ANALYSIS OF GHG EMISSION REDUCTION IN CARBON CAPTURE & UTILIZATION (CCU) FACILITY

[1]LEE BONG JAE, [2]LEE JIN KYEONG

[1,2] Korea Testing & Research Institute, University of seoul
E-mail: [1]jae8076@ktr.or.kr, [2]jinkyeong@ktr.or.kr

Abstract - The Carbon Capture & Utilization (CCU) which technology that captures and utilizes carbon dioxide (CO_2) from point sources such as power plants has been analyzed as the most cost-effective method for reducing GHG emissions among Carbon Capture & Storage (CCS) technologies. In this study, we propose a methodology of estimating GHG emission reductions by CCU facility. Basically, it is necessary to apply a conservative approach. Therefore, only CO_2 that is captured purely is considered though leakage calculation. According to the proposed methodology, 13,725 $tCO_{2\text{-eq}}$ can be reduced annually in the CCU facility of 2MW - capacity. As the capacity of CCU facility is increased, the impact of GHG emission reduction will be significant. The present analysis has calculated the GHG emission reductions during the 4-hour normal operation period of the CCU facility. However, if the emission reduction is estimated through continuous operation for more than 100 hours in the future, it is expected that the amount of GHG emission reduction for reliable CCU facility can be analyzed.

Index Terms - CCU, GHG emission reduction, methodogy

I. INTRODUCTION

In the Paris Agreement, all countries must reduce their greenhouse gas (GHG) emissions through the voluntary reduction target, and be verified every five years.

Therefore, each country is trying to develop technologies that reduce GHG emissions. In Korea, it set a goal to reduce GHG emissions by 37 % compared to the Business as Usual (BAU) in 2030 and is implementing various policies to achieve the reduction target. In accordance with Carbon Capture & Utilization (CCU), technology that captures and utilizes carbon dioxide (CO_2) from point sources such as power plants has been analyzed as the most cost-effective method for reducing GHG emissions among Carbon Capture & Storage (CCS) technologies. This study presents a methodology for estimating the amount of GHG reduced by CO_2 captured and utilized through CCU technology and evaluates the GHG emission reduction of CCU facility in operation.

II. CALCULATION METHOD FOR GHG EMISSION REDUCTION

In order to estimate the GHG emission reduction, it is necessary to establish a calculation method, in case that the CCU facility is not installed, the amount of CO_2 emission is set as the baseline emission. After the CCU facility is installed, the amount of additional energy that is used due to the operation of the CCU facility is set as the project emission. In case of leakage, which was calculated by comparing the TGA analysis value of the CO_2 capture product by sampling and the CO_2 concentration difference through the real time meter.

A. Baseline Emission

The baseline emission is estimated by measuring CO_2 concentration of the exhaust gas for inlet and outlet in the CCU facility. The baseline calculation method based on exhaust gas flow rate and CO_2 concentration is as follows.

$$BE = \sum_{h=1}^{n} (Q_{in,m,gas} \times C_{in,h,co2} \times \gamma - Q_{out,m,gas} \times C_{out,h,co2} \times \gamma) \times \left(\frac{P_{sale}}{P_{Product}}\right)$$

- BE = Baseline emissions in monitoring period (tCO_2-eq/monitoring period)
- $Q_{in,m,gas}$ = Exhaust gas flow rate at the front of the CCU facility (Nm^3/monitoring period)
- $C_{in,h,CO2}$ = CO_2 concentration at the front of the CCU facility (%)
- $Q_{out,m,gas}$ = Exhaust gas flow rate after the CCU facility (Nm^3/monitoring period)
- $C_{out,h,CO2}$ = CO_2 concentration after the CCU facility (%)
- γ = The conversion factor of m^3 and kg of CO_2 ($44kgCO_2 \div 22.4m^3$) = $1.964kgCO_2$ / Nm^3 t at 0 ℃ and 1 atmospheric pressure is applied to convert 10^{-3}
- P_{sale} = Sold CO_2 capture product (ton/monitoring period)
- P_{sale} = Produced CO_2 capture product (ton/monitoring period)
- m = monitoring period
- h = From monitoring start time to finish time

B. Project emissions

The project emission is calculated by the electric power consumption applied the power emission factor. The project emission is calculated as follows.

$$PE = EC_{EL,m} \times EF_{grid}$$

- PE = Project emissions in monitoring period (tCO_2-eq/monitoring period)
- $EC_{EL,m}$ = Electricity consumption (MWh/monitoring period)
- EF_{grid} = Power factor (tCO_2-eq/MWh)

C. Leakage

Leakage is the amount of CO_2 released by production of CO2 capture, meaning CO_2 captured by water or other material.

$$LE = BE \times LE_{emission\ factor}$$

If $LE_{emission\ factor}$ is negative, CO_2 capture and reaction are considered to have failed and are excluded from leakage.

$$LE_{emission\ factor} = \frac{P_h \times (1 - M_c) \times C_{sample,CO2}}{\sum_{min}^{min-1}(Q_{in,h,gas} \times C_{in,h,CO2} \times \gamma - Q_{out,h,gas} \times C_{out,h,CO2} \times \gamma)}$$

- LE = Leakage in monitoring period (tCO_2-eq/monitoring period)
- $Q_{in,h,gas}$ = Exhaust gas flow rate at the front of the CCU facility (Nm^3/sampling period)
- $C_{in,h,CO2}$ = CO_2 concentration at the front of the CCU facility (%)
- $Q_{out,h,gas}$ = Exhaust gas flow rate after the CCU facility (Nm^3/sampling period)
- $C_{out,h,CO2}$ = CO_2 concentration after the CCU facility (%)
- γ = The conversion factor of m^3 and kg of CO_2 ($44kgCO_2 \div 22.4m^3$) = $1.964kgCO_2$ / Nm^3 t at 0 ℃ and 1 atmospheric pressure is applied to convert 10^{-3}
- P_h = Produced CO_2 capture product (ton/sampling period)
- M_c = Moisture content of CO_2 capture product
- $C_{sample,CO2}$ = CO_2 concentration of CO_2 capture product by TGA

D. GHG Emission Reduction

The GHG Emission Reduction is calculated as follows.

$$ER = BE - PE - LE$$

- ER = GHG emission reduction in monitoring period (tCO_2-eq/monitoring period)

III. RESULT

In order to estimate the amount of GHG emission reduction, The CCU facility of 40 tCO_2/day (2 MW) capacity was installed in the power plant in Korea. Accordingly, the amount of GHG emission reduction that are captured and utilized by CCU facilities is estimated by applying the proposed methodology. The measured flow rate of inlet/outlet and CO_2 concentration of inlet/outlet are as follows.

Time	CO_2 amount of inlet	CO_2 amount of outlet	CO_2 amount of capture	CO_2 capture Product	TGA Analysis	CO_2 amount of CO_2 capture product
	tCO_2/hr	tCO_2/hr	tCO_2/hr	ton/hr	%	tCO_2/hr
14h	2.19	0.54	1.65	4	39.17%	1.47
15h	2.12	0.48	1.64	4	39.17%	1.46
16h	2.09	0.48	1.60	4	39.17%	1.43
17h	2.07	0.47	1.60	4	39.17%	1.43
total (4hr)	8.46	1.97	6.497	15	39.17%	5.78

Table 1. Result of measured flow rate and analyzed CO2 concentraton

※ CO_2 capture product (=sold CO_2 capture product) = CO_2 capture amount x 100/44

Baseline emissions are as follows.

BE = ($8.46tCO_2$/4h-$1.97tCO_2$/4h)÷(15ton/4h÷15ton/4h)
= $6.497tCO_{2\text{-}eq}$/4h

Project emissions are the GHG emissions generated by using the in-plant power from the grid, and the project emission in this study is assumed to be "0".

PE = 0

Leakage is compared by the CO_2 concentration of CO_2 capture product and the moisture content of CO_2 capture and continuous measurement results of flow rate and CO2 concentration of exhaust gas measured at the inlet/outlet of CCU facility during 1 hour. In this study, the moisture content is assumed to be '0', but the moisture content should be considered when estimating the actual leak amount.

The leakage emission factor is calculated as follows.

$LE_{emission\ factor}$ = 1-((15tCO_2/4h×39.17%)÷6.50$tCO_{2\text{-}eq}$/4h)
= 0.11

Also, the leakage is calculated as follows.

LE = $6.497tCO_{2\text{-}eq}$/4h × 0.11
= 0.715 $tCO_{2\text{-}eq}$/4h

Therefore, the amount of GHG emission reduction during the monitoring period is calculated as follows.

ER = $6.497tCO_{2\text{-}eq}$/4h - 0 - 0.715 $tCO_{2\text{-}eq}$/4h
= 5.78 $tCO_{2\text{-}eq}$/4h

Based on the above result, amount of the annual emission reduction for this study is 13,725 $tCO_{2\text{-}eq}$/year

CONCLUSION

In this study, we propose a methodology of estimating GHG emission reductions by CCU facility. Basically, it is necessary to apply a conservative approach. Therefore, only CO_2 that is captured purely is considered though leakage calculation. According to the proposed methodology, 13,725 $tCO_{2\text{-}eq}$ can be reduced annually in the CCU facility of 2MW - capacity. As the capacity of CCU facility is increased, the impact of GHG emission reduction will be significant. The present analysis has calculated the GHG emission reductions during the 4-hour normal operation period of the CCU facility. However, if the emission reduction is estimated through continuous

operation for more than 100 hours in the future, it is expected that the amount of GHG emission reduction for reliable CCU facility can be analyzed.

REFERENCES

[1] Global CCS Institute. (2011). Accelerating the Uptake of CCS: Industrial Use of Captured Carbon Dioxide

[2] IPCC. (2014). Climate change 2014: synthesis report. Summary for policy makers, International Panel on Climate Change.

[3] Miller D.C. et al., (2016). Toward Transformational Carbon Capture Systems, AIChE Journal,

[4] Paul Zakkour. (2013). Implications of the Reuse of Captured CO2 for European Climate Action Policies.

[5] CDM(Clean Development Mechanism) : http://cdm.unfccc.int/

★★★