High-Efficiency Post Combustion Carbon Capture System

DOE SBIR Phase 2 Contract # DE-SC0017221

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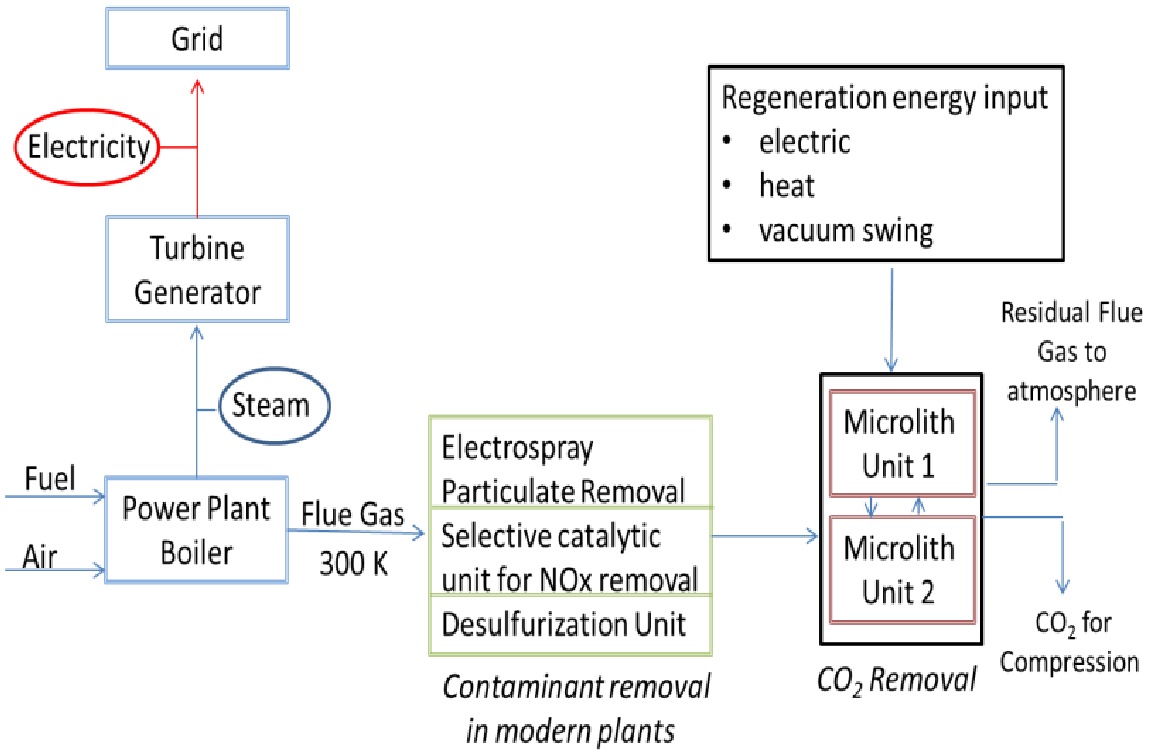
Outline

- Introduction
- Background
- Phase II Technical Objectives
- Phase II work plan
- Results to date

Innovation



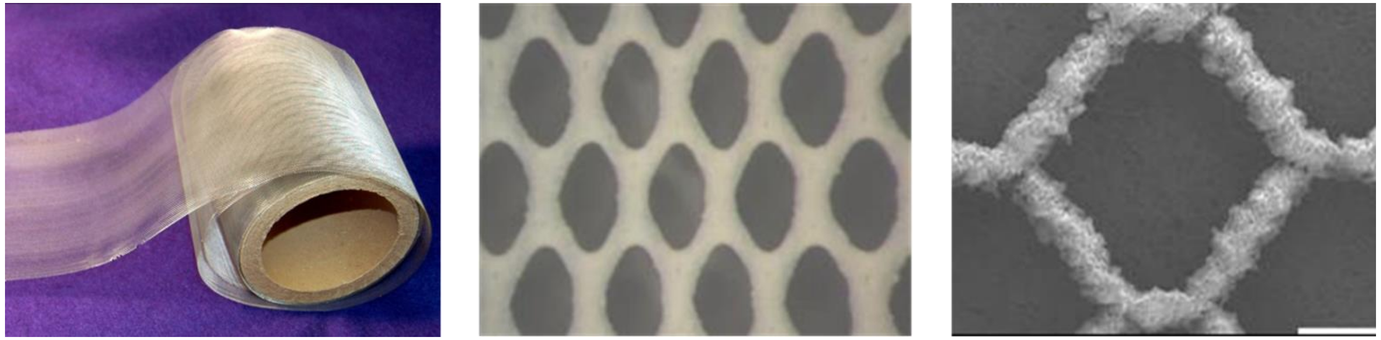
Compact, modular Post Combustion Carbon Capture System utilizing high internal volume nanosorbents, for carbon capture, supported on a tailorable mesh substrate (Microlith®).

Our system enables

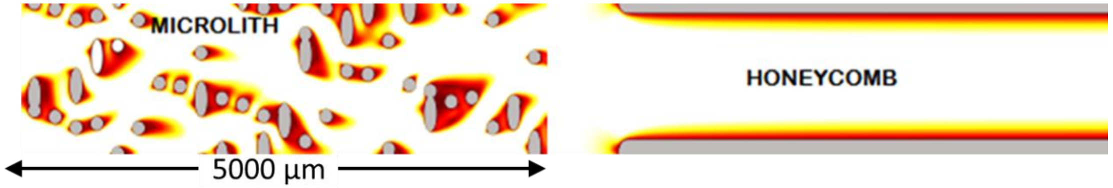
- low pressure drop,
- high volumetric utilization,
- high mass transfer,
- lower energy of regeneration.

Capital and operating costs are reduced based on lowered energy demand in capture and sorbent regeneration.

Microlith Substrate



Microlith mesh coated with sorbent, cell opening 600 μm

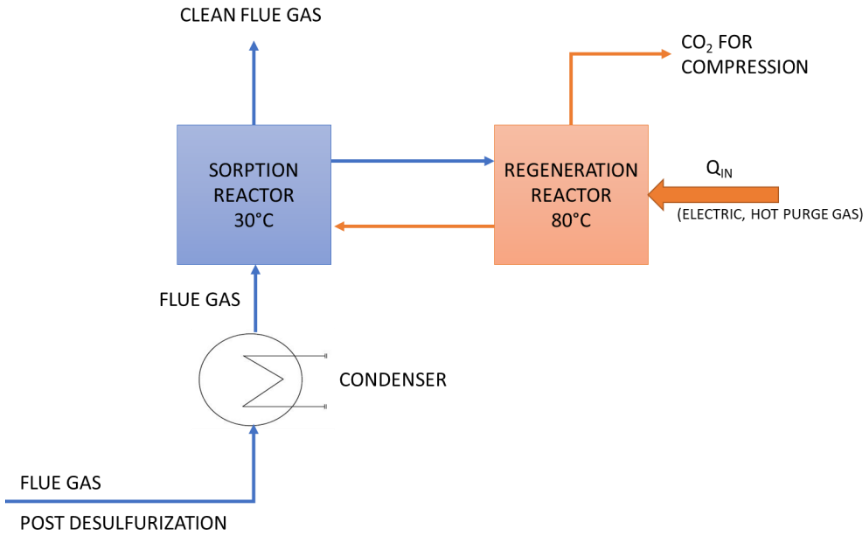


CFD analysis of fluid flow behavior in 2D cross-sections through a stack of 21 Microlith mesh elements (left), a single channel in a honeycomb monolith (right).

Benefits of Microlith® substrate:

- High surface area per unit volume
- High heat & mass transfer rates
- Low sorbent usage & small size
- Lower ΔP vs. pellet sorbent bed
- Comparable ΔP vs. monoliths
- Design flexibility (e.g., planar, radial)
- Modular design, easily scalable
- Resistive heating

PCCC Unit



Proposed PCCC module assembly:

- Two modules working in parallel one adsorbing and one desorbing
- Some water condensed at inlet – heat could be recovered for regeneration
- Regeneration heat can be supplied resistively (heating up the mesh) or by heating purge gas with waste heat.

Phase II Technical Objectives

- Optimize the sorbent to higher capacities with good selectivity towards CO_2 . Sorbents are produced at the large scale (can be easily scaled to tons) with acceptable cost.

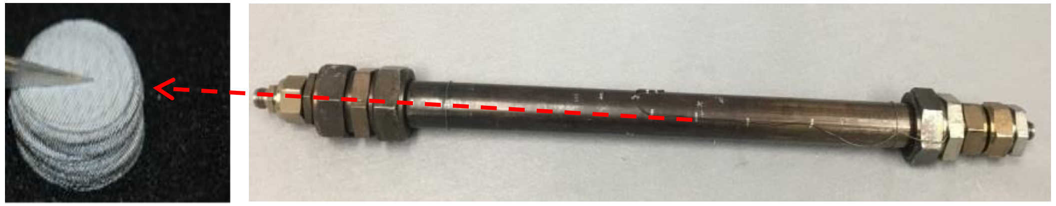
- Optimize mesh geometry to achieve higher loadings without affecting sorbent structure at increased production capacity.

- Continue plant modeling from Phase I with steady and dynamic process and CFD modeling of our system to simulate a scale-up design.

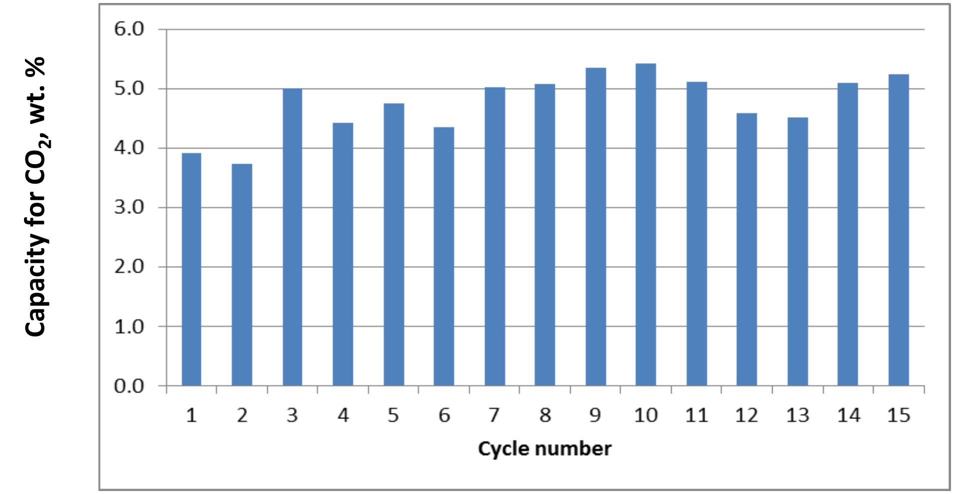
- Integrate with DOE Carbon Capture Initiative Software.

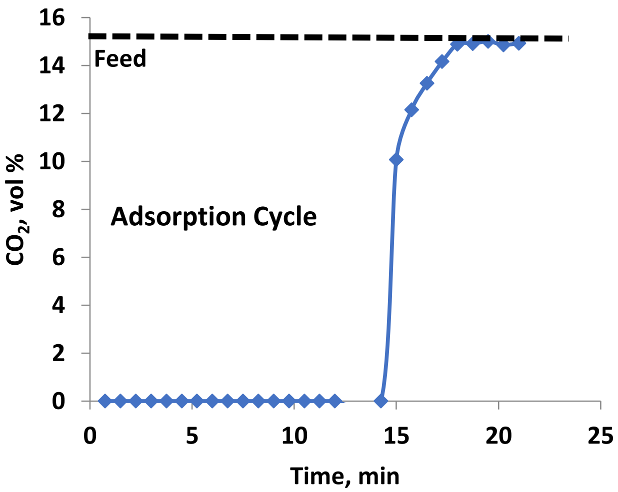
- Full scale economic modelling of CO_2 capture with sensitivity analysis and balance of plant components to demonstrate achievement of the DOE target of under 35 $/ton of CO_2 captured by 2035.

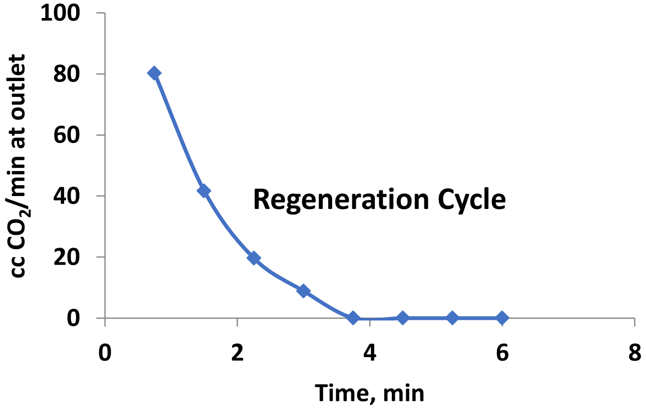
Sorbent/Microlith Test Results – Phase I



Test assembly for sorbent coated on Microlith mesh for rapid adsorption-desorption capability at low pressure drop; left- micrograph of sorbent coated on support (opening is 800 μm) .







- Stable performance over multiple cycles of adsorption desorption of CO_2 from simulated flue gas (15 % vol. CO_2).
- Fast breakthrough and fast regeneration.
- Means for increasing capacity currently being developed at PCI.

Phase II Work Plan

Task 1: Sorbent optimization (ongoing): Optimization of a durable, robust sorbent material that can meet the CO_2 working capacity demand.

Task 2: Substrate and coating optimization (ongoing): Demonstrate an adhesive and cohesive robust sorbent-based coating on the mesh substrate that meets target loadings without compromising CO_2 retention capacity.

Task 3: Lab-scale durability and operating envelope (ongoing): Determine a lab-scale operational envelope for the optimized system that meets target capacity is regenerable at low temperatures and demonstrates durability over at least 200 cycles with simulated flue gas.

Task 4: Modelling (ongoing): Develop a CFD model that accurately describes the Microlith-based full scale PCCCS unit with relevant energy and mass fluxes.

Phase II Work Plan – ctd.

PCI Precision Combustion, Inc.

Task 5: Small-scale module assembly and testing (not started): field trial with actual flue gas to demonstrate the efficacy of the system and further refine operating conditions and parameters.

Task 6: Economic modelling (not started): Fully develop an economic model that demonstrates we can meet projected cost targets for CO_2 capture 35 $/ton of CO_2 avoided by 2035.

Task 7: Quarterly reports and a final report as required will be prepared. The final report will include recommendations on the feasibility of proceeding with Phase III pilot scale testing and potential for full-scale commercialization.

Results to Date

Expand sorbent selection to additional sorbent materials and composites:

Rapid testing of material:

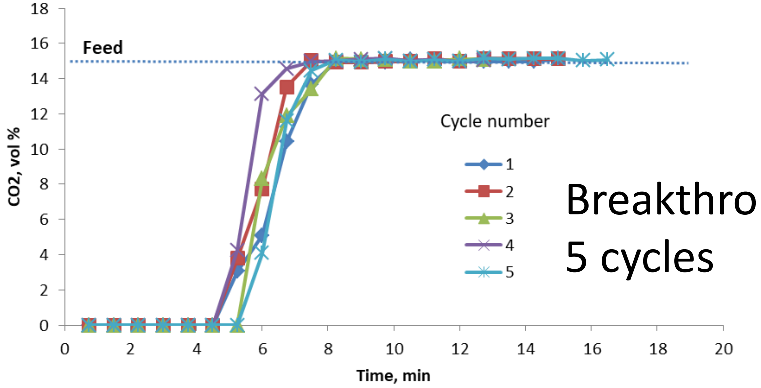
- Fixed bed flow-through with simulated flue gas.
- Multi-cycle TGA analysis.

Investigate pathways for rapid large-scale production of sorbent-substrate system with minimal material loss

Set up CFD model of full scale PCCC unit

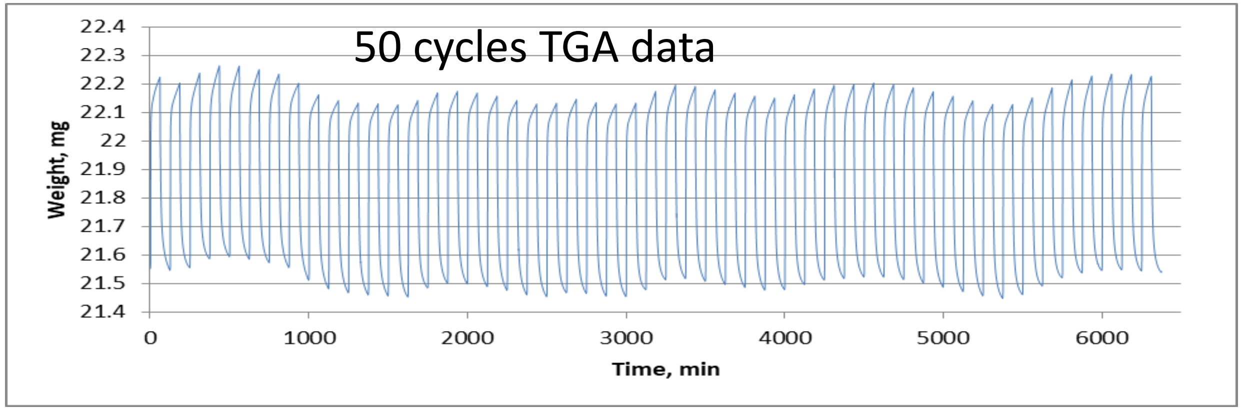
Sorbent Evaluation – Rapid Selection

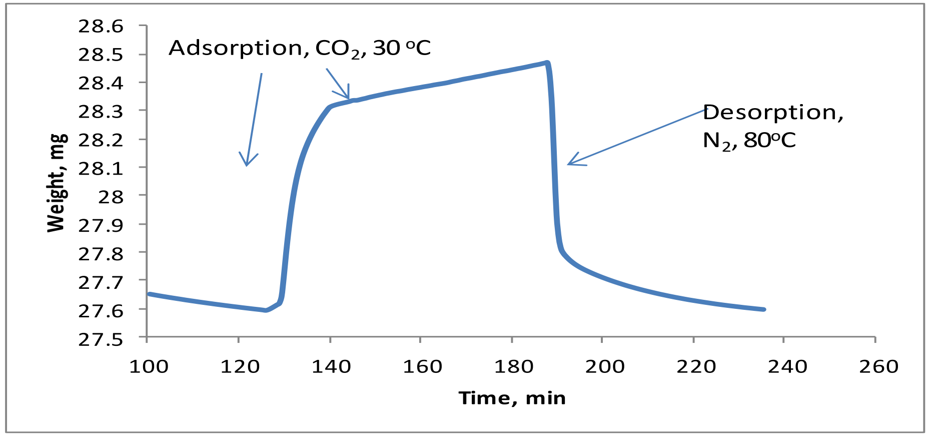
Fixed bed rapid breakthrough cycling with simulated flue gas (capacity) – thermal regeneration at 80 °C



Breakthrough curves
5 cycles

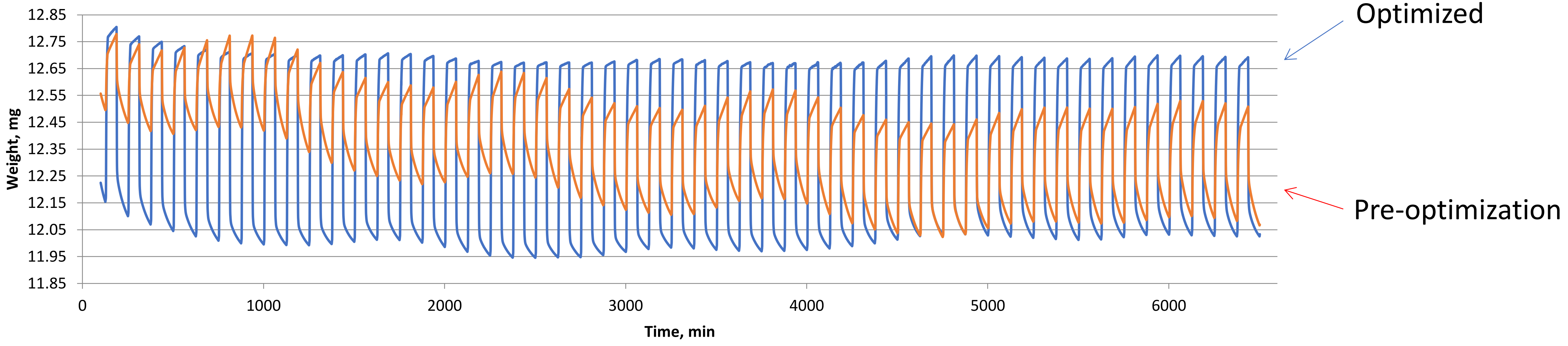
Thermal gravimetric analysis (cyclic stability)
Adsorption in CO_2 at 30 °C
Desorption in N_2 at 80 °C





Detail of TGA cycle showing fast adsorption/ desorption kinetics
Allows for operation at high space velocity (low residence time)

Sorbent Optimization



CFD Modelling

Axisymmetric model of the adsorber design is being developed in OpenFOAM with the Microlith substrate being modeled as porous media. Phase I experimental data is currently used to validate the CFD approach.

Model will yield:

- Simulated breakthrough behavior (Exit CO_2 as function of time for provided flow/temperature regimes).
- Simulated desorption behavior (Exit CO_2 as function of time for provided flow/temperature regimes).
- Flow, temperature, and species distribution for adsorption and desorption processes modelled.
- Pressure drop as a function of reactor design.
- Simulation campaign to investigate effects of design parameters on CO_2 capture.

CFD model will be integrated with DOE's Carbon Capture Initiative Software.

An economic model of the PCCCS will be developed using the model data to determine the overall cost per ton of CO_2 captured.

Phase II Targets

Regeneration Energy Phase I	618.5	KWh/ ton CO_2
Regeneration Energy Phase II	366.1	KWh/ ton CO_2
Amine system heat of regeneration	1100	KWh/ ton CO_2

CASE	No capture	MEA	PCI system
Increase in cost of electricity, %	0.0	63.3	39.2

Targets achieved through:

- Increased sorbent capacity
- Sorbent stability over multiple cycles
- Low regeneration temperature
- Fast kinetics of adsorption/desorption

Thank you!