Additional Analysis of Carbon Capture at Industrial Facilities

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Background

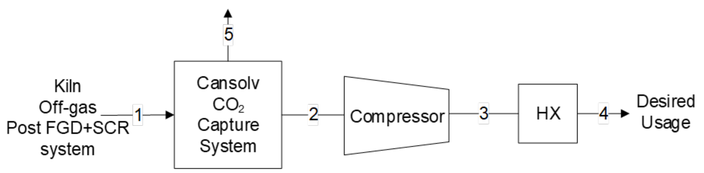
With a global initiative to reduce greenhouse gas (GHG) emissions, the cement industry presents an impactful decarbonization opportunity. In the United States (U.S.), cement production contributed just under 66 million (M) tonnes of carbon dioxide (CO_2) emissions in 2020, representing approximately 2.5 percent of total domestic GHG emissions based on reporting to the Environmental Protection Agency. [1] This poster builds on NETL's 2022 update to the industrial capture report and presents additional cost breakdowns for retrofit capture implementation at a generic cement plant.

Case Summary

The retrofit system captures CO_2 from the kiln off-gas of a 1.29 Mtonnes of Portland cement/year (assuming 91.4 percent clinker content and 100% capacity factor) representative plant. The system was modeled by leveraging performance data from legacy system analysis studies [2] and cement plant-specific vendor data:

- Wet flue gas desulfurization (FGD) and selective catalytic reduction (SCR) systems purify the kiln off-gas before entering the CO_2 capture unit
- A recent Shell Cansolv CO_2 capture system, which includes a direct contact cooler and prescrubber, separates CO_2 from the flue gas
- An integrally-geared centrifugal compressor (including intercooling, TEG dryer, and interstage water knockouts) and outlet cooler compresses and dries the CO_2 product
- A natural gas (NG)-fired industrial boiler provides the steam for the process
- A cooling tower and ancillary equipment support the capture process

CO_2 capture block flow diagram



Summary of base cases

Case		Cement plant retrofit with FGD, SCR, and 90% CO_2 Capture
Cement Plant Specifications	Representative Plant Size	1.29 Mtonnes cement/year
	Flue Gas Stream Description	Kiln Off-Gas: 14.7 psia, 320°F, and 22.4 mol% CO_2
Retrofit Capture System Specifications	NOx and SOx Control	FGD and SCR
	CO_2 Separation Technology	Cansolv
	CO_2 Available for Capture	1.21 Mtonnes CO_2/year
	Capture Rate	90%
	CO_2 Captured	1.09 Mtonnes CO_2/year

Financial Methodologies

The cost of CO_2 capture (COC) and the cost of CO_2 avoided (COA), excluding transport and storage (T&S), were calculated using Equation 1 and Equation 2, respectively. The cost of CO_2 capture and the cost of CO_2 avoided take into account the capital, operation and maintenance (O&M), power, and fuel purchase costs associated with CO_2 capture and compression, and the required balance of plant equipment. Capital costs are scaled from legacy system analysis studies and cement plant-specific vendor data. In this study, costs are presented in December 2018 real dollars. A retrofit factor of 1.05 was applied to the total plant cost. The financial assumptions were developed by NETL's Energy Markets Analysis Team in October 2021 based on cement industrial sector market data.

$$COC\left(\frac{\$}{tonne\ CO_2}\right) = \frac{TOC * CCF + FOM + VOM + PSG}{CF * tonnes\ CO_2\ captured\ per\ year}$$

Equation 1: Cost of CO_2 captured

$$COA\left(\frac{\$}{tonne\ CO_2}\right) = \frac{TOC * CCF + FOM + VOM + PSG}{CF * (tonnes\ CO_2\ captured\ per\ year - tonnes\ CO_2\ emitted\ from\ NG\ boiler)}$$

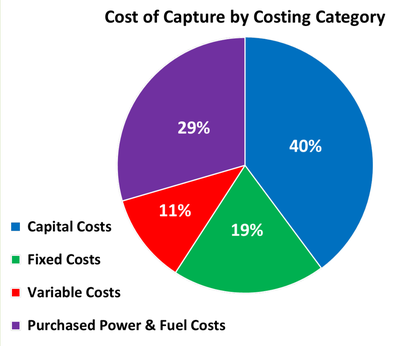
Equation 2: Cost of CO_2 avoided

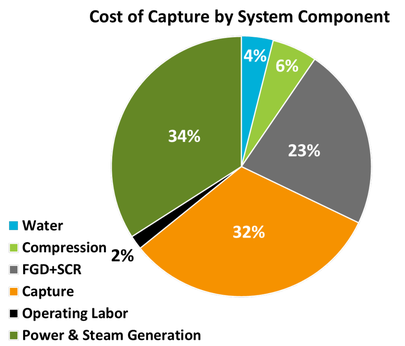
Where:

TOC – Total overnight costs of CO_2 capture equipment
CCF – Capital charge factor = 5.35%
FOM – Annual fixed O&M costs
VOM – Annual variable O&M costs
PSG – Power and steam generation (NG purchase) costs
CF – Capacity factor

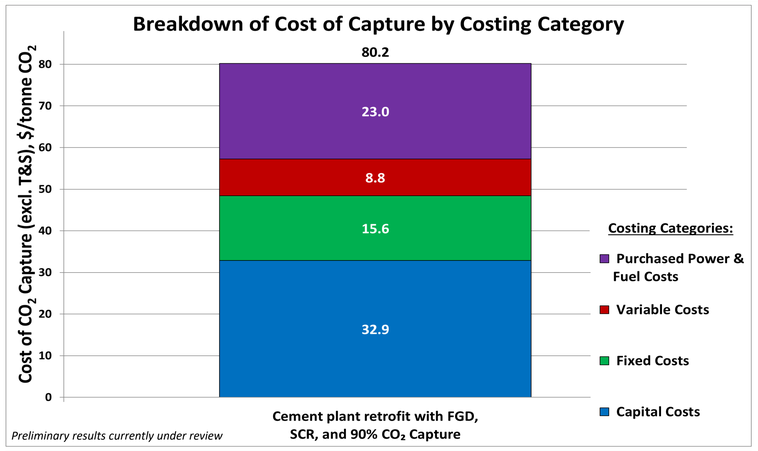
Results and Conclusions

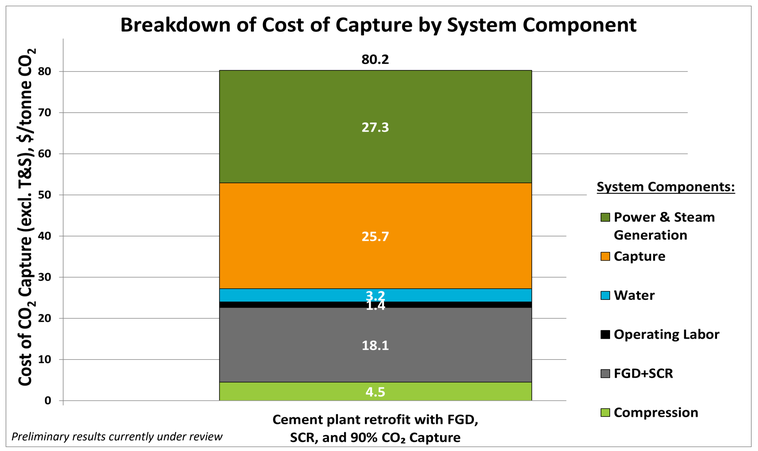
- For a CO_2 capture rate of 90 percent, the cost of CO_2 capture is \$80.2/tonne CO_2 and the cost of CO_2 avoided is \$99.0/tonne CO_2
- Costs attributed to the CO_2 capture system and power/steam generation make up about 60% of the overall cost of CO2 capture
- The compression, water, FGD and SCR systems, and operating labor shared costs make up about \$25/tonne CO_2 of the overall cost of CO2 capture (excluding T&S)
- Assuming kiln off-gas has tolerable levels of impurities and does not require pretreatment by FGD and SCR, the cost of CO_2 capture for the 90% CO_2 capture case is \$62.1/tonne CO_2

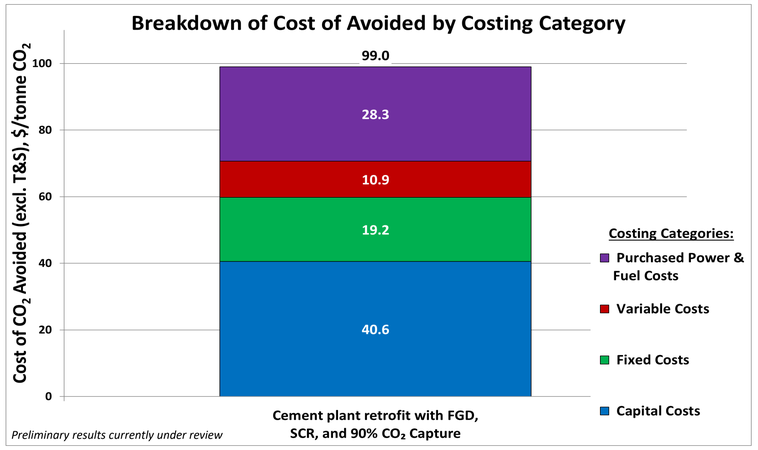




Cost of CO_2 Capture and CO_2 Avoided







References

[1] EPA, "Facility Level Information on Greenhouse Gases Tool (FLIGHT)," EPA, 2020. [Online]. Available: http://ghgdata.epa.gov/ghgp/main.do. [Accessed 3 September 2021].

[2] NETL, "Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity," U.S. DOE/NETL, Pittsburgh, 2022.