Techno-economic Analysis and Optimization of Point Source Solvent-Based Carbon Capture Systems at High CO_2 Capture Levels for NGCC Power Plants

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Project Objective

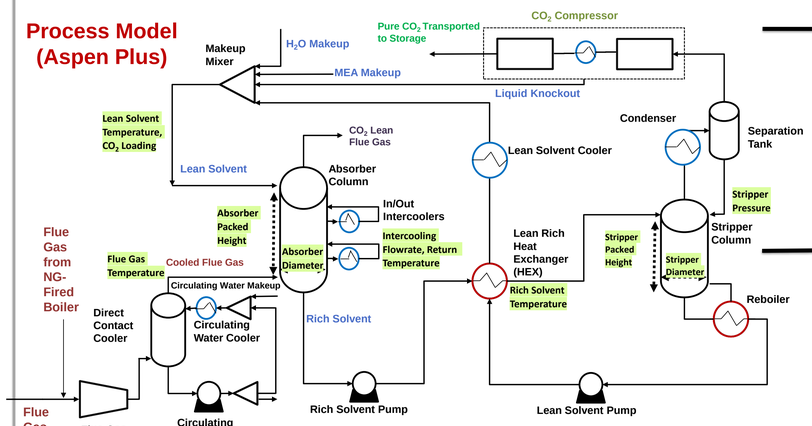
Determine the economically optimal process design and operating conditions of a monoethanolamine (MEA) solvent-based carbon dioxide (CO_2) capture system

- Set the point source of CO_2 emissions for a commercial-scale natural gas combined cycle (NGCC) power plant (690 MW) with flue gas containing ~4 vol% CO_2
- Perform techno-economic analysis at high CO_2 capture levels
- Study the effect of steam sources (NGCC steam cycle and natural gas auxiliary boiler) on the optimum performance and cost of the NGCC-carbon capture and storage (CCS) system
- Quantify process and model uncertainties for high CO_2 capture in solvent-based systems

Techno-economic Optimization Framework

Implemented in FOQUS (Framework for Optimization, Quantification of Uncertainty, and Surrogates) [1]

Process Model (Aspen Plus)



Highlighted items are decision variables for the optimization problem

Economic Model (Institute for Design of Advanced Energy Systems Framework)

Levelized cost of electricity (LCOE)
Cost of Avoided CO_2 (COAC)
NGCC-CCS system [2], [3]

Optimization Formulation

$\min_{\tilde{x}} f(\tilde{x})$ Minimize LCOE

s.t.

$\tilde{x}^L \leq \tilde{x} \leq \tilde{x}^U$ Bounded decision variables

$h(\tilde{x}) = 0$ CO_2 capture, material & energy balances, process economics

$g(\tilde{x}) \leq 0$ Flooding in columns ≤80%

Lean solvent temperature ≤125 °C

$\tilde{x}$	Unit	Range
Absorber diameter	meter	12–20
Absorber height	meter	20–45
Lean CO_2 loading	$\frac{\text{mol } CO_2}{\text{mol MEA}}$	0.1–0.25
Intercooler temperature	°C	25–45
Intercooler flow fraction	$\frac{\text{mass flow IC}}{\text{mass flow lean solvent}}$	1e-5–1
Lean solvent temperature	°C	25–45
Rich solvent temperature (lean/rich HEX exit)	°C	90–115
Stripper height	meter	4–15
Stripper diameter	meter	3–10
Stripper pressure	kPa	170–230
Flue gas temperature	°C	25–45

References

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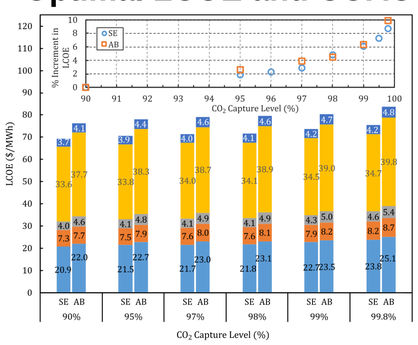
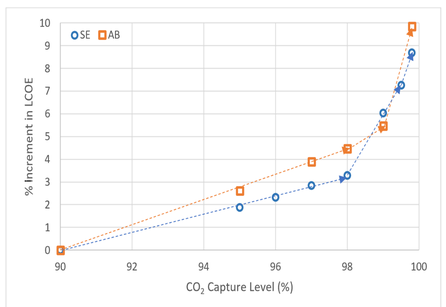
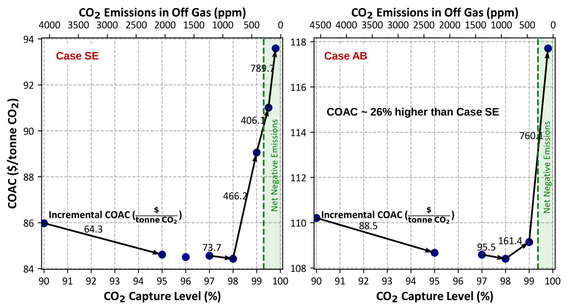
Optimal LCOE and COAC with Incremental Avoided Cost



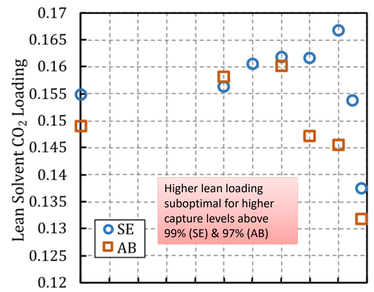


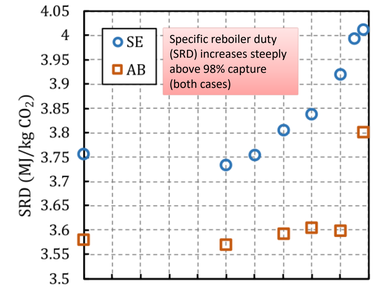
SE: MEA with steam extraction
AB: MEA with auxiliary boiler
O&M: Operation and maintenance

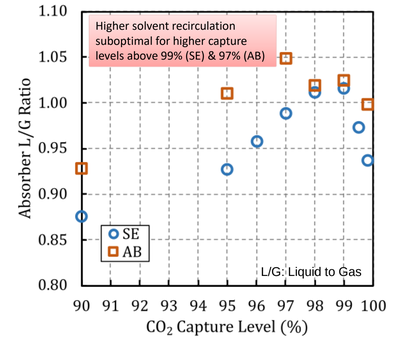


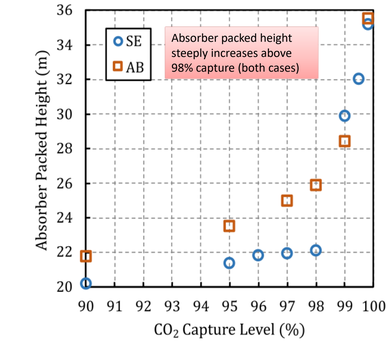
$$COAC[i] = \frac{LCOE[i] - LCOE[nocap]}{\frac{CO_2\ Emissions[nocap]}{Plant\ Net\ Power[nocap]} - \frac{CO_2\ Emissions[i]}{Plant\ Net\ Power[i]}} \quad i \in CO_2\ Capture\ Level$$

Optimum Design and Operation of the CCS Unit









Quantifying Impacts of Uncertainty on High Capture Absorber Height and SRD

Thirteen parameters were considered in the thermodynamic and mass transfer models, selected based on Sobol analysis [4], [5]

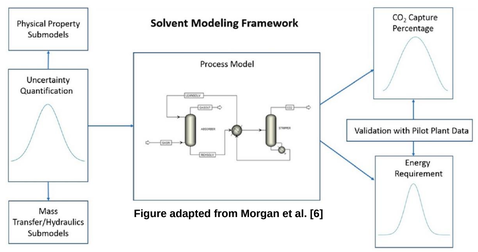
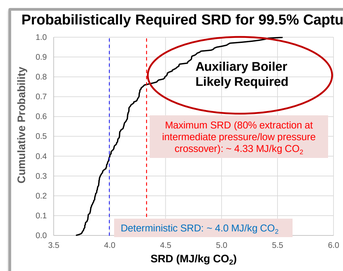
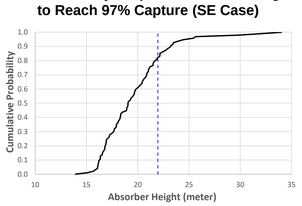
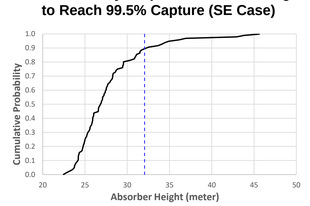
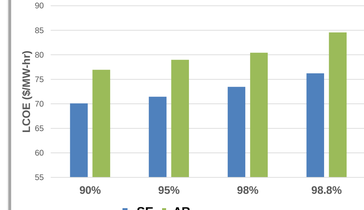


Figure adapted from Morgan et al. [6]









Blue dash = deterministic case

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