Techno-Economic Analysis and Optimization of NGCC Solvent-based Carbon Capture Systems at High Capture Levels

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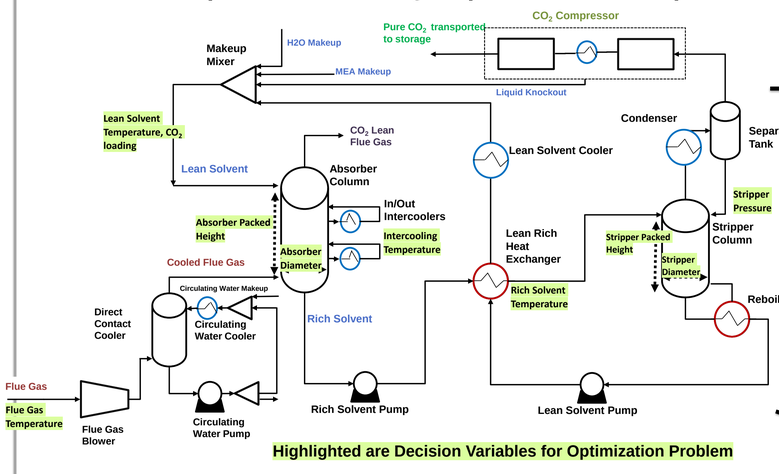
Project Objective

Determine the optimal process design and operating conditions of the solvent-based CO_2 carbon capture system.

- Capture CO_2 from flue gas from low concentration sources (i.e., NGCC power plants)
- Perform Techno Economic Analysis at high CO_2 capture rates
- Compare solvent-based CO_2 capture with alternative net-negative emission technologies.
- Quantify process and model uncertainties for high CO_2 capture in solvent-based systems.

Optimization Problem

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



Highlighted are Decision Variables for Optimization Problem

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: design and operation of capture unit

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

$g(\tilde{x}) \leq 0$ flooding in columns < 80%. IP/LP Steam extraction < 80%

Economic Model (IDAES Framework)

Levelized cost of electricity (LCOE)

NGCC-MEA system. [2] [3]

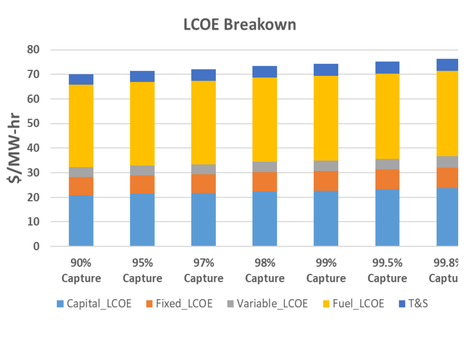
References

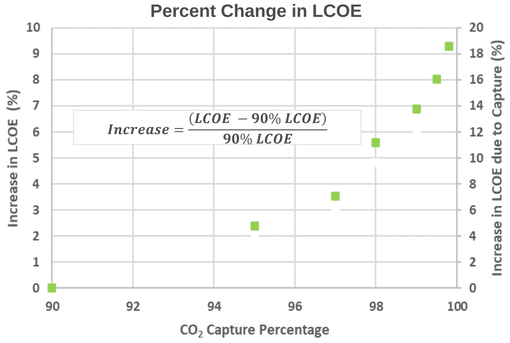
[1] Eslick, John C., Ng, Brenda, Gao, Qianwen, Tong, Charles H., Sahinidis, Nikolaos V., and Miller, David C.. A Framework for Optimization and Quantification of Uncertainty and Sensitivity for Developing Carbon Capture Systems. Netherlands: N. p., 2014. Web. doi:10.1016/j.egypro.2014.11.113.

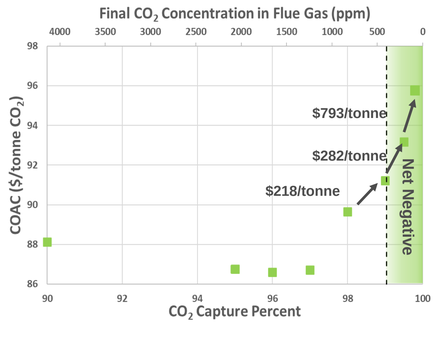
[2]Schmitt, Tommy, Leptinsky, Sarah, Turner, Marc, Zoelle, Alexander, White, Charles W., Hughes, Sydney, Homsy, Sally, Woods, Mark, Hoffman, Hannah, Shultz, Travis, and James III, Robert E.. Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity. United States: N. p., 2022. Web. doi:10.2172/1893822.

[3] Zoelle, Alexander, and Kuehn, Norma. Quality Guidelines for Energy System Studies: Capital Cost Scaling Methodology: Revision 4 Report. United States: N. p., 2019. Web. doi:10.2172/1573493.

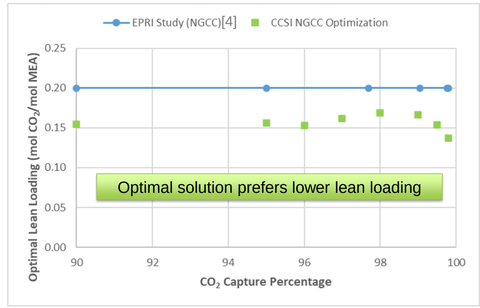
Optimal LCOE and Cost of Avoided CO_2 (COAC) with Incremental Avoided Cost

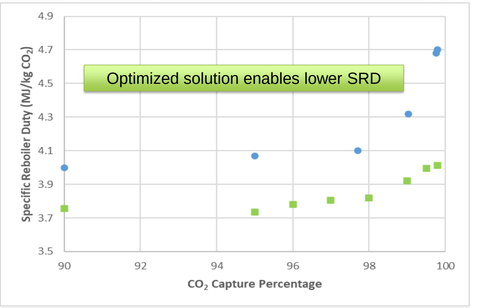


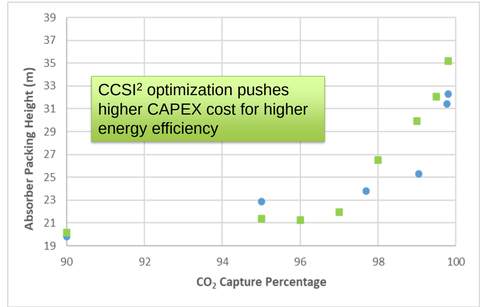


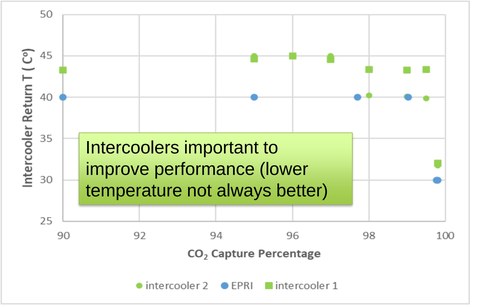


Optimal Designs (Compared to Sensitivity Analysis from Literature [4])









[4] EPRI Study: Du, Yang, et al. "Zero-and negative-emissions fossil-fired power plants using CO2 capture by conventional aqueous amines." *International Journal of Greenhouse Gas Control* 111 (2021): 103473.

Quantifying Impacts of Uncertainty on High Capture Designs

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

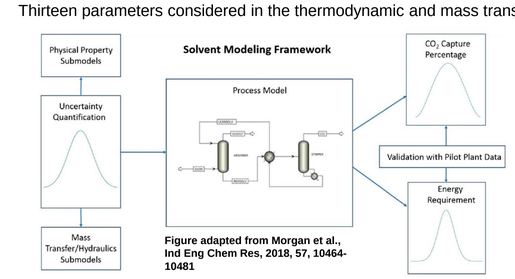
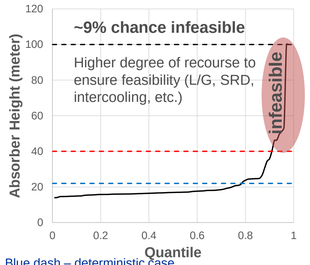
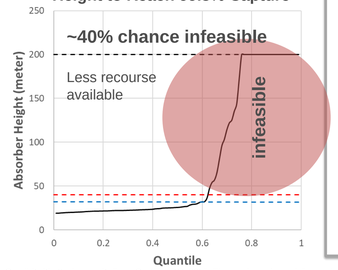
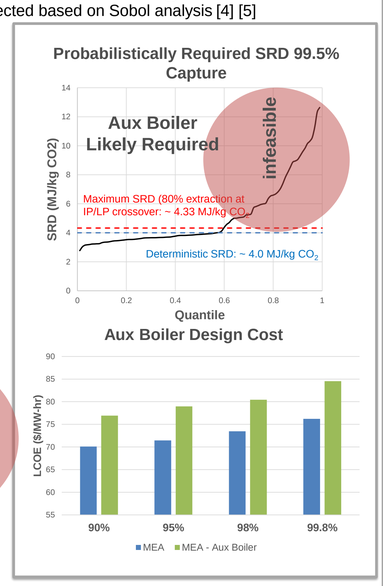


Figure adapted from Morgan et al., Ind Eng Chem Res, 2018, 57, 10464-10481







Blue dash – deterministic case
Red dash – technical feasible
Black dash – computational limit

[5] Morgan JC, Chinen AS, Omell B, Bhattacharyya D, Tong C, Miller DC, 2017. Thermodynamic modeling and uncertainty quantification of CO_2-loaded aqueous MEA solutions. Chem. Eng. Sci. 168: 309-324.

[6] Chinen AS, Morgan JC, Omell B, Bhattacharyya D, Tong C, Miller DC, 2018. Development of a rigorous modeling framework for solvent-based CO_2 capture. Part 1: hydraulic and mass transfer models and their uncertainty quantification. Ind. Eng. Chem. Res. 57: 10448-10463.

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