A New CO_2 Capture Platform: Hollow Fiber Adsorbents for Post-Combustion Recovery

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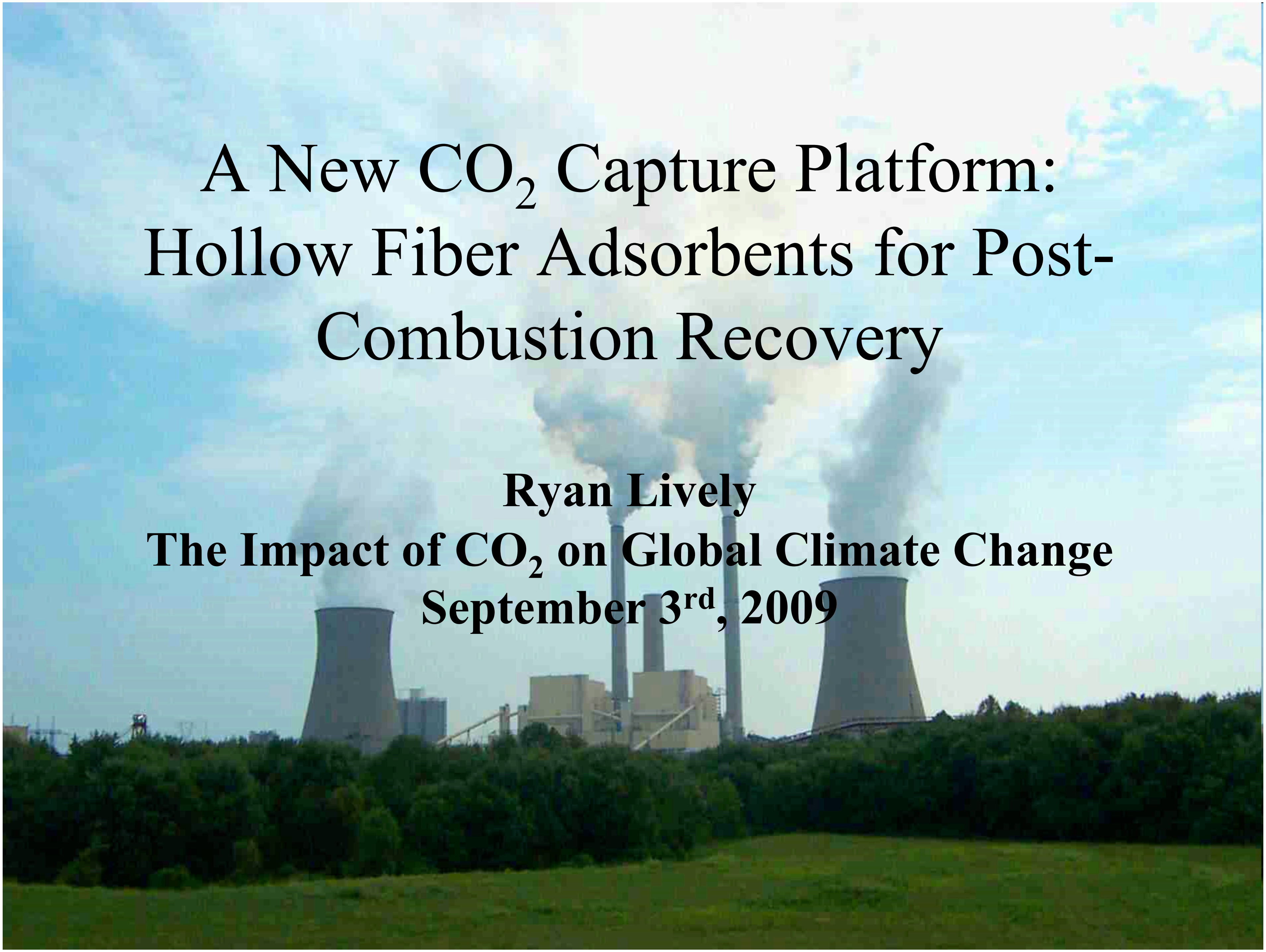
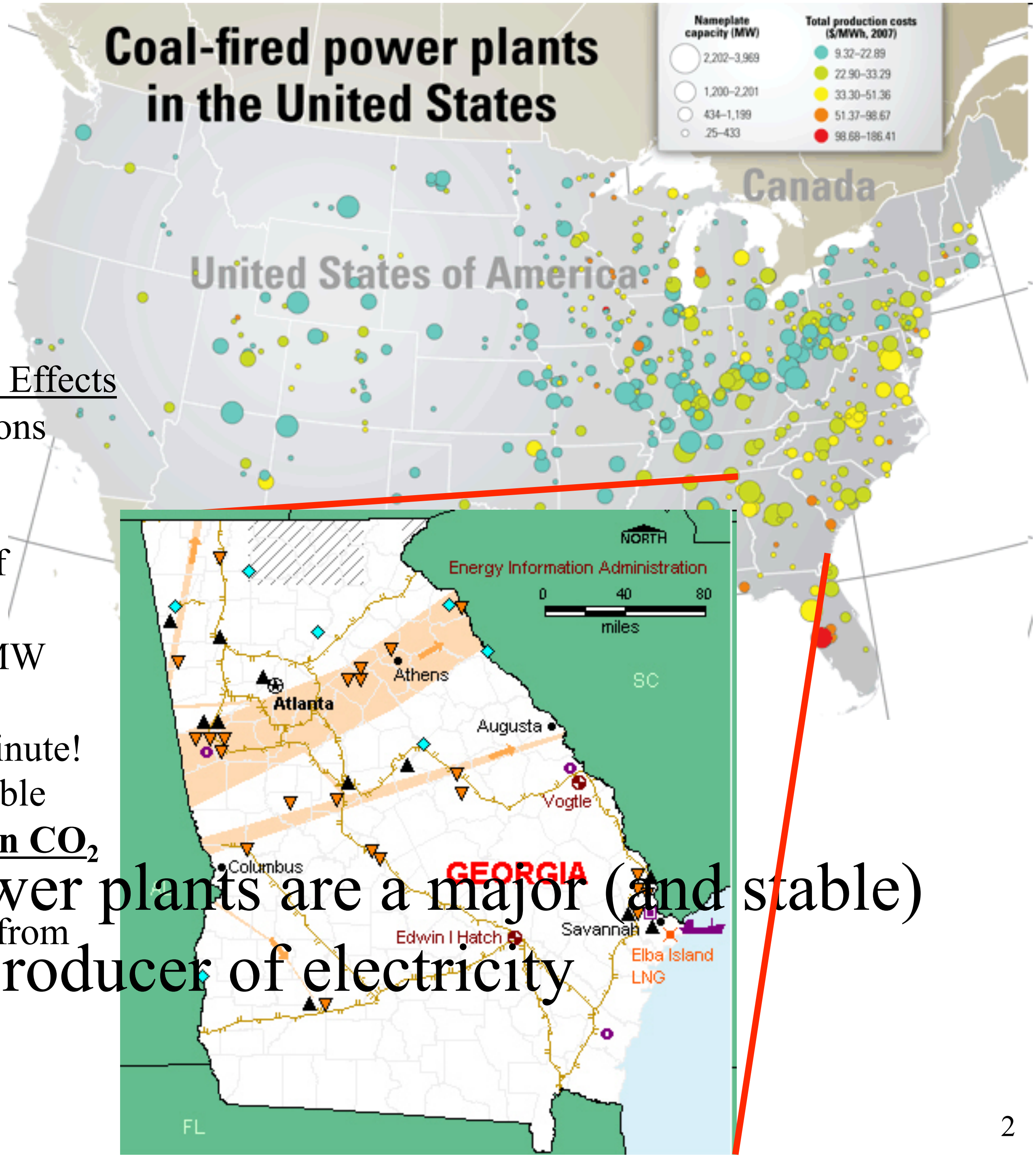
The Impact of CO_2 on Global Climate Change

September 3rd, 2009



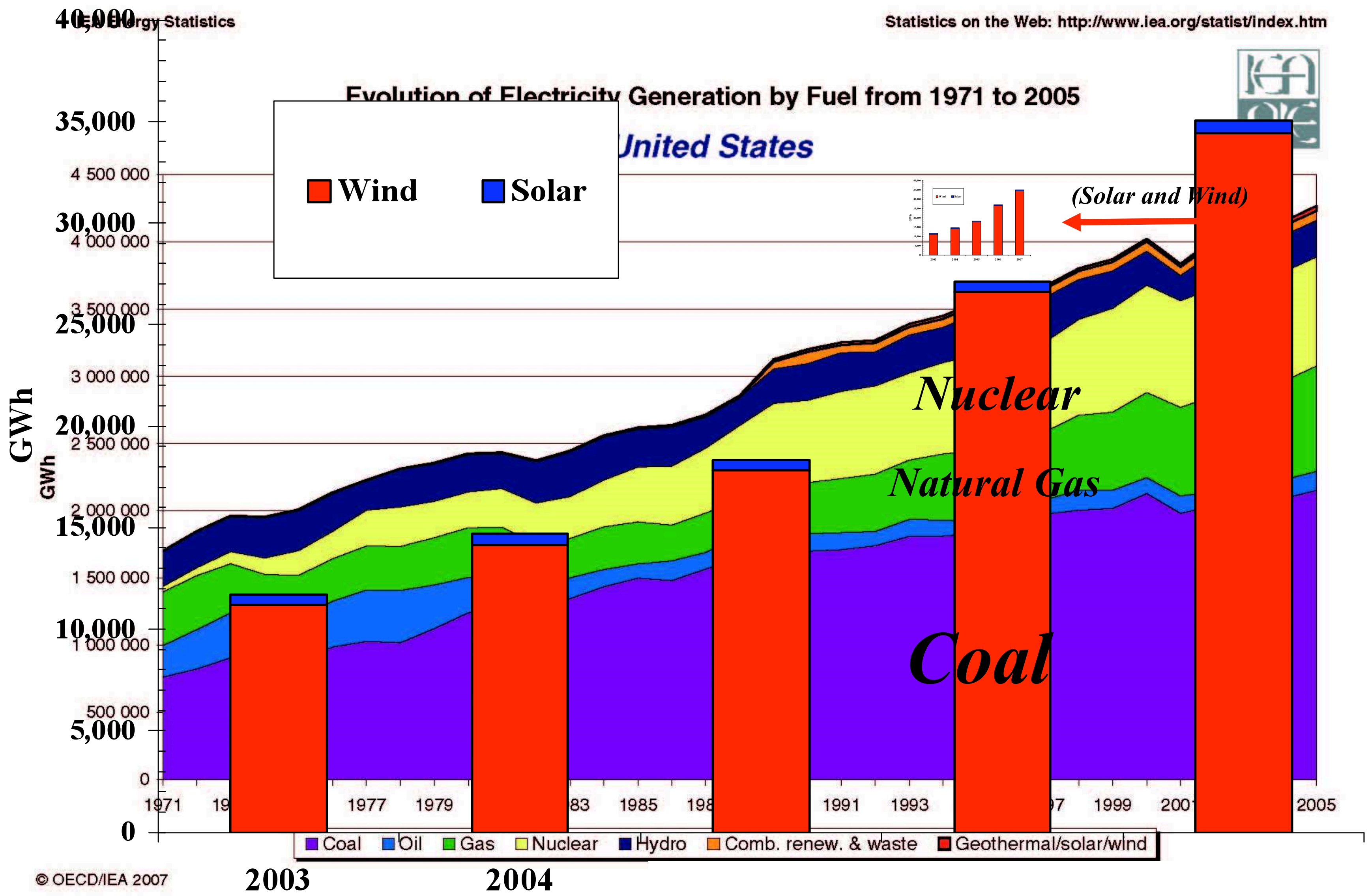


Coal-fired power plants are a major (and stable) producer of electricity

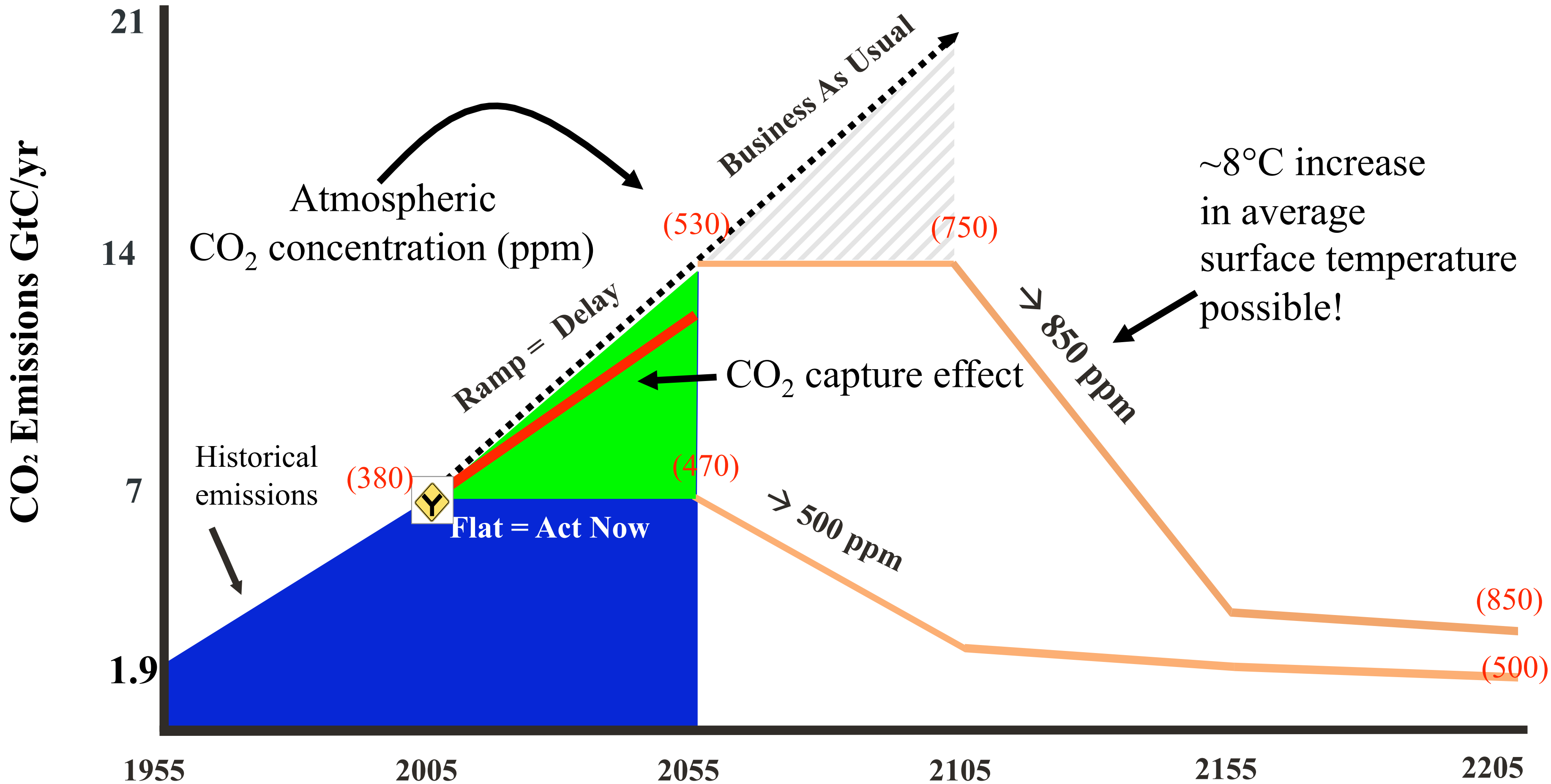
Coal Power Production Facts & Effects

- ~600 coal fired power stations in the US
- 11 are in Georgia
- Releases 1 kg CO_2/kWhr of production
- That means a typical 500 MW unit releases ~9 tons of CO_2 per minute!
- US power stations responsible for **~0.3ppm/yr rise in CO_2 concentration**
- 40% of CO_2 emissions are from power production!

Why not simply switch to less polluting power production? –*Scale.*



CO_2 capture from coal fired power plants is one bridging strategy to lower CO_2 emissions

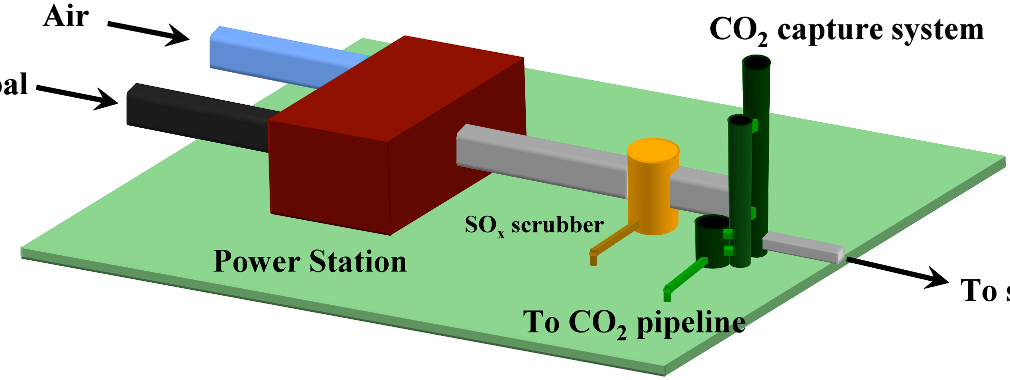


Source: Valerie Thomas

(Values) in parentheses are atmospheric ppm levels of CO_2

CO_2 Capture Strategies

- Post-Combustion Capture
  - Advantages
    - Straightforward retrofit
  - Disadvantages
    - Low CO_2 partial pressures
    - Large quantities of gas

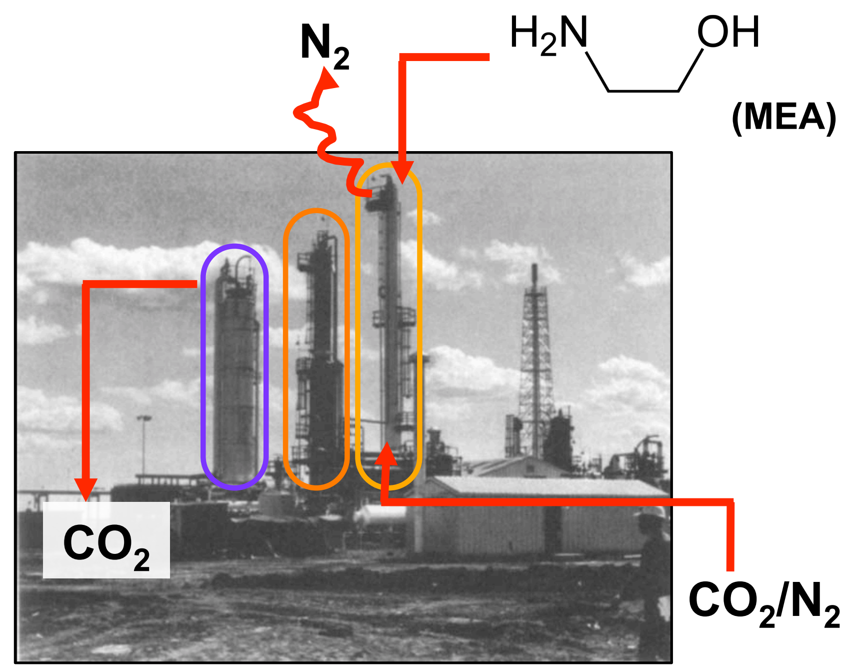


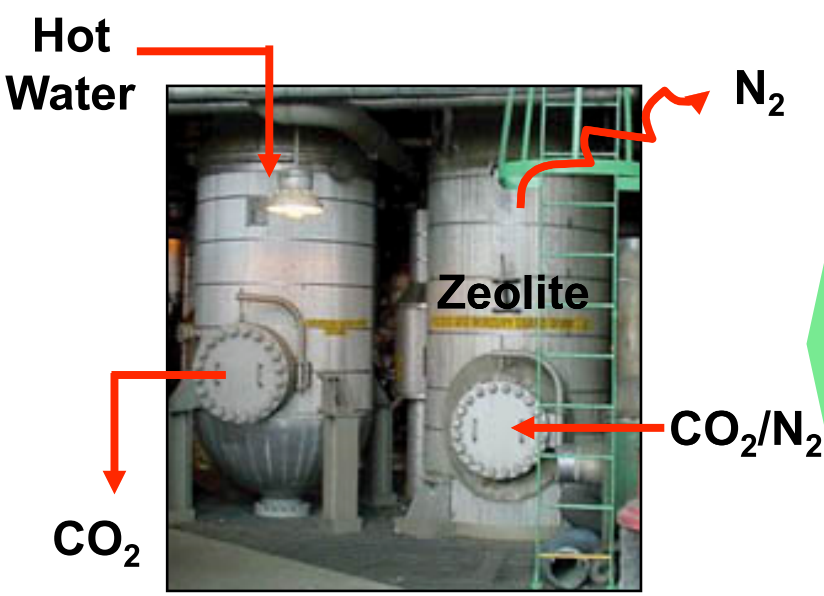
- The majority of the USA's power infrastructure cannot support other capture methods
- *Post-combustion capture is the single biggest target for effective carbon capture and storage*

Broad Routes for Post-Combustion CO_2 Capture

Absorption: Diffusion and/or reaction into a liquid (typically) to form a solution

– Examples: Liquid amines (monoethanolamine), chilled ammonia, ionic liquids

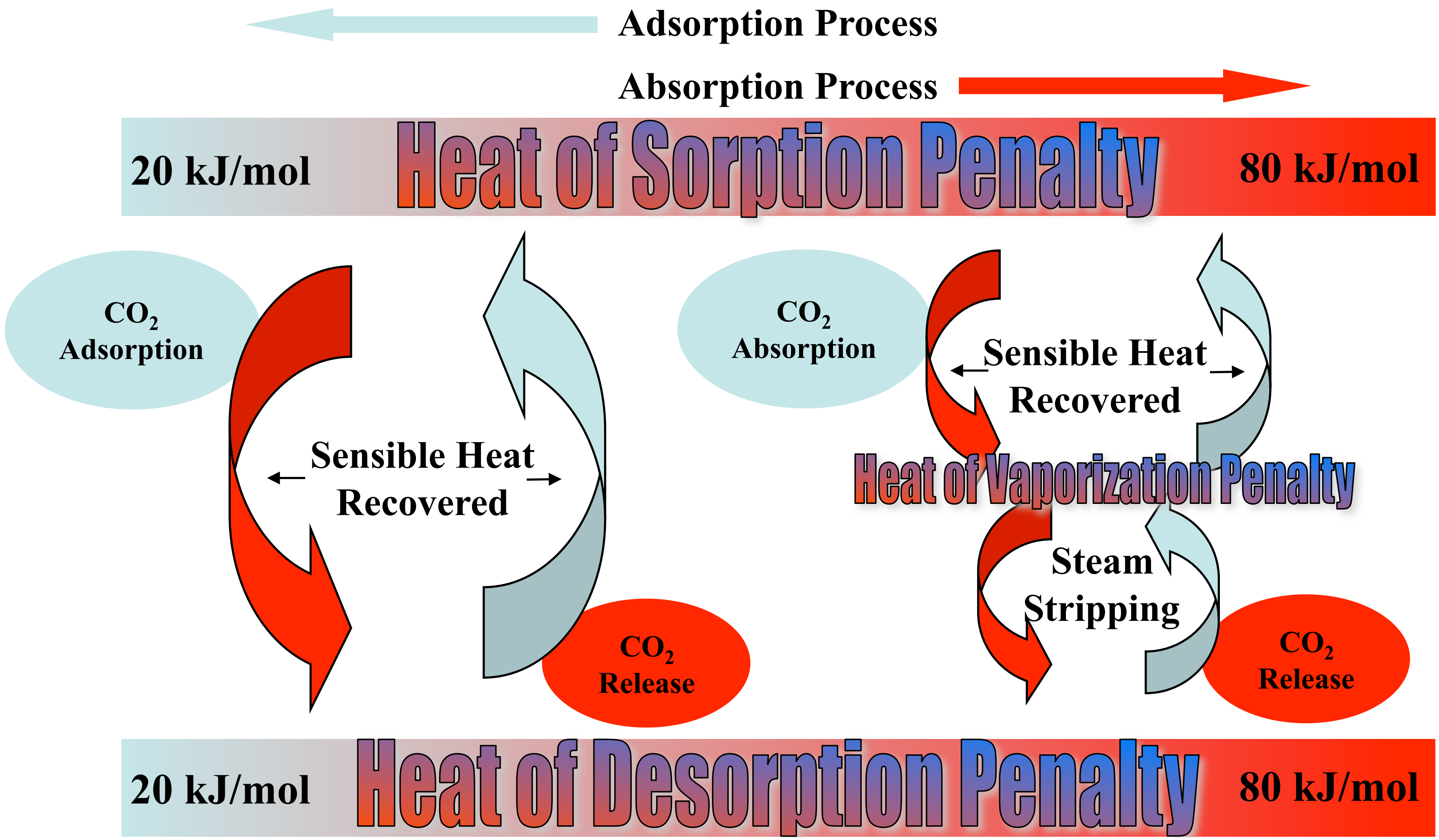




Adsorption: Accumulation of molecules on the surface of a material

– Examples: Zeolites, activated carbon, silicas, solid supported amines

Basic Energetic Comparison between Adsorption and Absorption

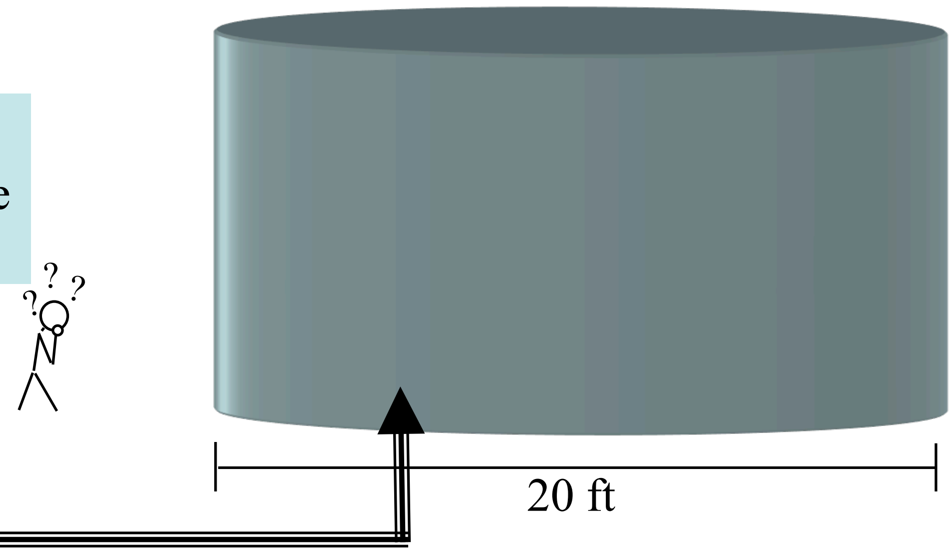


Fundamentally, adsorption processes have lower energetic needs than absorption processes

Issues with Packed Bed Adsorption Processes

Bed Pressure Drop:

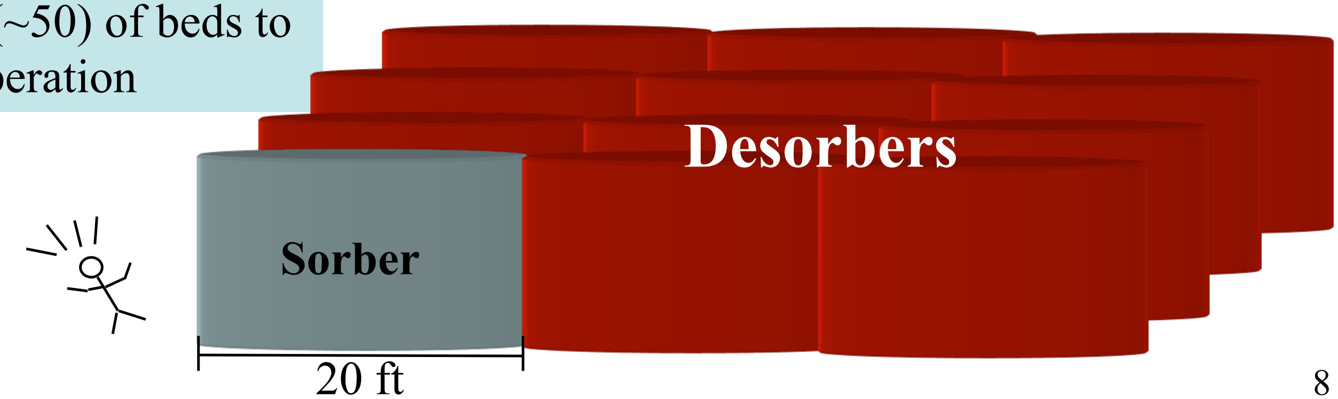
Need *very* large beds to minimize flue gas pressure drop



$1x10^6$ SCF per minute!

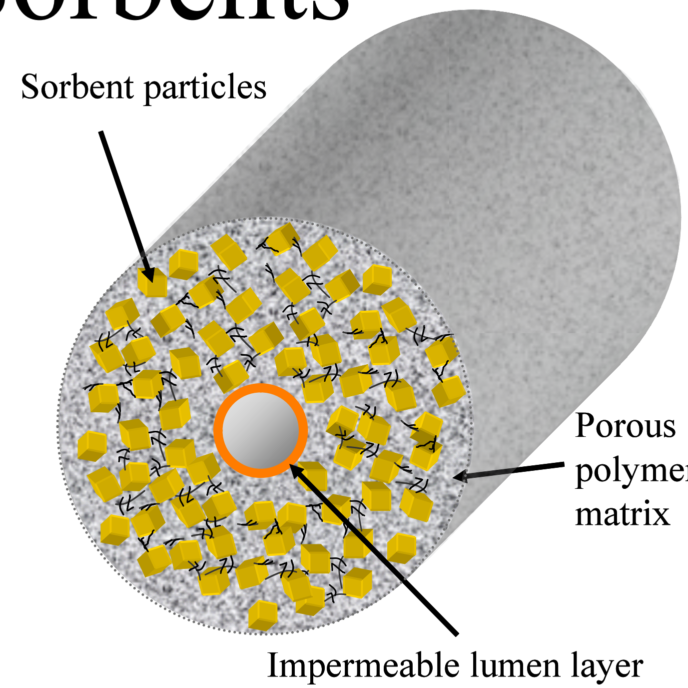
Slow Response Times:

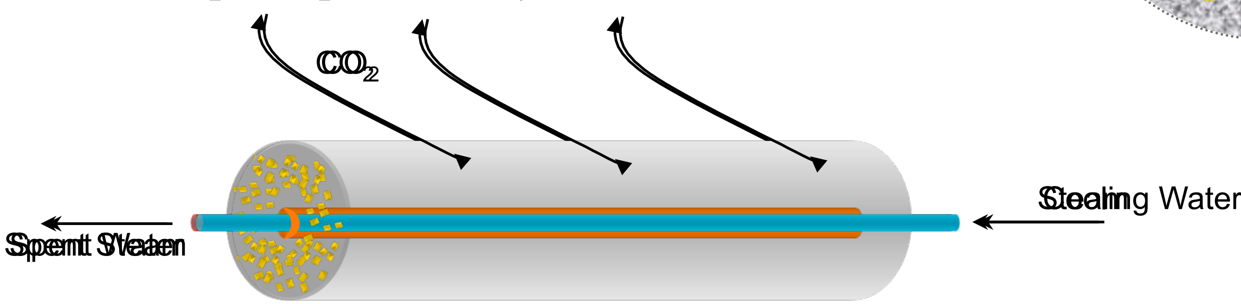
Need a high number (~50) of beds to ensure steady state operation



Hollow Fiber Sorbents

- **What is a hollow fiber sorbent?**
  - Hybrid material—polymer matrix with embedded sorbent particles
    - High solids loading
  - Designed for CO_2 capture
  - Novel lumen layer
  - *Utilizes favorable adsorption energetics while mitigating typical adsorption process deficiencies*

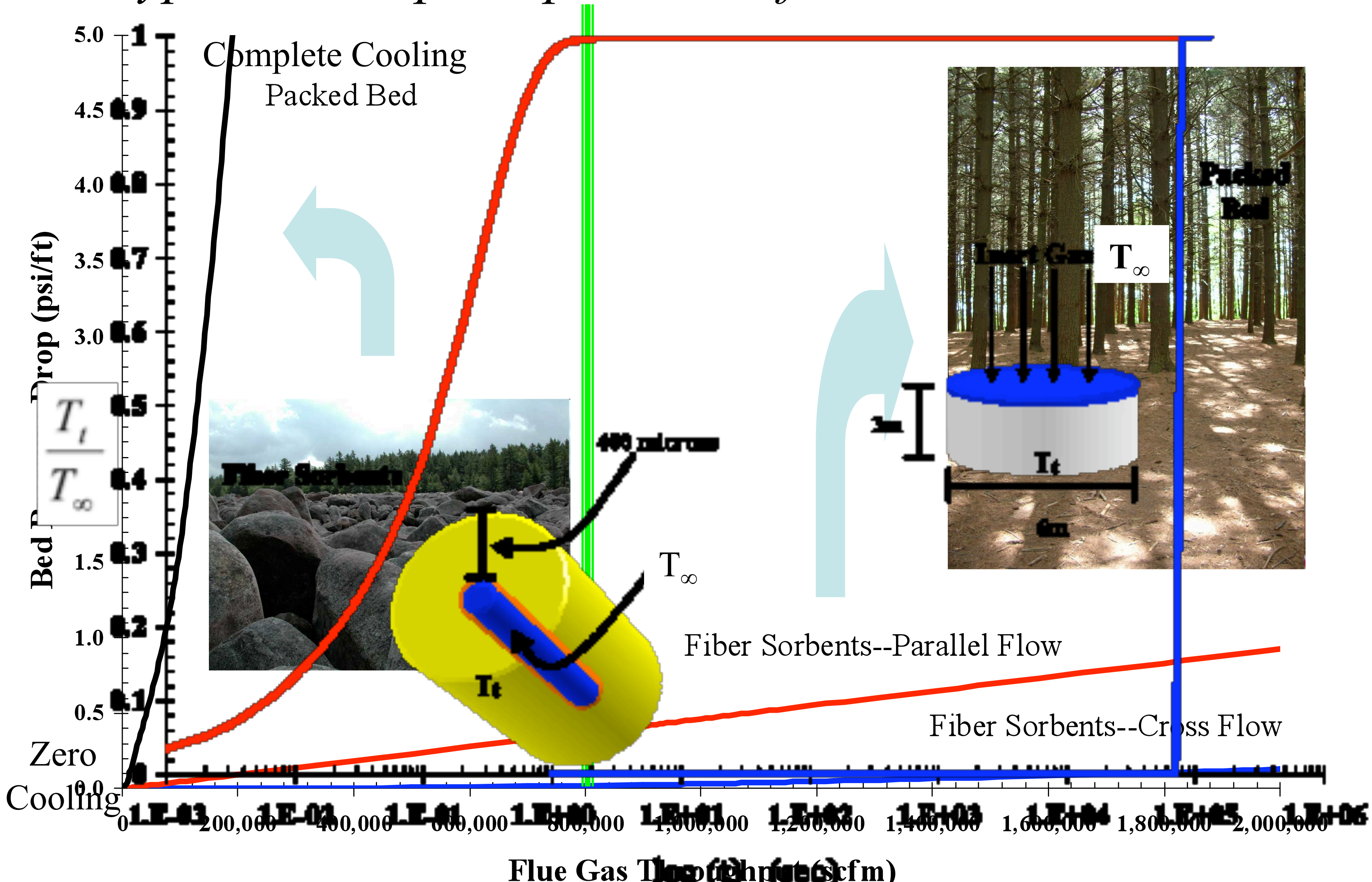




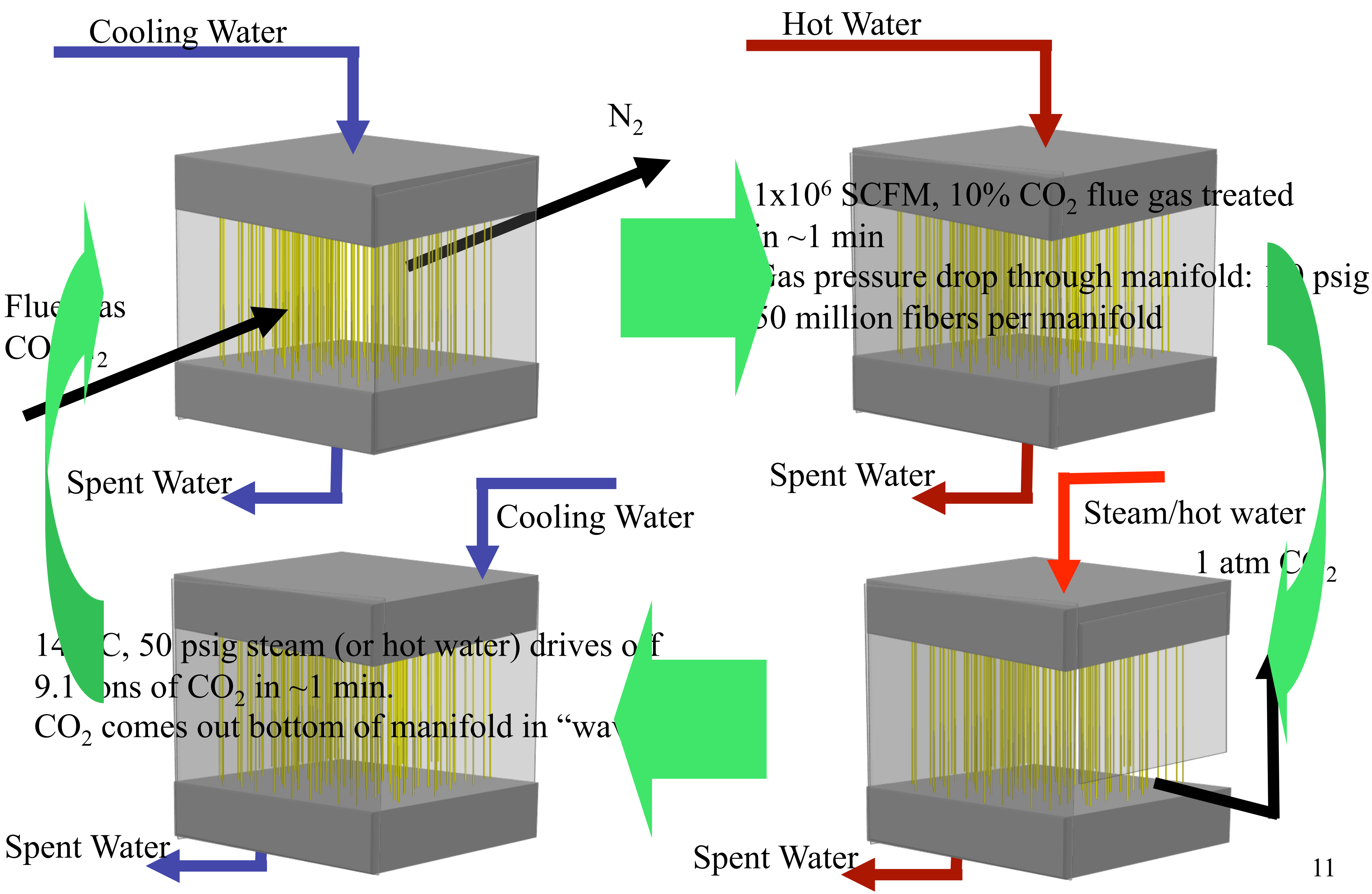
Cooling water used to aid in <u>sorption</u> process. Plant steam used for <u>desorption</u> step.

Thin fiber wall allows for rapid heat transfer. Barrier layer prevents mass exchange between heat transfer agent and CO_2

"Utilizes favorable adsorption energetics while mitigating typical adsorption process deficiencies"...but how?



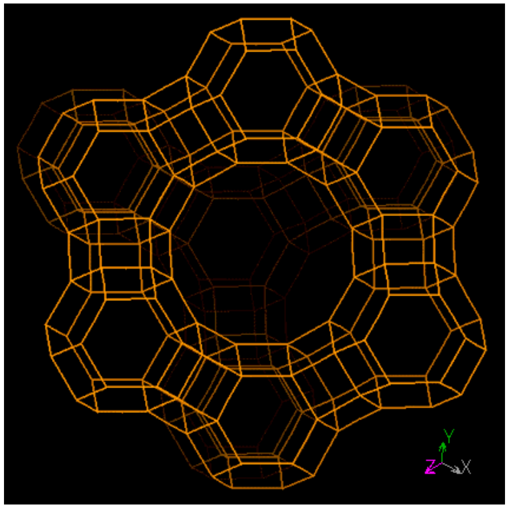
Using Fiber Sorbents in Thermal Swing Adsorption Mode



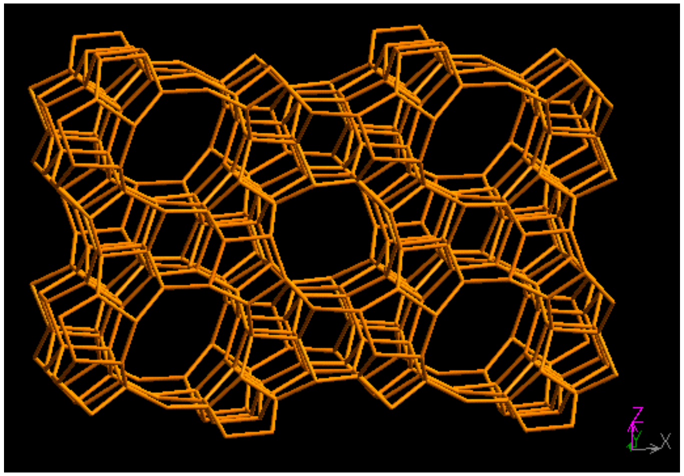
Adsorbent Selection

Sorbent	**Zeolite 13X**	**High Silica MFI**	**Anchored Amines**
CO_2 Dry Sorption Capacity	High	Medium	Low
CO_2 Wet Sorption Capacity	Very Low	--	Medium
Heat of Sorption	Medium	Low	High
Diffusion Coefficient [cm^2/s]	10^{-5}	10^{-7}	--

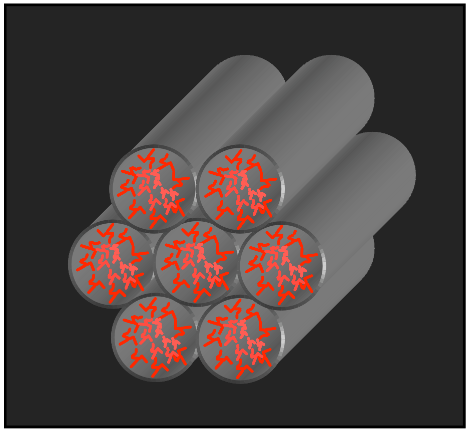
Zeolite 13X



High Silica MFI



Anchored Amines

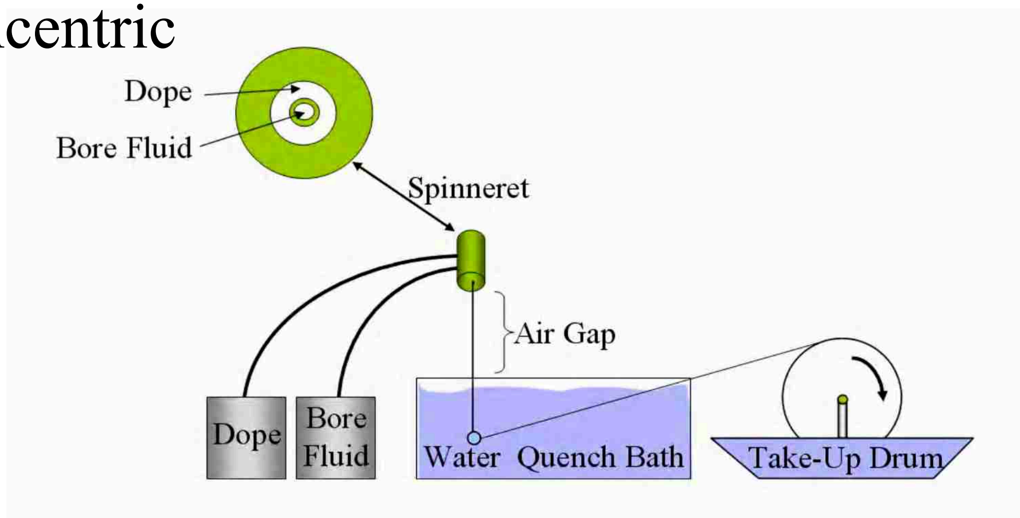


Hollow Fiber Sorbents: Fabrication

– Extrusion through a concentric annulus

– Fiber characteristics are controlled by:

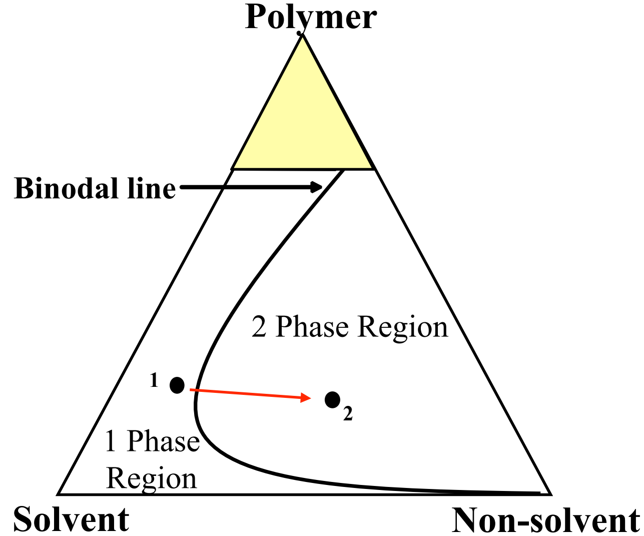
  - Extrusion rate
  - Fiber take up rate
  - Air gap height
  - Operating temperature



1 phase polymer solution

"Cloud Point"

2 phase polymer solution



Ternary Diagram

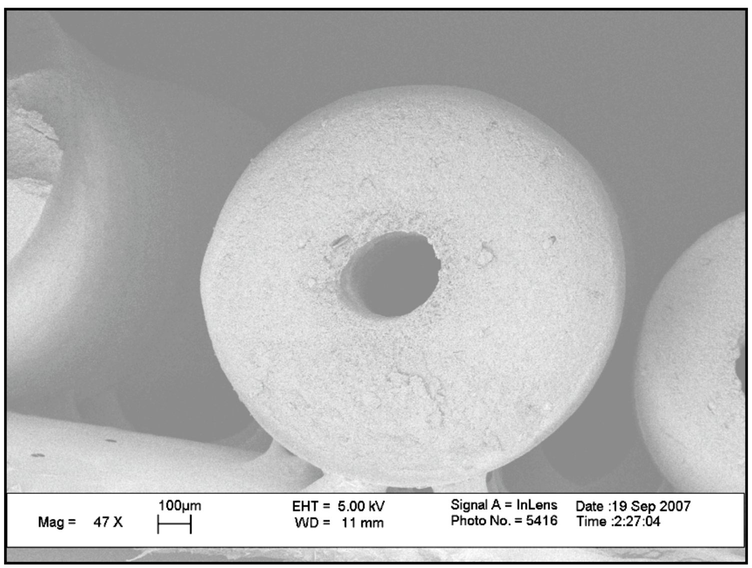
Fiber Sorbent Spinning: 75wt% Solids

Spinning Conditions

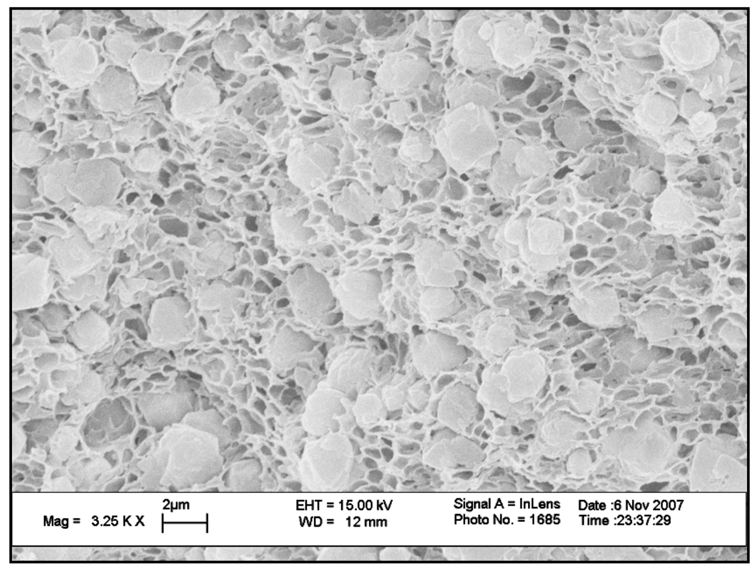
Core flow rate	1000 mL/hr
Bore flow rate	250 mL/hr
Bore Composition	80/20 NMP/H_2O
Operating Temp.	25°C
Take-up Rate	11.7 m/min
Air Gap	3.0 cm

Materials Used

Sorbent	Zeolite 13X
Polymer	Cellulose Acetate
Solvent	N-methylpyrrolidone
Non-Solvent	Water
Pore Former	Polyvinyl pyrrolidone

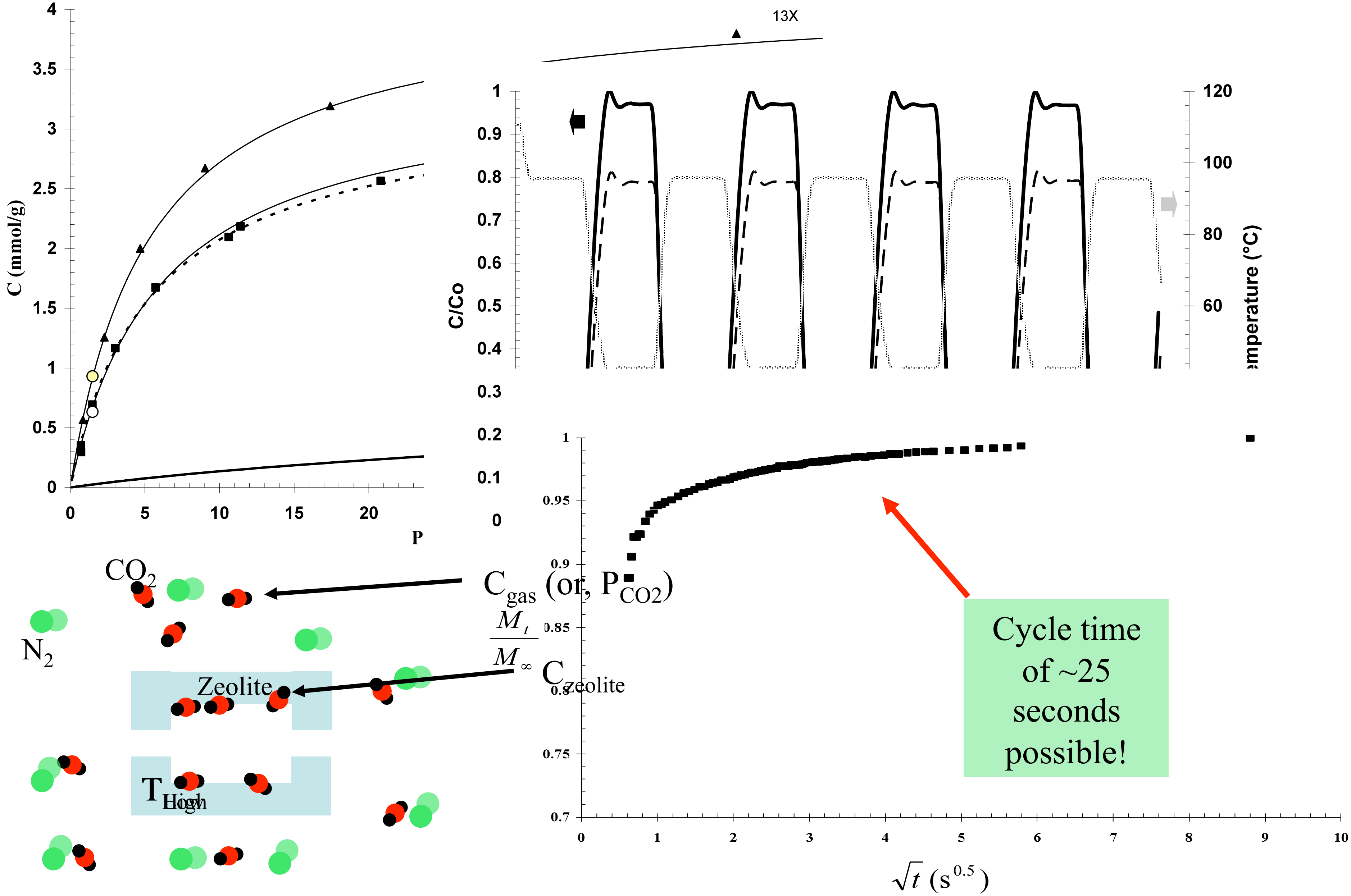


Fiber sorbent with correct dimensions



Zeolite 13X dispersed in cellulose acetate matrix

CO_2 Sorption Performance: Equilibrium, Cyclic, and Kinetic



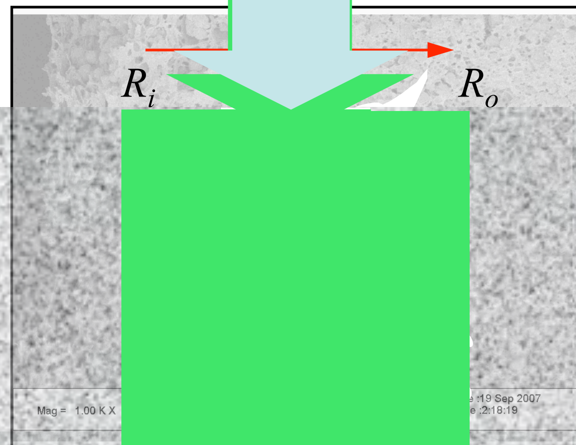
Barrier Layer Construction

N_2 Sweep

Neoprene/PVDC Latex Solution

Decreasing porosity in r-direction

- ~30 microns
- Gradient serves as a backstop for latex



Porosi… …orbents

Permeation Results:

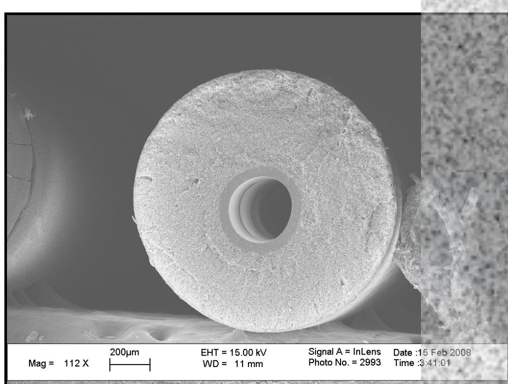
Uncoated: N_2~60,000 GPU

Coated: N_2~3.0 GPU

Expected: ~0.01 GPU

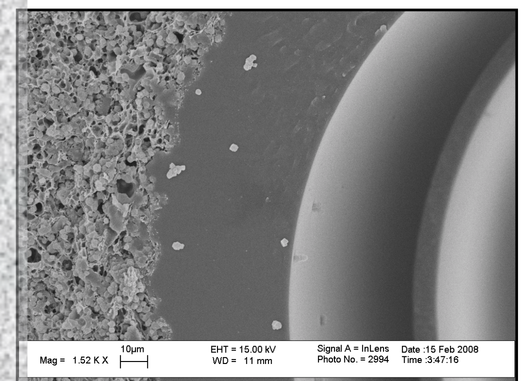
~5% steam/CO_2 losses

Fiber Sorbent Core Structure



PVDC lumen layer on fiber sorbents

…ion



Lumen layer surface

Neoprene/PVDC Barrier Layer

Future Work

- Improving barrier layer performance
- Extending fiber sorbent platform to new sorbents and polymers
  - MFI (sorbent) and Torlon (polymer)
- Fiber stability in constant water/steam cycles
- CO_2 capture costs and economics

Acknowledgements

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  – Particularly: Jason Ward, Ryan Adams, Vinod Babu, JR Johnson
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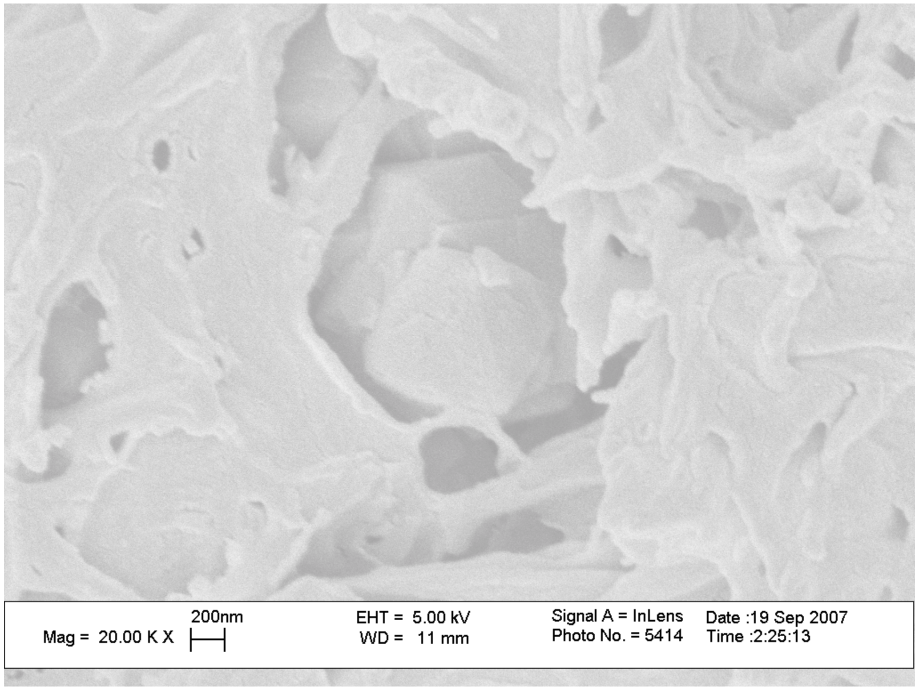
  – Particularly: Harry Deckman, Rusty Kelley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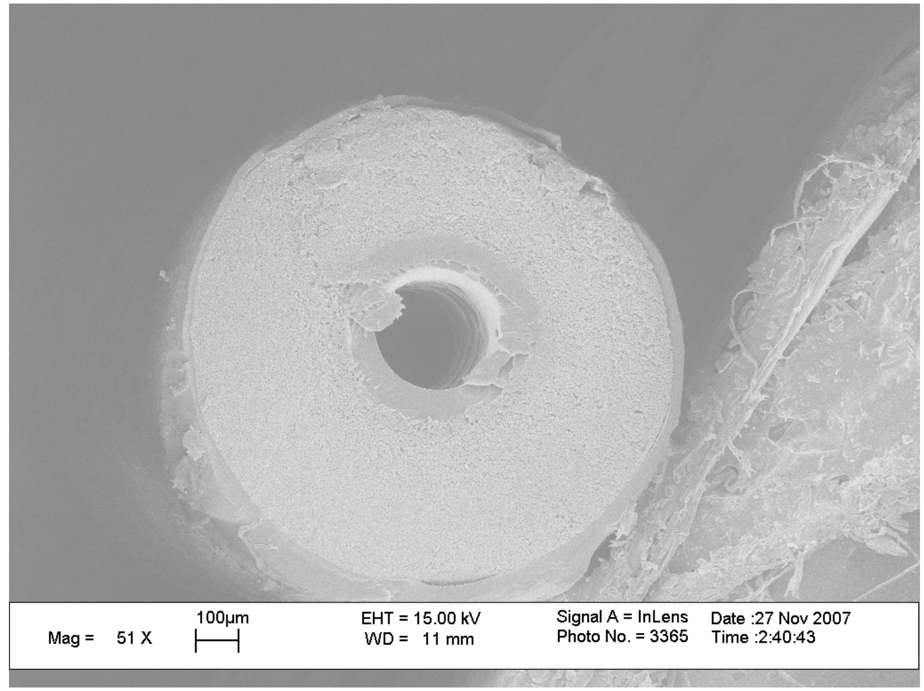
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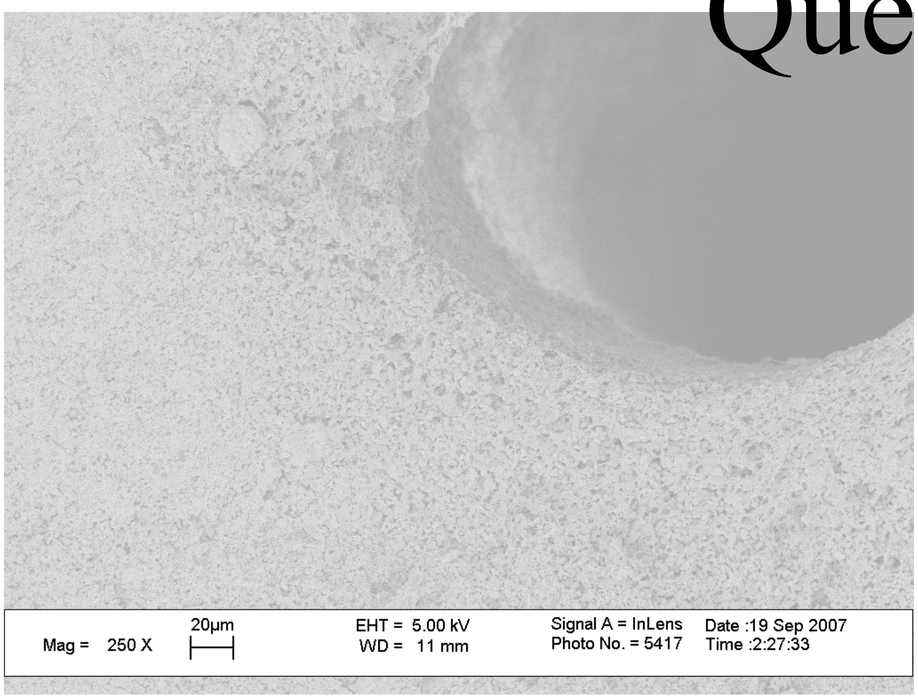
Questions?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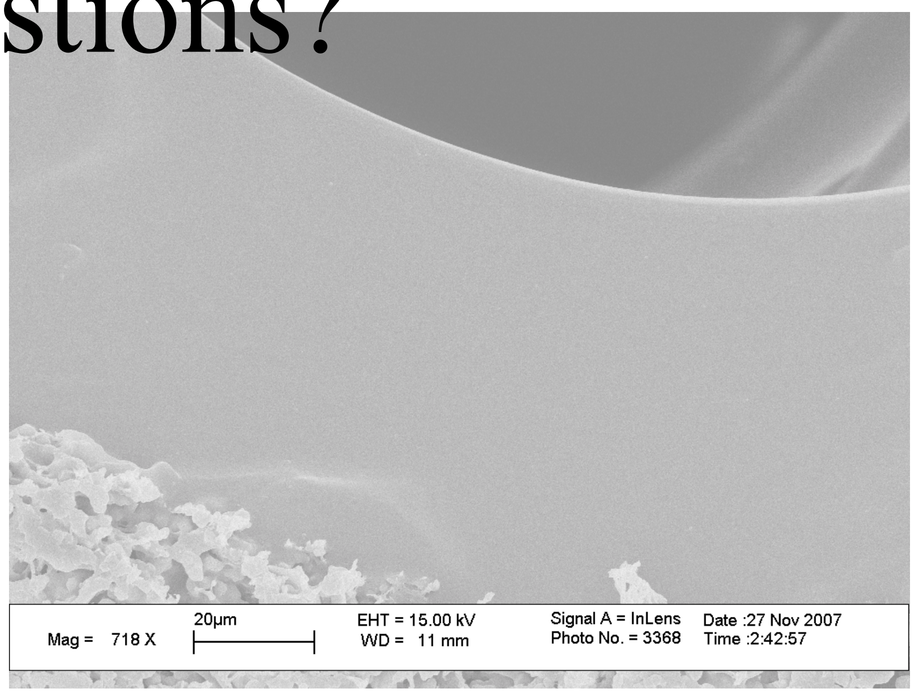
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