Cement Plant TEA/LCA

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Carbon Management Project Review Meeting 2024

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Overview

1. "Analysis of Carbon Capture Retrofits for Cement Plants" report, published in 2023

2. "The Impact of Cement Plant Air Ingress on Membrane-Based CO_2 Capture Retrofit Cost" Carbon Capture Science & Technology, 2024

3. Ongoing techno-economic analysis (TEA) and lifecycle assessment (LCA) work on capture from cement plants & other industrial capture projects will be highlighted

Analysis of Carbon Capture Retrofits for Cement Plants

Sydney Hughes[2], Patricia Cvetic[2], Sally Homsy[2], Alex Zoelle[3], Mark Woods[2], Charles White[2], Sandeep Pidaparti[2], Norma Kuehn[2], Hannah Hoffman[2], Katie Forrest[2], Travis Shultz[1], Tim Fout[1], Eric Grol[1], Robert James[1], Richard Bohan[3]

[1]NETL
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https://www.osti.gov/biblio/1970135

Analysis of Carbon Capture Retrofits for Cement Plants

Design Assumptions

- The base cement plants are not modeled. Emissions streams from representative plants are characterized
  - Heat integration potential and retrofit difficulty factors are applied as a mathematical exercise without consideration of host plant specifics
- In addition to capture and compression, all required balance of plant systems, including steam production via a natural gas-fired industrial boiler, are modeled
- NETL's library of legacy system analysis studies serves as the basis for cost scaling references, cement plant-specific vendor data for CO_2 capture systems, balance of plant performance and cost information, and financial methodologies

Analysis of Carbon Capture Retrofits for Cement Plants

Kiln Gas Conditions

- Average CO_2 emissions factors for the representative cement plants are based on Global Cement and Concrete Association (GCCA) "Getting the Numbers Right Project" data[1]
  - Each average total emissions rate is based on data collected from U.S. producers based on kiln type and accounts for kiln combustion fuel emissions and CO_2 from calcination

	For PH/PC Kilns	For Wet Kilns	Units
Cement Production Rate	**1,500,000**	**1,500,000**	tonnes per year
Percentage Clinker	91.4%	91.4%	per PCA EPD[2]
Clinker Production Rate	1,371,000	1,371,000	tonnes per year
Total Emissions Rate[1]	**848**	**1,026**	kg CO_{2e} per tonne clinker
Annual CO_2 Emissions from Kiln	1,162,608	1,406,646	tonnes per year
CO_2 Emissions from Kiln	**297,370**	**359,790**	lb/hr at 100% operating basis
Applicable Cases	CM99-B; CM95-B CM95-B1; CM95-B2 CM95-B5; CM95-B6 CM95-B7; CM95-B8	CM95-B3 CM95-B4	

Note: PH = pre-heater; PC = pre-calciner PCA = Portland Cement Association; EPD = Environmental Product Declaration

1- GCCA, "Getting the Numbers Right Project," 2019
2- PCA, "Environmental Product Declaration: Portland Cement," March 12, 2021

Analysis of Carbon Capture Retrofits for Cement Plants

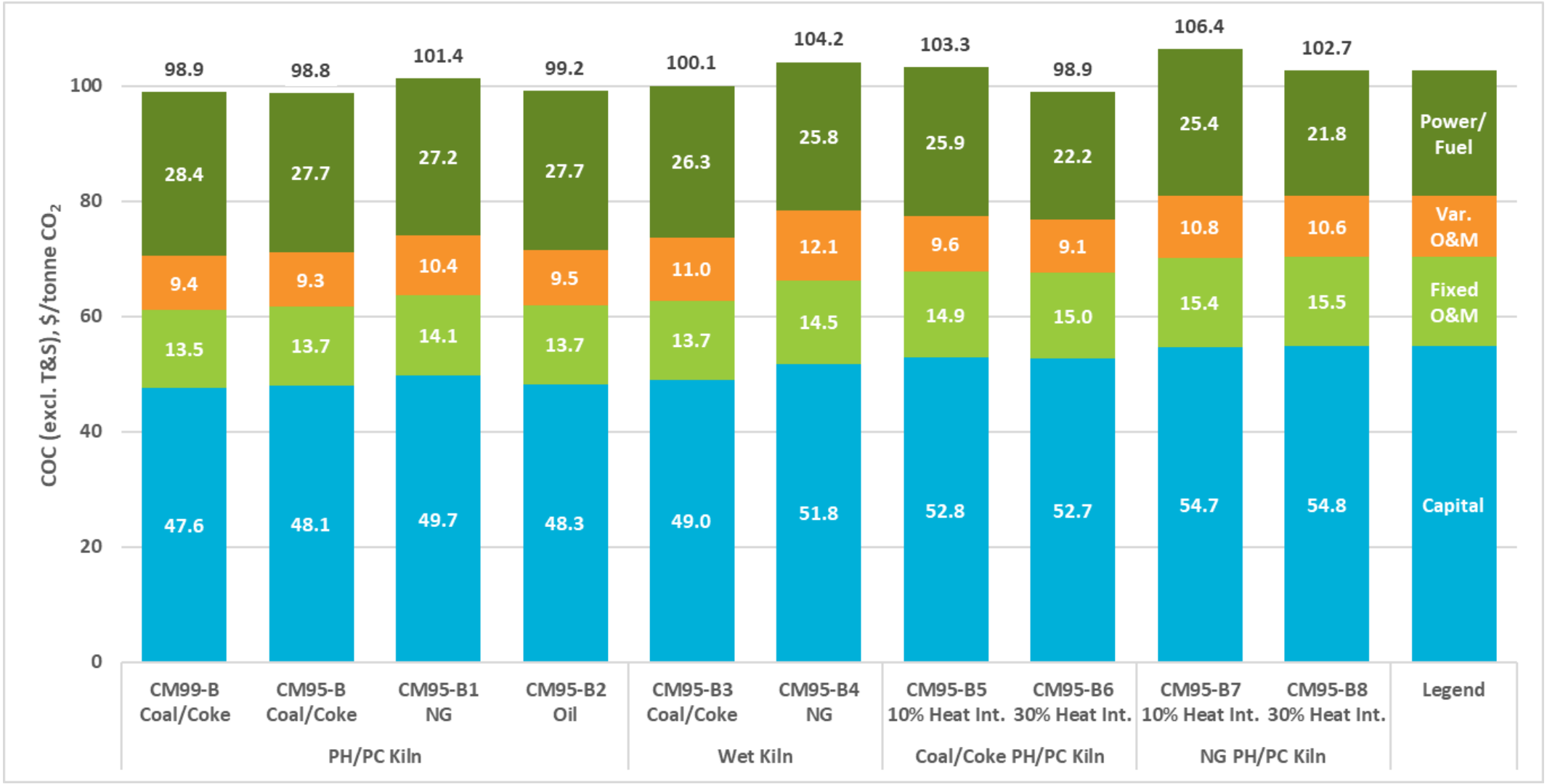
Study Base Cases

Case Number	CM99-B	CM95-B	CM95-B1	CM95-B2	CM95-B3	CM95-B4	CM95-B5	CM95-B6	CM95-B7	CM95-B8
Capture Rate	99%	95%								
Kiln Type	Pre-heater/Pre-calciner				Wet Process		Pre-heater/Pre-calciner			
Kiln Exit Gas CO_2 Concentration, mol %	31	31	25	30	17	13	31		25	
Kiln Fuel Type	Coal/Coke		NG	Oil	Coal/Coke	NG	Coal/Coke		NG	
Heat Integration (HI)	N/A						10	30	10	30
Combined Stream CO_2 Concentration, mol %	21	21	19	21	15	12	22	23	19	20

- The capture rate represents the % of CO_2 captured from the treated combined emissions stream
- The kiln off-gas CO_2 mol % is the assumed concentration directly from the kiln before processing through raw mill operations, prior to any additional air in-leakage, and not including comingled CO_2 from the NG boiler
- The combined stream CO_2 mol % is the assumed concentration of the comingled streams from the NG boiler and from the cement kiln before processing through raw mill operations and prior to any additional air in-leakage

Analysis of Carbon Capture Retrofits for Cement Plants

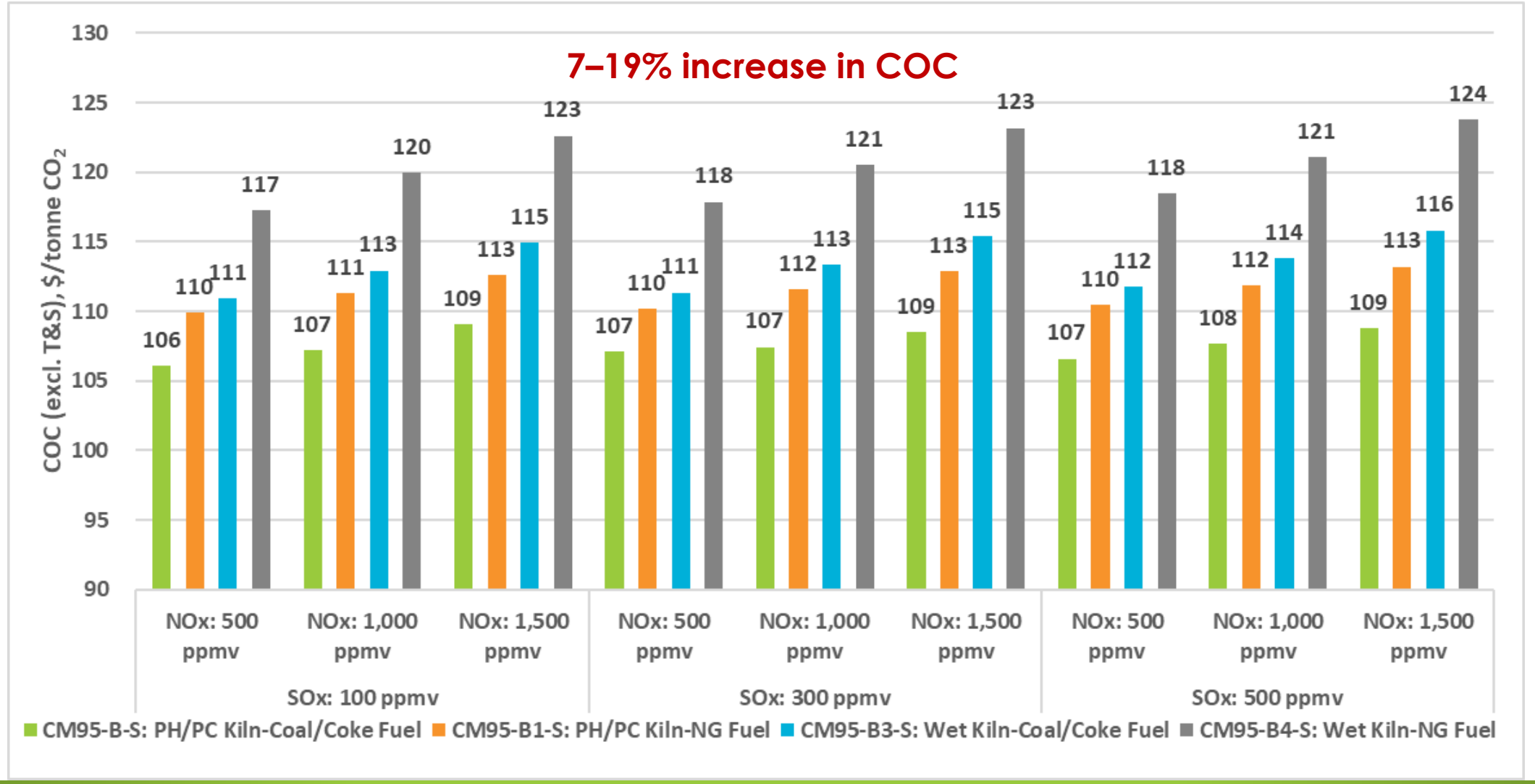
Study Base Cases



Note: All monetary values real, Nov. 2022 $

Analysis of Carbon Capture Retrofits for Cement Plants

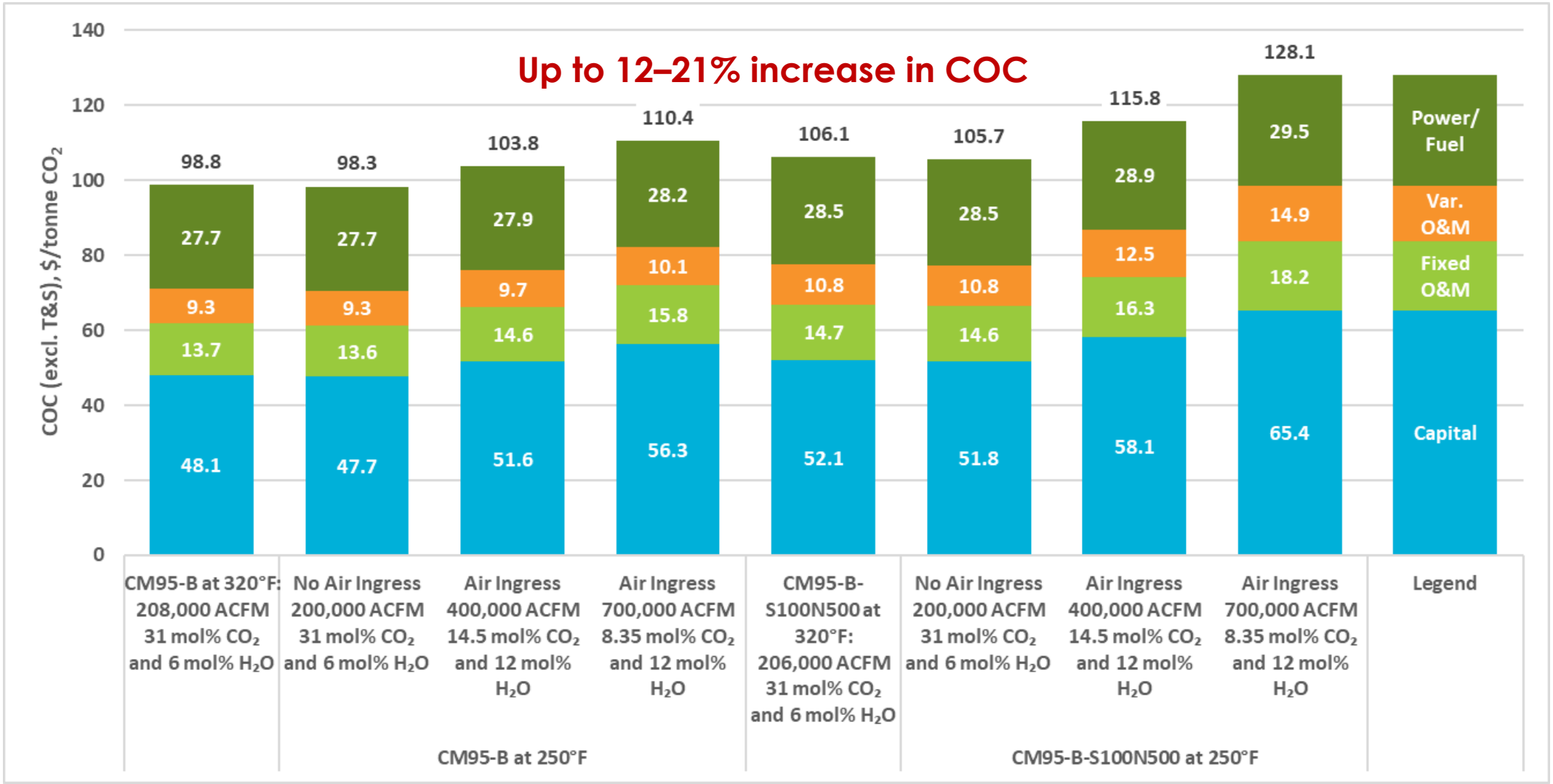
Removal of SO_x (dry FGD) and NO_x (SCR) & resulting PM (baghouse)



Note: All monetary values real, Nov. 2022 $

Analysis of Carbon Capture Retrofits for Cement Plants

Impact of Air Ingress



Note: All monetary values real, Nov. 2022 $

Analysis of Carbon Capture Retrofits for Cement Plants

Conclusions

- Increasing levels of SO_x, NO_x, and PM in the kiln emissions stream incur cost premiums associated with capital and O&M costs required to abate those contaminants and avoid detriment to the solvent system
  - A 7.4–18.8% increase in COC over the respective base case (i.e., analogous cases without additional SO_x/NO_x/PM abatement)
    - The capital cost increase associated with the addition of FGD and SCR was 8.4–13.7% relative to their respective base cases, suggesting that additional capital costs provide the most impact to the COC for cases with more advanced SO_x and NO_x control
- False air and moisture ingress into the kiln emissions stream can result in a notable increase to the COC due to the higher capital costs required to accommodate larger gas volumes at the capture system inlet
  - Capture costs can increase by as much as 11.7% for cases without FGD and SCR and 20.7% for cases with SCR and FGD
  - PCA contributors indicate that false air ingress and the presence of SO_x and NO_x in the emissions stream is the most likely scenario for plants in the current domestic fleet

The Impact of Cement Plant Air Ingress on Membrane-Based CO_2 Capture Retrofit Cost

***Sydney Hughes*[2], *Patricia Cvetic*[2], *Richard Newby*[2], *Sally Homsy*[2], *Alex Zoelle*[3], *Mark Woods*[2], *Eric Grol*[1], *Tim Fout*[1]**

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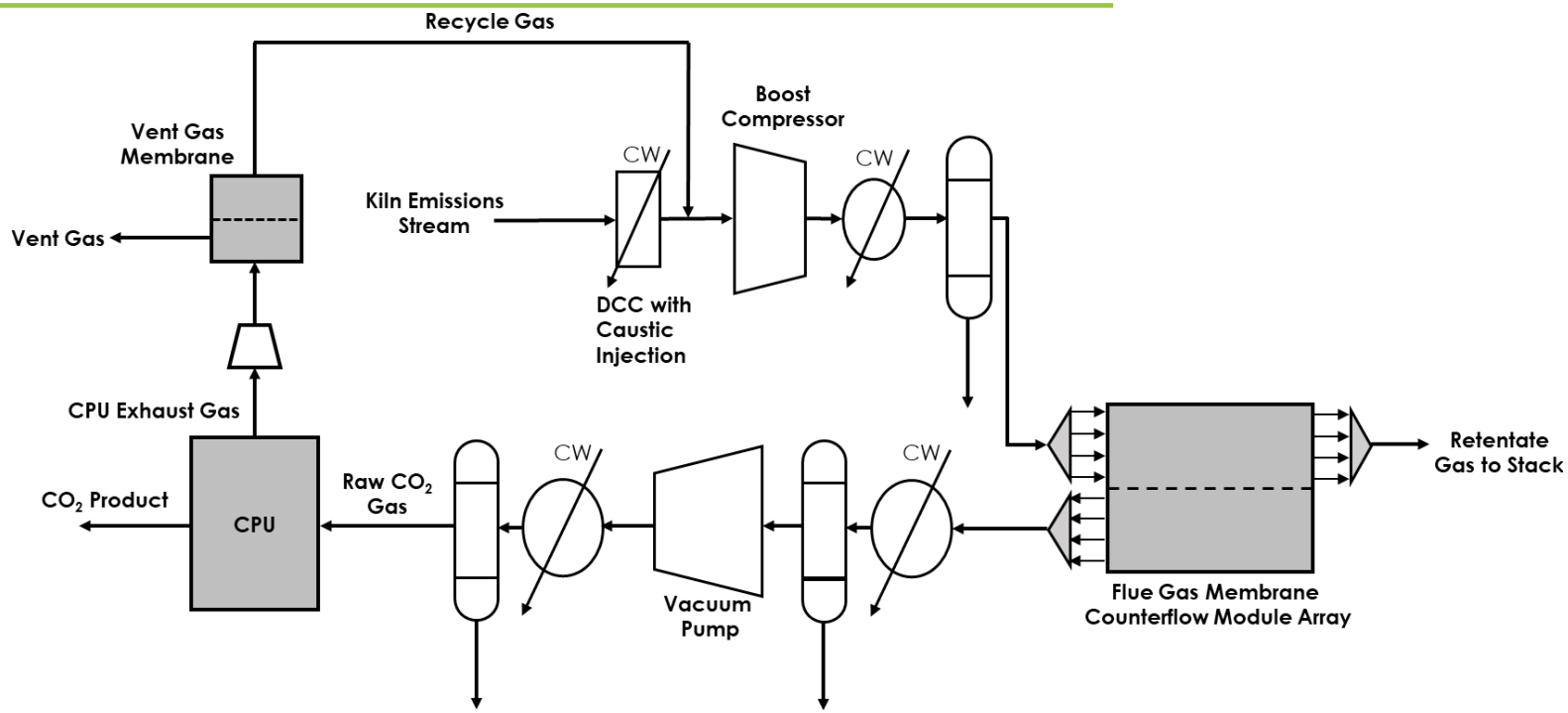
The Impact of Cement Plant Air Ingress on Membrane-Based CO_2 Capture Retrofit Cost

Design Assumptions

- Correlations for ideal countercurrent membrane separation and a CPU model[1] are used within an Aspen Plus® simulation of balance of plant equipment (e.g., boost compression, inlet conditioning, recycle) to estimate the performance of a simplified two-stage membrane system with CPU and permeate recycle



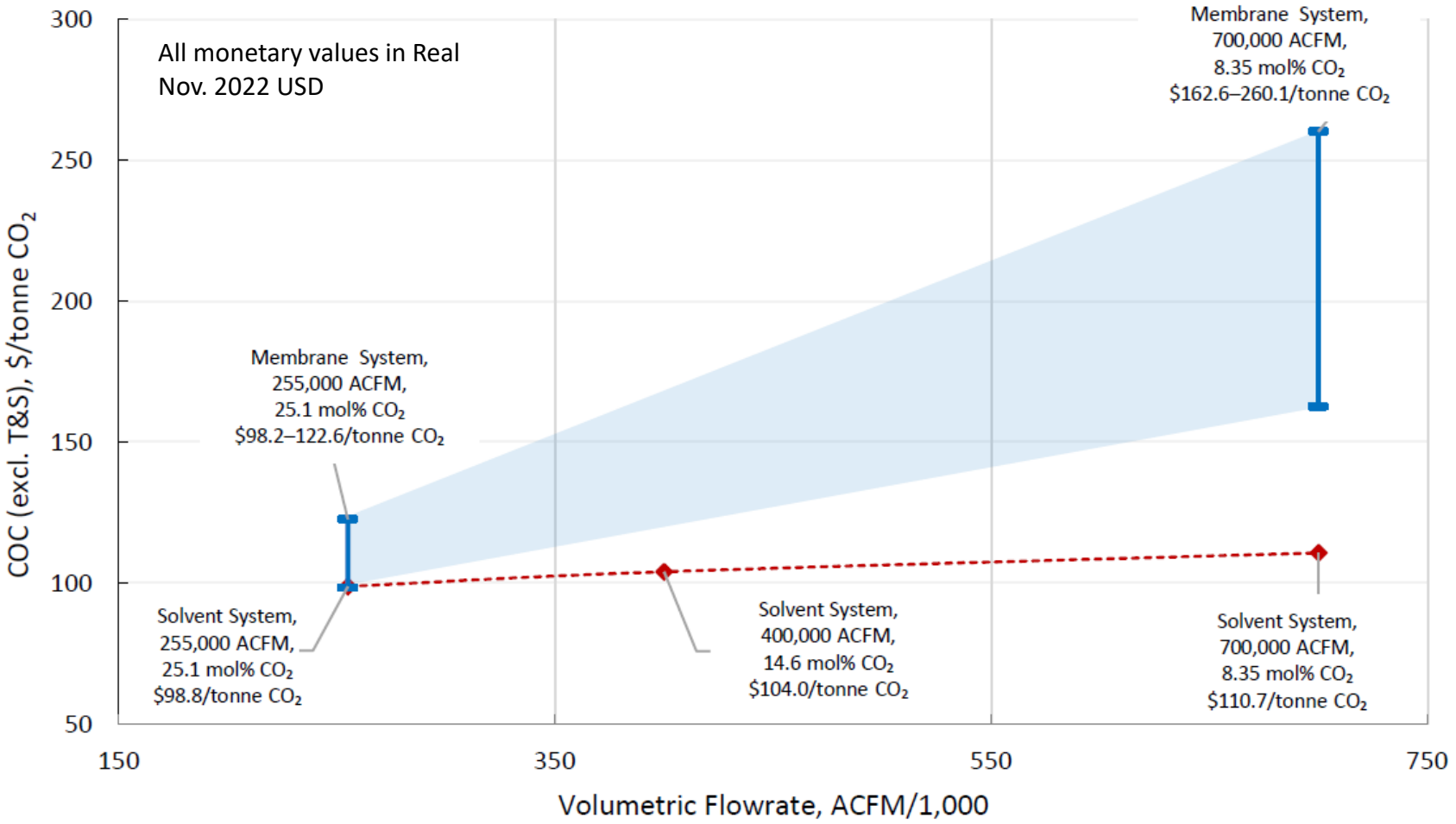
Note: CW = cooling water; DCC = direct contact cooler; CPU = compression and purification unit

The configuration chosen for this analysis is not optimized and is not particularly sensitive to changes in membrane performance. Other configurations, particularly configurations that do not consider such high flue gas compression (5 atm), would likely be more sensitive to membrane performance metrics

1. NETL, "Development of Carbon Dioxide Purification Unit and Compression System Spreadsheet Tool," U.S. DOE, Pittsburgh, 2015

The Impact of Cement Plant Air Ingress on Membrane-Based CO_2 Capture Retrofit Cost

Results



- Without false air ingress, capture costs for the unoptimized membrane-based capture system, under the design assumptions evaluated in this analysis, are comparable to a solvent-based system
- For the examined configuration, false air ingress results in a membrane system COC that is 47–135% higher than that of a solvent-based system

The Impact of Cement Plant Air Ingress on Membrane-Based CO_2 Capture Retrofit Cost

Conclusions

- Alternate configurations or operating scenarios for the membrane-based capture system are likely to be considered and have more favorable economics if the design accounts for false air ingress into the emissions stream, which is inherent to the cement production process
- Recommend examining approaches for and the cost of reducing false air ingress, and designing for lower CO_2 concentrations (considering multistage systems etc.)

Ongoing Studies

Ongoing Studies

- NETL has completed a model of a cement plant allowing in-depth analysis of analysis of applying capture to newbuild and retrofit cement plants
- LCAs are being completing examining the impact of adding capture to cement plants and as a compliment to NETLs Industrial Capture TEA report
- NETL's Cost of Capturing CO_2 from Industrial Sources report and Industrial Carbon Capture Retrofit Database (CCRD) are being expanded to include capture from a petroleum refinery and from a glass plant
- A journal article reporting learnings from recent industrial pre-FEED reports is being compiled

Disclaimer

Questions/ Comments

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