Cryogenic Carbon Capture Development
NETL FE-0028697

August 24, 2017

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CCC Value Proposition

- Energy efficient CO_2 capture (about ½ amine)
- Cost effective CO_2 capture (about ½ amine)
- Grid-scale, efficient, rapid, inexpensive energy storage
- Bolt-on technology (retrofit or greenfield)
- Widely deployable (NG, biomass, coal, waste)
- Multipollutant process (Hg, SO_x, HC, NO_2, $PM_{2.5}$, ...)
- Water conservation

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Cryogenic Carbon Capture

- General separation technology applicable to
  - Post-combustion systems (this presentation)
  - Pre-combustion systems (active development)
  - Natural gas processing (active development)
  - LNG production
- Retrofit or greenfield process
- Described in over 80 patent applications

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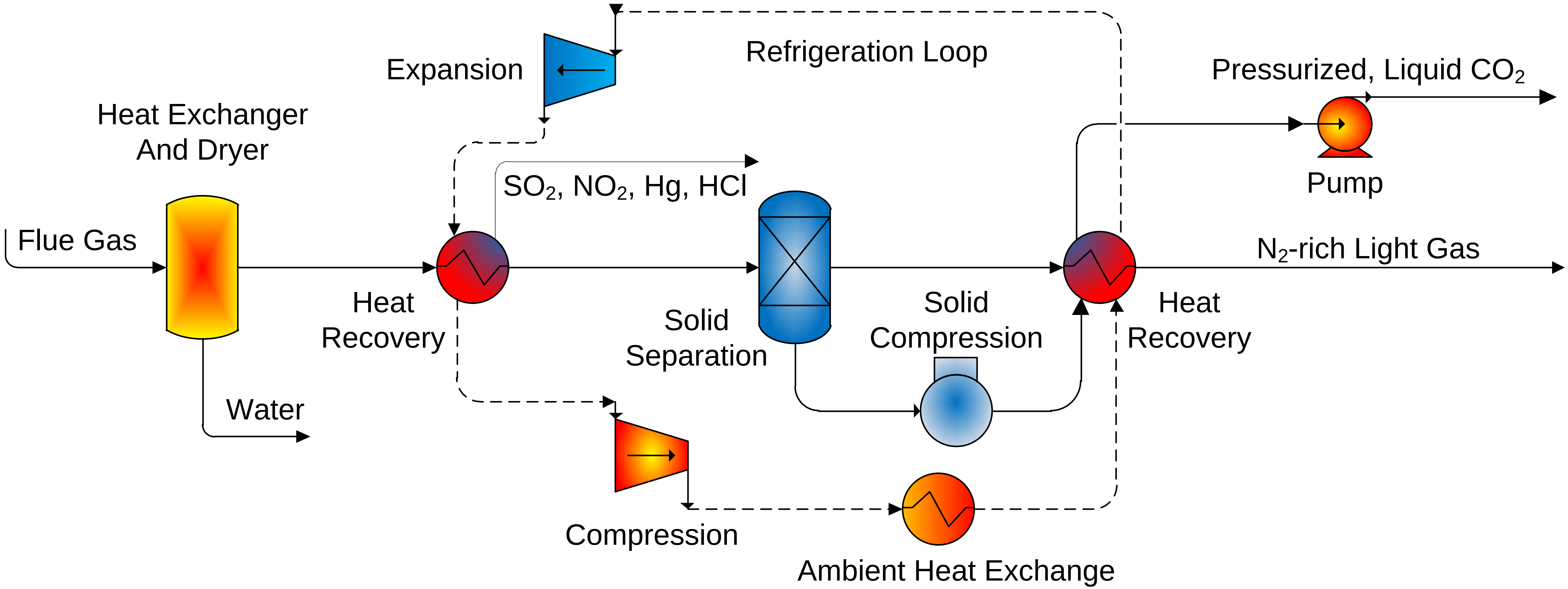
Simplified Flow Diagram (ECL)

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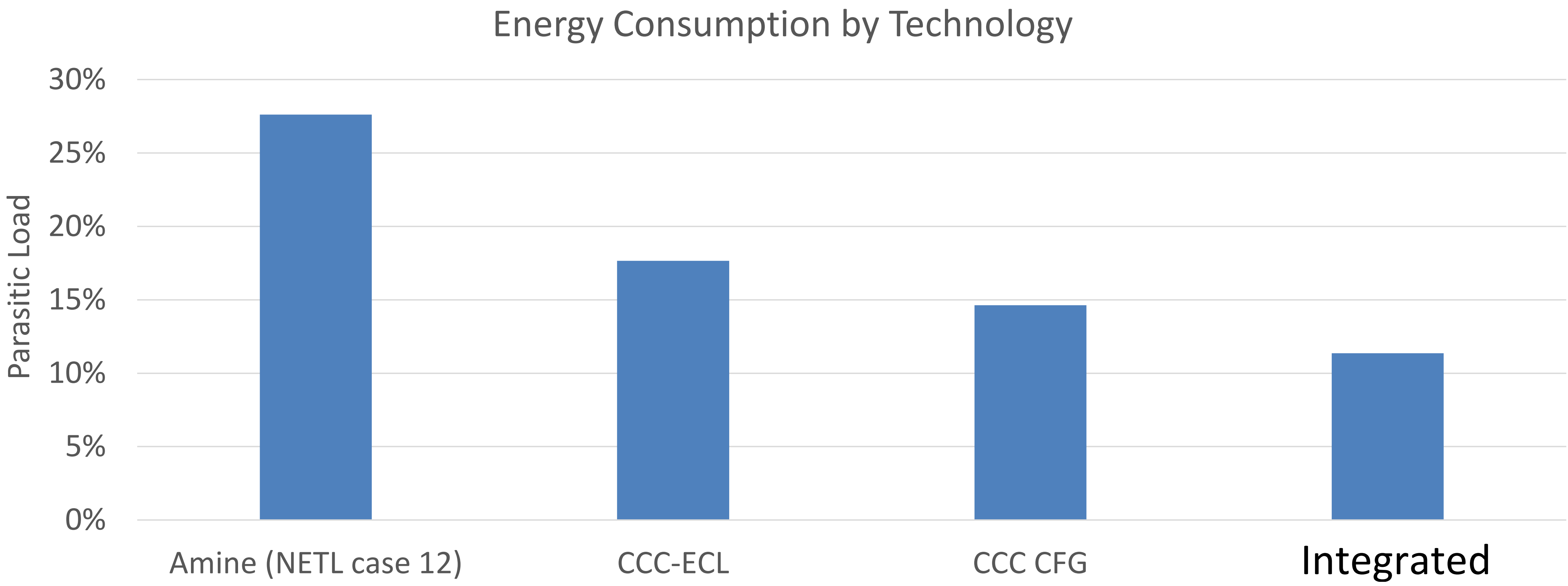
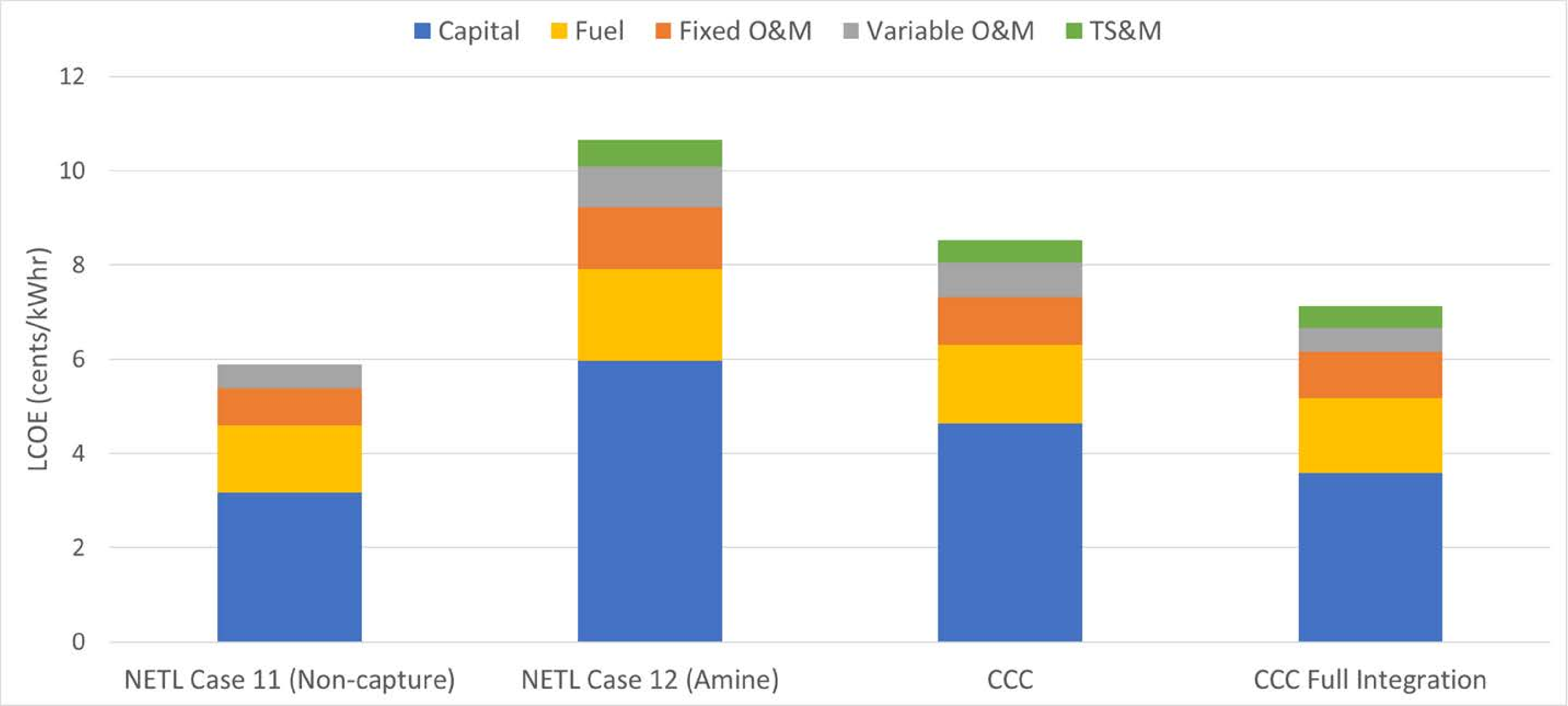
Energy Penalty



CCC nearly eliminates emissions while consuming half the energy of alternatives

CCC Greenfield Incremental Cost



CCC nearly eliminates emissions while increasing the cost of electricity by 2-3 ¢/kWh

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Completed Skid-scale Demonstrations

- Fuels
  - Coals (subbituminous and bituminous)
  - Natural gas
  - Biomass
  - Municipal waste, tires
- Technologies
  - Utility power plants
  - Industrial heat plants
  - Cement plant kilns
  - Large pilot-scale reactor
- Pre-combustion/NG Processing (lab scale)

Utility Power Plant

4-unit, 817 MW_e power plant in Wyoming

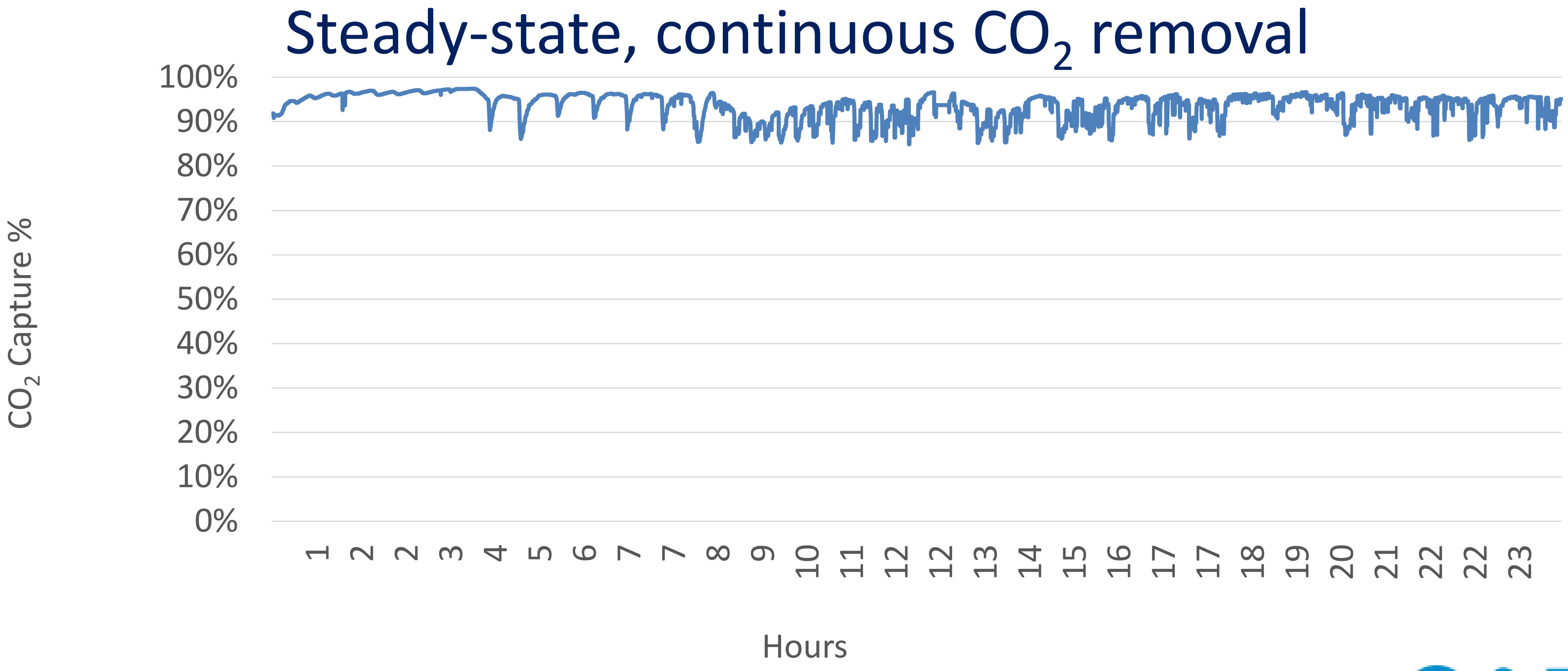
Slip stream on unit 4, which has a baghouse and a wet scrubber (on subbituminous coal).

Utility Power Plant Skid Test

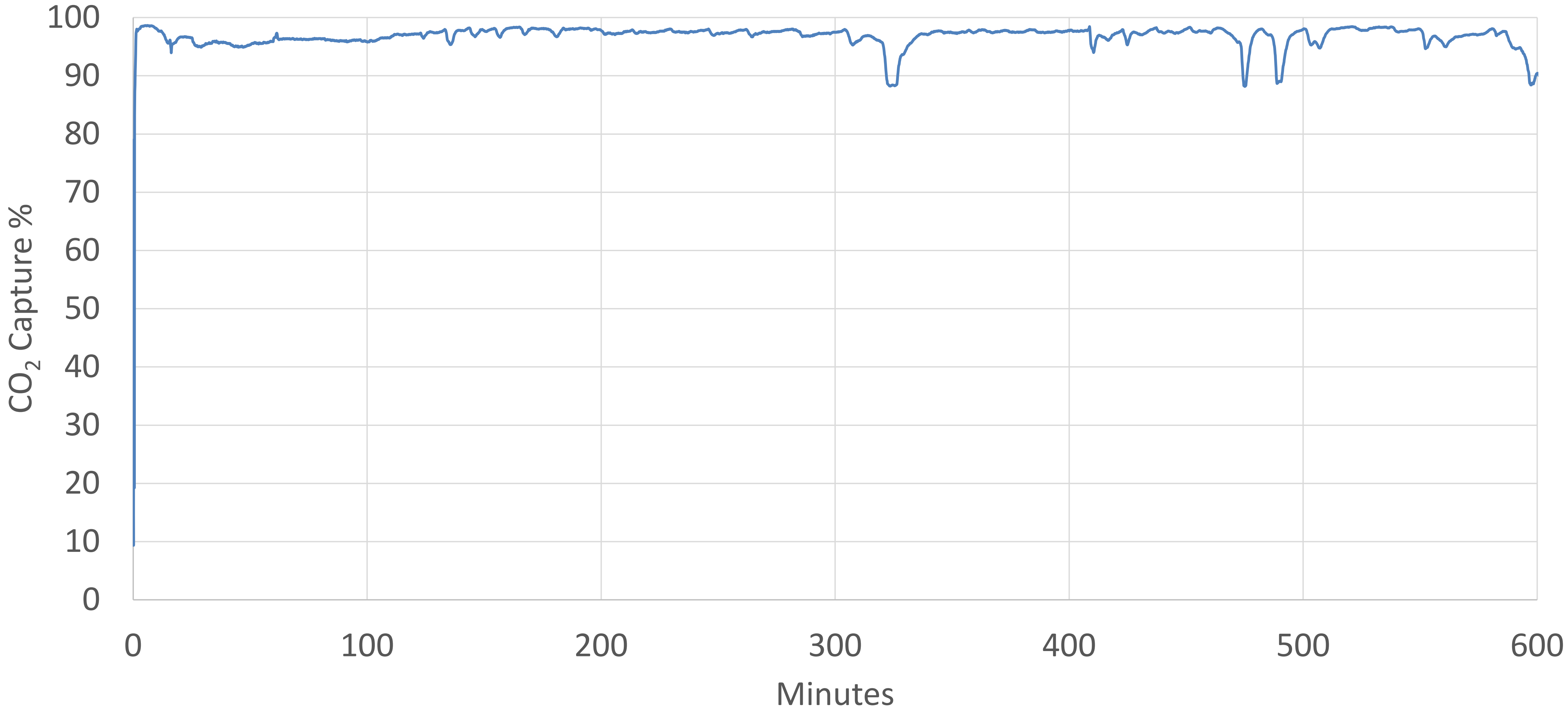
ECL Skid Photos

1 tonne/day CO_2 capture

Utility Power plant



Cement Kiln



100
90
80
70
60
50
40
30
20
10
0
CO_2 Capture %
0
100
200
300
400
500
600
Minutes

Objective

- Improve reliability and efficiency of unit operations based on field test experience.
- Implement improvements in skid system.
- Retest skid system (budget period 2) in field on power plant flue gas over 3-month period with minimum continuous operation of 500 hours.
- Project Partners: SES, Tri-state, Pacificorp, EPRI

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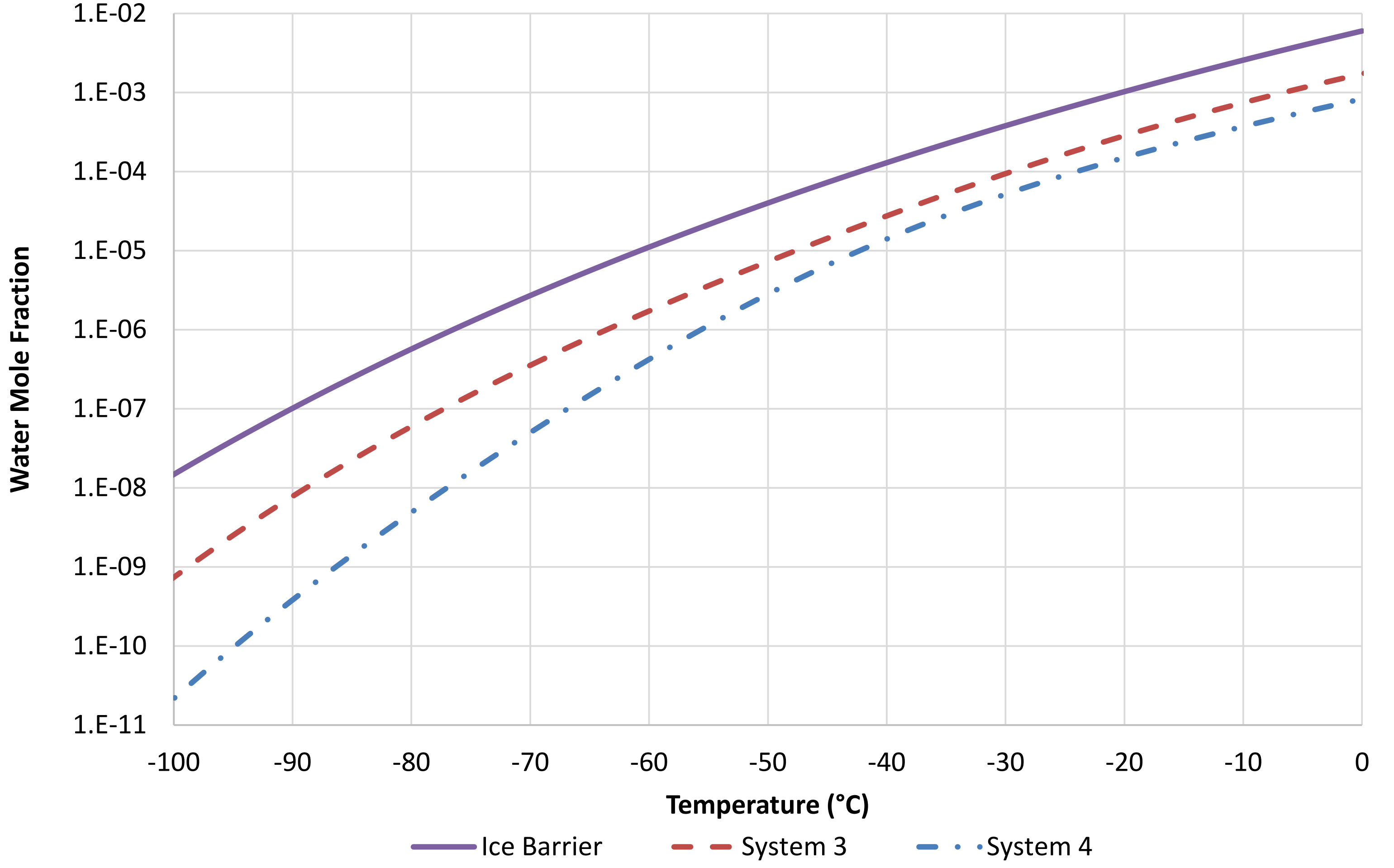
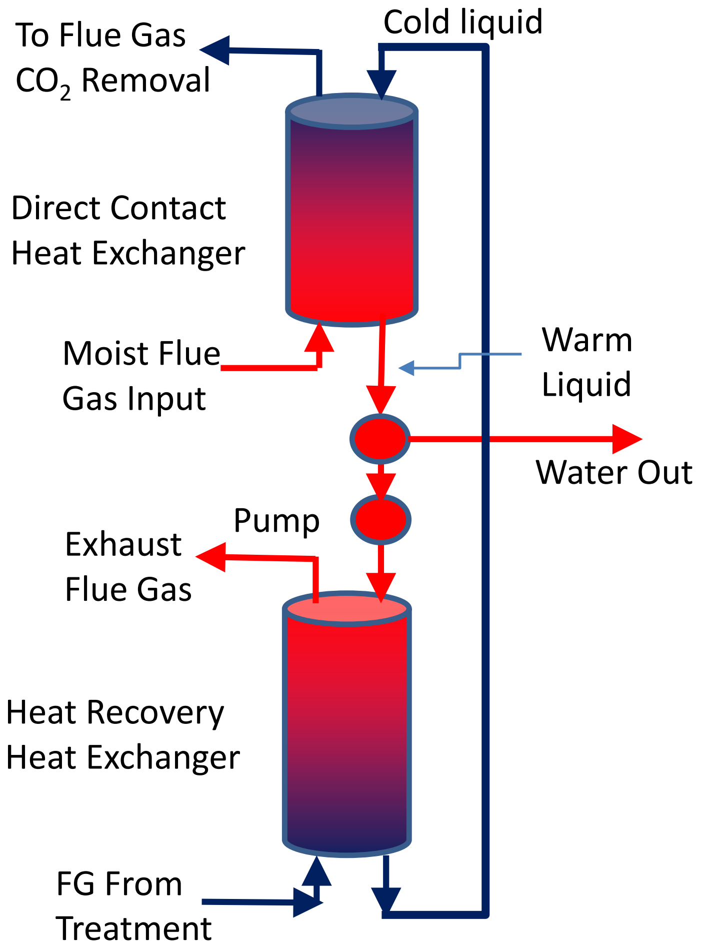
Tasks

1. Management
2. Flue gas drying
3. CO_2 in contact liquid
4. Solid-liquid separations
5. Desublimating heat exchanger
6. Instrumentation and controls
7. Light gas dispersal
8. Multipollutant capture
9. Techno-economic analysis

Task 2. Drying





Task 5. Heat Exchanger Testing

Major Activities

Spray Tower

- Initial droplet size testing done for spray nozzles and parallel spray device
- Designed new skid-scale hybrid spray tower HX
- Design incorporates the latest knowledge of slurry handling, desublimating heat exchangers, and maximizing heat exchange, from thousands of hours of experimental work
- Spray tower constructed in Q3 and testing began

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Task 6. Instrumentation and Controls

Major Activities

- New instrumentation includes thermocouples, pressure transducers, level transmitters, flowmeters, and control valves
- I/O channels will increase by 23% (i.e., 104 to 128)

Channel	Existing	New or modified	Planned
Analog outputs	12	14	16
Analog inputs	33	32	40
Discrete outputs	19	9	22
Discrete inputs	4	9	11
Thermocouples	36	26	39
Total	**104**	**90**	**128**

- Of the existing channels, 63% (i.e., 66) will be modified in some way, such as by repurposing for a different instrument, re-routing to a new process location, or rebranding tag
- All changes require some programming time

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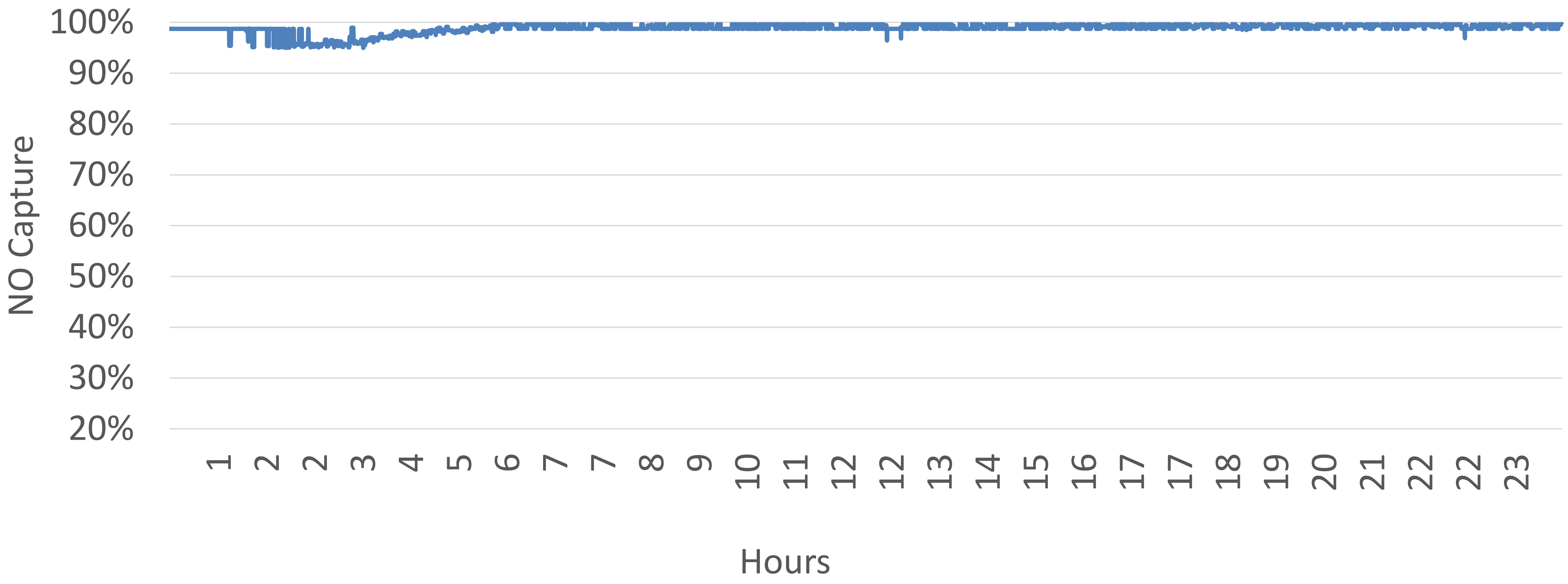
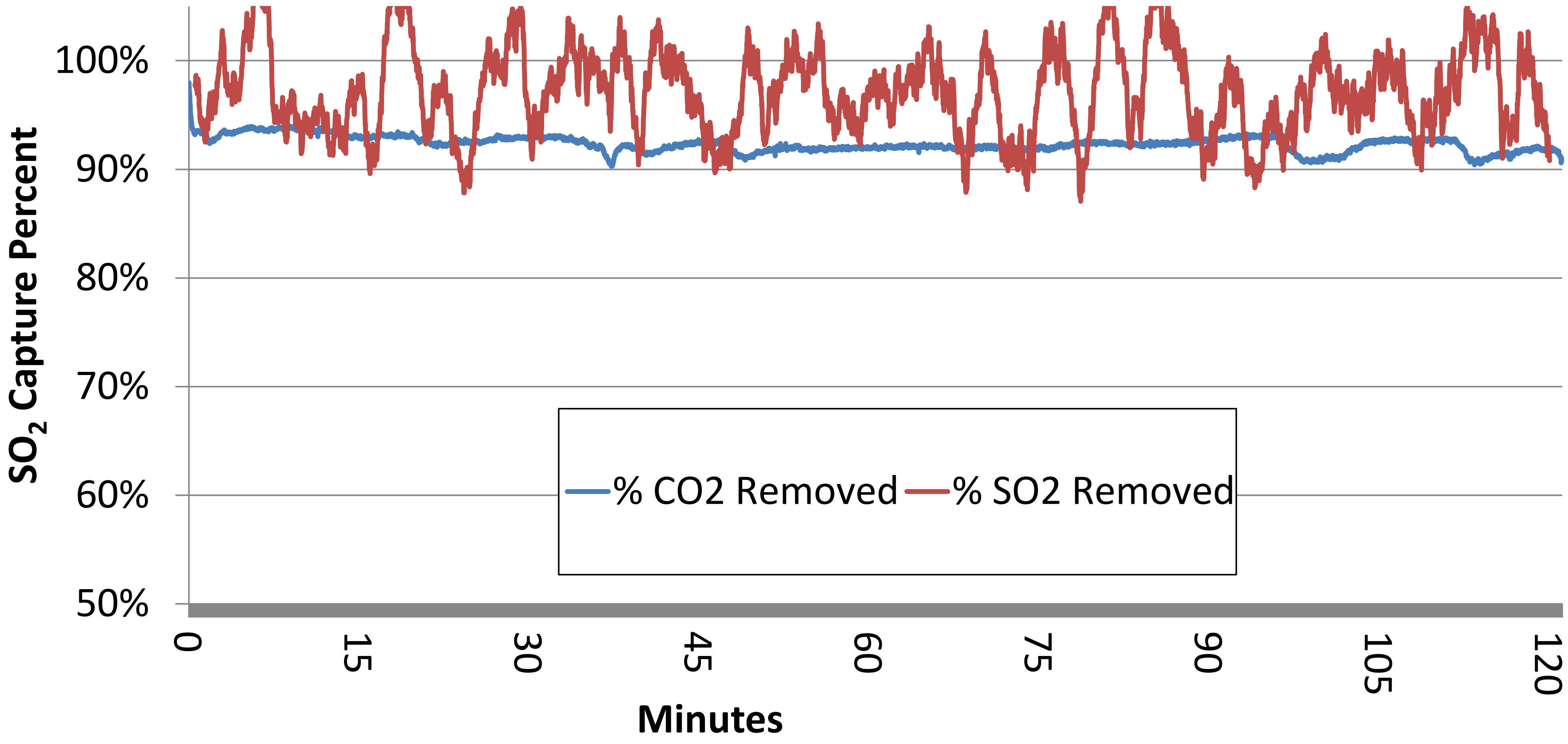
Task 8. Pollutant Removal

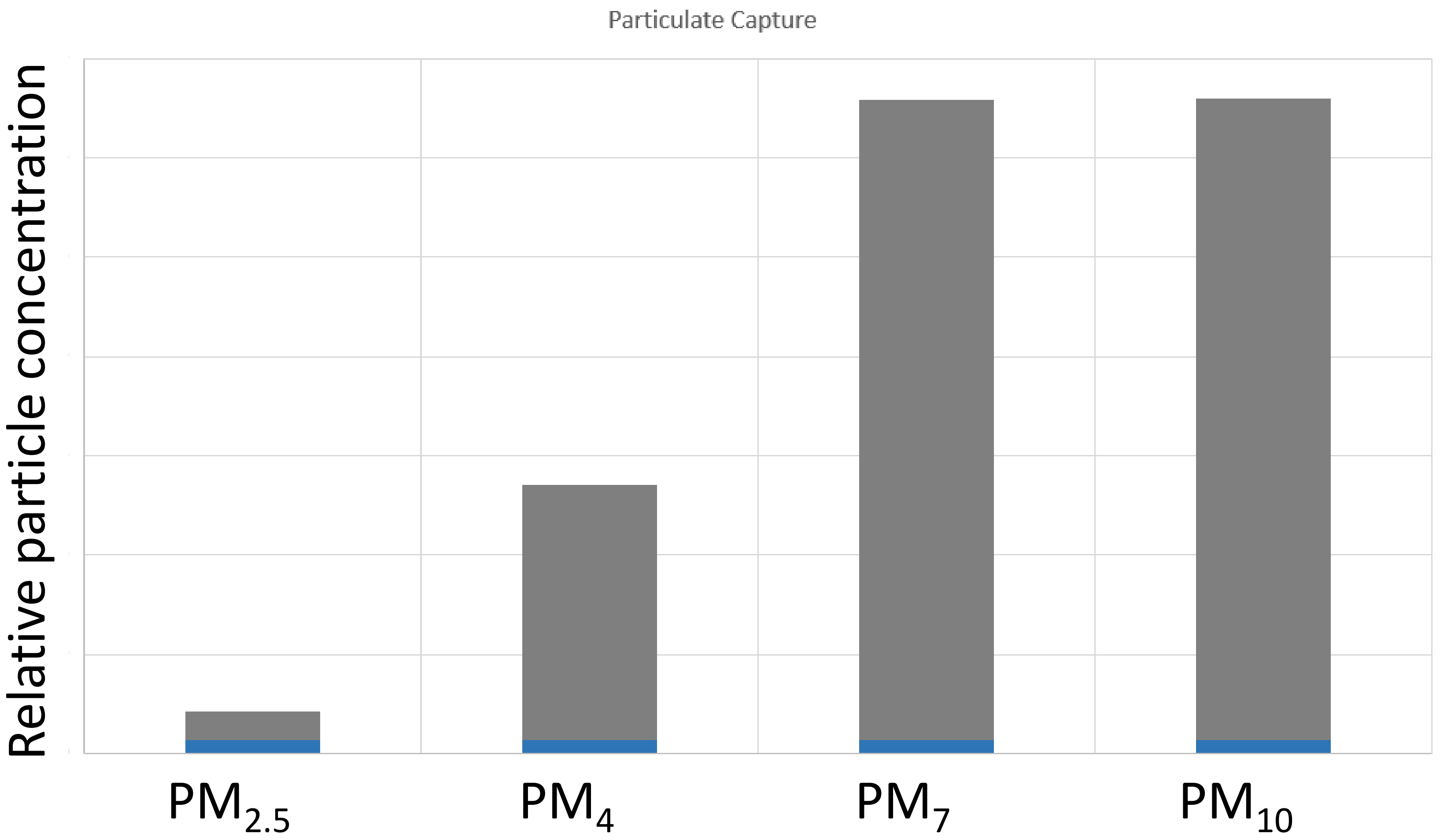
- NO - Captured at very high rates, likely reacted to NO_2



Task 8. Pollutant Capture Data



Task 8. Particulate Capture



Task 8. Mercury Testing

- Field test at utility power plant
- Inlet 735 ppt, or 5.77 $\mu g/m^3$ (after wet scrubber)
- Outlet below detection limit, which is 1 ppt, or 0.01 $\mu g/m^3$ for 99.9%+ capture.
- Actual concentrations predicted to be far below atmospheric levels (1-2 ng/m^3).

Acknowledgements

- DOE Project Manager: David Lang
- Collaborators: Pacificorp, Tristate, EPRI, (Air Liquide, GE, Holcim, Dong, Chart)
- Funding: Dong Energy, DoI, Wyoming Clean Coal Task Force, DOE-Arpa-E, CCEMC, DOE-NETL
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