Negative Emissions Overview

Maryland Energy Institute
April 23, 2021

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IPCC 1.5

What are negative emissions and why are they important?

How is carbon captured (technology overview)?

What can you do with captured carbon? Explain net-zero (fuels, chemicals) vs. negative (sequestration, permanent materials).

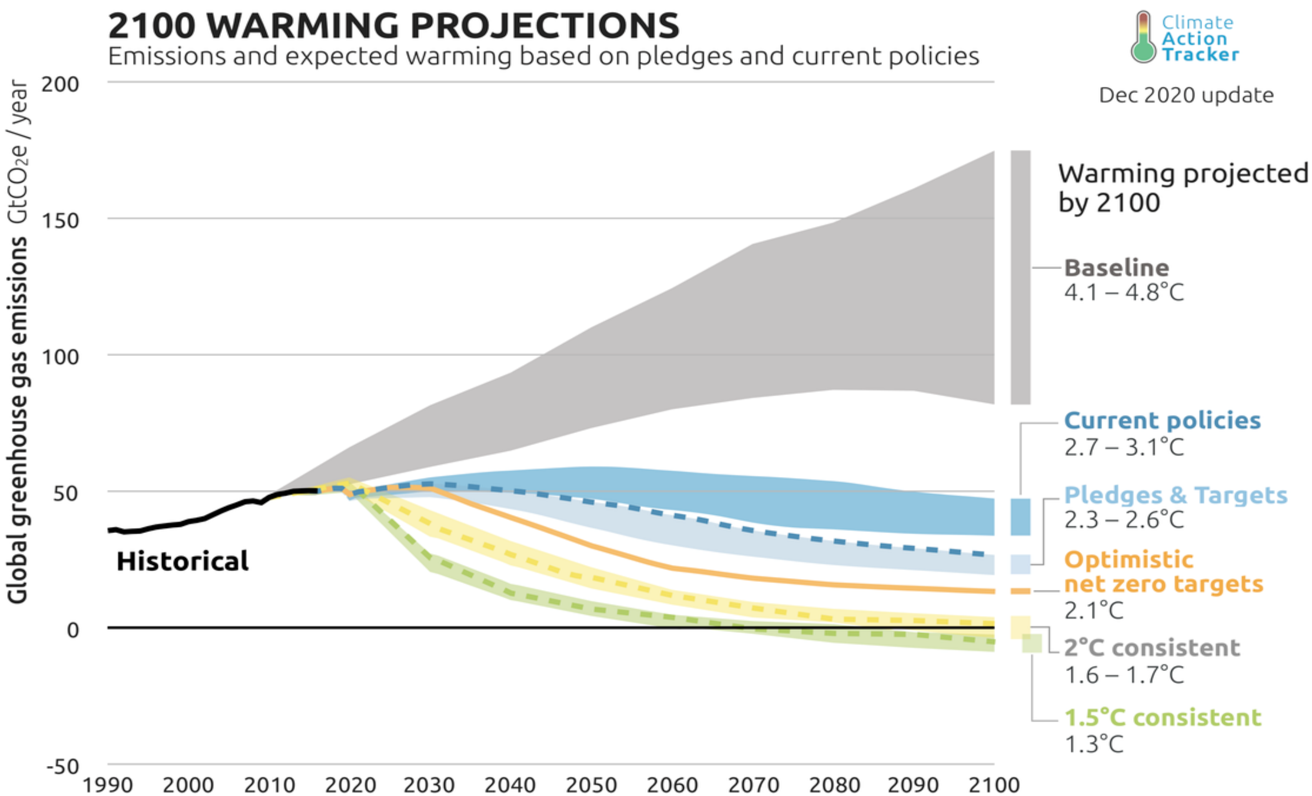
Recent history of federal CCUS/CDR programs.

Anticipated federal R&D spending and focus areas in CCUS/CDR

Comments on the State of the Art. Where are the gaps / R&D opportunities?

Q&A

STATUS QUO NOT SUFFICIENT



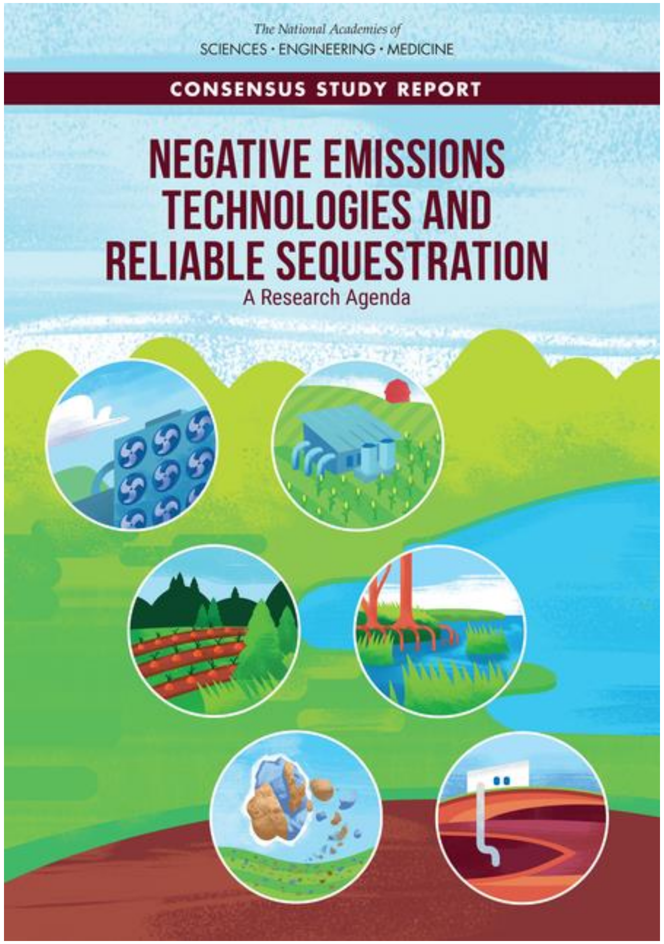
The **current challenges** with direct air capture solutions amongst established and emerging companies:

1. **Expensive**
2. **Require new manufacturing infrastructure for capture agents**
3. **Face gigaton scalability challenges**

NATIONAL ACADEMY OF SCIENCES (NAS) REPORT ON NETs

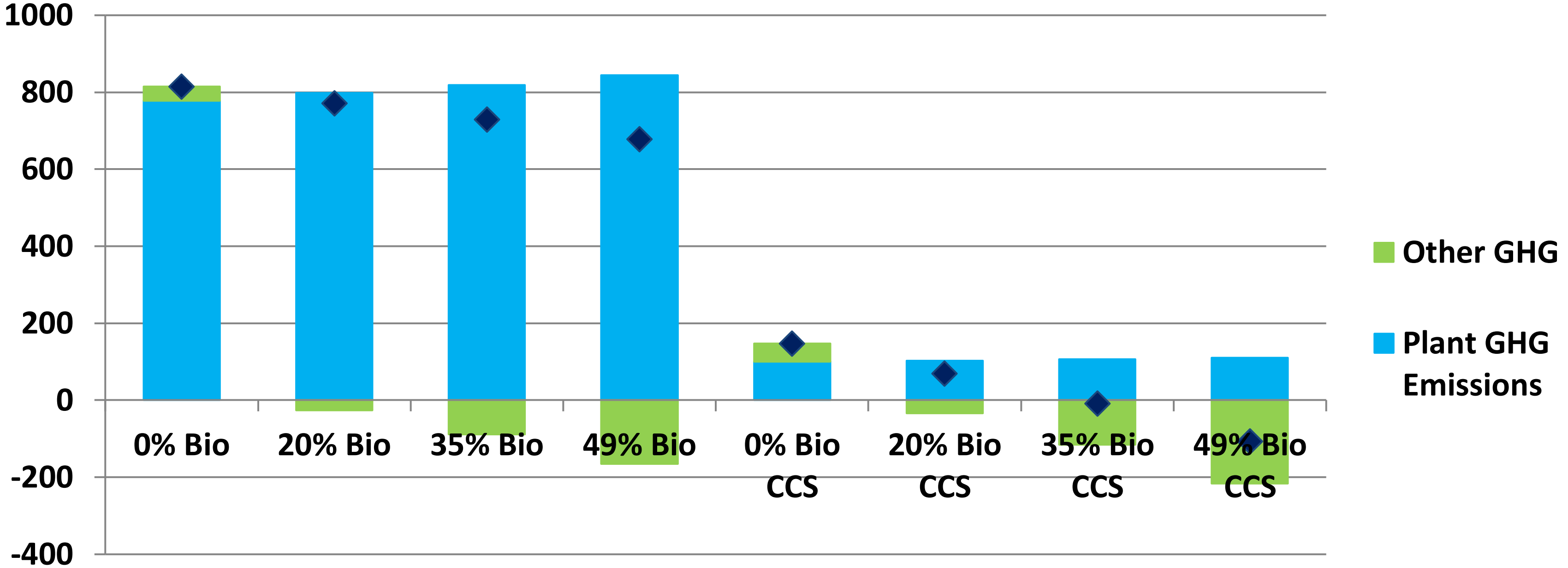
- **2017 - Co-funded by DOE-FE, EPA, NOAA, USGS, and private funders.**
- **2018 NASEM report released**
- **Defined six areas of NETs:**
  - Coastal Blue Carbon
  - Terrestrial Carbon Removal & Sequestration
  - Bioenergy with Carbon Capture and Sequestration (BECCS)
  - Direct Air Capture (DAC)
  - Carbon Mineralization of CO_2
  - Sequestration of Supercritical CO_2 in Deep Sedimentary Geological Formations

FE-related efforts



LIFE CYCLE GHG EMISSIONS CONTRIBUTION

Global Warming Potential [100-yr] (kg CO_2e/MWh)



- Carbon-neutral or –negative coal-fired electricity can be achieved by adding both biomass and CCS to PC systems
  - Neutrality occurs near 35% Biomass with 90% CCS
- Adding biomass decreases GHG emissions but increases other environmental impacts to air and water

CARBON MINERALIZATION OF CO_2/ENHANCED WEATHERING

- **NAS defines as both surface and subsurface**
- **Surface/Ex situ: reactive minerals (e.g., exposed rocks, mine tailings and alkaline industrial wastes)**
  - DOE-FE and NETL early research on utilization of magnesium silicate and calcium silicate minerals in surface processes
- **Subsurface (included within Carbon Storage Program)**
  - Regional Carbon Sequestration Partnerships – Carbon Storage Atlas - characterization efforts
  - Projects with PNNL, Yale, University of Washington, Virginia Tech on potential subsurface response/interactions of mafic/ultramafic rocks with CO_2
  - Big Sky RCSP – 1,000 ton injection project in Wallula, WA
  - CarbFIX project in Iceland – Columbia University
  - CarbonSAFE Phase 1 Project – Cascadia basin in offshore Washington state and British Columbia – Columbia University

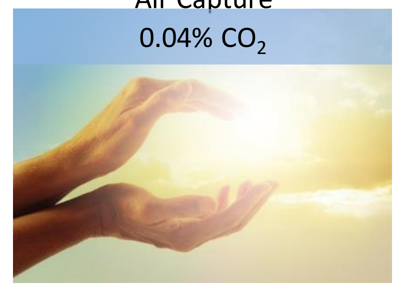
Carbon Dioxide Separations

Leveraging R&D for multiple applications

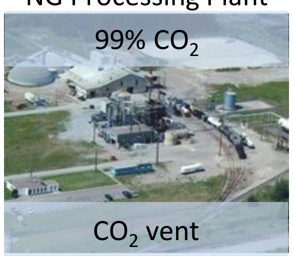
Coal Power Plant

Gas Power Plant

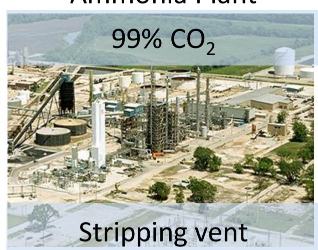
Air Capture



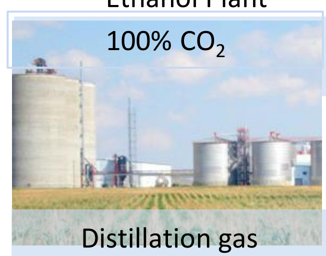
NG Processing Plant



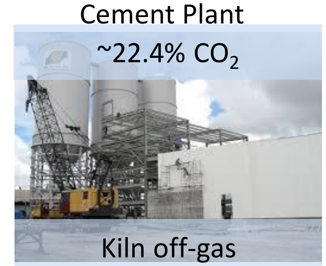
Ammonia Plant



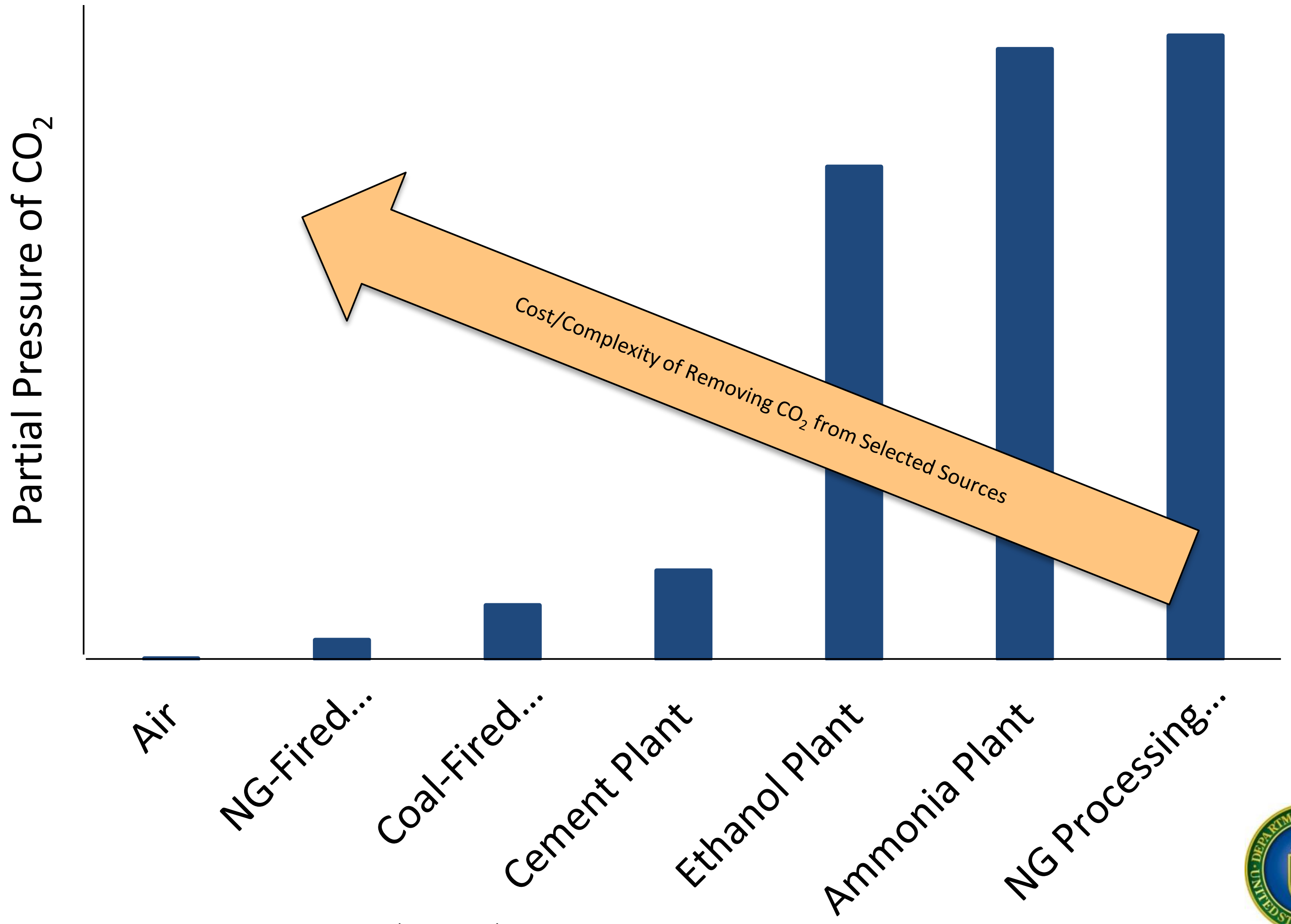
Ethanol Plant



Cement Plant



Cost of Capturing CO_2 from Industrial Sources, January 10, 2014, DOE/NETL-2013/1602



Cost of Capturing CO_2 from Industrial Sources, January 10, 2014, DOE/NETL-2013/1602

PIONEERS AND DOE-FE DAC – WORKSHOP

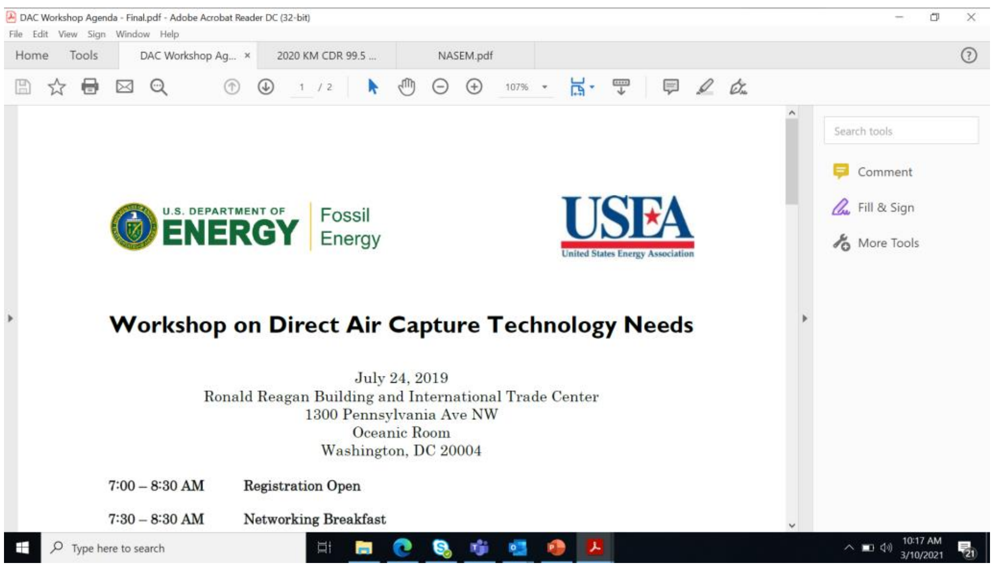
climeworks

Carbon Engineering

Global Thermostat

Klaus Lackner – Center for Negative Carbon Emissions - ASU

- **July 24, 2019**, FE and USEA convened a workshop, *Workshop on Direct Air Capture Technology Needs.*



U.S. DEPARTMENT OF ENERGY | Fossil Energy

USEA United States Energy Association

Workshop on Direct Air Capture Technology Needs

July 24, 2019
Ronald Reagan Building and International Trade Center
1300 Pennsylvania Ave NW
Oceanic Room
Washington, DC 20004

7:00 – 8:30 AM	Registration Open
7:30 – 8:30 AM	Networking Breakfast

Carbon Dioxide Capture

- ***Materials***
  - Solvents
  - Sorbents
  - Membranes

- ***Processes***
  - Absorption/Desorption
  - Fluidized, moving or fixed bed, TSA/VSA/PSA

CARBON CAPTURE VS CARBON DIOXIDE REMOVAL

	Point Source Capture	Carbon Capture Removal
Materials	Solvent, sorbent, membranes	Similar
Costs	$	$$$
Incentives	45Q	45Q & LCFS
CO_2 end use	EOR, Saline, utilization	EOR, Saline, utilization
Challenges	Capital	Pressure drop
Process	Absorber/Regenerator	Air Contactor
		Waste heat, modular

Courtesy of Carbon Engineering

ONE POSSIBLE APPROACH FOR TRANSFORMATIONAL GEN DAC AND UTILIZATION – DRAFT

2018
2nd gen R&D

2020
Transformational R&D

2022-2026
2nd Gen pilots across multiple utilization pathways

2027-2029
Initiate pilot scale tests for transformational technologies

2027-2030
FEED studies for Integrated transformational Gen DAC and Utilization Projects

2029-2032
Integrated DAC-Utilization 2nd Gen Demos

2035
Advanced technologies available for broad commercial-scale deployment

net-zero (fuels, chemicals) vs. negative (sequestration, permanent materials).

ENERGY LIFE CYCLE ANALYSIS (LCA)

- Cradle-to-Grave Environmental Footprint of Energy Systems

What is Life Cycle Assessment/Analysis (LCA)?

LCA is a technique that helps people make better decisions to improve and protect the environment by accounting for the potential impacts from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave).

THE NETL CO2U LCA GUIDANCE TOOLKIT

netl.doe.gov/LCA/CO2U

GUIDANCE DOCUMENT

LCA

Analysis requirements and instructions for using the supporting data and tools

Starting point for understanding LCA requirements

OPENLCA MODEL TRAINING

Provided to funding recipients to aid in modeling an LCA in openLCA

Training videos and live webinars will be available as developed at www.netl.doe.gov/LCA/CO2U

SUBJECT MATTER EXPERT SUPPORT

Available to funding recipients for all phases of the LCA from conception to documentation

Contact us with questions at LCA@netl.doe.gov

(for NETL Project Recipients)

Upcoming Knowledge Sessions (Tentative Schedule)

Webinar 1: **October 2021**

Webinar 2: **November 2021**

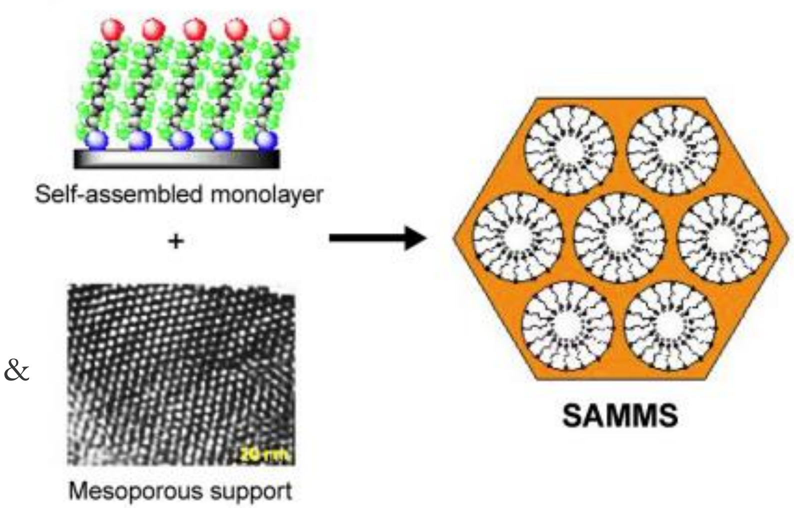
Webinar 3: **January 2022**

AOI2 - IWVC, LLC

Evaluate a Hybrid Direct Air Capture system (HDAC) that integrates PNNL's advanced CO_2 removal technology based on a novel solid sorbent known as self-assembled monolayers on mesoporous supports (SAMMS) & a high-performance desiccant to simultaneously capture CO_2 & water from the air

Objectives

- Conduct a detailed design for a 3000 CFM Hybrid DAC (HDAC) unit
- Fabricate desiccant beds & incorporate sorbent
- Conduct parametric & long-duration testing of complete HDAC unit on San Diego State University - Brawley Campus
- Complete TEA and LCA to demonstrate cost impacts of the technology & amount of carbon negativity provided



SAMMS is hybrid of self-assembly techniques and mesoporous materials

Relevance and Outcomes/Impact

- Reduced OPEX (zero water consumption & use of low-grade heat)
- Combining potable water generation & CO_2 capture in a single device with unique energy conserving features of proposed design enables an improved
- Ability to operate in regions with low- or zero water availability & below freezing temperatures

IWVC

Image Source: https://www.pnnl.gov/nano/research/pdf/samms_flier_12-03-2010.pdf

AOI2 - GLOBAL THERMOSTAT OPERATIONS, LLC

Develop a continuous motion DAC system that employs commercially-available monolith contactors & solid amine adsorbent with temperature swing desorption

Objectives

- Develop & validate mechanical components of DAC system
- Develop a phenomenological & systems level model of process to refine steps in cycle & support process development
- Fabricate process components & deliver to the Global Thermostat Technology Center for integration with mechanical system for testing
- Operate continuously for 1 month to collect on-stream data

Relevance and Outcomes/Impact

- Use of continuous process allows plant components to operate at steady state & reduces complexity required for starting & stopping system, leading to shorter cycle times, greater plant reliability, lower instantaneous utility demands, & lower CAPEX
- Process employs shallow honeycomb monolith contactors (~15 cm deep) that permit low pressure drops (100's of Pa) at gas approach velocities of 3-5 m/s while still maintaining a high geometric surface area per unit volume

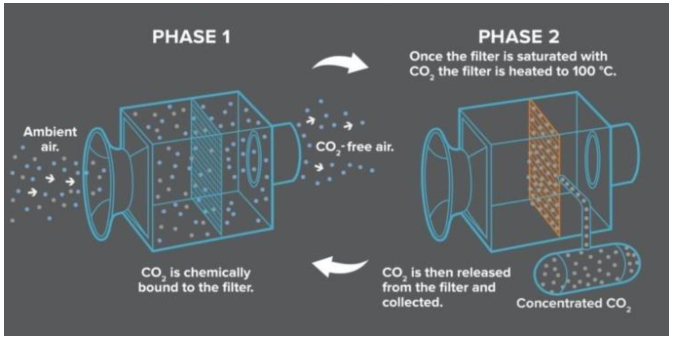
Global Thermostat

AOI2 - ELECTRICORE + SVANTE+ CLIMEWORKS

Design & construct an integrated DAC system that combines Climeworks' adsorption & temperature-vacuum swing desorption process with Svante's transformational structured adsorbent laminate material; test 30 kg/day pilot unit at a renewable energy facility in California

Objectives

- Complete a process flow design for the integrated DAC system based on a solid adsorbent with regeneration using vacuum & temperature swing desorption
- Optimize sorbent structure & sorbent manufacturing method
- Build, install & operate the system at Wintec Energy wind farm located in Palm Springs, CA



Climeworks' direct air capture technology

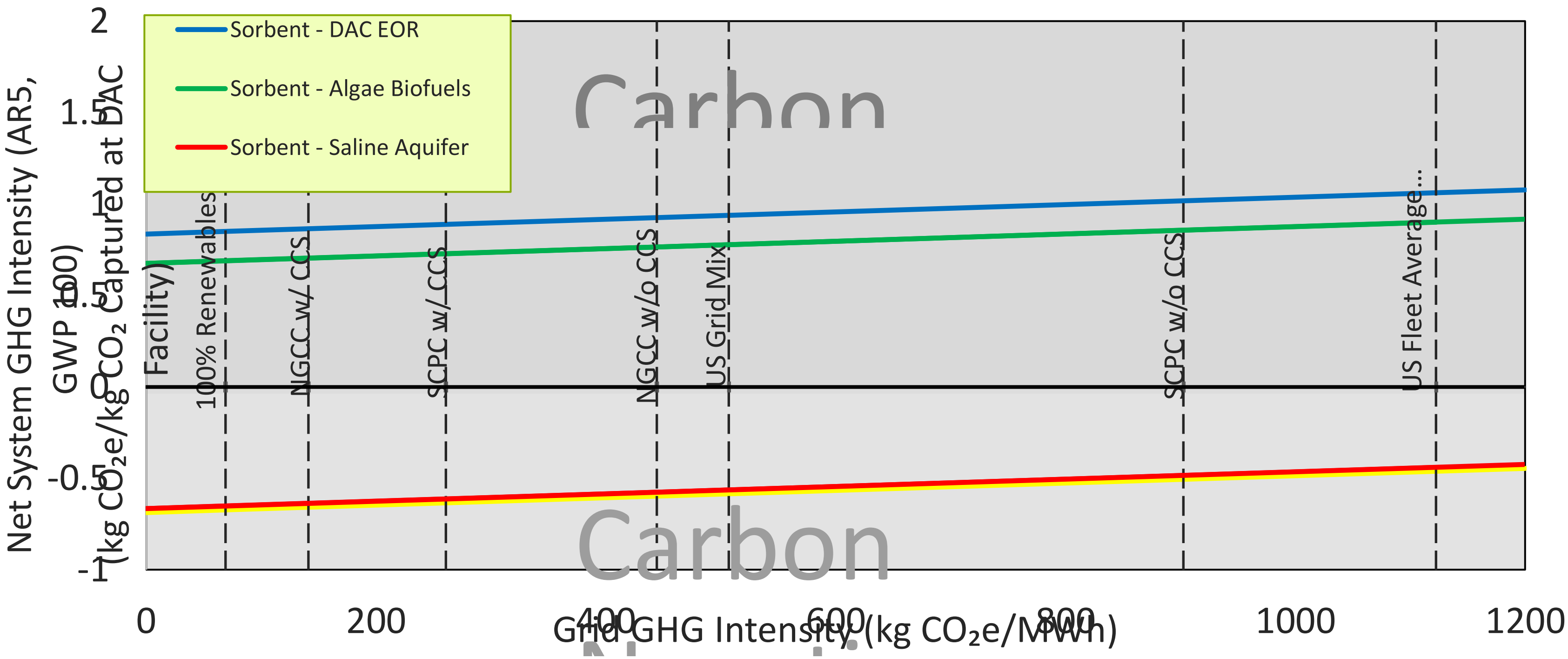
Relevance and Outcomes/Impact

- Cost reduction will be enabled by using advanced adsorbents in conjunction with optimization in process design (reducing pressure drop & improving heat recovery)
- Program will validate current state of the art DAC systems and sorbent materials & provide DOE & industry a benchmark

Palm Springs, CA

SORBENT-BASED DAC – NET GHG EMISSIONS

Cradle-to-Grave Impacts for Saline Aquifer Storage, EOR, & Algae Biofuel Production



Y-axis values below zero indicate life cycle carbon negative emissions. Results that are greater than zero indicate life cycle carbon positive emissions, as these results indicate that they emit more CO_2 than is removed from the atmosphere.

These values represent uncertain point estimates of nascent technology that may significantly change with development

FY21 DOE DAC/NETS APPROPRIATIONS LANGUAGE

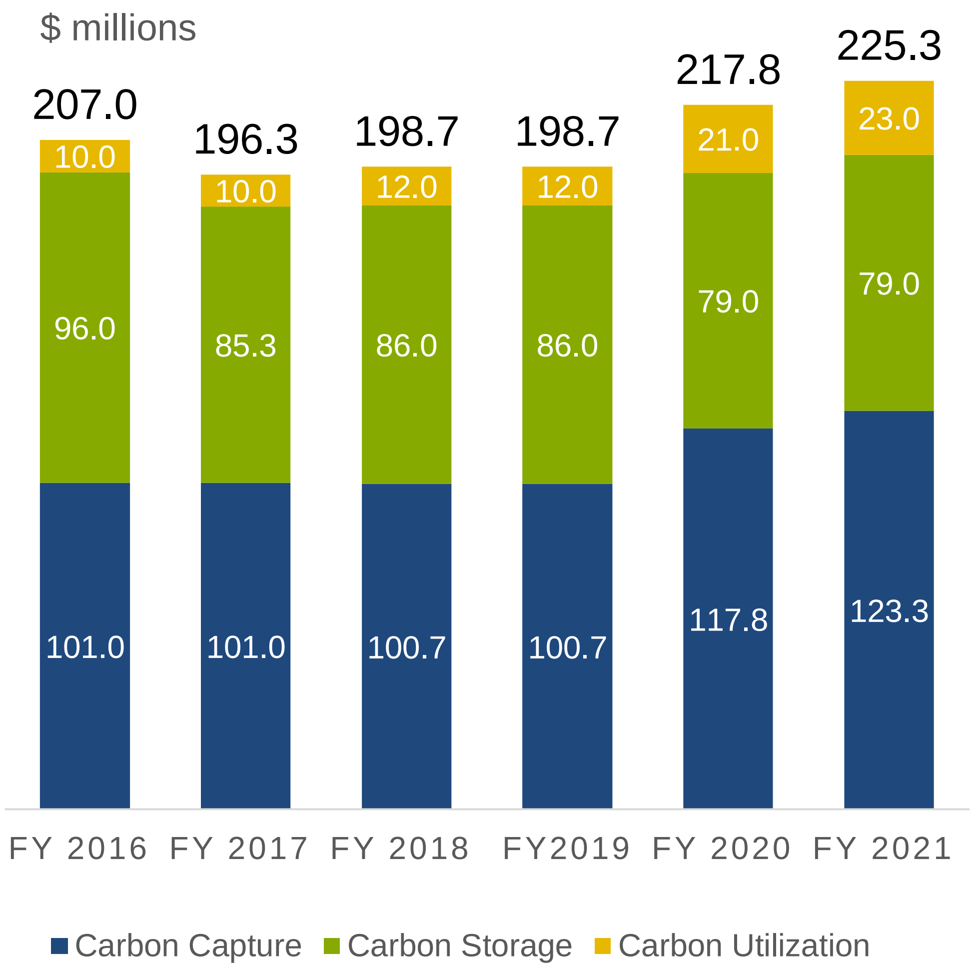
EERE: $ I 0,000,000 to support RD&D projects to advance the development and commercialization of DAC technologies. The program is directed to <u>continue collaboration with the Office of Science and the Office of Fossil Energy in this area.</u>

Science: Negative Emissions Technology.-The agreement provides not less than $22,500,000 in BES and Biological and BER for R&D of NETs, including not less than $7,500,000 for DAC. The Office of Science is directed to <u>continue to collaborate with the Office of Fossil Energy and the Office of Energy Efficiency and Renewable Energy to support research, development, and demonstration projects to advance the development and commercialization of carbon removal technologies on a significant scale.</u>

FE: Development of negative emissions technologies, including not less than $40,000,000, with not less than $15,000,000 for DAC

Department of Defense

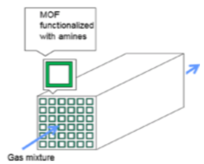
ANNUAL CCUS APPROPRIATIONS 2016-2021



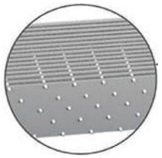
AOI 1 – BENCH-SCALE TESTING OF MATERIAL OR SYSTEMS (TRL 3)

Structured Material Systems

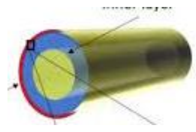
Simulated Exhaust / Batch Operation



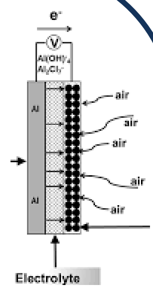
Monoliths



Laminate Structures



Membrane Bundles



Electrode

Input

DAC Composition

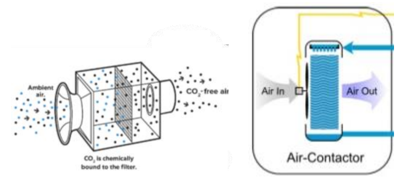
- CO_2 Working Capacity
- CO_2 Uptake kinetics
- CO_2 desorption Kinetics
- Sensible Heat
- Surface area

Success Criteria

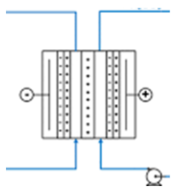
- Lower Pressure Drop
- Increase Space Velocity
- Increase CO_2 capture efficiency
- Lower Heat Duty
- Lower Capacity Fade
- Increase Volumetric Productivity
- Preliminary & final TEA
- TRL 3

Component Designs

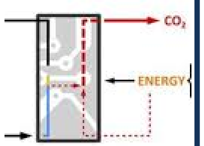
Simulated Exhaust / Batch Operation



Air Contactors Design (Sorbents / Solvents systems)



E-chem cells Design



Desorbers Design

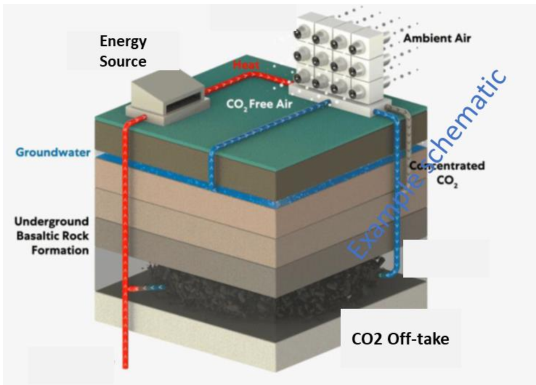
Success Criteria

- Lower Pressure Drop
- Lower Heat Duty
- Increase Volumetric Productivity
- Preliminary & final TEA
- Lower component cost
- TRL 4

Up to 5 awards (24 months)… \$1,500 K $_{\text{DOE share}}$ / award; 20% Cost Share (AOI 1)

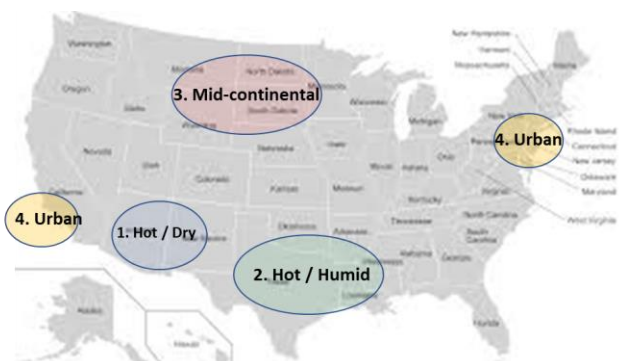
AOI 2 - INITIAL ENGINEERING DESIGN OF CCUS DAC SYSTEM (TRL 6)

CCUS System for DAC



100,000+ tonne/yr. net CO_2 from air.

Geographical pre-defined areas with distinct environmental/air quality conditions



Input:

- DAC Technology (TRL 6)
- Each application will select three distinct host sites from the pre-defined geographical areas
- Energy Source (Fossil or renewable & Energy storage)
- CO_2 Storage or Utilization Pathway

Output:

Initial engineering analysis for **three individual** case studies including:

- Energy source integration including CO_2 capture from fossil-fuel based BOP
- CO_2 utilization & storage pathways
- Business case analysis (i.e. LCFS / 45 Q credits)
- TEA, LCA

Up to 3 awards (18 months)… $2,500 K $_{\text{DOE share}}$ / award; 20% Cost Share (AOI 2)


Thank You
Questions?
Lynn.Brickett@hq.doe.gov