Future ship transport of CO_2

Mr. Knut Maråk
Principal Researcher
October 5th 2023

Part 1: Qualification of low pressure CO_2 ship transport
Part 2: Direct injection of CO_2 from transport ship

Part 1: Qualification of low pressure CO_2 ship transport

Temperature/pressure regimes for CO_2 shipping

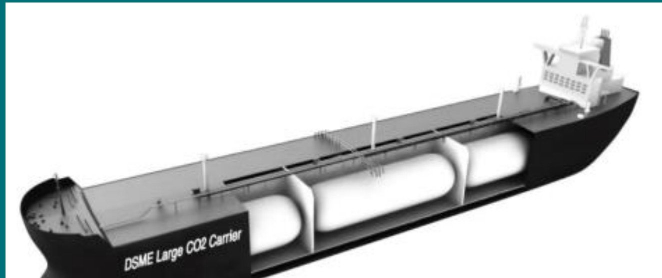
Medium pressure (13-15 barg, -30 to -26 °C)

- Mature technology - decades of operational experience
- Limitations to cargo tank size
- Selected for Northern Lights
- 3 ships ordered

Source: Yara International ASA

Low pressure (6-9 barg, -49 to -40 °C)

- Larger cargo tanks, high liquid density and reduced cost for shipping.
- No operational experience.
- 2 ships ordered
- Increased cost for liquefaction and processing for injection



Source:A Feasibility Study on CO2 Marine Transport in South Korea (sciencedirectassets.com)

High pressure (40-60 barg, 5 to 20 °C):

- Reduced cost for liquefaction and processing for injection
- Novel design, no operational experience
- Lower logistic efficiency - increased weight and size


Source: KNCC (kn-cc.com)

The Ceto JIP – de-risk low pressure ship transport

Objective

Identify, resolve and mitigate the **technical uncertainties** to qualify a low-pressure CO_2 shipping solution, enabling larger ships and **increased volume of CO_2** for a safe and **cost-effective** transportation chain

Feed Gas

Pre-combustion captured CO_2 source is selected

Liquefaction plant

Liquefaction to 7 bara, 1.6 MTPA

Storage tank 45 000 m^3, 7-7.1 bara -49 °C

Ship and containment system

Condition LCO_2: -46 to -49 °C at 7-8 bara

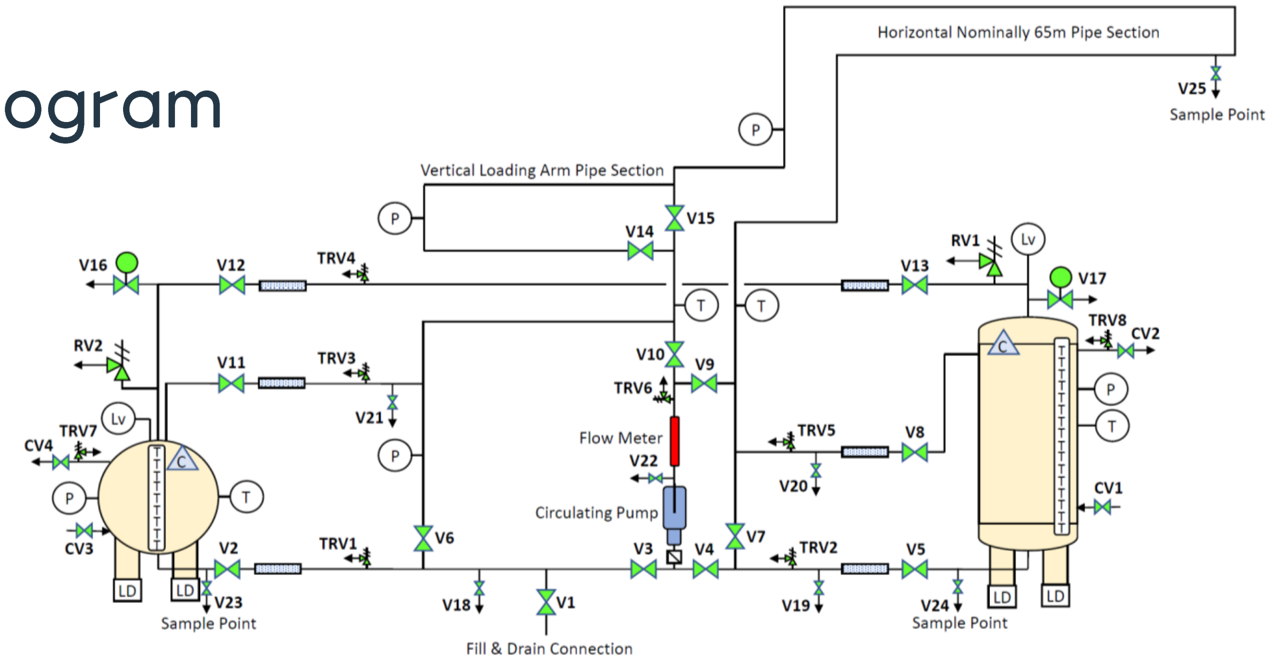
Gross volume: 30 000 m^3

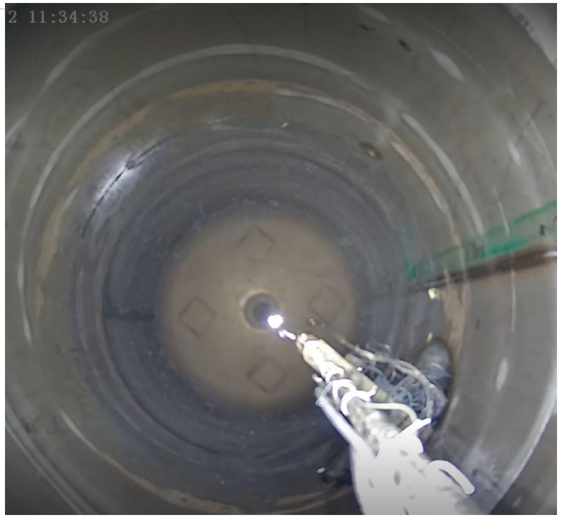
JIP-partners: TotalEnergies, Shell, Equinor, Gassco. Led by DNV.
https://www.dnv.com/maritime/jip/ceto/index.html

Ceto JIP – Cargo transfer test program

- Demonstrate handling of low pressure liquid and vapor CO_2 between tanks – resemble ship transfer
- Use measured data to verify performance of process simulation tools

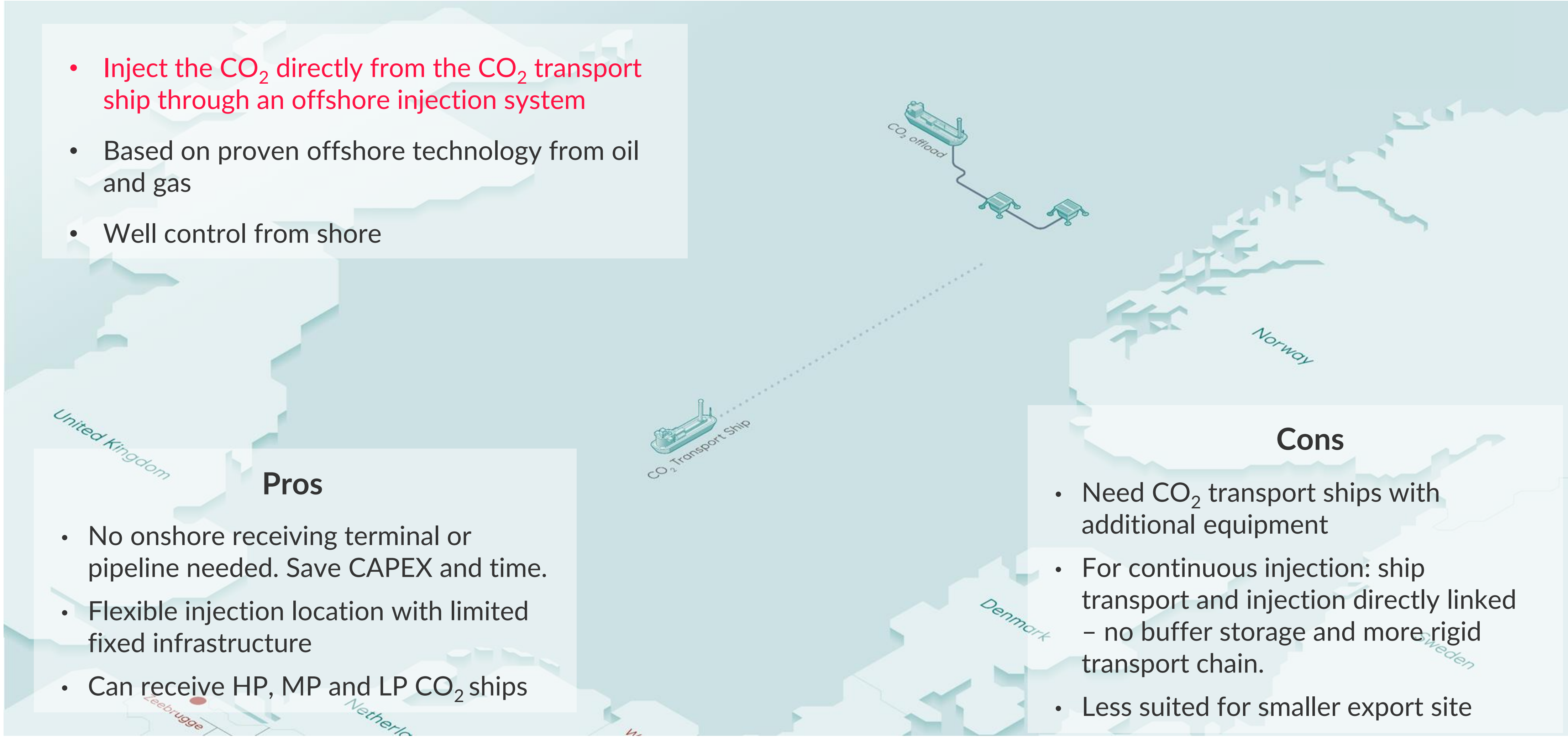
- Multiple transfers at 6 barg successfully performed
- Successful transfer tests also at 5.5 bara
- Tests with dry ice formation and recovery from dry ice
- Tests with impurities
- Performed at DNV Spadeadam, UK.





Part 2: Direct injection of CO_2 from transport ship

The offshore direct injection concept



- Inject the CO_2 directly from the CO_2 transport ship through an offshore injection system
- Based on proven offshore technology from oil and gas
- Well control from shore

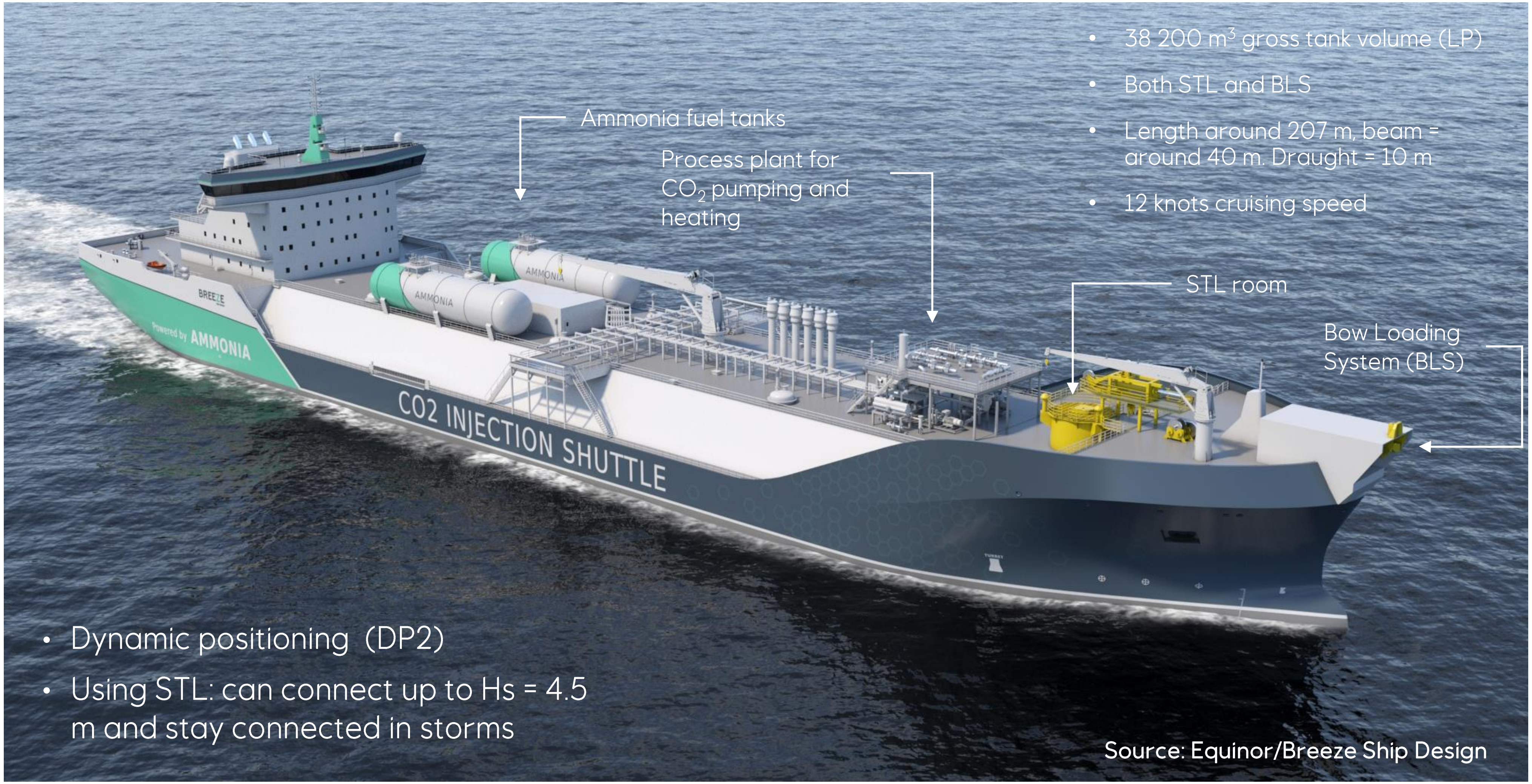
Pros

- No onshore receiving terminal or pipeline needed. Save CAPEX and time.
- Flexible injection location with limited fixed infrastructure
- Can receive HP, MP and LP CO_2 ships

Cons

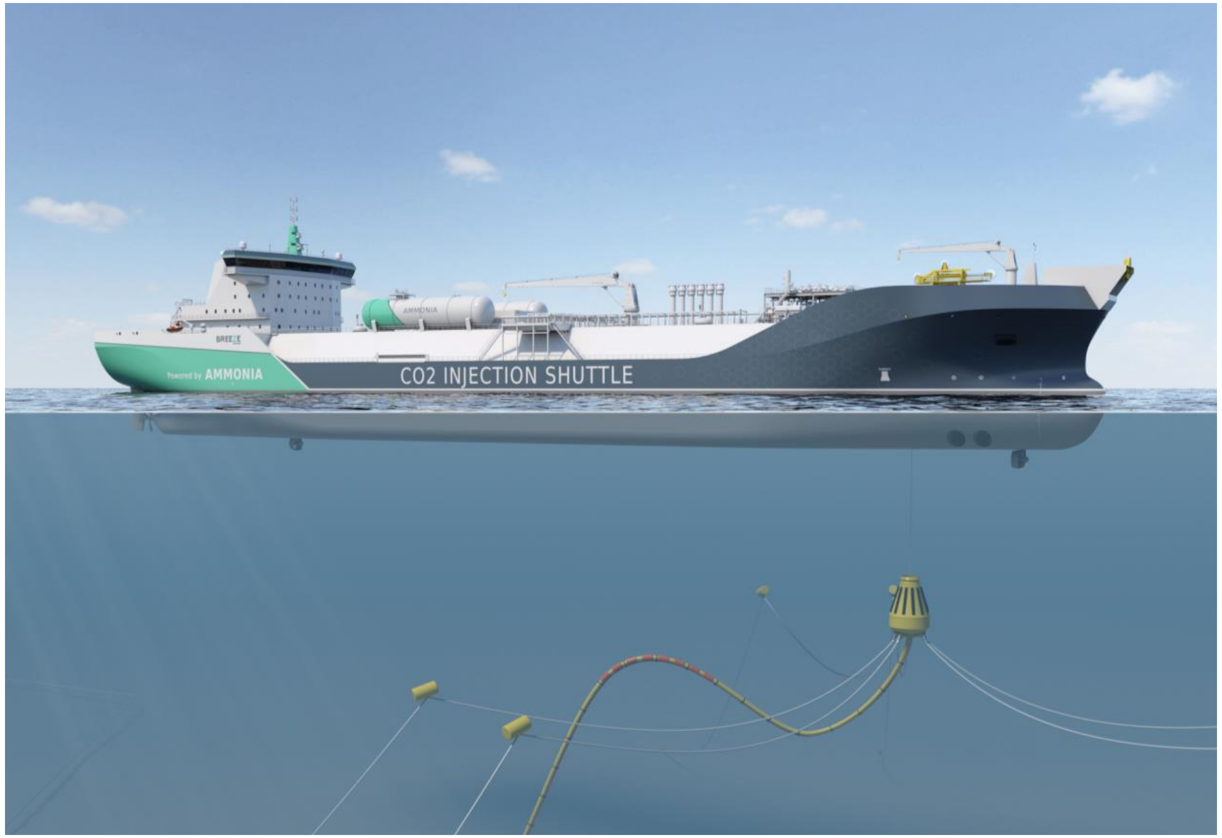
- Need CO_2 transport ships with additional equipment
- For continuous injection: ship transport and injection directly linked – no buffer storage and more rigid transport chain.
- Less suited for smaller export site

Ship design for direct injection



Highlights for direct injection

- Offshore direct injection is technically fully feasible
- Enables development of CO_2 infrastructure without onshore facilities or pipeline.
- Can be used as initial phase or permanent solution
- Proven offshore mooring and injection system
- Flexible with regards to injection location
- Ships can also be used as terminal-to-terminal tankers



Future ship transport of CO_2

Knut Maråk, Principal Researcher