Sixth Annual Conference on Carbon Capture & Sequestration

*Session: Capacity Building*

# Economics of $CO_2$ Capture from Flue Gas Using Solid Sorbents: *Carbon-on-Carbon* Clean-up

- **Carbonaceous materials – capacity, selectivity, rates**
- **Membrane and Zeolite cases**


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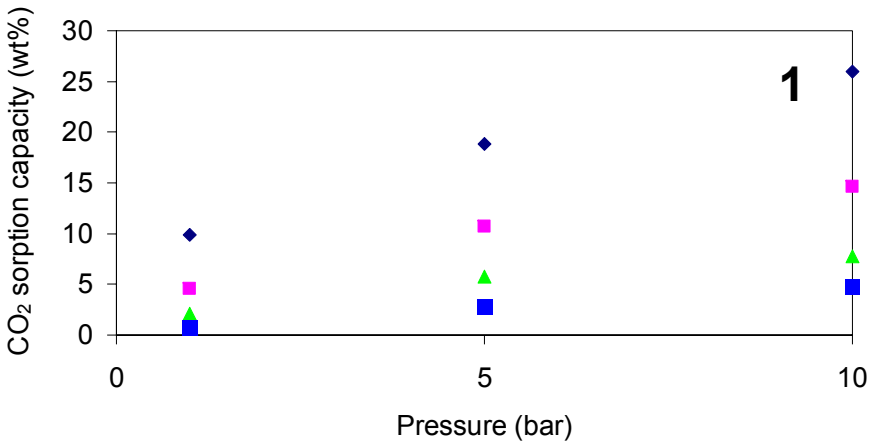
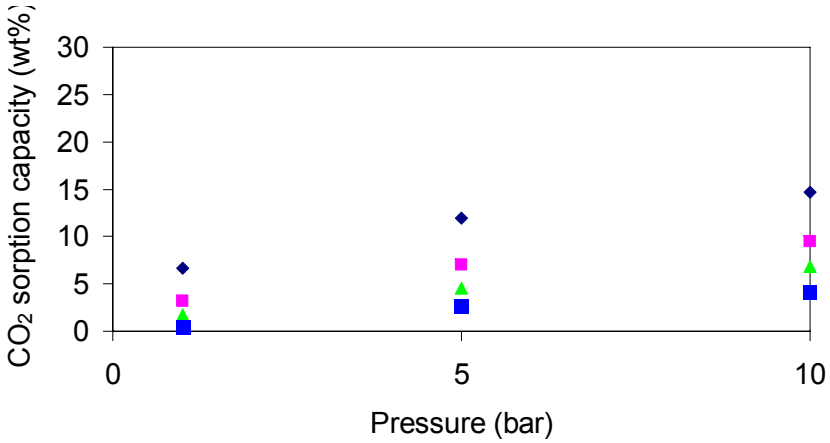
# Need an efficient Flue Gas “Filter”

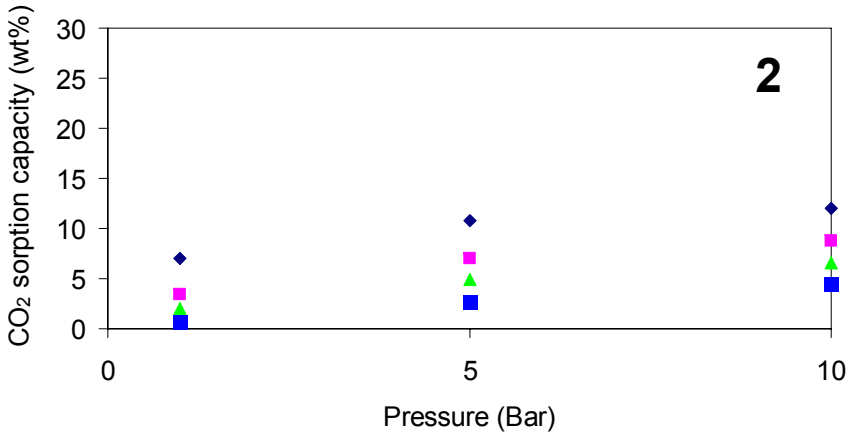
- No expensive compression
- Moisture insensitive
- Picks up $NO_x$ and $SO_x$ as well as $CO_2$
- Easy to regenerate by heating, hence
- Easy to integrate with power plant
- Inexpensive material
- Makes $CO_2$ production profitable
- Lower electricity rate?

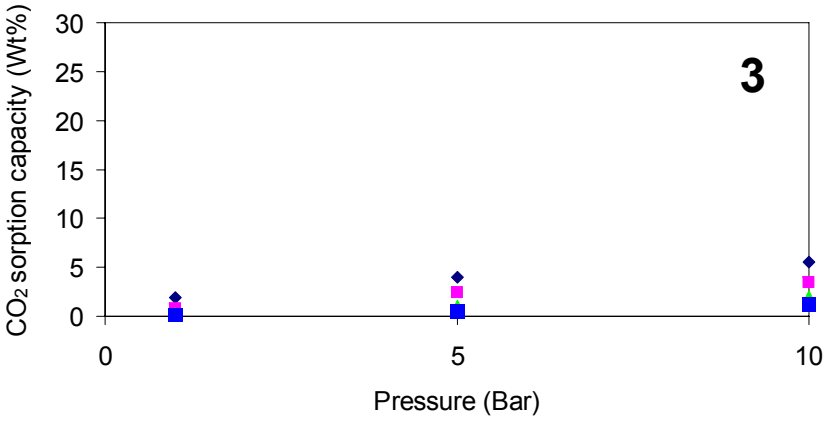
→ **Carbon-on-Carbon sorption**

# Carbonaceous Sorbents 1-2 mm



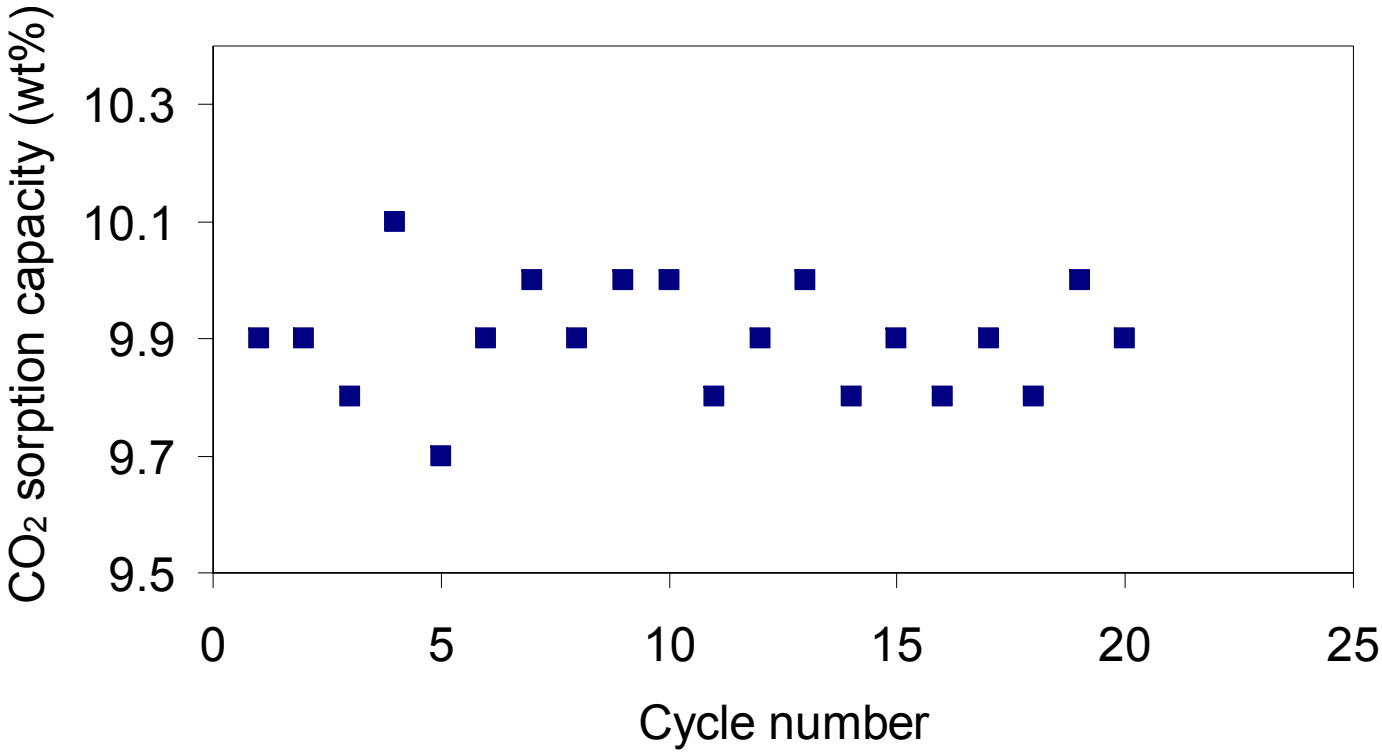



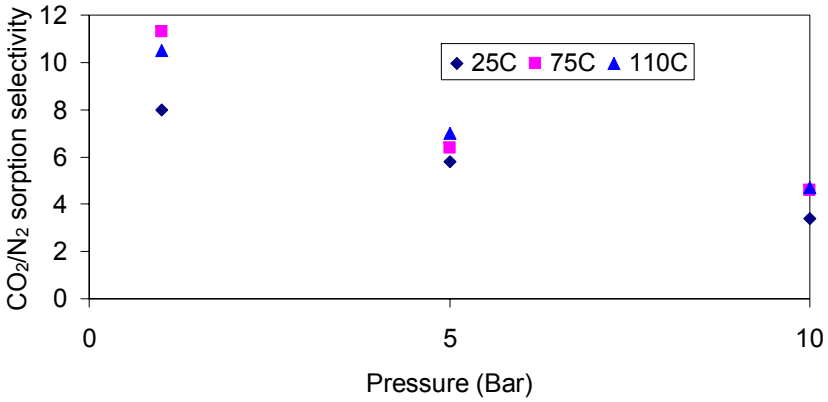

♦ 25°C ■ 75°C ▲ 110°C ■ 130°C

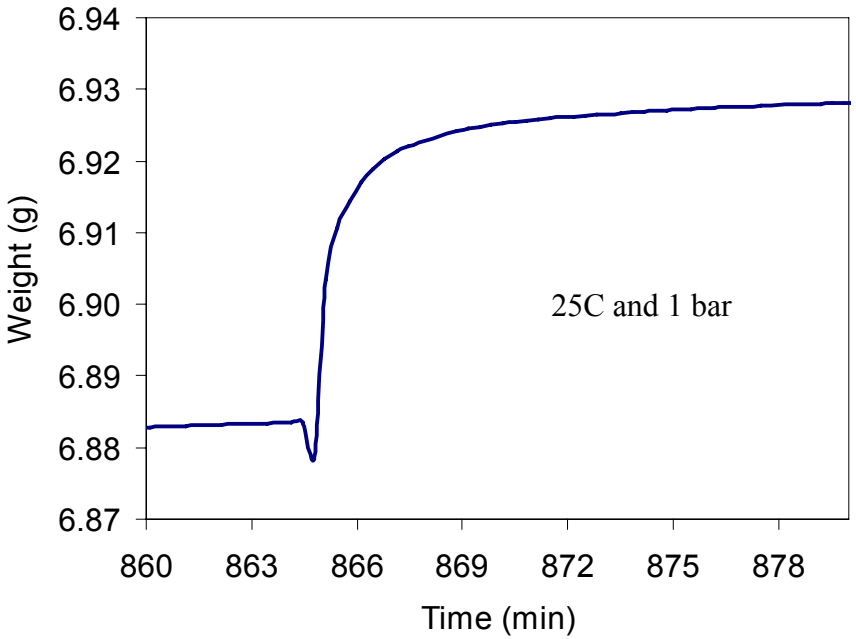
# Temperature cycles have no effect on carbonaceous sorbent $CO_2$ capacity




- Hydrophobic, hence moisture insensitive
- Pick up $NO_x$ and $SO_x$ as well as $CO_2$
- Easy to regenerate by heating, hence

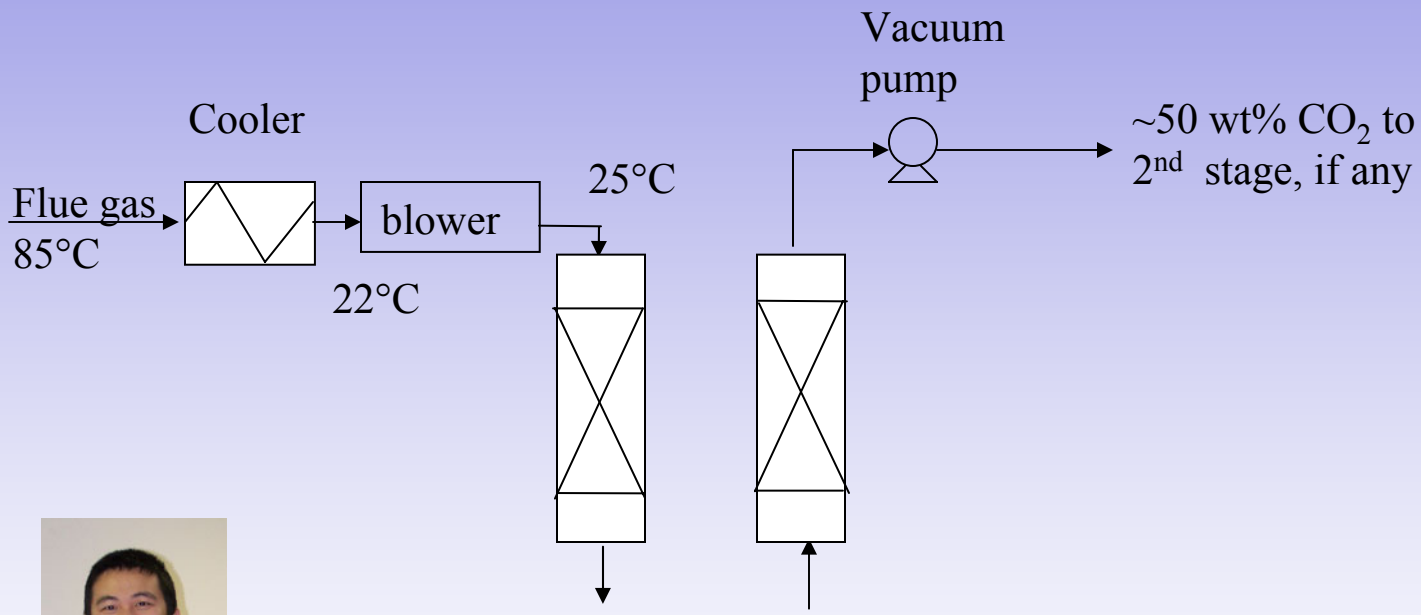
# Carbonaceous Sorbents Selective and Fast

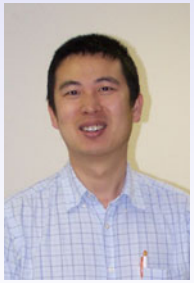


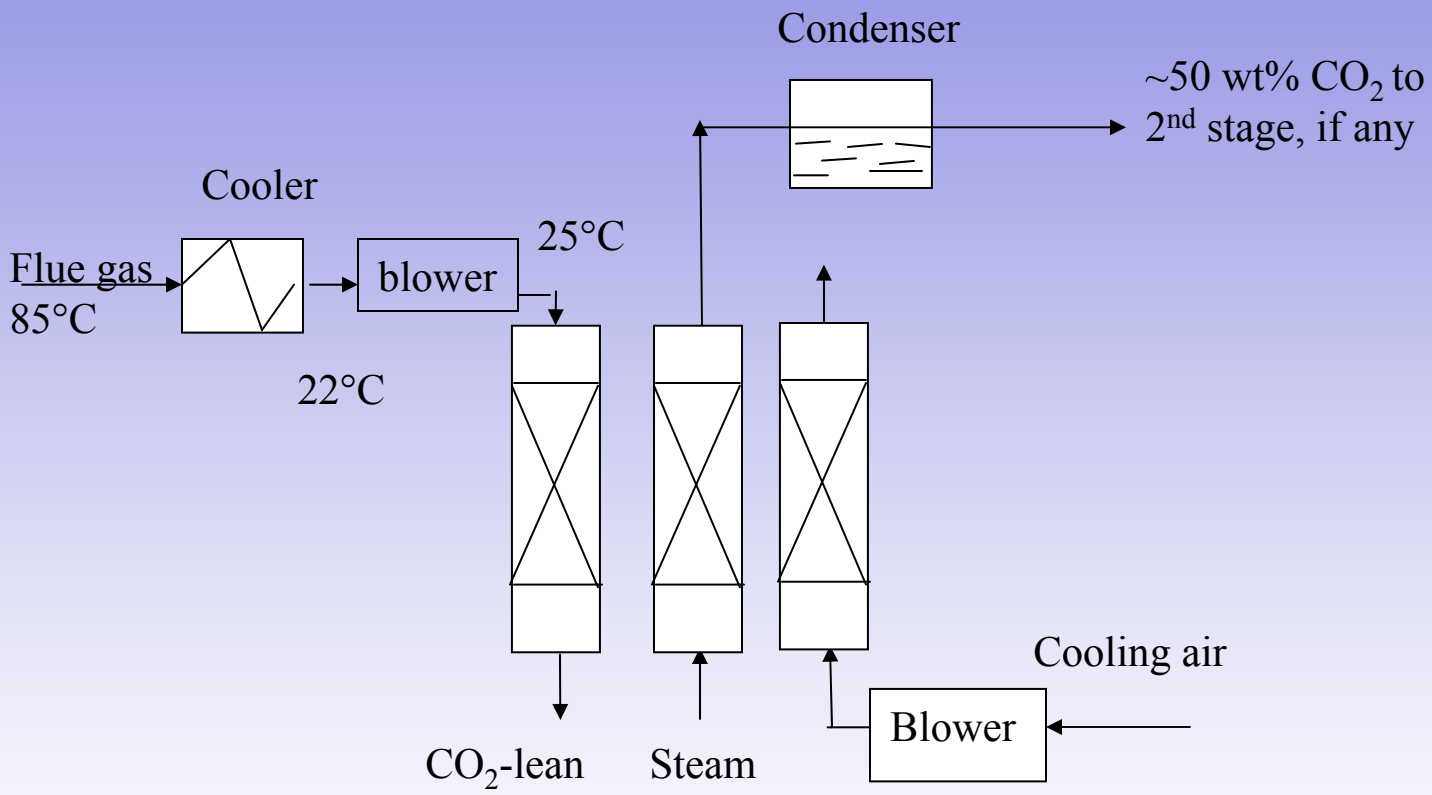

- Pressure swing – ambient to vacuum?
- Temperature swing – steam purge?
- Temperature swing – $CO_2$ purge?

# Pressure Swing to Vacuum



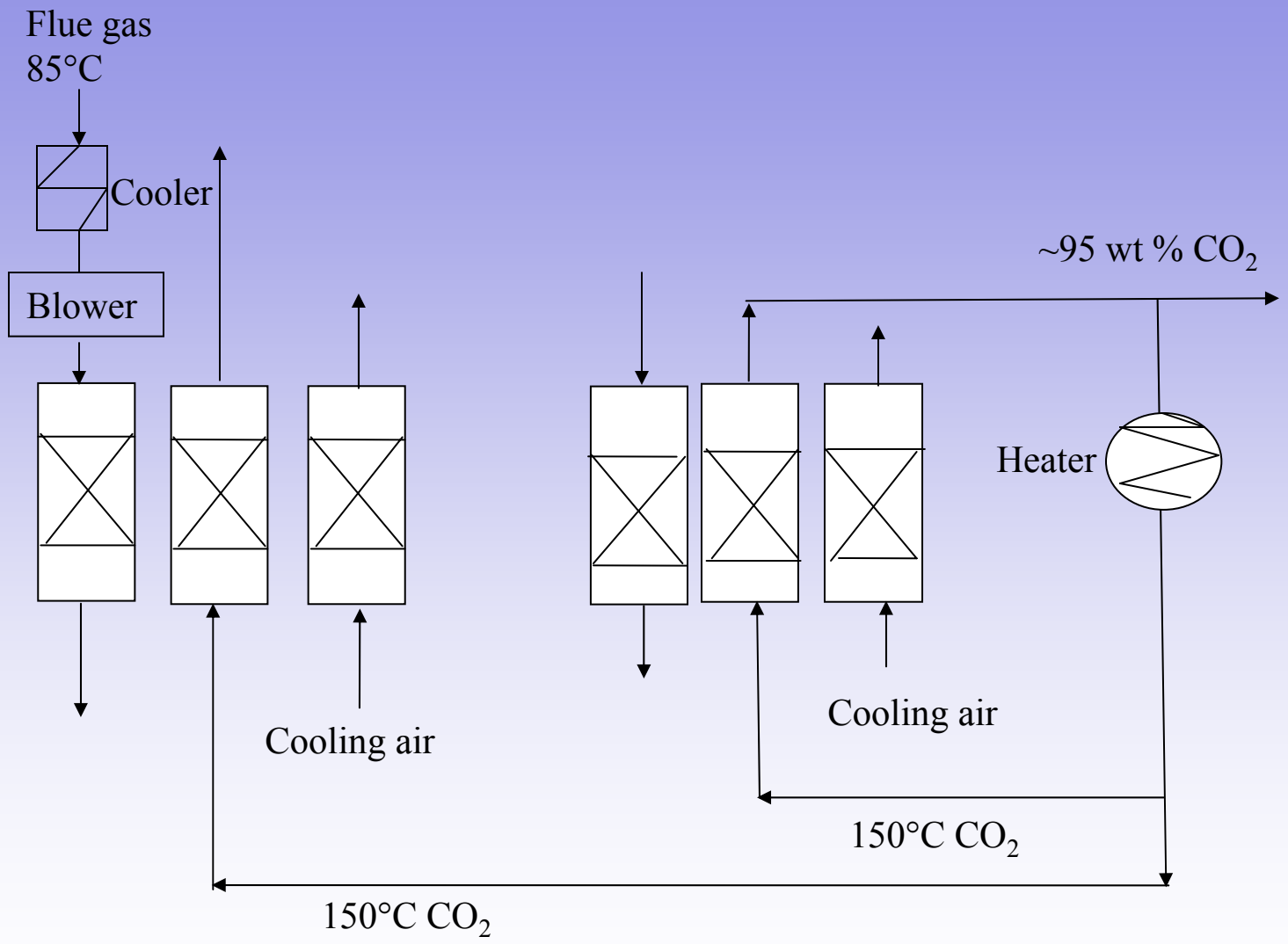



# Temperature Swing with Steam




~90 wt% $CO_2$

# Temperature Swing with $CO_2$



# Large stationary point source - Wyodak flue gas

| | |
|---|---|
| Capacity: | 335 MW |
| Flue gas flow rate: | 610 $m^3/s$ (STP) |
| Flue gas temperature through stack: | 85°C |
| Gas composition in weight percent: | |
| $N_2$ | 67% |
| $CO_2$ | 11.8% |
| $O_2$ | 12% |
| $H_2O$ | 8% |
| CO | 300 ppm |
| $SO_2$ | 180 ppm |
| NOx | 150 ppm |

Task: 90% recovery and 95% $CO_2$ purity

*UW Design Report 2006*

# Cost summary in million $ (steam recovery)

| Sorbent | 1-vac | 1 | 2 | 3 |
|---|---|---|---|---|
| Vessel | 4.0 | 4.0 | 4.8 | 4.5 |
| Blower | 34 | 3.6 | 3.6 | 4.8 |
| Sorbent | 11 | 11 | 1.6 | 0.4 |
| Misc | 0.3 | 0.9 | 1.5 | 1.6 |
| *Capital* | 49.3 | 19.5 | 11.5 | 11.3 |

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| | | | | |
| Electricity | 54.0 | 13.2 | 13.2 | 11.0 |
| Steam | 0 | 12.0 | 17.0 | 41.8 |
| Maintenance | 17.8 | 7.5 | 4.5 | 3.6 |
| Misc | 2.0 | 3.3 | 3.3 | 2.2 |
| *Annual* | 73.8 | 36.0 | 38.0 | 58.6 |

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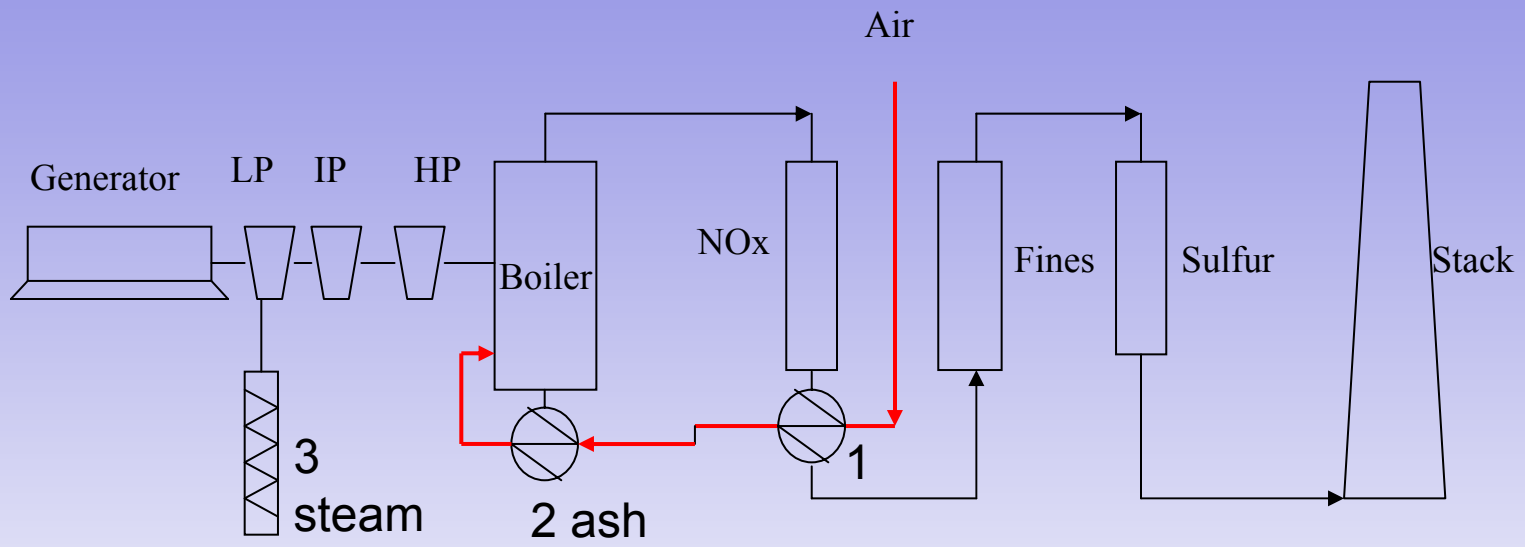
| | | | | |
| $/ton CO2 | 49 | 22 | 18 | 24 |

# Cost summary in million $ ($CO_2$ purge)

| Sorbent | 1 | 2 | 3 | |
|---|---|---|---|---|
| $/ton CO2 | 22 | 18 | 24 | (steam purge) |
| $/ton CO2 | 25 | 22 | 24 | ($CO_2$ purge) |

(costs up a bit, but purity up to 95%)

# Power Plant Integration (First Pass)

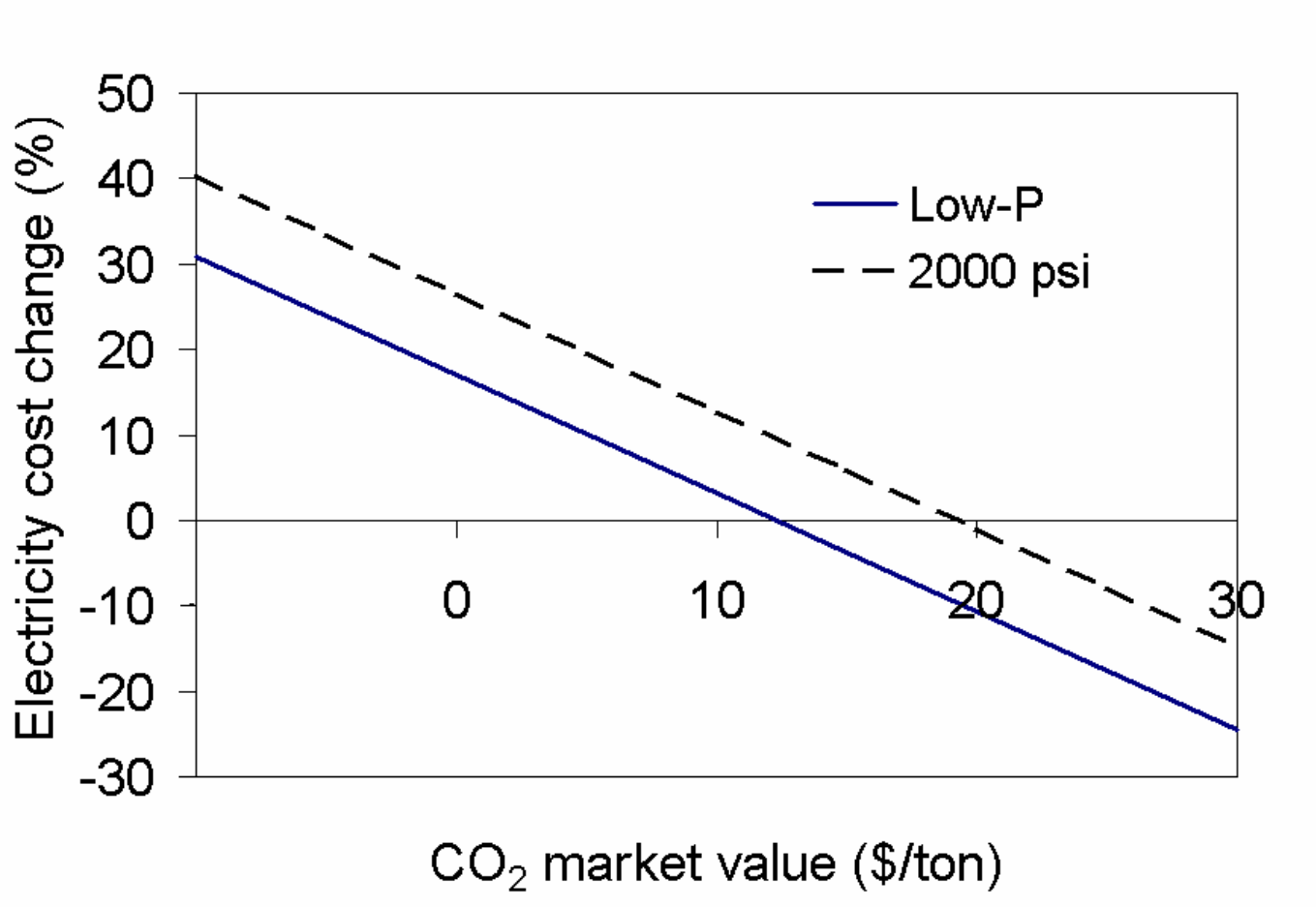



Sorbent 2/steam purge $18.1→ **$12/ton**
Sorbent 2/$CO_2$ purge $22.2→ **$14/ton**

**25-30% of amine benchmark → 20% after optimization**

**<$10/ton $CO_2$**

# Impact on electricity cost depends on $CO_2$ market value




$CO_2$ emission rate 3.5 MMt/year; 90% recovery rate; 90% $CO_2$ purity; 335 MW power plant capacity; 8760 hours of operation per year; Electricity price $0.07/kWh

$$\% = \frac{CO_2\ emission\ rate \times recovery \times purity \times (capture\ cost - market\ value)}{Power\ plant\ capacity \times 8760 \times electricity\ price} \times 100\%$$

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# Carbon-on-Carbon Flue-Gas Filter

- No need for expensive compression
- Moisture insensitive
- Picks up NOx and SOx as well as CO2
- Regenerated by low-level heat from steam or $CO_2$
- Integratable with power plant
- Inexpensive material
- Can makes CO2 production profitable → EOR
- Hence, small impact on the electricity rate (<10%)

**www.uwyo.edu/sml**

## Soft Materials Laboratory

University of Wyoming

# Capture cost of $CO_2$ versus purity of $CO_2$ recovered