

Knutsen NYK Carbon Carriers AS CCS and CO2 Shipping – A Green, Global Life Saver

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Key Features of the CCS Value Chain







Key Message

- KNCC's offering is to build and operate LCO₂ vessels
 - LP and MP vessels
 - EP vessels and also EP onshore/offshore floating storage
- JX Nippon Oil & Gas Exploration, NYK and KNCC have developed a "game-changing" liquefaction and storage process
 - Significant reduction in Capex and Opex for CCS value chains
 - Required land space minimized
- KNCC's recent development
 - Cooperation with COSCO Shipping Heavy Industries, Chiyoda Corporation and Pace CCS
 - Increased scope and more studies for the CO₂ test rig





Strong and Long Term Owners of KNCC



- Global logistics enterprise with terminals and vessels for most forms of maritime transport
- Extensive experience in cryogenic transport (LNG/LPG/etc)
- Ambitious green transition objectives



- Pioneered shuttle tanker market
- Unique track record of operational performance and know-how of complicated offshore operations
- Gas and LCO₂ transport technology development and marine engineering





Scope of Business



KNCC's Unique Market Approach

Wide offering to match the various market requirements

Mode	Temperature	Pressure	Scope	Vessel capacity	Tank
EP	0 to 10 degC	34 to 45 bar	TtT, DIO, FSIU	7,500-80,000cbm	Cargo Tank Cylinders (CTC)
MP	-30 to -25 degC	15 to 18 bar	TtT	7,500-20,000cbm	Type-C tanks
LP	-50 to -45 degC	6 to 10 bar	TtT	20,000-80,000cbm	Type-C tanks



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Optimizing Liquefaction and Storage!



JX Nippon Oil & Gas Exploration





Joint Study for optimization of CO₂ liquefaction and storage

- Joint development of a new liquefaction process *"Isenthalpic Expansion Cooling & Liquefaction"*
- Demonstration test successfully completed at KNCC's test rig facility, Aug 2024
- Data analysis and further study for full scale application in progress







What is Isenthalpic Expansion Cooling & Liquefaction?

External Refrigeration process (industry standard)



<u>LCO₂-EP Isenthalpic Expansion Cooling &</u>

Liquefaction Process



Hvdroaen

- Reduced CAPEX, less equipment as such
 Less energy required and reduced OPEX
 Little or no use for storage and required space
- Energy intensive driving OPEX

✓ CAPEX intensive and complicated

✓ Space intensive

Adapted from Shazawa, Y., et al. (2024). Development of Simplified CO2 Liquefaction & Loading Process at Elevated Pressure. ADIPEC 2024, Abu Dhabi, UAE. SPE-222354-MS. (In press)

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Key Features of Isenthalpic Expansion Cooling & Liquefaction



Environmentally friendly and safe (no use of NH3/ Propane/ CFC alternatives)



Approximately 20% energy saving compared to LP liquefaction



Simple and less device compared to external refrigeration



Economically applicable for EP mode only



Less footprint due to simplified process and possibility to skip intermediate storage



Cheaper CAPEX

compared to external refrigeration used for MP and LP



Applicable on barges, floaters, vessels



TRL 6 (demonstration completed)

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ydrogen



Continued Industry Cooperation - EP Vessel development / CO₂ specification



Joint development for building LCO2-EP x DIO Vessels

- No heating required prior to injection
 →Less energy and complexity onboard
- First class expertise for offshore operation through Knutsen NYK Offshore Tankers (KNOT)





Press release SEP 2024

Joint development for CO₂ Specification for EP Shipping

EP can ship more impurities than MP and LP
 → Cheaper CO₂ capture cost



EP can handle higher water content
 → EP is less sensitive to corrosion risk from induced aqueous phases, such as methanol



Continued Industry Cooperation

- CCS Value chain study







press release MAR 2024

Joint Study : Quantitative Comparison of CO2 Liquefaction, Temporary Storage, and Transportation

- EP is most energy efficient throughout the CCS VC
- \rightarrow Lower OPEX and emission
- Bottle-neck for LP tank production (both onshore spherical and Type-C for vessels)
- \rightarrow EP cargo tanks can be produced at automated pipe manufacturers.
- MP has challenge for scaling up.
- ightarrow large number of tanks required. (Huge cost and lead time)







CO₂ Test Rig : Building Deep Knowledge

	Phase1		Phase2		Phase3
	Completed		Ongoing		Future
\checkmark	Assembly	~	CO2 isenthalpic expansion test for optimization	✓	Effect of Impurities on phase diagram,
\checkmark	Safety tests including pressure testing		of Liquefaction and Storage for EP		operability of system and corrosion,
\checkmark	Drying			\checkmark	Crew training
\checkmark	Gassing up / Pressurizing			\checkmark	And more
\checkmark	Filling from MP System	75	and and	100	
\checkmark	Pressure buildup				
\checkmark	Transfer between tanks	-500 mm		Ariana Ariana	
\checkmark	Minor Leaks, Gas & Liquid				
\checkmark	Blowdown				
./	Forced Correction monitoring by				

- Forced Corrosion monitoring by \checkmark use of brine in LCO2-EP Tank
- Corrosion monitoring of LCO2-EP \checkmark Tank Cylinders full of CO2
- Scaled leak tests based on failure \checkmark of tank elements.

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The Green, Global Lifesaver

Status of the CCS industry

- The commercial assumptions need to be in place for FIDs
 - "Green" decision making criteria for CCS investments ?
- Chicken and egg challenges between emitters and storage providers to be resolved
 Increased level of cooperation and flexible approach

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- Increased level of cooperation and flexible approach
- Governments to provide a stable, long-term framework for the CCS industry
 - Regulatory
 - Domestic and International
 - Tariffs for emissions / Incentives for reducing emissions

\rightarrow CCS will ensure a smooth green transition for the society



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Thank You

https://www.kn-cc.com/

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