Dual-Loop Solution-Based Carbon Capture System for Net Negative Carbon Dioxide Emissions with Lower Costs (DE-FE0032134) and Enhancement of Carbon Capture Reactor Performance (DE-FE0032217)

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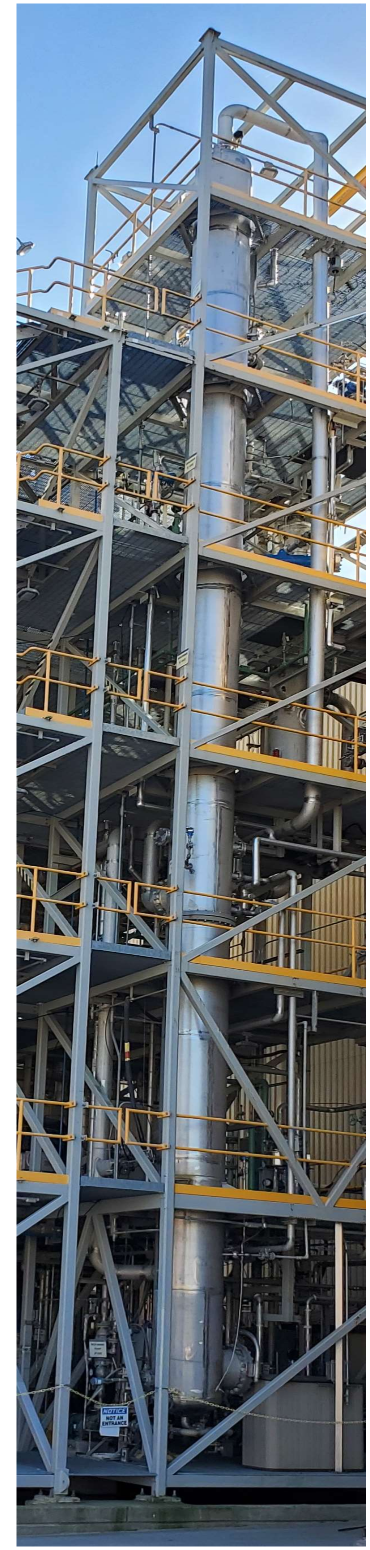
UK IDEA Approach

1. Match the capture technology to the driving force
2. Intensify mass transfer
3. Utilize H_2 production to offset cost
4. Allow power generation unit to run with less cycling by flexibly operating separate CO_2 capture loops
5. Integration with existing plant
6. Continue to minimize solvent degradation, recover heat from steam condensate to improve HRSG performance, maximize capture unit capacity factor by eliminating the flue gas blower

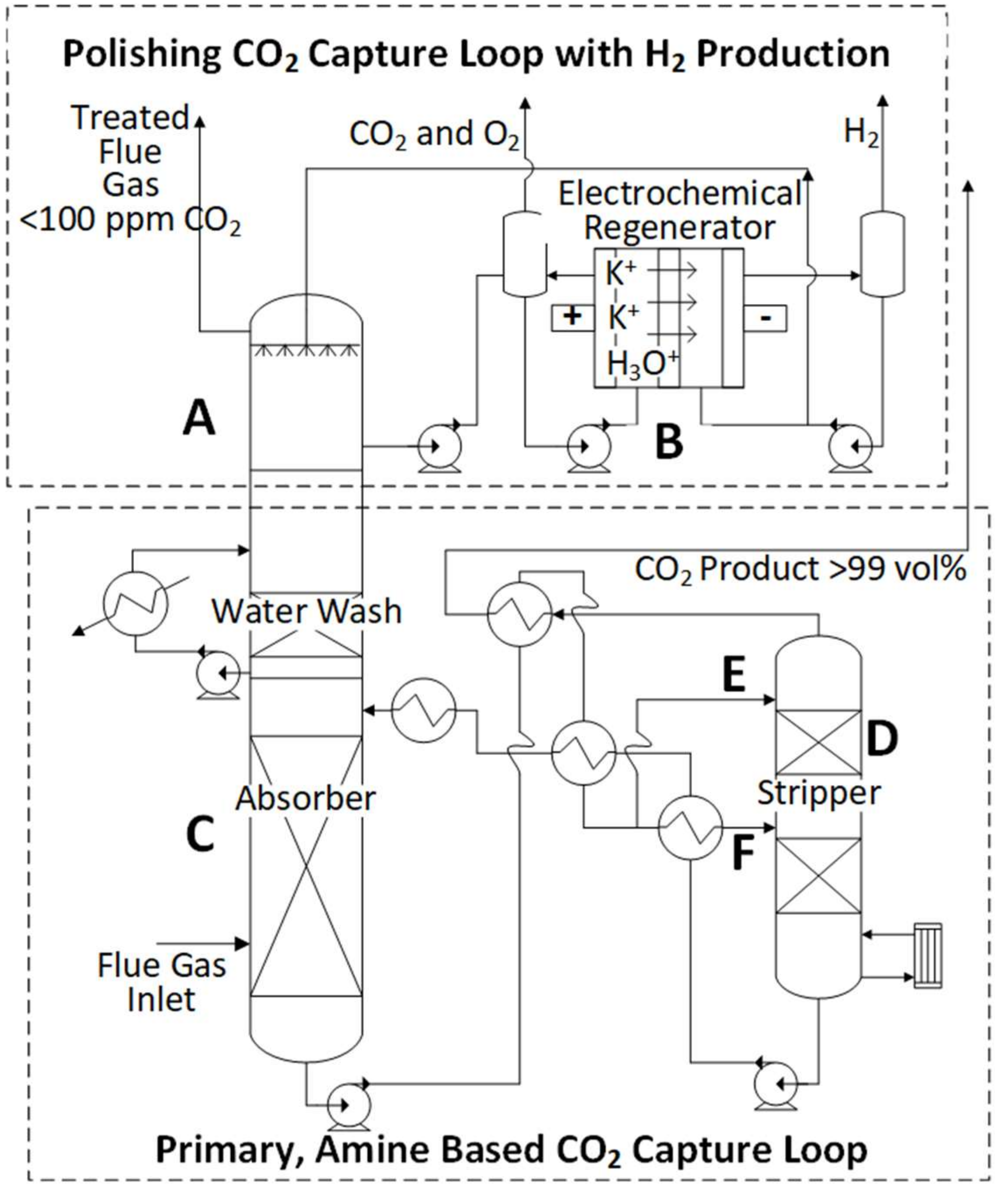
$$\boldsymbol{CO_2\, Mass\, Transfer = A\;\; K_G \left(P^{g}_{CO_2} - P^{*}_{CO_2}\right)}$$

$$\frac{1}{K_G} = \frac{1}{k_g} + \frac{1}{k'_g}$$

$$k'_g = \frac{\sqrt{D_{CO_2}\;\; K_2\;\; [Am]}}{H_{CO_2}}$$



UK Dual Loop Approach for Point Source Treated Flue Gas with <100 ppm CO_2



Adaptation of UK DAC with H_2 Production Technology

UK Point Source CO_2 Capture Technology, such as for NGCC

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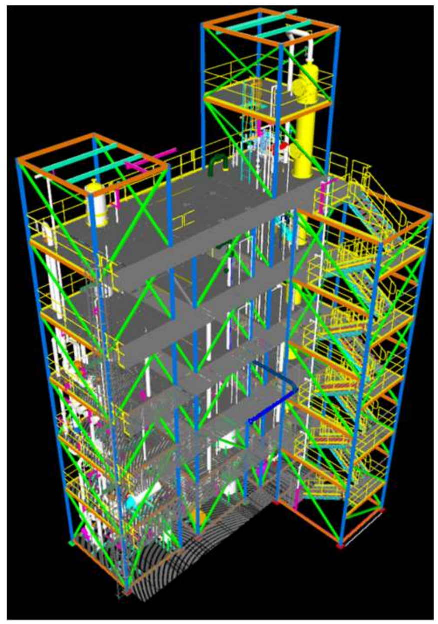
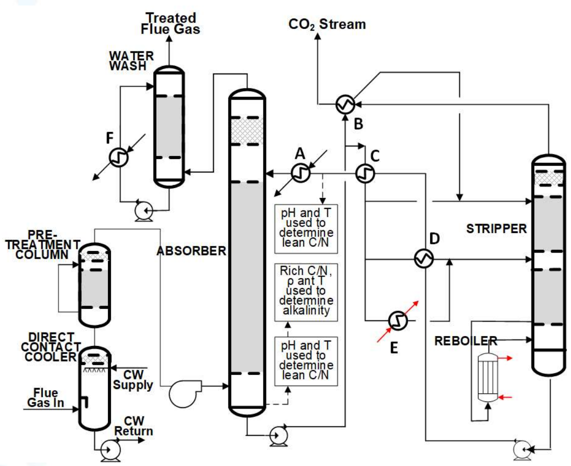
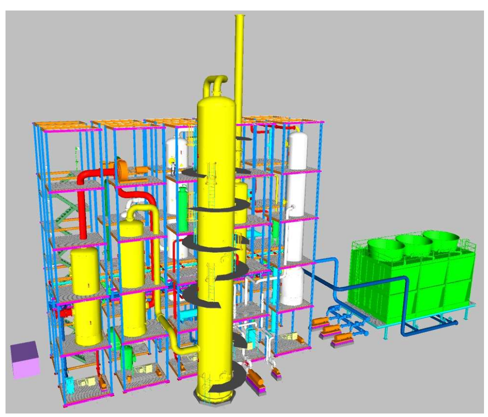
Building on Point Source Technology







- Bench Scale Since 2009
- Engineering Scale, 15 TPD, Since 2015 at EW Brown Generating Station, a PPL Corporation Facility
- 3 TPD, Nucor Steel Gallatin, 2025
- 9.3 TPD, Vitro Architectural Glass,
- 215 TPD, Cane Run Generating Station (CRGS), a PPL Corporation Facility, 20230
- 1.7M TPY, CRGS, FEED complete 8/2025
- Favorable carbon intensity scenario: 114.81 kg CO_2e/MWh_{net} cradle to delivered electricity was found, 13% reduction from 2019 B31B

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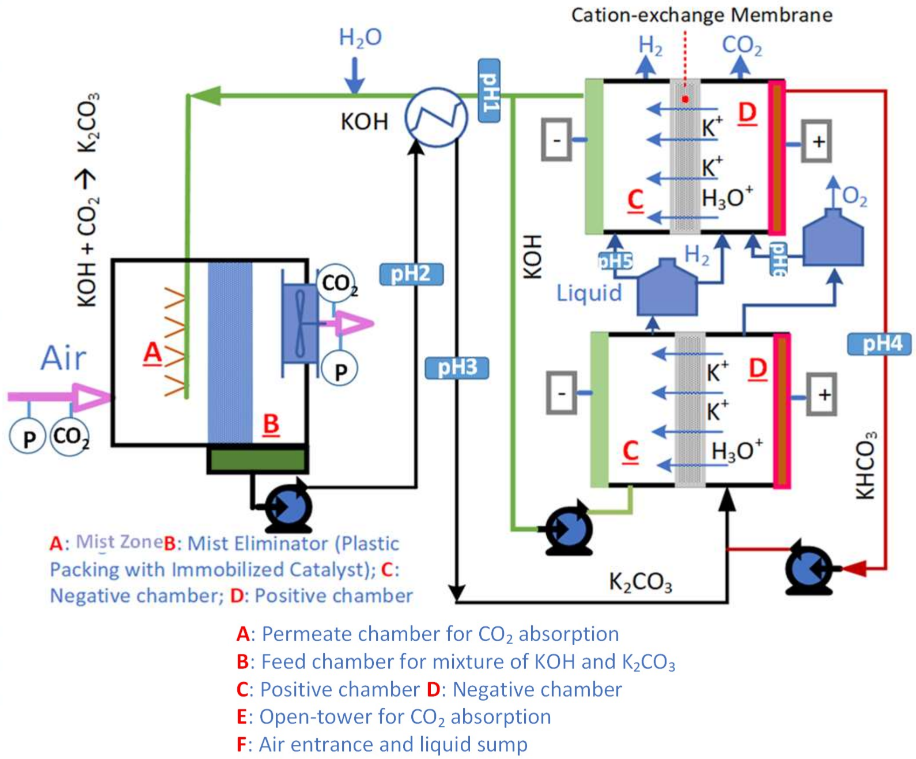
Building on DAC with H_2 Production Technology



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- ❑ Inorganic, solvent-based
- ❑ Catalyzed capture at mild pH for DAC energy cost minimization
- ❑ Simplified Process and Operation
- ❑ Electrochemical regeneration with H_2 and O_2 production
- ❑ 7,700 kg CO_2/year Demo at EW Brown Generating Station, a PPL Corporation Facility, 350 kg H_2/year, 470 W Regenerator, 2025-2026
- ❑ DAC Hub Feasibility Study, ≥3,500 tonne CO_2/year per capture location with 160 tonne H_2/year and 1040 kW regenerator
- ❑ Favorable carbon intensity found: 0.32 kg CO_2 is estimated to be abated per kg of CO_2 captured and permanently sequestered for the case where the H_2 production displaces H_2 produced via electrolysis, based on the expected 2050 U.S. grid carbon intensity

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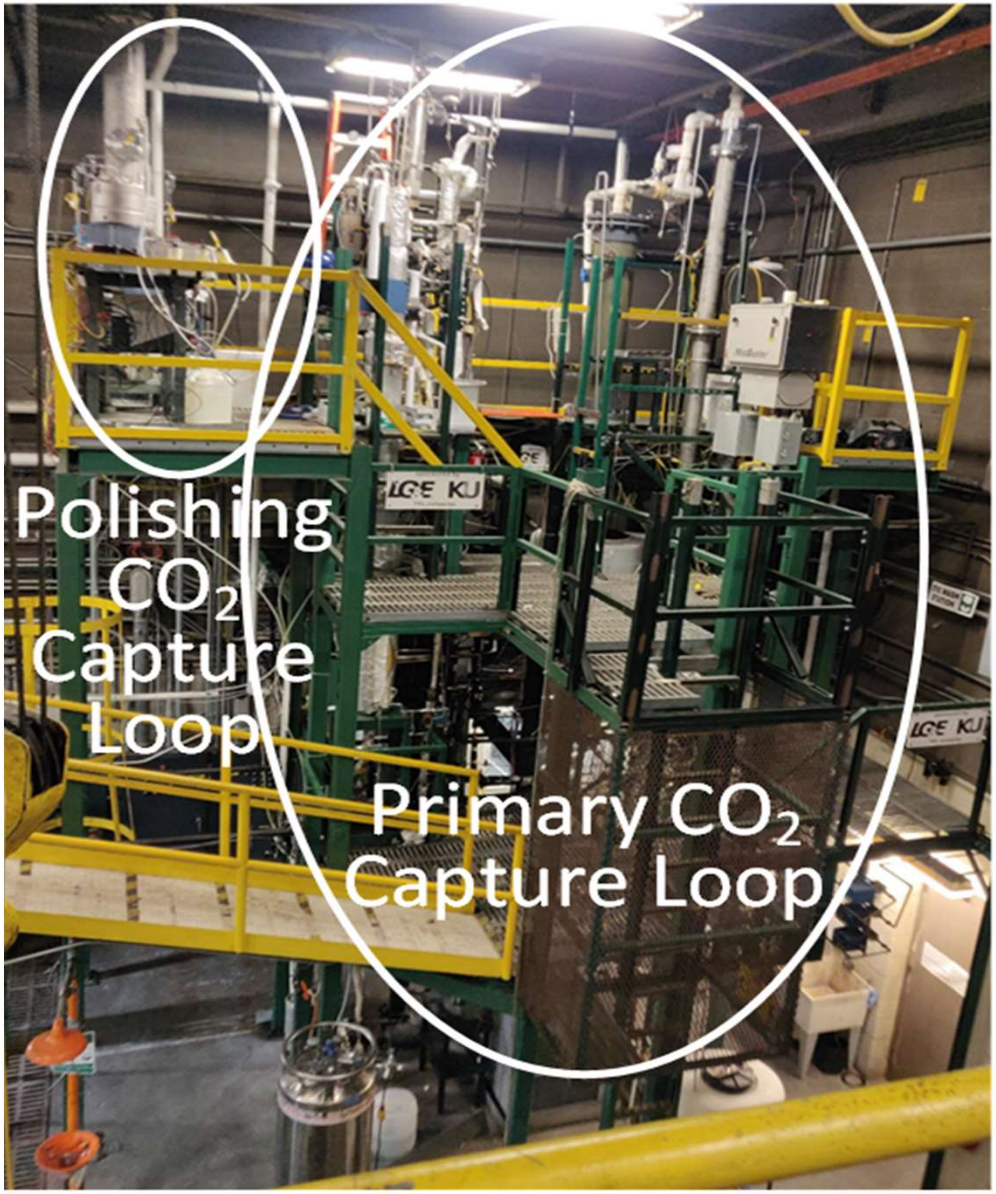
Dual-loop Solvent-based CCS for Net Negative CO_2 Emissions with Lower Cost



- ❑ Bench Scale Demonstration
- ❑ 3/1/2022 to 8/31/2025
- ❑ Resulting TRL 4
- ❑ Existing UK Amine-Based CO_2 Capture Unit Applied as Primary Loop
- ❑ Polishing Loop Designed, Integrated, Operational and Being Tested
- ❑ Variable CO_2 Capture Efficiency in the Primary Loop
- ❑ TEA, LCA, EH&S Upcoming

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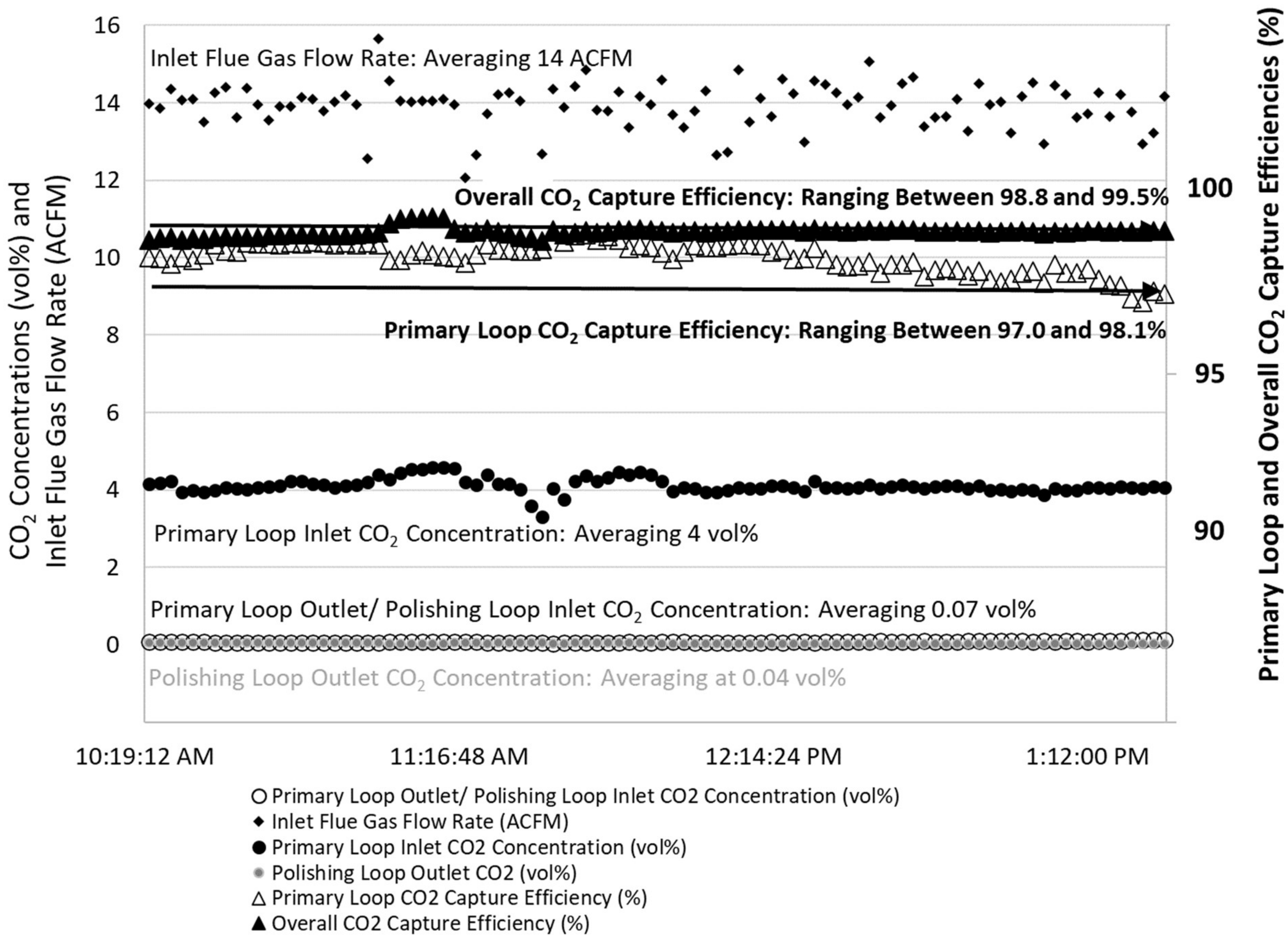
Bench Scale Operational Data



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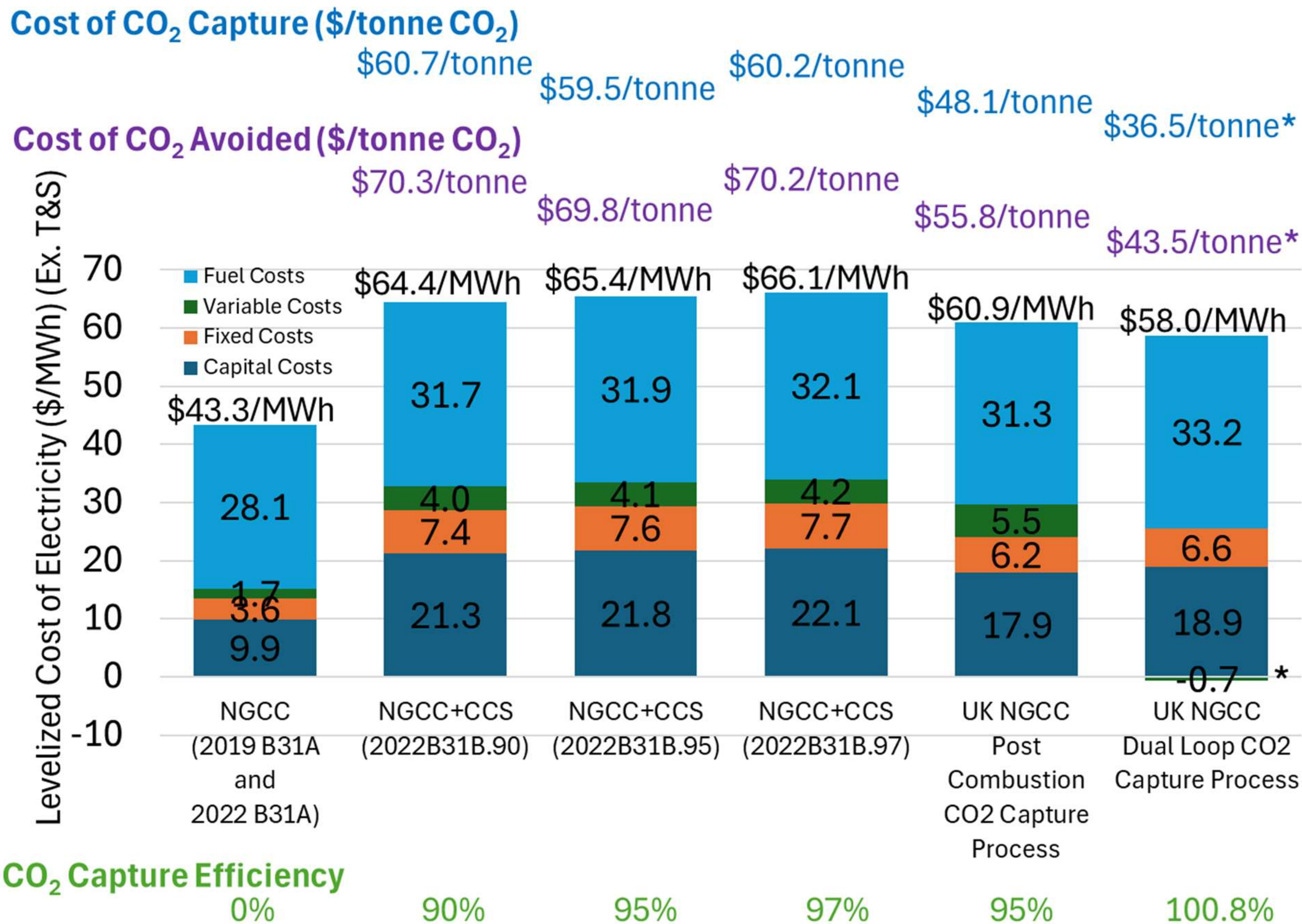
Preliminary TEA



* Assuming a H_2 sales price of $8/kg and a credit for CO_2 capture from air of $100/tonne

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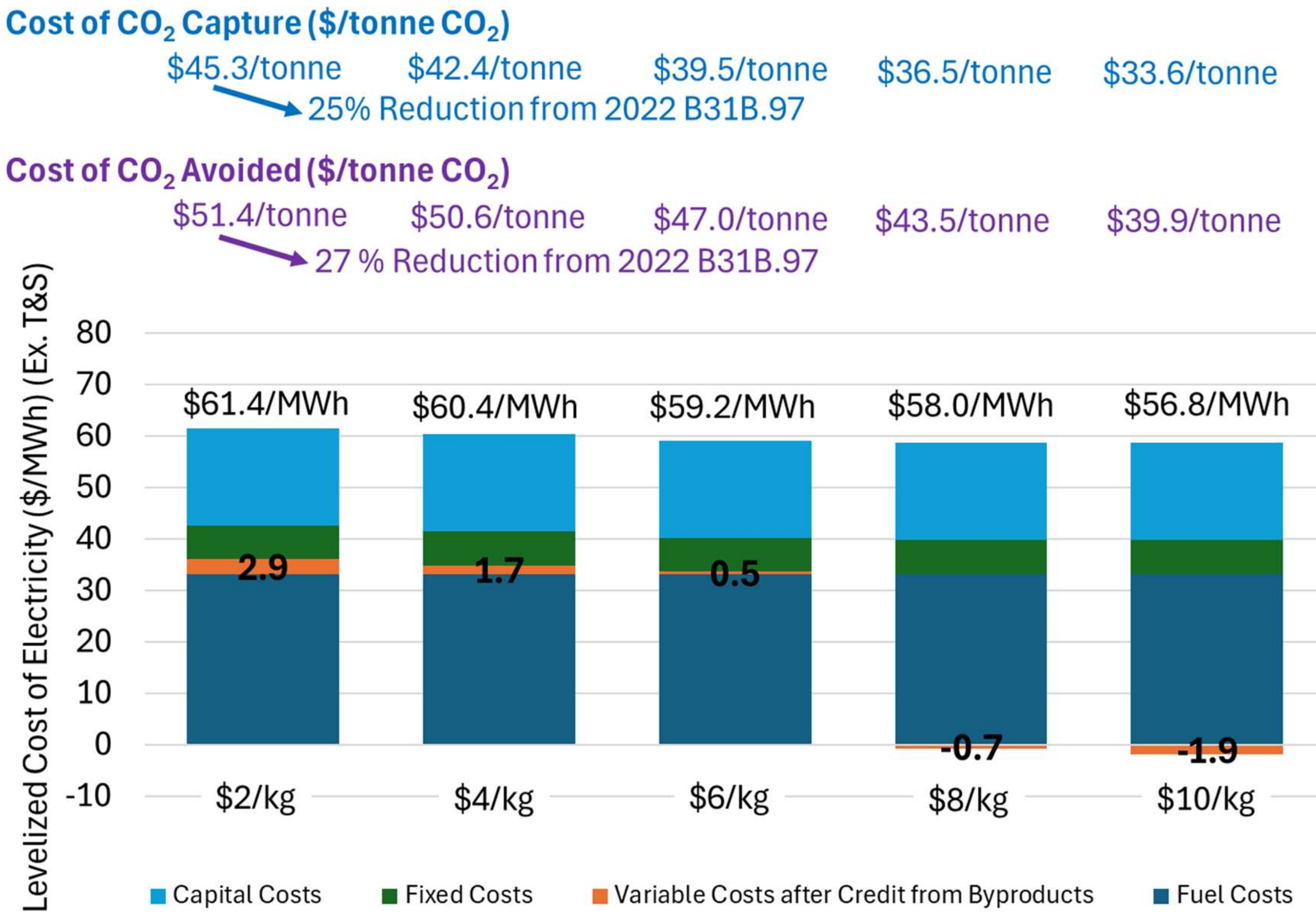
Effect of H_2 Sales Price on the UK Dual Loop CO_2 Capture Process Costs



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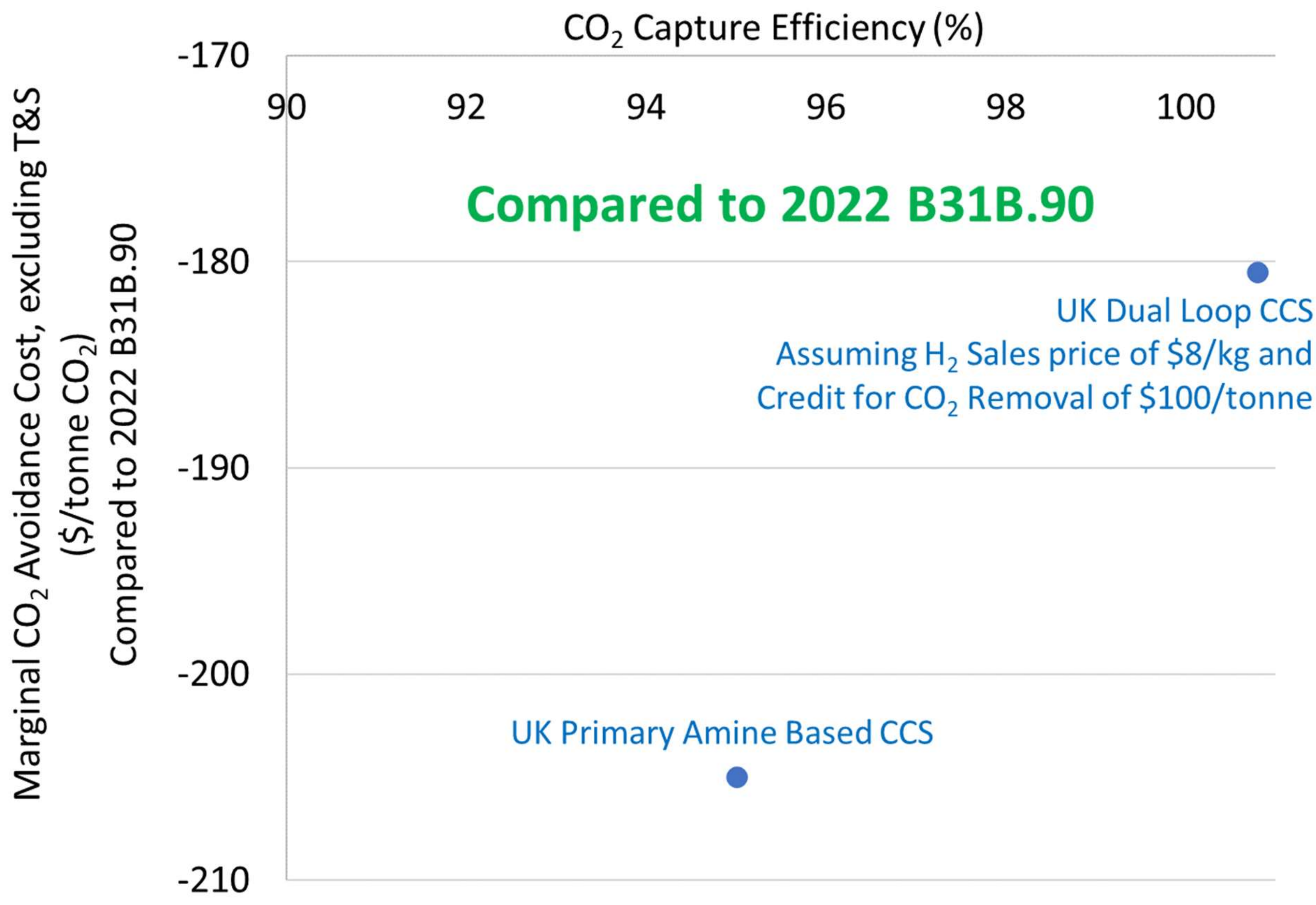
UK Marginal CO_2 Avoidance Costs



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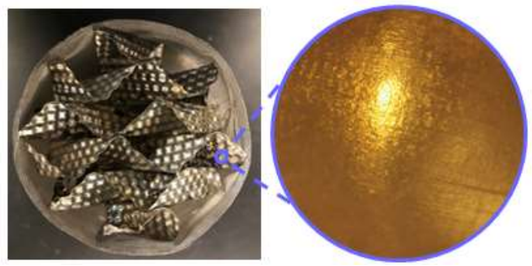
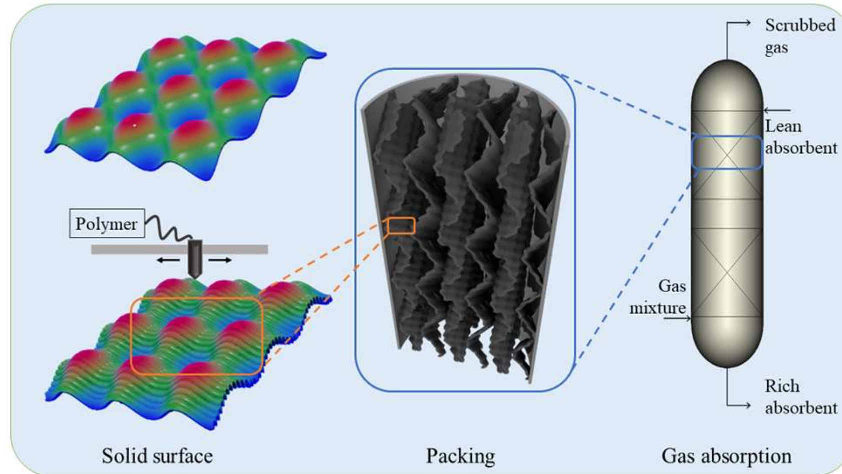
Process Intensification for High Capture & Short Absorber – Decrease Diffusion Resistance

Commercially Available Packing

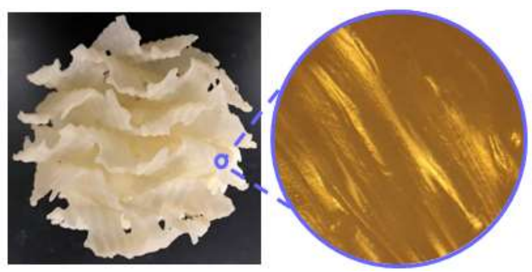


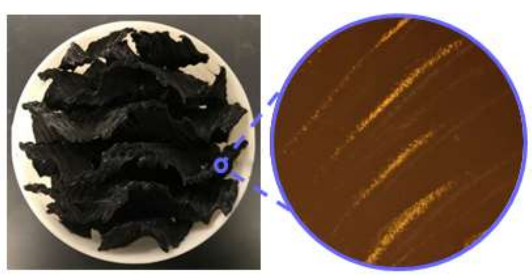
Steel packing



3D Printed Polymer Packing

Acrylonitrile butadiene styrene (ABS) packing





Nylon packing

3D printed polymer packing has additional wavy sub-texture that further improves liquid turbulence on the surface translating to improved CO_2 capture rates

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Xiao et al., Chemical Engineering Science 267 (2023) 118320

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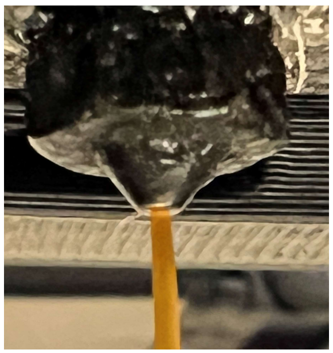
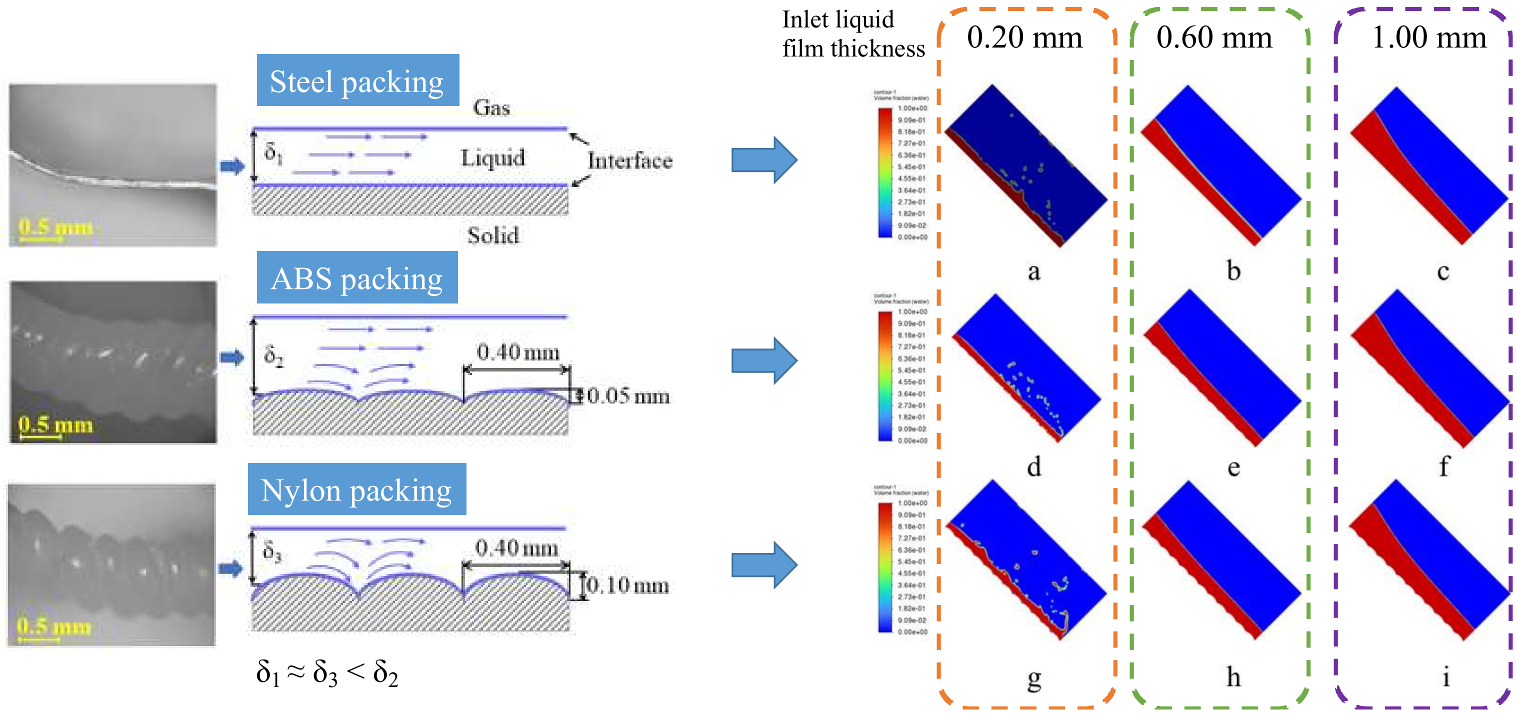
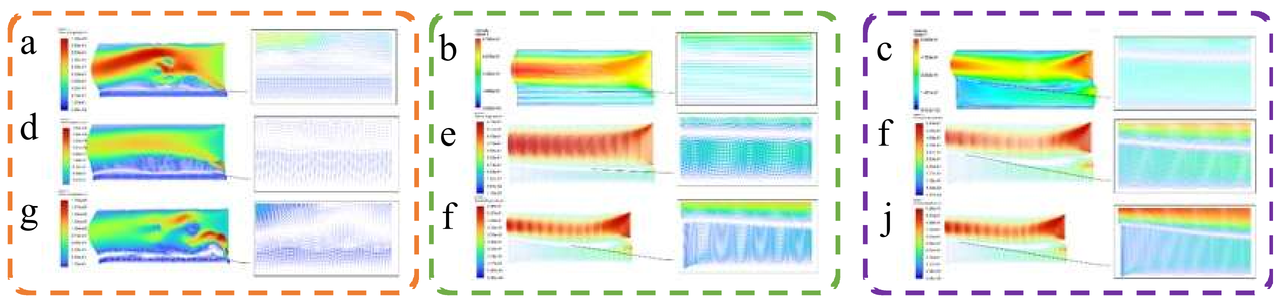
Process Intensification for High Capture & Short Absorber – Decrease Diffusion Resistance





- **Surface texture amplitude**
- **Liquid film thickness**

→ **Local mixing within the liquid**



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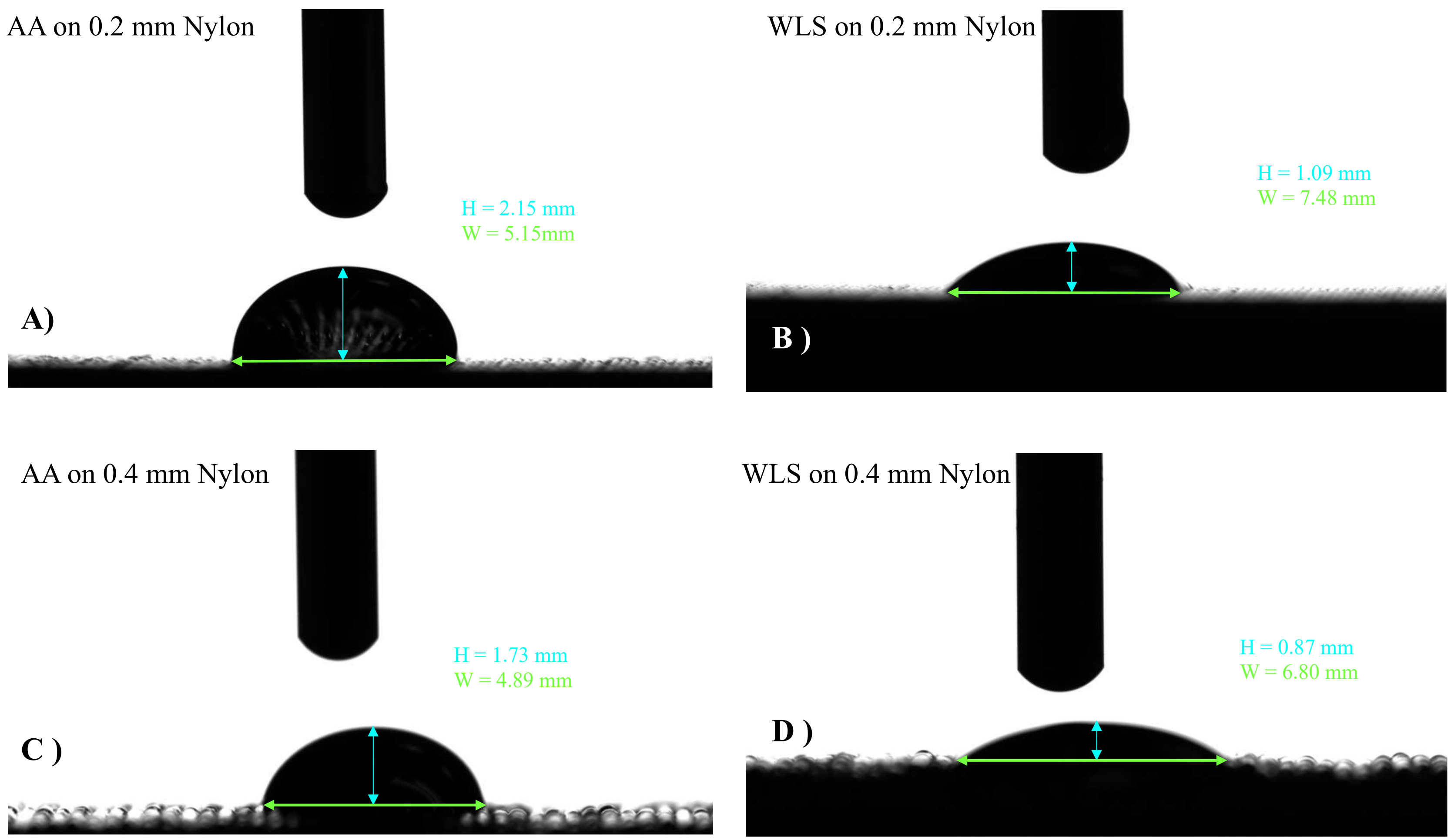
Process Intensification for High Capture & Short Absorber – Increase Liquid-Gas Contact Area

Solvent Contact Angle (Wetting)



The initial drop, prior to rolling, of A) AA on 0.2 mm nylon, B) WLS on 0.2 mm nylon, C) AA on 0.4 mm nylon, and D) WLS on 0.4 mm nylon.

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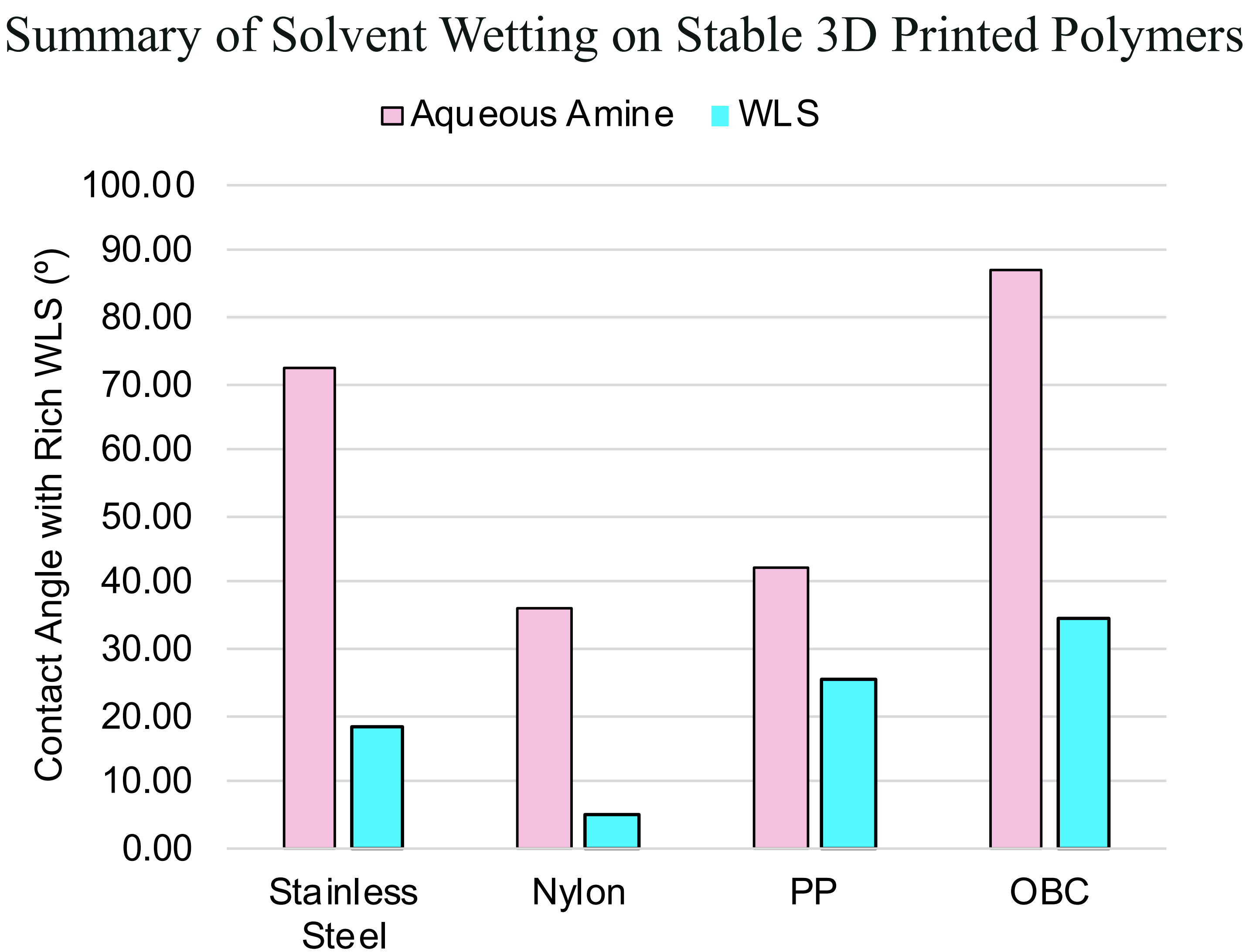
Enhancement of Carbon Capture Reactor Performance



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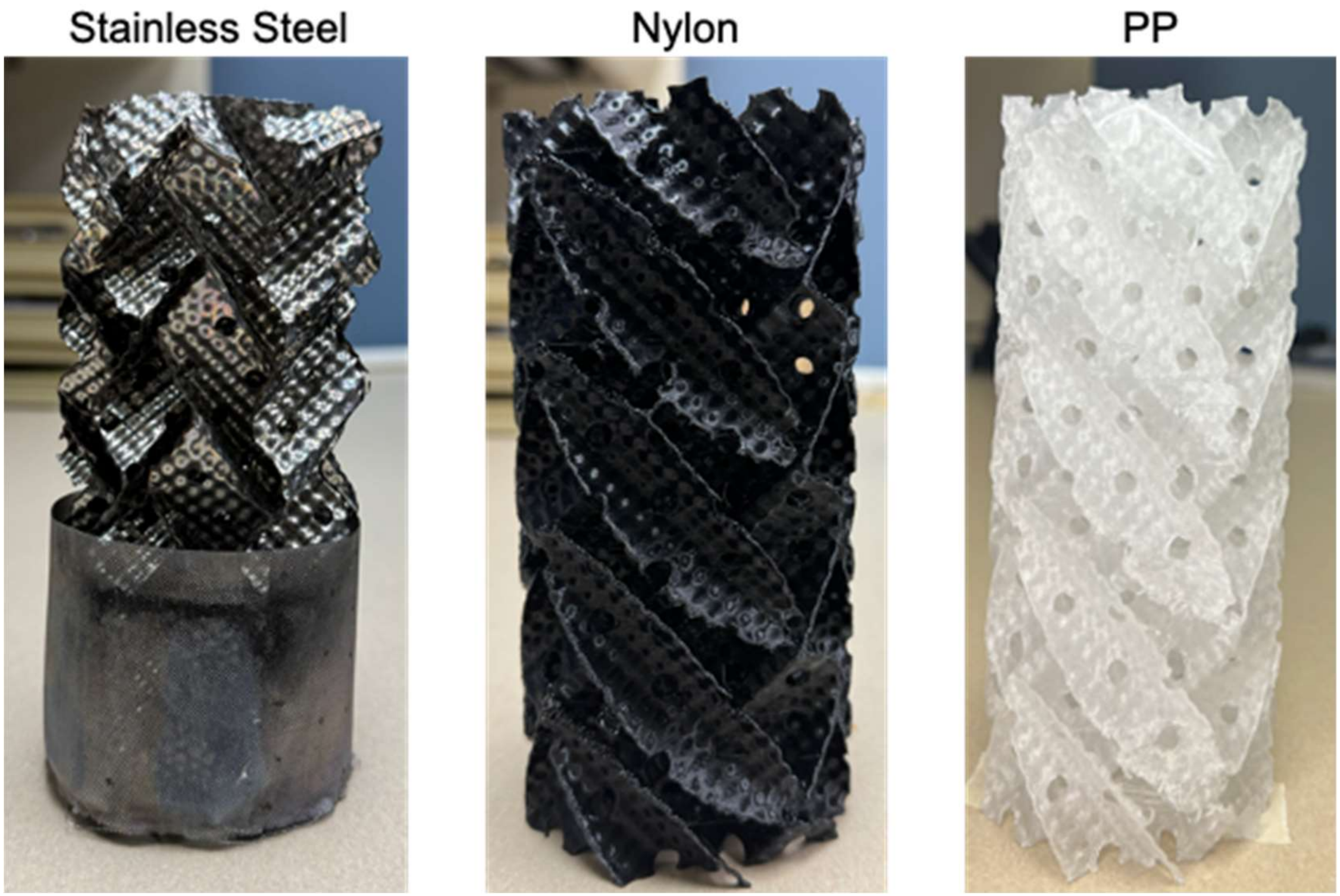
3D Printed Packing

Bench testing of steel packing with WLS as baseline, then with Nylon and PP packing to see benefit from improved wetting in the absorber leading to better CO_2 mass transfer



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