Scaling Up-Direct Air Capture (DAC): Learnings From Traditional Capture Projects

Kevin C. OBrien, PhD
Director, Illinois Sustainable Technology Center
Director, Illinois State Water Survey

Briefing Panel: Environmental and Energy Study Institute
May 25, 2022

ILLINOIS
Prairie Research Institute

EESI
Environmental and Energy Study Institute

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Skilled in transitioning from lab scale to build/operate scale

UNIVERSITY OF ILLINOIS / PRI: LEADER IN CAPTURE R&D

Prairie Research Institute (PRI): Addressing Societal Issues

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

ILLINOIS

↓

ILLINOIS
Prairie Research Institute

↓

Potential Endangered Species → ILLINOIS Illinois Natural History Survey PRAIRIE RESEARCH INSTITUTE

Water → ILLINOIS Illinois State Water Survey PRAIRIE RESEARCH INSTITUTE

Storage → ILLINOIS Illinois State Geological Survey PRAIRIE RESEARCH INSTITUTE

Potential Artifacts → ILLINOIS Illinois State Archaeological Survey PRAIRIE RESEARCH INSTITUTE

Capture → ILLINOIS Illinois Sustainable Technology Center PRAIRIE RESEARCH INSTITUTE

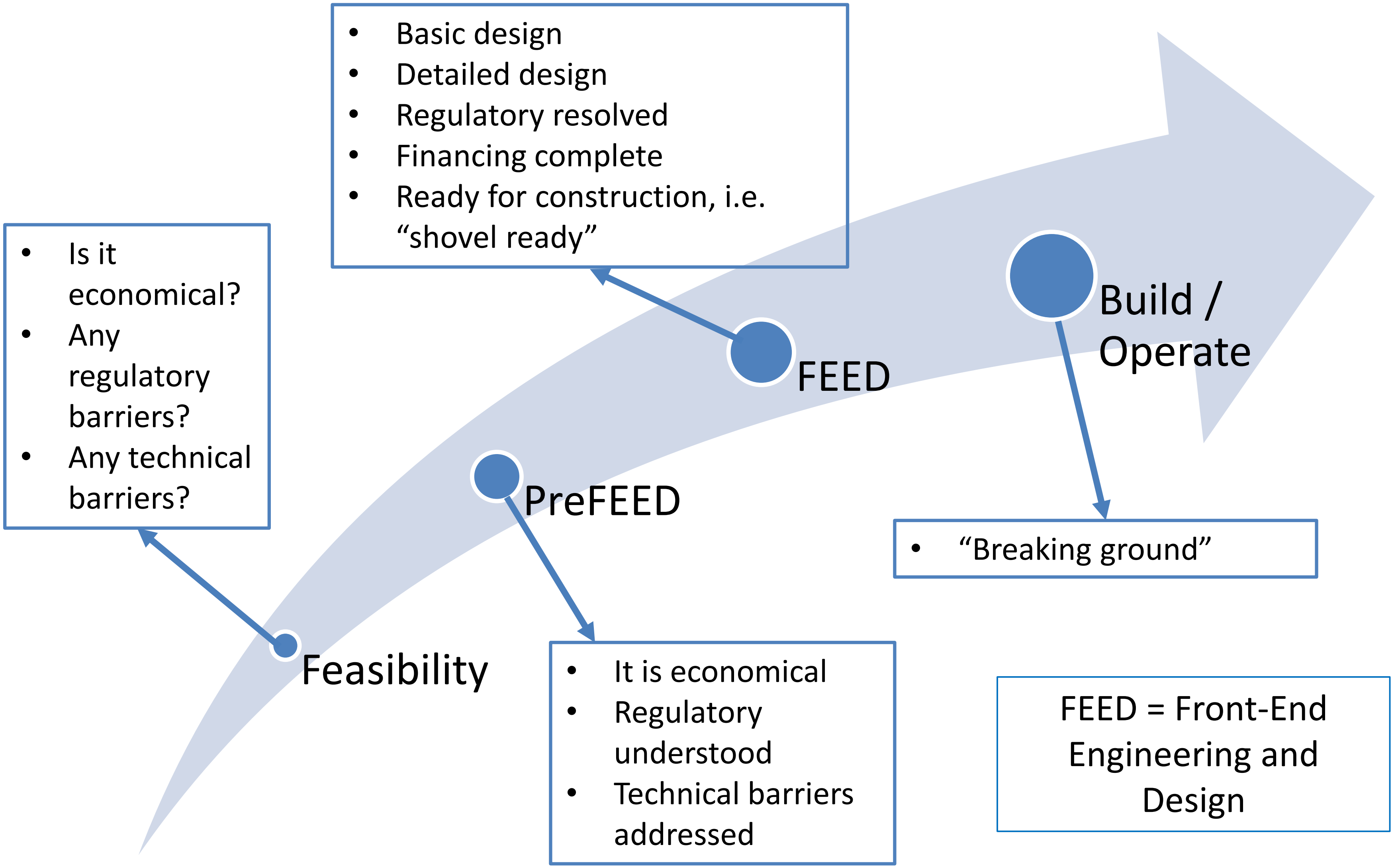
UIUC / PRI Network

Multi-organizational team is required

- Relationships and access to host sites in the region / US
- Network of Engineering Procurement and Construction (EPC) firms, OEMs, etc.
- Infrastructure in place (financial, project management, etc.) to meet US Department of Energy (DOE) requirements
- Typically functions as “prime” for projects
- “Agnostic” approach to technology, i.e. willing to work with any technology as long as it works

Pathway to Scaling-Up Capture Technologies

Traditional Capture Provides Good Lessons Learned for DAC scale-up



FEED = Front-End Engineering and Design

ILLINOIS
Prairie Research Institute

UIUC Project Portfolio

Color code: Complete / In Process

Lab	Small Pilot	Large Pilot / Full Scale
Next generation DAC materials	0.5 MW Capture w/Mixed Salts	816 MW capture plant (largest capture FEED in the world)
	40 kW – Biphasic Capture System	10 MW – Build / Operate (largest capture pilot in the world)
	0.5 MW aerosol reduction technologies	350 MW –Capture, energy storage, algae, hybrid coal/NG
	FGD blown-down water recycle	1 MW- Build/operate Utilize CO2 from flue gas for algae growth
		Capture from Cement Plant (largest single kiln in North America)
		Direct Air Capture (DAC) + renewables 100,000 tCO2/yr, 3 sites
		Direct Air Capture (DAC) + geothermal 5,000 tCO2/yr.
		Direct Air Capture (DAC) + nuclear 5,000 tCO2/yr.
		DAC + excess heat from steel plant+ utilization of CO2 for cement applications (DACU) 5,000 tCO2/yr.
		400 MWh energy storage using NG

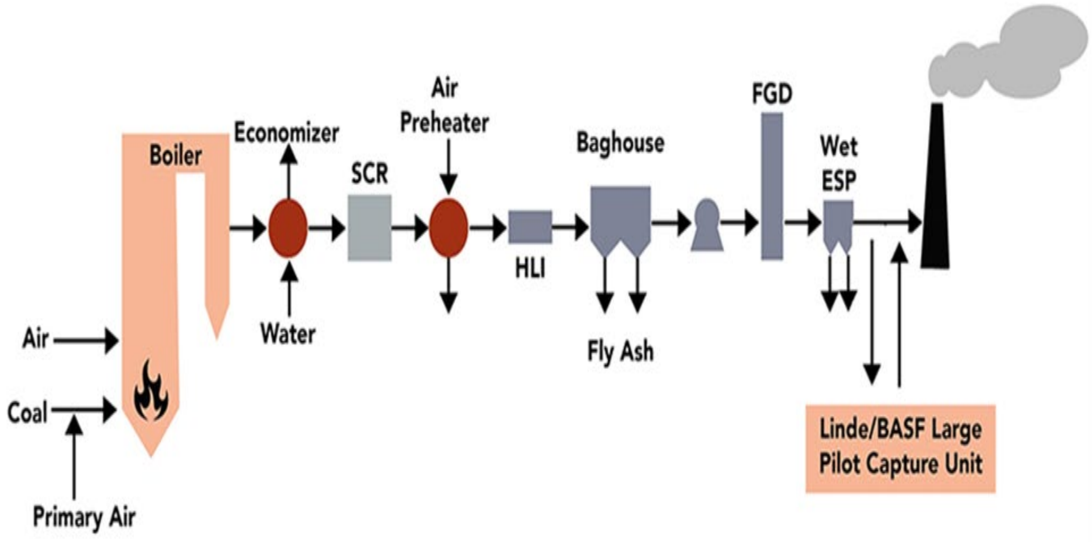
ILLINOIS
Prairie Research Institute

Scale-up studies and considerations

DIRECT AIR CAPTURE (DAC)

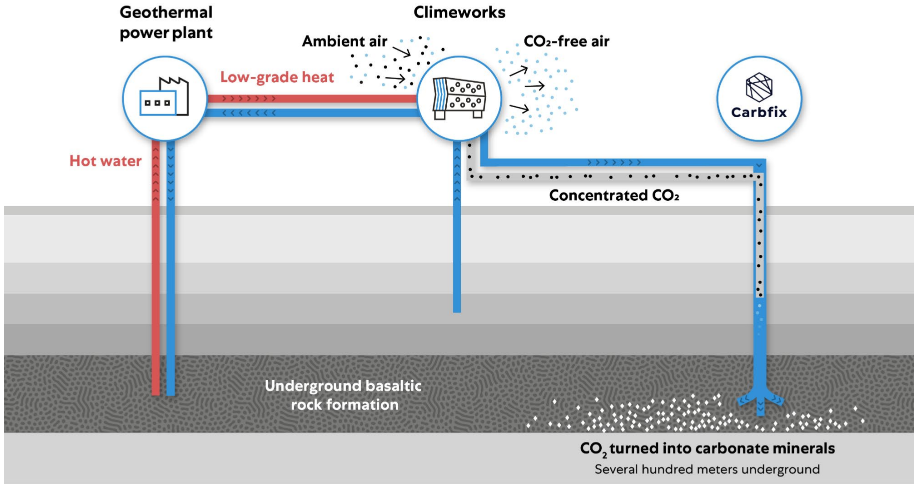
Some Engineering Scale-Up Considerations

Post combustion vs DAC



- Capture unit located before stack
- Heat / power from plant drives capture unit
- Capture CO_2 from flue gas
- CO_2 levels ~11% in flue gas
- Residuals could be present: NOx, SOx, etc.
- Industrial > 100,000; power generation >1,000,000 tCO2/yr. captured

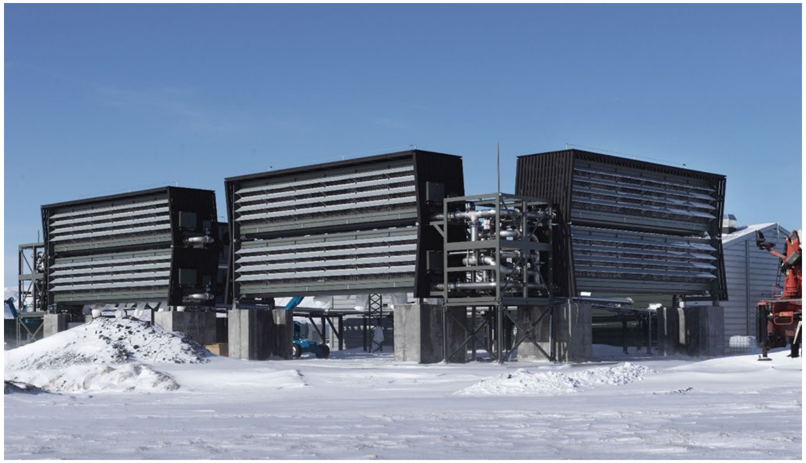
- Capture unit location flexible
- Heat / power can be from multiple sources
- Capture CO_2 from atmosphere
- CO_2 levels in ppm range
- Residuals seen in post combustion not present



ILLINOIS
Prairie Research Institute

Direct Air Capture-Based Carbon Dioxide Removal with Low-Carbon Energy and Sinks

US Department of Energy (DOE) Funded Project



Louisiana

California

Wyoming

climeworks
Kiewit
GULF COAST SEQUESTRATION
ORMAT
SUNPOWER
SENTINEL PEAK RESOURCES
north shore energy, llc
Lawrence Livermore National Laboratory

Goals:

- Initial engineering design for system that captures 100,000 tCO_2/yr..
- Evaluate effect of various climates within the US on engineering design for three sites
- Estimate cost and timeline for construction of facility
- Technoeconomics, Life Cycle Analysis, and Business Case at all three host sites

Total Project Funding: $3.1 MM
Project Duration: 18 months

Effect of Power Source and Climate on DAC Design

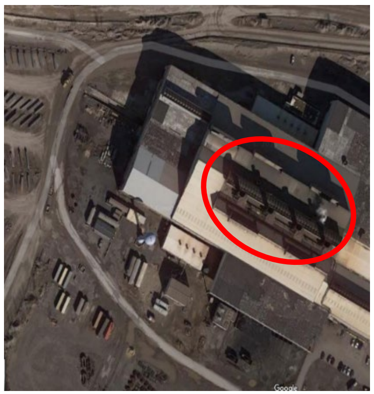
Evaluates impact of various factors on scale-up

Site Location	Volume CO_2 Captured (tCO_2/yr.)	Power Source	Existing vs New Power Source	Operator	Climate	Storage Site	Transport to Storage Site
Louisiana	100,000	Solar (SunPower)	New	Gulf Coast Sequestration	Hot & Humid	Deep Subsurface Rock	Co-located with DAC
California	100,000	Geothermal	Existing	Ormat	Hot & Dry	Saline Aquifer	Rail / Pipeline
Wyoming	100,000	Waste Heat (Gas plant) & Wind	Existing	North Shore Exploration & Production, LLC	Warm & Dry / Cold & Dry	Depleted Oil & Gas Reservoir	Co-located with DAC

Direct Air Capture + Utilization = DACU

Waste heat from Steel plant and utilize captured CO_2 for cement

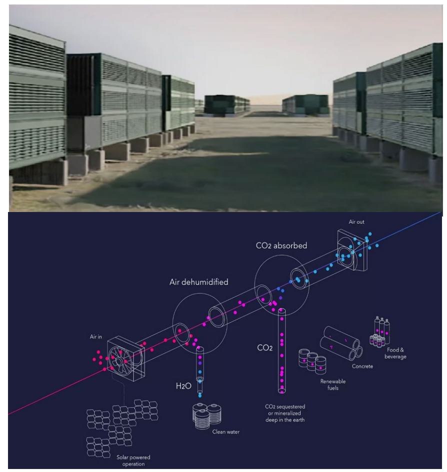
USS



US Steel Gary Works Facility Host Site Aerial View

Waste Heat →

Carbon Capture

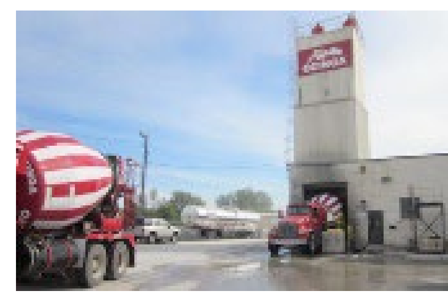


Captured CO_2 →

CARBONCURE
SIMPLY BETTER CONCRETE

CarbonCure's CO_2 Dosing Tank and Utilization System

CO_2 incorporated into cement ↓



OZINGA

5,000 tCO_2/yr.

Total Project Funding: $ 3.5 MM
Project duration: 18 months

Strategies / Tools to Assist in DAC Scale-up

Many under development by NETL / DOE

- Use FEED study results to drive R&D funding
  - Uncover the technology "gaps" that inhibit scale-up
- Build pilot scale systems to accelerate learnings
  - Building systems has demonstrated for many energy technologies the ability to transition on the "learning curves[1,2] "
- Technoeconomic Analysis (TEA) standards for DAC
  - Patterned after those established for Post Combustion Capture[3]
- Standardized scale-up pathway
  - Equivalent for post combustion: bench-scale / lab-scale / small pilot / large pilot / demonstration

[1] Edward S. Rubin; Margaret R. Taylor; Sonia Yeh; David A. Hounshell, Learning curves for environmental technology and their importance for climate policy analysis, Energy 29 (2004) 1551-1559

[2] T. Wiesenthal, P. Dowling, J. Morbee, C. Thiel, B. Schade, P. Russ, S. Simoes, S. Peteves, Technology Learning Curves for Energy Policy Support, ISBN 978-92-79-25676-9, 2012

K. Schoots, M. Londo

[3] COST AND PERFORMANCE BASELINE FOR FOSSIL ENERGY PLANTS VOLUME 1: BITUMINOUS COAL AND NATURAL GAS TO ELECTRICITY (Sept. 2019, NETL-PUB-22638)

Acknowledgements

Organization	Name
Krista Hill	National Energy Technology Laboratory / US Department of Energy
Dirk Nuber, Daniel Sutter, Karina Veloso	Climeworks
Vinod Patel, Jason Dietsch, Chinmoy Baroi	Prairie Research Institute / University of Illinois
Matt Thomas, Scott Vargo, Bob Slettehaugh	Kiewit
Steve Swanson	North Shore Energy
Colin Williams	Gulf Coast Sequestration
Brian Meichtry	SunPower
Roger Aines, Bill Bourcier, Joshuah Stolaroff	Lawrence Livermore National Laboratory
Bob Sullivan	ORMAT
Mike Whitezell	Sentinel Peak

This project is supported by the U.S. Department of Energy / National Energy Technology Laboratory (DOE/NETL) through Cooperative Agreement No. DE-FE0032100

ILLINOIS
Prairie Research Institute