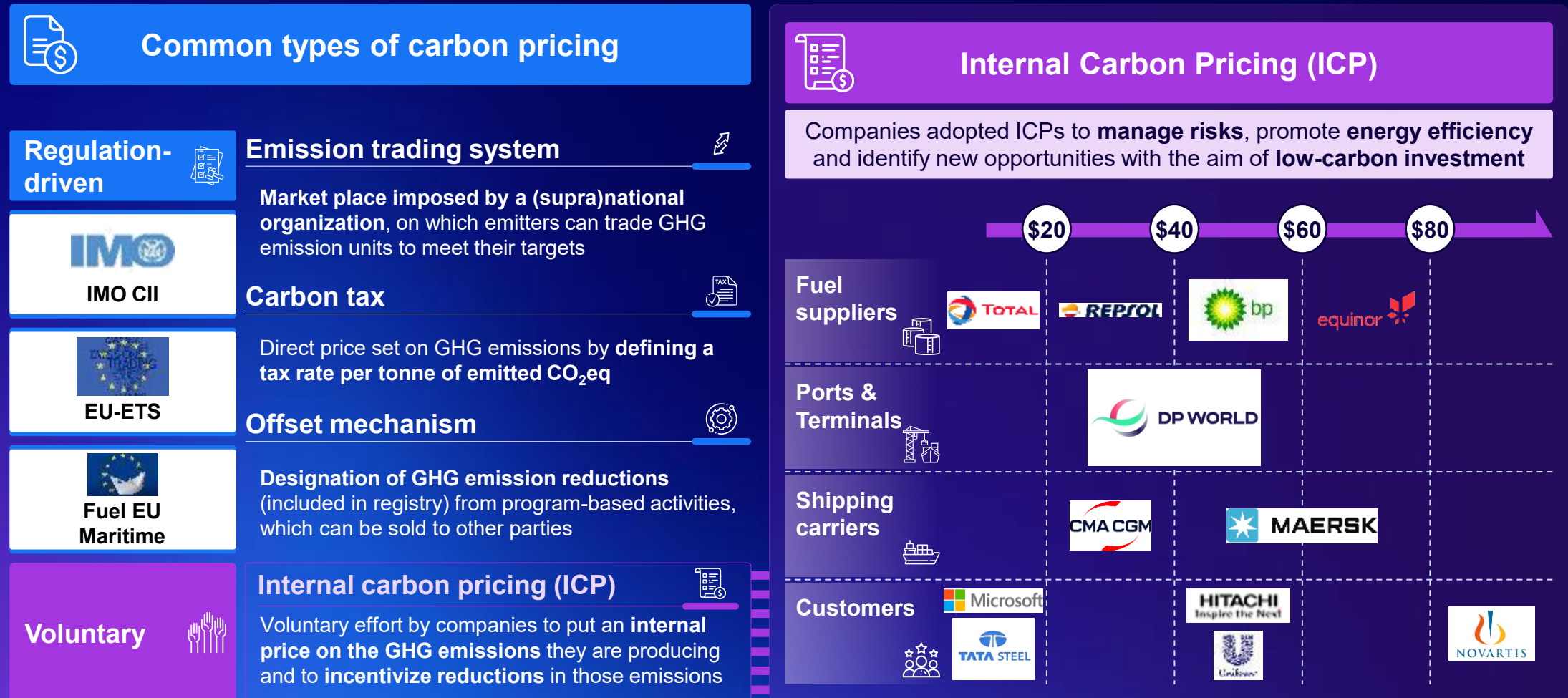


Note: 1) Decarbonization benefit based on the approximate percentage of carbon emission reduction in comparison to crude oil / HFO (heavy fuel oil) ; Will vary slightly depending on feedstock and production process used

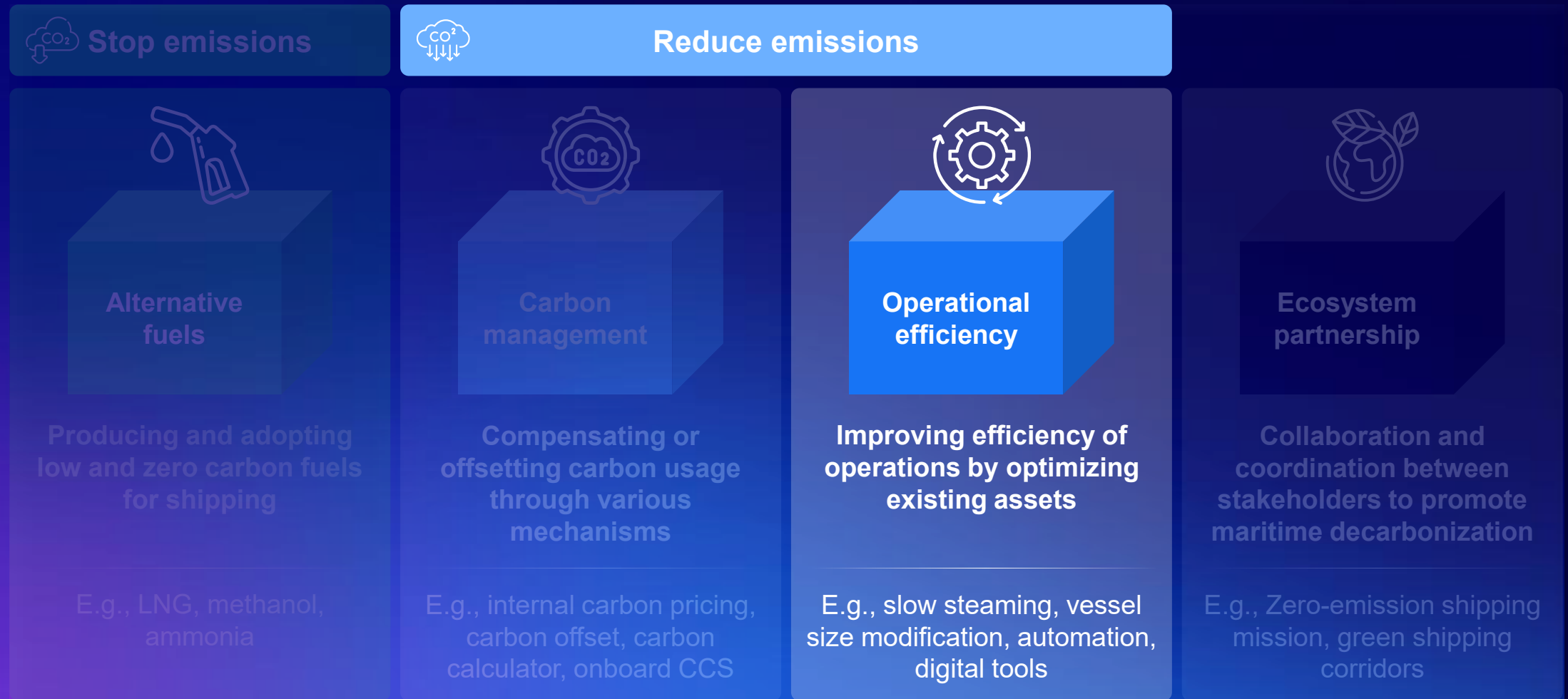
Decarbonization pathways the maritime industry can consider



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



Decarbonization pathways the maritime industry can consider



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



Operations improvement at sea



MAERSK



Hapag-Lloyd

SLOW STEAMING

- **2010:** Introduced during recession to absorb capacity, lower cost and emissions
- **2018:** Against adopting global legislation to regulate speed limits to reduce CO₂ emissions
- **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
- **2010:** COSCO extent their slow steaming regime on Asia-Europe and Mediterranean trades
- **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

LARGE VESSELS

- Order book capacity 1.4X of vessel in operations
- Order book capacity 2X of vessel in operations
- Order book capacity 3X of vessel in operations
- 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..**

Digitalization & Sustainable Design Case Study: Singapore



Green ports initiatives – Singapore



World's **largest automated** terminal by 2040

Existing container terminals

consolidated into

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 CO₂ 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

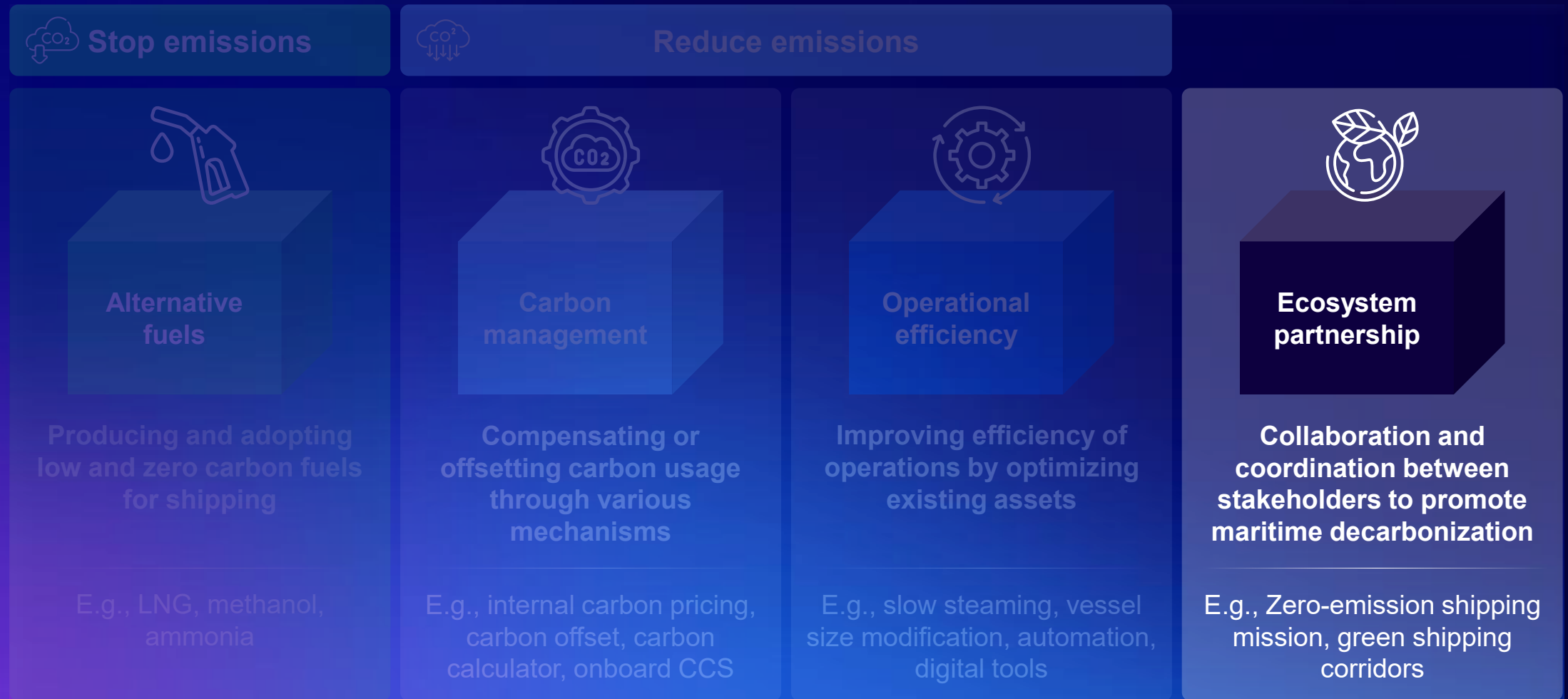
Green construction

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

Digital and AI tools can translate operational efficiency into measurable emissions reduction



Decarbonization pathways the maritime industry can consider



Green corridors help drive rapid deployment of zero-emission shipping

<i>NON-EXHAUSTIVE</i>	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 CO₂ 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	

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

3 MARITIME DECARBONIZATION ROADMAP

Our view: Decarbonization should not pause – but the pathway must become more pragmatic

Decarbonization remains a must, but the execution model needs to change

From ambition-led planning to energy-risk adjusted execution

1.

Do not pause

Regulation, customer pressure and 2030 targets continue to move the industry forward

2.

Prioritize no-regret moves

Efficiency, carbon visibility and digital tools reduce cost and emissions under any fuel scenario

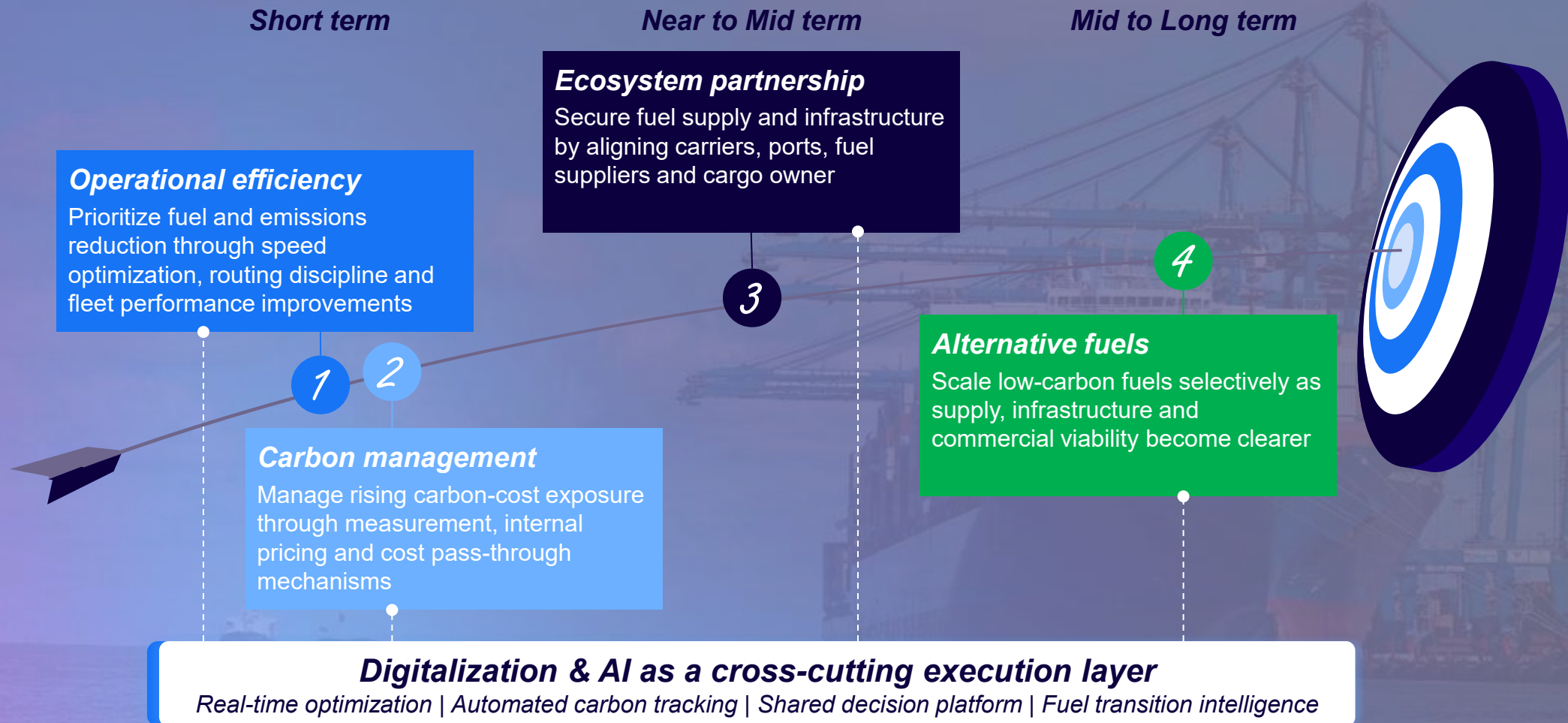
3.

Scale fuels through partnerships

Alternative fuels remain essential, but supply, cost and infrastructure risks require ecosystem coordination

Energy volatility does not weaken the case for decarbonization; it changes the execution model

Decarbonization requires a pragmatic sequence, with digitalization and AI enabling every pathway



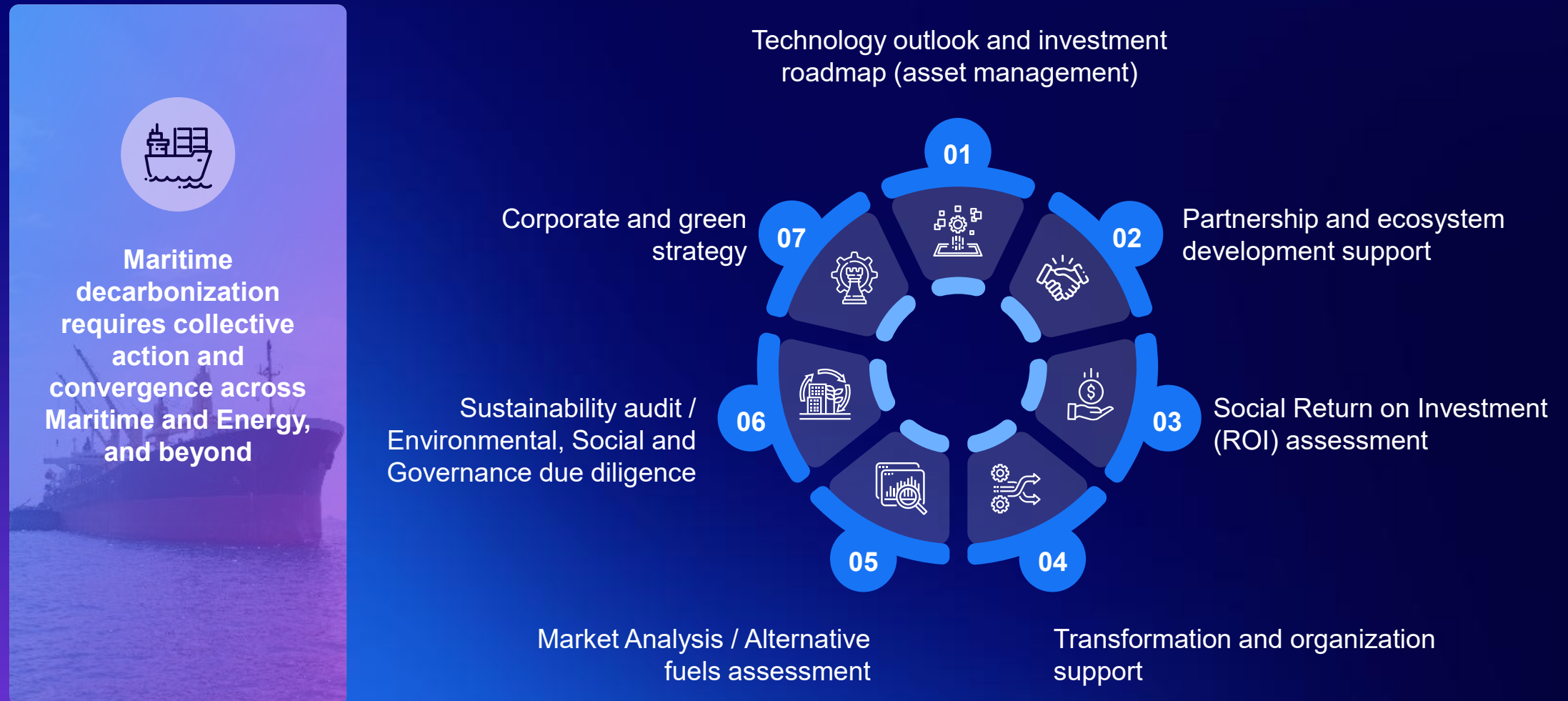
Decarbonization – a collective effort of policies, supply chain and digitalization

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 emissions-reduction protocols e.g., slow steaming - Adopt digital tools e.g., fleet performance monitoring	Adopt carbon offset solutions	- Introduce internal carbon pricing scheme - Provide incentives - Mobilize capital / funding
Operational efficiency	N/A (Not relevant to maritime decarbonization)				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

4 CONCRETE ACTIONS TO DECARBONIZATION

Concrete actions, interventions and strategies for maritime decarbonization



Arthur D. Little has been at the forefront of innovation since 1886. We are an acknowledged thought leader in linking strategy, innovation and transformation in technology-intensive and converging industries. We navigate our clients through changing business ecosystems to uncover new growth opportunities. We enable our clients to build innovation capabilities and transform their organizations.

Our consultants have strong practical industry experience combined with excellent knowledge of key trends and dynamics. ADL is present in the most important business centers around the world. We are proud to serve most of the Fortune 1000 companies, in addition to other leading firms and public sector organizations.

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THE DIFFERENCE