Technical and Economic Assessment of CO_2 Transportation Options for Large-scale Integrated Carbon Capture & Sequestration(CCS) Project in South Korea

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Abstract

In order to examine the feasibility of Carbon Capture & Sequestration, a major technological strategy for the national goal of greenhouse gas reduction, this paper studies the various methods and corresponding costs for the transportation of CO_2 captured at the domestic thermal power plants, as well as performing comparative analysis with overseas CCS demonstration projects. It is predicted that the investment cost would be about 98 million USD when the using land-based pipelines to transport captured CO_2 from the thermal power plant located in the south coast. And using marine-based offshore pipelines, it will cost about twice the amount. When the captured CO_2 is transported from the power plant in the west coast instead, the cost is expected to increase substantially due to the transportation distance to the storage site being more than double to that of the south coast power plant case.

Keywords: Carbon Dioxide, CO_2 Capture, Transportation, Sequestration

I. INTRODUCTION

In relation to the recent global response against climate change due to GHG emissions, the Korean government has presented the goal of reducing greenhouse gas emissions by 37% compared to business-as-usual (BAU) levels by 2030 to the UN [2] and is pursuing a variety of policies to achieve its goals. The government is also conducting feasibility studies on CO_2 capture and sequestration (CCS) projects [2], where greenhouse gases (CO_2) generated from large-scale sources such as thermal power plants are collected and stored.

As currently the track record of CCS demonstration projects is lacking worldwide, systematic and integrated analysis and review of source-CO_2 capture-compression-transportation/storage technologies will be necessary for a successful demonstration of CCS technology in Korea. In addition, there are various options in the transportation of CO_2, each with varying investment and operating costs, hence producing the optimal CO_2 transportation plan will be a crucial part for successful CCS demonstration.

In relation to the CCS integrated demonstration project currently under review by the government, this paper analyses the cost of transportation of CO_2 using pipelines (onshore and offshore piping), a major gas transportation system, using various domestic and overseas literature data. Also, this paper analyses the feasibility of domestic CO_2 transportation and presents policy and economic data for future large-scale integrated CCS projects (LSIPs). In addition, this study analyses the circumstances of CCS integration demonstration projects in Korea and produces suggestions when compared to major CCS projects around the world.

II. ANALYSIS

A. Overview of CCS Technology

The processes of integrated CCS projects related to CO_2 capture, transportation and storage are as follows [3]. In coal-fired power plants, the flue gas generated from the combustion of the fuel enters the CO_2 capture process after a series of post-treatment processes (desulfurization, deNOx, dust collection, etc.). In the CO_2 capture process, more than 90% of the CO_2 in the flue gas is removed, and the CO_2-removed gas is discharged to the atmosphere through the stack. The high-concentration CO_2 that has been captured is then compressed or liquefied, then transported to the storage site via pipelines or CO_2 transport vessels.

The International Energy Agency (IEA) evaluates CCS technology as the most cost-effective way to address climate change [4]. At the SaskPower Boundary Dam Power Plant located in Saskwatchewan, Canada, the post-combustion CO_2 capture plant (160 MW scale) that utilizes the chemical absorption method as of 2016 is operating in conjunction with the enhanced oil recovery (EOR) project (CO_2 treatment scale: 1 million tons) [2]. In Korea, the 10 MW scale post-combustion wet and dry CO_2 capture plants (200 tons/day, 70,000 tons/year CO_2 treatment scale) developed by KEPCO and subsidiary companies are currently in operation in the Boryeong Thermal Power Plant (KOMIPO) and the Hadong Thermal Power Plant (KOSPO) [5] .The 10 MW wet post-combustion plant in particular has been recently evaluated to be highly reliable with excellent performance with over 3,000 hours of non-stop continuous operation [6].

In the case of CO_2 storage technology, studies are underway on the selection of storage sites and CO_2 potential capacity evaluation by the Korea National Oil Corporation (KNOC), the Korea Institute of Geoscience and Mineral Resources, and Gongju National University. 100 tons of CO_2 injection tests at Pohang basin have been successfully carried out for the "POSCO

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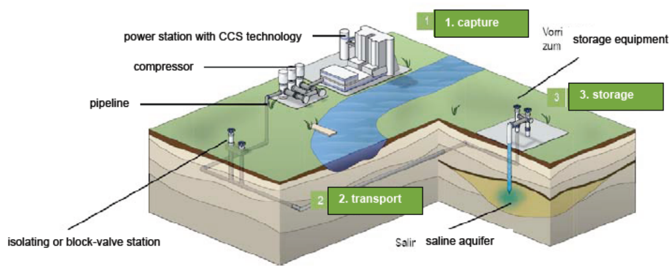


Fig. 1. Whole integrated CCS Chain. [3].

(a)

(b)

Fig. 2. KEPCO Post-combustion CO_2 Capture Plant. [5]. (a) Post-combustion Wet-amine CO_2 Capture Plant. (b) Post-combustion Dry CO_2 Capture Plant.

Maritime CO_2 Storage Demonstration Project", currently underway at Gongju National University. Based on this, a medium-scale storage demonstration project with an annual capacity of over 10,000 tons (over 5,000 tons per year) is being pursued [7].

In Korea, research on CO_2 storage projects is proceeding at a small-scale of less than 10,000 tons per year, which consequently leads to relatively inadequate research on related CO_2 transportation. According to the data published in some reports, the Korea Ocean Research & Development Institute plans to build a 3,000-ton small CO_2 transportation vessel to facilitate to the goal of realizing a 3 million ton/year CO_2 marine underground storage site by 2020, with the plan to remodel a domestic small-scale LPG transportation vessel [8]. Additionally, Daewoo Shipbuilding & Marine Engineering (DSME) reports that it has completed the conceptual design of a 100 K large-scale CO_2 carrier for the transportation of large quantities of CO_2 [9].

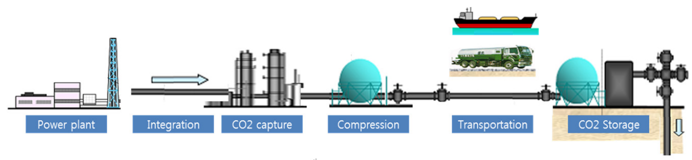


Fig. 3. Large-scale Integrated CCS Chain.

1) Overview of CCS Integration Demonstration

CCS integration demonstration largely consists of CO_2 capture, plant integration, capture, compression and transportation storage in Fig. 3. The process most important in terms of technology and cost in CCS integration demonstration is the CO_2 capture process, which collects and processes the CO_2 generated from the source. This is because the CO_2 capture process is the most energy intensive process in the entire CCS chain (such as steam energy used to regenerate the absorbent added in the turbine section of the power plant), and is a major factor that determines the overall cost of the CCS integration demonstration, as well as determining the design scheme of the processes following capture process (compression, transportation, storage, etc.).

In the case of CO_2 capture technology, KEPCO and its subsidiary companies secured FEED (Front End Engineering Design) design data and track record data from the operation of 10 MW pilot plant for large scale CCS integration demonstration. With this as a basis, cost analysis data was calculated and partially presented. According to the study results of Lee, Ji Hyun et al., cost analysis using domestic wet amine technology predicted the CO_2 reduction cost to be about 42 USD/tCO_2. Compared with cases from oversea countries, the CO_2 reduction cost is very low, which is attributed to the excellent performance of CO_2 capture technology and the low cost of electricity (COE) produced by coal-fired power plants in Korea [5].

The transportation of captured CO_2 requires different processes depending on the transportation method. CO_2 transportation is possible in the gaseous, liquid and solid states, but as transporting in gas state in atmospheric pressure requires equipment for large capacities to handle large volumes, compression or liquefaction procedures are necessary. Among various CO_2 transportation methods, ship and truck transportation methods require compression/cooling under conditions of low temperature and atmospheric pressure before transportation. In order to store compressed CO_2, it is necessary to install temporary storage sites in power plants and storage sites. Pipeline transportation is also operated under conditions of room temperature and high pressure for long distance transportation.

Unlike ship and truck transportation, pipeline transportation does not require the installation of special temporary storage sites in power plants, but for systems with integrated operation of capture-transportation-storage processes, CO_2 supply failure in any part can affect the entire CCS chain. Therefore, it is

Fig. 4. Integrated CCS Project Scenario in South Korea.

necessary to prepare complementary measures such as the installation of temporary storage sites at the hub terminal before CO_2 supply.

Currently, the East Sea Gas Field area near Ulsan city is considered the optimal site as a repository of captured CO_2 for the CCS integrated demonstration project (1 million tons of CO_2 disposal per year) being reviewed by related government departments. The East Sea Gas Field is the first gas field of Korea, with commercial production initiated in July 2004 and commercial operation to be decommissioned in 2019 [1]. Analysing the investigated data of the East Sea Gas Field the potential storage capacity for CO_2 of the gas field is expected to be 16 million tons, which means an annual supply of 1 million tons of CO_2 can be sustained for over 15 years.

In particular, 10 years of sustained commercial operation has verified the safety of the gas field as a CO_2 storage site, and much investigation data on the site have been produced. Therefore, when CO_2 supply of the gas field is completed in the future, further study for the storage in nearby areas can be easily conducted. Additionally, the site has an advantage in terms of utilizing existing facility, as the gas field has a constructed marine platform, the Ulsan hub station, as well as offshore piping between the hub station and the gas field.

For the transportation of CO_2 from the CO_2 source to the East Sea Gas Field, methods such as pipelines (offshore and onshore pipelines), tanker trucks and ship transportation can be considered. Based on this, a schematic diagram of the overall scheme for a domestic large-scale CCS demonstration project is described in Fig. 4.

B. Analysis of Technology/Cost of CO_2 Transportation Options

The aforementioned CO_2 transportation technologies are all methods that are already well-developed, and the final selected transportation technology will be decided by taking into consideration cost and environmental impact aspects. Various methods such as ship, pipeline, railway, and tanker trucks for CO_2 transportation exist, and the features of each method are as follows.

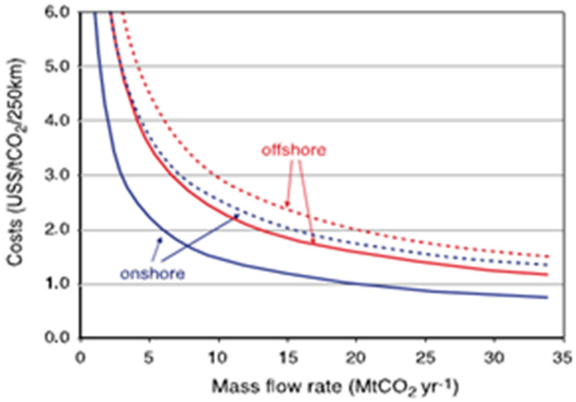
1) Pipeline Transportation

Among the various CO_2 transportation options, transportation by pipeline is the main method used in North America and Western Europe [4][10][11]. This is due to the fact that dedicated pipelines for transporting CO_2 that are already installed as part of the infrastructure in North America allow for easy utilization, and in Western Europe, which is near the coast, using existing gas and oil pipelines for transporting CO_2 is considered one of the best options [12]. Pipelines are divided into onshore pipelines and offshore pipelines, depending on the installation location. The installation costs of offshore pipelines per kilometer are reported to be at least 1.5 times greater [11].

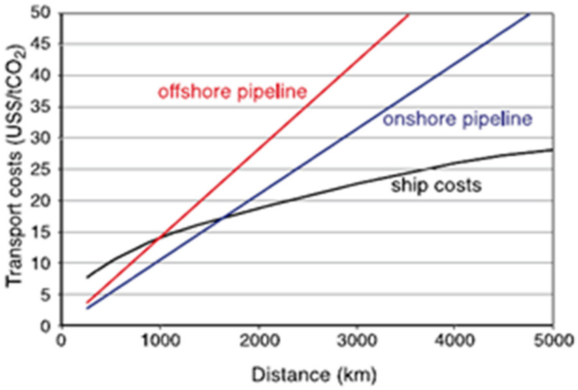
2) CO_2 Transportation by Ship

One of the most recent published research data on ship CO_2 transportation is the aforementioned feasibility study by Chiyoda [12], which was carried out with the support of GCCSI (Global CCS Institute). The CO_2 transport ship presented in this study had a storage capacity of 3,000 m^3 and could store CO_2 at 2.86 MPa and -10°C. In addition, as a characteristic feature, operating costs (labor cost, etc.) could be reduced due to the fact that the vessel does not need a manned platform for operating CO_2 supply, as it possessed a constructed CO_2 supply facility onboard. As the CO_2 is supplied directly onboard, the designs require no separate reservoir for temporary storage of conventional liquefied CO_2.

Various feasibility studies have shown that the use of ships in the transportation of CO_2 is costly compared to pipeline transportation [11]-[13]. As there are presently no existing data on the cost of CO_2 transportation vessels, predictions using similar-scale vessels are necessary to estimate the investment cost of CO_2 transportation by ships. According to IEA data, it is estimated that the price of CO_2 transportation ships will be about 30~50% higher than that of semi-cooled LPG carriers, in the case of newly constructed CO_2 transportation carriers. The estimated



(a)



(b)

Fig. 5. Cost of CO_2 Transportation. [11]. (a) Onshore and Offshore Pipeline Transportation. (b) CO_2 Transportation Costs by Distance for Various Transportation Methods.

cost of ship CO_2 transportation based on this is as follows [11].

10,000 ton CO_2 Transportation Ship: Approx. 34 million USD
20,000 ton CO_2 Transportation Ship : Approx. 50 million USD
30,000 ton CO_2 Transportation Ship : Approx. 65 million USD
50,000 ton CO_2 Transportation Ship : Approx. 85 million USD

While it is true that the longer the transportation distance from the CO_2 capture source, the greater the economic efficiency of CO_2 transportation by ship compared to pipeline transportation, in the case of Korea, the distance between the CO_2 capture source and the storage site (East Sea Gas Field) does not exceed a maximum distance of 1,000 km (e.g. marine transportation distance for Boryeong Thermal Power Plant → Ulleung Basin: approx. 700 km) CO_2 transportation by ship is expected to be a less competitive option compared to pipeline transportation in terms of cost. Additionally, unlike pipeline transportation, CO_2 transportation by ship requires many additional facilities for multiple purposes such as fuel use, temporary storage for liquefied CO_2, as well as CO_2 shipment and cargo handling facilities, all of which are expected to lead to greater costs than pipeline transportation.

According to research data from the International Energy Agency (IEA) on the cost of transportation by transportation distance for various transportation methods, it is estimated that costs of offshore and onshore pipeline transportation costs are lower than ship transportation costs, when the distance is within

(a)

(b)

(c)

Fig. 6. Various Options for CO_2 Transportation. [13]. (a) Onshore Pipeline. (b) CO_2 Carrier. (c) CO_2 Tanker Truck

1,000 km [11].

Taking into consideration these circumstances, in order to overcome the problem of high costs of ship transportation compared to other technologies, research on the development of CO_2 ship transportation are under way, focusing on large CO_2 transportation ships rather than small transportation ships. However, due to many reasons, the introduction of transportation ships for the transportation of CO_2 is currently not receiving much attention in the industry. Despite this, there are advantages of ship transportation compared to other transportation methods; the following are the main advantages.

- If the area nearby the CO_2 emissions source is deemed to be unfavorable for CO_2 storage, ships may be used to access remote storage sites
- Easy to modify CCS project plan
- Ease of licensing compared to pipeline methods
- Disassembly, relocation, re-use of offshore underground facilities [12].

Table 1. Scheme of CCS project in South Korea

<table>
<tr><th>Plant Location</th><th>Distance
(Power Plant→ CO_2 Storage Site)</th></tr>
<tr><td>
</td><td>· Candidate Power Plant #1
- Location: West Coast
- Transportation(Length):
(1) 400 km (Onshore Pipeline)
+ 65 km (Offshore Pipeline)
(2) 700 km (Offshore Pipeline)

· Candidate Power Plant #2
- Location: South Coast
- Transportation(Length):
(1) 200 km (Onshore Pipeline)
+ 65 km (Offshore Pipeline)
(2) 250 km (Offshore Pipeline)</td></tr>
</table>

3) Transportation by Tanker Trucks

Tanker trucks are also available as an alternative method of CO_2 transportation. Fig. 6 shows an example of CO_2 truck transportation used by Chinese oil companies. The truck stores liquefied CO_2 in a deep-cooling storage tank, with a storage capacity of 20~30 tons, and CO_2 storage conditions of about 1.7 MPa, -30°C. The proposed CO_2 transportation method of using tanker trucks is highly flexible and reliable, and is expected to be applicable to relatively smaller scale CO_2 treatment [13].

However, the use of tanker trucks for large-scale CO_2 transportation being considered in this study will require compression and temporary storage facilities like ship transportation methods, and in order to treat CO_2 of more than 1 million tons per year (2,700 tons of CO_2 per day), over 100 tanker trucks will be required per day. Not only will this induce costs to purchase multiple tanker trucks, but also environmental problems and complaints due to road congestion etc. will arise, making this method not a feasible solution for CO_2 transportation.

C. Cost Analysis for CO_2 Transportation

1) Selection of Capture Source

Based on the above analysis of the various options for CO_2 transportation, this study analysed the CO_2 transportation cost from the capture source to the storage site for the method that was analysed as the most practically suitable option for large capacity CO_2 transportation in Korea: pipeline transportation.

The main assumptions for the analysis are as follows. The CO_2 capture sites were selected as representative power plants of the west and south coast, Candidate Power Plant #1 (west coast) and Candidate Power Plant #2 (east coast), to confirm the effect of distance to the storage site. Both power plants are adjacent to the ocean and are assumed to be coal-fired power plants using bituminous coal as fuel. The distance between each candidate coal-fired power plant (CO_2 capture source) and the CO_2 storage is shown in Table 1. The corresponding CO_2 transportation distances are also shown in Table 1.

2) Main Assumptions

The cost of transporting large volumes of CO_2 captured at a coal-fired power plant based on the capture source was estimated. The total CO_2 transportation volume is assumed to be 1 million tons of CO_2 per year, as indicated above. In addition, the purity of the CO_2 transported and the transported amount are also very important in the transport process and when estimating

Table 2. Cost of CO_2 Transportation (Plant #1, Onshore-Offshore Pipelines)

Currency: USD

	Plant #1 (West Coast)		
	Onshore (400 km)	Offshore (65 km)	Total
Pipeline Capital Cost (Sum)	193,019,582	47,853,340	240,872,922
Material	33,480,914	8,249,350	41,730,264
Labor	112,814,333	27,965,630	140,779,963
Miscellaneous	35,360,643	8,804,140	44,164,783
Right of Way	11,363,692	2,834,220	14,197,912
Other Capital Cost (Sum)			
CO_2 Surge Tank	1,244,724		1,244,726
Pipeline Control System	111,907		111,907
Pipeline O&M Costs (Sum)			
Fixed O&M Costs	1,050,614	341,450	1,392,064

Table 3. Cost of CO_2 Transportation (Plant #1, Exclusively Offshore Pipelines)

Currency: USD

	Plant #1 (West Coast)	
	Offshore (700 km)	Total
Pipeline Capital Cost (Sum)	505,955,672	505,955,672
Material	87,808,257	87,808,257
Labor	295,719,294	295,719,294
Miscellaneous	92,656,031	92,656,031
Right of Way	29,772,090	29,772,090
Other Capital Cost (Sum)		
CO2 Surge Tank	1,244,724	1,244,726
Pipeline Control System	111,907	111,907
Pipeline O&M Costs (Sum)		
Fixed O&M Costs	3,677,149	3,677,149

costs for the captured CO_2 transportation. This is due to increase in O&M costs from pipeline corrosion when there are more impurities such as water in the CO_2 during transportation. In this study, the conditions such as the purity of captured CO_2 reflect the operation results of a 10 MW post-combustion wet amine CO_2 capture plant, operated by the Boryeong Thermal Power Station, KOMIPO. Currently, the purity of captured CO_2 from the post-combustion wet amine 10 MW CO_2 capture plant is over 99.9%, which meets the impurity content guidelines for transporting CO_2 via pipelines proposed by international institutions [4][11]. Regarding the fully integrated CCS project, Whole CCS Chain modelling including CCGT power plant, CO_2 capture, CO_2 compression, transportation, Injection & Storage is also underway.

For the techno-economic evaluation of large scale CO_2 transportation, overall scheme was designed using gCCS ver 1.1.0, PSE [16].

3) Investment Cost Analysis

For the cost analysis of large-scale CO_2 transportation via pipelines, widely-used international literature data are used as references. This study estimates the investment costs of pipeline transportation by using results from the “Quality Guideline for Energy Systems Study” by the U.S. DOE-NETL [4]. The formula used for this study from the DOE-NETL Quality Guideline to calculate the transportation costs of pipelines is as follows. The diameter of the pipeline, taking into account the CO_2 transport flow (1 million tons of CO_2 per year), was set as 10 inches.

(1) Pipeline Capital Costs

· Materials Costs = USD 70,350 + USD 2.01 × L × (330.5 × D^2 + 686.7 × D + 26,960) (1)

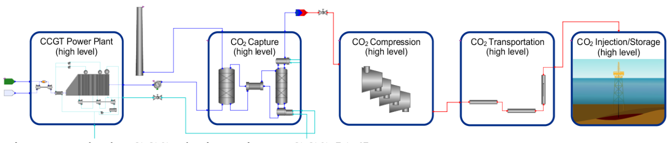


Fig. 7. Whole CCS chain using gCCS [16].

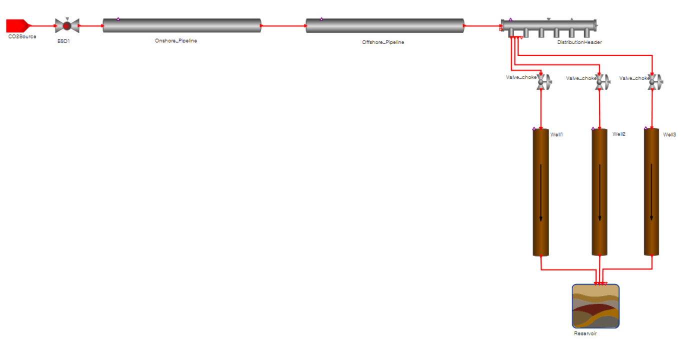


Fig. 8. CO_2 transportation modeling using gCCS.

- Labor Cost = USD 371,850 + USD 2.01 × L × (343.5 × D^2 + 2,074 × D + 170,013) (2)
- Miscellaneous = USD 147,250 + USD 1.55 × L × (8,471 × D + 7,234) (3)
- Right of Way = USD 51,200 + USD 1.28 × L × (577 × D + 29,788) (4)

(2) Other Capital Costs

- CO_2 Surge Tank = USD 1,244,724
- Pipeline Control System = USD 111,907

(3) Pipeline O&M Costs

- Fixed O&M = USD 8,454/mile/year

L: Transportation Length(km), D: Pipeline diameter(inch)

The results analysed based on the above formula are as follows. Tables 2 and 3 below show the CO_2 transportation costs for onshore + offshore piping and exclusively offshore piping for a coal-fired power plant located on the west coast (700 km from the storage site, based on offshore piping). As a result of the analysis, labor cost accounted for about 60% of the entire investment cost, followed by other expenses, material costs and land compensation, which make up the remaining portion. Operating expenses comprise of less than 1% of the total investment cost, being a minor portion of the investment costs.

Tables 4 and 5 below show the CO_2 transportation costs for onshore+offshore piping and exclusively offshore piping for a power plant located on the south coast (250 km from the storage site, based on offshore piping). It can be seen that investment cost decreases substantially as the distance decreases, compared with the result of the power plant located in the west coast.

III. RESULTS AND DISCUSSION

A. Transportation Cost Analysis

The results of cost analysis for each aforementioned case are as in Fig. 9. From the analysis results, it was predicted that the investment cost would sum up to approximately 98 million USD (approximately 116 billion KRW) if the CO_2 is transported from the candidate power plant located in the south coast (closest to the storage site) to the hub terminal through onshore pipelines, and then transported through offshore piping from the hub terminal to the storage site, while transportation with only offshore pipelines estimated to be approximately two times the amount (approximately 183 million USD, 220 billion KRW).

Table 4. Cost of CO_2 Transportation (Plant #2, Onshore-Offshore Pipelines)
Currency: USD

	Plant #2 (South Coast)		
	Onshore (200 km)	Offshore (65km)	Total
Pipeline Capital Cost (Sum)	96,830,116	47,853,340	144,683,456
Material	16,775,632	8,249,350	25,024,982
Labor	56,593,092	27,965,630	84,558,722
Miscellaneous	17,753,946	8,804,140	26,558,086
Right of Way	5,707,446	2,834,220	8,541,666
Other Capital Cost (Sum)			
CO_2 Surge Tank	1,244,724		1,244,726
Pipeline Control System	111,907		111,907
Pipeline O&M Costs (Sum)			
Fixed O&M Costs	1,050,614	341,450	1,392,064

Table 5. Cost of CO_2 Transportation (Plant #2, Exclusively Offshore Pipeline)
Currency: USD

	Plant #2 (South Coast)	
	Offshore (250 km)	Total
Pipeline Capital Cost (Sum)	505,955,672	505,955,672
Material	31,427,929	31,427,929
Labor	105,972,603	105,972,603
Miscellaneous	33,233,431	33,233,431
Right of Way	10,682,261	10,682,261
Other Capital Cost (Sum)		
CO2 Surge Tank	1,244,724	1,244,726
Pipeline Control System	111,907	111,907
Pipeline O&M Costs (Sum)		
Fixed O&M Costs	1,313,268	1,313,268

The investment costs of cases involving power plants located on the west coast increases substantially compared to that of power plants located on the south coast, due to the significantly greater transportation distance. The investment cost of onshore pipelines is lower than the costs for offshore pipelines for the same length of piping, as operating conditions are simpler for onshore pipelines. However, in addition to investment and operation costs, site purchase costs, license fees, and costs that may be incurred in the event of various civil complaints must be taken into consideration when installing pipelines. These costs depend heavily on the surrounding site environment.

Therefore, it will be necessary for future studies to quantify into cost data the various qualitative aspects related to CO_2 transportation (civil complications, environmental pollution, difficulty of construction, etc.) to allow for quantitative comparisons as well as reliable cost analysis for onshore and offshore pipeline transportation technology.

B. Comparative Analysis with Overseas Cases

In addition to the above cost analysis, this paper analysed the major features of integrated CCS demonstration projects operating worldwide as well as performing cost analysis on transportation/storage aspects to analyse the geological and technological feasibility of domestic integrated CCS demonstration projects. Major overseas CCS project in 2016 as summarized by

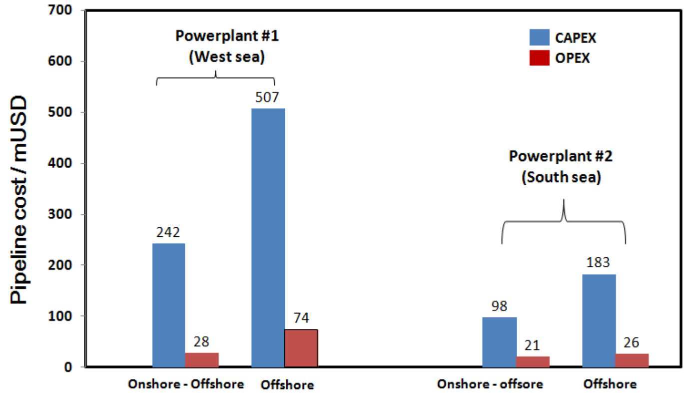


Fig. 9. Cost of CO_2 Transportation via Pipelines.

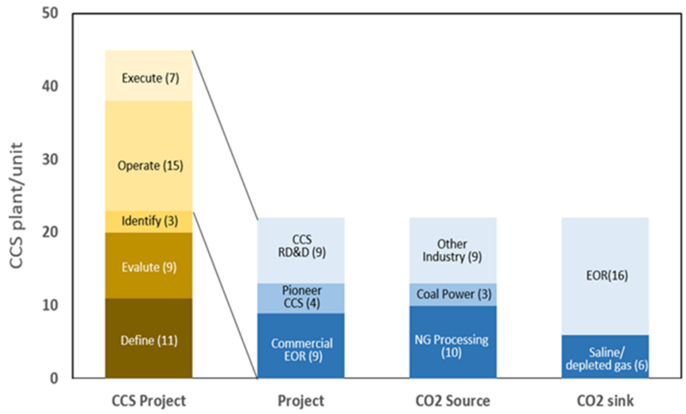


Fig. 10. CCS Project Pipelines as reported by the GCCSI [15].

MIT [14] based on the latest report [15] published by GCCSI (Global CCS Institute) were analysed. According to the MIT report, 22 projects are in operation or under way as of 2016. These 22 projects are further classified by project type. Nine projects utilize artificial CO_2 for EOR, 4 projects are focused on storing captured CO_2 in saline aquifers or depleted gas fields, and 4 projects are RD&D-type CCS projects. When the 22 projects are classified according to CO_2 source, 10 cases capture CO_2 generated from natural gas processing, 3 cases apply to coal-fired power plants, and 9 cases consist of the remaining industries (steel, refinery, natural gas refinery, etc.). Classifying the projects by CO_2 sinks have 16 projects that associate the captured CO_2 with EOR projects and the remaining 6 store the CO_2 in saline aquifers or depleted gas fields.

As shown in Fig. 10, most large-scale CCS projects currently utilize EOR as a CO_2 sink, and some technologies for storage in saline aquifers are used in processes for treating CO_2 from natural gas, methanol, and ethanol refining processes. However, there are presently no existing cases of CCS demonstration project that is being promoted by the Korean government (coal-fired power plant → saline aquifer storage). This indicates that the economic feasibility of a project to store CO_2 emissions from coal-fired power plants is currently low, as there are no strong regulations and support measures for CO_2 emissions. With the absence of CCS regulations, carbon credits are the only real means to portray feasibility of the project, though this is also difficult due to carbon credits being traded at less than 20,000 KRW/ton as of 2016.

As shown from the analysis from this study, large-scale integrated CCS projects are currently under way when in conjunction with EOR projects or when the CO_2 transportation distance is very short. However, as the distance between the capture plant and the storage site is very long, CCS demonstration projects are considered to have low technical and policy feasibility.

IV. CONCLUSION

In order to examine the feasibility of Carbon Capture & Storage (CCS) for national GHG reduction goals, various technical options and costs for CO_2 capture at domestic thermal power plants were calculated, and comparatively analysed with overseas CCS demonstration projects. As a main assumption for the analysis, the CO_2 capture source was set as coal-fired power plants located on the west and south coasts of the Korean Peninsula in order to confirm the effect of distance to the storage. The CO_2 transportation method to be analysed was selected as the most practical solution based on the technical and economic analysis of various transportation methods: pipelines (onshore and offshore pipelines). The location of the large-scale storage site for the treatment of captured CO_2 is set at the East Sea Gas Field (about 60 km southeast of Ulsan, potential CO_2 storage of 16 million tons), which is expected to be decommissioned. As a result of analysis using various literature values, it is predicted that the investment cost to transport CO_2 to the East Sea Gas Field using onshore pipelines would be approximately 98 million USD (approximately 116 billion KRW) when the CO_2 is captured from thermal power plants located in the south coast, which is geographically close to the East Sea Gas Field, and using offshore pipelines would increase the cost by about two times the amount. Setting the capture site as power plants located on the west coast will more than double the transportation distance to the storage site, which in turn will significantly increase the transportation costs. By comparing the costs and scenarios analyzed by this study with currently operating major CCS demonstration projects (including EOR-related cases), it is very unlikely in the present that CCS plant can be connected with EOR in Korea, and as the distance between the capture source and the storage site is relatively long, the techno-economic feasibility of large-scale CCS demonstration projects is low under current GHG emission control and support policies.

Therefore, this study shows that further study on the selection of CO_2 storage sites will be needed. In other words, it is imperative that investigations and surveys are made on not only the East Sea Gas Field, but also other areas such the west coast Gunsan basin adjacent to the Boryeong Thermal Power Plant or the southern coast area. Also, considering the potential utilization and storage capacity of existing infrastructure of the East Sea Gas Field, it will be necessary to review CCS demonstration projects for the petroleum and oil refinery industry in the Ulsan area adjacent to the East Sea Gas Field.

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