

Future Energy Systems Center

Cost-Performance Analysis and Benchmarking of CO₂ Capture Systems for Hard-to-Abate Industries

Project Updates
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Project Team

Principal Investigators



Alan Hatton

Ralph Landau Professor of Chemical
Engineering Practice
MIT Department of Chemical Engineering



Betar Gallant

Class of '22 Career Development Professor,
MIT Department of Mechanical Engineering



Guiyan Zang

Research Scientist
MIT Energy Initiative

Postdocs and Graduate Students



Bosong Lin

Postdoc
MIT Energy Initiative



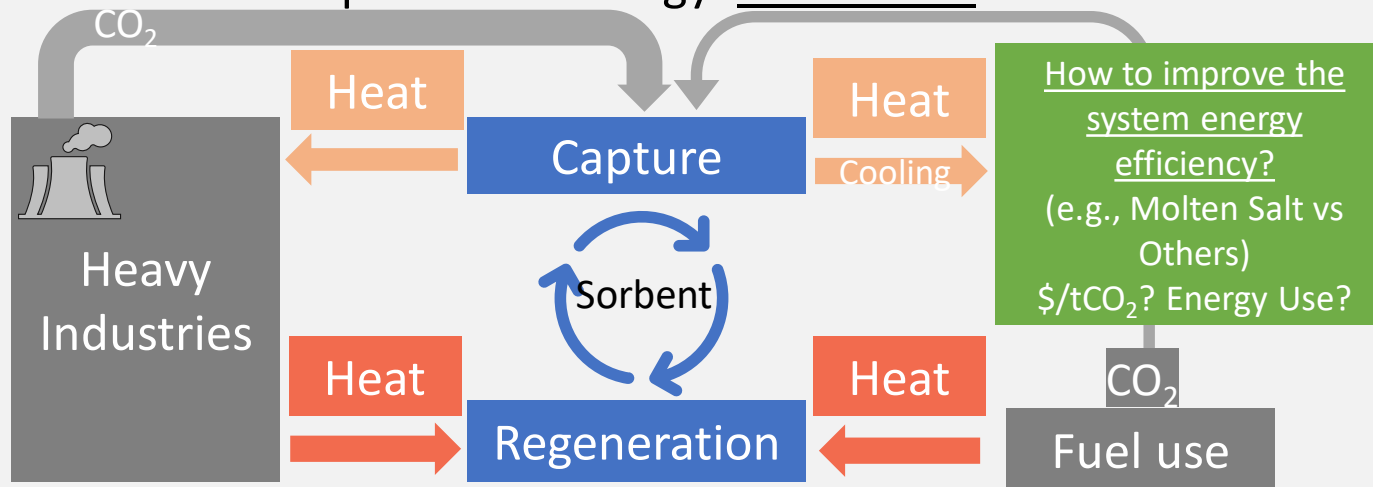
Haoxiang (Hundey) Lai

Postdoc
MIT Energy Initiative

Project motivation and objectives

Motivation

- ~25% of CO₂ emissions are from hard-to-abate industries: cement, iron/steel, ethylene, hydrogen, and others, with variable emissions characteristics: concentration (CO₂ %), temperature (~300 - ~1500 °C), flow rate, etc.
- The most industrially mature processes based on temperature-swing separation with amines are optimized for ~40-120 °C. Cost and system efficiency are major challenges.
- Molten salts capture technology: 600-650 °C

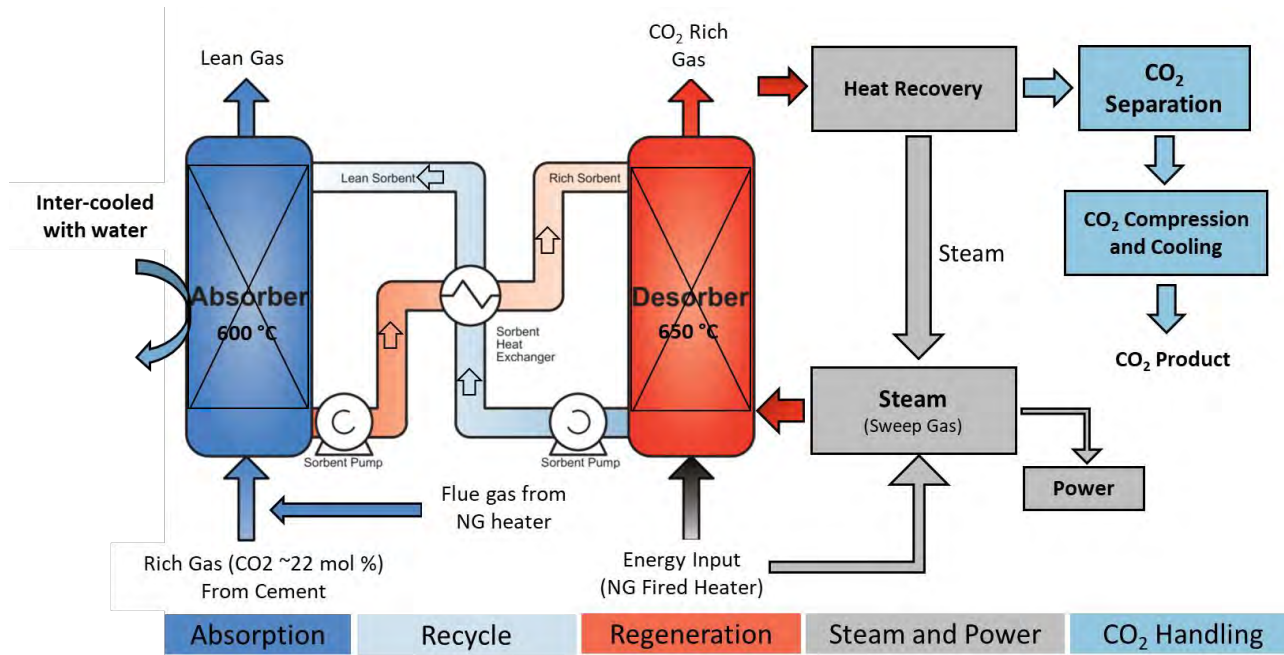


Objectives

1. What are the emissions, efficiency, and cost impacts of temperature-matched capture?
2. Develop a universal framework to cross-compare across different emissions types and capture technologies.
3. Use model outputs to assess greatest potential for impact (efficiency/emissions savings x scale of industry) that can guide future technology development.

Research and analysis performed

- Case study: Cement plants decarbonization using Molten Salt carbon capture

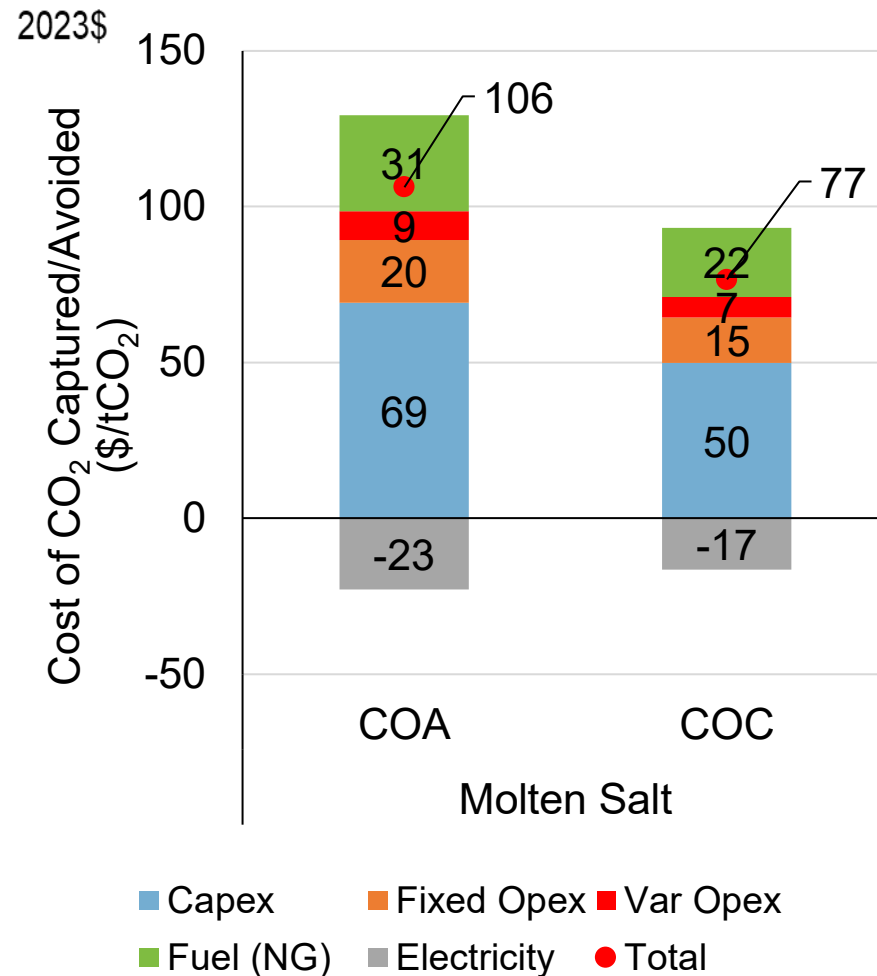


- “Temperature-Swing” carbon capture
- Desorption needs high-quality heat by NG fired heater
- Steam is used as a sweep gas for desorption
- High-quality heat can be recovered to generate steam and power (byproduct)

Process Evaluation		Note
CO ₂ Emissions, M tonnes/yr	1.68	72% from Cement, 28% NG fired heater
CO ₂ Capture Rate, %	95	/
NG HHV Thermal Input, MW _t	260	1.42 kWh _t /kgCO ₂
Total Gross Power, MW _e	45	0.25 kWh _e /kgCO ₂
Net Power, MW _e	28	0.15 kWh _e /kgCO ₂
Total Auxiliary Power, MW _e	17	0.09 kWh _e /kgCO ₂
Pumps, MW _e	4.6	0.025 kWh _e /kgCO ₂
Compression, MW _e	12.4	0.065 kWh _e /kgCO ₂

The simulation results were based on molten salt data from Mantle Carbon Co.

Results and take-aways



Key Take-aways

- CAPEX is the major driver, followed by NG fuel cost
- Main drivers to CAPEX: the capture system and HRSG and steam turbine; main drivers to OPEX: NG consumption
- For the base case, COA: \$106/tCO₂ for emissions from a cement plant; COC: \$77/tCO₂ for emissions from a cement plant and additional emissions from NG heater
- Molten salts technology appears to be comparable with the amine technology under similar TEA assumptions
- The variation in CAPEX and financial parameters could lead to a large uncertainty range of about $\pm \$50/\text{tCO}_2$ on COA
- To reduce the costs, there is a need to reduce capital investment and reduce energy consumption to improve overall cost efficiency

Remaining project activities and next steps

Refining TEA Assumptions



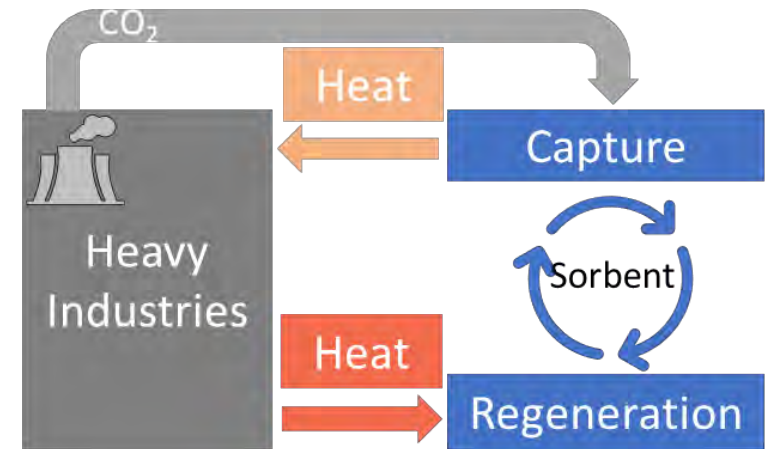
Exploring an optimal design



Assessing different capture systems

- Refining the assumptions for techno-economic analysis, especially for the capture system
- Exploring a design for the high-grade heat integration potential between the heavy industries (e.g., cement plant) and molten salts
- Assessing the potential impact at scale of deploying a range of capture technologies tailored to specific emission sources, covering the breadth and variability of industrial emissions.

“Hot Flue Gas Capture” Configuration

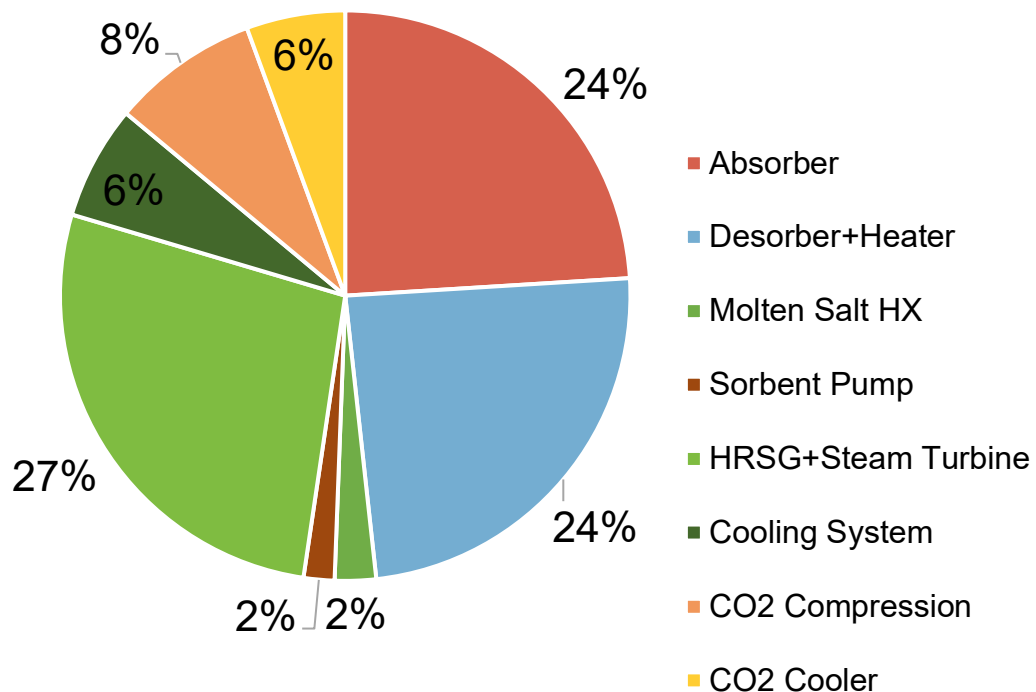


Q&A and Project Discussions

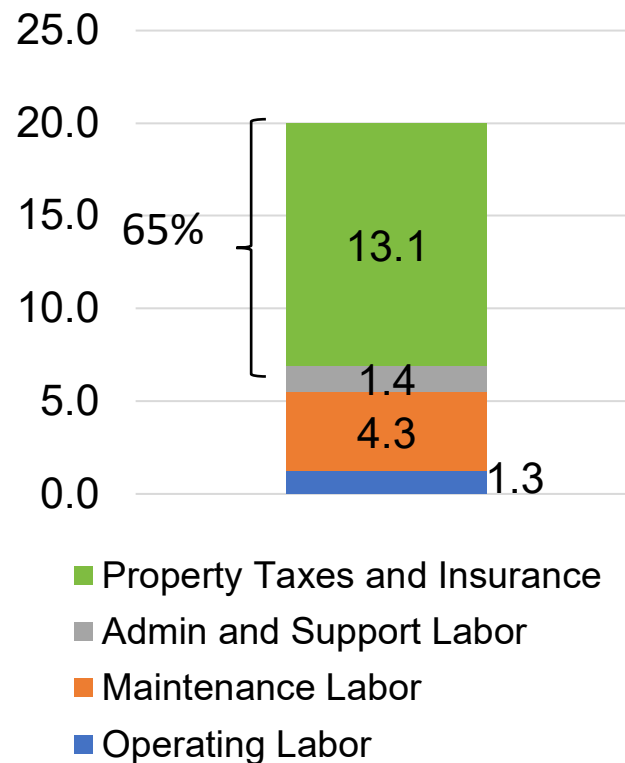
Backup Slides

Back-up slide

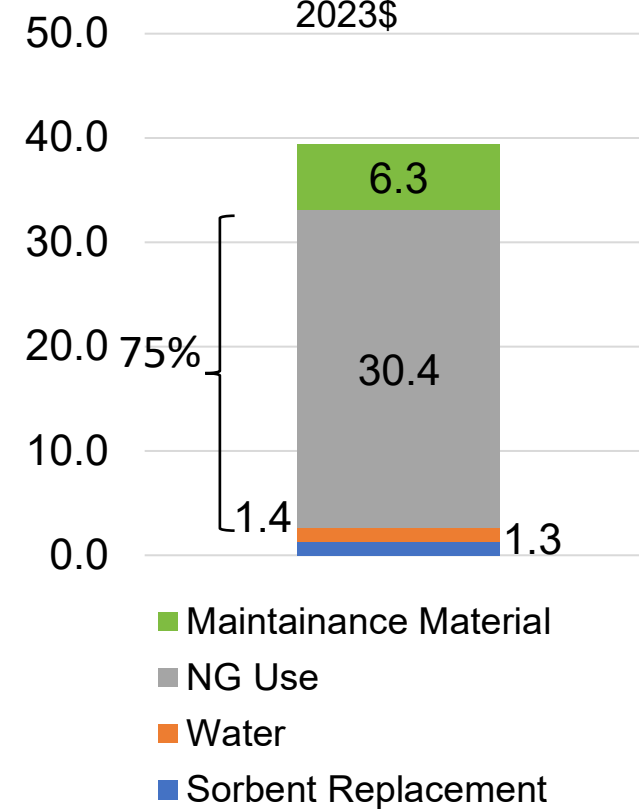
Total Plant Cost (\$654 MM)
2023\$



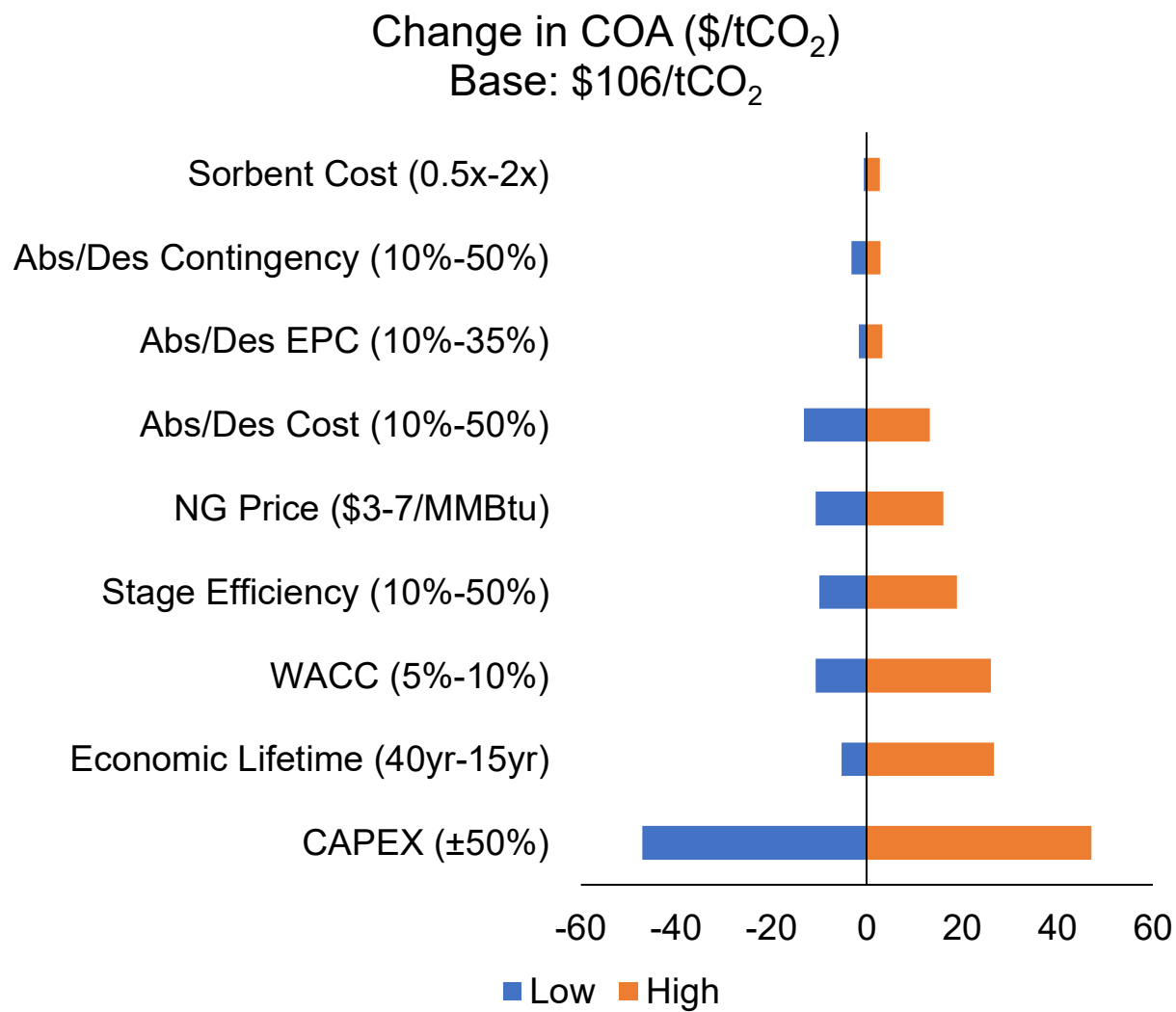
Fixed Operating Costs
(\$20 MM/year)
2023\$



Variable Operating Costs (\$40 MM/year)
2023\$



Back-up slide



COA: Cost of CO₂ Avoidance

Key Takeaways

- Base COA: \$106/tCO₂
- The uncertainty on CAPEX leads to a large change in COA varying from -47 to +47
 - Resulting in COA varying from 59 to 153 (\$/tCO₂)
- Followed by financial parameters like economic lifetime and WACC
- Absorber column stage efficiency uncertainty could cause large variation in COA