WHEN TRUST MATTERS

Onboard Carbon capture potential in shipping

Technical Seminar on Onboard Carbon Capture and Storage (OCCS) Systems, International Maritime Organization

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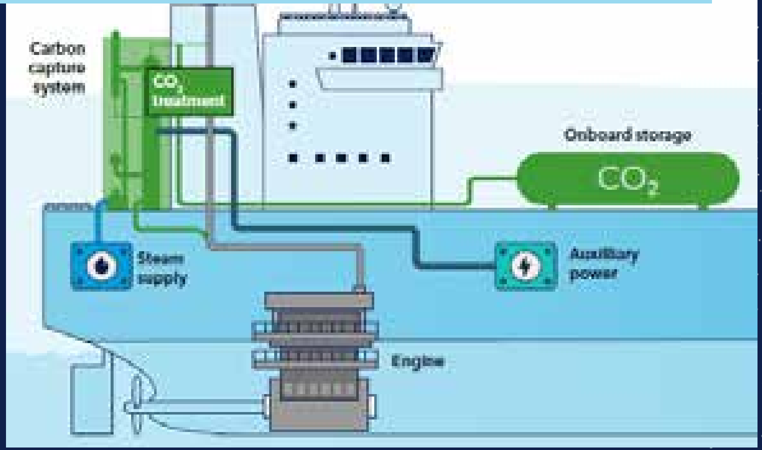
Achieving net-zero emissions demands shipping transformation: access to carbon neutral fuels, uptake of zero to near-zero GHG emission technologies, improvement of energy efficiency, and adoption of innovative practices

Pieces of the decarbonization puzzle

FUELS

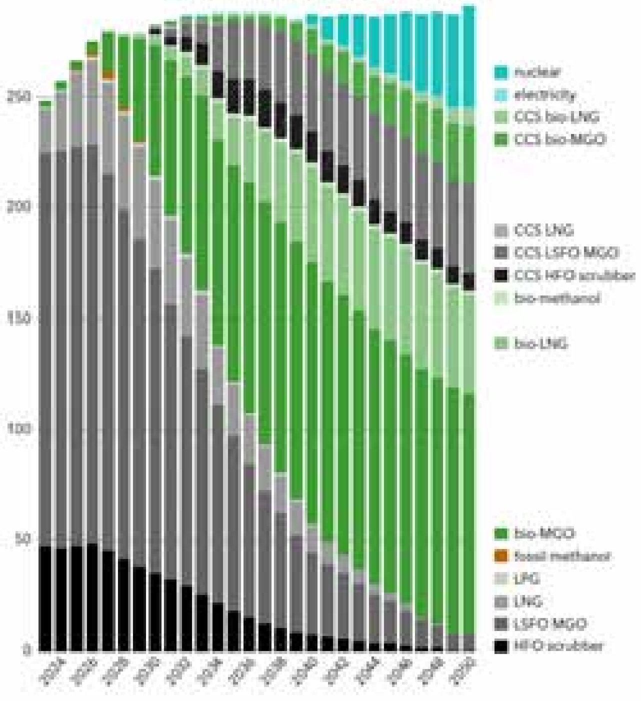
ENERGY EFFICIENCY MEASURES

OTHER SOLUTIONS

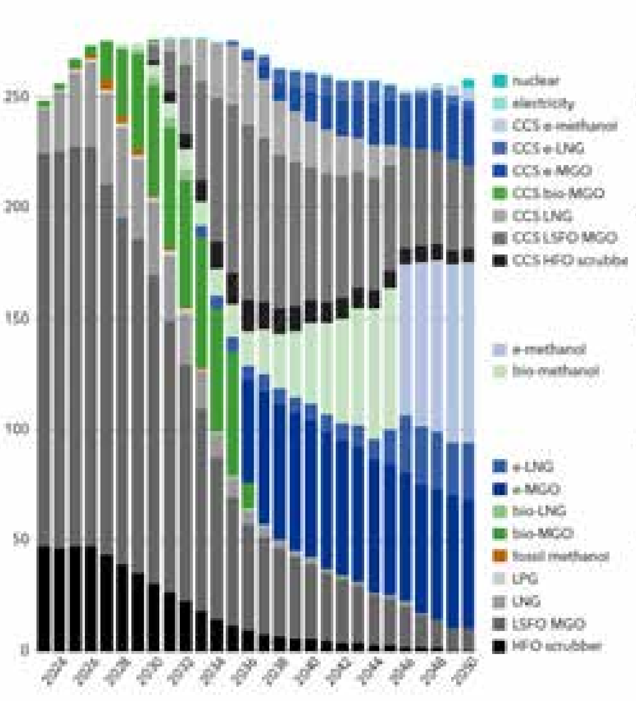


To achieve IMO's ambitious decarbonization goals, combinations of options is foreseen

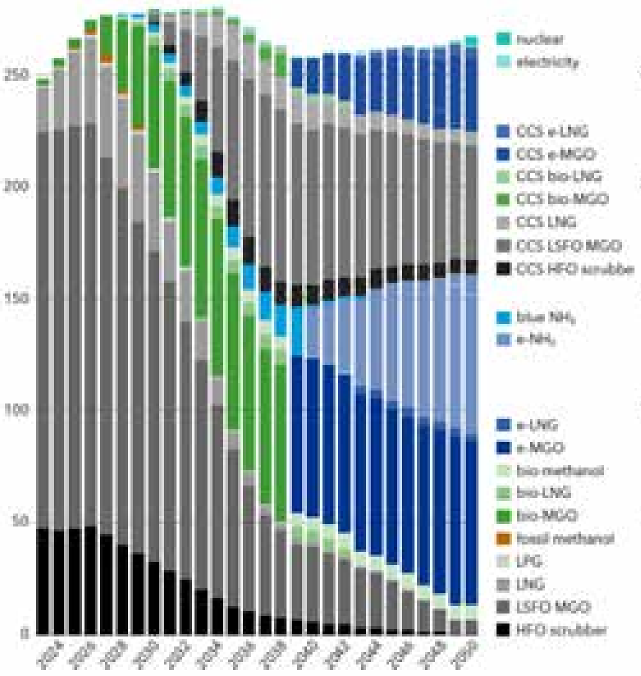
BIO & FOSSIL



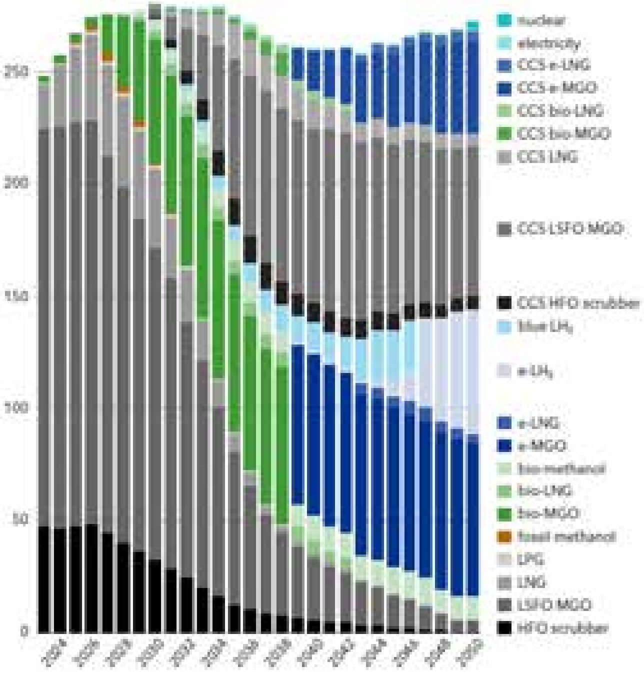
METHANOL



AMMONIA



HYDROGEN



ONBOARD CARBON CAPTURE SYSTEMS ARE EXPECTED TO BE PART OF THE SOLUTION

Growing industry momentum on the topic

STAGE 1: Technology validation

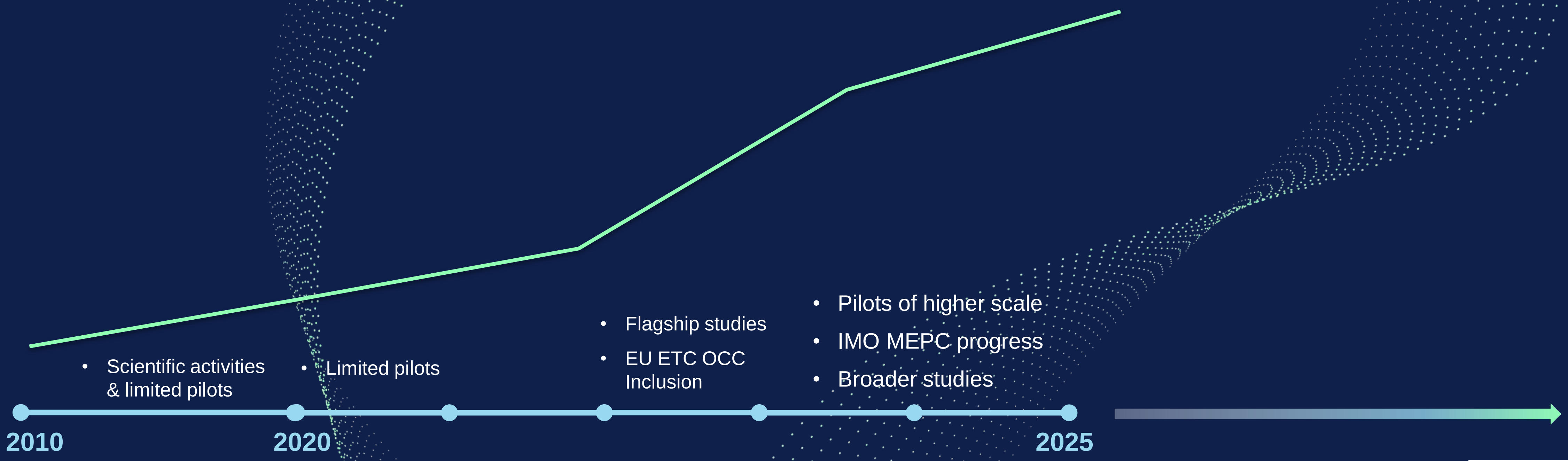
Exploration of concepts; Technology R&D; Validation of primary safety and feasibility

STAGE 2: Ecosystem & framework development

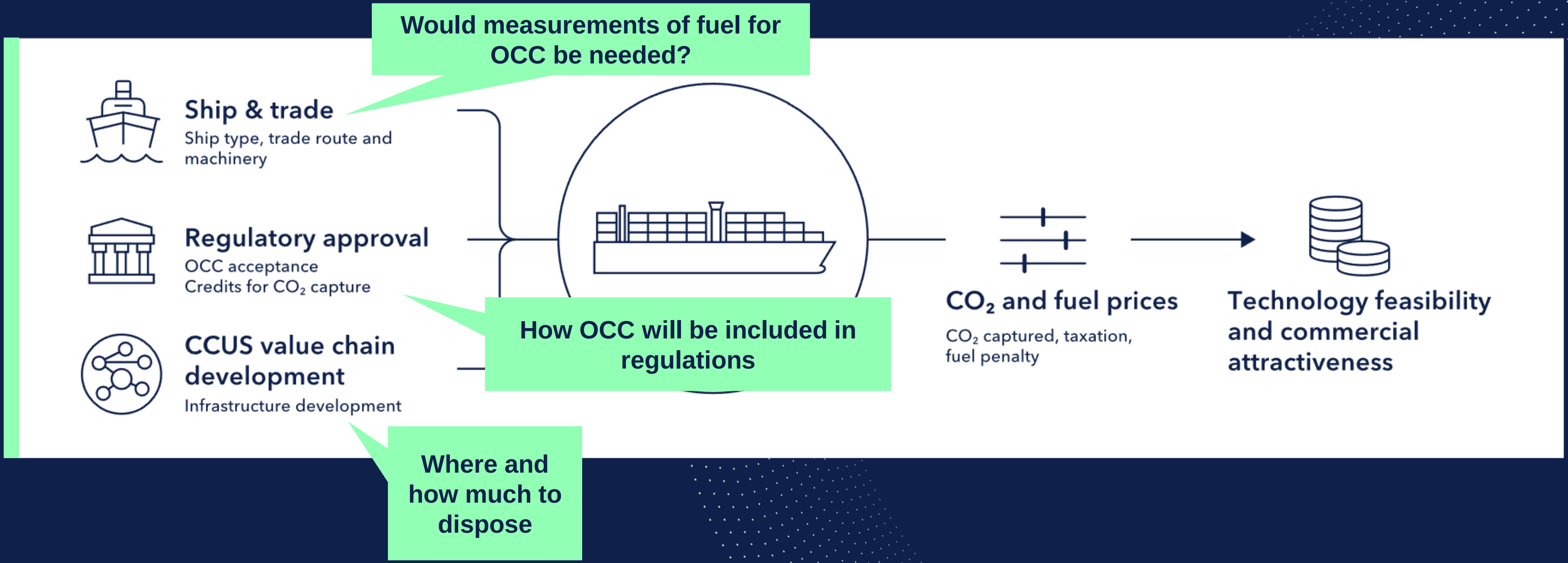
Standards; business models; stakeholder; engagement in partnerships needed for deployment

STAGE 3: Commercial scaling

Development of supportive infrastructure; incentivization; policy and regulation adaptation; real-life performance verification

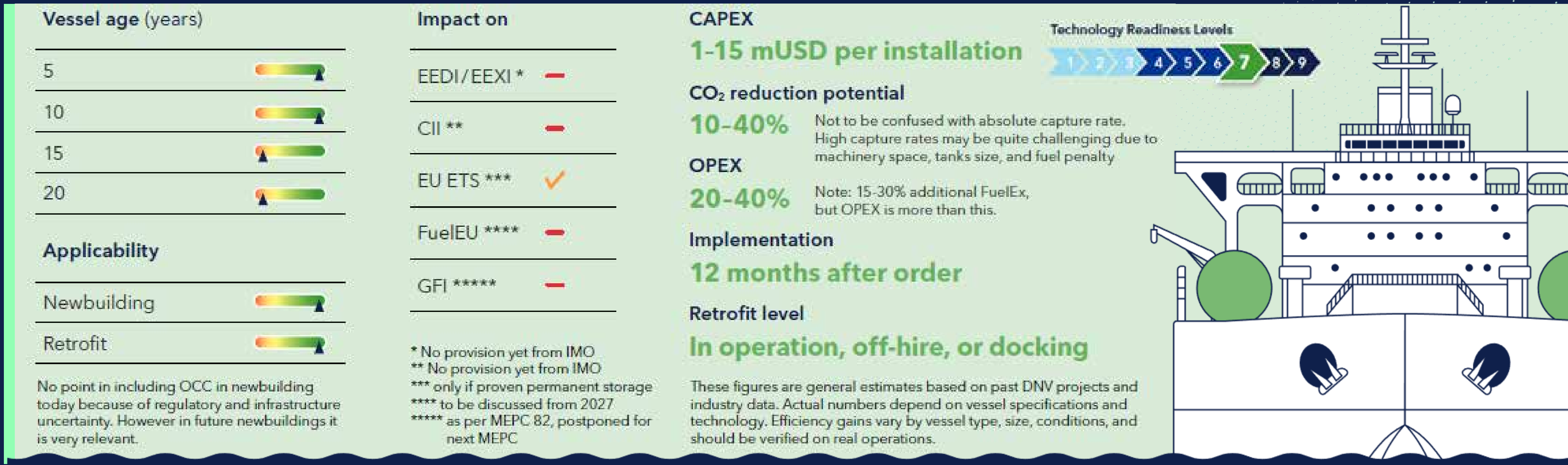


OCCS is technically feasible & proven, but wider adoption requires overcoming barriers



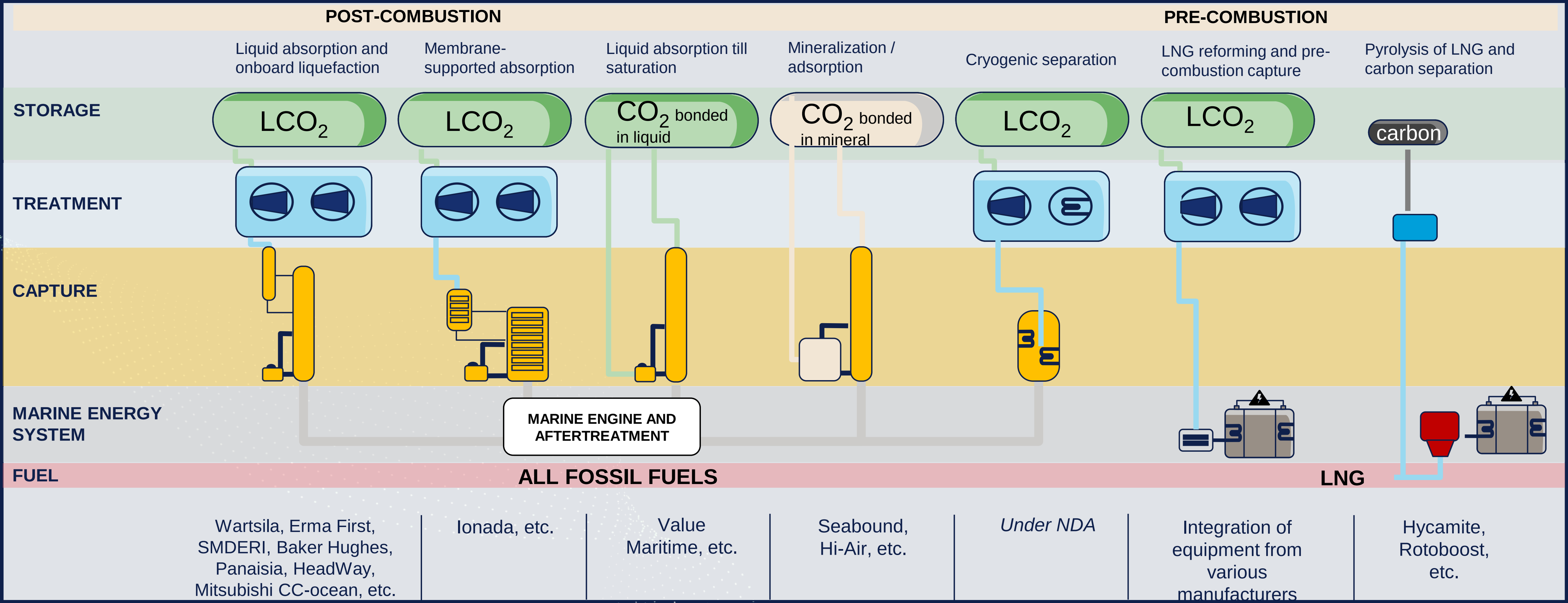
Technical perspective: Onboard implementation

OCCS can be a technically feasible decarbonization solution



Source: Energy efficiency measures and technologies. DNV Report 2025

OCC methods by technology, energy converter and fuel

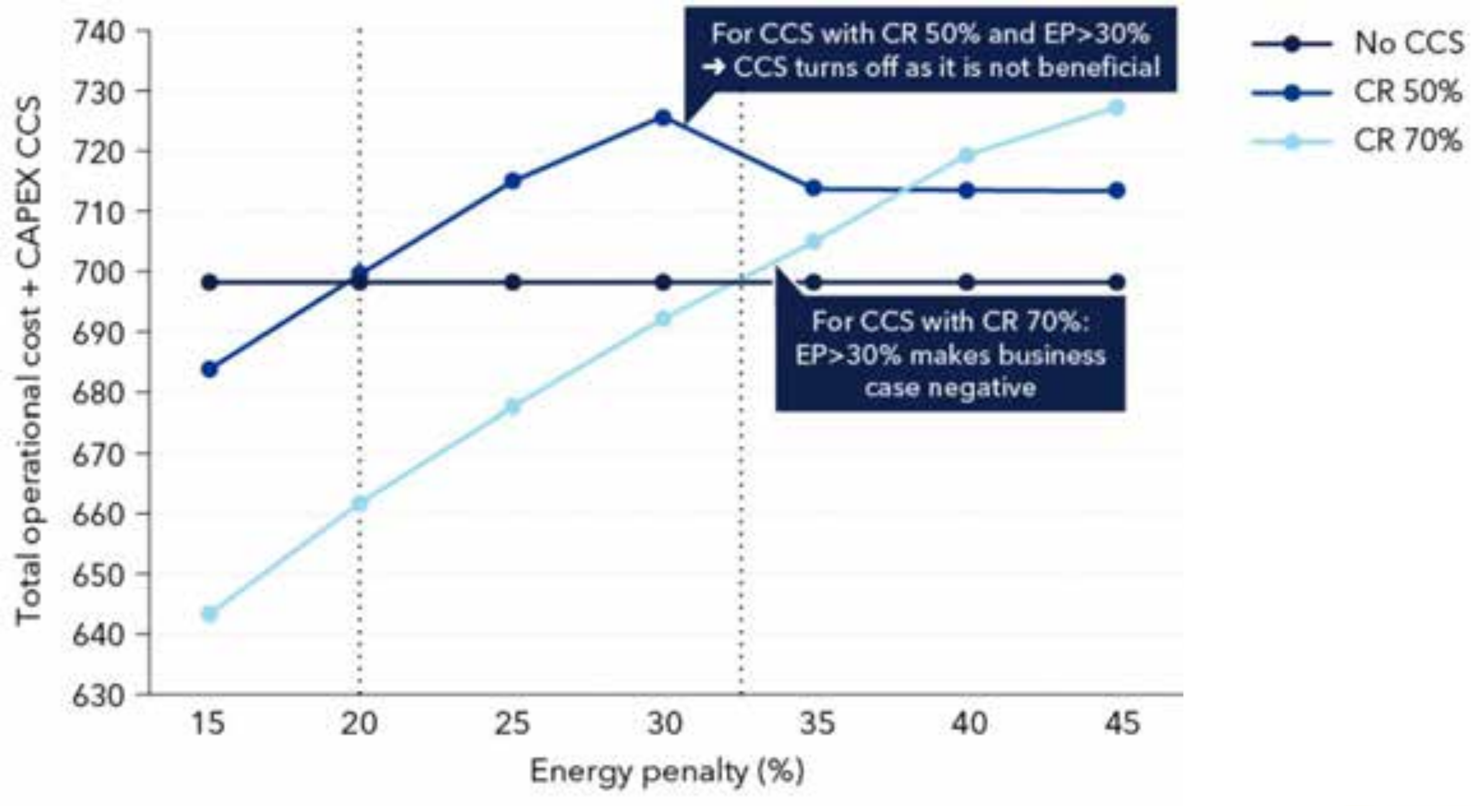


CCS CAPEX cost estimates: 150 to 800 USD/ton captured annually

Economic impact of systems performance

Example for a conventional LNG Carrier: Joint Development Project with TotalEnergies, Hyundai Heavy Industries, SK Shipping, Marubeni and DNV.

Source: Investigating Carbon Capture and Storage for an LNG carrier



Onboard systems integration

With an efficient OCC technology and onboard integration, the business case is 5% more commercially attractive than alternatives

OPEX

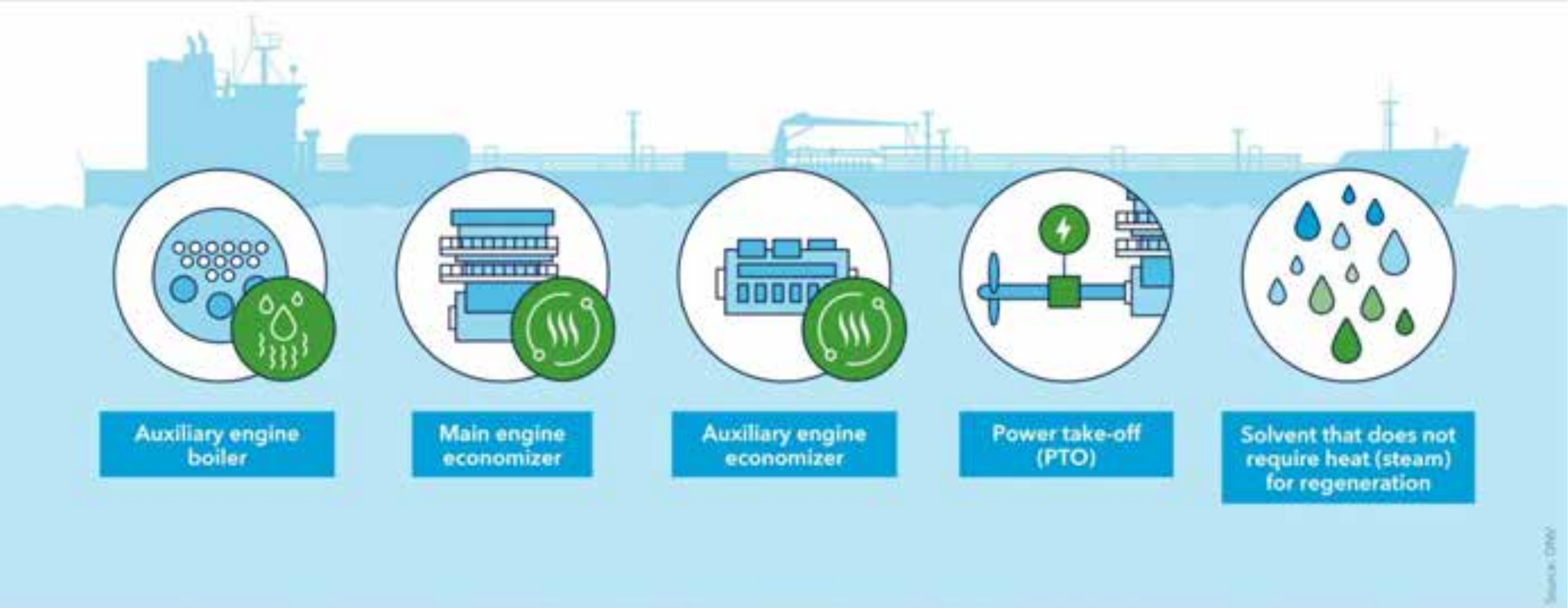
Regulatory gaps do not allow monetization of all potential OPEX savings (e.g. FuelEU)

Systems utilization

Respecting operating constraints of the vessels

DNV

Impact of enhancements



- Reduced steam demand of the carbon capture plant
- Improve power demand of the liquefaction and CO_2 treatment plants

Challenges and opportunities per ship segment

LNG carrier

\+ Cooling load integration with LNG fuel

\+ Less pre-treatment because of cleaner LNG fuel

\+ Capacity for steam use in steam-driven ships

– Extra weight constraints capture rate

Tanker

\+ Place on deck for the CO_2 tanks

\+ Available heat production on board

+/– Electric power plant capacity (engines and shaft generator, if any) delimits capture capacity

– Potential cargo capacity loss / max draught

Bulk carrier

\+ Low steam utilization / Available heat

+/– Bigger ship have more capacity for onboard integration. Smaller vessels have less capacities in terms of energy supply and space for tanks

– Potential cargo capacity loss / deck storage challenge. LCO_2 tank position and hatch covers opening are critical.

– Auxiliary engine capacities restrict capture rate because of liquefaction power demands

RoPax

\+ Less volume because of frequent port calls. Acceptance of simultaneous operations affect business case

+/– Integration capability with locally-grown CO_2 value chains

– Less capacity for additional weight on board

! Passenger safety and accidental release of stored CO_2 is an issue. Affects location of the temporary CO_2 storage location.

Container

\+ Less volume required because of frequent port calls. This benefit is expected when a global CCUS chain is fully developed.

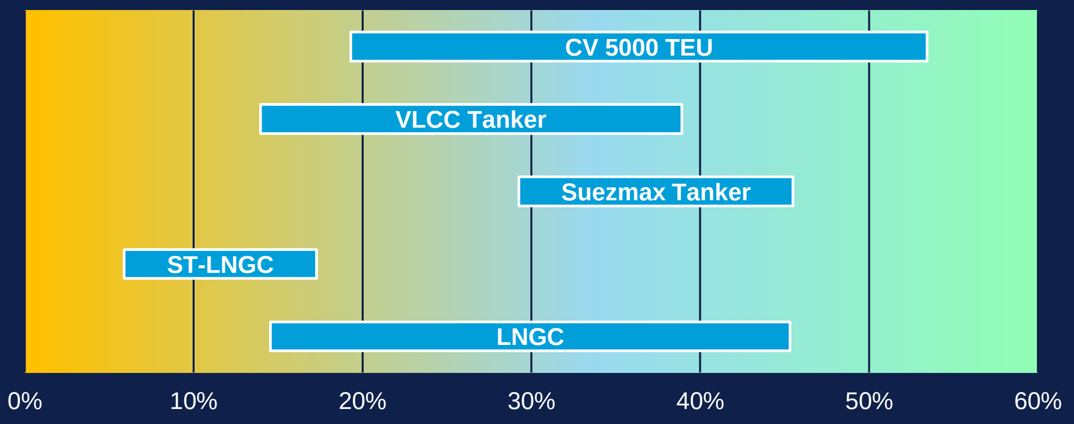
\+ Bigger vessels connecting major shipping hubs may have access to the growing CCUS value chain.

+/– Frequent port calls for smaller feeders. But possibly less timing for CO_2 offloading. Challenge tackled with simultaneous operations.

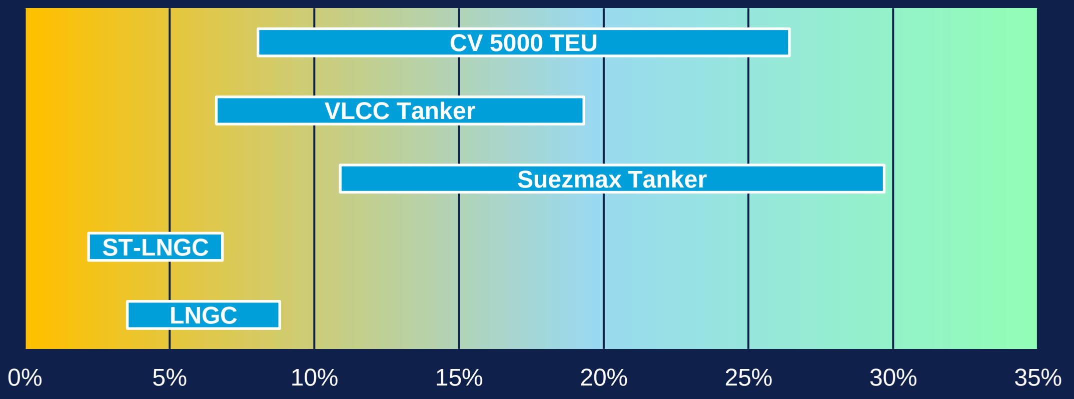
+/– Space for OCC components comes at a premium due to the potential loss of boxes. But cargo load factor may support the business case.

The integration of OCC systems necessitates a reassessment of design parameters – stability, strength, visibility, safety, and **systems integration for energy efficiency** – to ensure safe access, maintenance, and operational integrity

Emissions reduction



Fuel consumption increase



Overview of OCCS factors affecting commercial feasibility analysis

COST FACTORS

- Capital costs
- Fuel penalty
- Operating costs
- Cargo carrying capacity losses
- Carbon discharge cost

SAVINGS

- Unknown impact on compliance costs

Regulatory perspective: Unknowns

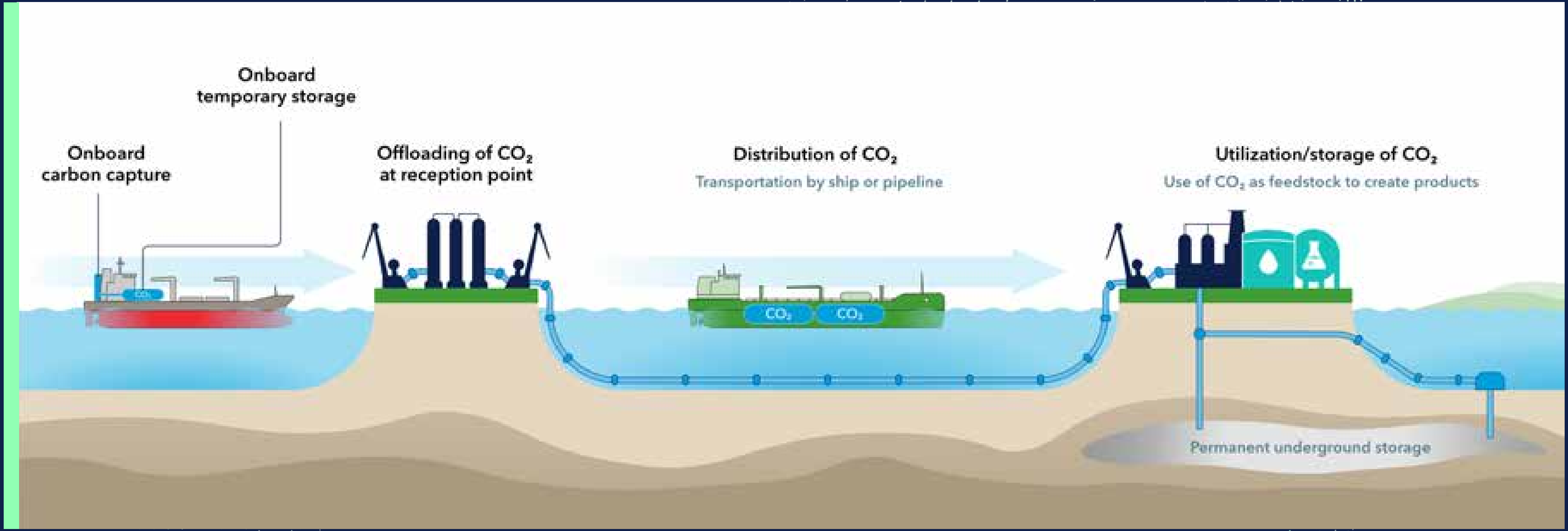
Wider application of OCC in shipping depends on regulatory acceptance

- **Regulatory need**: Shipowners need regulations that credit captured carbon dioxide to make it commercially attractive.
- **EU regulations**: EU Emissions Trading System only regulation by now that incentivizes carbon capture on ships.
- **IMO's initiative**: IMO plan to incorporate OCC in IMO Lifecycle Assessment (LCA) guidelines and is working on a regulatory framework for OCC.
- **Uncertainty reduction**: Quick regulation development reduces industry uncertainties and supports carbon capture technology development.
- **Safety guidelines:** Class provides guidelines, rules and notations for safe onboard implementation.

		STATUS	GAPS
Environmental and GHG accounting	EEXI/EEDI & CII	✗	**For future considerations:** • Fuel penalty • Design implications • Emissions derogation
	Future IMO regulations	…	• Impact on well-to-wake emissions
	EU MRV & ETS	✓	• Lacking verifiable method for monitoring
	FuelEU Maritime	…	• Provision of update by 31/12/2027
Waste handling	MARPOL	✗	• Allowance or banning of effluents to sea
	London Protocol	…	• How onboard captured CO2 will be managed
Safety	SOLAS	✗	• Offloading procedures • Training requirements • Certification of components
	Class	✓	

Value chain perspective: Status and expectations on CO2 volumes from shipping

Uptake of OCC closely linked to CCUS value chain developments



Potential storage capacities and CO_2 volumes from shipping

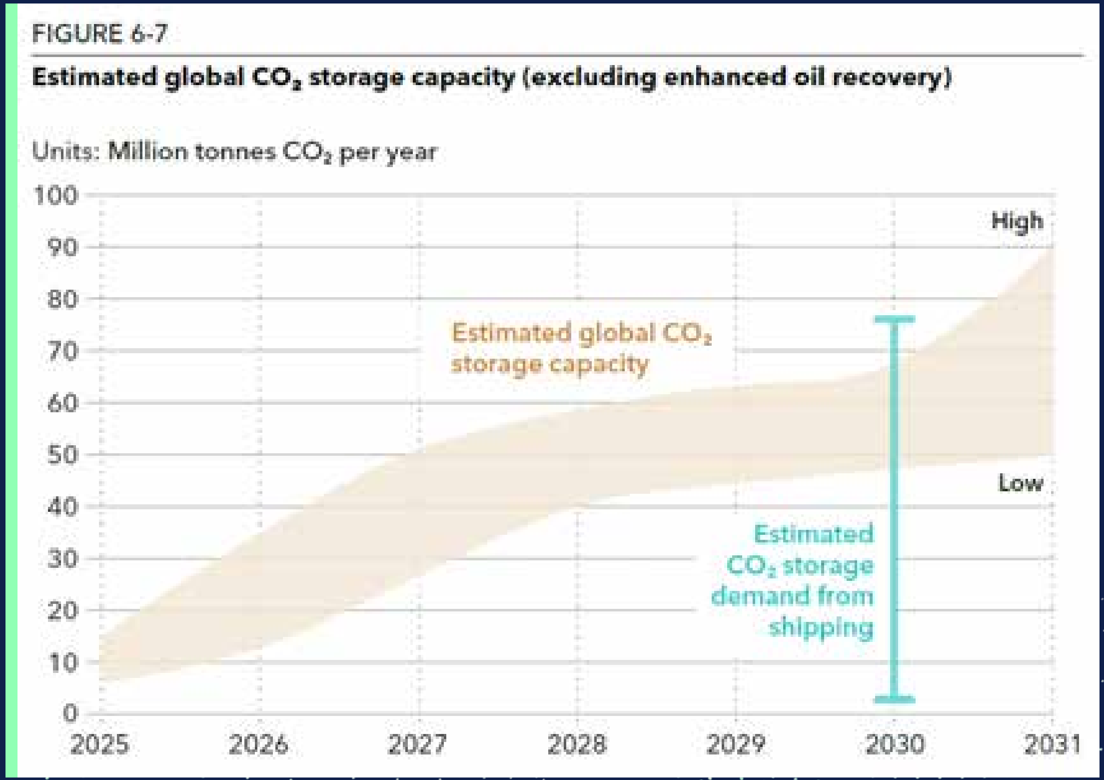
FIGURE 1-4

Planned and existing carbon storage projects, excluding enhanced oil recovery (EOR), by capacity (size of bubble) and location as well as voyage-based estimates of CO_2 emissions from direct voyages into major shipping ports, by annual tonnes of CO_2 emissions and location

Sources: AFI.dnv.com, April 2024; AIS data, 2022. Figure from (DNV, 2024b)

Port	Project
Wilhelmshaven LNG terminal	CO2nnectNow
Gdansk LNG terminal	PL – EU Interconnector
Montoir-de-Bretagne LNG terminal	GOCO2
Dunkirk	D'Artagnan
Zeebrugge	Zeebrugge Multi-molecule Hub
North Sea Port and ArcelorMittal	Ghent Carbon Hub
Antwerp	Antwerp@C CO_2 Export Hub
Rotterdam	CO2next

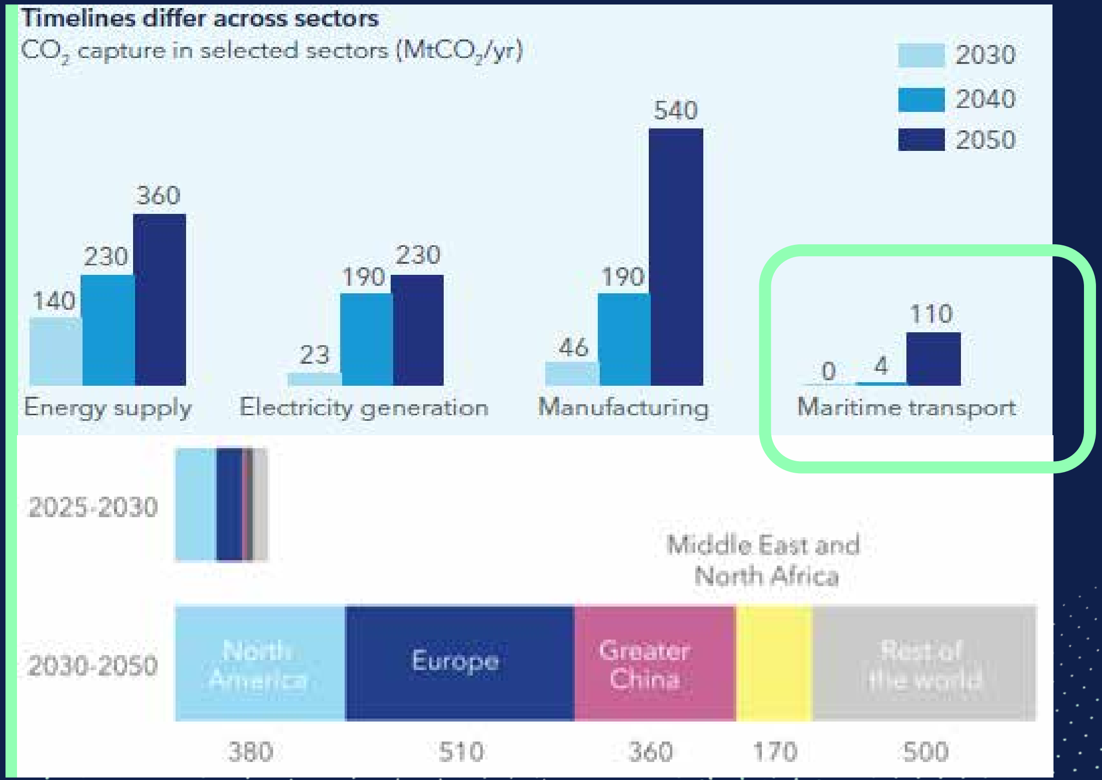
CO2 volumes from shipping: Current estimates



ESTIMATES

- Source: DNV Maritime Forecast to 2050, Edition 2024
- Estimated CO2 storage demand from shipping ~80Million tonnes of CO2 per year.

Scenarios on CO2 volumes from shipping



ESTIMATES

- If DNV's 2024 scenarios hold with OCCS technology, 84–315 Mt CO_2 capacity will be required by 2050.
- DNV ETO CCS Outlook Edition 2025 Estimate represents a most likely scenario – not a net zero as for DNV Maritime Forecast, Ed. 2024.
- OCCS to contribute by ~5% of global capacity by 2050.

Other value chain practicalities

Disposal to an intermediate receiving unit, e.g. a LCO2 barge

+ Experience from other cryogenic transfers
- Lack of current infrastructure
? Documentations for emissions derogation
? CO2 specifications for LCO2 receiving segment

Connection to the CCUS value chain nodes

+ Experience from other cryogenic transfers
- Specifications for exchange
? Purification technology

WHEN TRUST MATTERS

Thank you

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