Novel, Efficient Contactor Technology to Substantially Lower the Cost of Direct Air Capture of CO_2

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Introduction:

- Direct CO_2 removal from air, also known as Direct Air Capture (DAC), is gaining much attention to extract CO_2 from air and to decrease its atmospheric concentration.
- To have a major impact, DAC must be performed at large scales, requiring costly infrastructure, equipment, and sorbents, as well as high adsorption / desorption energy.
- A well-known Techno-Economic Analysis (TEA) from the National Academy of Sciences shows sorbent cost to be a major contributor to the high DAC cost; i.e., saving on sorbent utilization can distinctly reduce the DAC cost.[1]
- Superior mass transfer in Emissol DAC contactor makes available sorbent saving by 40% and no reduction in captured CO_2 , educing the overall DAC cost by 30%.

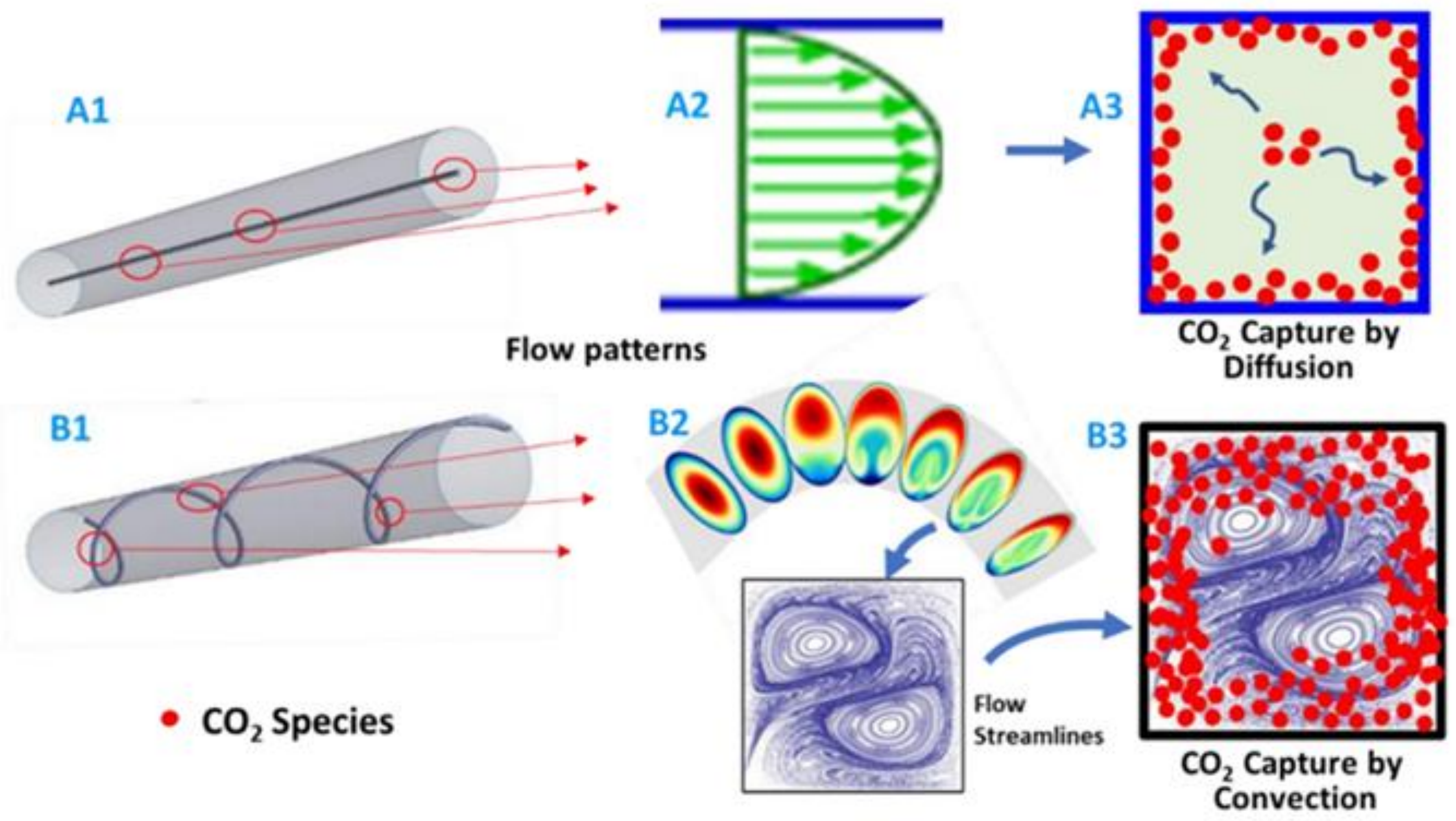


Figure 1. Comparing conventional, monolithic contactor having straight channels with Emissol novel contactor having spiral channels. A1: Straight channels. A2: Laminar flow in straight channels. A3: CO_2 capture through diffusion. B1: Spiral channels. B2: formation of vortical flows. B3: CO_2 capture via convection, shown (Figure 2) to outperform conventional contactors.

Results & validation:

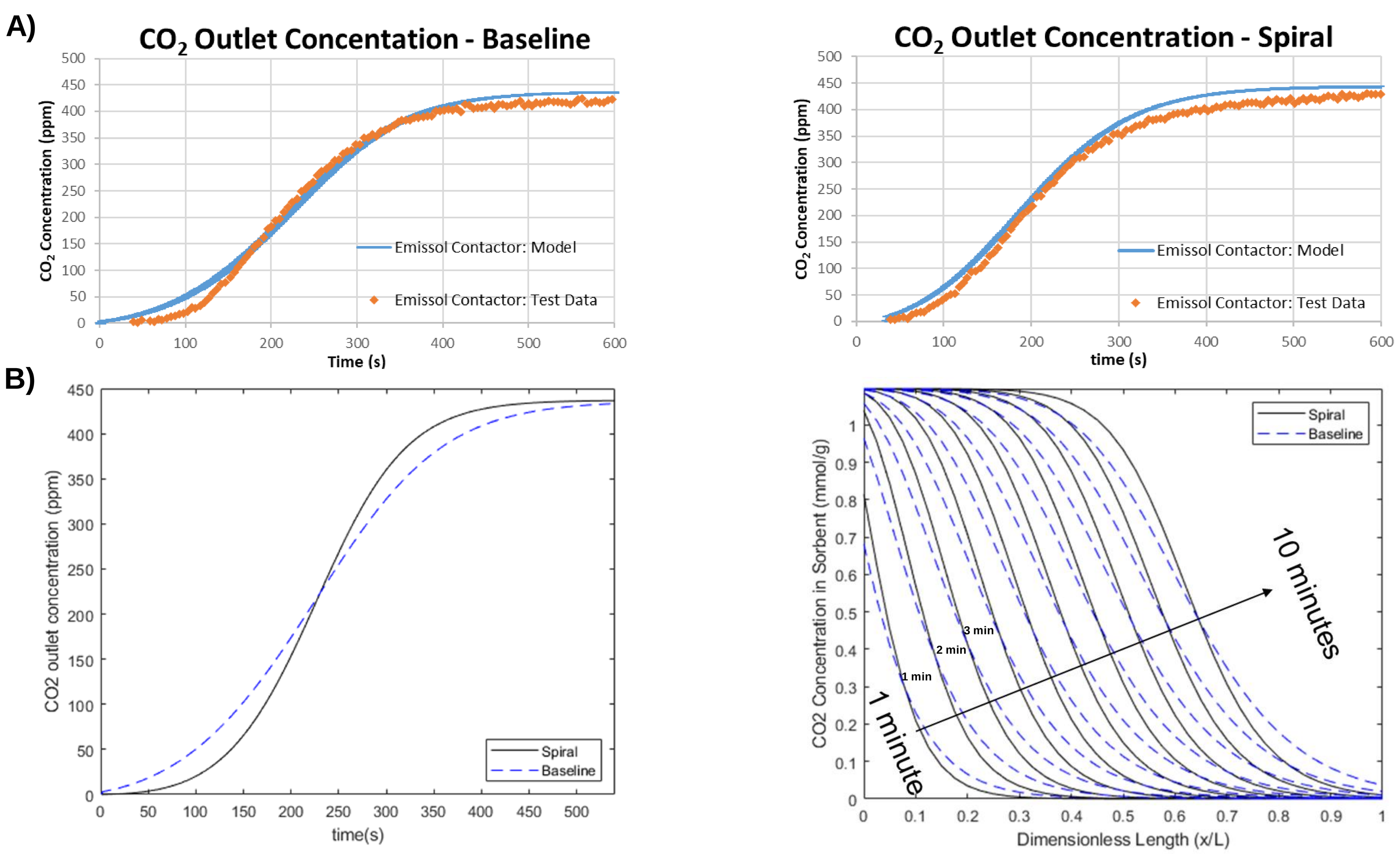


Figure 2. (A) Comparing model and experimental data: Baseline (straight channel) vs. spiral channel shaped contactor. (B) Comparing their breakthrough curves, CO_2 concentrations. Spiral outperforms baseline, enabling surface area and sorbent reduction by 40%.

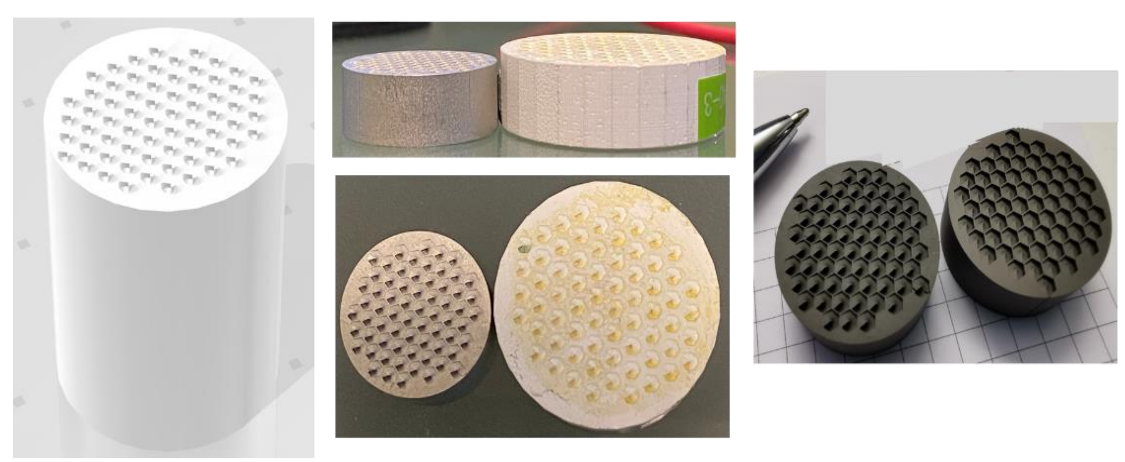


Figure 3. Prototypes of high efficiency Emissol contactor to save sorbent, lowering DAC costs. Left, center: metallic. Right: Metallic.

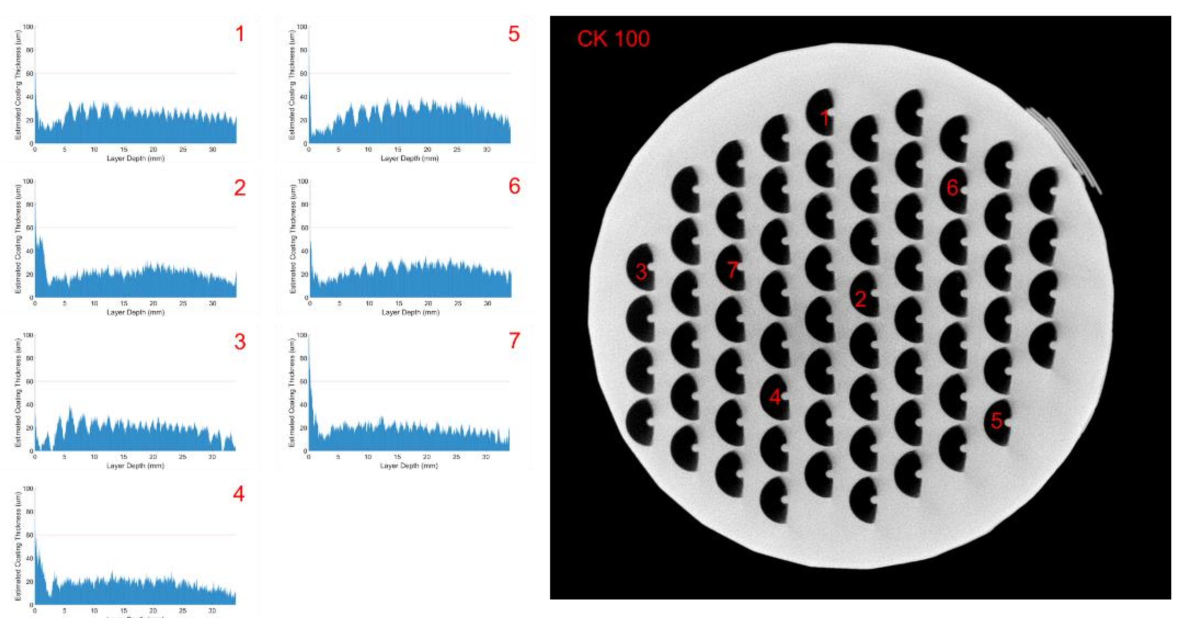
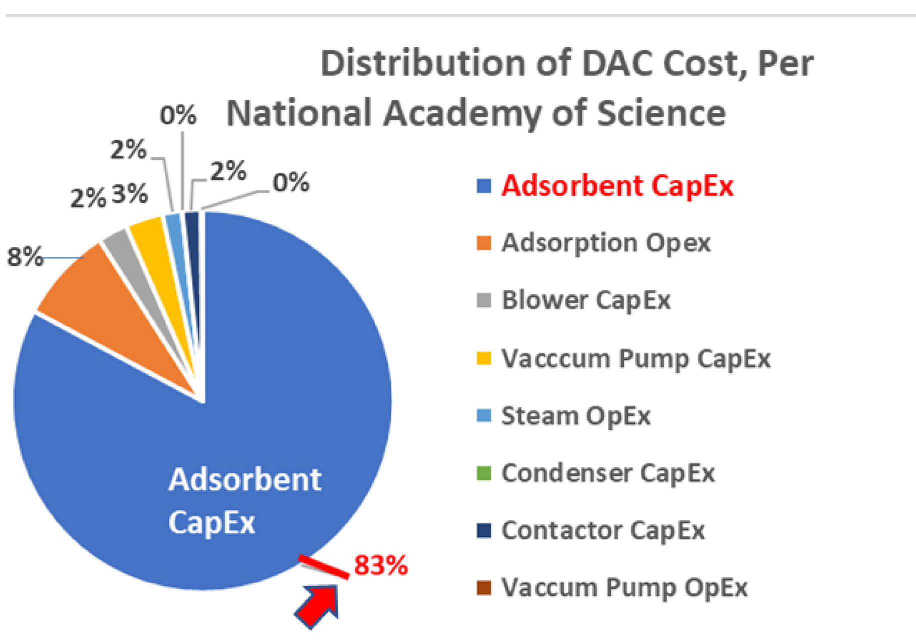


Figure 4. Left: Sorbent coating inside a few Emissol contactor channels (X-ray CT images): Sorbent thickness (y-axis) vs. axial channel length (x-axis).

Lowering DAC Cost



Annual Costs, Solid Sorbent System, 1 Mt/yr. Ref.[NAS]	Standard Contactor Cost ($)	Emissol Contactor Cost ($)	
Adsorbent CapEx	$ 122	$ 77	40%↓
Adsorption Opex	$ 12	$ 14	
Blower CapEx	$ 3.70	$ 3.70	
Vacccum Pump CapEx	$ 4.70	$ 4.70	
Steam OpEx	$ 2.40	$ 2.40	
Condenser CapEx	$ 0.08	$ 0.08	
Contactor CapEx	$ 2.30	$ 2.30	
Vaccum Pump OpEx	$ 0.20	$ 0.20	
TOTAL	$147.38	$ 105.25	30%↓
=> Total DAC Cost Reduction by 30%			

Figure 5. Lowering DAC cost using Emissol high efficiency contactor. Emissol contactor reduces sorbent use by about 40% and the total DAC cost by about 30%. (Benchmark DAC cost is based on Ref. (1).)

Methods:

- Spiral channel contactor configuration was tested against a straight channel baseline in the one-dimensional model using MATLAB. The baseline contactor properties were selected based on the modeling work of Sinha [2], with channel properties slightly modified to match our experimental setup.
- Coating uniformity and quality were checked using industrial x-ray computed tomography (x-ray CT) at the University of Washington. The images were analyzed in MATLAB using a technique developed in-house.
- Adsorption and desorption cycles were conducted at the University of Washington Environmental Health Laboratory. Adsorption was done under a 9 L/min flow of air containing 420 ppm CO_2 at ambient temperature.

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Future Works:

- Techno-economic analysis for the DAC process employing Emissol high-efficiency contactor.
- Reducing contactor energy use during CO_2 desorption (unloading).
- Contactor optimization to further reduce total DAC cost (i.e., beyond 30%).
- Develop manufacturing technique and reduced contactor production costs.
- Investigate CO_2 flux within sorbent pore structures so to enhance its diffusion-scale transport.

(1) National Academies of Sciences, Engineering and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, The National Academies Press. (2019).

(2) A. Sinha, L.A. Darunte, C.W. Jones, M.J. Realff, and Y. Kawajiri. Industrial & Engineering Chemistry Research 56, no. 3 750-764. (2017).

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