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Partnership for CO_2 Capture: Results of the Pilot-Scale Solvent Evaluations

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Pittsburgh, Pennsylvania
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Grand Forks

Partnership for CO_2 Capture (PCO_2C) Summary

Advancing the state of CO_2 capture by evaluating and demonstrating those technologies that are nearest to commercial viability for utility applications.

- Multiple-phase program.
- Phase I of PCO_2C includes $3,785,000 of funding from private sector sponsors (15), the North Dakota Industrial Commission (NDIC), and the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL).
- Construction of oxy-firing and industrial-scale postcombustion platforms, with water capture and reuse through WEST.
- Identification of technology challenges and opportunities for improvement.
- Development of strategies for cost-effective and efficient implementation at the power utility scale.

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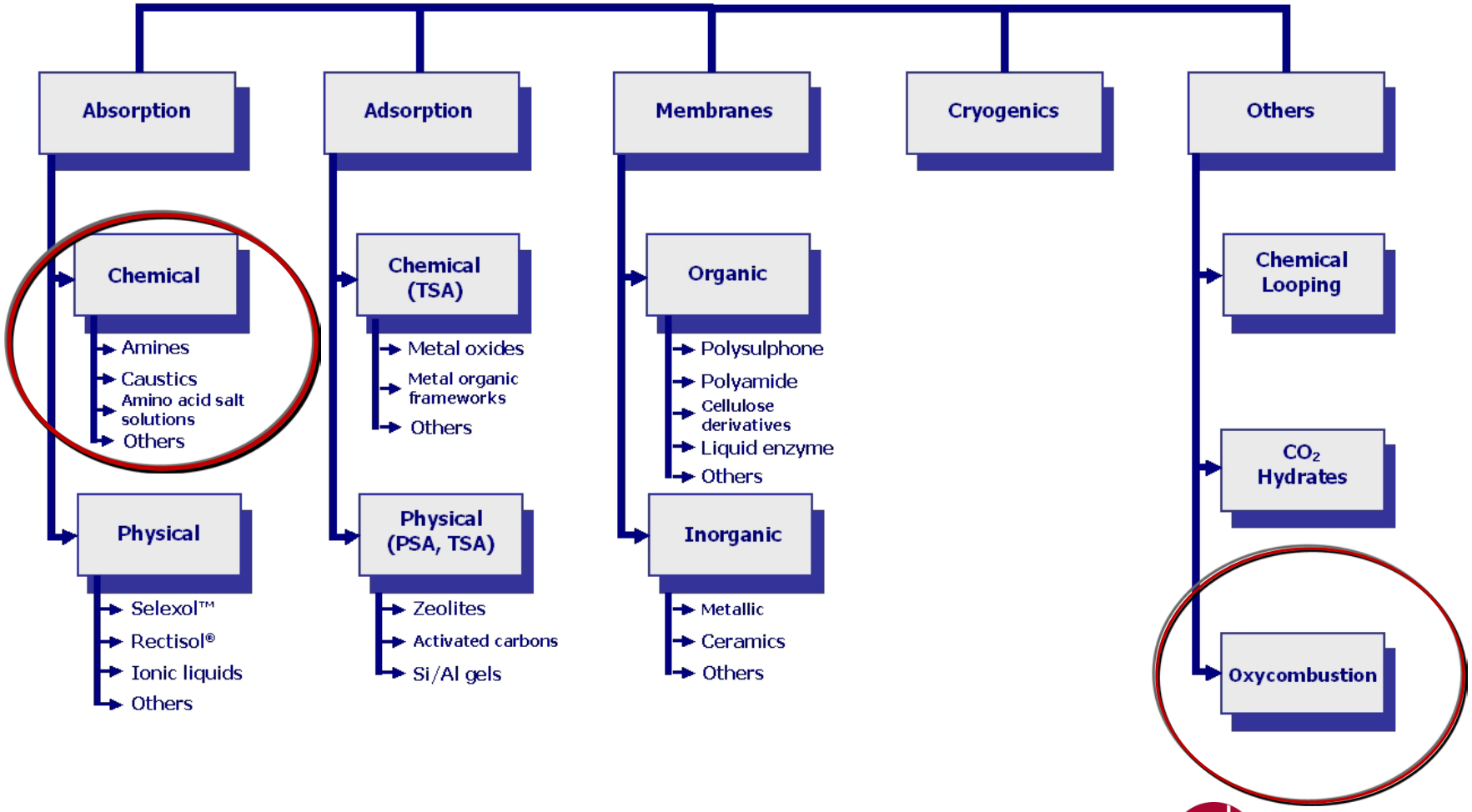
Sponsors

- U.S. Department of Energy
- Black & Veatch
- C-Quest
- Midwest Generation
- Hitachi
- Huntsman
- Minnesota Power
- PPL
- Puget Sound Energy
- Avista
- Portland General Electric
- Pacificorp
- NorthWestern Energy
- SaskPower
- TransAlta
- ATCO Power
- Metso Power
- Constellation Energy
- North Dakota Industrial Commission
- Baker Hughes
- Nebraska Public Power District

Summary of CO_2 Capture Technologies



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PCO_2C Project Overview

- Scope of work includes five main tasks:
  - ***Task 1 – Postcombustion Test System(s) Design, Construction, and Implementation***
  - ***Task 2 – Oxygen-Fired Retrofit***
  - ***Task 3 – Conduct CO_2 Capture Technology Testing***
  - ***Task 4 – Systems Engineering and Design***
  - ***Task 4.5 – WEST***
  - ***Task 5 – Management and Reporting***

Combustion Test Facility (CTF)

- 550,000 Btu
- Up-fired
- Air- or O_2-fired
- Multifuel capability
  - Coal, biomass, gas, liquid fuel, sludge, and municipal solid waste

- Features
  - Air preheater and heat exchangers
  - Adjustable swirl burner
  - Deposition section
  - Numerous ports
  - Selective catalytic reduction (SCR) reactor
  - Baghouse
  - Electrostatic precipitator (ESP)
  - Sulfur scrubber
- Testing of fuels and additives
  - Fouling and slagging
  - Corrosion
  - Hg
  - NO_x
  - SO_x
  - CO_2 capture
  - Particulates
  - Heat flux
  - Infrared (IR) flame characterization

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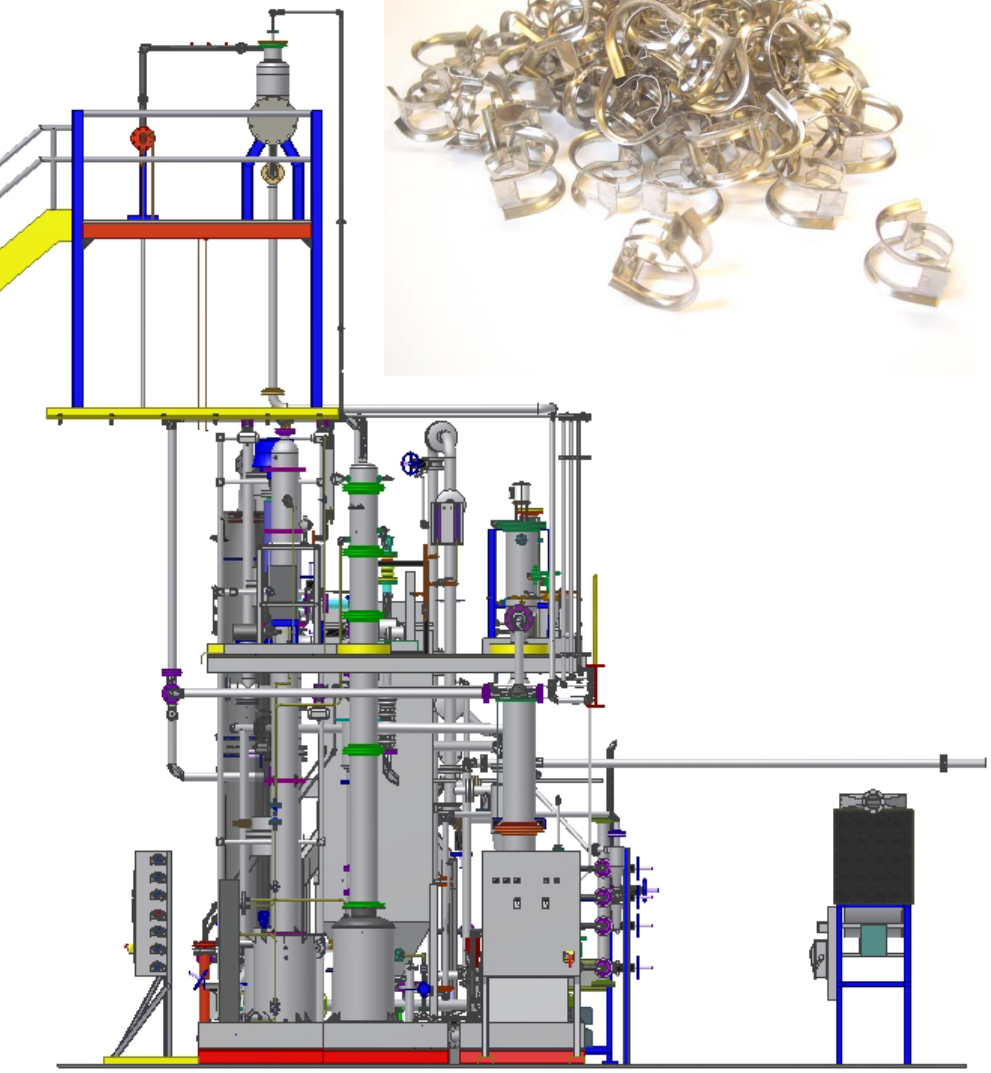
Task 1 – Postcombustion Test System(s) Design, Construction, and Implementation

- Based on sponsor review and an analysis of the current status of CO_2 capture, a solvent-based capture system was chosen as the platform technology to evaluate.
- An absorption and stripping system was designed and fabricated with the aid of design review performed by Huntsman.
- This system was designed to mimic typical solvent systems.
- The design was as flexible as possible to allow for several design modifications to evaluate several solvent types.

CO_2 Capture System



- 10-inch-diameter columns designed to be flexible.
- Capable of evaluating different solvents with column height adjustment.
- Packed column with the ability to easily change packing type.
- Very highly instrumented to allow for high control and greater measurement.

Task 3 – Postcombustion Testing

- Several weeks of postcombustion testing were scheduled to occur. It was initially intended that several solvents would be chosen for evaluation during this task.
- The coal chosen for all postcombustion testing was an Antelope coal from the Powder River Basin (PRB). Because postcombustion technologies are less dependent on fuel type, a mid-rank coal was chosen.
- Back-end control devices included SCR, an ESP, wet flue gas desulfurization (WFGD), and the WEST system.
- Test parameters included 1) heat of regeneration required, 2) solvent flow rates (liquid-to-gas ratio), 3) temperatures, 4) energy consumption (fans, pumps, regeneration), 5) flue gas components (SO_x, NO_x, O_2, CO_2, Hg), 6) final CO_2 purity, 7) flue gas flow rates, 8) CO_2 capture efficiencies, 9) impact of impurities (solvent degradation), 10) corrosion, and 11) stripper pressure.

Postcombustion Testing

- MEA (30 wt%)
- Hitachi H3-1
- Monodiethanolamine (MDEA)–piperazine
- Huntsman solvent additive
- Baker Hughes additives

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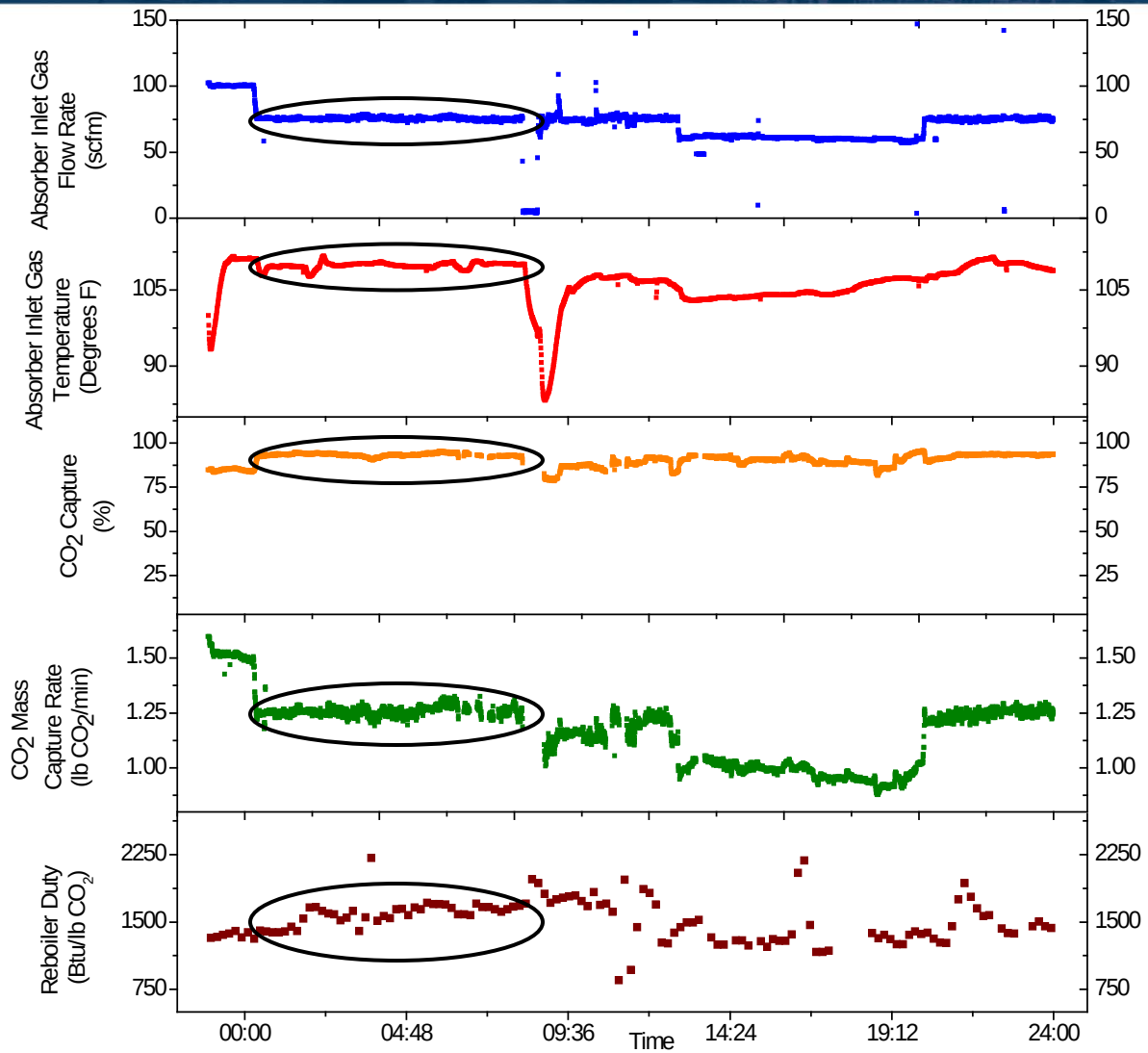
Test Parameters

Table 5.2. SASC Variable Test Parameters

CTF System Variations		Typical Range
	Inlet Gas Flow Rate	60–130 scfm
	Inlet Gas Temperature	90°–120°F
	NO_x to Columns	0 to 600 ppm
	SO_2 to Columns	0 to 600 ppm
SASC System Variations		
	Solvent Flow Rate Through Absorber	3–10 gpm
	Condenser Cooling Water Flow Rate	1–6 gpm
	Lean Solvent to Absorber Temperature	80°–150°F
	Stripper Static Pressure	3–14 psig
	Steam Reboiler Pressure	10–40 psig
	Solvent Concentration	As requested
	Makeup Rate	0–500 mL/min

MEA CO_2 Capture Daily Data



- Test periods averaged for single set of conditions.
- Increase in CO_2 capture rate does not always cause increase in mass of CO_2 captured.

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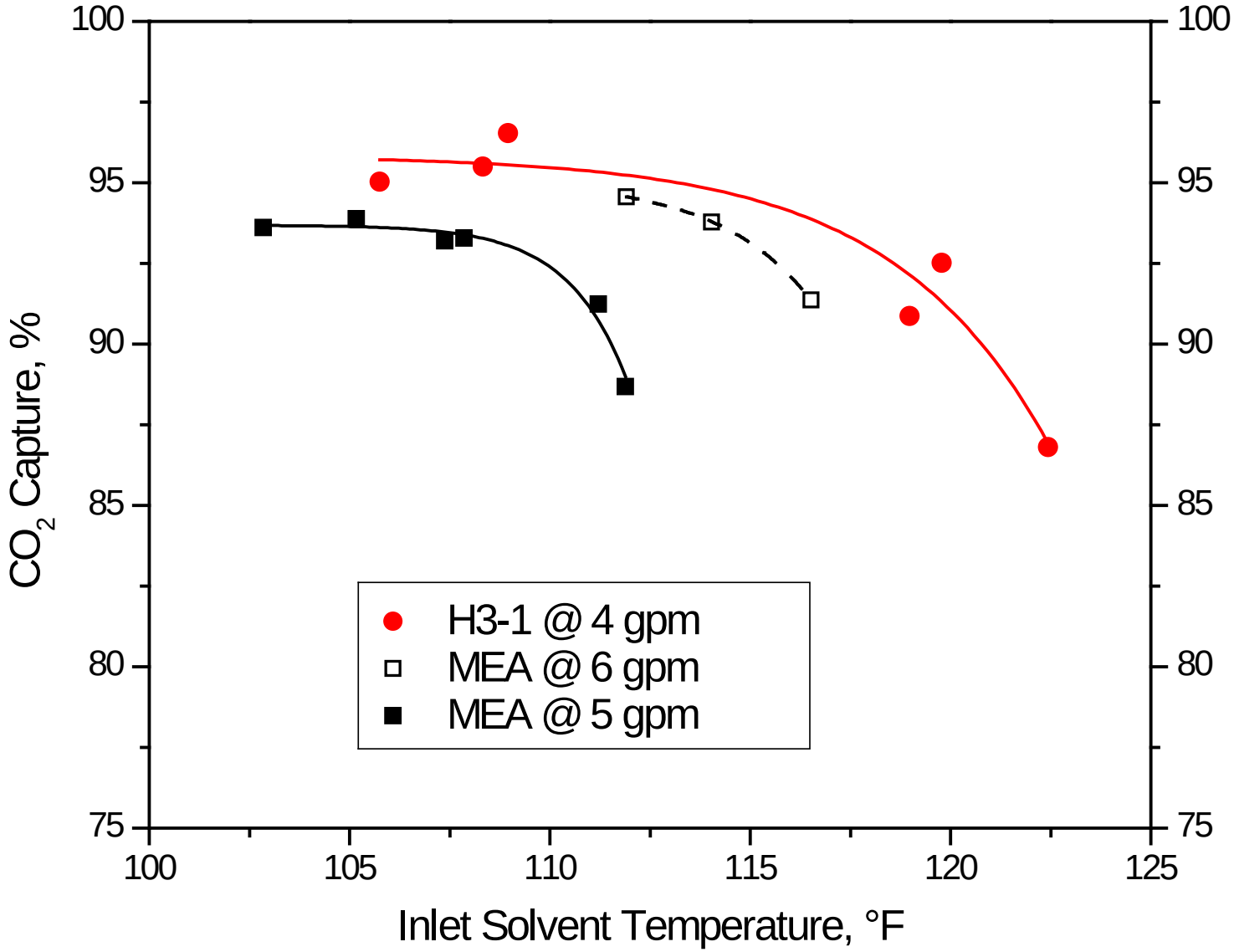
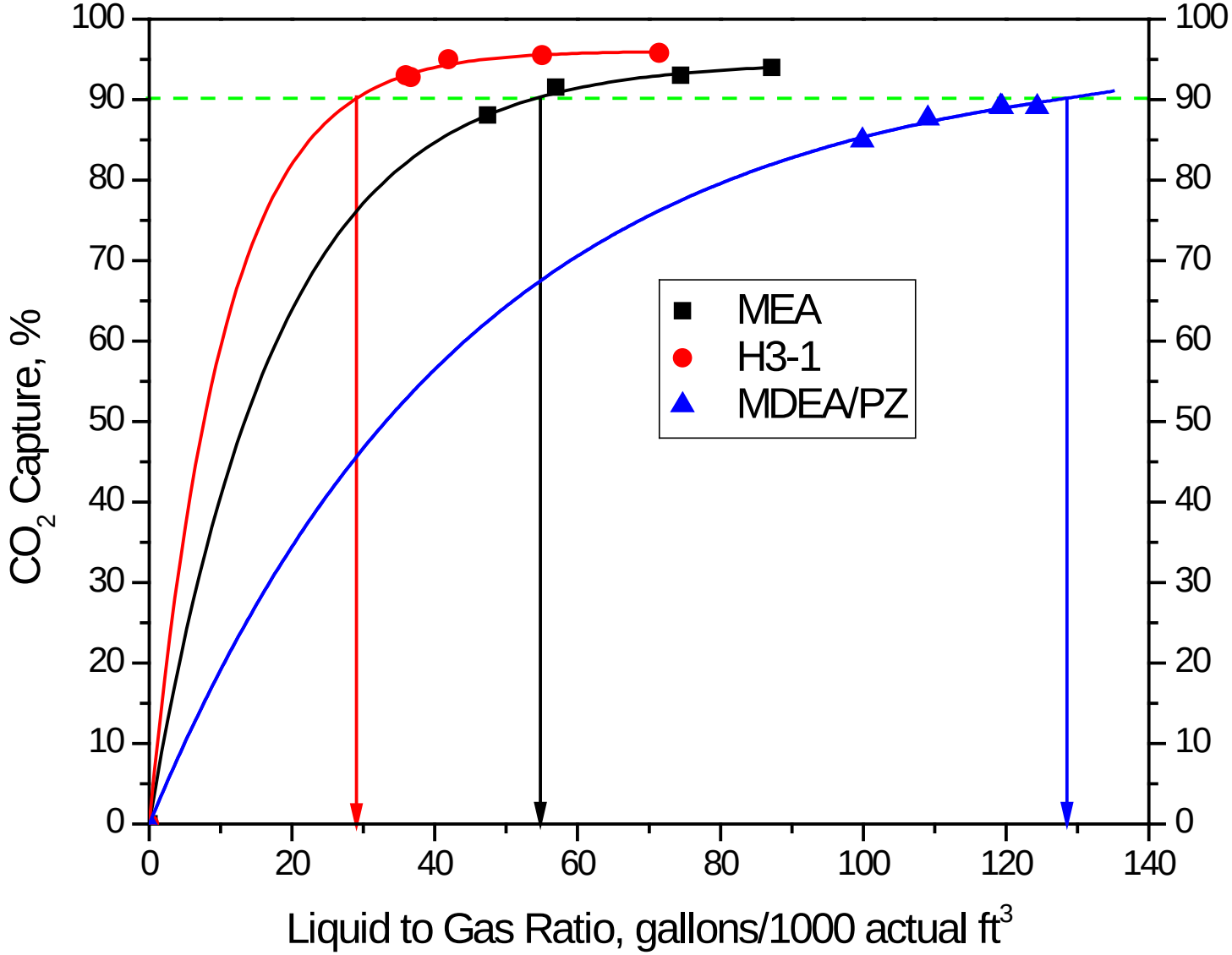
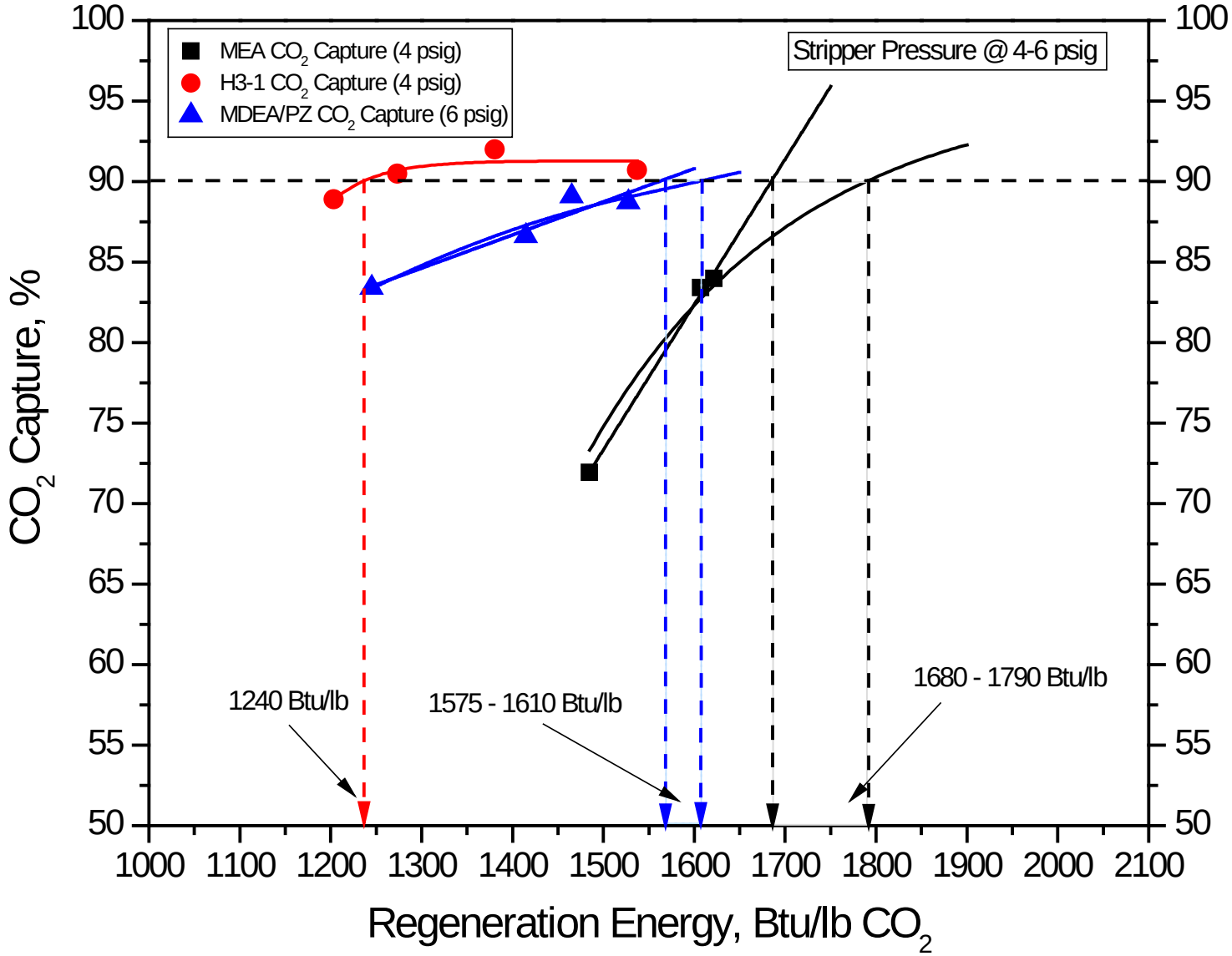
CO_2 Capture vs. Solvent Temperature



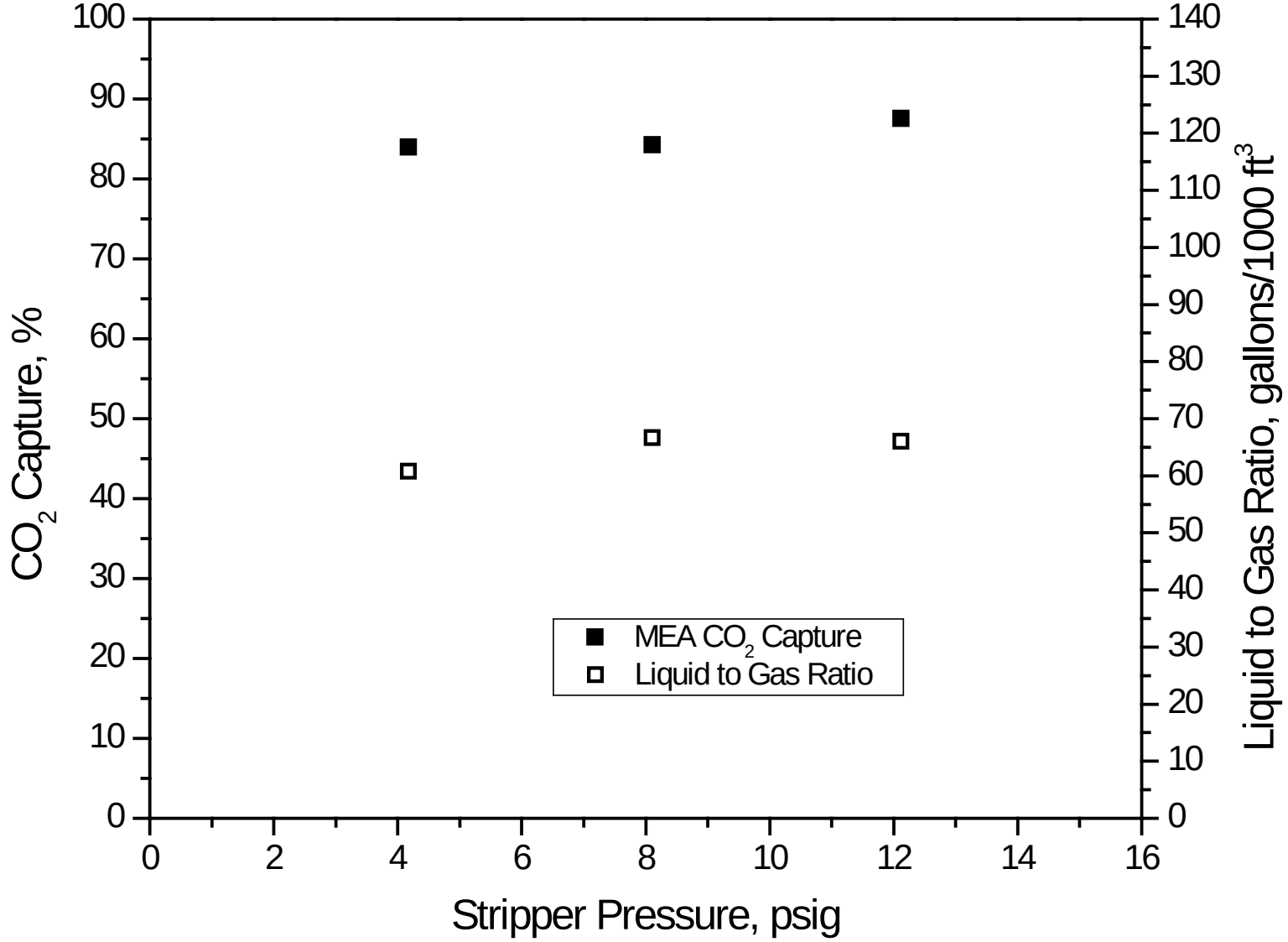
CO_2 Capture vs. Liquid-to-Gas Ratio



CO_2 Capture vs. Regeneration Energy

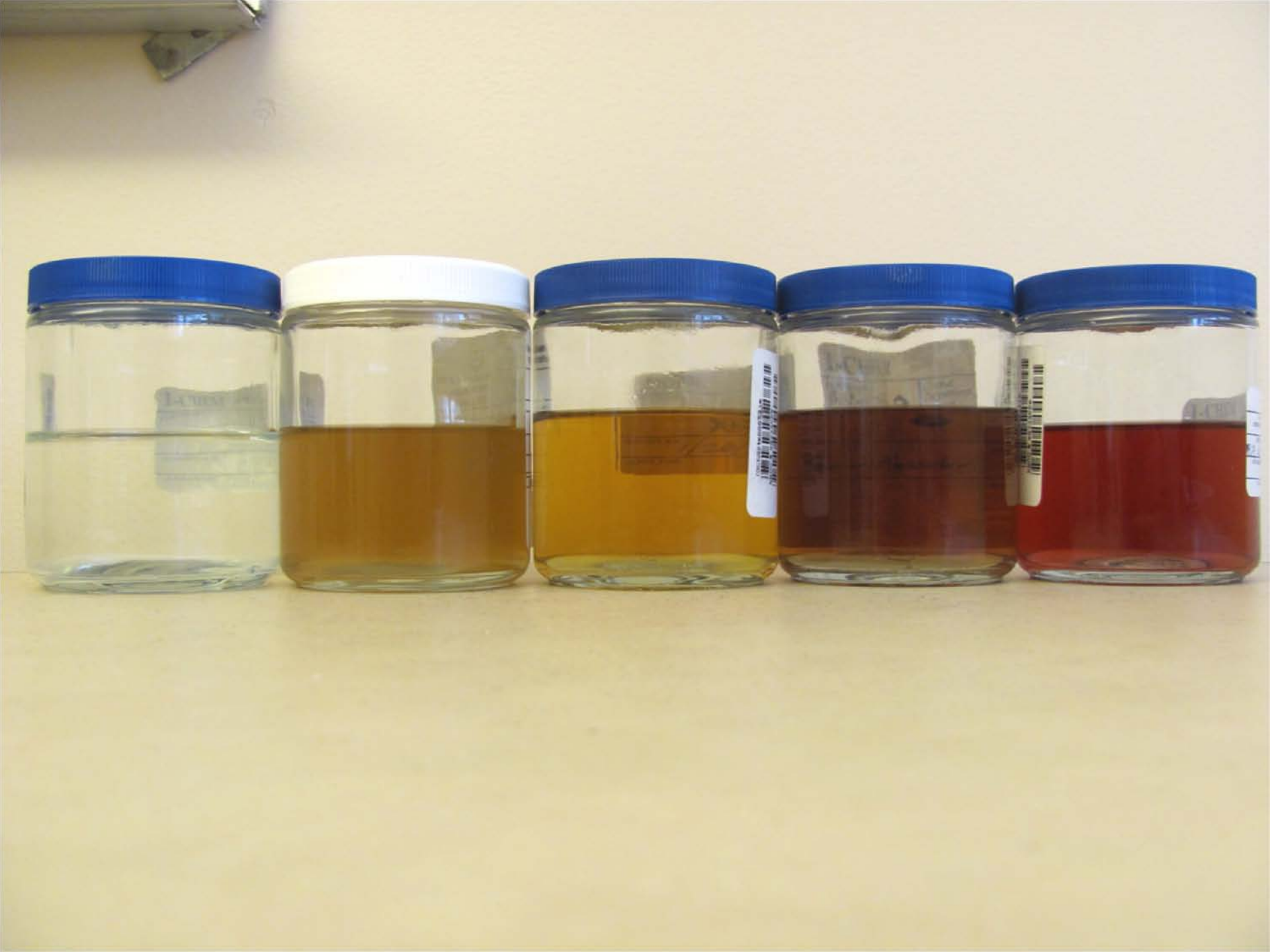


CO_2 Capture vs. Stripper Pressure for MEA



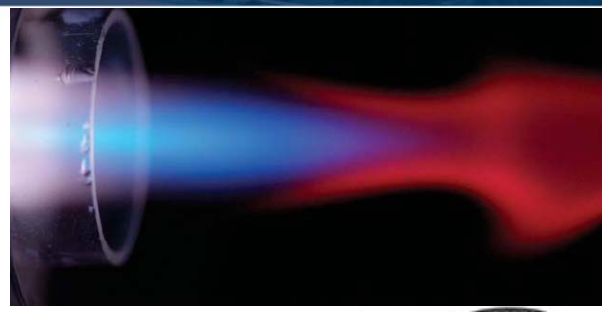
Postcombustion System Testing Results Summary

- Testing complete on 30 wt% MEA and three advanced amine-based solvents.
- Fuel – Antelope PRB coal.
- Achieved at least 90% CO_2 capture with all solvents for extended time periods.
- Reboiler duty ranged from 1250 to 1900 Btu/lb CO_2 at 90% capture level.
- Liquid to gas ranged from 25 to 130 gal/1000 actual ft^3 at 90% capture level.



Analytical Data Collected

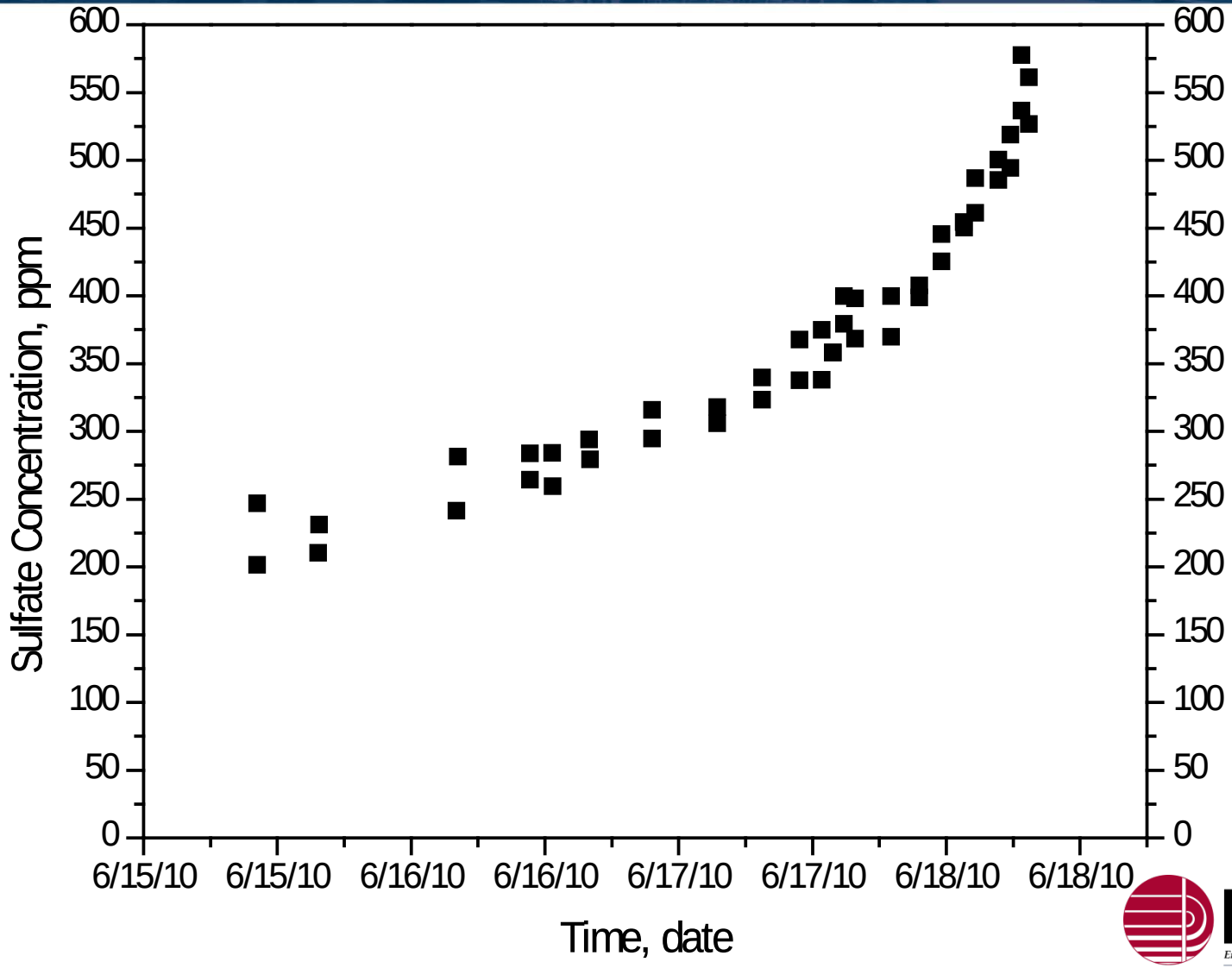
- HSSs
  - Ion chromatography (IC)
    - Inorganic anions
    - Organic anions
- CO_2 loading
  - Free amine
    - Acid titration
  - Bound amine concentration
    - Base titration
- Major and trace metals
  - Inductively coupled plasma–atomic emission spectroscopy (ICP–AES)



HSS Organic and Inorganic Anions

University of North Dakota
Grand Forks

Sulfate Concentration MDEA–Piperazine



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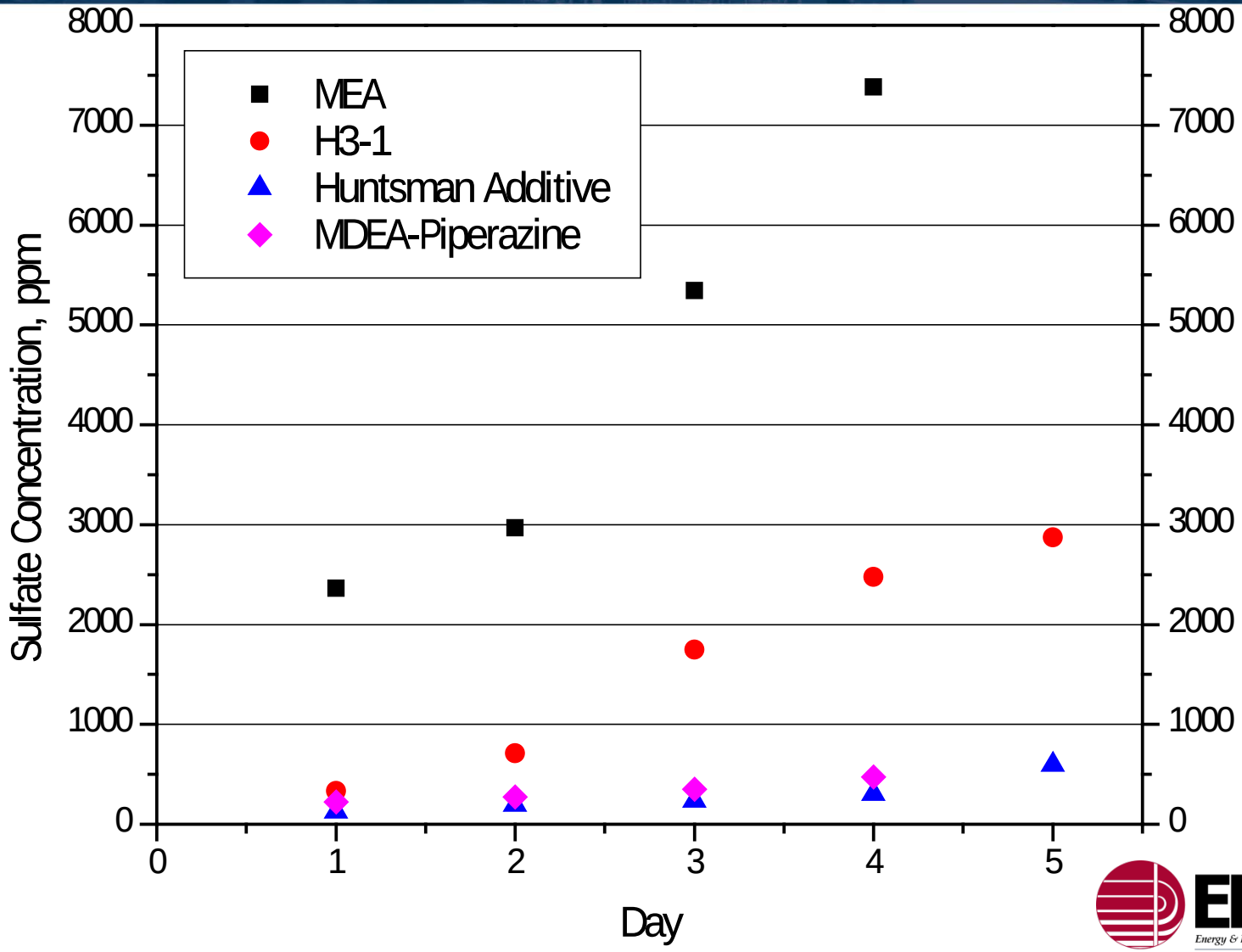
Sulfate Concentration



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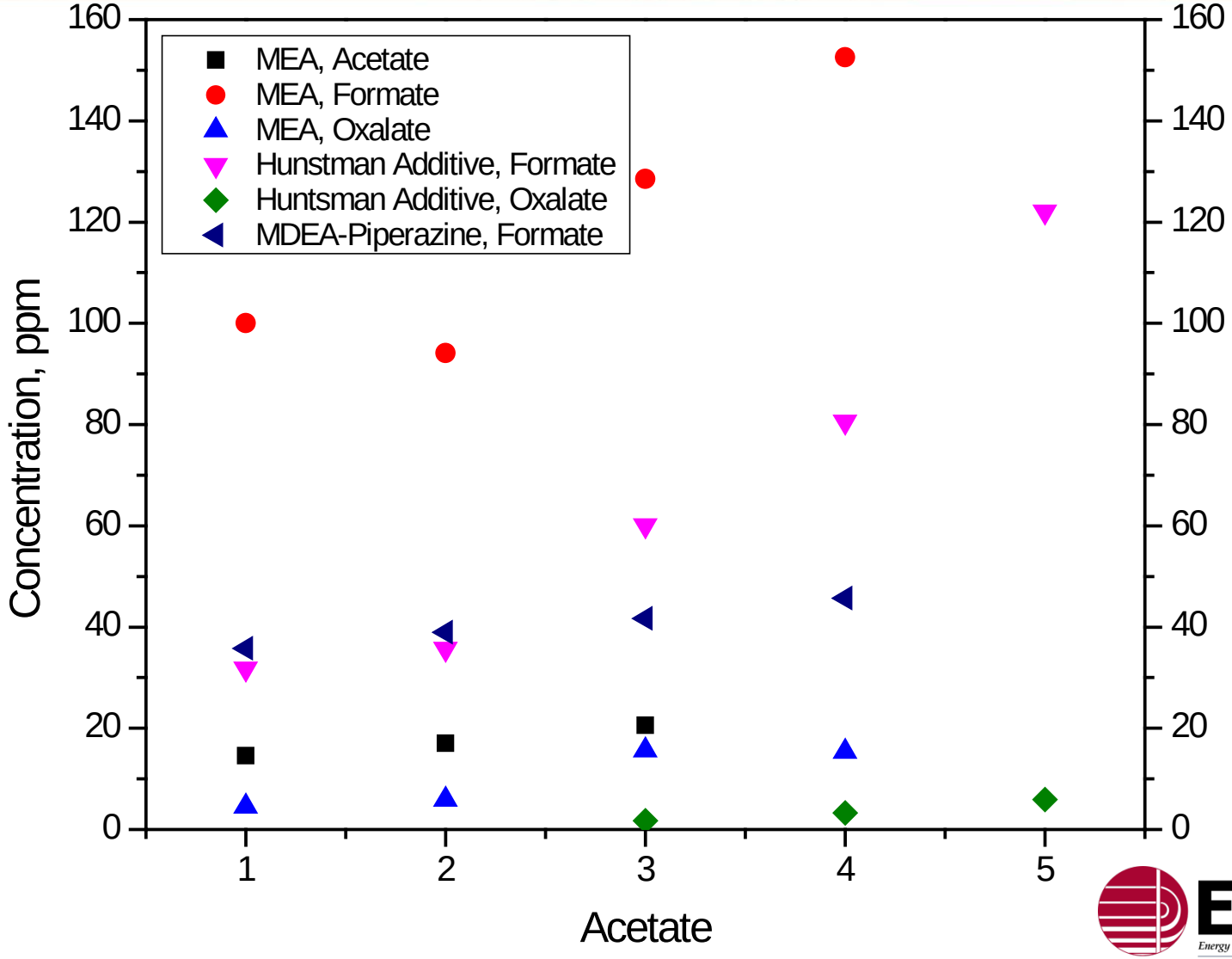
Organic Anions



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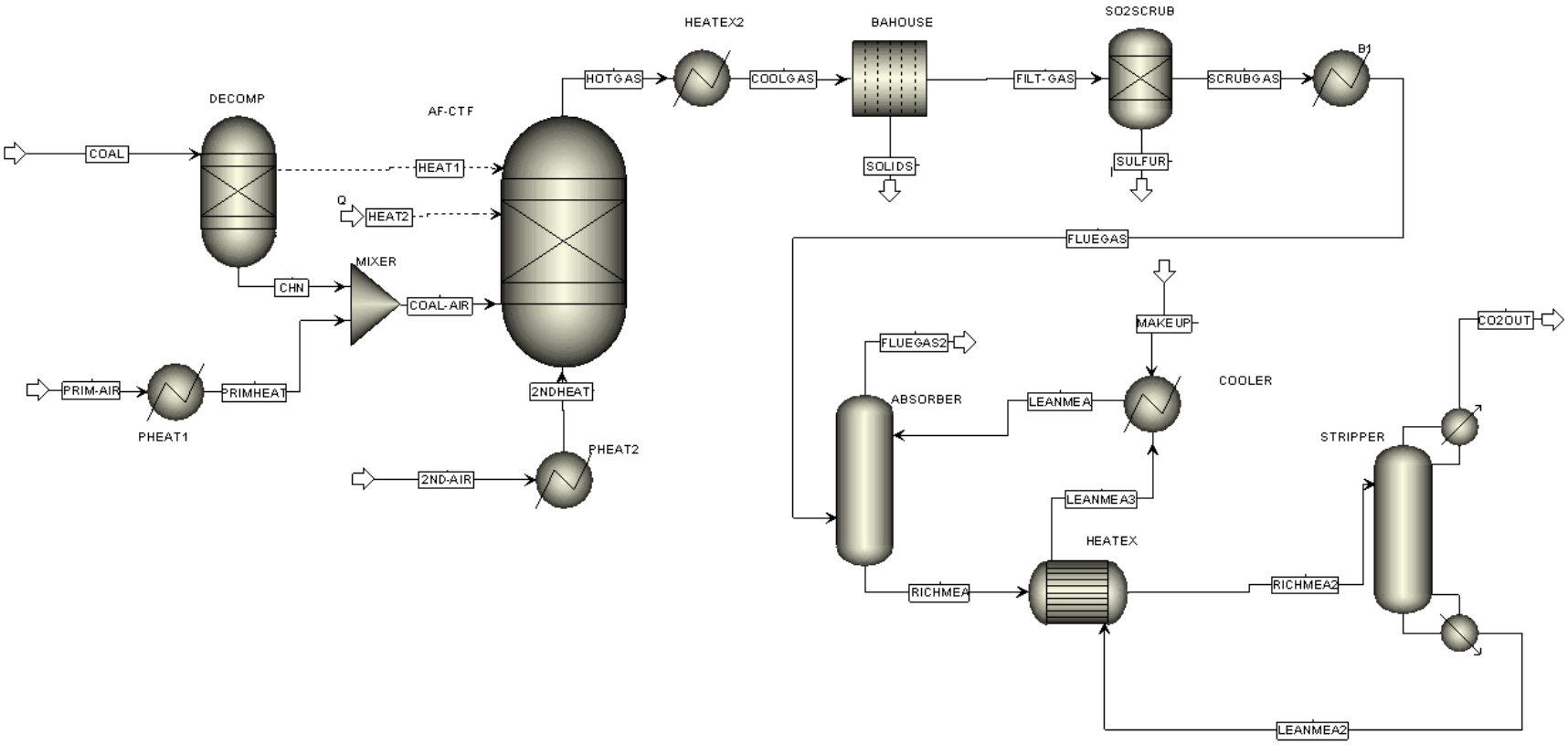
Integrated Combustion–Capture Model

- Coupled the combustion model with all back-end flue gas-cleaning units, including the CO_2 capture unit.
- Convergence becomes much more difficult because of the instability of the model.



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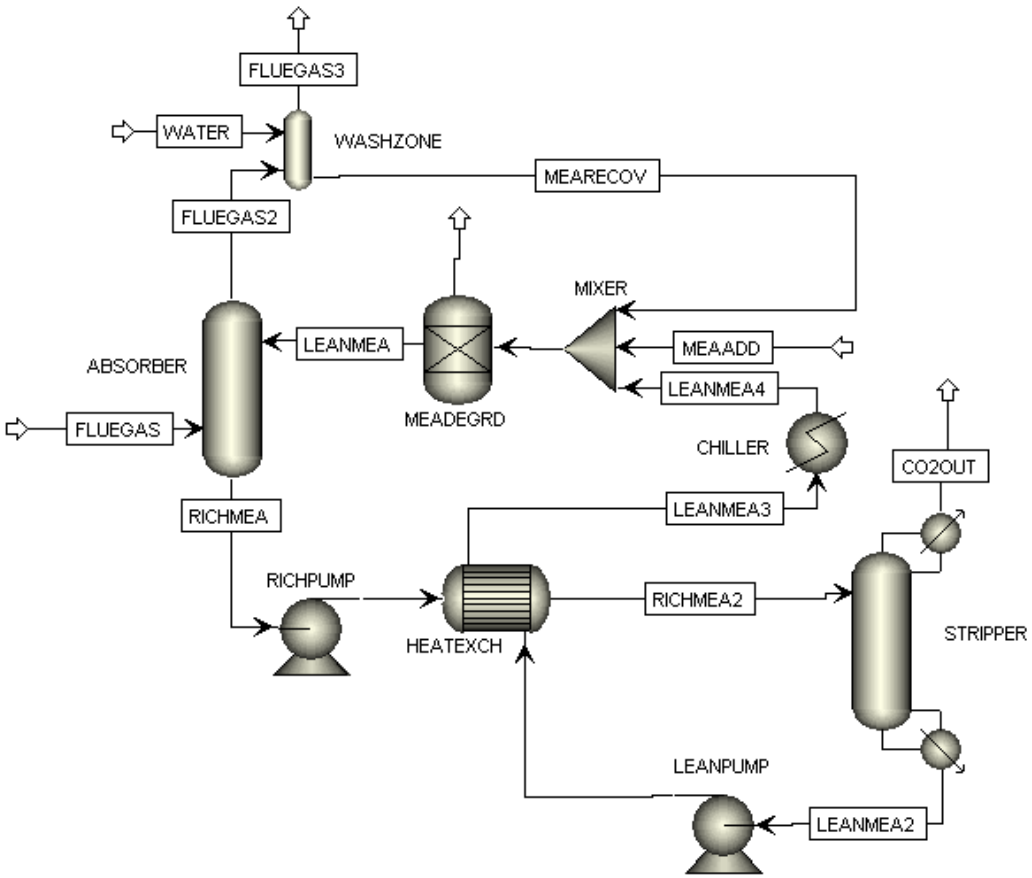
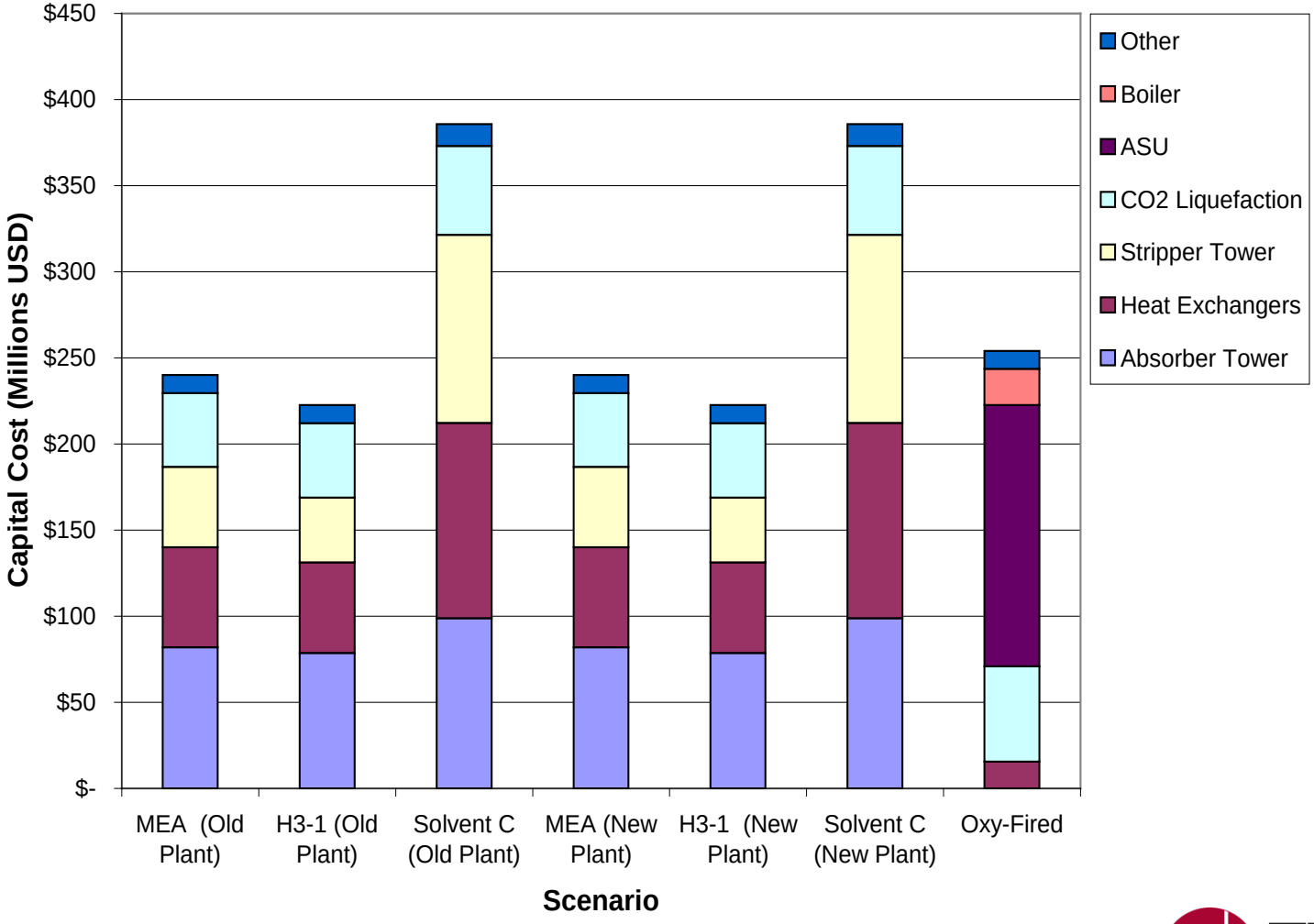
500-MW Aspen Plus Model for CO_2 Capture

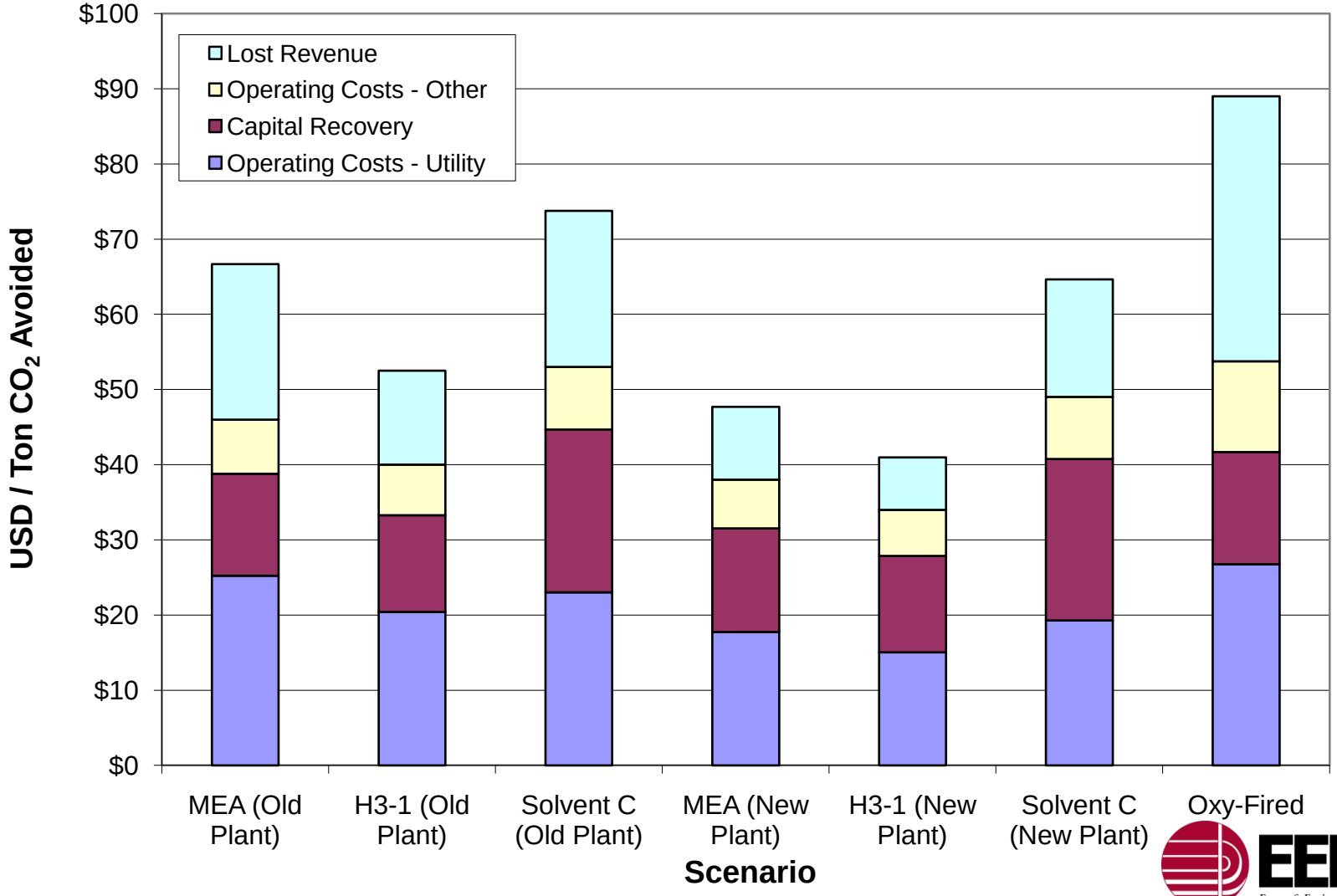


- 90% of CO_2 is removed from flue gas in absorber tower by MEA solvent.
- MEA losses from degradation are estimated from pilot-scale data.
- Wash zone minimizes MEA evaporation losses in absorber tower.

Capital Cost Comparison



Cost of CO_2 Avoided



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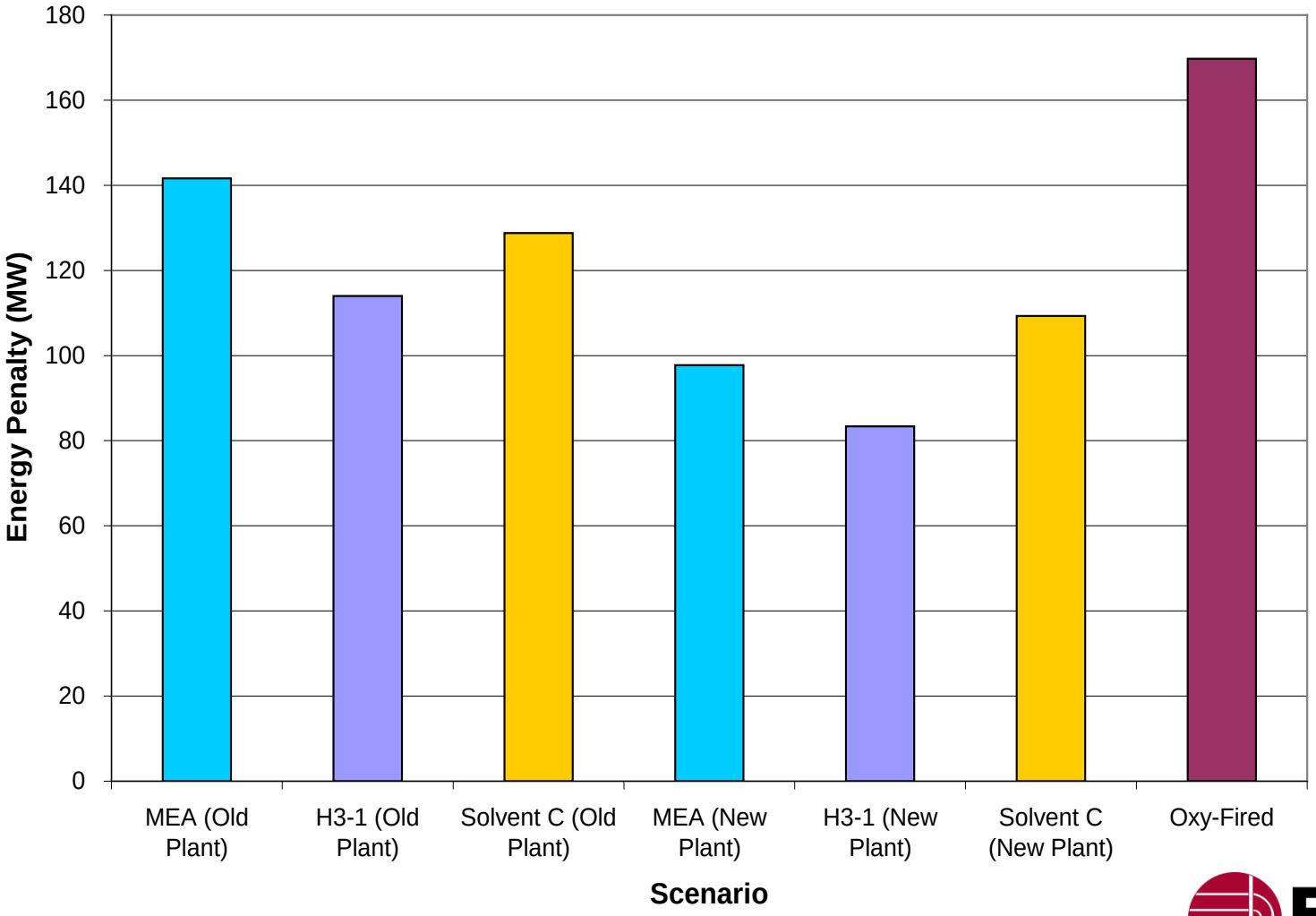
Energy Penalty



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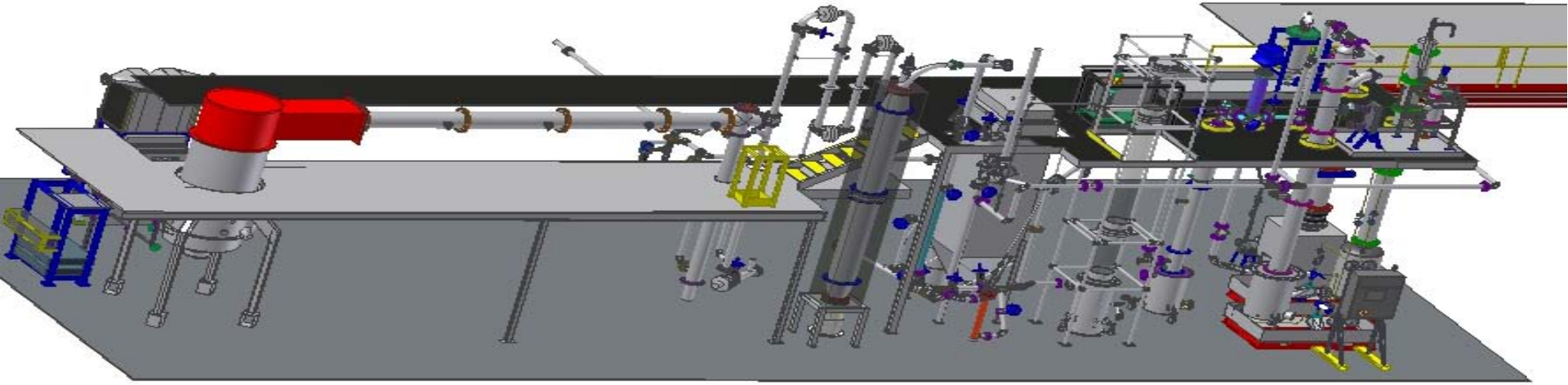
The Partnership for CO_2 Capture: Phase II

- The overall goal of Phase II is to further evaluate the most promising technologies from Phase I that may be ready for large-scale demonstration.
- Demonstrate/develop novel technologies (solid sorbents, enzymatic processes, ionic liquids).
- Determine ways (integration options) to reduce cost and power consumption.

Evaluation of Promising and Novel Technologies

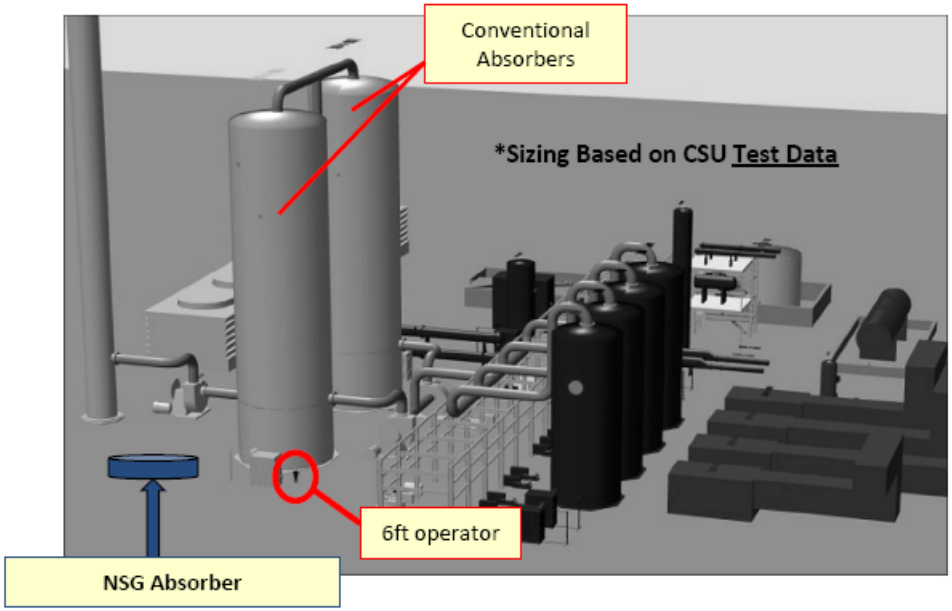
Pilot-scale testing of CO_2 capture technologies

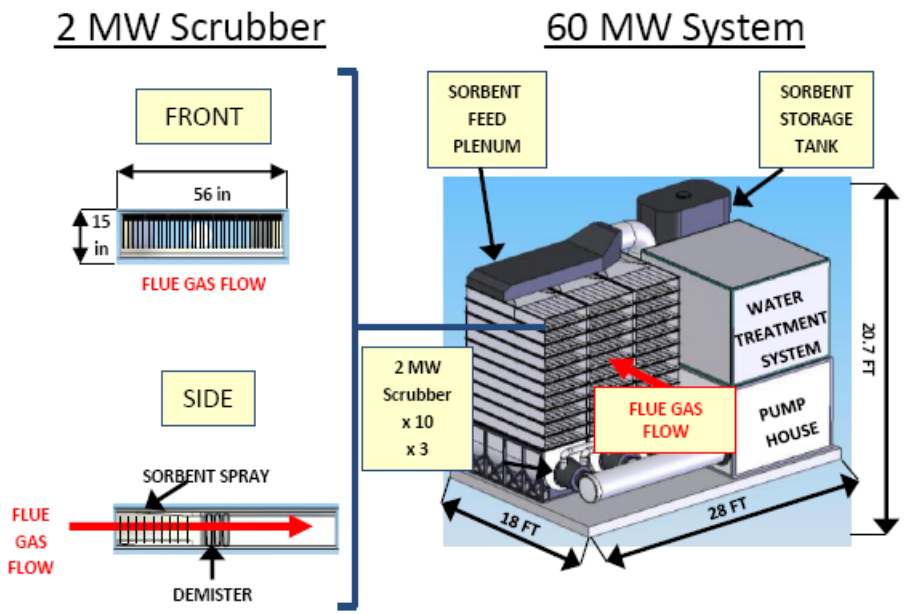
- **Several technologies will be further evaluated and new novel approaches will be tested.**
  - Solvents (Huntsman, Hitachi, and GE) and Advanced Systems
  - Solid sorbents
  - Oxy-fired combustion
  - Potentially looking at an Ionic liquid and enzyme based process.
  - Integration technologies/options



Multi-Pollutant Capture And Processing Systems

NSG
NEUMANN SYSTEMS GROUP, INC.





90% Smaller

Modular Design

50% Lower CapEx
40% Lower OpEx

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Contact Information/Questions

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