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Plastic Additive, Sorbent-Coated, Thermally Integrated Contactor for CO_2 Capture (PLASTIC4CO2) DEFE0032132

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DOE/NETL Contract #FE0032132

$2.5MM program (40% cost share)

POP 02/25/22 to 12/31/24

Team Contributors

- GE Global Research
- TDA Research
- University of South Alabama
- Univ. of California-Berkeley (BP1 only)

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Program Team

GE Research

Additive Contactor Design & Production, Sorbent and Binder Coating Integration, Small & Large Coated Parts Testing & Process & Techno-Economic Modelling

TDA RESEARCH

Metal Organic Framework Sorbent Synthesis, Characterization & Testing, Sorbent Integrated Parts Testing

Berkeley UNIVERSITY OF CALIFORNIA

Covalent Organic Framework Synthesis, Characterization & Testing

UNIVERSITY OF SOUTH ALABAMA

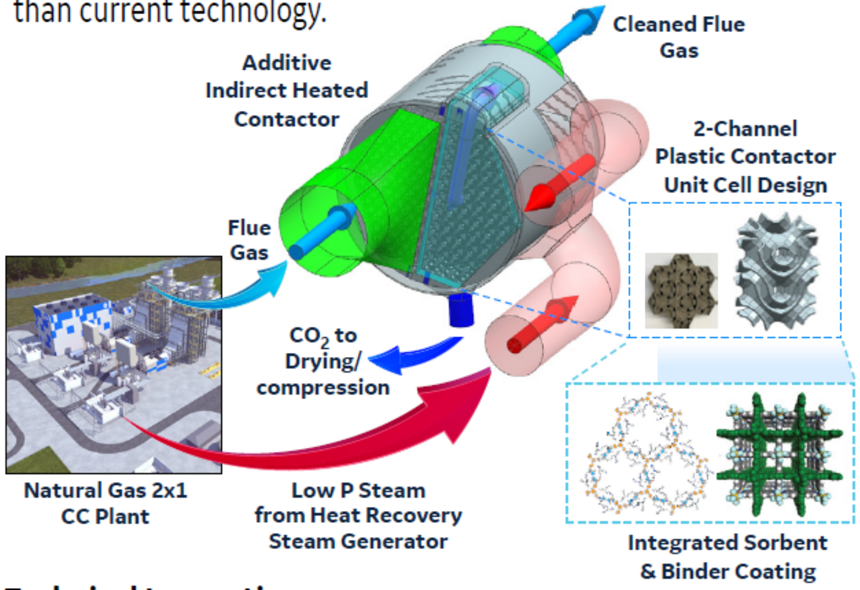
Multi-Component Adsorption & Kinetics Characterization

Relevant Prior Work

- DARPA AIR2WATER (HR001-21-C-0020)
- DOE-FE AIR2CO2 (DE-FE0031956)

36 Month, $2.5MM Program to Deliver a "Plastic Additive, Sorbent-Coated, Thermally Integrated Contactor for CO_2 Capture (PLASTIC4CO2)"

Project Objectives: Demonstrate feasibility (TRL 3) of an additive plastic 2-channel sorbent coated contactor that removes 95% of CO_2 from NGCC flue gas and achieves 15% lower LCOE than current technology.



Technical Innovations

- A novel additively manufactured plastic trifurcating contactor component that exhibits **low thermal mass, a high surface area/volume ratio, and minimal pressure drop.**
- A PLASTIC4CO2 system which utilizes a 2-channel sorbent-coated contactor that enables indirect heating of sorbent during regeneration to reduce thermal and CO_2 separation energy requirements.
- A unique rotating contactor prototype that exhibits robust cycle performance at low CO_2 concentrations and reduces capital and **operating** expenses.

Program Deliverables

- Sorbent coated PLASTIC4CO2 system design that removes 95% CO_2 from NGCC flue gas
- Techno-economic analysis built on process models
- Program Management & Technology Maturation Plans to guide contactor system development and integration.

Program Benefits

- Revolutionary engineered contactor system that will reduce capital costs by 40-50% and lower LCOE by 15% vs current technology.
- An additive contactor technology platform amenable to integration with any solid sorbent that is foundational to achieving low CAPEX.

TRL3 Feasibility for Plastic Additive Contactor Design

Sorbent to Coated Contactor

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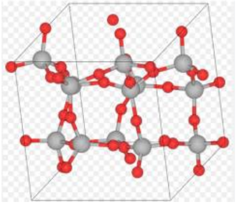
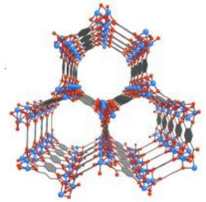
Chemical Synthesis → Coatings & Structure → Adsorptive Kinetics & Capacity





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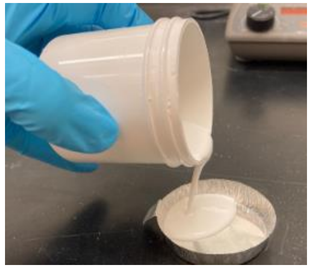

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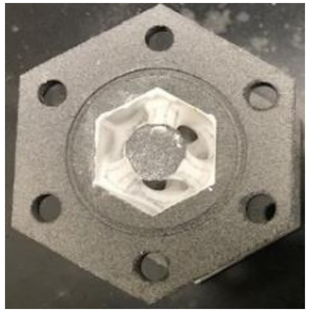

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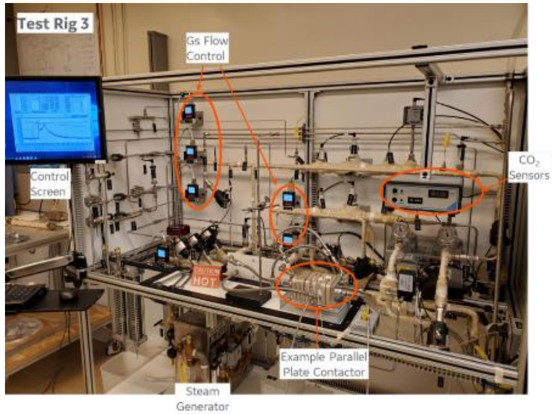

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TDA RESEARCH

USA UNIVERSITY OF SOUTH ALABAMA

\+ Binders + Rheology Modifiers

\+ Additive Contactor

Sorbents

Coating Formulation & Composite Film

PLASTIC4CO2 Contactor

Testing Systems

CO_2 Capacity
CO_2 Kinetics
Energetics

Viscosity, % Solids
Stability, Surface Tension, Drying Time/T
Adhesion, Porosity

Pressure Drop, Energetics
CO_2/H_2O Capacity/Kinetics
Stability/Lifetime

%CO2 & RH control
Flow Rates
Operating T
Dead Volume

Task 3 Final Plastic Additive Material Testing Results

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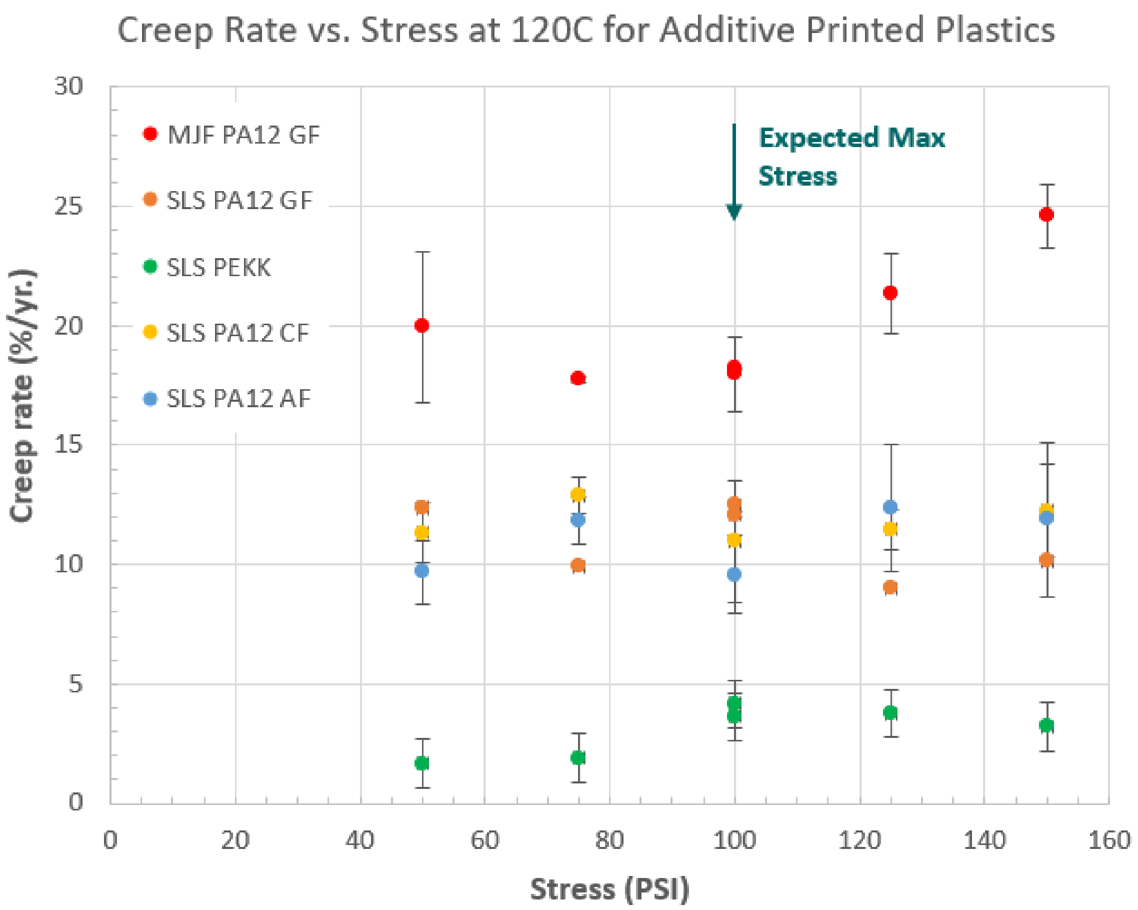
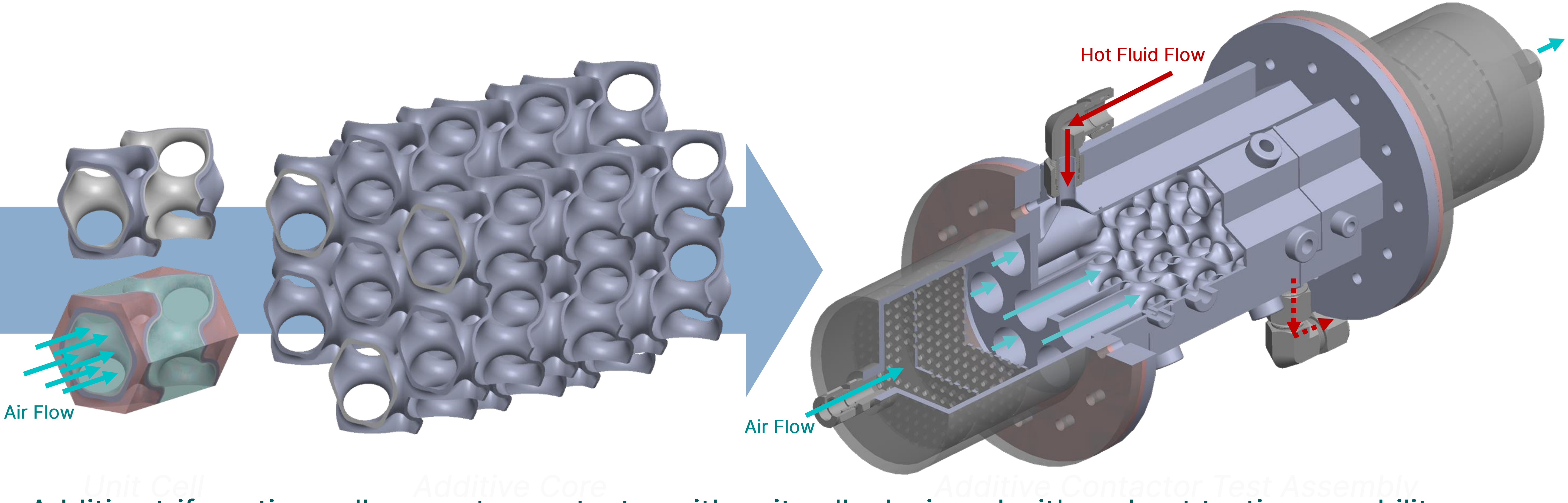
Material	T_g (C)	HDT@66 psi	HDT@264 psi
PA12 CF	100	160	130
PEKK	143		171



- MJF PA12 GF shows most deformation at ~20%/yr.
- SLS PA12 filled with glass, carbon and aluminum have similar deformation at ~12%/yr.
- PEKK has best performance with less than 5%/yr. creep rate

Task 3 Additive Contactor Design

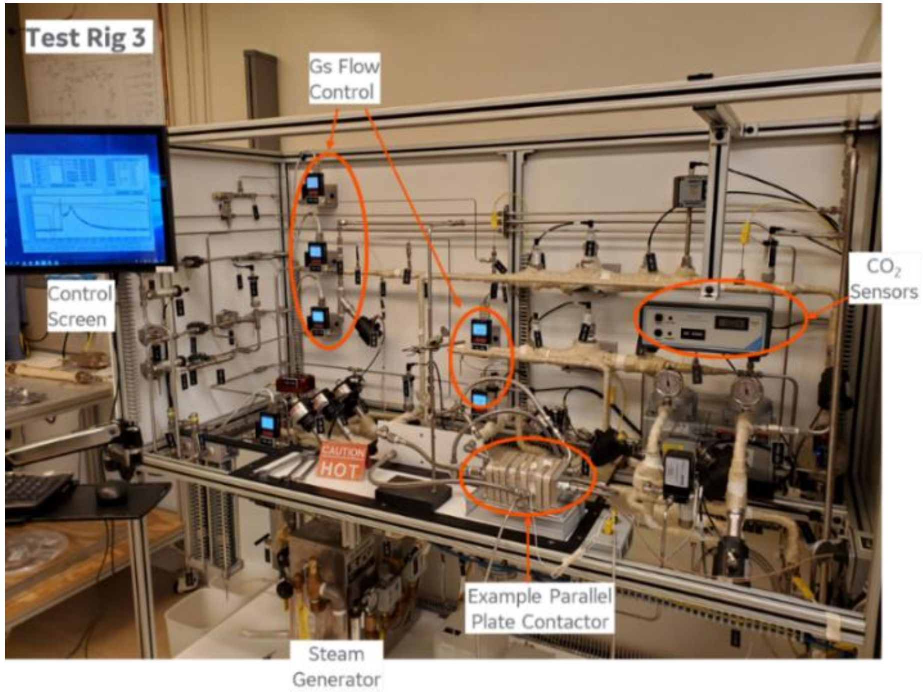


Additive trifurcating cell geometry contactor with unit cells designed with sorbent testing capability

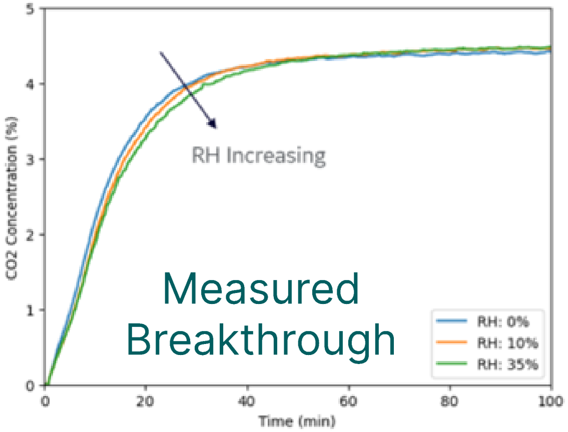
- Sorbent thickness = 0.5-1.0 mm
- Additive wall thickness = 0.75 – 1.2 mm
- Air Flow nominal Diameter = 13 mm
- Hot Fluid Flow nominal Diameter = 6 mm

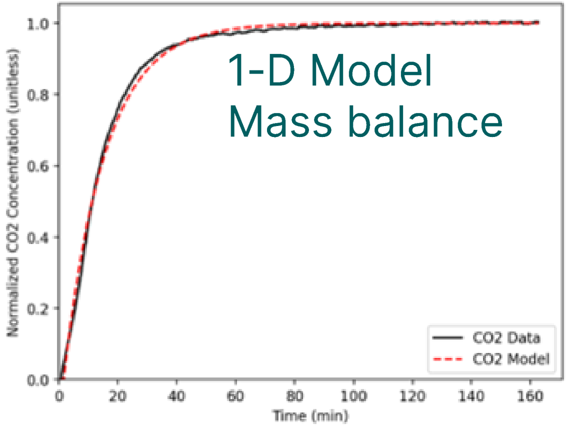
Task 5 Dynamic Flow Testing

- Contactor test rig
- Built by TDA
- 20 SLPM Flows
- 400PPM to >20% CO_2 feed
- Up to 40C and 50% RH feed
- N2, steam, electric & vacuum desorb



GE-X5: 40C and 0.75mm film thickness





1-D Model $$\frac{\partial c}{\partial \tau} + DN_1 \frac{\partial c}{\partial x} = -DN_1 DN_2 \left(n^{eq} - n\right)$$

- Flat plate and additive contactor tests
- Measure CO_2 breakthrough vs. RH, T, film thickness
- Fit mass transfer model
- Get capacity, kinetics and productivity
- Determine contactor sizing for 7F/7HA flow rates
- Generate TEA costing models

Task 6 Current TEA Modelling

0-D Equilibrium Model vs. 1-D Model Study

Model Inputs based on NETL Requirements

- 7F02 and 7HA02 flows per NETL cases B31B and B32B
- 85% Capacity Factor = 7500 hr./yr.
- 30-minute cycle time (15 min adsorb & 15 min desorb)
- 0.75 mm thick coating at sorbent density of 0.5 g/cm^3
- 50, 75 and 90% working capacity vs. equilibrium capacity
- Additive contactor, plate and tube contactor and BOP equipment costs based on capital estimates
- Use of NETL methodology for CAPEX, OPEX, LCOE, COC and COA
- 25% sorbent replacement annually
- 30% thermal heat integration

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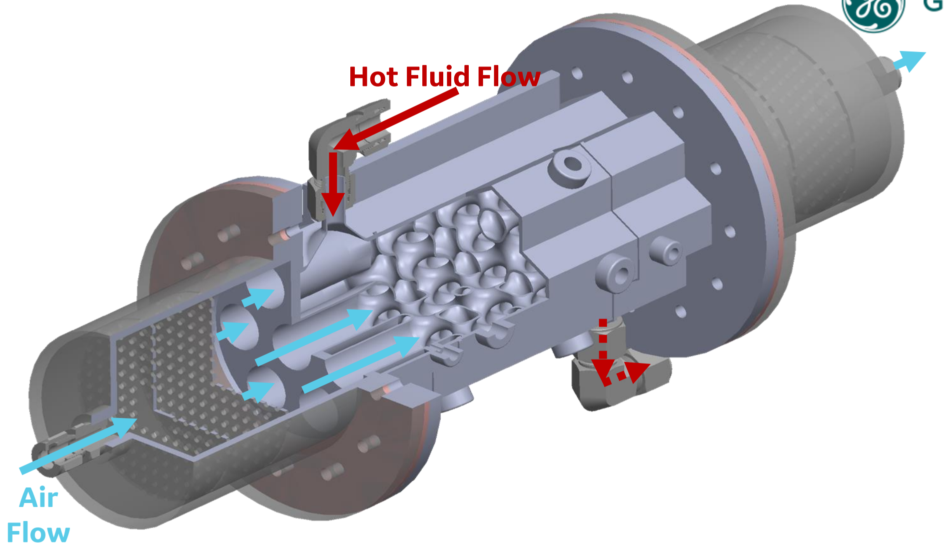

Plastic Additive Contactor Test Assembly

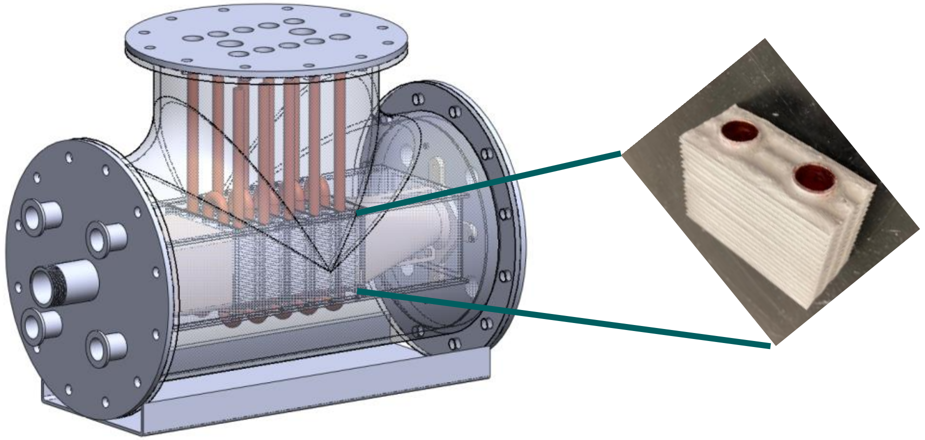

Plate-Tube Test Assembly

0-D Model for trends(ideal) vs. 1-D model for experiments(actual)

0-D vs. 1-D Model 7F & 7HA LCOE

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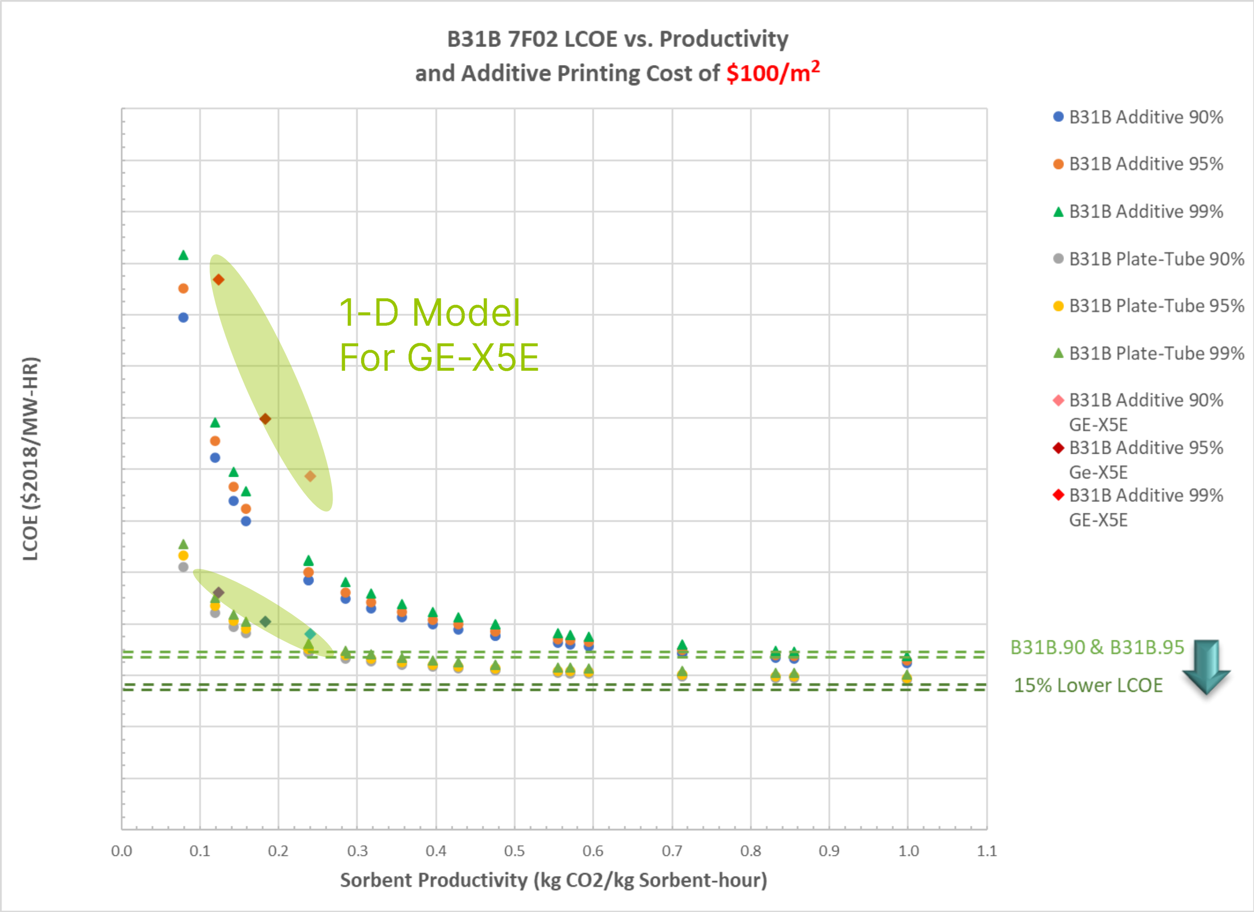
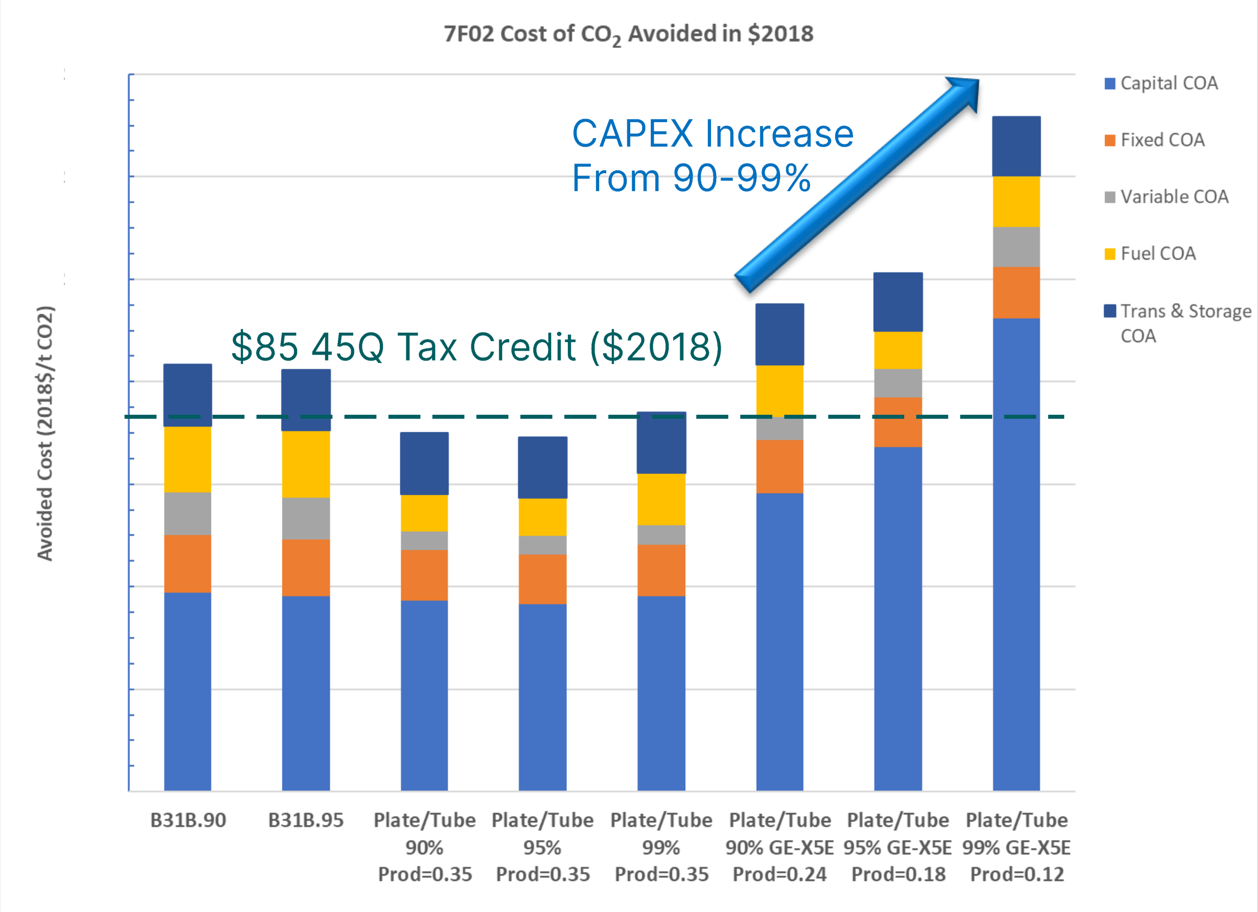
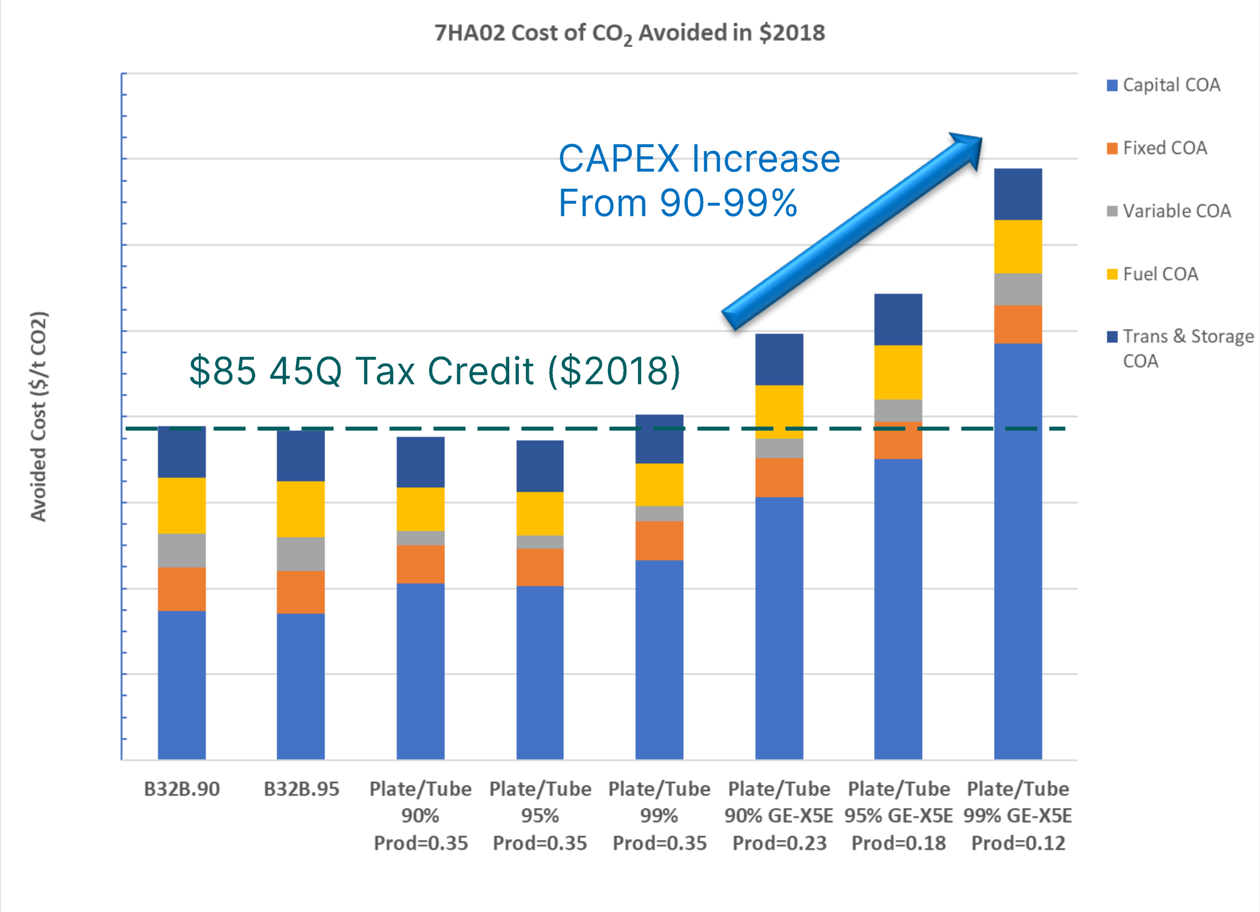


- All costs in $2018
- LCOE for lower CAPEX Intensive process has lower incremental removal cost
- 1-D experimental results marginally higher 0-D equilibrium model due to non equilibrium cycling
- Higher sorbent productivity needed to reach 10% lower LCOE

COA Breakdown





- Transport and storage add 12-15% to the total cost of sequestration.
- Sorbents competitive at productivities >0.3 kg/kg/hr.
- Incremental costs from 90% to 99% are driven by CAPEX for contactors and sorbent.

Summary & Next Steps

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Major Learnings

- Sorbent productivity is the biggest driver in CAPEX and OPEX
- Small incremental costs in going from 90% to 99% CO_2 capture
- CAPEX is biggest differentiator of system costs
- Plate & Tube Contactors offer lowest CAPEX scalable option
- Additive contactors will need to scale to <$100/m^2 to compete on system CAPEX
- H_2O latent heat is biggest driver of energetics

Further Work

- TEA for >99% capture calculations for net zero and net negative emissions – expect steeper rise in costs at >99% removal
- Study effects of film thickness, contactor cost sorbent cost & life and thermal integration

NGCC Emission Concentration vs. CO_2 Removal

CO_2 Removal %	CO_2 Exit Conc. (PPMV)	CO_2 Exit Conc. (PPMW)
90%	4,359	6,779
95%	2,179	3,389
97%	1,308	2,034
98%	872	1356
99%	436	678
99.10%	392	610
99.25%	327	508
99.50%	218	339

Higher sorbent productivity is challenge for high capture rates

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