NETL RWFI Energy 101- Point Source Carbon

Welcome to the Webinar

✓ Please place yourself on Mute

✓ Presentation will be posted on the NETL RWFI website Webinar Archives

✓ Workforce Forum at end of presentations

✓ Submit questions via chat

Agenda

1. Introductions to the NETL RWFI – Anthony Armaly, NETL RWFI Coordinator
2. Point Source Carbon Capture Program- Ron Munson, Technology Manager
3. Economic & Workforce Development Roundtable Discussion

The NETL RWFI Energy 101 Series provides a basic primer on the research and development conducted at NETL. Researchers at the Lab present information on their work in an easy-to-follow and thus easy-to-communicate fashion. Discussion topics include the potential economic and workforce development opportunities that successful research into these topics and their related challenges.

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY

NETL Regional Workforce Initiative (NETL RWFI)

A Focus on Appalachia and the future of Energy and Advanced Manufacturing Regional Workforce Readiness and Economic Development

NETL RWFI Mission Statement

NETL RWFI is a platform for engagement and collaboration with key stakeholders who are critical for the deployment of U.S. DOE and NETL Energy and Advanced Manufacturing technological research.

Supporting Regional Economic and Workforce Development opportunities.

Measuring Our Impact - People First

Key Metrics are Levels of Engagement and Outreach

NETL | NATIONAL ENERGY TECHNOLOGY LABORATORY

800+ individual stakeholders

400+ institutions and organizations represented

1300+ registrants to the NETL RWFI Webinar Series

300+ subscribed to the NETL RWFI e-Note Monthly Newsletter

Catalyzed over 1M in energy/advanced manufacturing workforce & economic development funding

The U.S. Skilled Technical Workforce

Expected Future Challenges to the U.S. Skilled Technical Workforce

Significant shortfall of nearly
3.4 million
skilled technical workers by 2022*

RECOMMENDATION

Build national and regional coalitions and partnerships of stakeholders to address skills gaps and collaborate to harness shared resources

NETL RWFI's Tri-State Energy and Advanced Manufacturing consortium panel on the workforce of the future.

Consistent Engagement & Output

Outreach Tools

- Webinars

- Networking (meetings, lab tours, site visits)

- E-note (monthly) Webinars Archive

- RWFI website and archives

- www.netl.doe/gov/rwfi

Regional in Focus, National in Reach

400+ Organizations Representing Multiple Stakeholder Groups

Stakeholder groups include:

- Economic Development Organizations
- Federal, State, & Local Governments
- Community Colleges & Universities
- Philanthropic Organizations
- National Laboratories
- Workforce & Other NGOs
- Industry

Appalachian Regional Commission	Siemens Corporation
America Makes	Eastern Community College West Virginia
Belmont College	E2 Network
TEAM Consortium	IACMI
Benedum Foundation	ARM consortium
BRITE Energy Innovators	IN-2-Market, Inc.
Catalyst Connection	Manufacturing Extension Partnership
Carnegie Mellon University	West Virginia University
Claude Worthington Benedum Foundation	WVU Industrial Extension/MEP
Energy Futures Initiative	Allegheny Conference
National Association of Workforce Boards	Charleston Area Alliance
Coalfield Development Corporation	Electric Power Research Initiative
Community College of Allegheny College	Pittsburgh Regional Alliance
Westmoreland Community College	Robert C. Byrd Institute
PA Department of Economic Development	Oak Ridge National Laboratories
University of Pittsburgh	West Virginia University

U.S. DEPARTMENT OF **ENERGY**

Key Outcomes to Date

Establishment of a new network of regional stakeholders

Consistent engagement with key regional partners

Integration of Workforce Workplan

Increased communication of NETL mission

Increased growth for potential collaborative opportunities

R-AME Innovation Group

NETL RWFI Advanced Manufacturing & Energy (R-AME)

- **5 themes**/questions

- **Engagement platform** for region

- **Network** for regional entrepreneurship and innovation

- **Best practices** in the issue areas

- **Regional funding** opportunities

REGIONAL FOCUS

Supporting innovation, entrepreneurship, and economic development

Workforce Training 1.0

Advanced Welding Workforce Initiative

- **1st** workforce training funding effort, worked with DOE & ARC to structure

- **$1M** award for Advanced Welding

- **5 awardees** across Appalachia

- **More women** than ever enrolled in 3 of the 5 tech schools

NETL RWFI Workforce Readiness Plan

Pilot Program

✓ Available and accessible training programs

✓ Ongoing or planned collaborations with education and training providers

✓ Identify necessary certifications or other educational attainment involved in technology/activity

✓ Identify Economically Distressed Communities or state or federal designated Opportunity Zones or other geographically defined empowerment zones where this activity may occur

Originated from conversations with stakeholders and through ARC workshop participation (2017-18)

Prevalent questions were:
- What are the occupations needed?
- What skills/education is required for those occupations? "Future casting"

NETL technologies 3-5 years from commercialization

Effort to understand occupations and skills necessary for the present and the future

DOE now requires a statement of job creation on FOAs

Workforce Readiness Plan Database

| Job/Career Field Name	Skills Needed	Education Requirements	Availability of Training Programs	Any Other Relevant Items Provided?
Big Data Programmer/Analyst	• Efficiently extract large scale complex business data (time series data, structured/unstructured) from various data sources and prepare them for data analytics. • Partner with product experts, leverage common open-source machine learning/deep learning packages for identifying data patterns/trends or building predictive models. • Deploy solutions to business units using software technologies to generate measurable values for businesses. • Grasp the application of the latest machine learning and artificial intelligence open-source packages, cloud, and distributed computing technologies to ensure the best technologies are implemented to meet businesses' data challenges.	• Undergraduate degree in Data Science, Computer Science, Math, or Statistics. • For candidates who hold an engineering degree, we require candidates have taken data science classes already. • 7 years of experiences with a minimum of 2 years experiences in extracting the data, using common classification or regression open-source packages through R or Python.	Yes	
Geologists	• Geologists with a passion for subsurface materials and skillsets such as geologic characterization, well log and core analysis, petrophysical calculations, geostatistics, model development, and field work are needed to quantify rock property estimations and integrate subsurface interpretations using different datasets.	• Undergraduate & Professional	Yes	

Pilot Conclusions

✓ **Skilled technical workforce** is essential

✓ Technical workforce occupations are high paying and in-demand

✓ Energy and Advanced Manufacturing industries are rapidly evolving towards high skilled and increased experience

✓ The Workforce **W**orkplan is an effective tool in identifying emerging skills and occupations in energy industries **= a skills/occupations early warning system**

2021 NETL WORKFORCE READINESS PLAN

January 11, 2022

DOE/NETL-2022/3726

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Opportunity?

- **What if the Workforce Readiness Plan could be implemented at other labs?**

- **Indirect benefits and support of occupations and skills being supported by DOE funding**

- **Clearer picture of future industry sector needs**
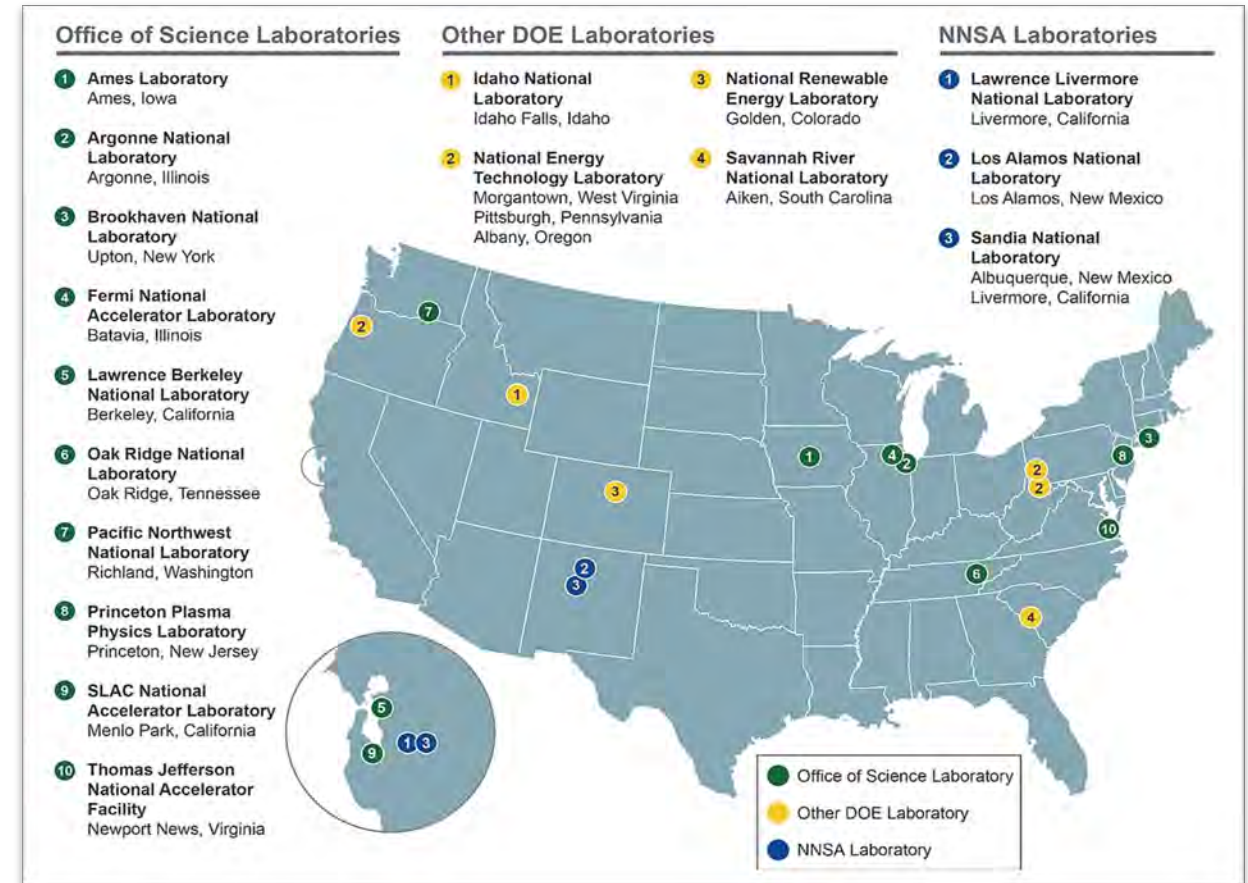
Next Steps

Let's Connect, Communicate and Collaborate!

- Pursuing external funding opportunities to amplify our impact

- Continuing to work closer with the other national labs and creating a National Lab community of practice

- Developing new focus groups regionally around emerging technical areas such as DAC, Hydrogen, etc.

- Increasing our reach with our webinars and E-Note growth by working closer with DOE HQ Comms

www.netl.doe.gov/rwfi
netl.rwfi@netl.doe.gov
Anthony.Armaly@netl.doe.gov

Solutions for Today | Options for Tomorrow

Carbon Capture Research & Development

RWFI Energy 101 – Point Source Carbon Capture –
March 9, 2023

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Ron Munson
Point Source Carbon Capture
Technology Manager
National Energy Technology Laboratory

U.S. DEPARTMENT OF ENERGY

Integrated Approach to Carbon Management...

Low Carbon Energy Input

Point Source Capture (PSC)

Carbon Dioxide Removal (CDR)

Long Duration Carbon Storage
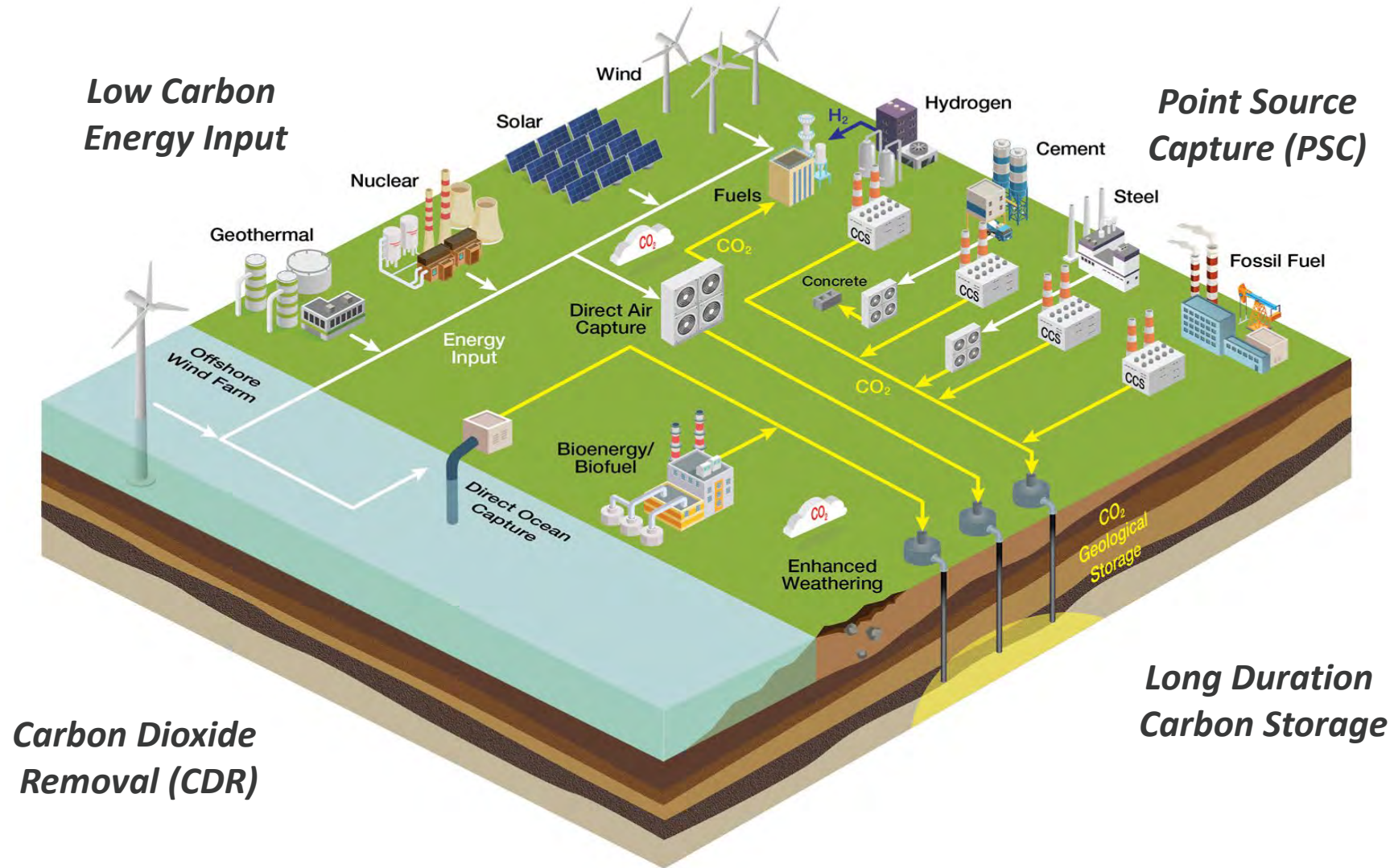
Graphic adopted from: https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/612e4603a57548759c38d779/1630422541002/LEP-Building_to_Net-Zero-June-2021-v4.pdf"

Carbon Capture Definition

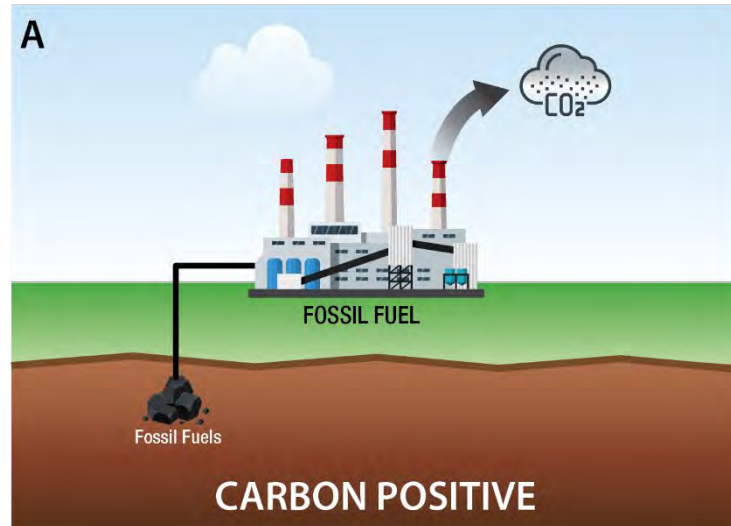Separation of the CO_2 from a gas stream produced in a power station or an industrial process to obtain pure CO_2 for geological storage or further use
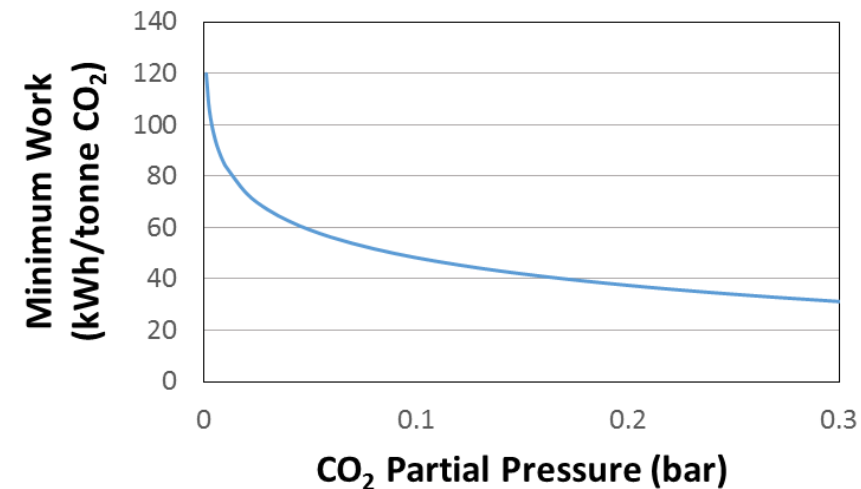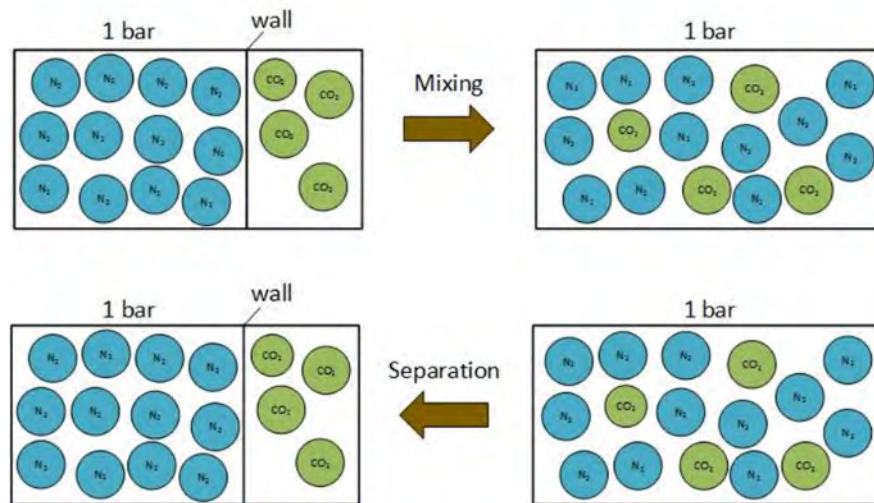
CO$_2$ Concentrations: Select Sources
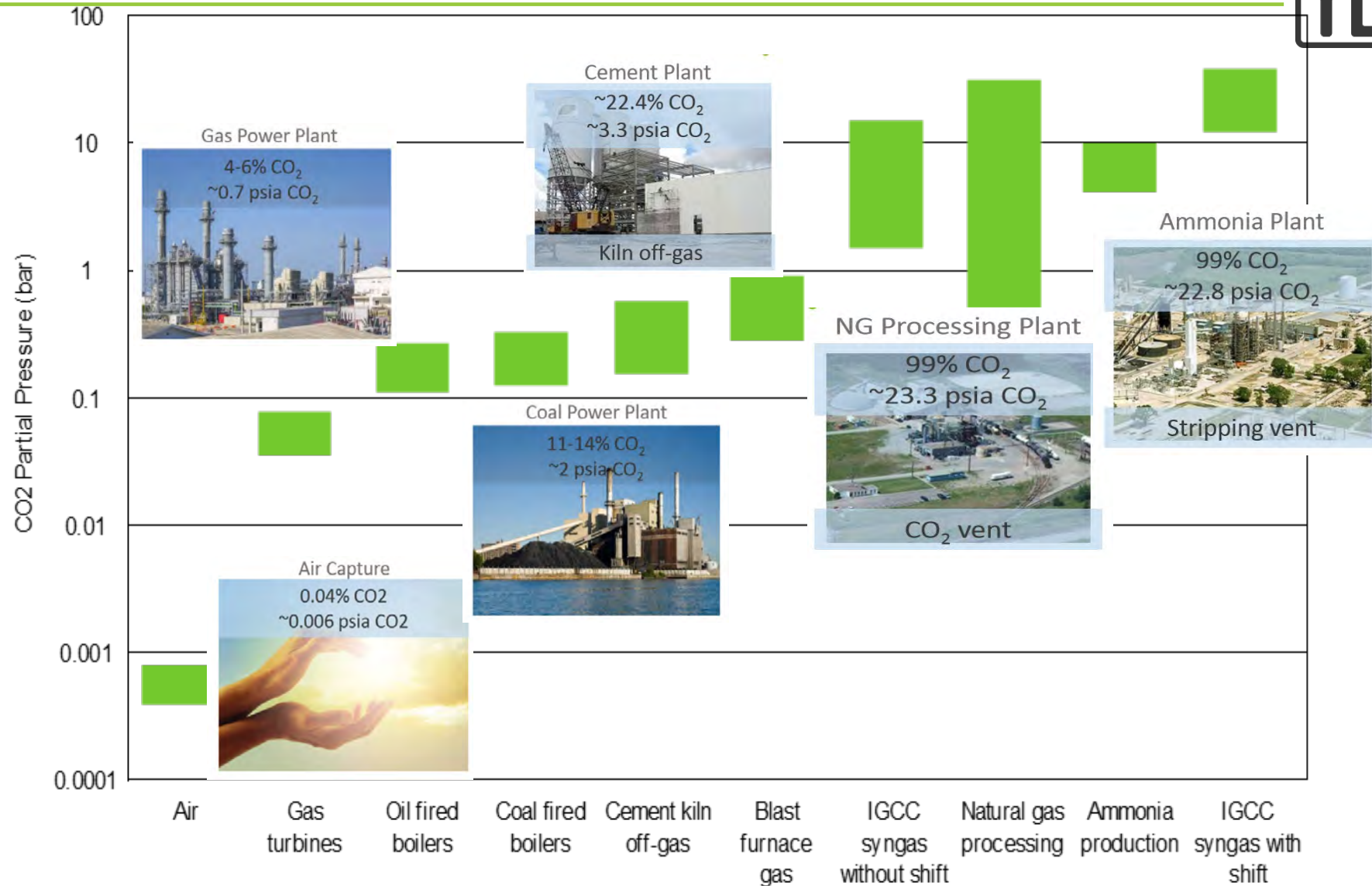
Historic CCS Deployments
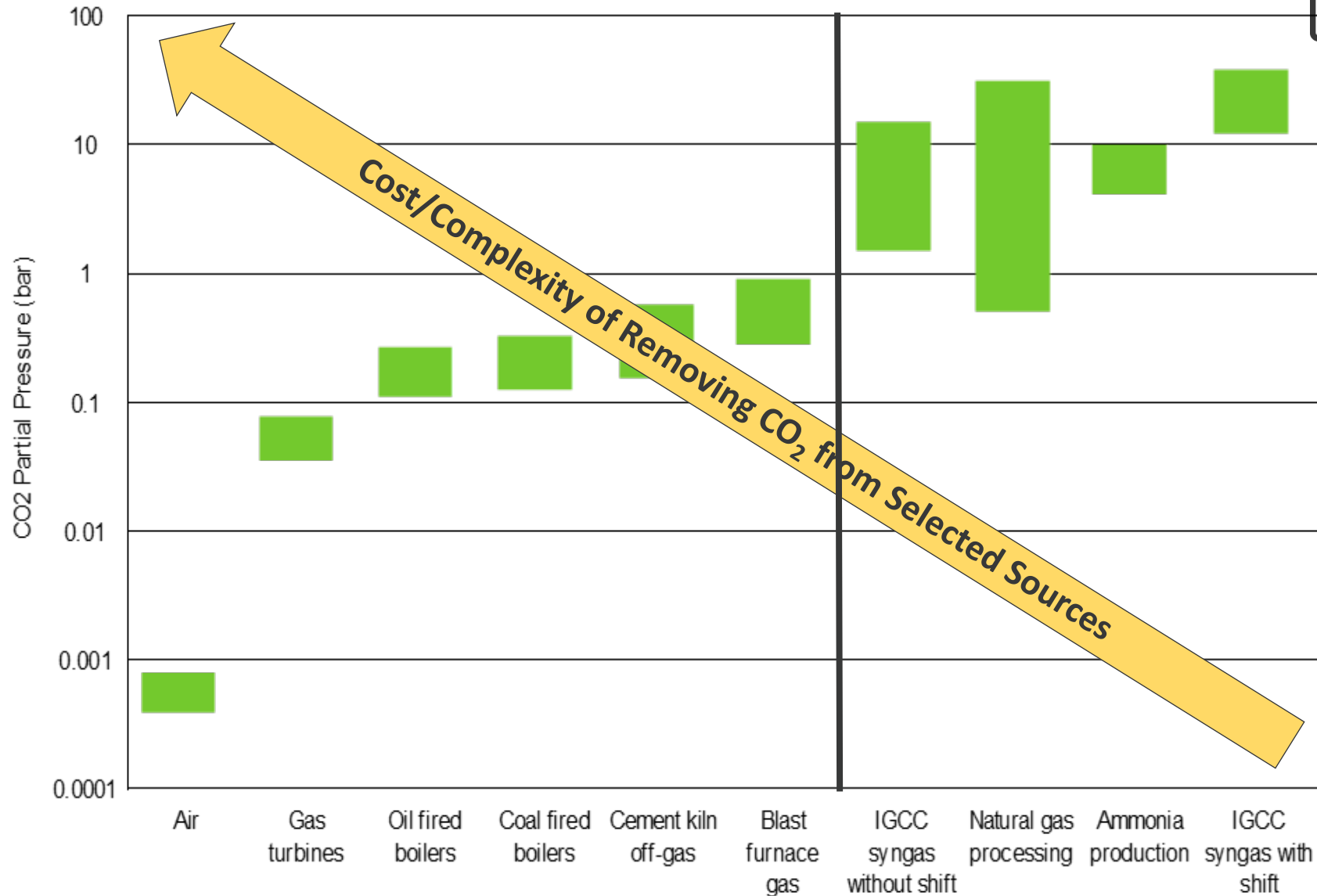
Carbon Reducing vs Removal
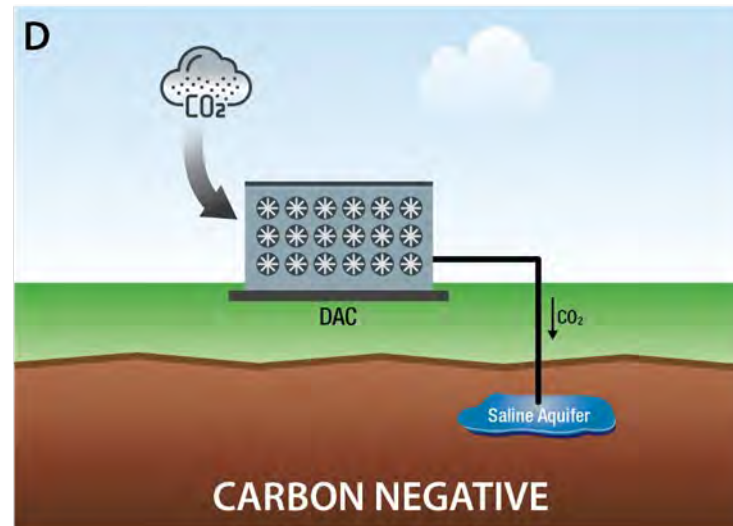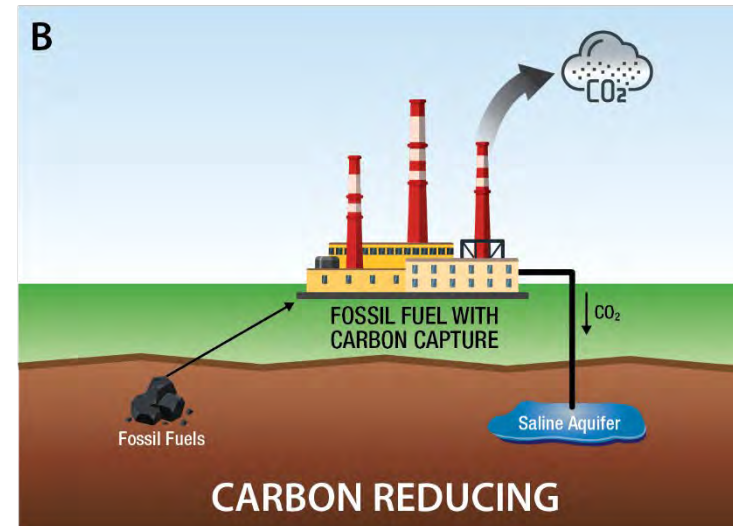
Carbon Reducing vs. Carbon Negative

CARBON REDUCING

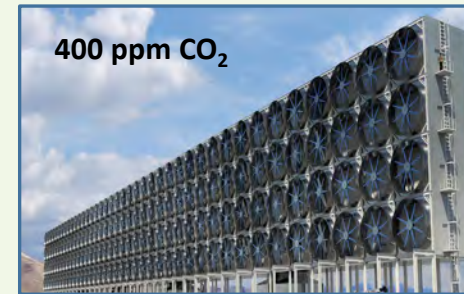### Point-Source Capture (PSC) for Power Generation and Industrial Sectors

NG: 4 % CO_2

Power Plants

15-20% CO_2

Cement Plants

20% CO_2

Steel Plants

15 – 45% CO_2

Hydrogen Plants

CARBON NEGATIVE

Carbon Dioxide Removal (CDR) from Air

400 ppm CO_2

Direct Air Capture [1]

Enhanced Weathering

Bioenergy Carbon Removal and Storage (BiCRS)

(1) Assume C storage as CO_2 off-take

Point Source Capture Program…Mission

- ## Mission
  - Develop advanced cost-effective CO_2 capture technologies throughout the power-generation and industrial sectors
  - Ensure the U.S. will continue to have access to safe, reliable, & affordable low-carbon energy generation
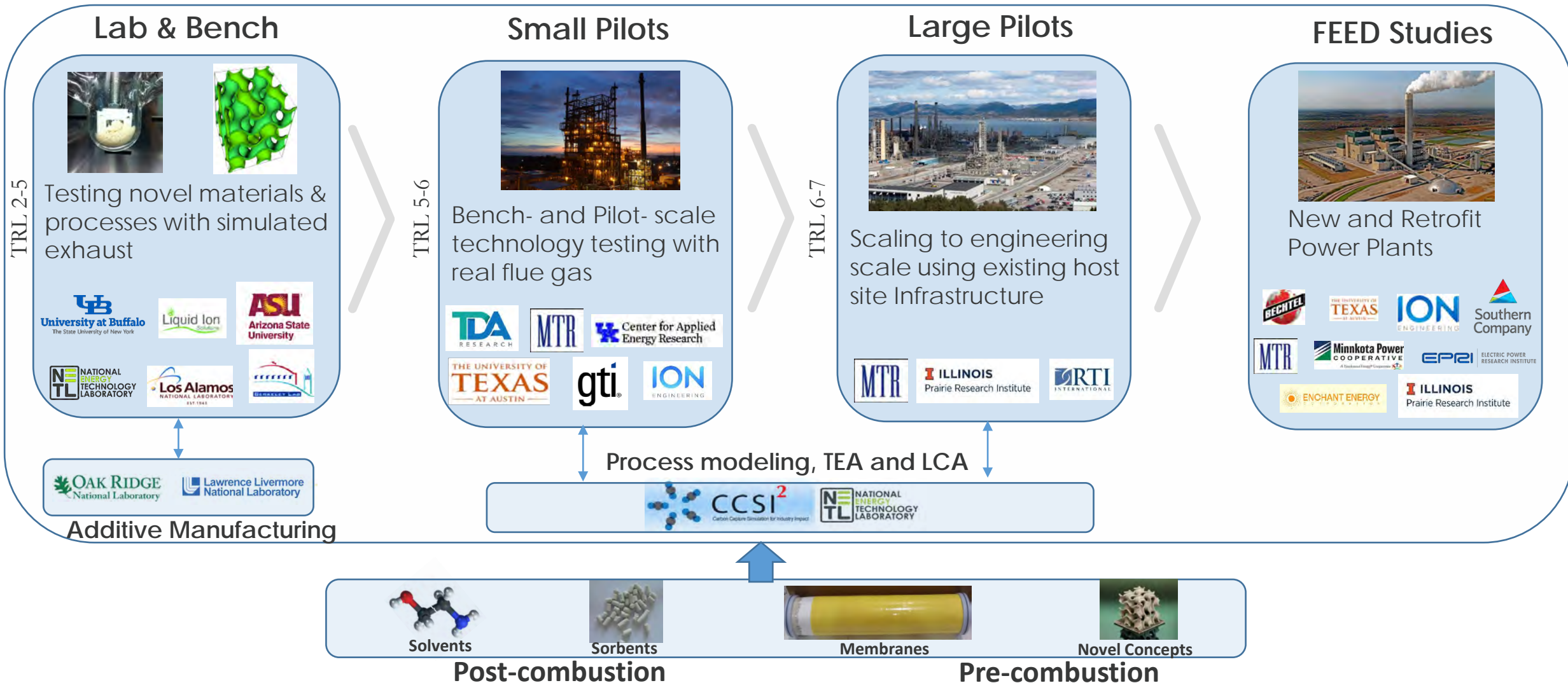
- ## Drivers/Challenges
  - Reduce carbon capture CAPEX/OPEX under a wide range of feed conditions and high capture efficiencies
  - Demonstrate first-of-a-kind carbon capture on power and industrial sectors coupled to dedicated and reliable carbon storage, that will lead to commercially viable n^{th}-of-a-kind opportunities for widescale deployment

- ## Goal & Metrics
  - Support U.S goal to achieve carbon pollution-free power sector by 2035 and zero-carbon economy by 2050 (facilitated by an interim goal of achieving 50% reductions by 2030)

$40
Per tonne of CO_2

$30
Per tonne of CO_2

95% Purity

2nd Generation

Transformational

Ready to demo by **2025**

Ready to demo by **2030**

DOE's Carbon Capture performance goals for coal-fired power plants
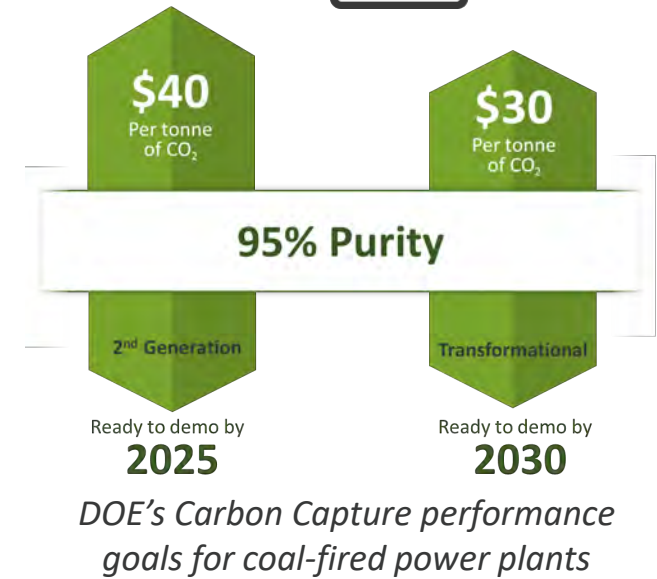
Carbon Capture.. Program Structure

NATIONAL ENERGY TECHNOLOGY LABORATORY

Lab & Bench

TRL 2-5

Testing novel materials & processes with simulated exhaust

Additive Manufacturing

Small Pilots

TRL 5-6

Bench- and Pilot- scale technology testing with real flue gas

Large Pilots

TRL 6-7

Scaling to engineering scale using existing host site Infrastructure

FEED Studies

New and Retrofit Power Plants

Process modeling, TEA and LCA

CCSI² Carbon Capture Simulation for Industry Impact — NATIONAL ENERGY TECHNOLOGY LABORATORY

Solvents Sorbents Membranes Novel Concepts

Post-combustion **Pre-combustion**

Carbon Capture Program.. Evolution

1st and 2nd Generation Technologies

2025: $40/tonne CO_2

Hollow Fibers

3D Print

Biphasic Solvent

2008 -

- ✓ Lower CAPEX/OPEX
- ✓ Reduced regeneration energy
- ✓ Increased working capacity

Transformational Technologies

2030: $30/tonne CO_2

2015 -

- ✓ Water Lean Solvents
- ✓ Adv. Membranes
- ✓ Hybrid Systems
- ✓ Process Intensification

Scale-up

TCM

2018 -

- ✓ Engineering Scale testing
- ✓ FEED studies

Negative Emissions Technologies & Industrial
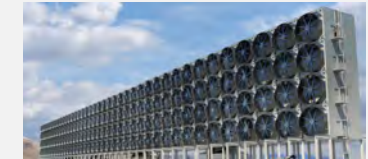
Carbon Engineering, DAC

Ethanol Plant

2020 -

- ✓ DAC & BECCS
- ✓ Industrial
- ✓ NG
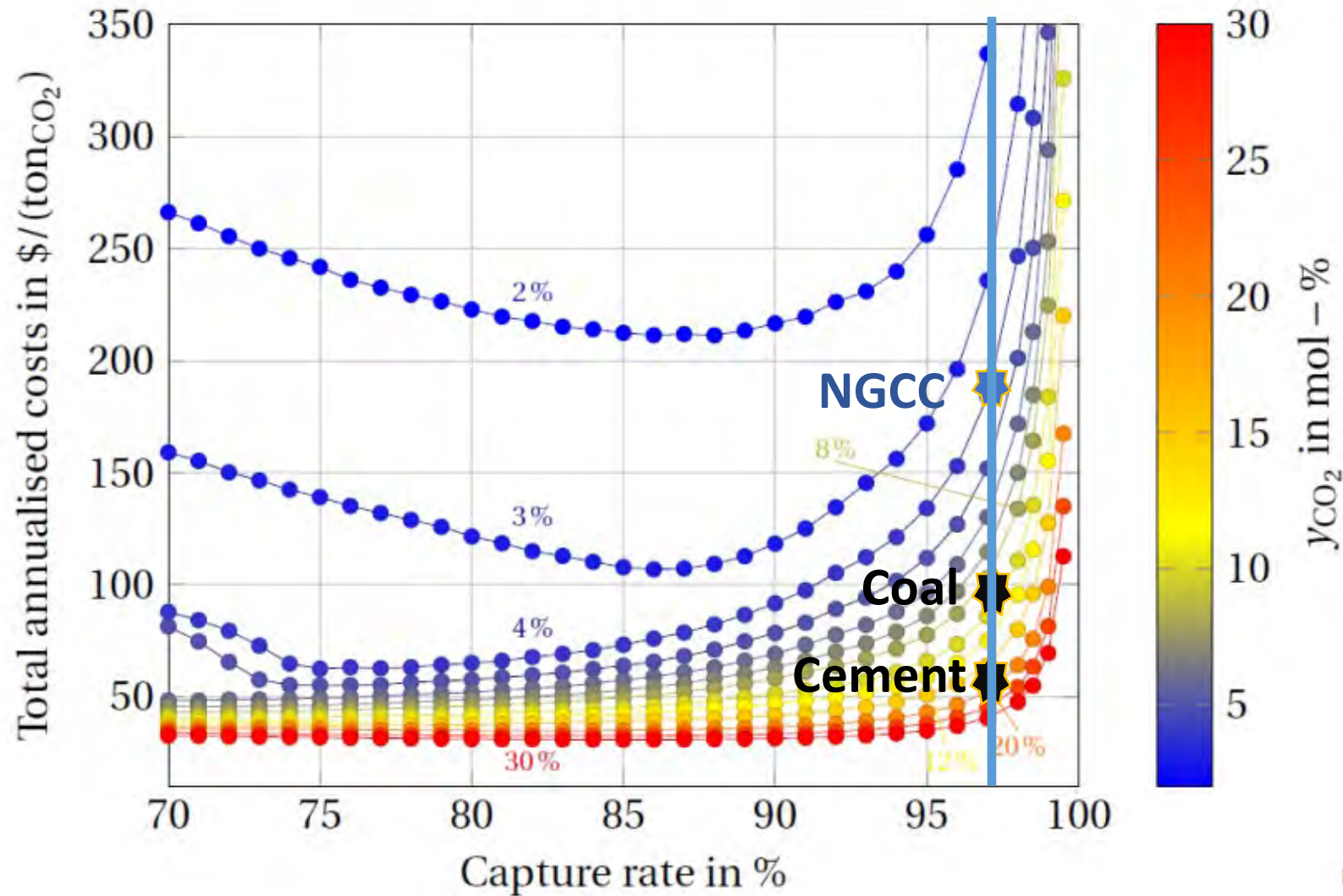
Brandl, *et al*, Int J GHG Con, 2019

Point Source Carbon Capture.. FOAs Issued

Fiscal Year	Funding Opportunity Announcement Number	Funding Opportunity Announcement Title	Issue Date	Close Date
2022	DE-FOA-0002515/ Amendment 000002	Carbon Capture R&D For Natural Gas and Industrial Point Sources, and FEED Studies for Carbon Capture Systems at Industrial Facilities and Natural Gas Plants ($96M) AOI-4: Carbon Capture R&D: Laboratory-Scale Testing of Highly-Efficient Materials or Novel Concepts for Natural Gas Combined Cycle (NGCC) Power Plants AOI-5: Engineering-Scale Testing of Transformational Post-Combustion Carbon Capture Technologies for NGCC power plants AOI-6: Engineering-Scale Testing of Transformational Carbon Capture Technologies for Industrial Plants and Waste-to Energy Plants AOI-7: Front-End Engineering Design Studies for Carbon Capture Systems at Existing (Retrofit) Domestic Industrial Facilities and NGCC Power Plants	3/08/2022	4/11/2022
2022	DE-FOA-0002400/ Modification 000007	Clean Hydrogen Production, Storage, Transport and Utilization To Enable A Net Zero Carbon Economy ($28.6M total; $18M for AOI-8) AOI-8: Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Industrial Facilities Producing H_2 from Natural Gas AOI-8A: Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Steam Methene Reforming (SMR) Facilities Producing H_2 from Natural Gas AOI-8B: Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Autothermal Reforming (ATR) Facilities Producing H_2 from Natural Gas	2/07/2022	3/30/2022

Pre-FEED and FEED Study Projects with Host Site Locations

Coal
NGCC
Industrial
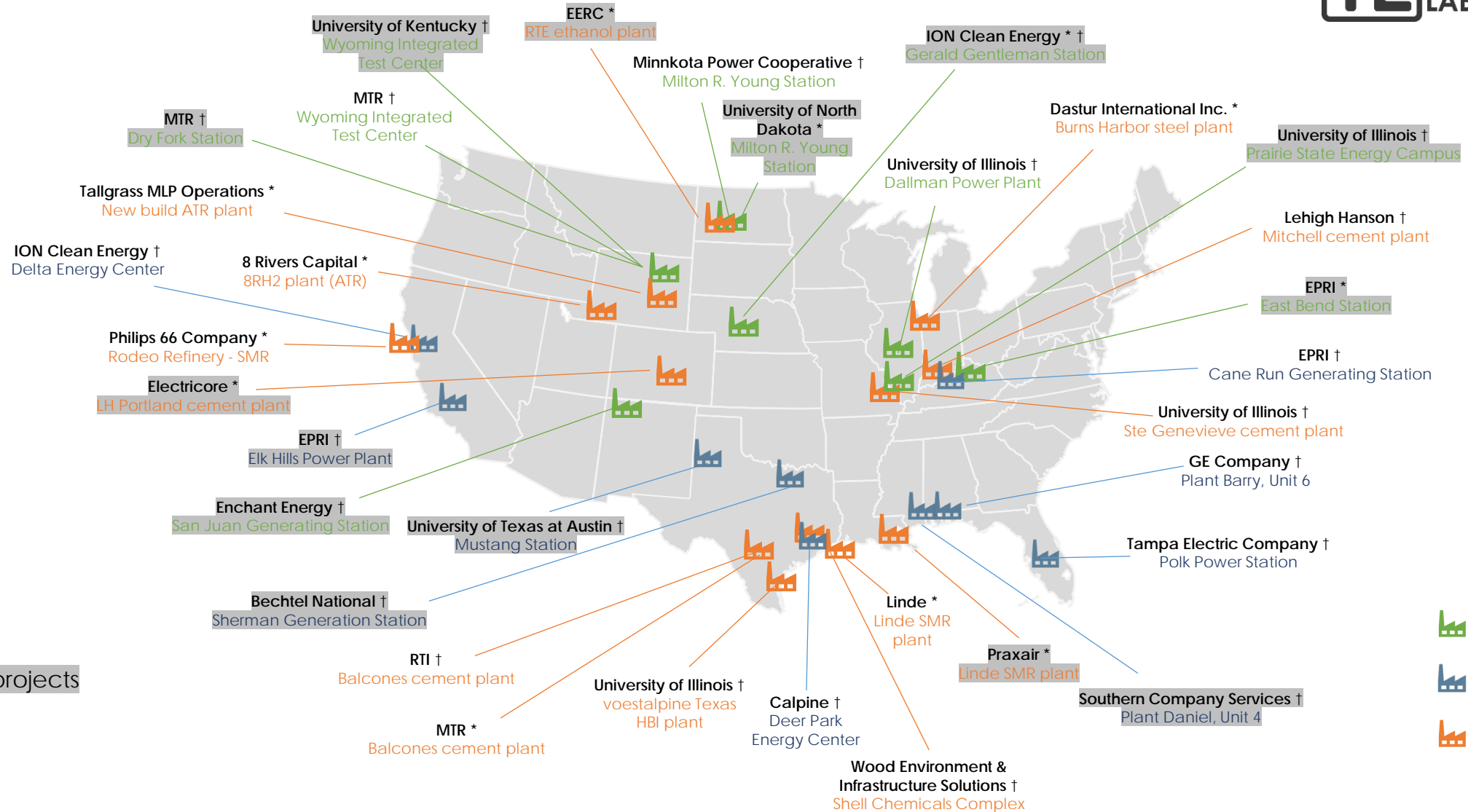
Completed projects

* Pre-FEED
† FEED

Pre-FEED and FEED Study Projects with Host Site Locations

FEED Projects

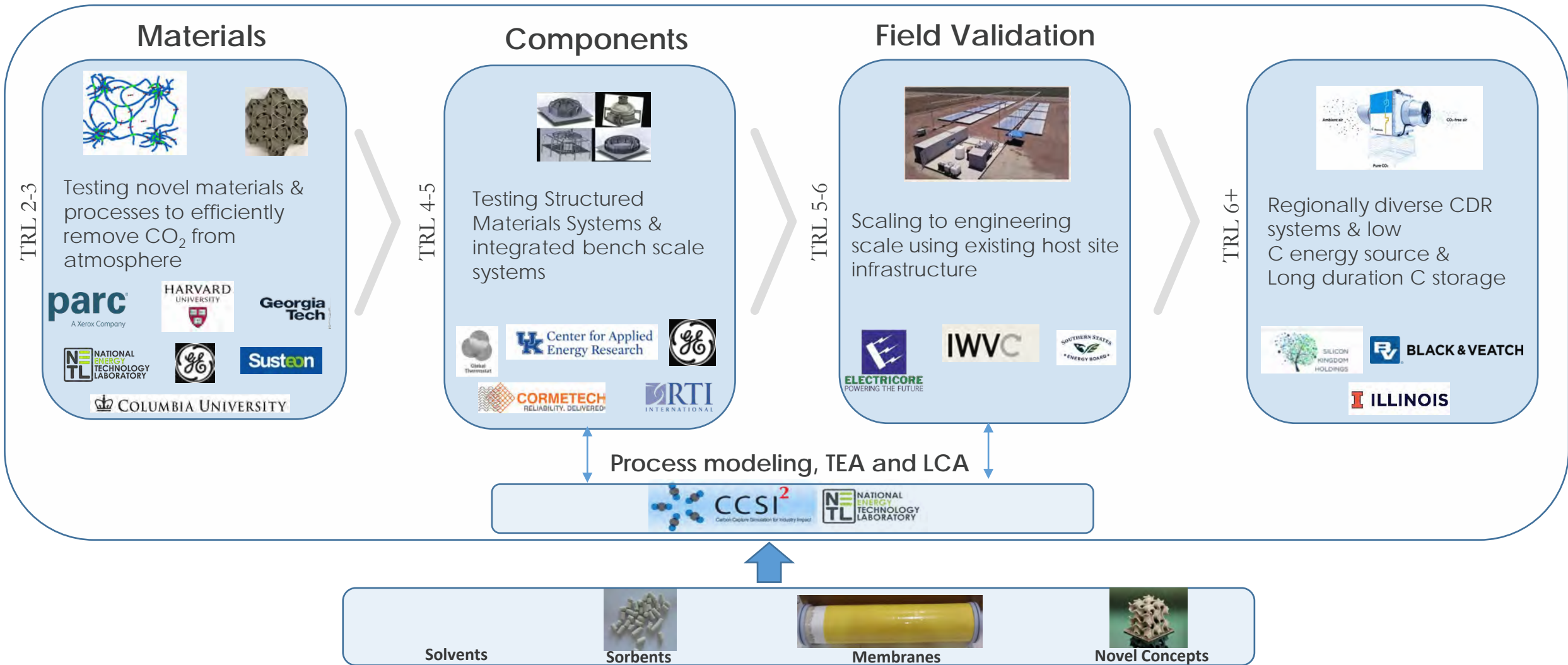| Project Title	Prime Performer	Host Site	Host Site Location	Project Status
Large Pilot Testing of Linde-BASF Advanced Post-Combustion CO2 Capture Technology at a Coal-Fired Power Plant	University of Illinois	City, Water, Light, and Power's Dallman Power Plant	Springfield, IL	Active*
Large Pilot Testing of the MTR Membrane Post-Combustion CO_2 Capture Process	Membrane Technology and Research, Inc.	Wyoming Integrated Test Center (with support from Basin Electric Dry Fork Station)	Gillette, WY	Active*
Industrial Carbon Capture from a Cement Facility Using the Cryocap FG Process	University of Illinois	Holcim Ste Genevieve cement plant	Bloomsdale, MO	Active
FEED for Carbon Capture from Shell's Deer Park Chemical Complex	Wood Environment & Infrastructure Solutions	Shell Chemicals Complex	Deer Park, TX	Active
Deer Park Energy Center NGCC Carbon Capture System FEED Study	Calpine Texas CCUS Holdings	Calpine's Deer Park Energy Center	Deer Park, TX	Active
FEED for a CO2 Capture System at Calpine's Delta Energy Center	ION Clean Energy Inc.	Calpine's Delta Energy Center	Pittsburg, CA	Active
Retrofittable Advanced Combined Cycle Integration for Flexible Decarbonized Generation	GE Company – GE Gas Power	Southern Company's Plant Barry –Unit 6	Bucks, AL	Active
CO_2 Capture at Louisville Gas & Electric Cane Run Natural Gas Combined Cycle Power Plant	Electric Power Research Institute (EPRI)	LG&E-KU Cane Run #7 NGCC unit	Jefferson County, KY	Active
FEED: Project Tundra Carbon Capture System	Minnkota Power Cooperative, Inc.	Square Butte Electric Cooperative's Milton R. Young Station, Unit 2	Center, ND	Active
UKY-CAER Heat-Integrated Transformative CO_2 Capture Process for Pulverized Coal Power Plants	University of Kentucky Research Foundation	Wyoming Integrated Test Center (w/ support from Basin Electric Dry Fork Station)	Gillette, WY	Completed
Commercial Carbon Capture Design and Costing: Part Two (C3DC2)	ION Clean Energy, Inc.	NPPD's Gerald Gentleman Station	Sutherland, NE	Completed
Full-Scale FEED Study for Retrofitting the Prairie State Generating Station with an 816 MWe Capture Plant Using MHIA's PCC Technology	University of Illinois	Prairie State Generation Company's Station	Marissa, IL	Completed
FEED Study for Retrofit Post-Combustion Carbon Capture on a NGCC Power Plant	Electric Power Research Institute	California Resources Corporation's Elk Hills Power Plant	Kern County, CA	Completed
PiperaZine Advanced Stripper (PZAS) FEED	The University of Texas at Austin	Golden Spread Electric Cooperative's Mustang Station	Denver City, TX	Completed
Commercial-Scale FEED Study for MTR's Membrane CO_2 Capture Process	Membrane Technology & Research, Inc.	Basic Electric's Dry Fork Station	Gillette, WY	Completed
Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station	Enchant Energy LLC	Public Service Company of New Mexico's San Juan Generating Station	Waterflow, NM	Completed
FEED of Linde-BASF Advanced Post-Combustion CO_2 Capture Technology at a Southern Company Natural Gas-Fired Power Plant	Southern Company Services, Inc.	Mississippi Power's Plant Daniel, Unit 4	Moss Point, MS	Completed
FEED Study for a Carbon Capture Plant Retrofit to a Natural Gas-Fired Gas Turbine Combined Cycle Power Plant	Bechtel National Inc.	Sherman Generating Station	Sherman, TX	Completed

Pre-FEED Projects

Project Title	Prime Performer	Host Site	Host Site Location	Project Status
Enabling Production of Low Carbon Emissions Steel through CO2 Capture from Blast Furnace (BF) Gases	Dastur International, Inc.	Cleveland-Cliffs' Burns Harbor steel plant	Burns Harbor, IN	Active
Blue Bison ATR Advanced CCUS System	Tallgrass MLP Operations, LLC	ATR plant under construction	Douglas, WY	Active
The 8RH2 Process for Producing Clean Hydrogen with Autothermal Reforming and Carbon Capture	8 Rivers Capital, LLC	New build 8 Rivers Hydrogen (8RH2) plant	Evanston, WY	Active
Initial Engineering Design Study for Advanced CO2 Capture from Hydrogen Production Unit at Phillips 66 Rodeo Refinery	Phillips 66 Company	Rodeo refinery (green field)	Rodeo, CA	Active
Engineering Study of Svante's Solid Sorbent Post-Combustion CO2 Capture Technology at a Linde Steam Methane Reforming H2 Plant	Linde, Inc.	Linde SMR plant	Port Arthur, TX	Active
Engineering Design of a Polaris Membrane CO2 Capture System at a Cement Plant	Membrane Technology and Research, Inc.	CEMEX Balcones cement plant	New Braunfels, TX	Active
Initial Engineering and Design for CO2 Capture from Ethanol Facilities	University of North Dakota Energy and Environmental Research Center	RTE Ethanol plant	Richardton, ND	Completed
LH CO2MENT Colorado Project	Electricore, Inc.	LafargeHolcim's Portland cement plant	Florence, CO	Completed
Engineering Design of a Linde-BASF Advanced Post-Combustion CO2 Capture Technology at a Linde Steam Methane Reforming H2 Plant	Praxair, Inc.	Linde SMR plant	St James Parish, LA	Completed
Initial Engineering Design of a Post-Combustion CO2 Capture System for Duke Energy's East Bend Station Using Membrane-Based Technology	Electric Power Research Institute (EPRI)	Duke Energy's East Bend Station	Boone County, KY	Completed
ION Engineering Commercial Carbon Capture Design and Costing (C3DC)	ION Engineering, LLC	NPPD's Gerald Gentleman Station	Sutherland, NE	Completed
Initial Engineering, Testing, and Design of a Commercial-Scale, Post-Combustion CO2 Capture System on an Existing Coal-Fired Generating Unit	University of North Dakota	Milton R. Young Station	Center, ND	Completed

Large-scale Carbon Capture Pilot Studies

Project Title	Performer	Host Site	Host Site Location
Large Pilot Testing of the MTR Membrane Post-Combustion CO2 Capture Process	Membrane Technology and Research Inc.	Wyoming Integrated Test Center	Gillette, WY
Large Pilot Testing of Linde-BASF Advanced Post-Combustion CO2 Capture Technology at a Coal-Fired Power Plant	University of Illinois	City, Water, Light, and Power Dallman Power Plant	Springfield, IL
Engineering Scale Testing of Transformational Non-Aqueous Solvent-Based Carbon Dioxide Capture Process at Technology Centre Mongstad	Research Triangle Institute	Technology Centre Mongstad	Mongstad, Norway

Membrane Technology and Research, Inc.
Wyoming Integrated Test Center

University of Illinois
Dallman Power Plant

Coal

Mongstad, Norway

RTI International
TCM
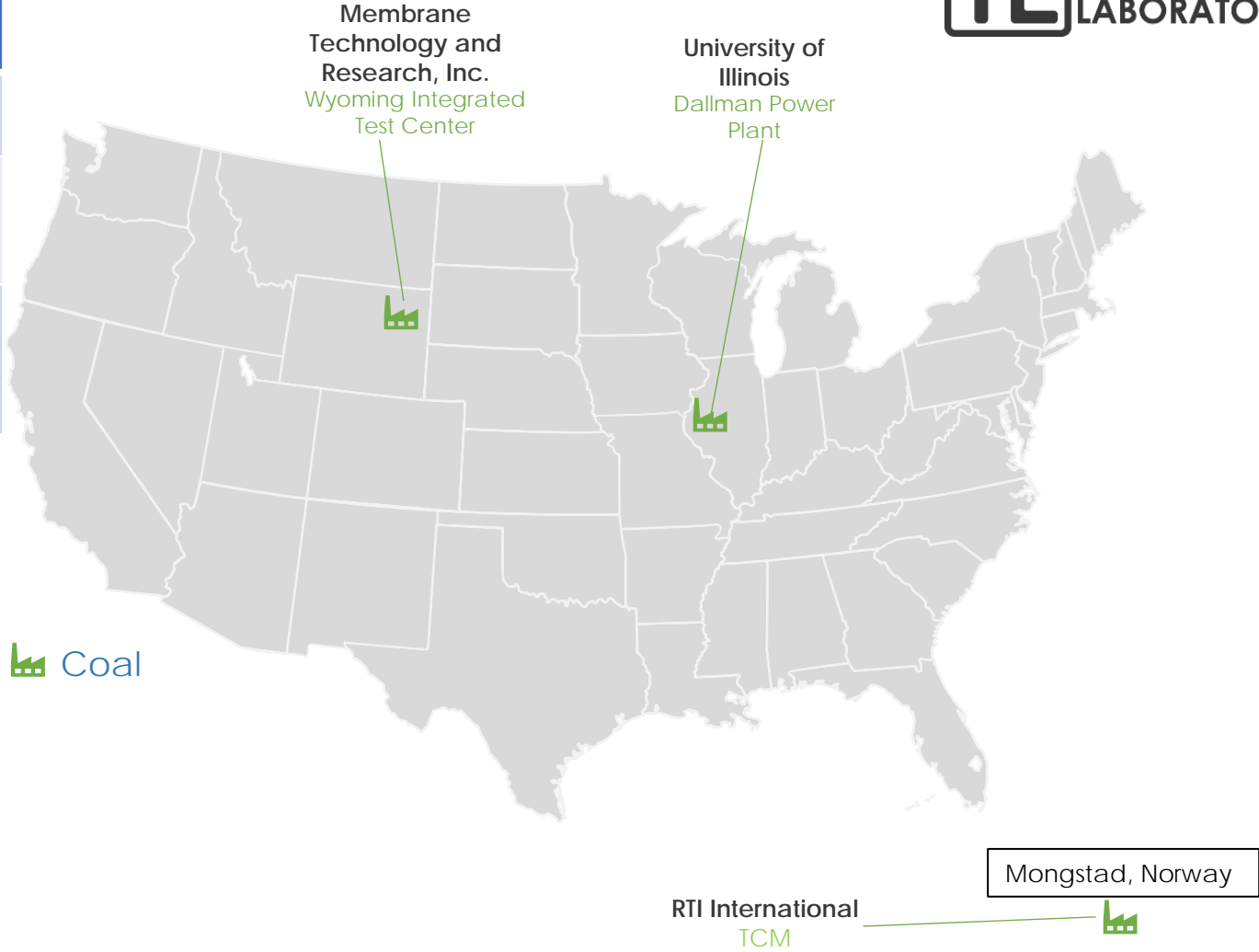
Carbon Dioxide Removal... Program Structure

Materials

TRL 2-3

Testing novel materials & processes to efficiently remove CO_2 from atmosphere

parc A Xerox Company

HARVARD UNIVERSITY

Georgia Tech

NATIONAL ENERGY TECHNOLOGY LABORATORY

GE

Susteon

COLUMBIA UNIVERSITY

Components

TRL 4-5

Testing Structured Materials Systems & integrated bench scale systems

Global Thermostat

UK Center for Applied Energy Research

GE

CORMETECH RELIABILITY. DELIVERED.

RTI INTERNATIONAL

Field Validation

TRL 5-6

Scaling to engineering scale using existing host site infrastructure

ELECTRICORE POWERING THE FUTURE

IWVC

SOUTHERN STATES ENERGY BOARD

TRL 6+

Regionally diverse CDR systems & low C energy source & Long duration C storage

SILICON KINGDOM HOLDINGS

BLACK & VEATCH

ILLINOIS

Process modeling, TEA and LCA

CCSI² Carbon Capture Simulation for Industry Impact

NATIONAL ENERGY TECHNOLOGY LABORATORY

Solvents   Sorbents   Membranes   Novel Concepts

Pre-FEEDs (TRL 6+)... Gen 1 DAC Systems
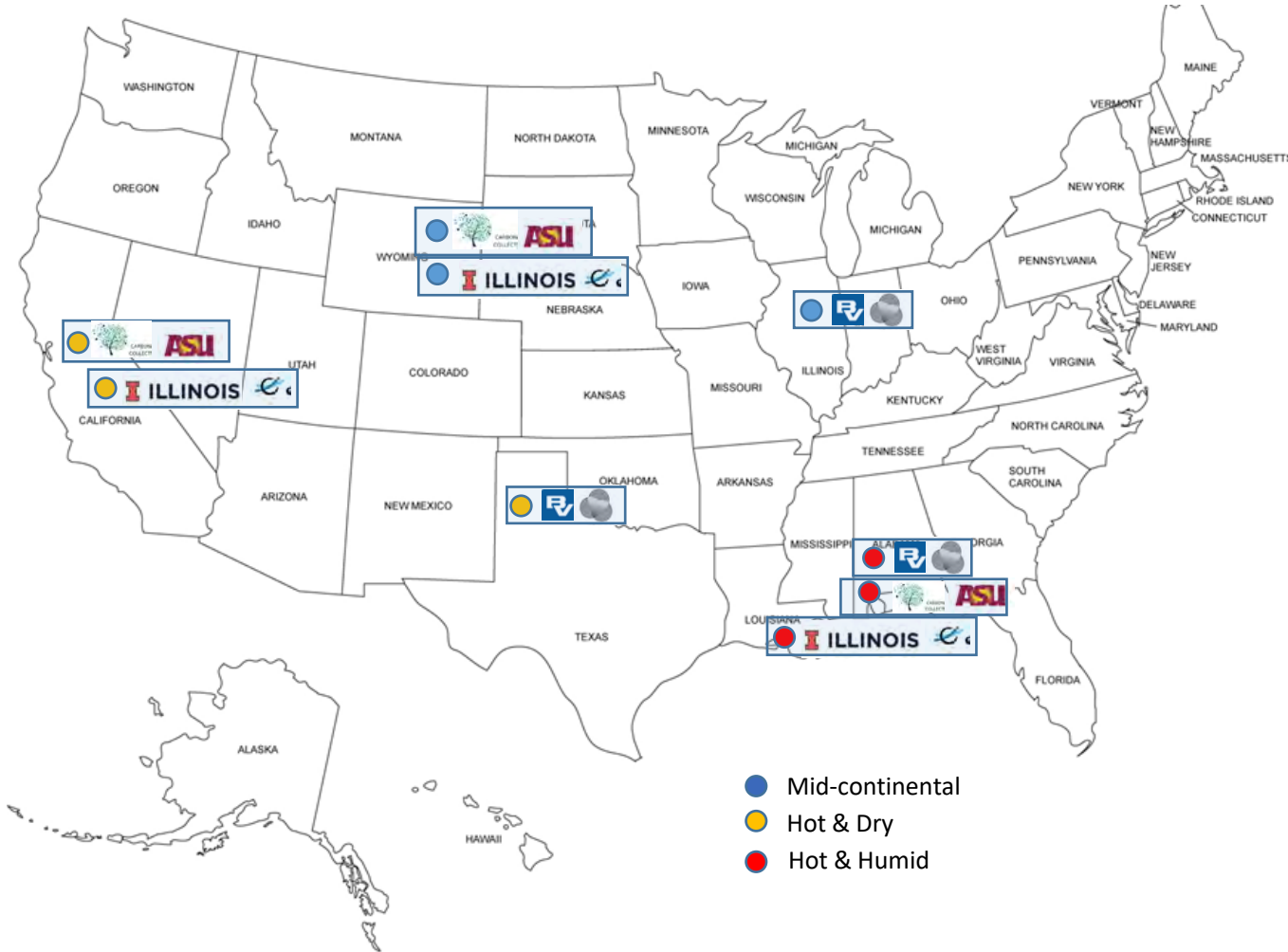
Input:
- DAC Technology (TRL 6), 100,000 tpy net CO_2
- 3 host sites from the pre-defined geographical areas

Output:
Pre-FEEDs for **three individual** case studies including:
- Energy source integration
- CO_2 storage pathways
- Business case analysis (i.e., LCFS / 45Q credits)
- TEA, LCA

Legend:
- Mid-continental
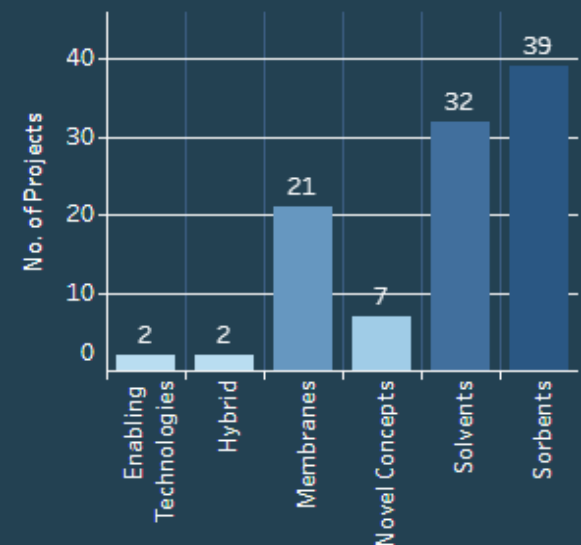- Hot & Dry
- Hot & Humid

Carbon Capture Newsletter

Carbon Capture Program R&D Compendium

Point Source Carbon Capture Program Website

Carbon Dioxide Removal Program Website

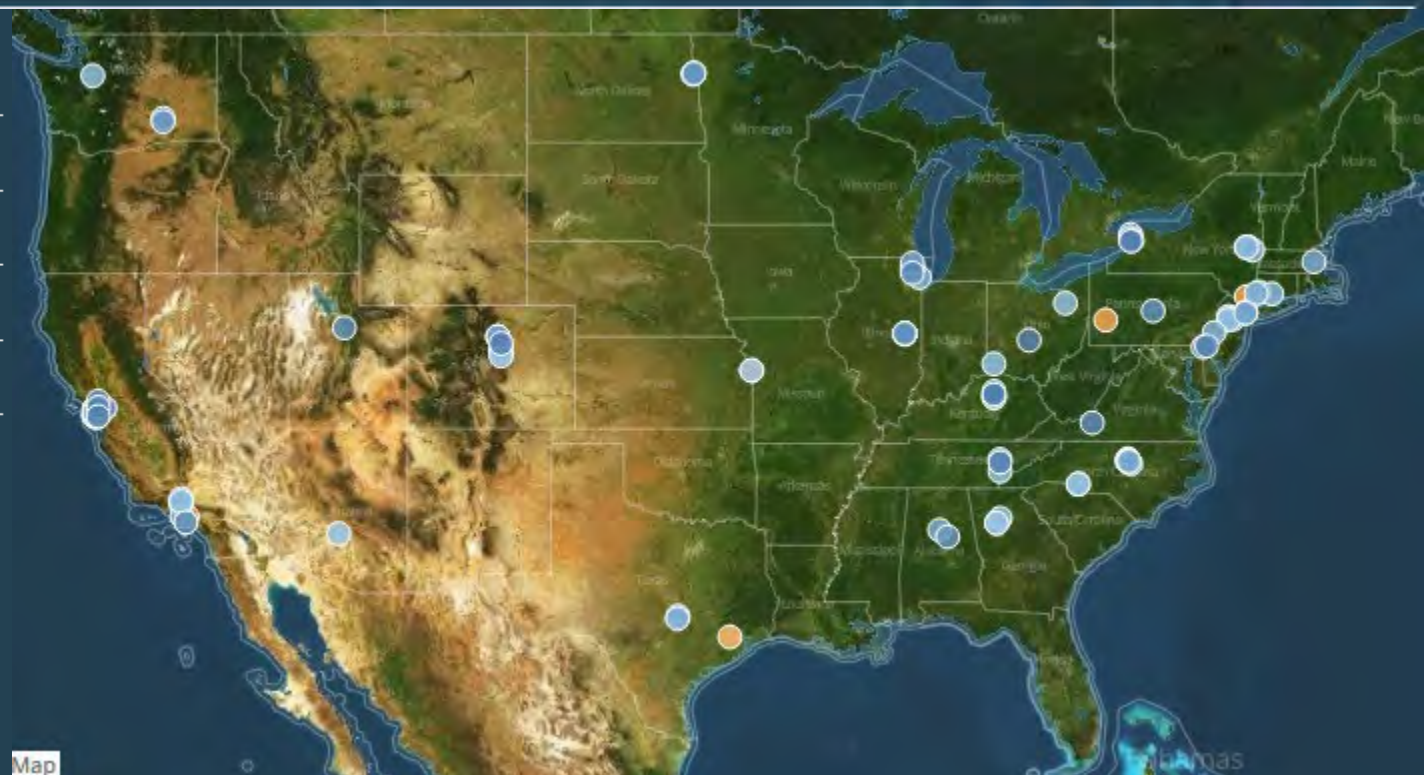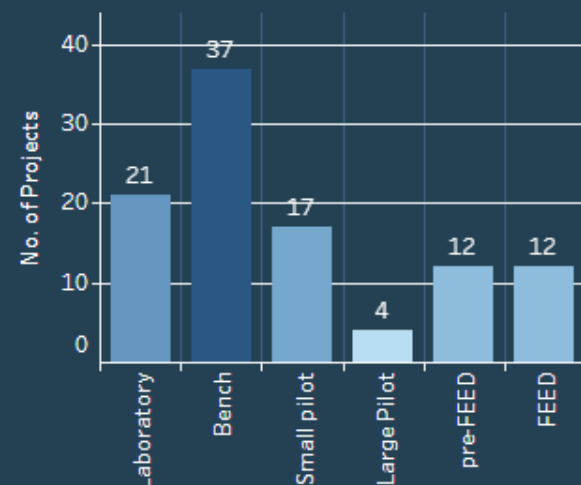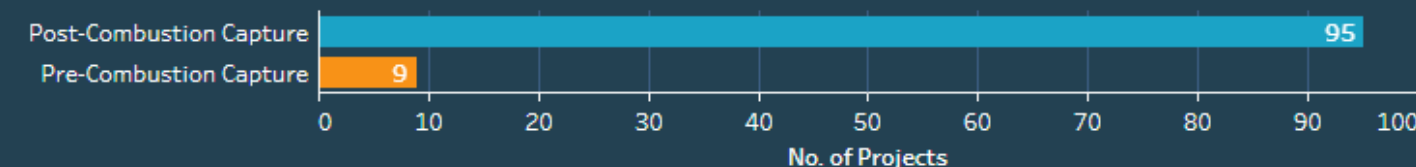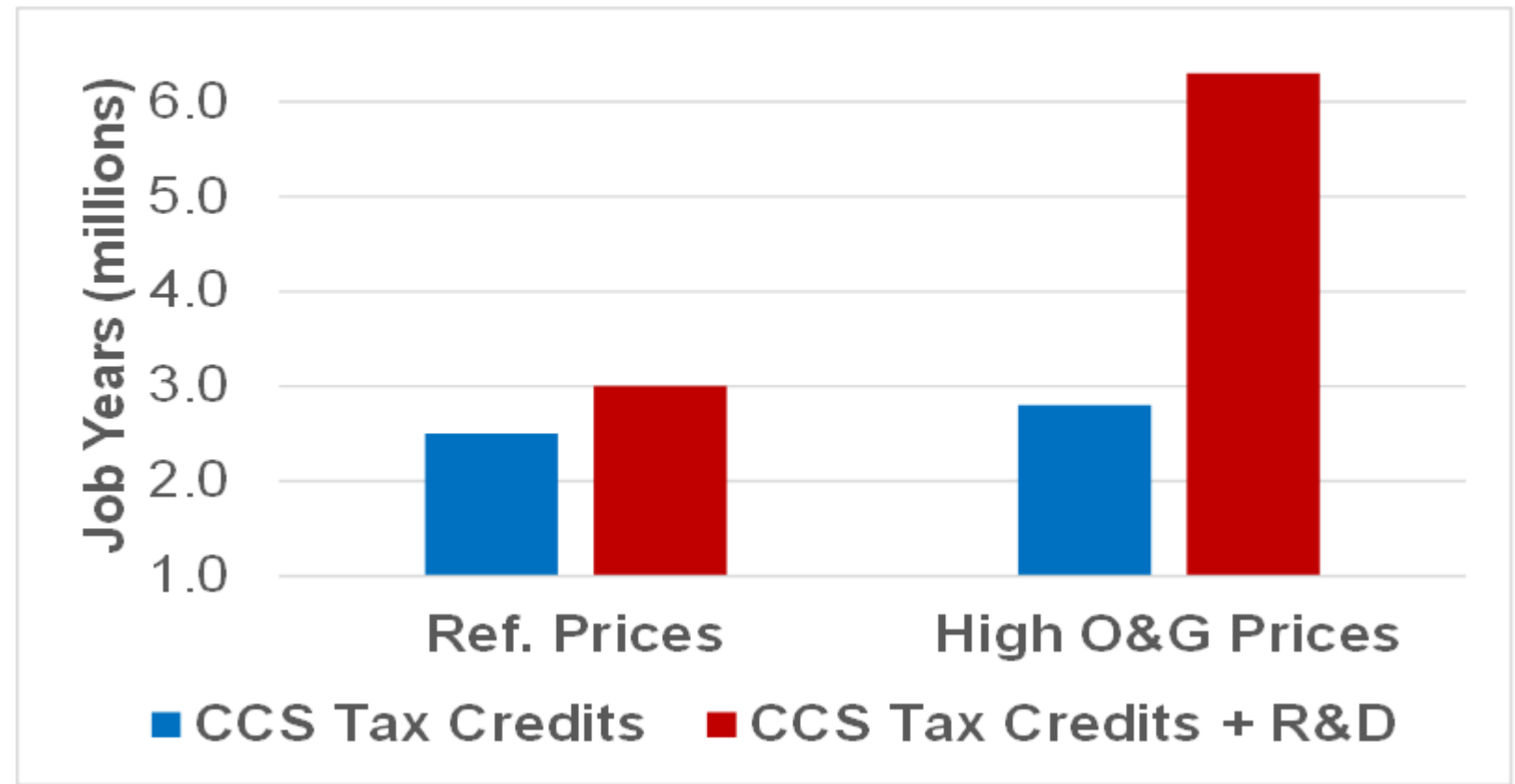Carbon Capture Interactive Project Map
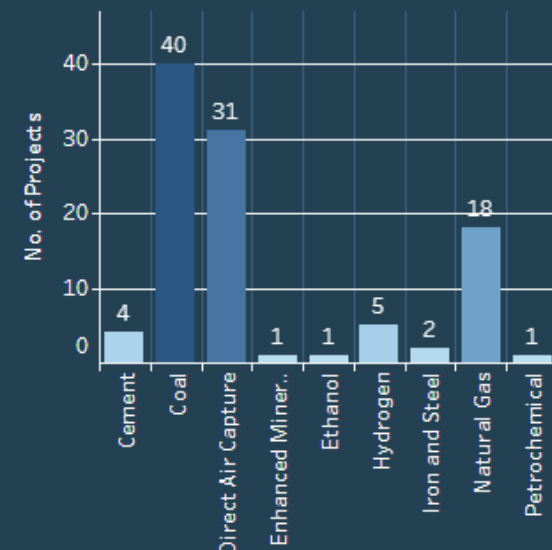
Assessing the impacts of Capture R&D

By comparing model runs without and with inputs from R&D, metrics such as employment impacts can be assessed

Marginal Jobs Impacts of CCS Tax Credits and DOE/NETL R&D Program, 2020-50

IIJA/BIL

Infrastructure Investment and Jobs Act (IIJA) - Bipartisan Infrastructure Law (BIL)

❖ **BIL: Carbon Capture Demonstration Projects Program**

FOA 1
- FOA 2738 "FEED Studies for Integrated Carbon Capture, Transport, and Storage Systems" - released September 22, 2022
- $189M; up to 20 projects

FOA 2
- FOA 2962 - released February 23, 2023
- Letters of Intent due 3/28; Applications due 5/23 @ 5pm
- $1.7B; ~6 projects (transformational domestic, commercial-scale, integrated CCS, demonstration projects)
  - 2 projects at new or existing coal electric generation facilities
  - 2 projects at new or existing natural gas electric generation facilities
  - 2 projects at new or existing industrial facilities not purposed for electric generation

❖ **BIL: Carbon Capture Large-Scale Pilot Program**
- FOA 2963 - released February 23, 2023
- $820M; up to 10 projects (transformational carbon capture technologies applied to existing coal or natural gas electric generation facilities and existing industrial facilities)

❖ **BIL: Carbon Dioxide Removal Provisions**
- $3.5B   Four Regional Clean Direct Air Capture Hubs
  - DE-FOA-0002735 issued on December 13, 2022
- $100M Commercial Direct Air Capture Technology Prize Competition
- $15M   Pre-Commercial Direct Air Capture Prize Competitions

Inflation Reduction Act (IRA)

$369B for Clean Energy and Climate Provisions

For Carbon Management: Enhanced 45Q

- *Direct Pay Option*
- *Broadens Qualifying Facilities: Capture Thresholds*
- *Extends Commence Construction Date to 2033*
- *Increases 45Q Credit Values ($35/$50 previously)*
  - *$60/metric ton for point source capture and utilization*
  - *$85/metric ton for point source capture and carbon storage in saline formations*
    - *$130/metric ton for Direct Air Capture and utilization*
    - *$180/metric ton for DAC and Saline Geologic Storage*

Questions

http://www.netl.doe.gov/research/coal/carbon-capture

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Thank you for your Participation

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✓ Presentation will be posted on the NETL RWFI website Webinar Archives

✓ Workforce Forum at end of presentations

✓ Submit questions via chat

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Economic & Workforce Development Roundtable Discussion

Discussion topics include the potential economic and workforce development opportunities that successful research into these topics and their related challenges.

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