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Air Quality Co-benefits of Carbon Capture Indicated in Front-End Engineering Design Studies

Dan Hancu[a]*, Timothy Fout[b], Sara Hamilton[a], Ayaka Jones[a], Jonah Williams[a], Gregory Hackett[c], Sally Homsy[d]

[a]*Office of Fossil Energy and Carbon Management, U.S. Department of Energy, 1000 Independence Ave. SW, Washington, DC 20585, USA*
[b]*Office of Fossil Energy and Carbon Management, U.S. Department of Energy, 3610 Collins Ferry Rd, Morgantown, WV 26505, USA*
[c]*National Energy Technology Laboratory, 3610 Collins Ferry Rd, Morgantown, WV 26505, USA*
[d]*National Energy Technology Laboratory, 626 Cochran Mill Rd, Pittsburgh, PA 15236, USA*

Abstract

Integrating carbon capture with power generation and industrial processes can result in environmental co-benefits by reducing the point source's air emissions of sulfur oxides (SO_x, mainly SO_2 and SO_3), nitrogen oxides (NO_x, mainly NO and NO_2), particulate matter (PM, especially $PM_{2.5}$ and its precursors). The magnitude of the co-benefits will vary with the types of the point sources (fuel type or process gas stream), carbon capture technologies, the controls in use prior to the integration of a carbon capture unit, the air permitting requirements, and the trade-off between pre-capture clean-up cost and the cost associated with capture media degradation and reclamation.

This paper reviews findings from the Office of Fossil Energy and Carbon Management's (FECM) efforts to quantify changes in emissions after the integration of carbon capture. As part of the efforts, FECM reviewed 15 front-end engineering design (FEED) studies that it supported on integrating carbon capture with coal- and natural-gas-fired power generation and industrial processes (cement, hydrogen, petrochemical production, etc.). The capture technologies used in these studies range from solvent-, sorbent-, and membrane-based to novel concepts such as sorbent combined with cryogenic capture and other hybrid systems. Combined with inputs from the principal investigators of the 15 projects on the subject, the consolidated results are presented in Table 1. Significant reductions of SO_x are consistently observed in most studies, as scrubbing of inlet flue gas in the direct contact cooler (DCC) removes the bulk of SO_x, followed by further removal of SO_2 by solvents and membranes. Cryogenic and membrane-based carbon capture reduce NO_x emissions, while solvent-based carbon capture can reduce NO_2 emissions with NO emissions hinged on the sourced electricity for the capture unit. Similarly, $PM_{2.5}$ emissions can be reduced when cooling towers with mist eliminators are deployed in addition to its removal in the DCC.

In the case of amine-based carbon capture, degradation of capture media can generate other non-CO_2 emissions, which can be managed and avoided with appropriate engineering controls and monitoring and measurement methods. FECM's support for developing relevant analytical tools and engineering approaches to carefully monitor, measure, and reduce secondary emissions are also discussed in this paper.

* Corresponding author. Tel.: +1-240-220-1186
E-mail address: dan.hancu@hq.doe.gov

Table 1. FEED-Estimated Changes in Criteria Air Pollutant Emissions after Integrating Carbon Capture with Power Generation or Industrial Processes

Host	**FEED by**	**Capture tech**	**Material**	**SO_x**	**NO_x**	**$PM_{2.5}$**
Power coal	LED	Solvents	KS-21, MHI	-98%	0%	0%
Power coal	Minnkota	Solvents	EFG+, Fluor	-100%	0%	-90%
Power coal	MTR	Membranes	2-stage Polaris, MTR	-95%+	-10%	-80% excl aerosol
Power gas	UT	Solvents	PZAS, UT	0%	7%	0%
Power gas	EPRI	Solvents	EFG+, Fluor	-100%	0%	not analyzed
Cement	UIUC	Novel Concepts	Cryocap FG, Air Liquide	-99%+	-95%+	-99%+
Cement	S&L/MTR	Membranes	Polaris, MTR	-95%+	-10%	-80% excl aerosol
Cement	RTI	Solvents	NAS, RTI	-90~93%	15%	-60%+
Hydrogen	Linde	Solvents	Aqueous, BASF	-99%+	5~10%	-90%+
Hydrogen	Dastur	Sorbents	Cryocap FG, Air Liquide	-100%	-95%+	-100%
Hydrogen	Electricore	Hybrid	multiple tech	-99.9%+	7%	not analyzed
Iron/Steel	UIUC	Novel Concepts	Cryocap FG, Air Liquide	-99%+	-92%+	-65%

Keywords: carbon capture, solvent, sorbent, membrane, cyrogenic, novel concept, air emissions, front-end engineering design, power generation, industrial process, coal, natural gas