Maritime Industry Decarbonisation Symposium 2025

UK maritime decarbonisation supply chain – opportunities and challenges

30 October 2025

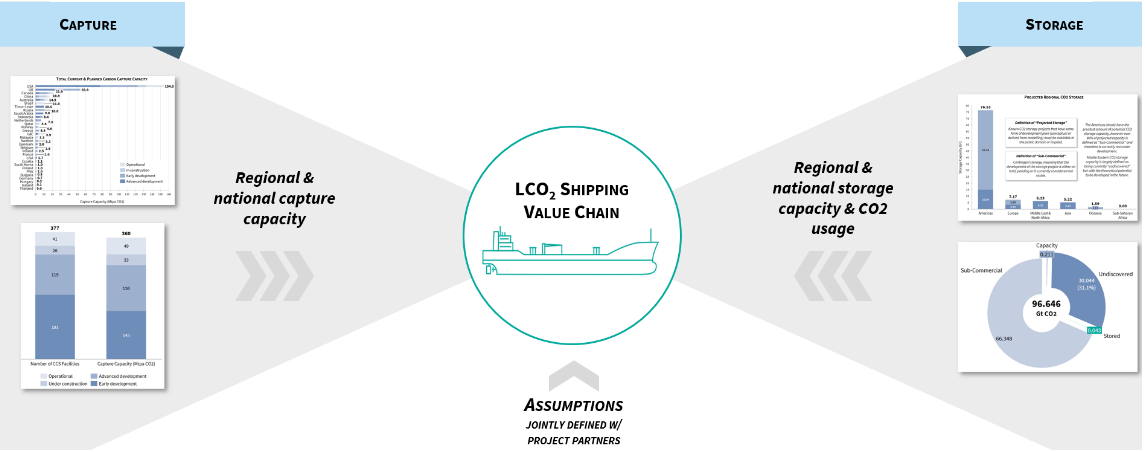
Nikkii Ng
Lloyd's Register
Technical Directorate Specialist

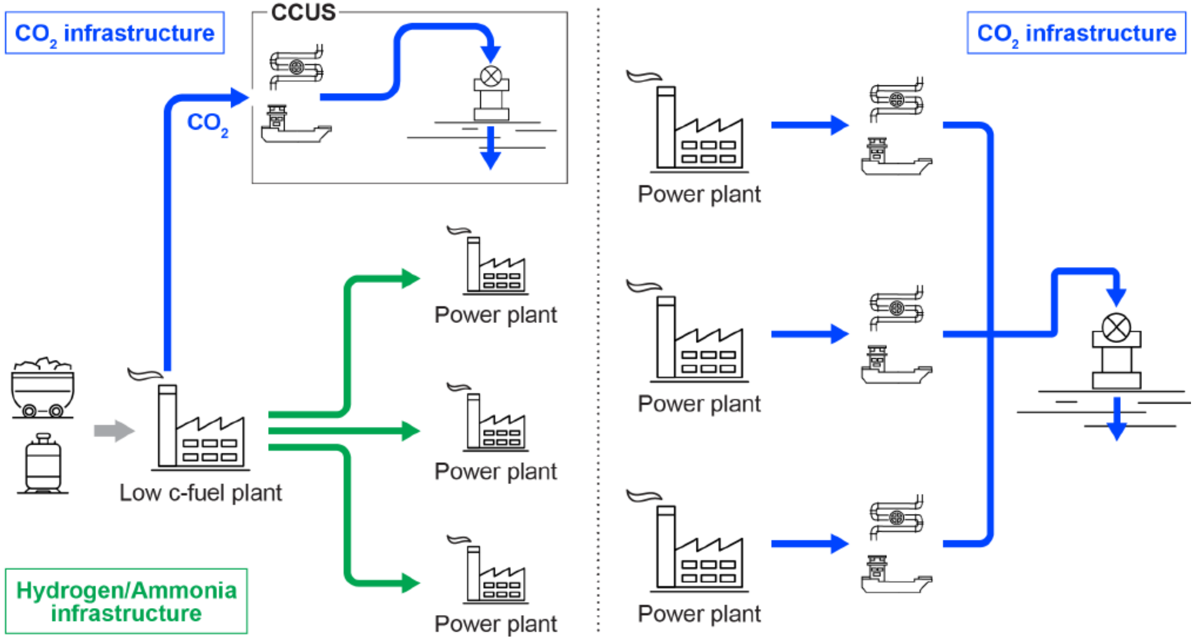
Our vision

Working together for a safer, sustainable, thriving ocean economy

The Maritime Sector's Role in Decarbonisation Opportunities

The maritime sector is a critical part of the global energy transition, and carbon capture, utilisation and storage (CCUS) can play a key role in reducing global CO_2 emissions.



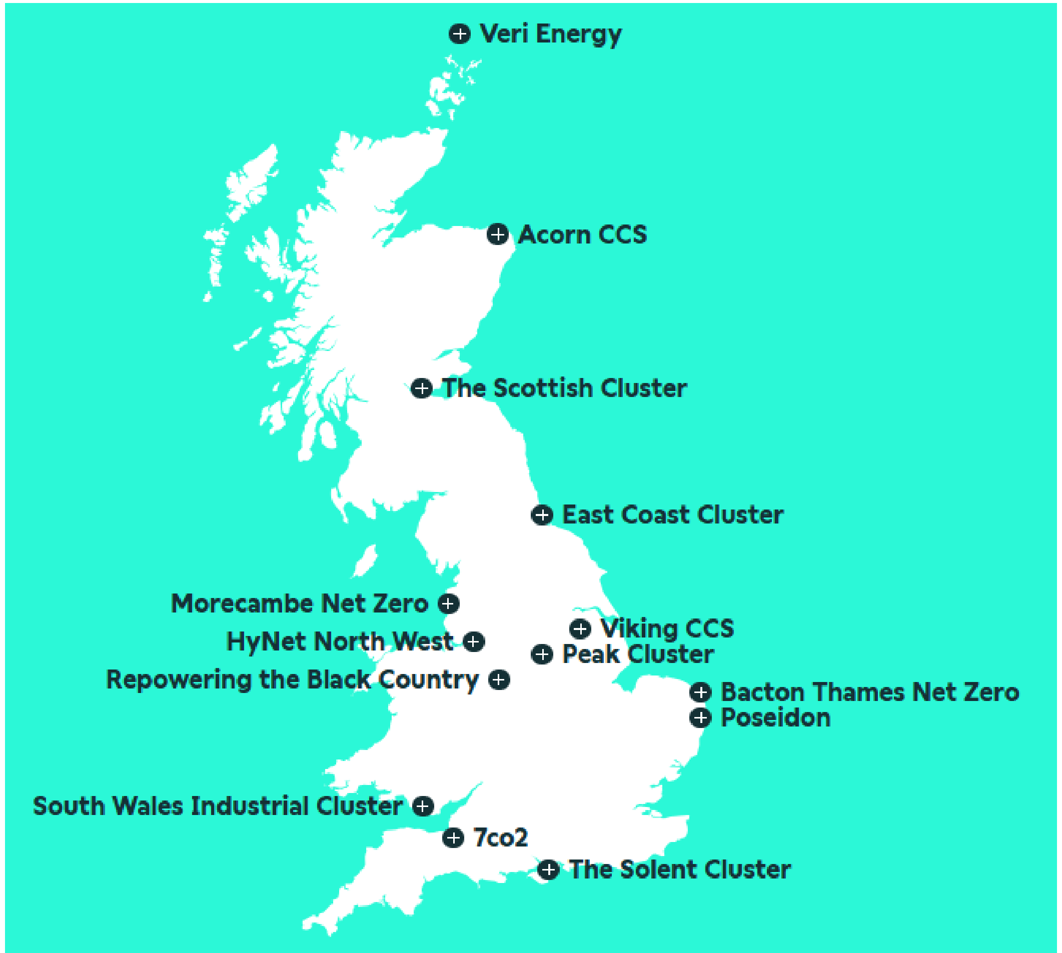


Source: https://ammoniaenergy.org/articles/new-iea-report-using-low-carbon-ammonia-to-decarbonise-power/

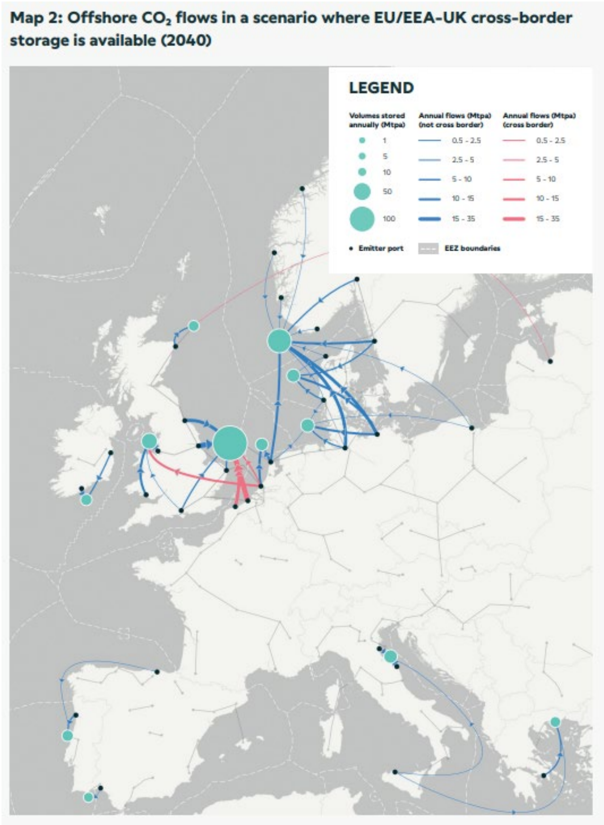
An extensive transport and storage infrastructure is a prerequisite for establishing global value chains:

- Innovations of solutions to increase CO_2 capture and storage
- Production of low carbon fuel alternatives
- Connection of scattered emitters to storage locations or usage of capture CO_2 as input or feedstock to create products

CCUS Opportunities in the UK



Source: https://www.ccsassociation.org/discover-ccus/ccus-in-action/

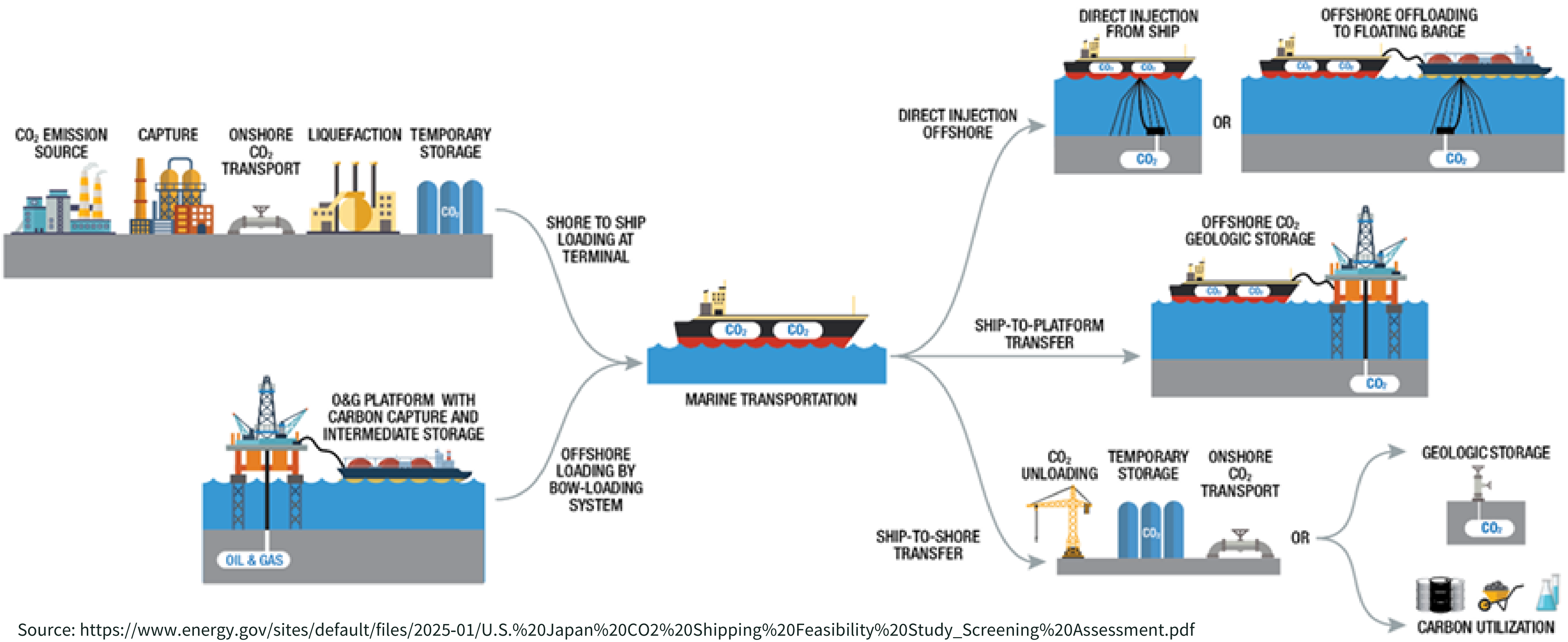


The modelling demonstrates that if cross-border CO2 transport and storage is enabled, the most cost effective storage location for just over a quarter of the EU's captured CO2 destined for offshore storage (44 $MtCO_2pa$) in 2040 would be in geological areas owned and licensed by the UK.

This translates to a 28% (€16/t)cost reduction for EU emitters, whilst those in the UK will benefit from improved CO_2 storage utilisation and from providing geological CO_2 storage as a service.

Even as early as 2030, 16$MtCO_2pa$ from EU sources would go to UK storage sites if they were available, highlighting the need for urgent action to enable EU/EEA-UK cross-border storage.

Shipping as the "midstream" function in the CCUS value chain



Source: https://www.energy.gov/sites/default/files/2025-01/U.S.%20Japan%20CO2%20Shipping%20Feasibility%20Study_Screening%20Assessment.pdf

Policy and Regulation Challenges to Cross-border CO_2 transport and storage

UK ETS and EU ETS

- UK Emissions Trading Scheme (UK ETS)
  - January 1, 2021
  - scheme replaced the UK's participation in the EU ETS after the EU exit transition period.

- No recognition of emission trading schemes between the EU and the UK
  - EU emitters storing their CO_2 in the UK North Sea would not benefit from the storage
  - EU emitters still need to purchase allowances for their emissions in the EU.

- Call for EU legislation amendments to be made to enable EU/EEA-UK cross border transport and storage of CO_2 by allowing CO_2 captured in the EU/EEA but stored in the UK to be recognised by the EU ETS as not having been emitted

Source: https://www.ccsassociation.org/all-news/a-europe-wide-co2-market-can-reduce-storage-costs-by-20-2

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (the "London Convention") and its 1996 protocol (the "London Protocol")

An amendment to Article 6 of the London Protocol which forbids cross-border transport of CO_2 as part of its scope to prevent the export of "waste to other countries for dumping" proposed in 2009 allows cross-border transport of CO_2 for CCUS purposes with the following conditions:

- the countries involved in cross border transport of CO_2 will have to enter into bilateral agreements or understandings, and allocate permitting responsibilities between the parties
- if the CO_2 is exported to a state which is not a party to the London Protocol, the agreement or arrangement shall include "provisions at a minimum equivalent to" the ones of the London Protocol
- the International Maritime Organization ("IMO") must be notified of such agreements and shall include "confirmation and allocation of permitting responsibilities" between the involved countries consistent with the London Protocol and other applicable international law.

Ratification by two-thirds of the London Protocol's contracting parties (or 36 countries) is required to allow the 2009 Amendments to be entered into force, which has not yet happened to date. In the interim, countries wishing to participate in cross-border transport of CO_2 for sequestration submit a provisional application to IMO to implement the Article 6 amendment.

The International Convention on Liability and Compensation for Damage in connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS Convention)

- Adopted in 2010 (amending original 1996 convention)
  - Requires enough states have ratified it in order to come in force

- an international agreement that establishes a framework for compensating those who suffer loss or damage from incidents involving HNS cargo. It covers substances like oils, liquefied gases, and dangerous materials carried by sea and includes a two-tier system for compensation:
  - compulsory insurance for shipowners and
  - a fund for remaining claims.

- Convention will apply to CO_2 carriers because CO_2 is listed in the International Gas Carrier (IGC) Code, and the Convention's scope is broad enough to cover any cargo referenced in IMO instruments like the IGC Code

- Its design might not be suited for the specific characteristics of CO_2 transportation in the context of Carbon Capture and Storage (CCS), potentially requiring further amendments to address unique issues.

- Meanwhile - the owners/charterers should be aware of their potential liabilities based on the 1996 Convention on Limitation of Liability for Maritime Claims (LLMC)

LCO_2 Ship Design & Regulatory Developments

LCO2 Carriers

Transporting liquefied CO_2 via ship is a proven technology deployed in food grade and other industrial use cases, typically at

- low pressure (6 – 10 barg, -50 to -40 Deg C)
- medium pressure (13-20 barg, -30 to -20 Deg C)

US-listed **Capital Clean Energy Carriers** ordered four ammonia-ready LCO_2 low-pressure (LP) LCO_2 carriers in **July 2023**, to be built at **HD Korea Shipbuilding & Offshore Engineering's** (HD KSOE) **HD Hyundai Mipo**, all classed by LR. The LP LCO_2 carriers are designed to operation at ~ 8barg and -55 ^oC.

Cargo size: 25,000 m3 , multi gas carrier (Ammonia & LPG), dual fuel

The Northern Lights project has already taken delivery of the first of four carriers designed to operate at medium pressure of 15 barg (max. 19 barg) and -26^{o}C (min. -35^{o}C).

Cargo size: 7,500 m3

LCO2 Carriers – Hazards considerations

CO_2 presents a complex hazard profile that combines the following properties:

Toxicity:

At high concentrations, CO_2 is a toxic substance that can cause confusion, dizziness, and loss of consciousness.

Asphyxiation:

As it is a non-flammable gas, it can displace oxygen, posing a significant risk of asphyxiation in enclosed spaces

Cryogenic and pressure risk:

CO_2 is transported as a liquefied gas under pressure and cryogenic conditions, presenting risks from cold burns and the potential for brittle fracture of the hull in case of an uncontrolled release.

Impurities influencing the phase properties of the CO_2 and corrosiveness:

Impurities can change the pressure-temperature conditions at which CO_2 transitions between gaseous, liquid, and supercritical phases - the risk of solidification due to the pressures and temperatures falling below the triple point of CO_2

Synergistic effect of multiple impurities (e.g. O_2, H_2S and SO_2 together) affects corrosion and stress corrosion cracking

Source of impurities in CO_2 streams

CO_2 source
Type of emitter & product.

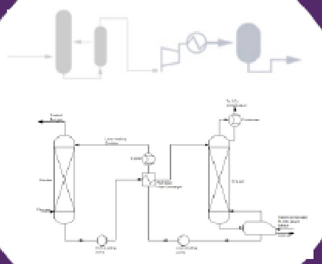
Anthropogenic source (Steel plants, cement plant, coal plants, etc)

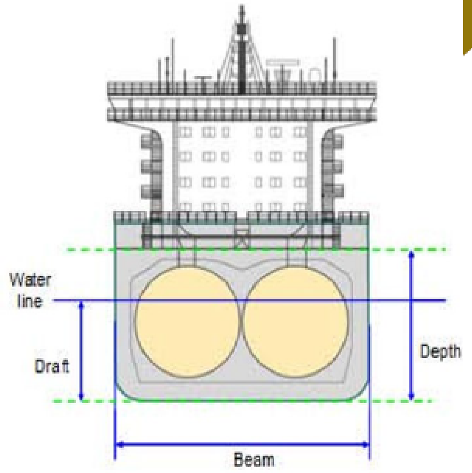
CO_2 Conditioning , purification- multiple streams- Impurity removal during compression, conditioning and purification impacts the composition

Varied impurities;
NO_x, SO_x, H_2O, O_2, H_2S, CO, heavy metals, N_2, H_2

Alcohols, Amine, Glycols, Aldehydes

CO_2 capture technology
Impacts the composition





Energy conversion process (Post combustion, pre-combustion, oxyfuel)

LCO_2 Ship Design & Regulatory Developments

Classification of CO_2 as Toxic & Asphyxiant product under **IGC Ch.19** triggers several mandatory changes for ships covered by the IGC Code:

Hazard monitoring and detection

- **Toxic vapor detection:** The vapor detection requirement for CO_2 has been changed from "Asphyxiant (A)" (which measures oxygen depletion) to "Toxic vapor detection (T)".
- **Fixed gas detection:** A fixed gas detection system is now mandatory for ships carrying CO_2 as cargo, ensuring proactive monitoring for the gas itself.

Safety protocols and equipment

- **Designated ship type:** CO_2 requires containment in reliable, robust, pressure-vessel-style Independent Type C tanks.
- **Revised fire protection:** Specific amendments to fire protection systems have been made to account for CO_2's properties.
- **Updated personnel training:** Crew training now places greater emphasis on the specific hazards of CO_2 operations, including toxicity, in addition to general gas carrier training.

Operational considerations

- **Density of CO_2:** Because CO_2 is denser than air, safety procedures must account for its tendency to accumulate in low-lying, enclosed spaces where it can displace oxygen.
- **Cargo purity:** The purity of the captured CO_2 cargo is a major factor, as certain impurities (e.g., water) can become corrosive and require special material considerations.

LR Rules and Regulations for the Classification of ships

Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk

(LR-RU-008)

LR 19.1-05 Amendment of the product table

(part only shown)

a	b	c	d	e	f	g	h	i
Product name		Ship Type	Independent tank type C required	Control of vapour space within cargo tanks	Vapour detection	Gauging		Special requirements
Carbon Dioxide (High Purity)		3G			A+T*	C		14.4.2 14.4.4 17.21
Carbon Dioxide (Reclaimed quality)		3G			A+T*	C		14.4.2 14.4.4 17.22
T* - Only applicable the requirements listed in these rules and the applicable relevant requirements indicated in the following rules' paragraphs: 3.2.6, 5.6.5.1, 12.1, 18.8.1 and 18.9.4.								

Chapter 17 Special Requirements | Additions to 17.21 and 17.22

Rules and Regulations for the Classification of Ships

(LR-RU-001)

- *Section 13*
  Carbon emissions abatement plant

13.1 General

13.1.1 The requirements given in *Pt 5, Ch 24, 1 General* to *Pt 5, Ch 24, 10 Storage and use of chemicals* are applicable to Carbon emissions abatement plant unless otherwise stated.

13.1.2 The requirements in this section apply to Carbon emissions abatement plant making use of amine-based chemical solvents for carbon capture and are considered to satisfy the safety goals and corresponding functional requirements for emissions abatement systems in *Pt 5, Ch 24, 1.1 Scope* and *Pt 5, Ch 24, 2.1 Functional requirements of emissions abatement plant*. To support innovation, where the use of other carbon capture technologies or deviation from the requirements in this section is proposed, compliance with goals and functional requirements themselves will need to be demonstrated to the satisfaction of LR.

Onboard Carbon Capture & Storage (oCCS)

Detailed review of Technology Providers with a comprehensive overview of the developing technologies on the market and joint learning from a ship specific feasibility study with shortlisted Makers

- **Global Technology Survey, oCCS technology pathways**
  Technologies used to capture carbon analyzed in terms of TRL and IRL, as well as their suitability for onboard applications based on LNGC propulsion technology

- **Makers by Technology, applications and track record**
  A complete record of systems in the market or systems projected to attain high TRL in the forthcoming years along with existing or planned applications

- **Technical normalization of solutions**
  Benchmarking, of available solutions, on equal terms, based on a number of selection factors

- **Deep dives with Specific makers**
  Following the shortlisting of specific makers, deep dives can be undertaken including a ship specific feasibility study and a joint workshop

- **Examination and prospect assessment of more innovative pathways**
  What is the prospect of more competitive oCCS solutions, analyzing technologies with lower TRL but greater prospects like cryogenic carbon capture and MCFC

- **Assessment of technology risk**
  Projection of technology , efficiency and TCO of existing mature technology against other prospects

Work packages

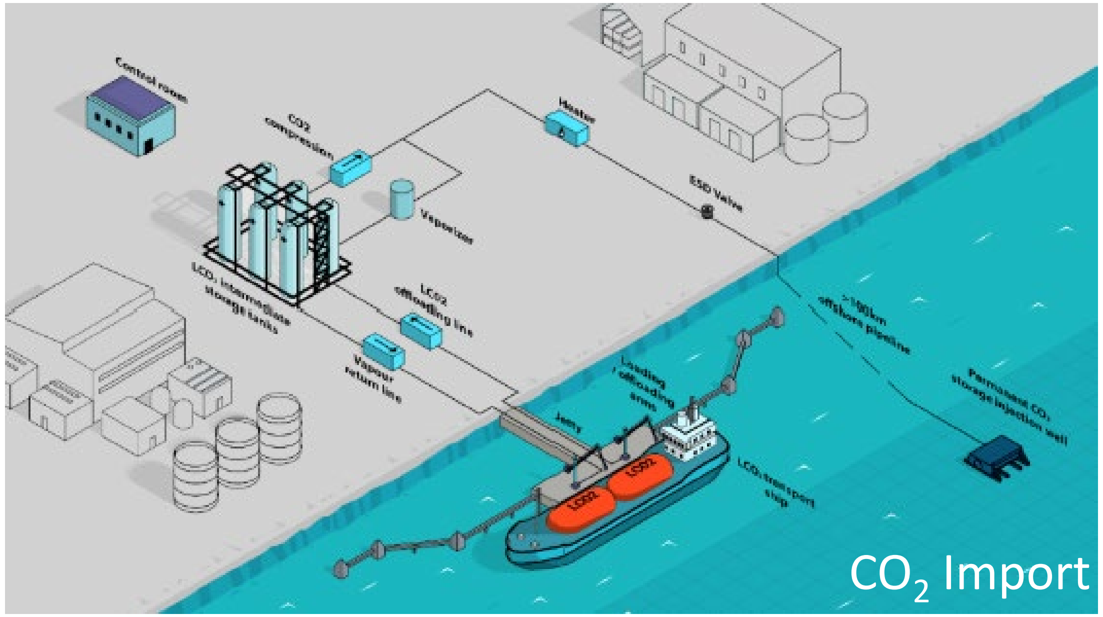
Including, but not limited to:

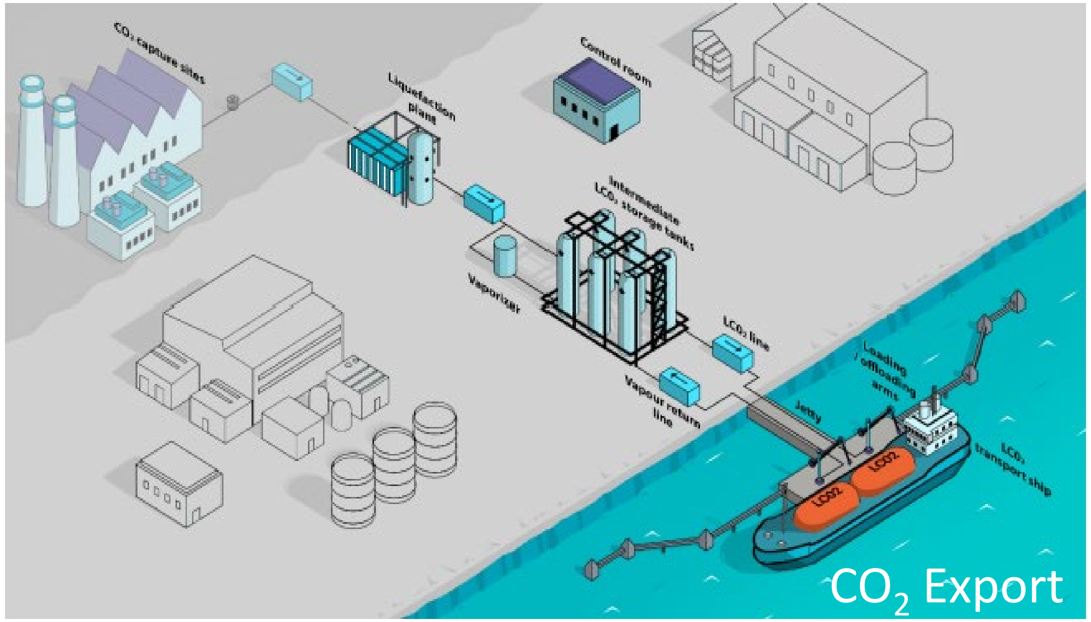
- Calcium looping
- Chemical absorption
- Membrane technology
- Cryogenic carbon capture
- Oxyfuel combustion
- Molten carbonate fuel cell
- Methane cracking

Port infrastructure and flexibility

Port infrastructure and flexibility

- Developing flexible CO_2 reception facilities capable of handling various ship designs, volumes, and offloading intervals
- Quayside infrastructure/facilities
  - Space available for key infrastructure for loading/offloading, buffer storage, and perhaps CO_2 conditioning
  - Bunkering facilities
  - Utilities: water and electricity supply, waste removal facilities





Source: NetZero Technology Centre

Concluding Remarks

Concluding Remarks

- The Martime represents an **irreplaceable component** towards energy transition and meeting decarbonization targets
- Adding this option in our portfolio of solutions may eventually prove **critical** to an **efficient transition pathway**
- A vital element of this new value chain will be shipping and needs to assume its role as a critical link in this value chain
- We obtain greater **awareness**, **clarity** and better **understanding**, **technology development** and **readiness** , a more focused and tailored **regulatory framework** and **industry guidelines**
- Next stages aiming to facilitate **synergies** and the creation of a **global framework** of various stakeholders pursuing activity and investments

Thank you

Nikkii Ng

Lloyd's Register

Technical Directorate Specialist