Optimal strategies of liquid CO2 transportation for geological carbon storage : A case study of South Korea

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Abstract

Geological CO_2 storage, a prominent facet among carbon capture and storage technologies aiming for net-zero emissions, has received substantial attention. Existing studies have investigated liquid CO_2 transportation conditions based on CO_2 emissions from individual plants through a central CO_2 hub terminal. Nevertheless, a misalignment persists between the CO_2 capture assumptions made in previous studies and the actual quantities necessitated for capture from various industrial sources. To address these challenges, we propose comprehensive liquid CO_2 transportation strategies incorporating numerous CO_2 emission sites and multiple CO_2 hub terminals in South Korea. Furthermore, we ascertain the optimal conditions for large-scale liquid CO_2 transportation. The results of this study are expected to contribute to the achievement of net-zero emissions by providing insights into the optimal conditions and transportation strategies for liquid CO_2 in South Korea.

Keywords: **Carbon Capture and Storage (CCS), Geological CO2 storage, CO2 transportation, CO2 hub terminal, Techno-economic analysis**

Method and Results

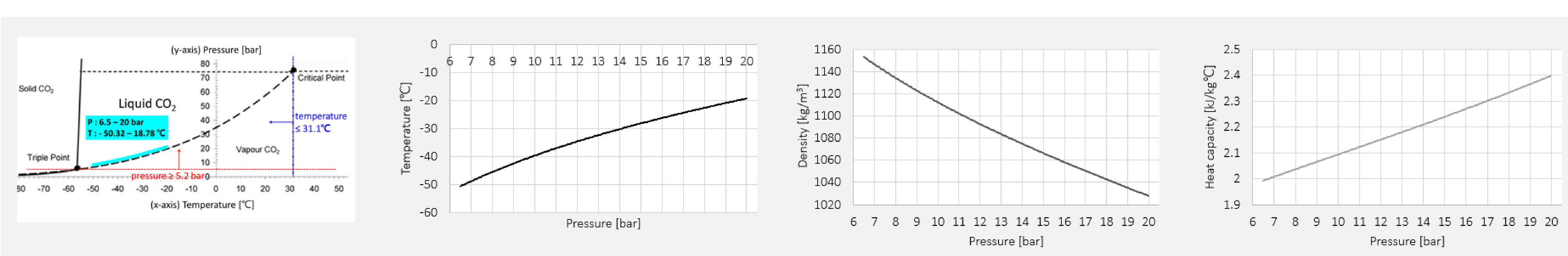
1.Introduction

- MOTIVATION

- With the growing severity of global warming attributed to greenhouse gas emissions, the implementation of post-combustion CO2 capture processes is on the rise in diverse industries, including power generation, steel production, and petrochemicals.
- If the substantial volume of CO2 gas, continuously separated from the capture process, is not directly integrated into utilization processes, a volume reduction process is necessary for efficient storage and transportation.
- Liquefaction results in higher density compared to compressing it into high-pressure gas.

	Pressure [bar]	Temperature [℃]	Density [kg/m3]
High-pressure gas	300	30	870
Liquid	20	-20	1030

- Then why do we need to ponder about the pressure conditions of liquid CO2?



: Liquid CO2 has a higher density at lower pressures than at higher pressures.
: Liquefaction and boil-off gas re-liquefaction energy depending on pressure can vary significantly.
: Under low pressure conditions, the equilibrium temperature and heat capacity are lower, so the amount of boil-off gas produced during storage is higher.

- The development of ships to transport captured CO2 to utilization and storage sites is actively underway.

- CCS VALUE CHAIN

- Capture → Liquefaction → Buffer Tank → Ship Transport → Injection

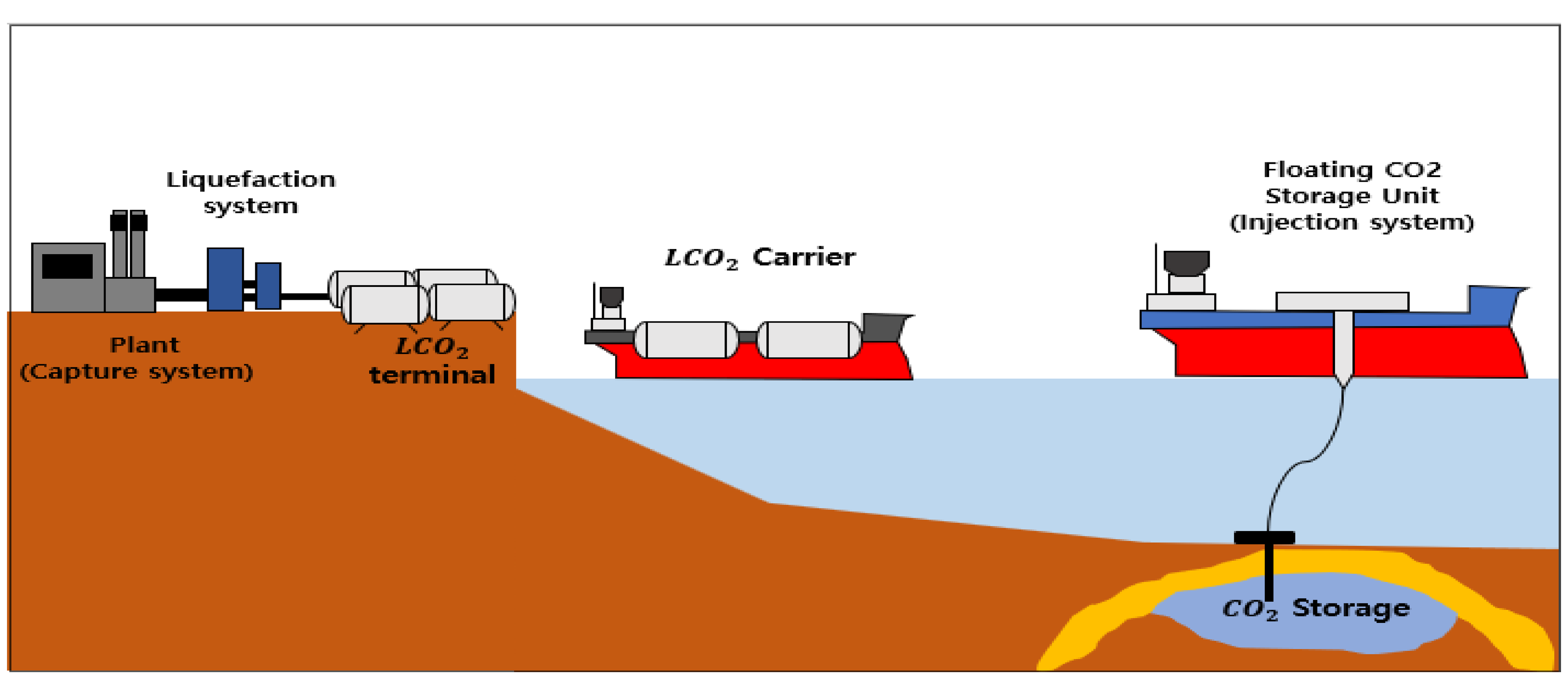


Figure 1. CCS value chain

- OBJECTIVE

- A comparative analysis of CO2 transport pressures (6.5 bar, 7 bar, 10 bar, 15 bar, 20 bar) was conducted to determine the optimal pressure.

2. Methodology

- DEFINE OF MASS FLOW RATE

$$W_c = \mathbf{m}[H_v(P_2,T_2) - H_v(P_1,T_1)]$$ - If **m** is defined, W_c is a function of **P**

- CACULATION BASIS

(CO2 capture amount) = (CO2 emission from sources) – (free quota)

- THE AMOUNT OF CO2 EMISSION

- The CO2 capture sources are assumed to be domestic power plants, steel mills, oil refineries and petrochemicals.

i) Power plant – coal-fired power plant (based on generated electricity)
ii) Petrochemicals – naphtha cracking facilities (based on annual ethylene production)
iii) Steel mills – furnace facilities (based on annual crude steel production)

Annual amount of CO2 entering the terminal $[m^3/h]$	6.5 bar	7 bar	10 bar	15 bar	20 bar
Ulsan	742	746	770	804	835
Yeosu	1,257	1,265	1,305	1,363	1,416
Daesan	2,619	2,634	2,719	2,839	2,949

3. Results & discussion

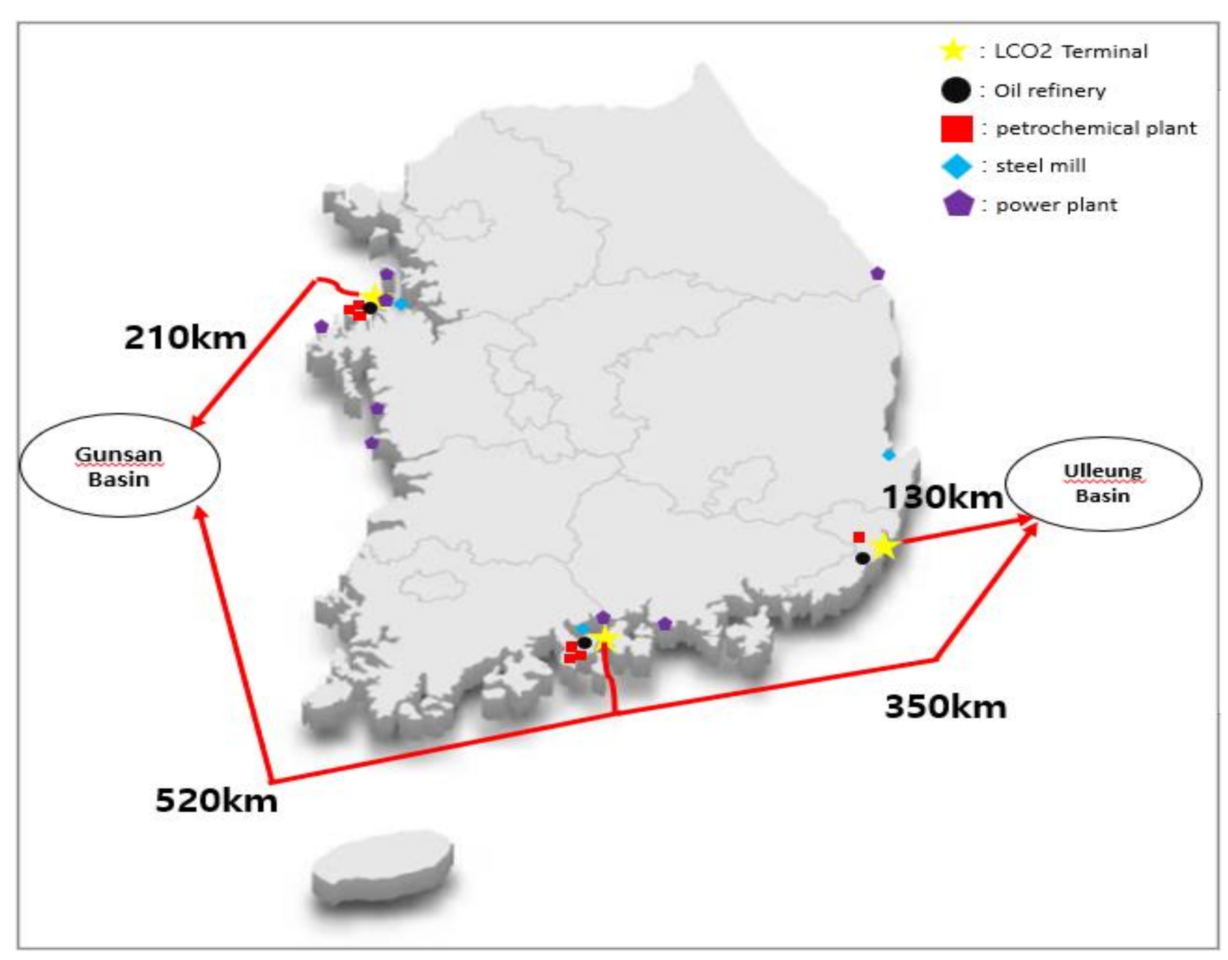


Figure 2. Distance between CO2 emission source and Storage

- Assumption
LCO2 ship speed : 15knot
Loading speed : 2,500m^3/hr
Ship capacity= 40,000 m^3

-There are three LCO2 Cluster, each of which is located in Daesan, Yeosu, and Ulsan

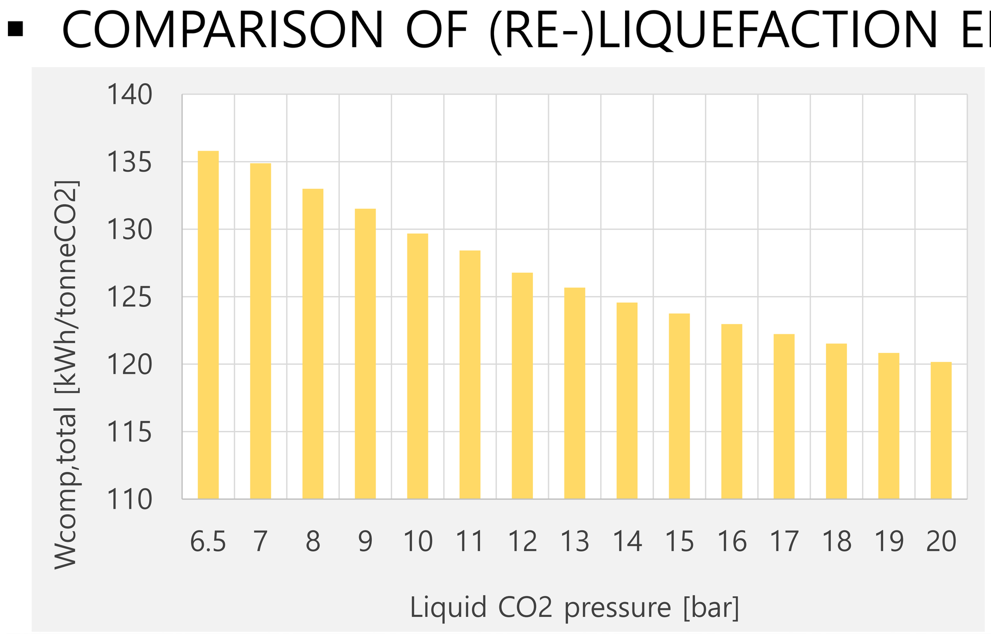
-Captured CO2 is sent to the LCO2 terminal close to the source of discharge

-Korea's CO2 emission sources are concentrated on the coast, and the leading CO2 reservoirs are Gunsan Basin and Ulleung Basin

- DETERMINATION OF BUFFER TANK SIZE AND NUMBER

Liquid CO2 terminal	Ulsan	Yeosu	Daesan
Time required shipping [hr]	62	77	67
Minimum number of ships	1	2	4
Buffer tank size $[m^3]$	5,000 X 16	5,000 X 17	5,000 X 16

- COMPARISON OF (RE-)LIQUEFACTION ENERGY



- Liquefaction and re-liquefaction energy tends to decrease linearly as pressure increases.

- Currently, liquefaction energy has been derived, and the amount of boil-off gas and re-liquefaction energy are being derived.

Conclusion

- Density differences, liquefaction and re-liquefaction energy, the amount of boil-off gas, domestic CO2 emission and captured CO2, and expected capacity of storage site are considered to determine optimal liquid pressure for efficient transport and intermediate storage.
- Currently, the results of liquefaction energy have been derived, and the results of boil-off gas and re-liquefaction energy are being derived. By combining these results, we will present the optimal pressure for each scenario we set.

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