Introduction of Three Modes of handling LCO2
- A viable option contributing to the realization of a CCS Value Chain

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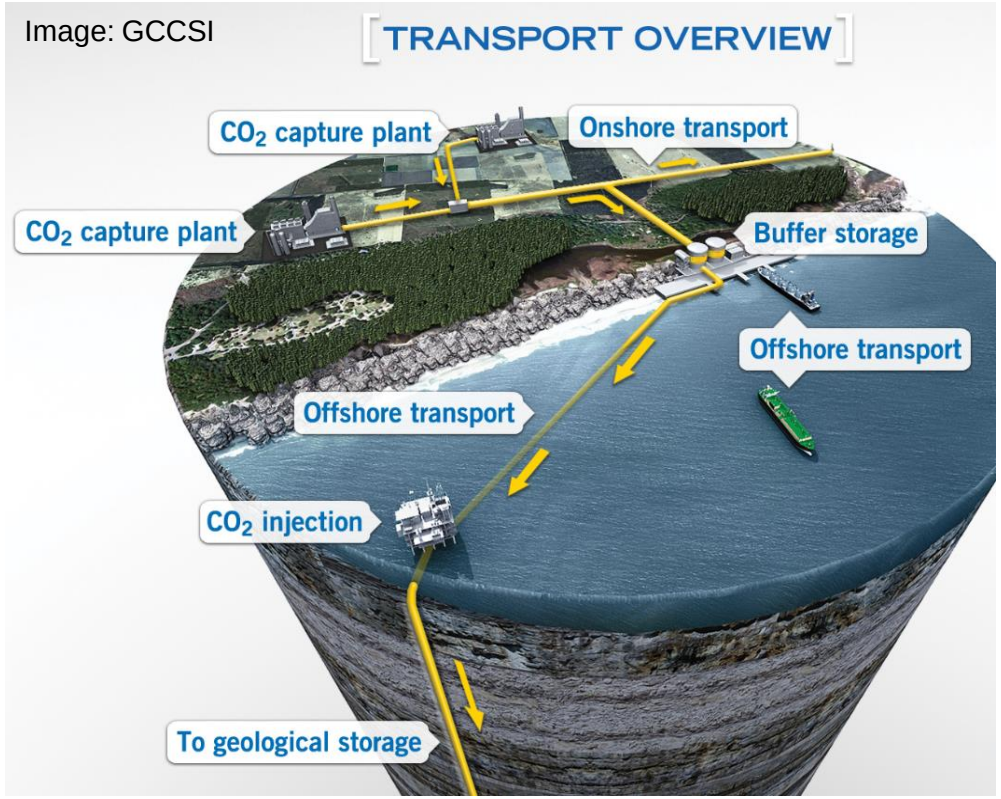
Key features of the CCS value chain

Image: GCCSI



- Waste management
- Scale game
- Capital intensive
- Long term commitments

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Key message

PART 1 : Introduction of KNCC and the three modes for LCO2 in the CCS VC

- ✓ **KNCC is NYK's and Knutsen's gateway for LCO2 shipping**
- ✓ **KNCC is offering also EP technology for shipping and onshore storage**

PART 2 : Qualitative comparison of the three modes and why EP is a viable option

- ✓ **EP is a favorable option from a holistic approach, taking commercial,- technical matters and operational risk into consideration**

PART 3 : KNCC's technical development

- ✓ **KNCC is continuing to progress on all three modes**
- ✓ **Deep CO2 knowledge inhouse**

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Part 1 :
Introduction of KNCC and the three modes for LCO2 in the CCS VC

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 LCO_2 transport technology development and marine engineering

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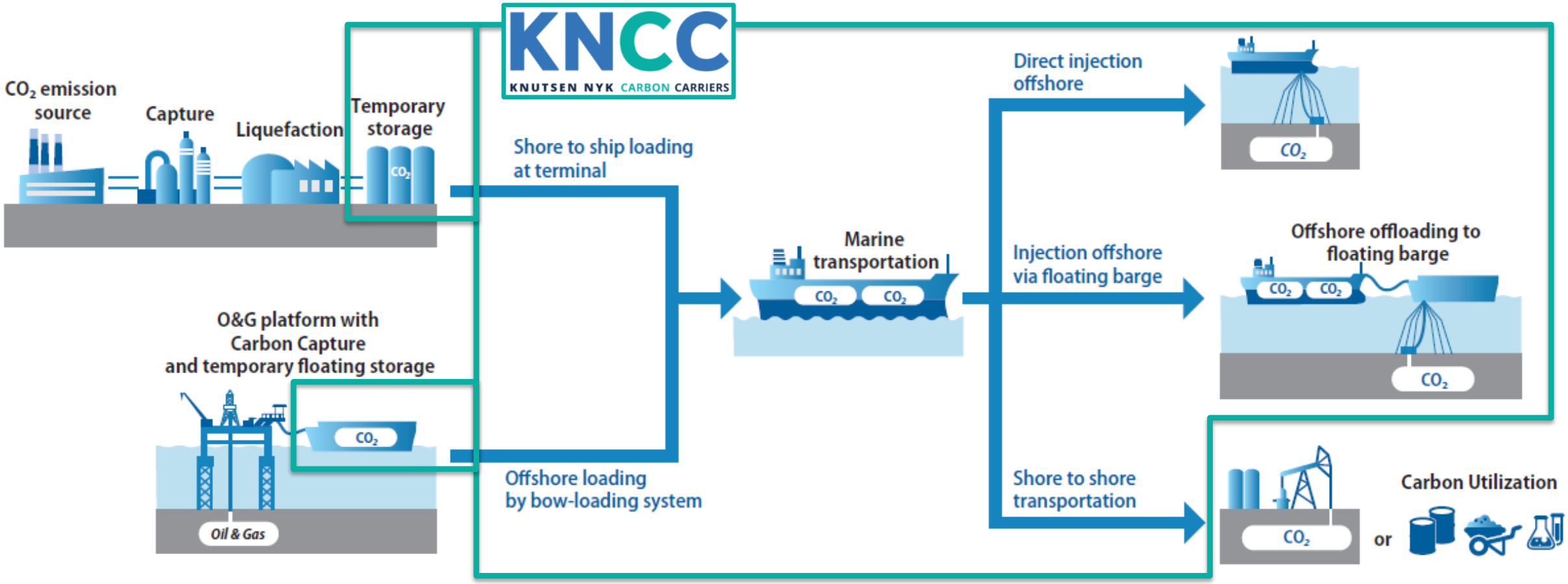
Scope of Business



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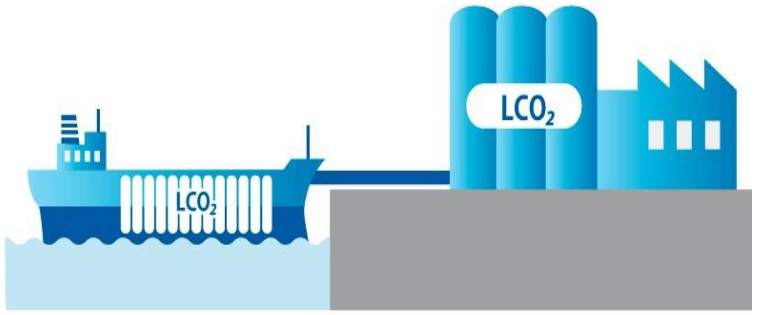
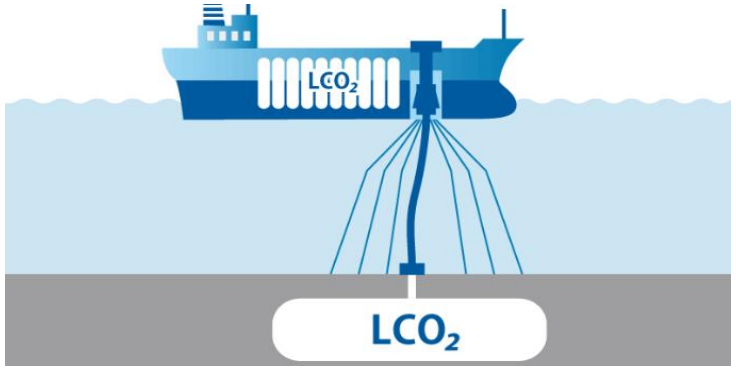
Our unique market approach

KNCC offers

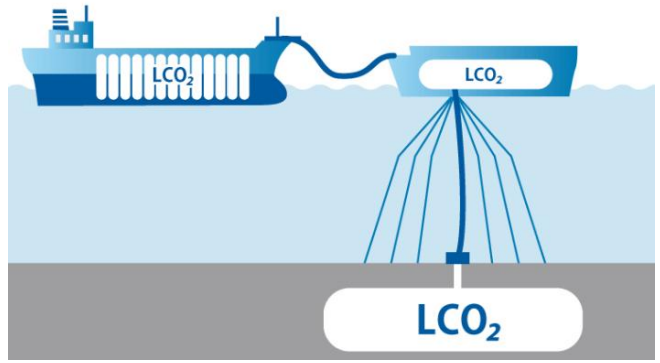
Mode	Temperature	Pressure	Scope	Vessel capacity	Tank
EP	0 to 10 degC	34 to 45 bar	TtT, DIO, FSIU	7,500-80,000cbm	Cargo Tank Cylinders (CTC)
MP	-30 to -25 degC	15 to 18 bar	TtT	7,500-20,000cbm	Type-C tanks
LP	-50 to -45 degC	6 to 10 bar	TtT	20,000-80,000cbm	Type-C tanks



TtT: Terminal to Terminal



DiO: Direct injection Offshore



FSIU: Floating Storage Injection Unit

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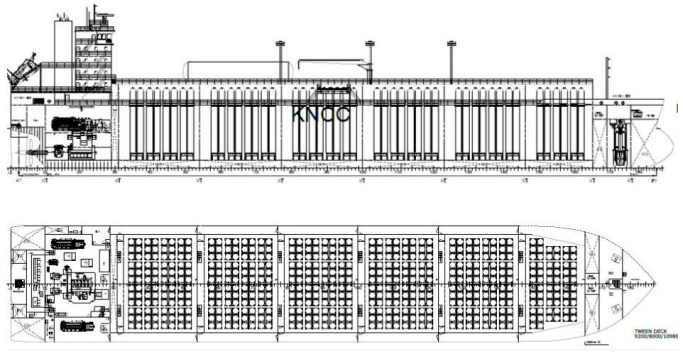
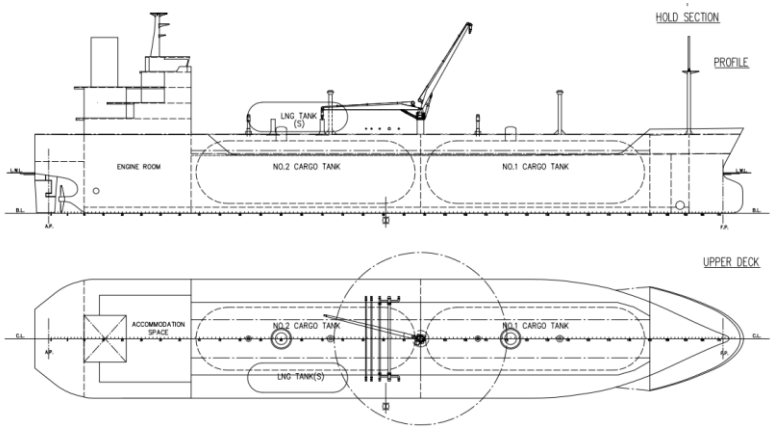
Examples of vessel designs

Wide offering to match the various project requirements

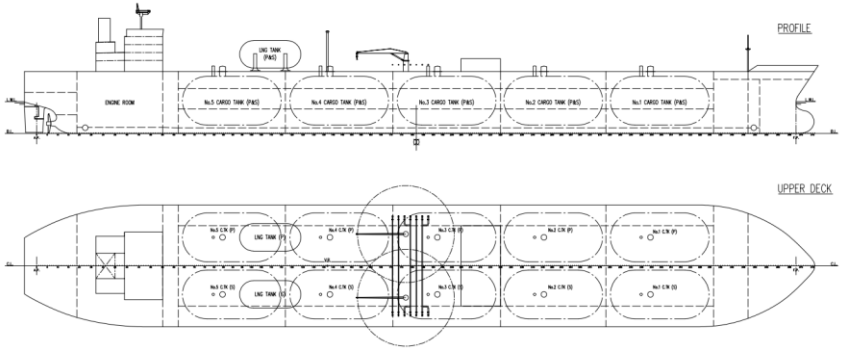
Elevated Pressure (EP)			
Capacity	LOA	Breadth	Draft
20,000cbm	190m	30m	9.5m
40,000cbm	225m	42.5m	11.0m
50,000cbm	265m	42.5m	11.4m
80,000cbm	300m	50m	12.0m



Medium Pressure (MP)			
Capacity	LOA	Breadth	Draft
7,500cbm	130m	22m	7.5m
12,000cbm	150m	25m	8.5m
20,000cbm	190m	30m	9.0m



Low Pressure (LP)			
Capacity	LOA	Breadth	Draft
40,000cbm	230m	35.3m	11.4m
50,000cbm	235m	38m	11.5m
80,000cbm	300m	46m	12.0m



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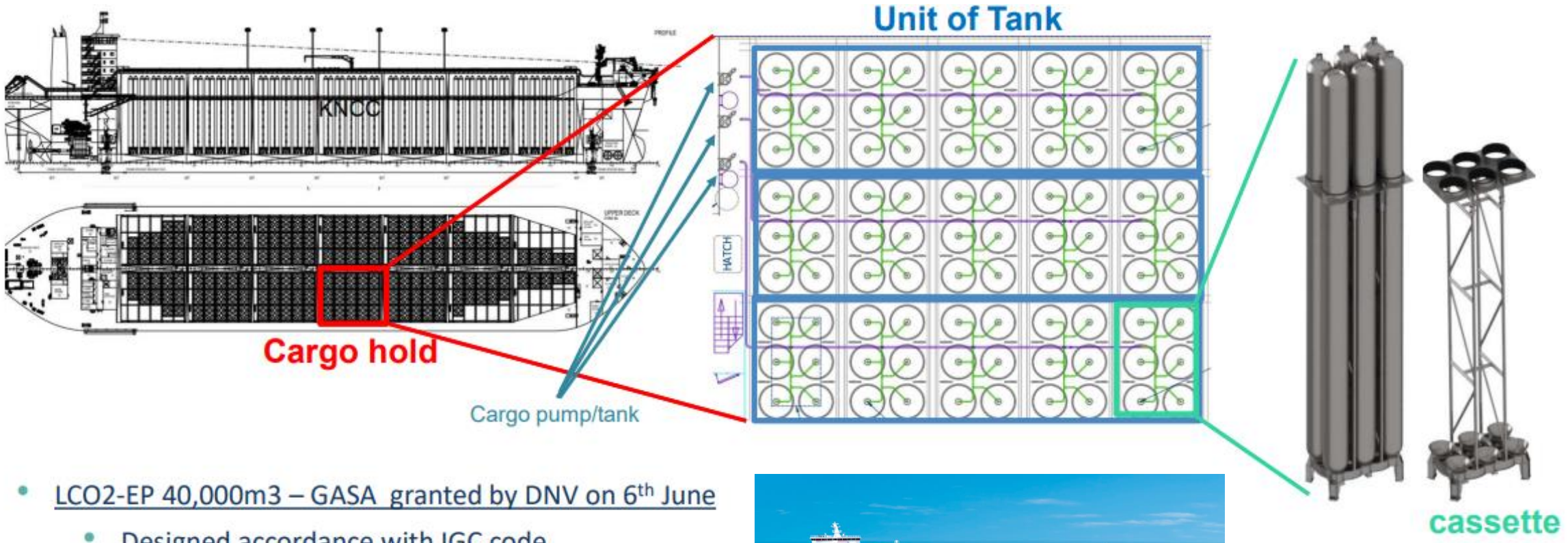
Vessel design for EP



- LCO2-EP 40,000m3 – GASA granted by DNV on 6th June
  - Designed accordance with IGC code
    - 1 cargo hold consists of 3 tanks
    - 1 tank consists of 30 CTCs (Cargo Tank Cylinder)
    - 1 cassette contains vertically stacked 6 CTCs
  - Operational concept
    - All CTCs, 1028pcs, works as 1 system, i.e. uniform loading and unloading of LCO2

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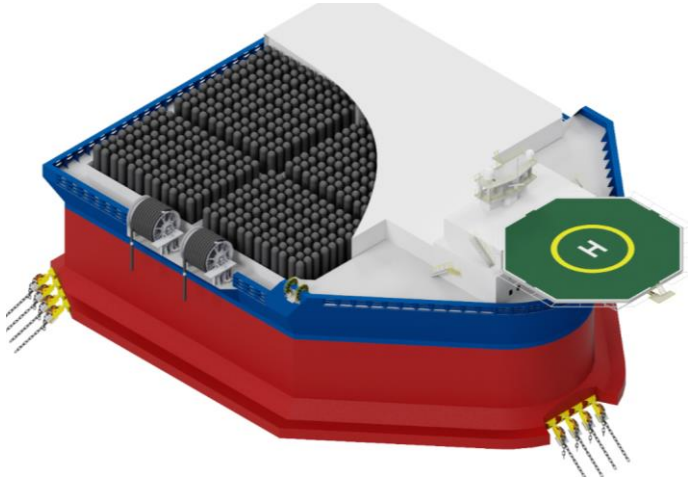
Completing the value chain -onshore/offshore storage with EP-

Onshore temporary storage with EP CTC

Floating temporary storage on barge with EP CTC



FSIU (Floating storage and injection units) with EP CTC

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Part 2 :
Qualitative comparison of the three modes and why EP is a viable option

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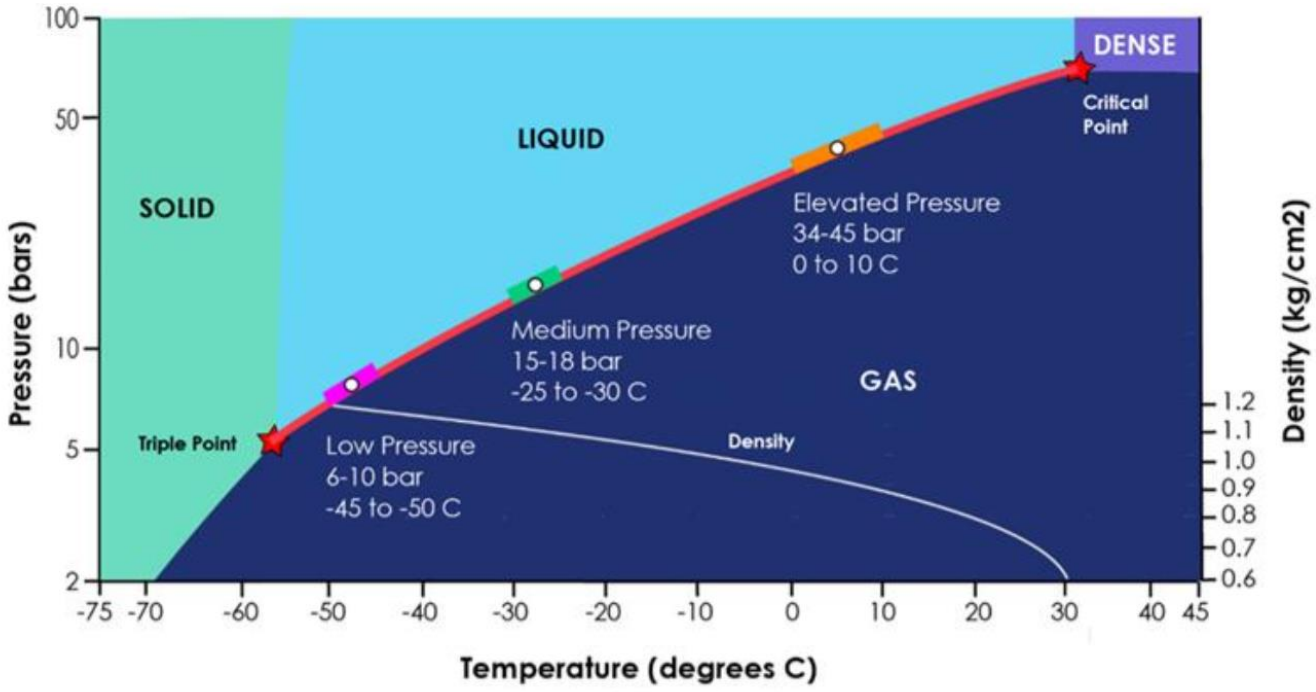
① Operation Matters

Safety margin across the CCS VC

- Important to keep buffer from dry ice point (triple point)
- Impurities impact the CO_2 phase envelope and operating range varies



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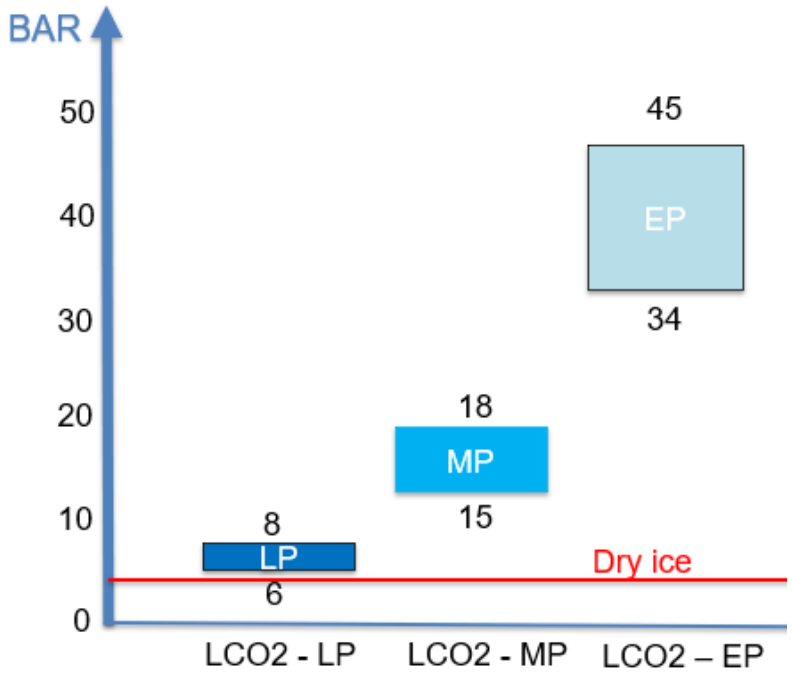

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② Energy Consumption

Lower energy consumption per ton-CO2 across the VC

- Cooling and heating is more energy intensive than pressurizing
- Injection must at be at ambient temperature and very high pressure

Mode	Liquefaction	Temporary storage/cargo handling	Marine transportation	Temporary storage/cargo handling	Pre-heating & boosting prior injection	**CCS VC TOTAL**
EP	+	+	++	+	+	**+**
MP	++	++	+ (*small vsl only)	++	++	**++**
LP	+++	+++	+	+++	+++	**+++**

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③ Transporting efficiency

Mode	EP	MP	LP
Density	930kg/cbm	1050kg/cbm	1150kg/cbm
Loading Volume (98% at 20,000cbm)	18,228ton (-19.1% vs LP)	20,580ton (-8.7% vs LP)	22,540ton
Heel	<1%	5-10%	5-10%
Net transporting volume (apply heel 7.5% or LP, MP and 1% for EP)	18,046ton (-13.4% vs LP)	19,036ton (-8.7% vs LP)	20,850ton

Key Facts: LP is more efficient in transportation volume. Required heel for EP is lower.

- **Design of tanks** : EP using CTCs can drain all the CO2 due to it's unique design (patent filed)
- **Heel as coolant** : EP does not require heel as coolant and can maintain pressure by temperature control in the cargo hold.
- **Heat ingress:** Heat ingress into the CTC is extremely slow (ref. GASA calculation and test rig observation)

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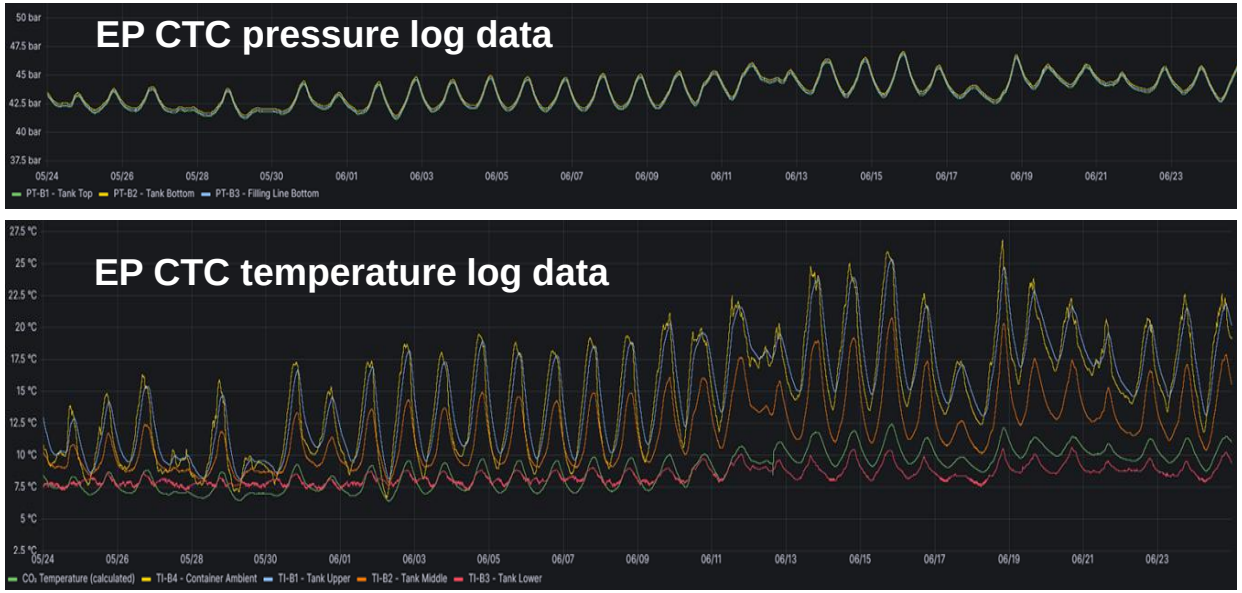
④ Reliquefaction and BOG management

Mode	EP	MP	LP
Reliquefaction BOG management	No	Yes (for long sailing only)	Yes



KNCC test rig data for EP mode in CTC

Key findings from KNCC's EP CTC test rig

- **Stable** : Temperature and pressure of CO2 and the CTC steel temperature following the atmosphere temperature.
- **No venting :** Heat ingress is very small(slow) the CO2 inside test rig has been stable with no actions to the test rig for months and no pressure vent.

Key Facts : No Reliquefaction for BOG management even in tropical conditions.

- Environment Control (controlling air temperature) inside cargo hold is enough.

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⑤ Cargo tanks

Mode	EP	MP	LP
Material	X70	P690 or equivalent	5%Ni / LT36 / LT51 or equivalent
Material unit cost	+	++	+++
Tank wall thickness	Abt 14mm	Abt 50mm	Abt 50mm
Tank type	Cargo tank cylinders	Type-C	
Empty tank Weight (for 20,000 cbm Incl support)	7,700ton (+260% vs LP)	2,850ton	2,100ton
Cargo Weight	18,228ton	20,580ton	22,540ton
Tank + Cargo Weight	25,928ton (+5.2% vs LP)	23,430ton	24,640ton
Production lead-time	Serial pipeline production	Competition with LNG/LPG tanks	

Key Facts : EP vessel (CTCs) are heavy. Including cargo, total weight is quite similar due to density difference.

- Draft and fuel consumption per day is similar among LP and EP vessels.

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Part 3 :
KNCC's technical development

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Class approval and HAZID

Class approval development

Mode	Technology development	Class	Approval	Date
Elevated Pressure	Knutsen NYK Carbon Carriers	Class DNV	AIP GASA	(AIP)Apr 2022 (GASA) Jun 2023
Medium Pressure	NYK/Mitsubishi Ship Building	Class NK	AIP	(AIP)May 2022
Low Pressure	NYK/Mitsubishi Ship Building	Class NK	AIP	(AIP) May 2022

HAZID completed with no red-flag(intolerable) risks for EP technology.

❑ **Scope of HAZID**

1. Design of EP vessel
2. Leakage Handling
3. Loading/Unloading operations
4. Product in transit
5. Maintenance and Inspection

Risk rating	
Continuous improvement	67
Risk reduction measures	3
Intolerable risk	NIL

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CO2 test rig :Building deep knowledge

Phase1 Completed

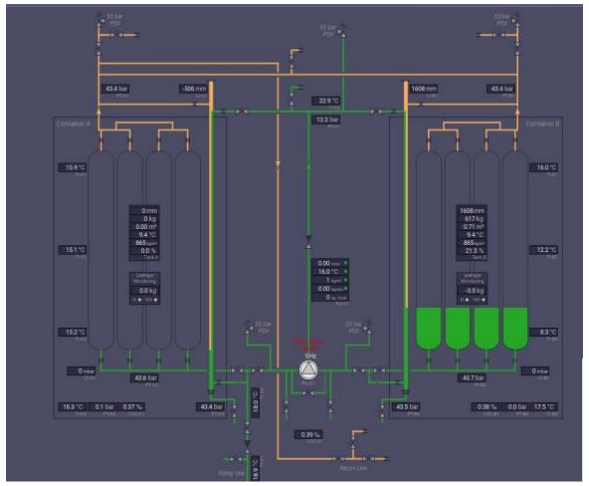
- ✓ Assembly
- ✓ Safety tests including pressure testing
- ✓ Drying
- ✓ Gassing up / Pressurizing
- ✓ Filling from MP System
- ✓ Pressure buildup
- ✓ Transfer between tanks
- ✓ Minor Leaks, Gas & Liquid
- ✓ Blowdown

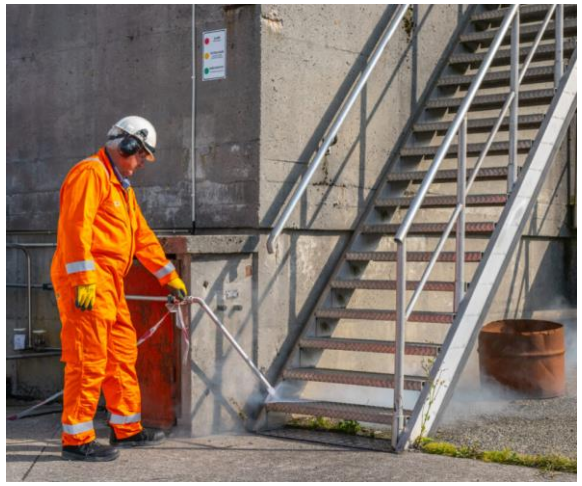
Phase2 Ongoing

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

Phase3 Future

- ✓ Effect of Impurities on phase diagram, operability of system and corrosion,
- ✓ Crew training
- ✓ And more…





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Attention for EP is growing

Companies that have shown interest also to EP to realize CCS projects.
Engagement expanding globally and across the whole CCS value chain.

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Summary

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Thank You

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

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