Offshore CO2 Storage

The importance of an integrated Value Chain

Asle Solheim
Lime Petroleum AS, Oslo Norway

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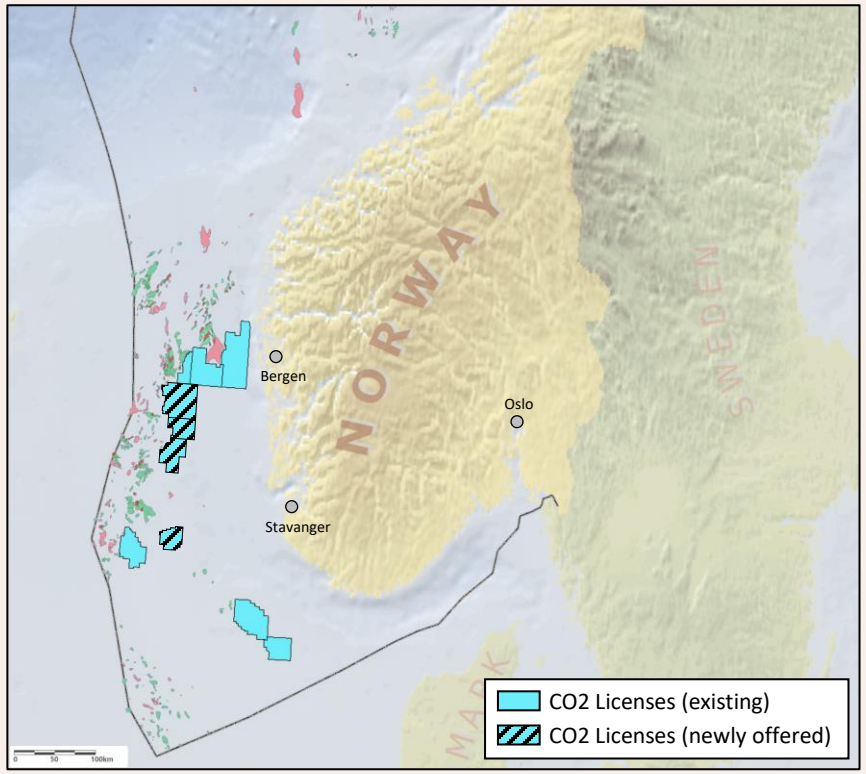
Norway Offshore CCS – High Capacity and Long Term

- 11 CO2 Storage Licences awarded in Norway North Sea per June 2024 and more to come
- Capacity to store around 40 MTPA from 2030, starting in 2024 or 2025 with Northern Lights



- EL001 Northern Lights (Equinor, Shell Total E)
- EXL002 Smeaheia (Equinor)
- EXL003 Polaris (Horizont Energy, PGNiG)
- EXL004 Luna (Wintershall DEA, Total E)
- EXL005 Poseidon (Aker BP, OMV)
- EXL006 Havstjerne (Wintershall, Stella Maris)
- EXL007 Trudvang (Sval Energi, Vår Energi, Storegga)

- New Licences:
- EXL TBN Atlas (Aker BP, PGNiG)
- EXL TBN Kinno (Equinor)
- EXL TBN Albondigas (Equinor)
- EXL TBN Iroko (Vår Energi, OMV, Lime Petroleum)

Offshore CCS – Important element to meet decarbonization

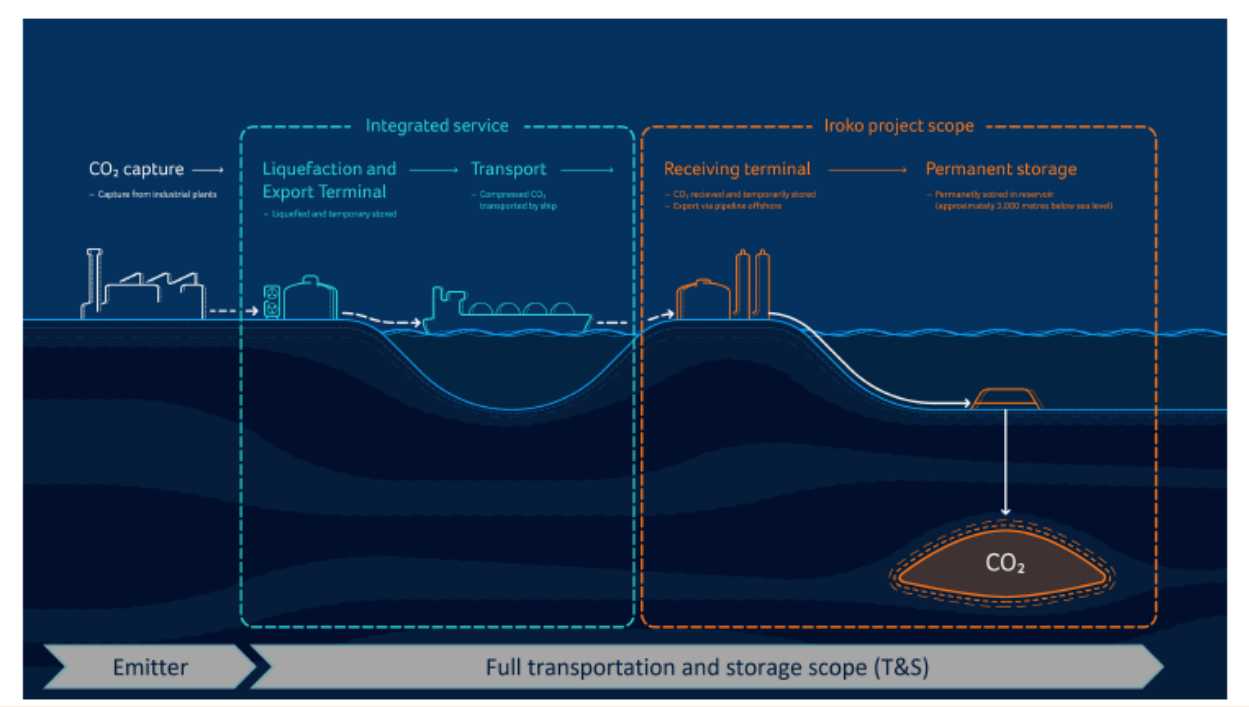
- Many projects are in the planning
  - Regulations, Legislation and Policies are in development

- Lack of infrastructure to form the Value Chain
  - Huge investments
  - Lack of standardised technical solutions
  - All links in the Chain must be developed in parallel

- CCS is currently a loss making business
  - Economies of Scale
  - Cost effetive Value Chains for large volumes
  - CCS business similar to the Waste Management Business

- Cost of CO2 emissions (ETS) expected to increase?
  - 80-100 Eur per ton today
  - 200 – 300 Eur per ton in 2030?

- Governmental and political support and co-ordination
  - EU – Net Zero Industry Act (NZIA)



CO2 Pressure and Temperature

Pressure Cases:

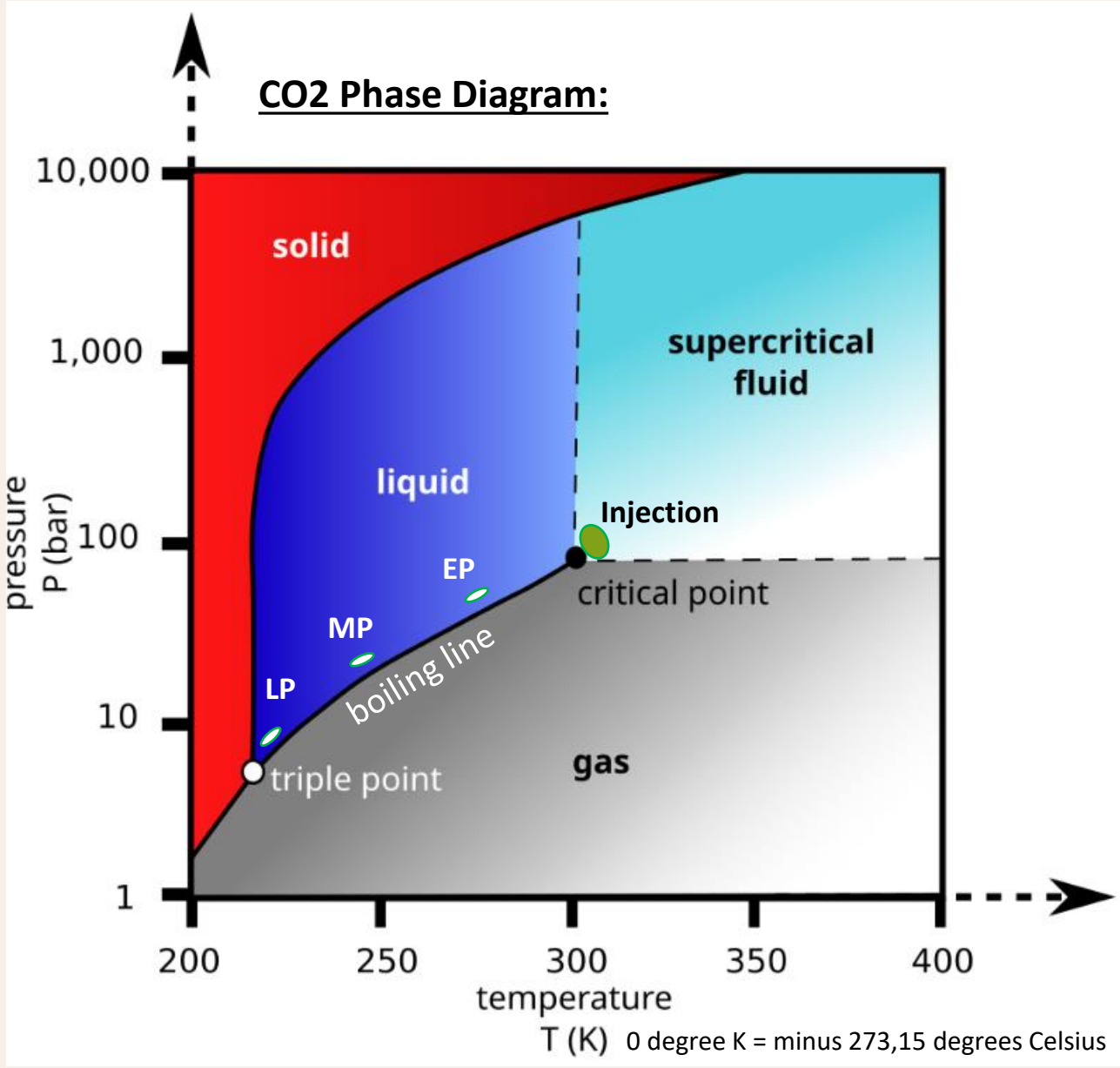
- Elevated Pressure - EP
- Medium Pressure - MP
- Low Pressure - LP

Level	Temperature (°C)	Pressure (barg)
Elevated Pressure	0 – 10	34 – 44
Medium Pressure	-30 – -20	12 – 17
Low Pressure	-55 – -40	5 – 7

Value Chain Criteria to meet:

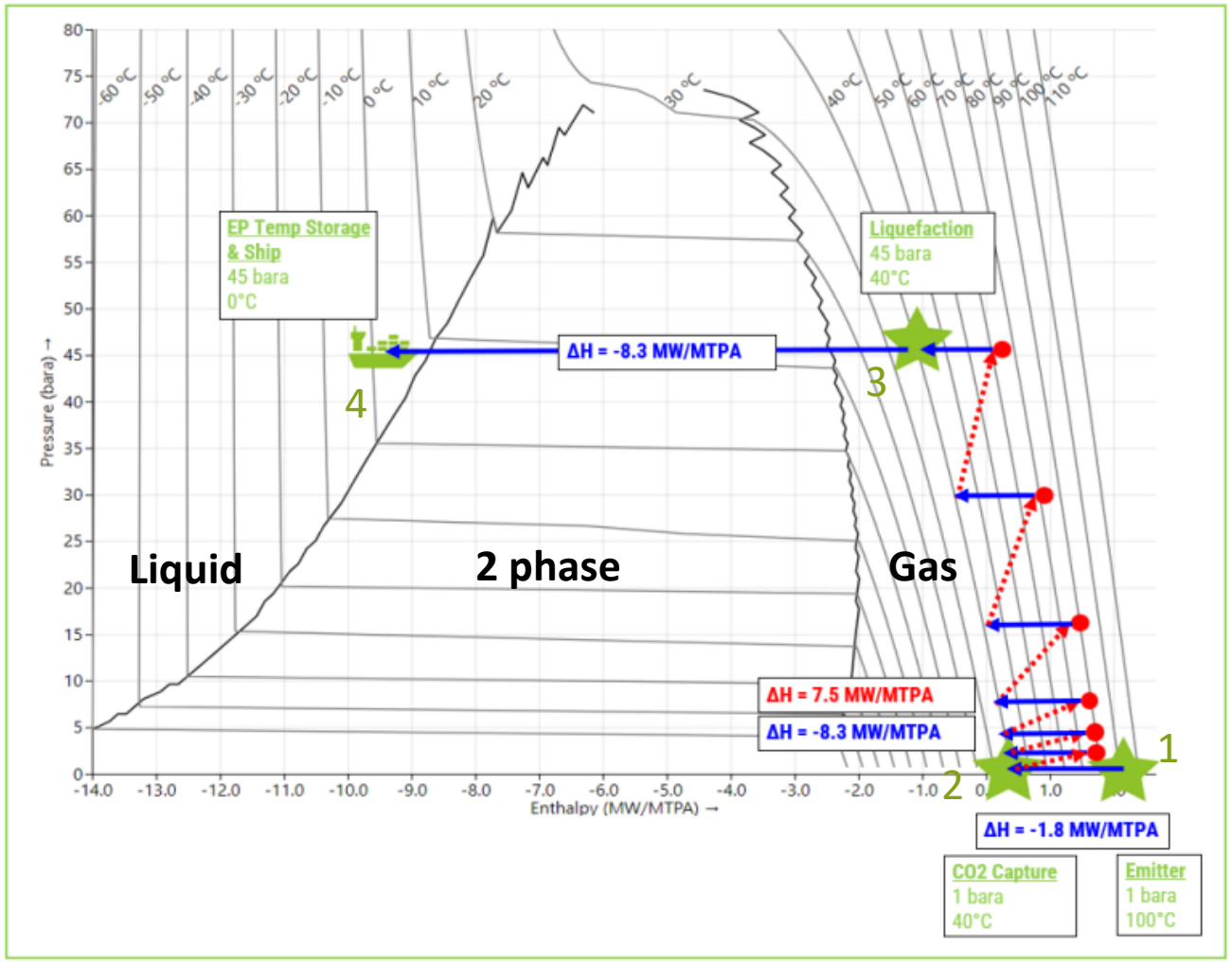
- Safe
- Reliable
- Cost and Energy effective

CO2 Phase Diagram:



0 degree K = minus 273,15 degrees Celsius

CO2 Energy Modelling – Pressure vs. Enthalpy charts



Example chart showing CO2 from Emitter to Liquefaction and loading onto vessel in the EP case

Entalphy H = U + PV

Entalphy is a thermodynamic quantity equivalent to the total heat content of a system where U = interal energy, P = pressure and V = volume

How much energy (MW) needed to liquefy 1 MTPA CO2:

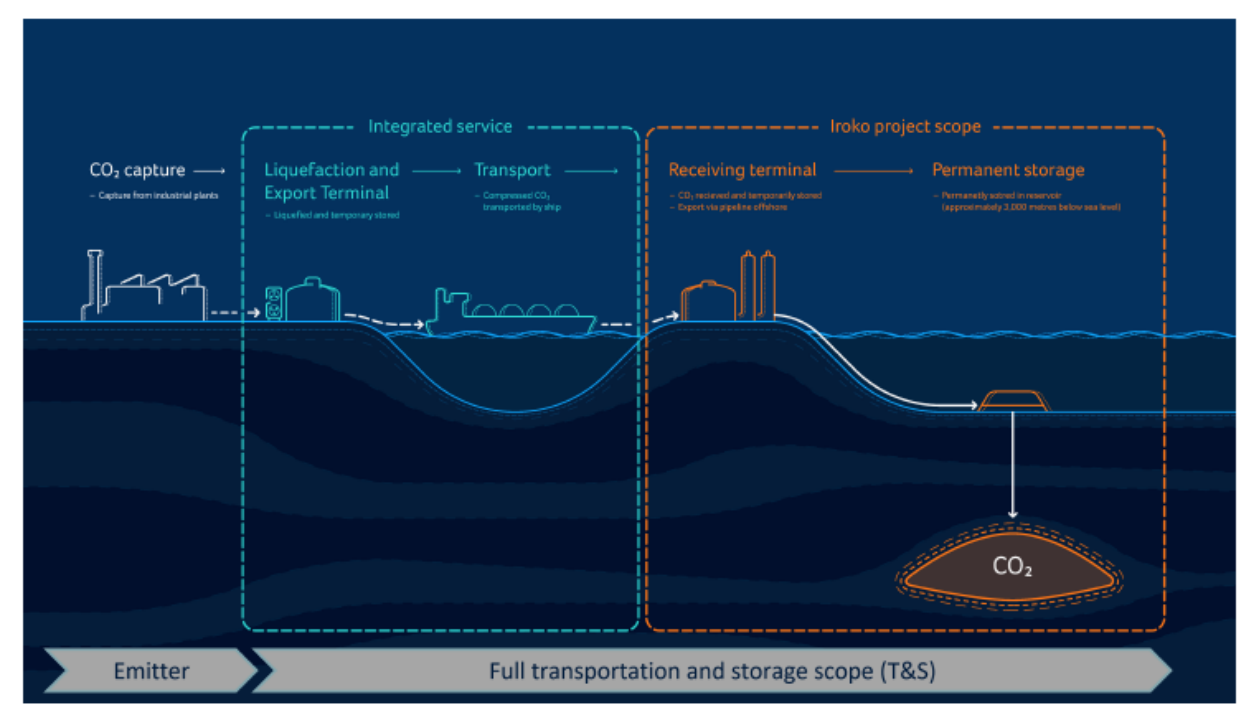
• Initial cooling	-1.8 MW/MTPA
• Multistage compression	7.5 MW/MTPA
• Cooling	-8,3 MW/MTPA
TOTAL	17,6 MW/MTPA

Types of Energy:

- Low cost Heat Exchange (with sea water)
- High cost Electrical Energy for pumps & compressors

Offshore Value Chain – 4 Main Technical Scenarios for deep water

1. Ship Transport to Onshore Terminal with pipeline to store (Northern Lights)
2. Ship Transport to Offshore Terminal (Floating Storage and Injection Unit - FSIU)
3. Ship Transport directly to store and injection
4. Offshore pipeline directly to store and injection



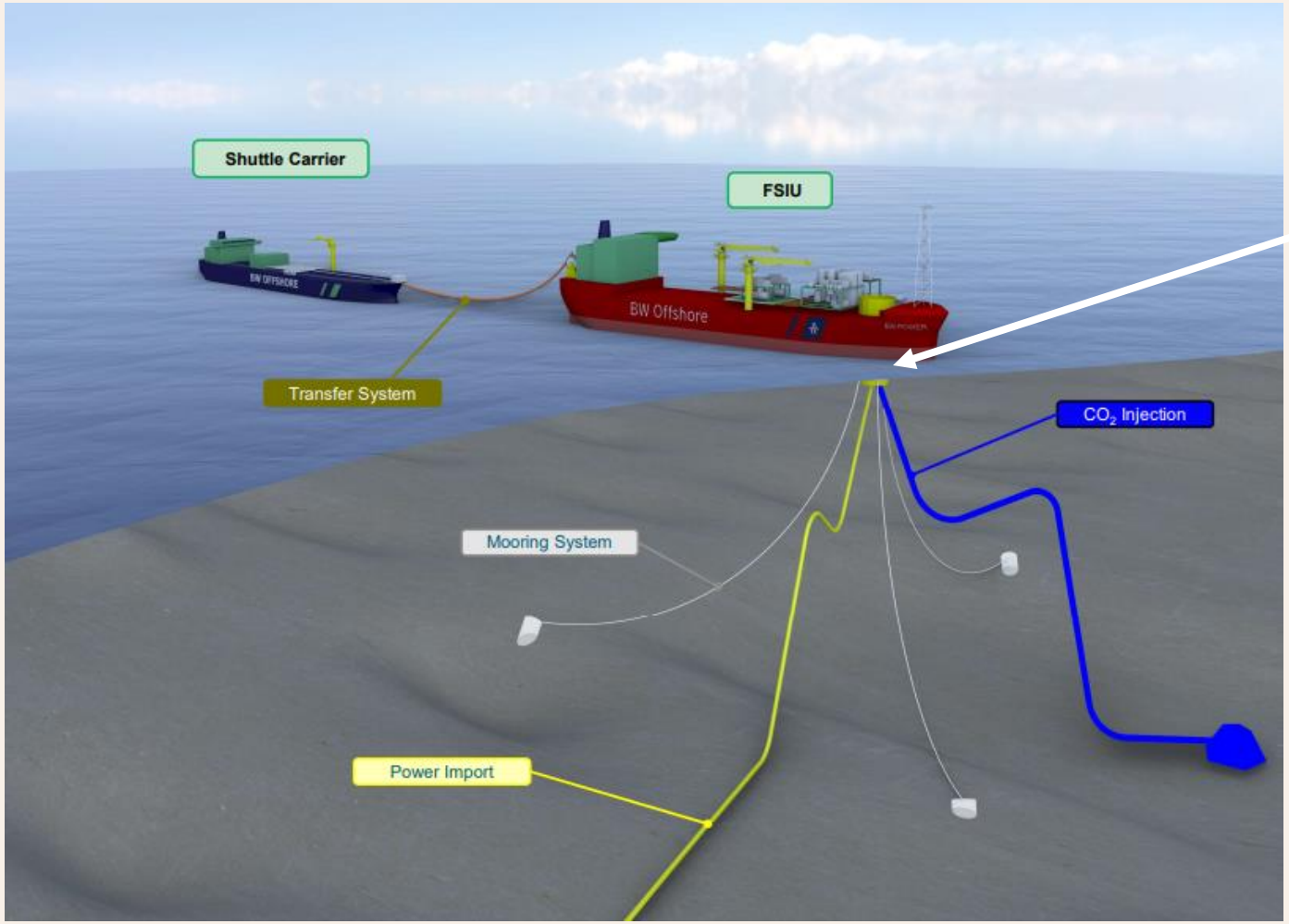
Offshore Value Chain – Alternative 2 w/ FSIU

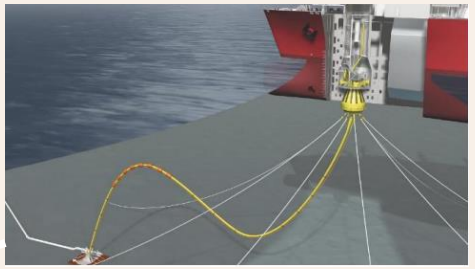
Shuttle Carrier:

- 40-70 000 ton capacity preferred
- Floating hose Transfer system

FSIU:

- 80 000 ton typ storage capacity
- Weather vaning
- Injecting 7,5 MTPA continuously





STL:

- Single Turret Loading (STL)
- Developed for oil loading applications
- 30 years successful use

CO2 Shipping – Shuttle Tankers

Commercial Shipping: 1989 >

Source: Yara International ASA

Northern Lights: 2024 >

Large Scale LP Carriers: 2030 >?

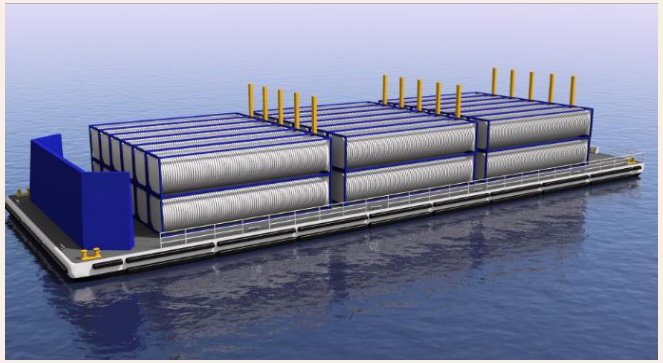
Mitsubishi Shipbuilding

Large Scale HP Carriers: >?

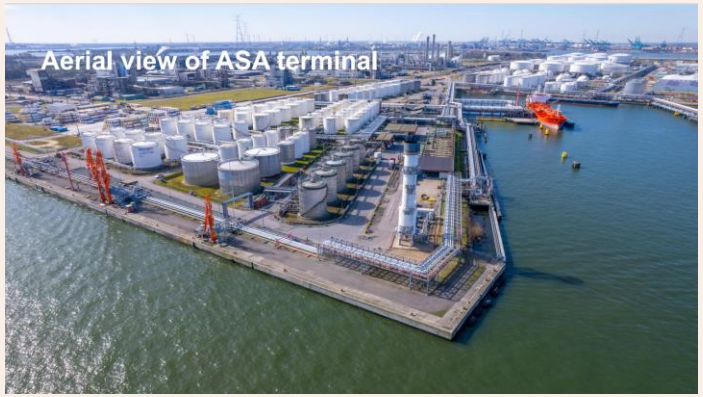
Knutsen HP carrier concept - source: DNV

CO2 Collecting Terminals & Logistics

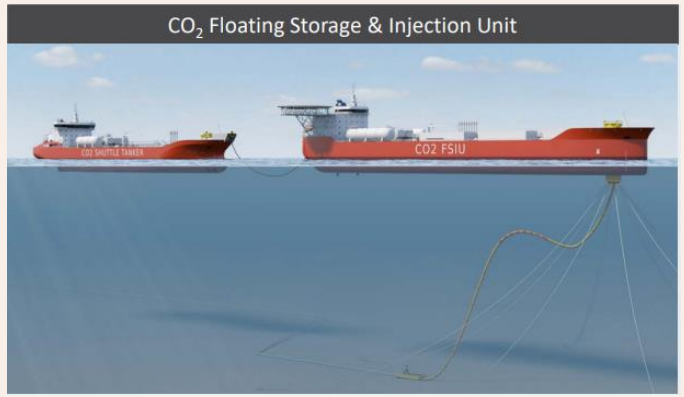
- Several emitter sites for capture and liquefaction
- Intermediate small scale transport from emitter site to collection hubs by vessels, barges, train and trucks
- Land based collecting hub or terminals
  - Require deep water quay (13 m)
  - Large area sea front property
- Offshore Collecting Hubs (FSU) may be an alternative in the **Baltic Sea** due to:
  - Shallow water near shore
  - Preserving beach front
  - Potential ice problems during winter season near shore



Examples of Floating Intermediate Transport Solutions



Onshore Collecting Terminal



Offshore Collecting Terminal
Floating Storage Unit (FSU)

Sum-up

- Offshore CCS is an important element in the decarbonization strategy
- Integrated and optimized large-scale Value Chain is key to offshore CCS success
- The elements in the chain must be developed in parallel – huge investments
- Standardised solutions
  - Pressure cases
  - Technical solutions
- Governmental support in structuring CCS as a profitable business
  - Cost of CO2 emissions must increase

THANK YOU !