DOE Award #: DE-FE0007804

Rapid Temperature Swing Adsorption using Polymer/Supported Amine Composite Hollow Fibers

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Post-Combustion Sorbent-Based Capture
2012 NETL CO_2 Capture Technology Meeting
Sheraton Station Square, Pittsburgh, PA
Tuesday, July 10, 2012

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Budget:

DOE contribution:

Year 1:	$ 691,955
Year 2:	$ 847,672
Year 3:	$ 847,006
Total:	$2,386,633 (79%)

Cost Share Partners:

GE Energy:	$ 420,000
Algenol Biofuels:	$ 183,900
Southern Company:	$ 33,147
Total:	$ 637,047 (21%)

Total Budget: $3,023,680

Project Performance Dates – October 2011 to September 2014

Key Idea:

***Combine*:**

(i) state-of-the-art supported amine adsorbents, with

(ii) a new contactor tuned to address specific weaknesses of amine materials,

to yield a novel process strategy

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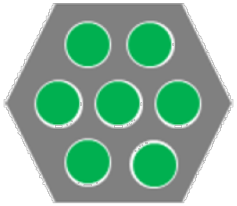
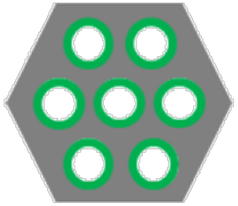
Supported Amine Adsorbent

Pros:
1) Can achieve high capacity in lab studies
2) Appear to achieve acceptable kinetics
3) Simple, scalable synthesis
4) High heat of adsorption (heat integration!)

Cons:
1) High heat of adsorption
2) Deactivation with O_2, steam, NOx, SOx
3) Low working capacity or degradation in practical contactors (fluidized bed)
   (i) can deactivate with direct steam contact
   (ii) can deactivate at high T in concentrated CO_2


Class 1


Class 2

No effective contactor demonstrated that addresses multiple “cons.”

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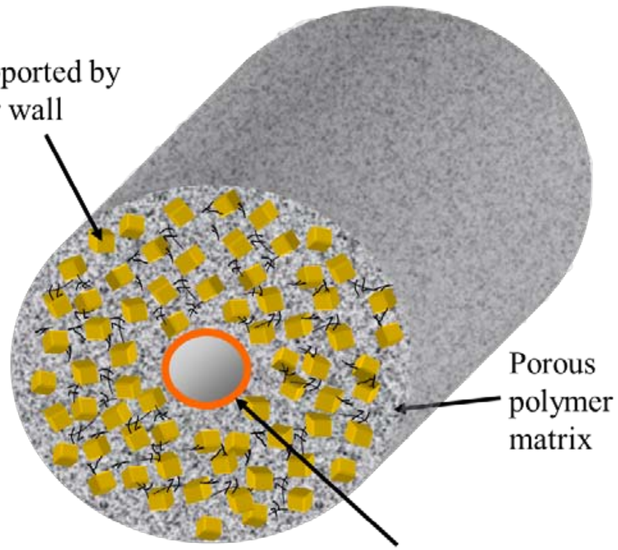
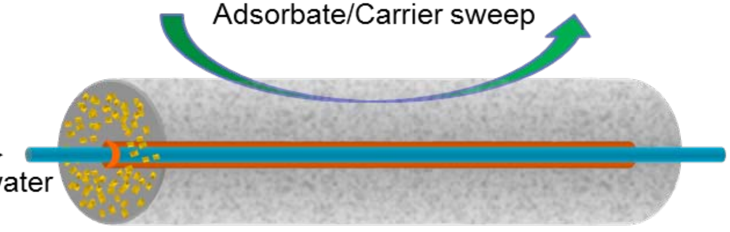
Hollow Fiber Contactor:

Fiber Bed: Achieves high surface area without excessive pressure drop

Hollow Fiber: Allows rapid heat transfer without contact of steam with amine





1) Spinning of high solid content (50-66 volume%), flexible hollow fibers, using low cos commercial polymers (e.g. cellulose acetate)

2) Building and demonstrating an RTSA system for CO_2 capture from simulated flue gas (13X as sorbent).

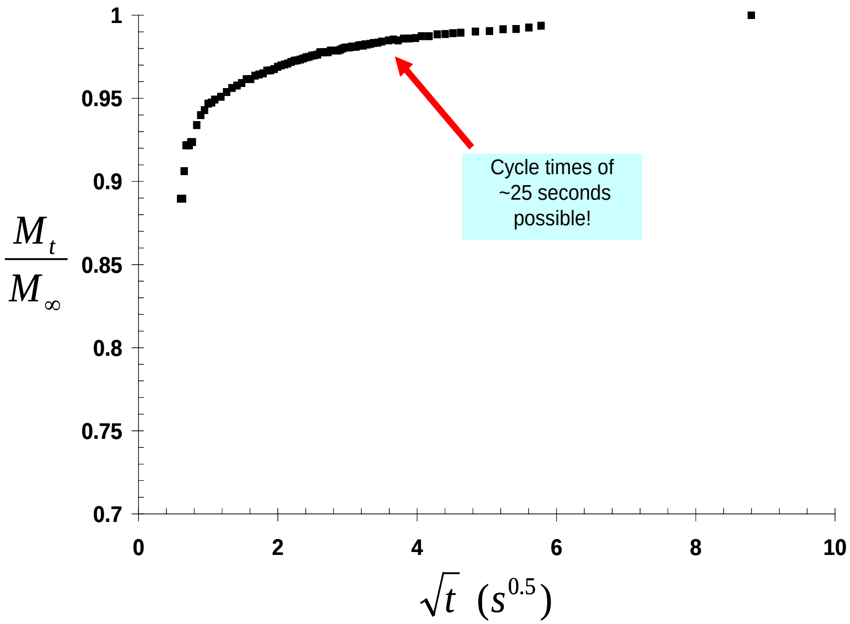
Lively, et al., *Ind. Eng. Chem. Res*. **2009**, 48, 7314.

Lively et al, International Journal of Greenhouse Gas Control, Accepted (In Press July 13th)

3) Constructing a barrier lumen layer in the fiber bore, allowing the fibers to act as a shell-in-tube heat exchanger.

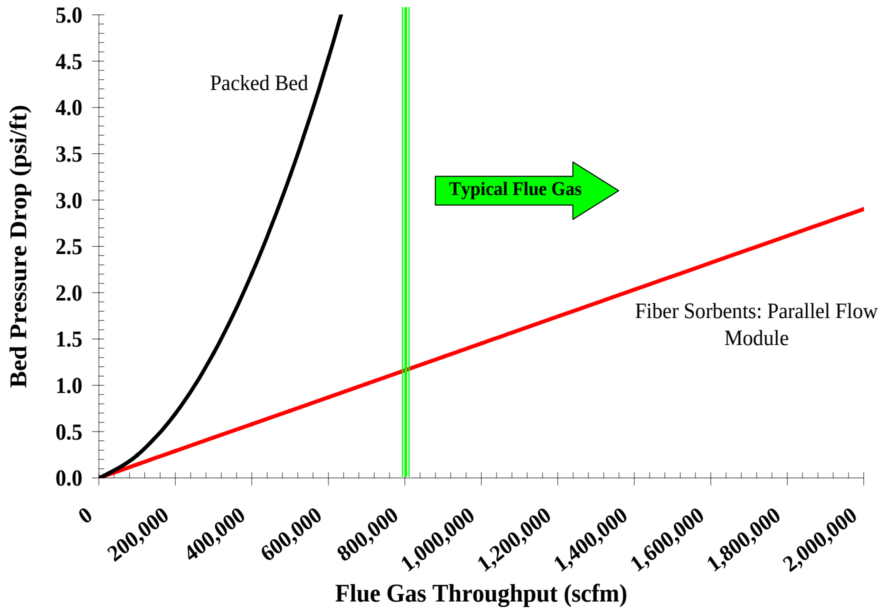
Lively et al. *ACS Appl. Mater. Interfaces* **2011**, 3, 3568.

Parallel Flow Hollow Fiber Contactors:



- Rapid adsorption cycles possible with zeolite 13X.
- Not yet experimentally demonstrated with amine sorbents

- Pressure drop through fiber modules is very low compared to fixed beds



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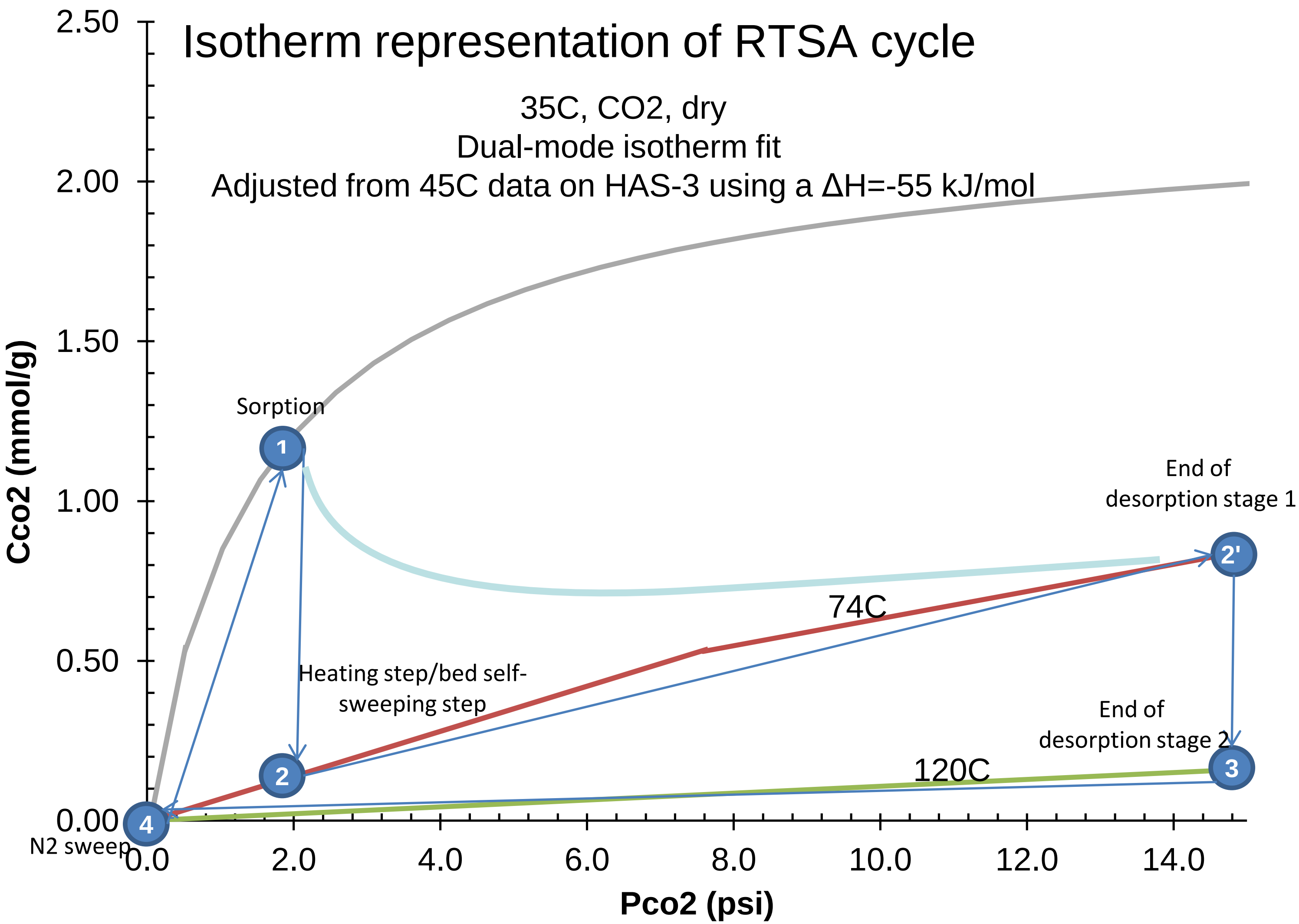
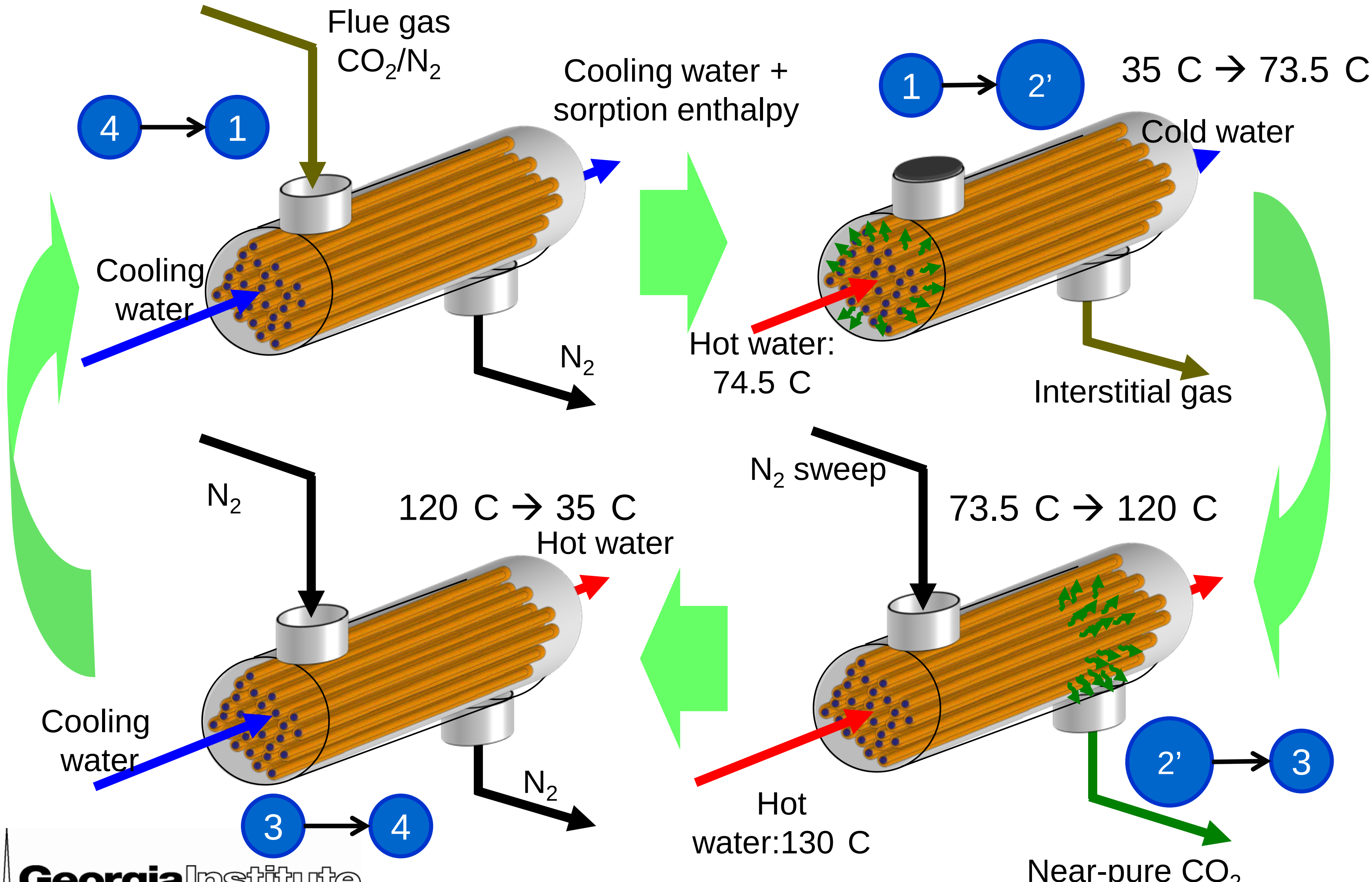
RTSA Representation on Isotherm



Drese, J. H., Choi, S., Lively, R. P., Koros, W. J., Fauth, D. J., Gray, M. L., & Jones, C. W. *Adv. Funct. Mater.*, 2009, 19, 3821-3832.

RTSA Qualitative Cycle



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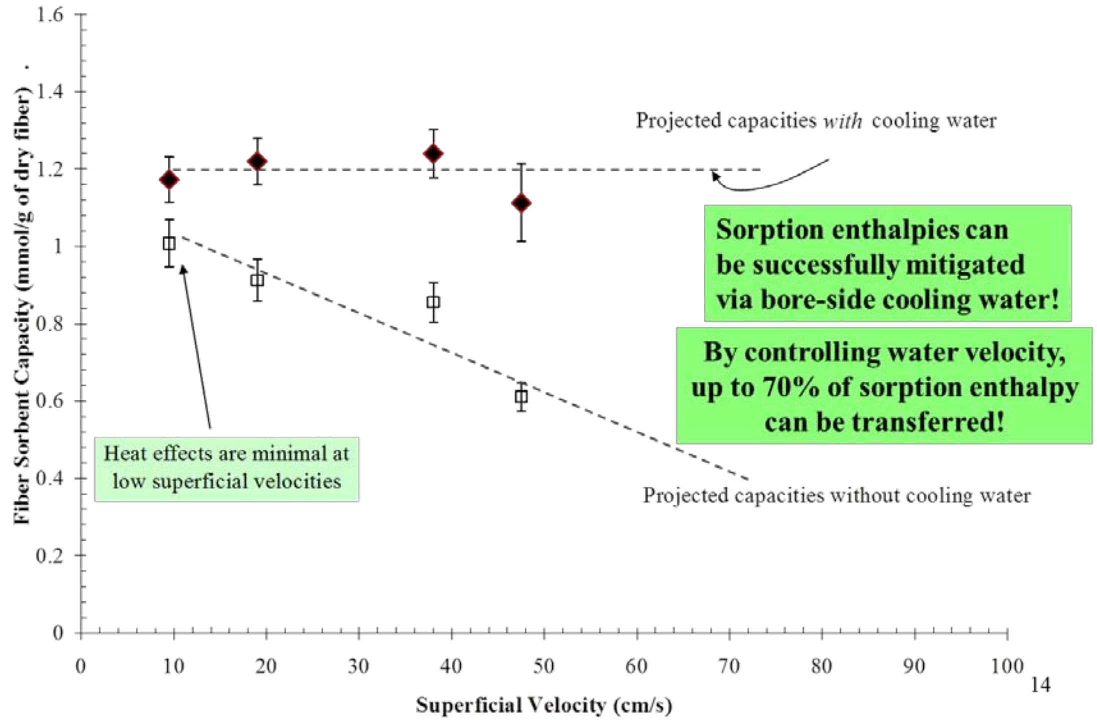
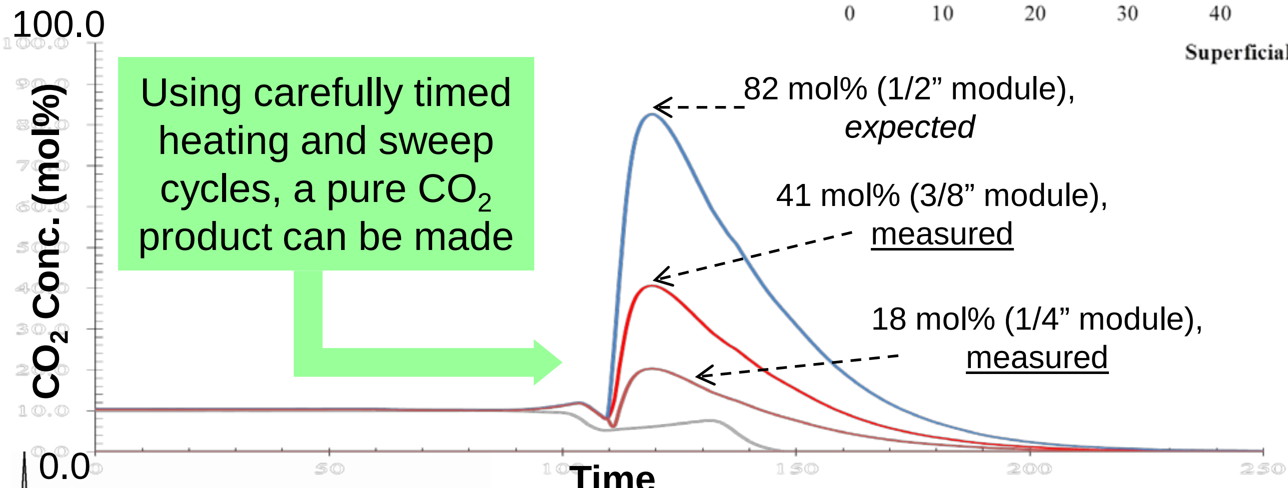
Key Points from Zeolite 13X Studies:

- Fiber sorbents show rapid (<10 second) CO_2 uptakes
- Fibers can be repeatedly thermally cycled with <u>no loss in capacity</u> or physical damage
- External boundary layers can be removed via close fiber packing (ε~0.3)
- Low pressure drops (< 1.5 psig) at high superficial velocities (~ 1 m/s)





Larger modules should result in near-pure CO_2 product streams

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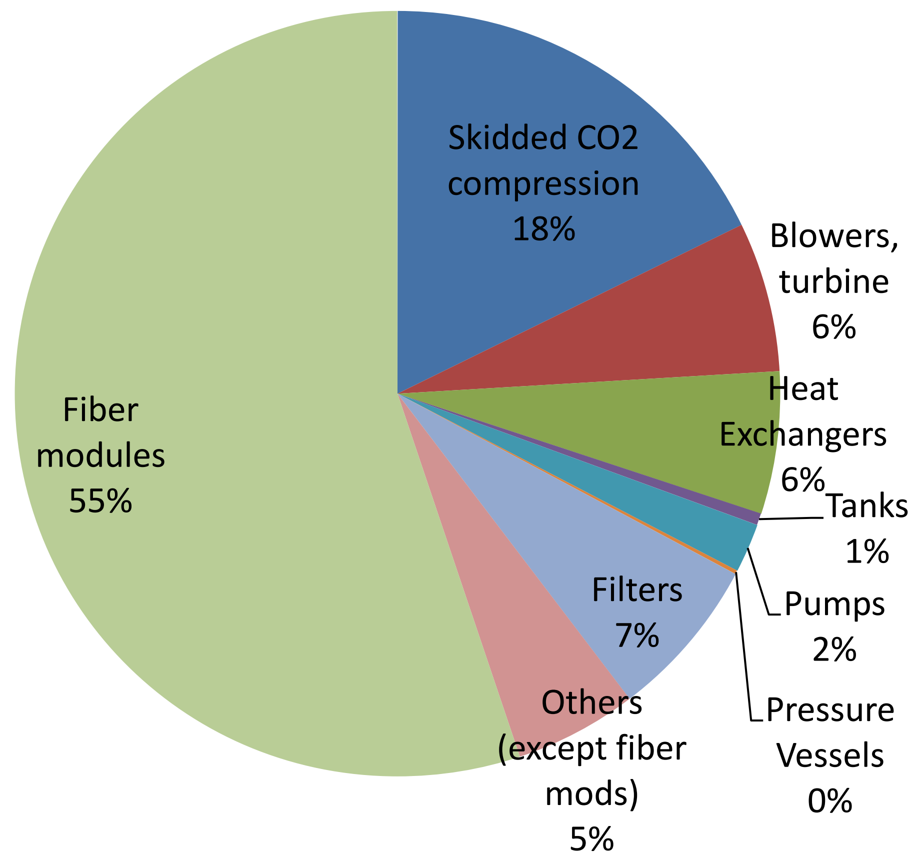
Cost Summary (Analysis performed by Trimeric Corp.)

Assumed installed fiber costs were $30/m^2 life of 3 years.

Total O&M Costs	MM$/year	57.87
Averaged annual cost of fiber replacement	MM$/year	24.07

		RTSA
Cost of CO2 Capture		
Total Annual Cost of CO2 Capture	MM$/year	176.6
CO2 captured	ton/year	4,342,000
	tonne/year	3,939,000
Cost of CO2 Capture	$/ton	40.7
	$/tonne	**44.8**
Impact of CO2 Capture on Plant Efficiency		
Change in Net Plant Efficiency	%	-7.3

RTSA System Cost Estimate
Total Purchased Cost $130.9MM



Escalation Factor = 1.249

DOE Technoeconomic Metrics – Sensitivity

- Sensitivity to fiber cost and fiber life

		Base Case	70% Fiber Costs	130% Fiber Costs	50% Fiber Life	200% Fiber Life
Cost of CO_2 Capture						
Annual Capital Charge	MM$/yr	118.8	97.1	140.4	118.8	118.8
Annual O&M Costs	MM$/yr	57.8	50.2	65.5	81.9	45.8
Total Annual Cost of CO_2 Capture	MM$/year	176.6	147.4	205.7	200.6	164.6
Cost of CO_2 Capture	$/ton	40.7	33.9	47.4	46.2	37.9
	$/tonne	44.8	37.4	52.2	50.9	41.8
Change in Cost of CO_2 Capture	%		-17	17	14	-7

Summary & Future Work

- Rapid Temperature Swing Adsorption enabled by a new contactor combined with solid amine sorbents.
- Cycle allows effective recovery of heat of sorption and sensible heat of module through integration of modules in different phases of operation.
- Preliminary Technoeconomic analysis indicates promise: $37 to $50/tonne
    - Relatively low parasitic load (1.25 escalation factor)
    - Capital cost sensitive to fiber life and base fiber costs

- Synthesize amines, spin fibers, and construct benchscale modules (0.5”x3’ 150 fibers)
- Model single fiber through the cyclic behavior and validate against benchscale
- Optimize sorbent, fiber and module parameters to maximize heat recovery
- Refine Technoeconomic model with experimental parameters

Acknowledgements

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People

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Dr. Fateme Rezaei – sorbent synthesis and fiber modeling
Ms. Jayashree Kalyanaraman – fiber modeling
Ms. Grace Chen – sorbent synthesis & characterization / fuel gas upgrading

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