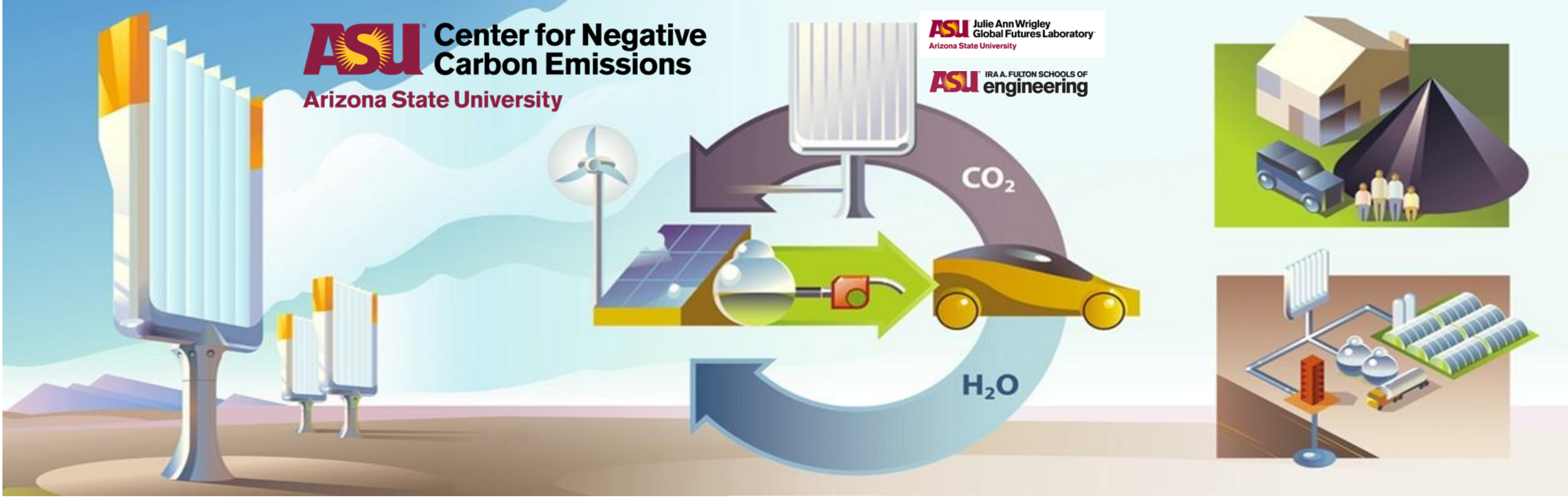
Center for Negative Carbon Emissions

Matt Green

Associate Professor, Chemical Engineering
School for Engineering of Matter, Transport & Energy (SEMTE)
Director, Center for Negative Carbon Emissions
mdgreen8@asu.edu
WCPH 326

Disclosure: Green is co-founder and owns 50% equity of NuAria, LLC



ASU Center for Negative Carbon Emissions
Arizona State University

ASU Julie Ann Wrigley Global Futures Laboratory
Arizona State University

ASU Ira A. Fulton Schools of engineering

Mission:

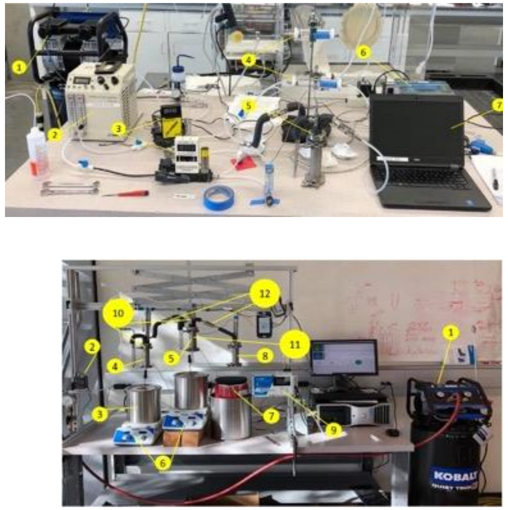
(1)Pioneer fundamental and applied research in Negative Emission Technologies

(2) Grow transdisciplinary research programs that advance our understanding of sorbent design, systems integration and deployment, utilization and sequestration technologies, and political and socioeconomic landscapes

(3) Invent and innovate at length scales spanning from the molecular level to the pilot plant

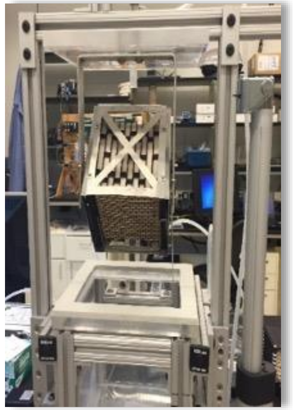
(4) Develop the next generation workforce needed for the new carbon economy

Sorbent Synthesis and Characterization
Process Modeling and CFD
System Scale-up



milligram → gram
characterization

Wind tunnel
Passive DAC emulation



Automated continuous
outdoor testing

Sapling Regenerator
kilogram scale

passive DAC
MSA pilot plant
now at London Science Museum

Full Scale
Demonstration Facility

Center for Negative
Carbon Emissions

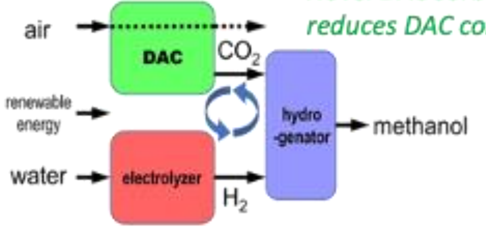
CNCE Technology Deployment

DAC Pilot at ASU
Low Energy Capture
Arizona State University

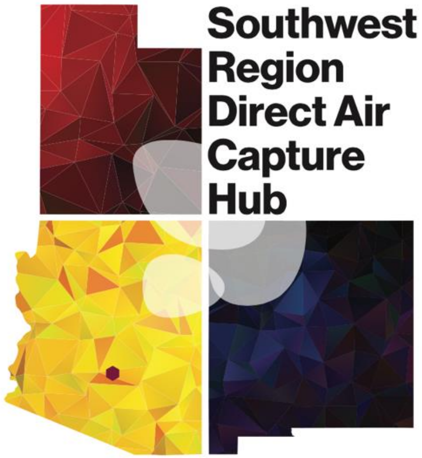
Carbon-Free H_2 Pilot at NREL
Novel H_2 Designs
NREL

CO_2 to MeOH Pilot at Air Company
Transformational Catalysts
AIR COMPANY

Air2Fuel: Mobile methanol production

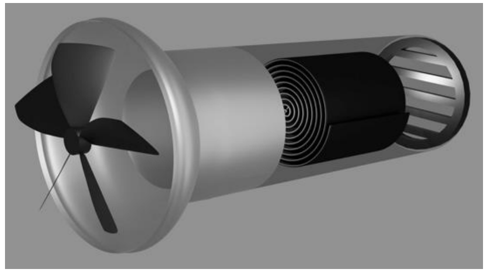


Novel DAC sorbent/form reduces DAC cost ~5x

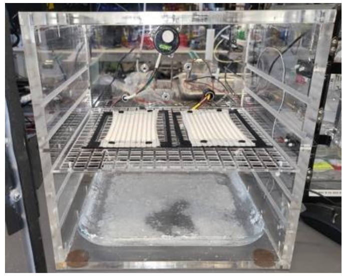


MechanicalTree™

Carbon Collect



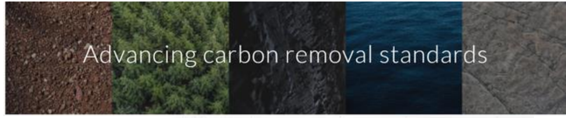
NuAria, TRL 6, 2 kg/d



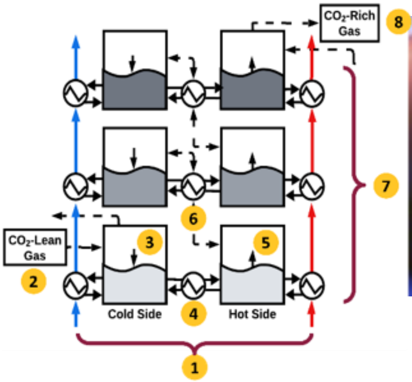
DACBox

CarbonCapture™

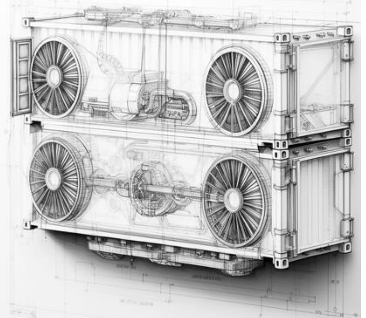
Standardizing CDR Credits



DAC in Data centers

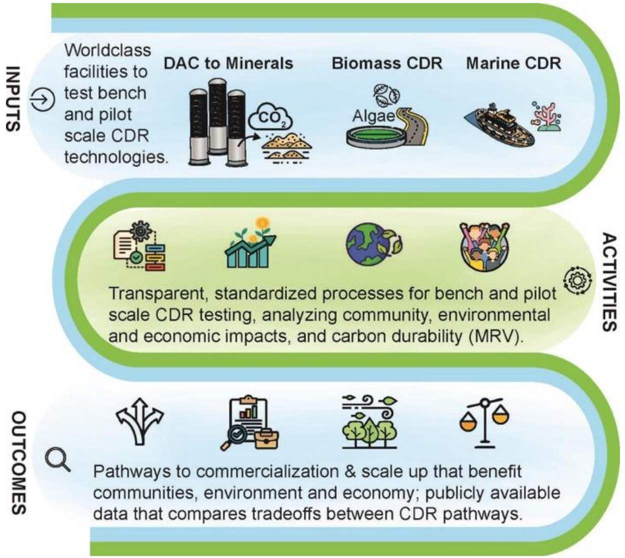


Meta



DACLab

DOE-funded DAC Testbed

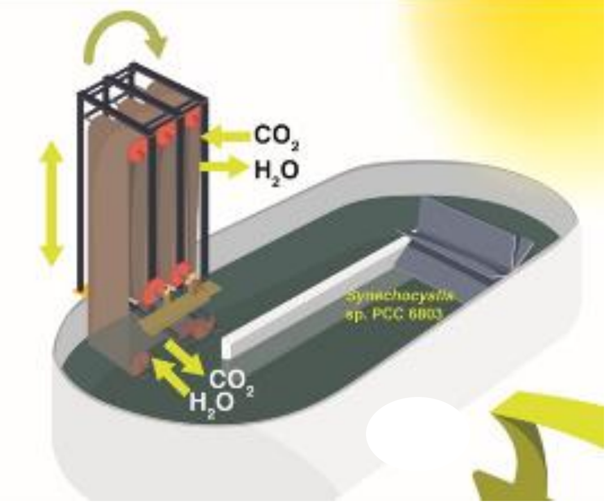


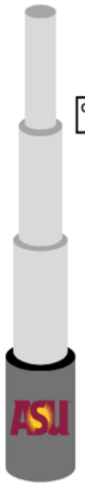
Worldclass facilities to test bench and pilot scale CDR technologies.

Transparent, standardized processes for bench and pilot scale CDR testing, analyzing community, environmental and economic impacts, and carbon durability (MRV).

Pathways to commercialization & scale up that benefit communities, environment and economy; publicly available data that compares tradeoffs between CDR pathways.

AUDACity, Integrated biological utilization





New Passive DAC IP:
"Telescope"

New partners for DAC Hub

280earth

Carbon Utility

Clairity TECH

Mobile Air to Methanol (Air2Fuel)

The **Air2Fuel system** integrates three technologies:

DAC Pilot at ASU

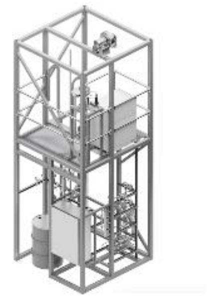
Low Energy Capture

Arizona State University

Carbon-Free H_2 Pilot at NREL

Novel H_2 Designs

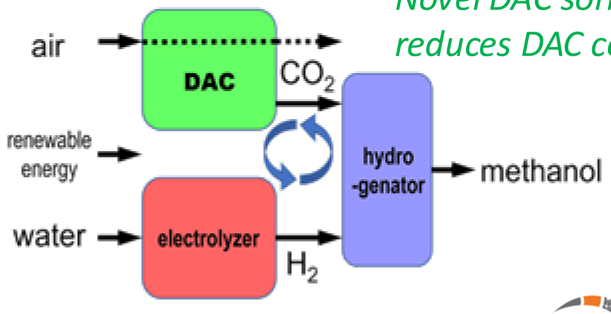
NREL NATIONAL RENEWABLE ENERGY LABORATORY



CO_2 to MeOH Pilot at Air Company

Transformational Catalysts

AIR COMPANY



H_2 production provides heat needed for DAC, but requires $0.02/kWh electricity to be economical

Water can be sourced from Air and 85% recycled

Novel DAC sorbent/form reduces DAC cost ~5x

And **community benefits planning** experts:

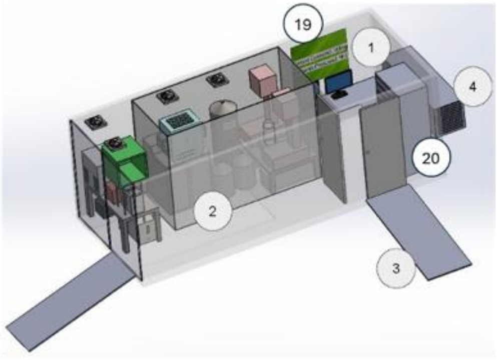
1. Jeremy Babendure (SciTech & ASU): Workforce
2. Lauren Keeler, Joni Adamson: Environmental Justice and Community Engagement
3. Jennifer Chandler: Diversity, Equity and Inclusion

Phase I Project Summary (12/23-12/24)

Conceptual designs for a 770k tonne methanol (MeOH) per year facility & 1 L MeOH per day mobile system

Workshop with +30 stakeholders evaluated community risks and benefits of producing chemicals/fuels and energy storage with Air2Fuel

Phase II Proposal Submitted

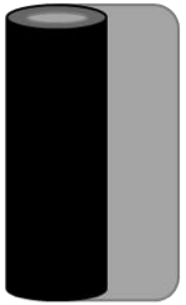


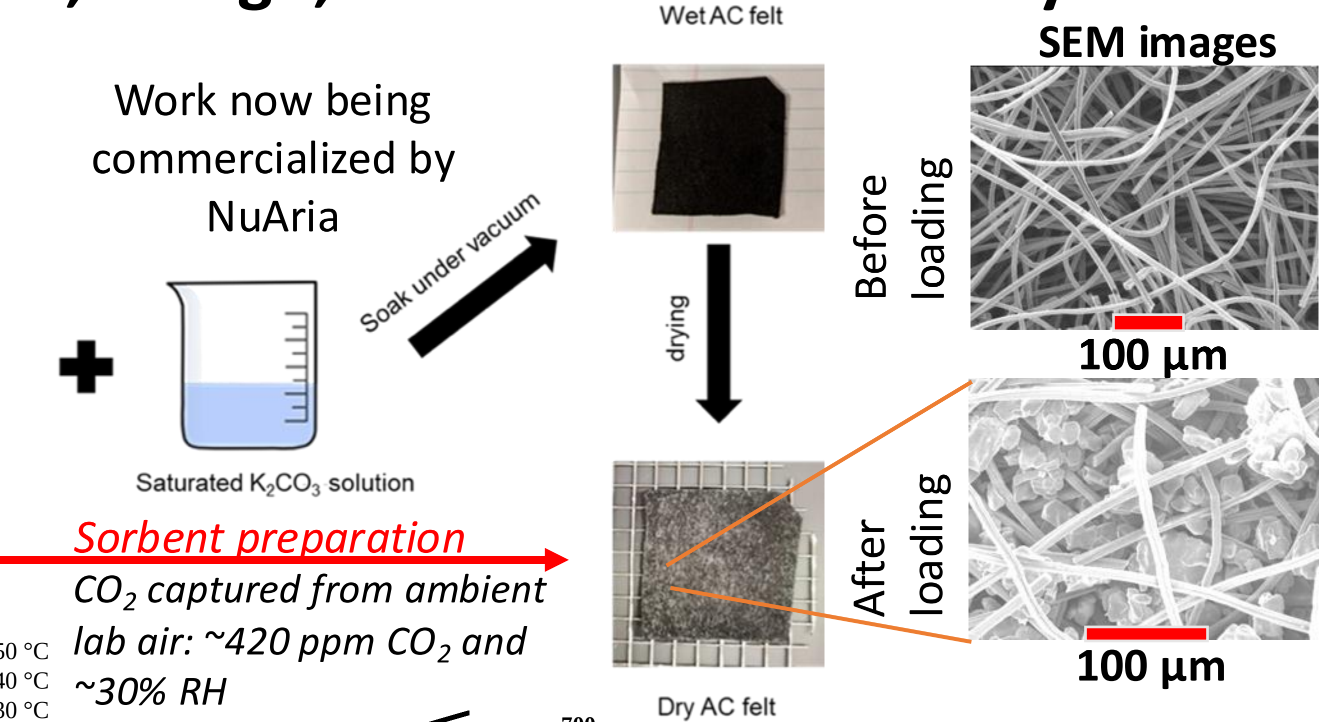
Methanol car
& generator demo

Potential NREL site for Phase II demo: Energy Systems Integration Facility

Low cost, benign, scalable sorbent and system for direct air capture of CO_2

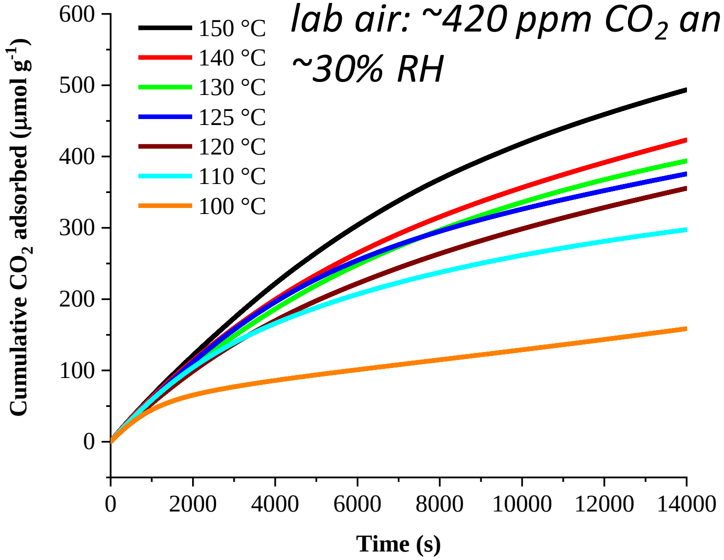
Work now being commercialized by NuAria



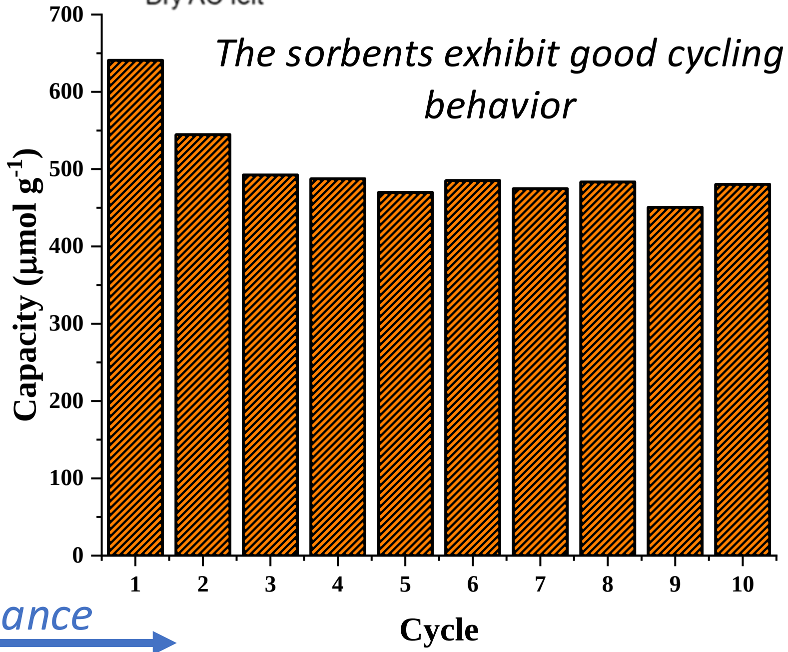


Sorbent preparation

CO_2 captured from ambient lab air: ~420 ppm CO_2 and ~30% RH



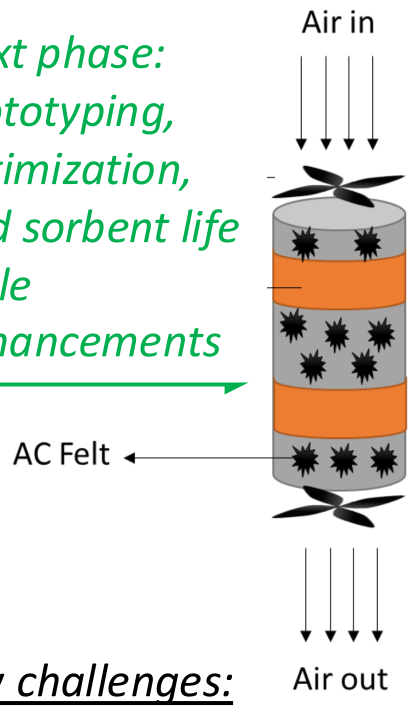
CO_2 desorption increases with temperature; so do energy costs



The sorbents exhibit good cycling behavior

Sorbent performance

Next phase: prototyping, optimization, and sorbent life cycle enhancements



**Sorbent engineering and process optimization could further improve this number

Key challenges:

- *Current sorbents face significant life cycle issues (petroleum-derived materials, landfilled at end-of-life, etc.)*
- *Long term stability and estimated end-of-life unknown for polymeric sorbents*

Biomass-derived sorbents could be a drop-in replacement for the sorbents we are studying

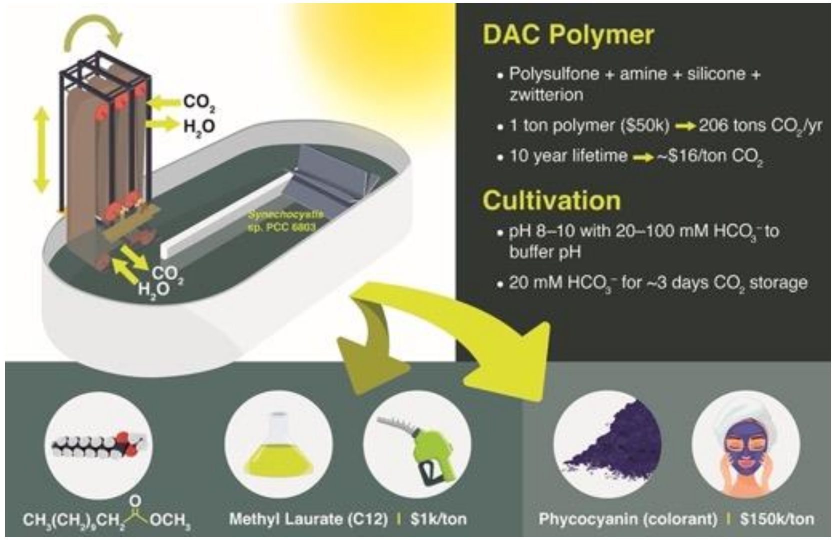
Patent Apps PCT/US2022/015647 and 63/550,426

Polymers for CO_2 capture and cyanobacteria productivity

Green Research Group

Questions?

Can we capture CO_2 from air and release in cyanobacterial culture?
Can we prepare a polymer with Q.A. groups without bactericidal effect?

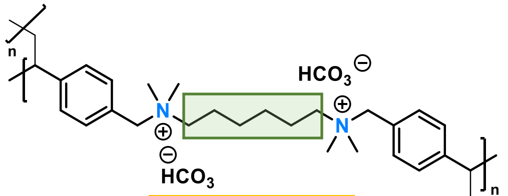


DAC Polymer

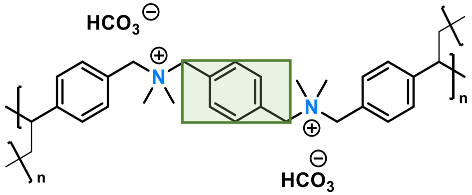
- Polysulfone + amine + silicone + zwitterion
- 1 ton polymer ($50k) → 206 tons CO_2/yr
- 10 year lifetime → ~$16/ton CO_2

Cultivation

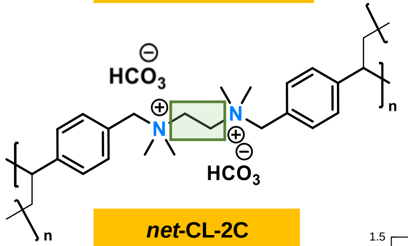
- pH 8–10 with 20–100 mM HCO_3^- to buffer pH
- 20 mM HCO_3^- for ~3 days CO_2 storage



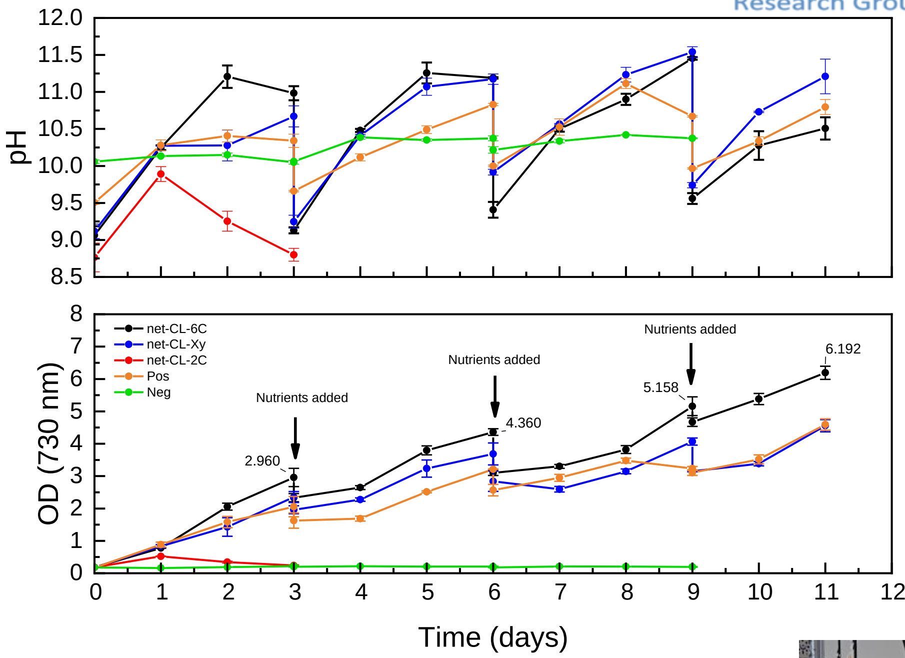
***net*-CL-6C**

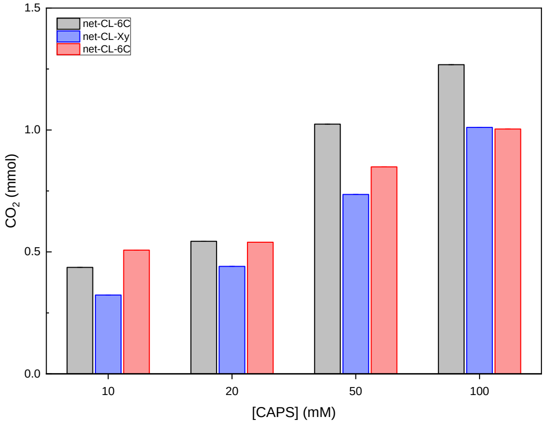


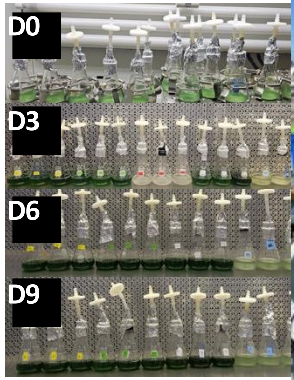
***net*-CL-Xy**



***net*-CL-2C**







	IEC$_{theo}$ [mmol g^{-1}]	IEC$_{exp}$ [mmol g^{-1}]	CO_2 release $_{exp}$ [mmol g^{-1}] D0	CO_2 release $_{exp}$ [mmol g^{-1}] D12	Remaining capacity (%)
net-CL-6C	4.0	3.1	2.3	1.5	65
net-CL-Xy	4.2	3.6	2.7	0.7	27

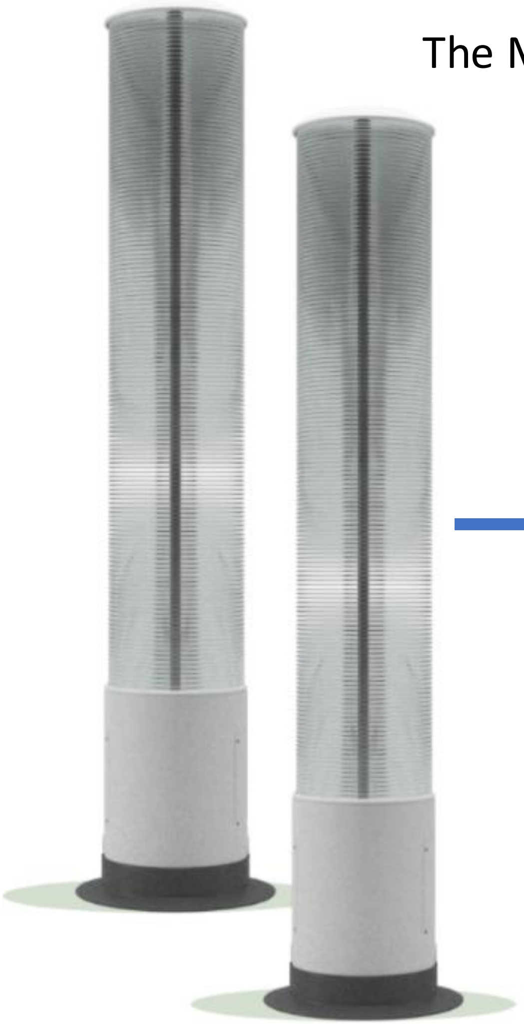
Velazco Medel, *In preparation*

ASU Center for Negative Carbon Emissions

Scaling up to make a difference in the global CO_2 concentrations

The Mechanical Tree™

CARBON
COLLECT



~100 kg CO_2/day/tree

Dr. Gokhan Demirci

the center for negative carbon emissions

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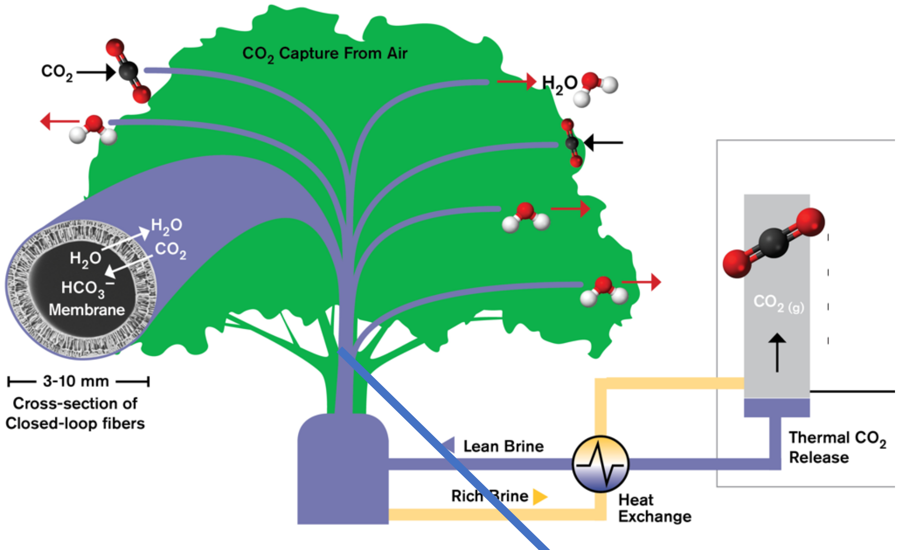
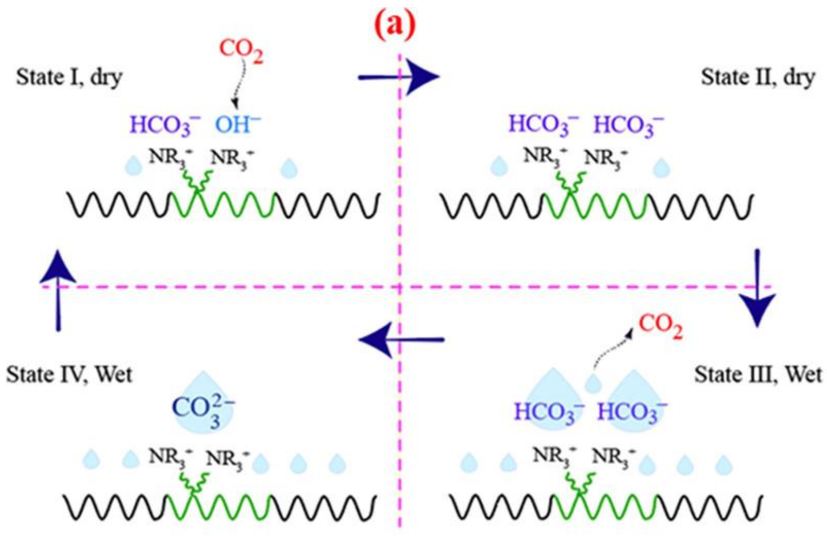
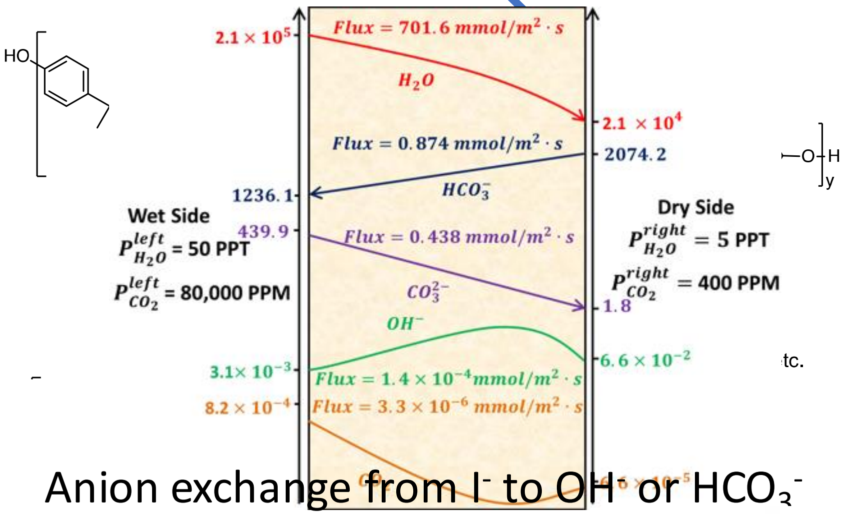
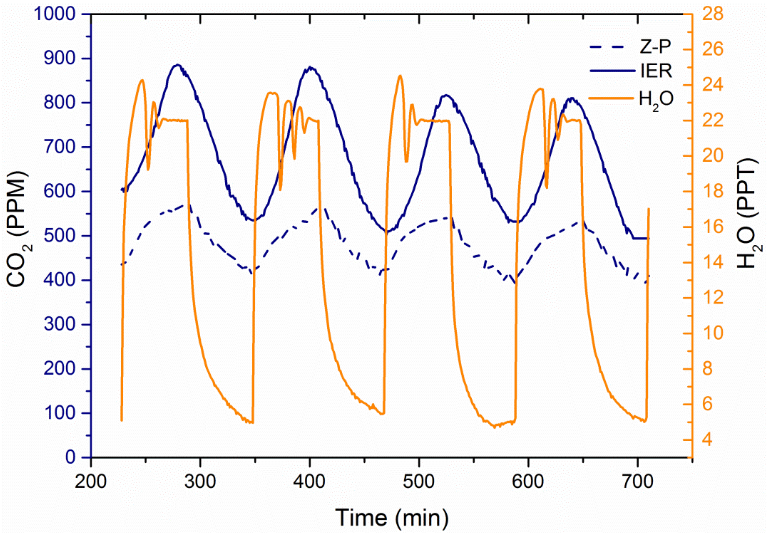
Continuous moisture-driven CO_2 capture





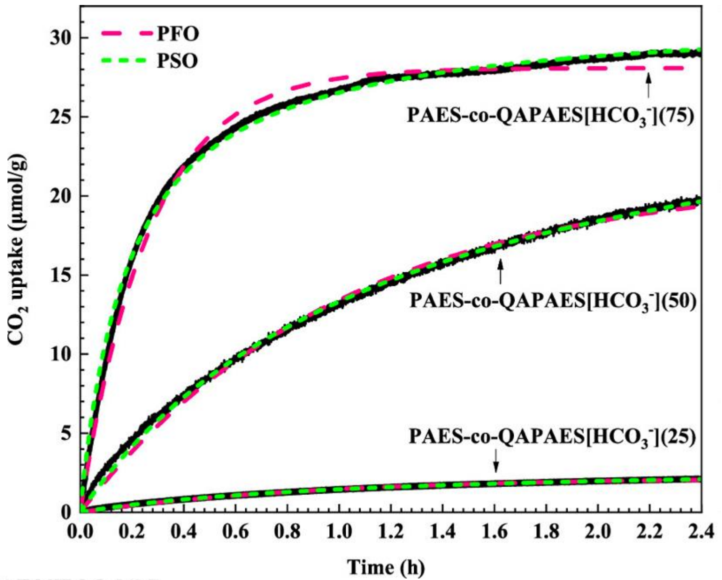


Anion exchange from I^- to OH^- or HCO_3^- by precipitation and/or dialysis

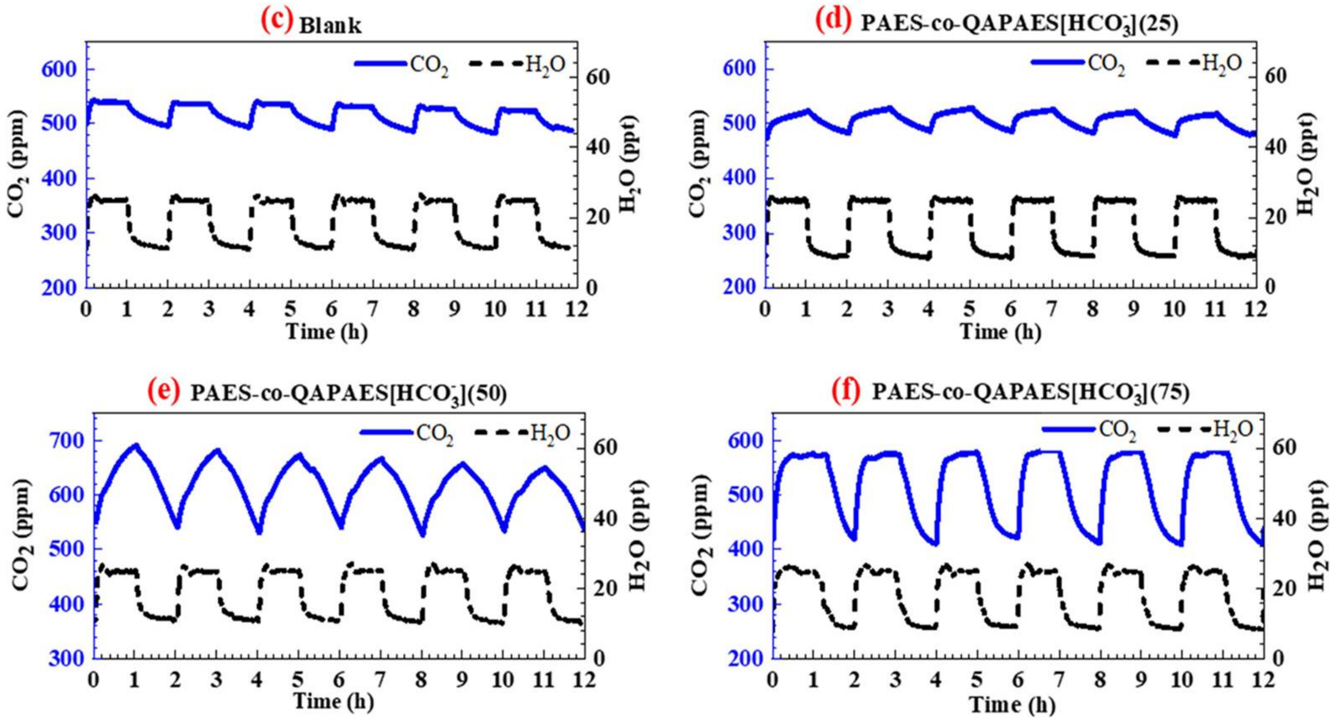


QPAES copolymer analysis

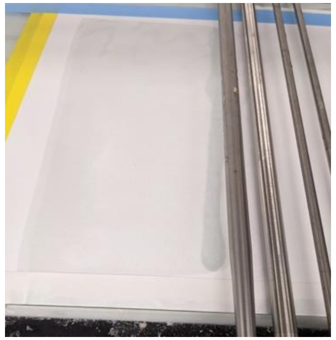
	M_n (kDa)	M_w (kDa)	Đ
16 KDa Udel® PSU	23.7	42.7	1.80
22 KDa Udel® PSU	49.3	79.8	1.60
(PAES)(75)-co-(APAES)(25)	21.7	43.1	1.99
(PAES)(50)-co-(APAES)(50)	73.5	146.2	1.99
(PAES)(25)-co-(APAES)(75)	83.1	246.6	2.98

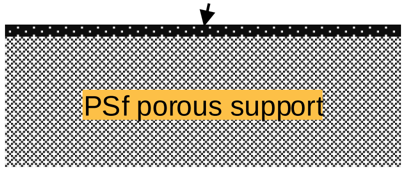


<3% of active sites utilized



Drawn down machine





Thin active layer

PSf porous support

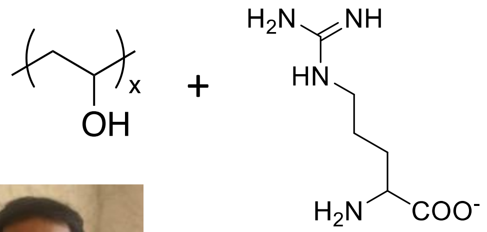
41% of sites utilized in moisture swing

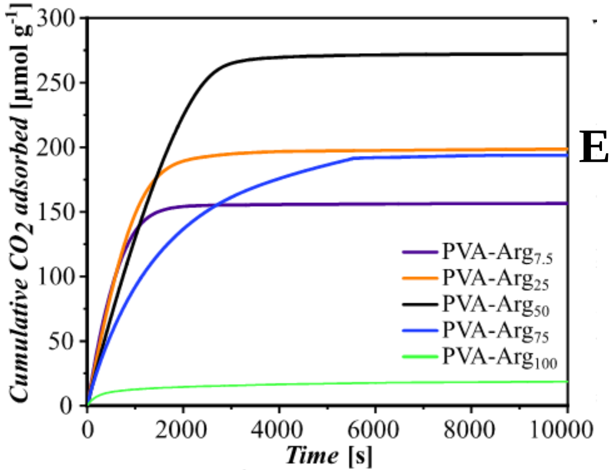
~3.5 m^2 membrane (~1 ft x 38 ft)

Continuing this effort w/ Prof. Tom Miller (UCL)

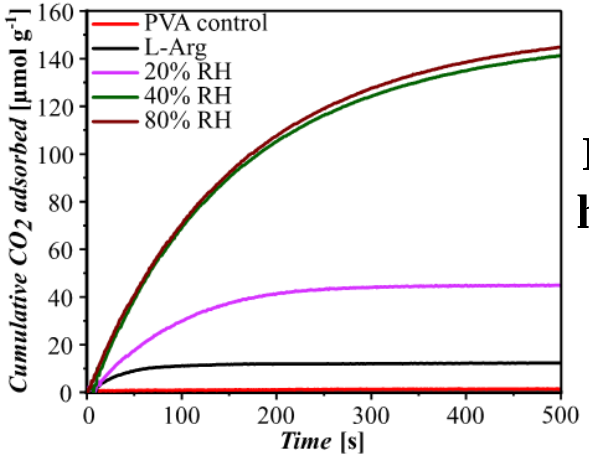
Shokrollahzadeh Behbahani, H. *Macromolecules*, **2023**, 56(16), 6470

PVA-arginine nanofiber composites

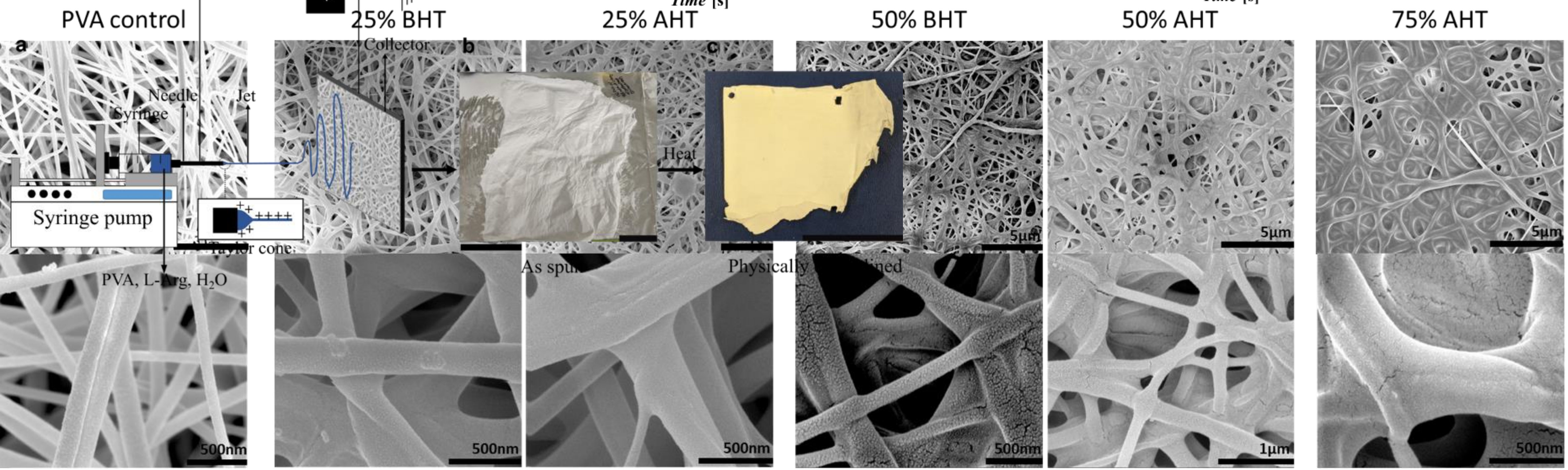




Effect of Arg conc.

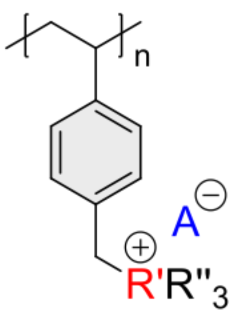


Effect of humidity


PVA control
25% BHT
25% AHT
50% BHT
50% AHT
75% AHT

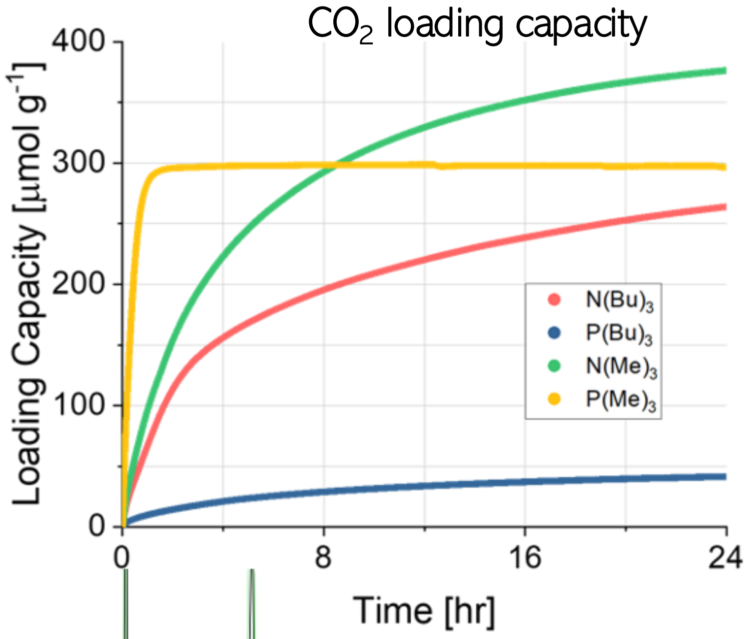
Korah, M.M. *ACS ES&T Eng*, **2023**, *3*(3), 373–386

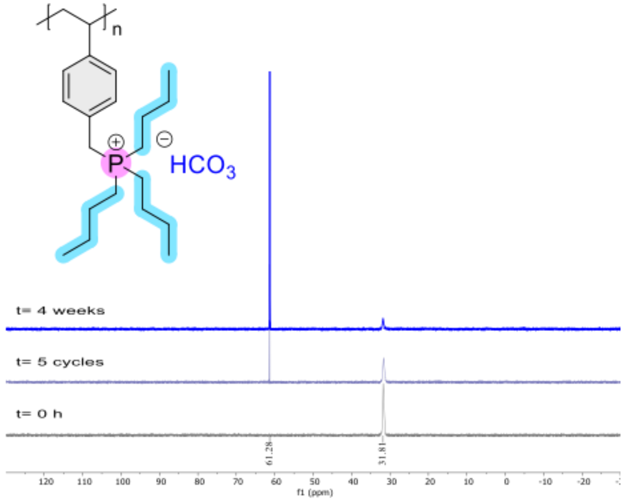
Exploring phosphonium-containing polymers for CO_2 capture via moisture-swing

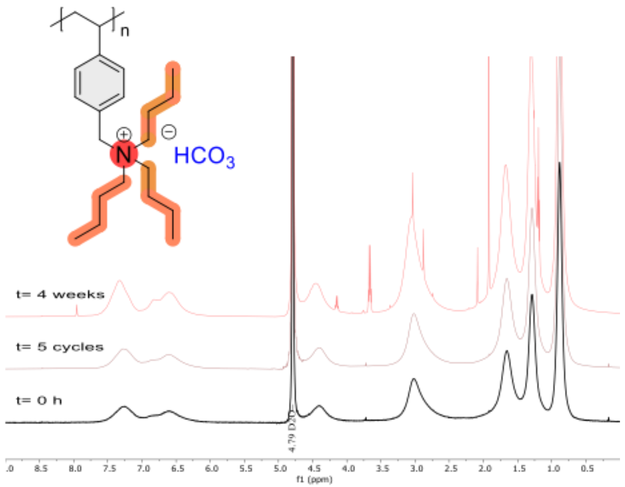


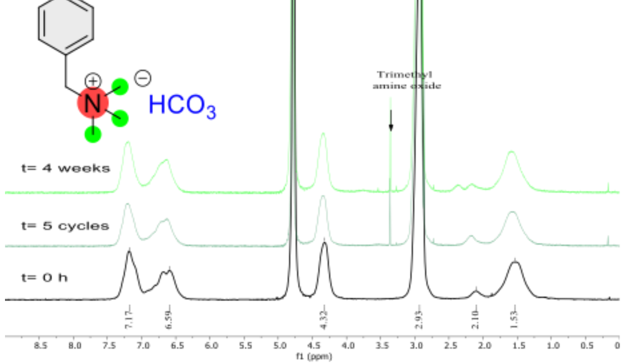
R'= P, N
R"= Me, Bu
A= $^-HCO_3$

Polymer	$^1IEC_{theo}$ [mmol g^{-1}]	$^2IEC_{exp}$ [mmol g^{-1}]
$[PVBTMeA]^+[HCO_3]^-$	4.2	3.5 ± 0.30
$[PVBTBuA]^+[HCO_3]^-$	2.7	2.2 ± 0.23
$[PVBTMeP]^+[HCO_3]^-$	3.9	3.9 ± 0.3
$[PVBTBuP]^+[HCO_3]^-$	2.6	2.3 ± 0.15









Velazco-Medel *in preparation*

Velazco Medel, *In revision*

Center for Negative Carbon Emissions

Summary

- The CNCE is a thought leader in DAC materials, systems, and integration globally
- The expertise of CNCE students, staff, and faculty extends from atomic to pilot scales
- Graduates from the CNCE are equipped to tackle global challenges in sustainability through use-inspired, transdisciplinary training programs and projects
- We are an incubator for IP and early stage ventures
- We want to collaborate!