NETL Regional Workforce Initiative

The Energy 101 Series

- **About the NETL RWFI Energy 101 Series:**

The Energy 101 series is an effort to provide stakeholders with easy to use, non-technical information on NETL's research foci and goals, and to increase the awareness of NETL's capabilities, and importance in serving National and regional economic growth. In this series, we utilize NETL staff expertise to describe NETL's portfolio of cross cutting technologies as well as to discuss the potential economic, workforce and jobs impacts that these innovations may bring to the region and Nation.

Webinars are posted at netl.doe.gov/rwfi

Submit questions for Q&A via chat function

Welcome to the Webinar

NETL Regional Workforce Initiative (RWFI) Presents

Energy 101 – Carbon Capture, Utilization and Storage

In this webinar, we will discuss NETL's research focus on CCUS and the potential for economic and workforce development opportunities that successful research, development and commercialization may bring. Subject matter experts from NETL will present background on NETL's research goals and aims in both the Carbon Capture and Carbon Storage portfolios.

Today's Agenda

I. The NETL RWFI Initiative, Energy 101, Anthony Armaly, NETL RWFI Coordinator
II. Carbon Capture 101, Dan Hancu, NETL Technology Manager – Carbon Capture
III. Carbon Storage 101, Mark McKoy, NETL Technology Manager – Carbon Storage
IV. Workforce and Economic Development Online Roundtable

NETL Regional Workforce Initiative (NETL RWFI)

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, Equitable, Durable Regional Economic and Workforce Development opportunities.

Key NETL RWFI Metrics

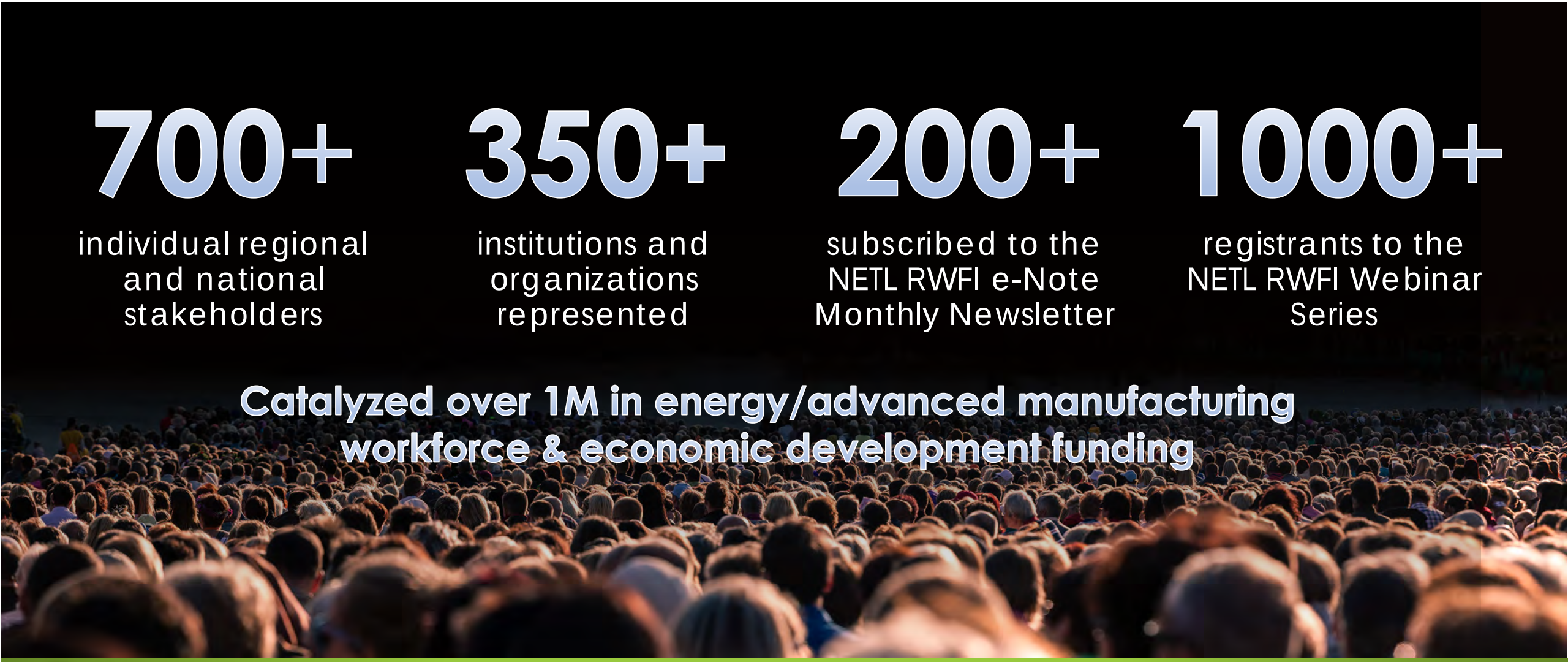
700+
individual regional and national stakeholders

350+
institutions and organizations represented

200+
subscribed to the NETL RWFI e-Note Monthly Newsletter

1000+
registrants to the NETL RWFI Webinar Series

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



NETL/ARC Advanced Welding Workforce Initiative

NETL and ARC Advanced Welding Workforce Initiative (AWWI)

- NETL and ARC Collaborative effort totaling **1M Dollars** for advanced manufacturing workforce training
- 750K was allocated by DOE's High-Performance Materials program to support the Advanced Welding Workforce Initiative (AWWI) and prepare a new generation of welders to manufacture and service high-temperature alloy components in electric generating stations.
- The funding awards based on regional need: Expanding offerings into economically distressed areas, targeting designated Opportunity Zones and recruiting workers in long-term recovery from substance use disorder.
- Presents a model for other topics, Carbon Capture Utilization and Storage, Rare Earth Metals, Composite and Advanced Materials, Remediation

NETL/ARC Advanced Welding Workforce Initiative

- **Robert C. Byrd Institute at Marshall University in Huntington, West Virginia,** $336,796
- **Belmont College in St. Clairsville, Ohio,** $281,603
- **Calhoun Community College in Decatur, Alabama,** $198,000
- **Southeast Community and Technical College in Cumberland, Kentucky,** $105,281
- **Westmoreland County Community College (WCCC) in Youngwood, Pennsylvania,** $78,320

Key Take-aways

NETL Regional Workforce Initiative

- Providing a platform for communication, outreach, & engagement is an important part of creating a foundation for predictive planning of workforce needs
  - Energy Workforce focused webinars
  - Energy 101 Webinars
  - E-Note Communication
  - TEAM Consortium & Energy Futures Initiative
- Promoting & Catalyzing Energy & Advanced Manufacturing Workforce and Collaborative Efforts and Partnerships
  - ARC POWER Grants
  - EDA Economic Development Grants
  - Innovation & Entrepreneurship
- Primed for partnerships
  - We welcome dialogue, ideas and conversations
  - Further unlock the positive impact of NETL & DOE research investments

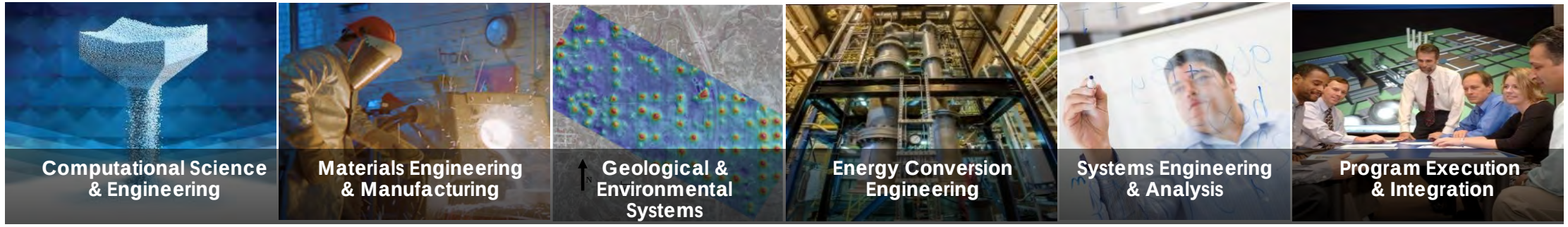
Identifying challenges and opportunities in the regional and National energy and advanced manufacturing ecosystem

Items of Note*

- $75M Carbon Capture FOA: DE-FOA-0002515 asking for jobs/recruitment info
- DOE Loan Program Office with $8.5B for CCUS
- Initial Report to the President on Empowering Workers Through Revitalizing Energy Communities

Core Competencies & Technology Thrusts

NATIONAL ENERGY TECHNOLOGY LABORATORY



COAL

Carbon Storage | Carbon Capture | Sensors & Controls | Advanced Materials | Advanced Computing | Advanced Energy Systems | Water Management | Rare Earth Elements

OIL & GAS

Enhanced Resource Production | Environmentally Prudent Development | Methane Hydrates | Offshore | Natural Gas Infrastructure | Unconventional

Support to Other DOE Offices

Energy Efficiency & Renewable Energy (EERE)

Vehicles | Solid State Lighting | Geothermal

Office of Electricity (OE)

Microgrid | Energy Storage

Cybersecurity, Energy Security, and Emergency Response (CESER)

Energy Security & Restoration | Cybersecurity

Contact Information

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Carbon Capture Program Overview

Energy 101 Seminar
April 29, 2021

NATIONAL ENERGY TECHNOLOGY LABORATORY

Dan Hancu
Carbon Capture Technology Manager
National Energy Technology Laboratory

Carbon Capture Program…Mission

Mission

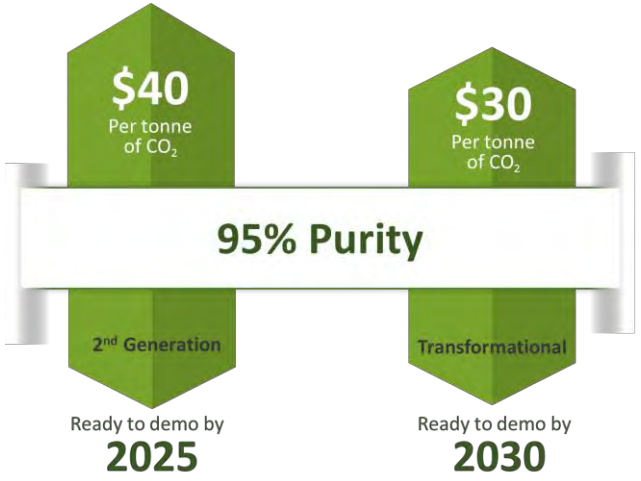
- Develop advanced cost-effective CO_2 capture technologies throughout the power-generation and industrial sectors as well as negative emission technologies
- Ensure the U.S. will continue to have access to safe, reliable, & affordable energy generation

Drivers/Challenges

- Reduce CO_2 capital & operating costs under a wide range of feed conditions
- Increase efficiency & reduce cost of CO_2 compression

Goal & Metrics

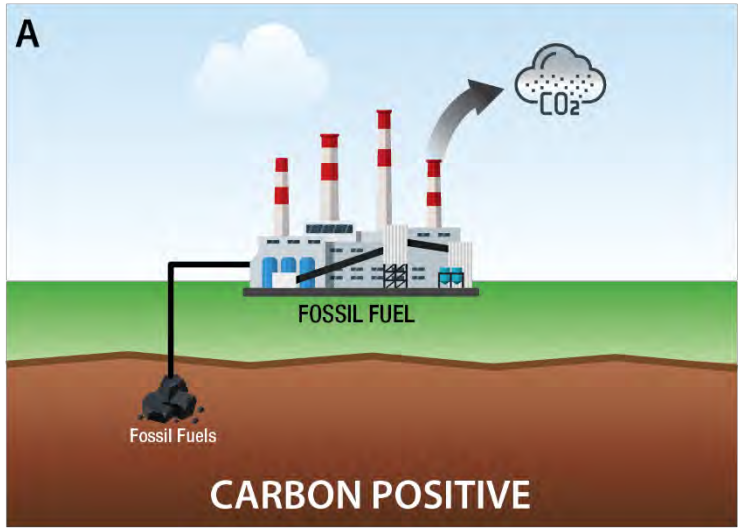
- Support U.S goal to achieve carbon pollution-free electricity sector by 2035 and zero-carbon economy by 2050

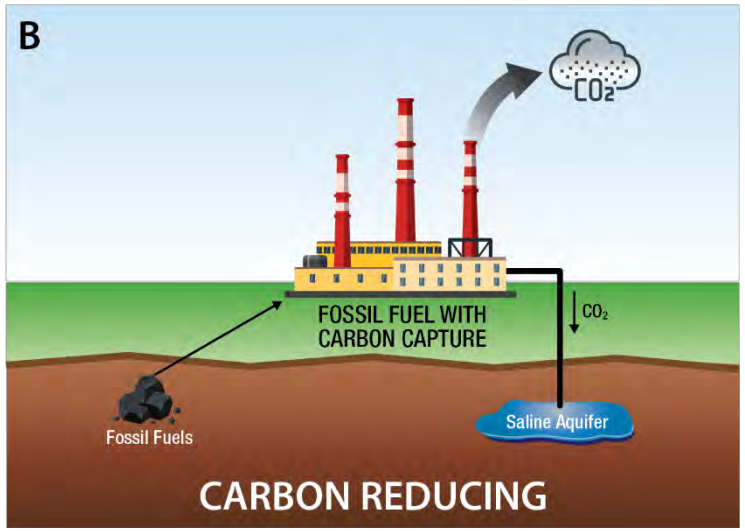


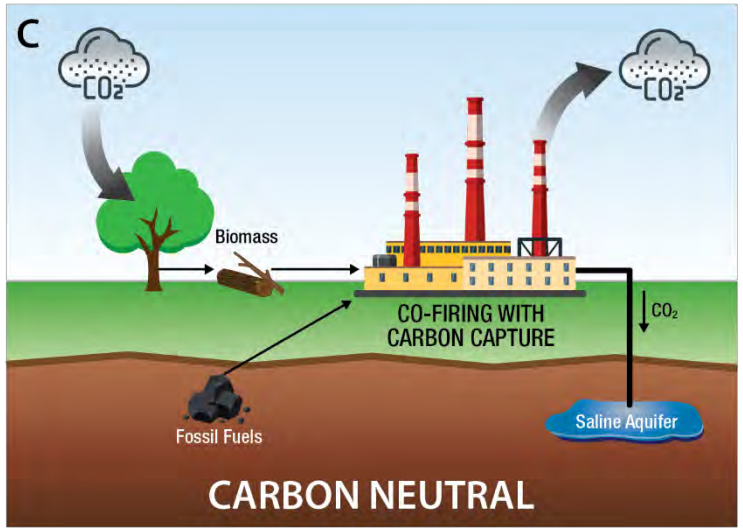
National Carbon Capture Center

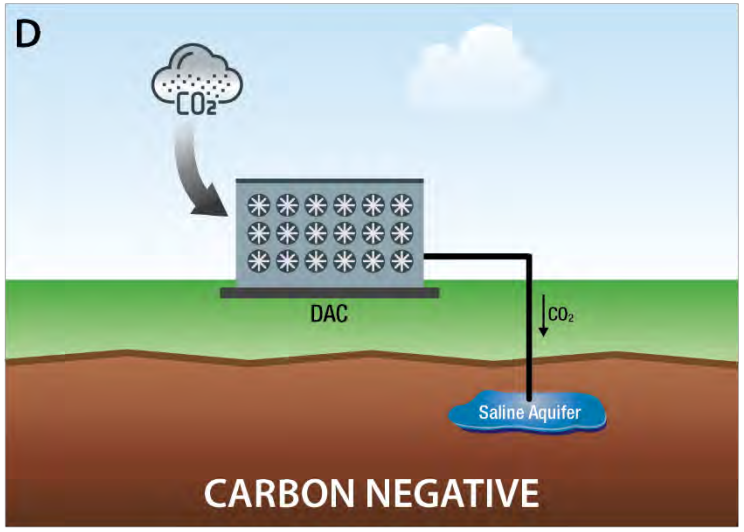
Photo Source: Southern Company Services

Carbon Dioxide Removal vs Carbon Reducing









Carbon Dioxide Removal vs. Carbon Reducing

Carbon Reducing.. CCS for Power Generation and Industrial Sectors

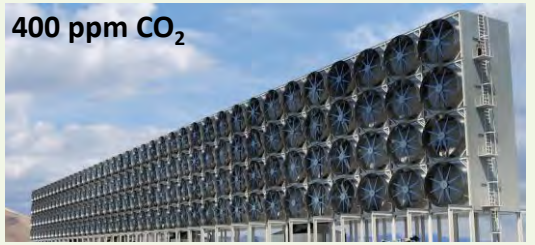
Power Plants

Cement Plants

Steel Plants

Hydrogen Plants

Carbon Dioxide Removal from Air



Direct Air Capture(1)

Ethanol Plants(1)

Bioenergy with Carbon Capture (BECCS)(1)

(1) Assume C storage as CO_2 off-take

Carbon Reducing Technology

Commercial Demo: H_2 Plant with Carbon Capture

- CO_2 capture from steam methane reformers (SMR)
- Located in Port Arthur, Texas
- DOE funding ~$284 million
- Capture ~1 million tons CO_2/year

Steam Methane Reforming:

$CH_4 + H_2O \leftrightarrow CO + 3H_2$

Water Gas Shift

$CO + H_2O \leftrightarrow CO_2 + H_2$

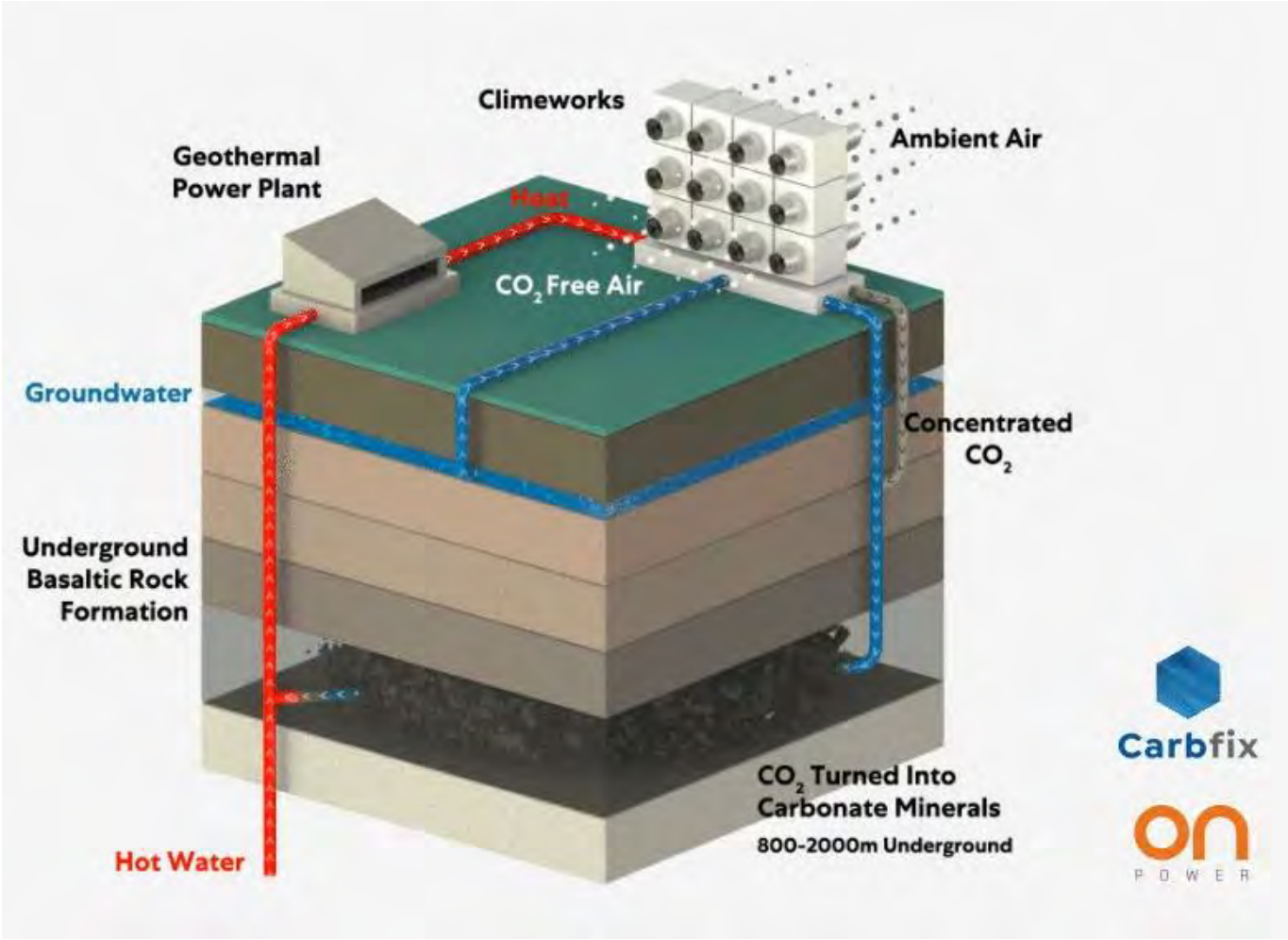
Air Products - Port Arthur
2012, 1 Mtpa CO_2

https://www.netl.doe.gov/sites/default/files/netl-file/FE0002381.pdf

Carbon Dioxide Removal (CDR)

Direct Air Capture Climeworks Plant (Orca)

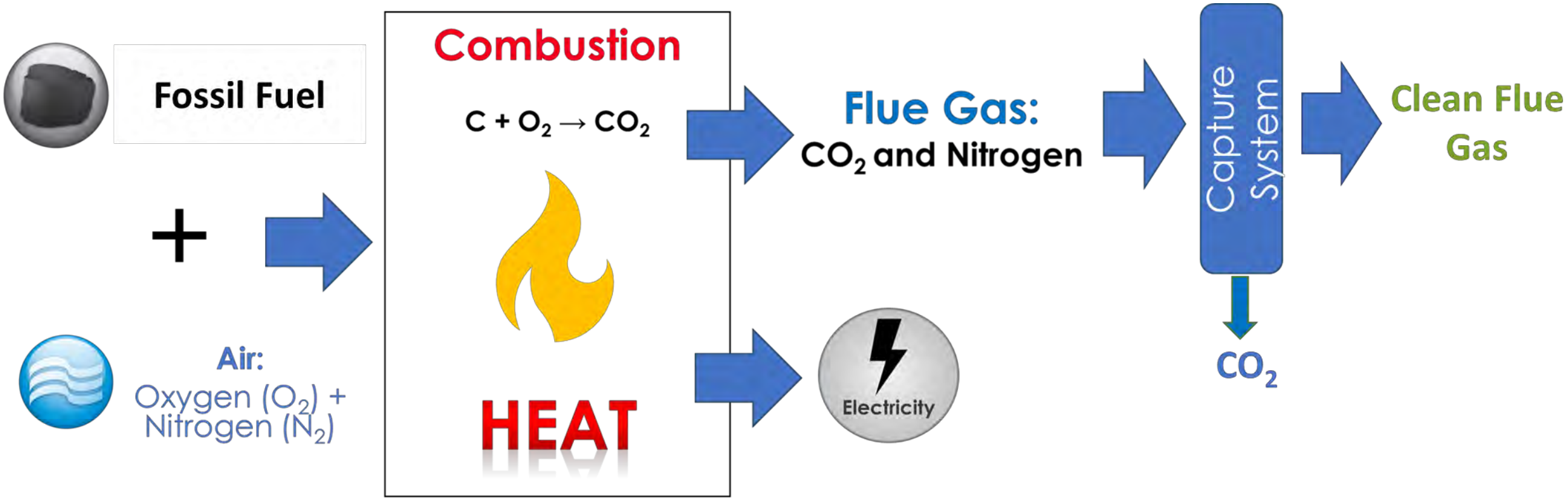
- Location.. Iceland
- 4,000 tons CO_2 / yr.
- Energy input.. geothermal
- CO_2 Off-take.. Storage (Carbfix)
- Operation in late summer 2021



https://climeworks.com/news/climeworks-makes-large-scale-carbon-dioxide-removal-a-reality

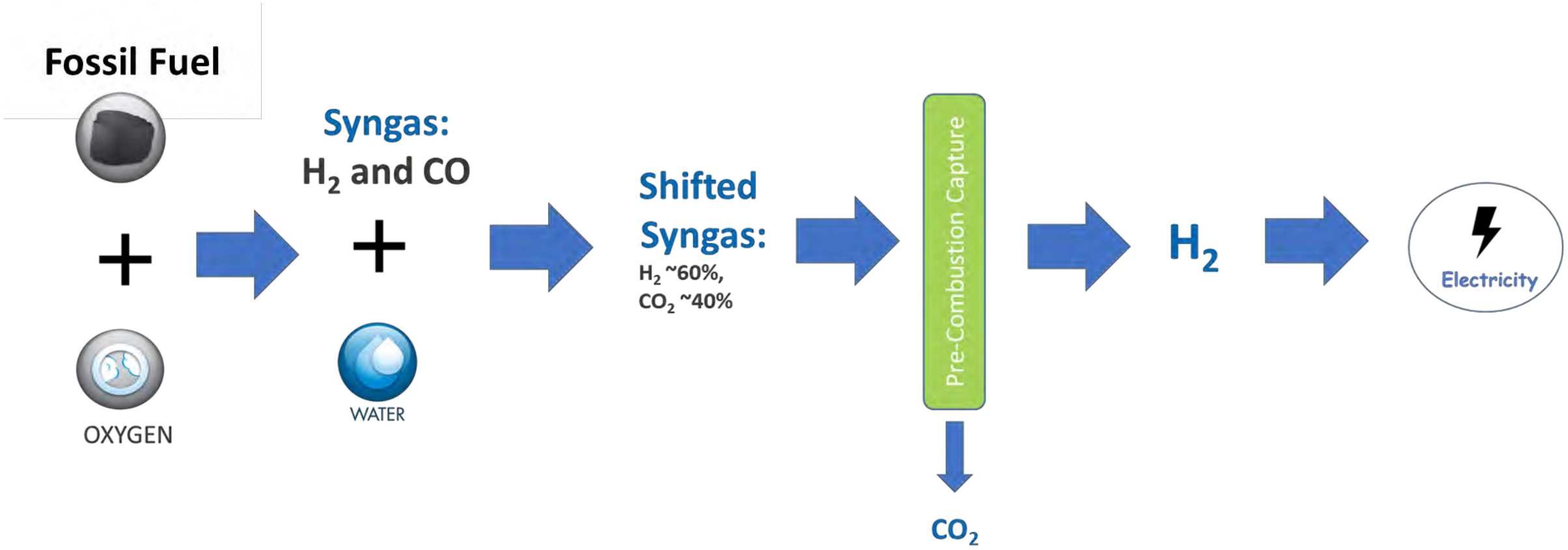
Process Description.. Post-Combustion

Fossil fuel is combusted in air to produce heat
CO_2 is separated from flue gas after combustion



Process Description.. Pre-Combustion

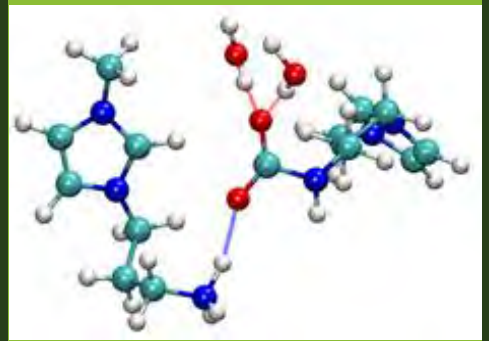
Fossil fuel is partially oxidized in pure oxygen to make Syn-gas. CO_2 is separated from flue gas before combustion to make H_2.



Approaches to CO_2 Capture

NATIONAL ENERGY TECHNOLOGY LABORATORY

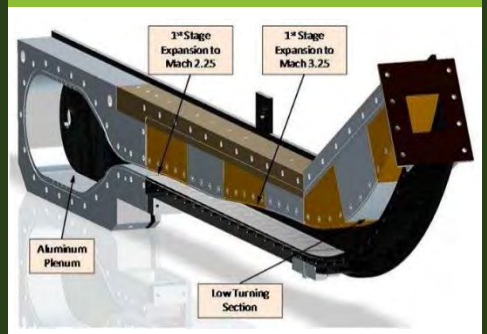
Solvents



Membranes

Sorbents

Novel Concepts



Carbon Capture Program…Evolution

NATIONAL ENERGY TECHNOLOGY LABORATORY

1st and 2nd Generation Technologies

2025: $40/tonne CO_2

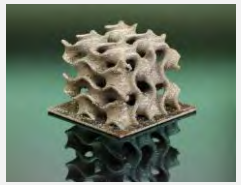
2008 -

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

Transformational Technologies

2030: $30/tonne CO_2

Hollow Fibers



3D Print

Biphasic Solvent

2015 -

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

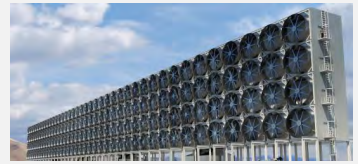
Scale-up

TCM

2018 -

- ✓ Engineering Scale testing
- ✓ FEED studies

Negative Emissions Technologies & Industrial



Carbon Engineering, DAC

Ethanol Plant

2020 -

- ✓ DAC & BECCS
- ✓ Industrial
- ✓ NG

Carbon Capture.. Program Structure

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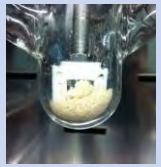
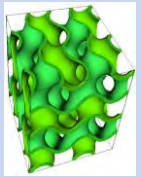
Lab & Bench

TRL 2-5





Testing novel materials & processes with simulated exhaust

University at Buffalo · Liquid Ion Solutions · Arizona State University · NETL · Los Alamos National Laboratory · Berkeley Lab

Oak Ridge National Laboratory · Lawrence Livermore National Laboratory

Additive Manufacturing

Small Pilots

TRL 5-6

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

Center for Applied Energy Research · The University of Texas at Austin · gti · TDA Research

Large Pilots

TRL 6-7

Scaling to engineering scale using existing host site Infrastructure

ION Engineering · MTR · RTI International

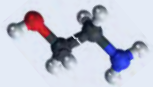
FEED Studies

New and Retrofit Power Plants

Bechtel · The University of Texas at Austin · ION Engineering · Southern Company · MTR · Minnkota Power Cooperative · EPRI Electric Power Research Institute · Enchant Energy · Illinois

Process modeling, TEA and LCA

CCSI² Carbon Capture Simulation for Industry Impact · NETL National Energy Technology Laboratory



Solvents

Sorbents

Membranes

Novel Concepts

Post-combustion

Pre-combustion

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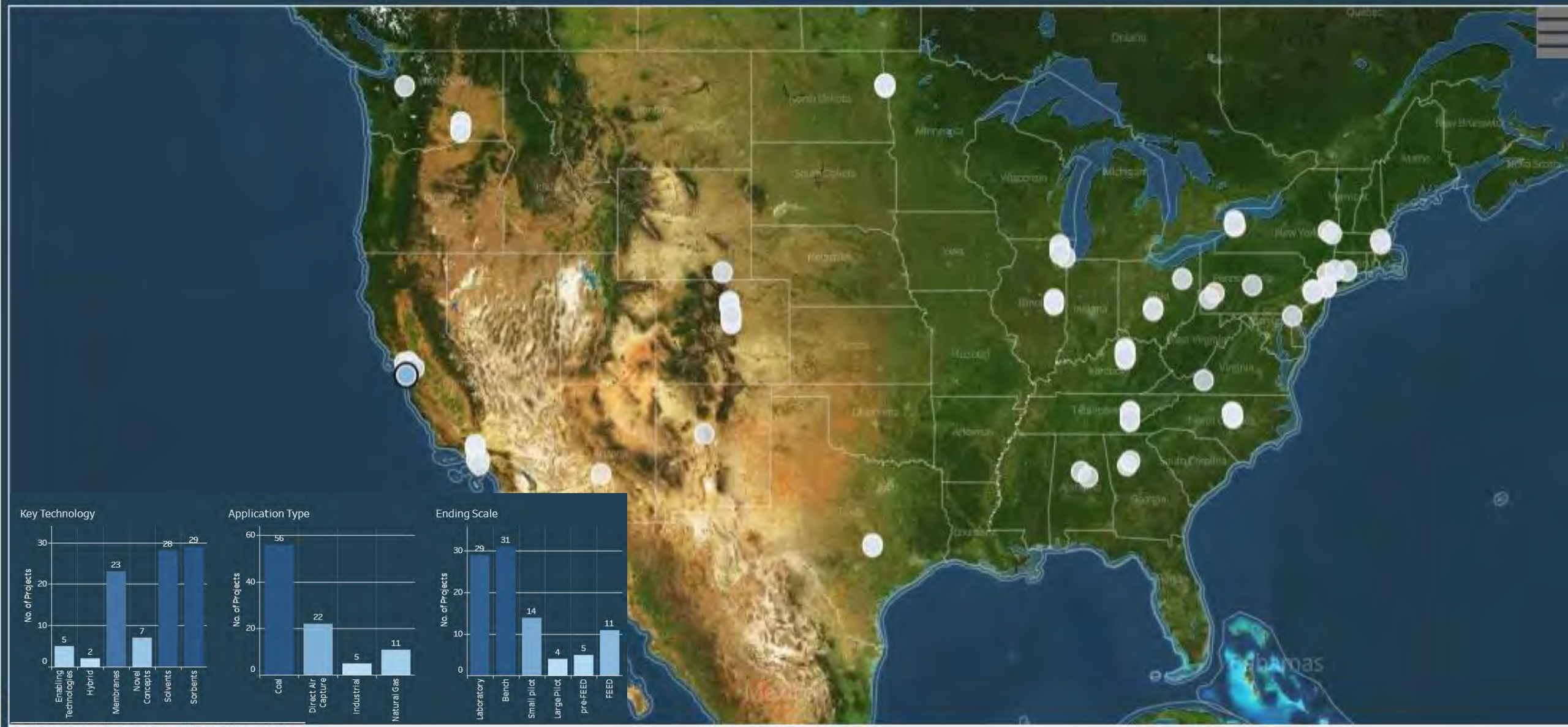
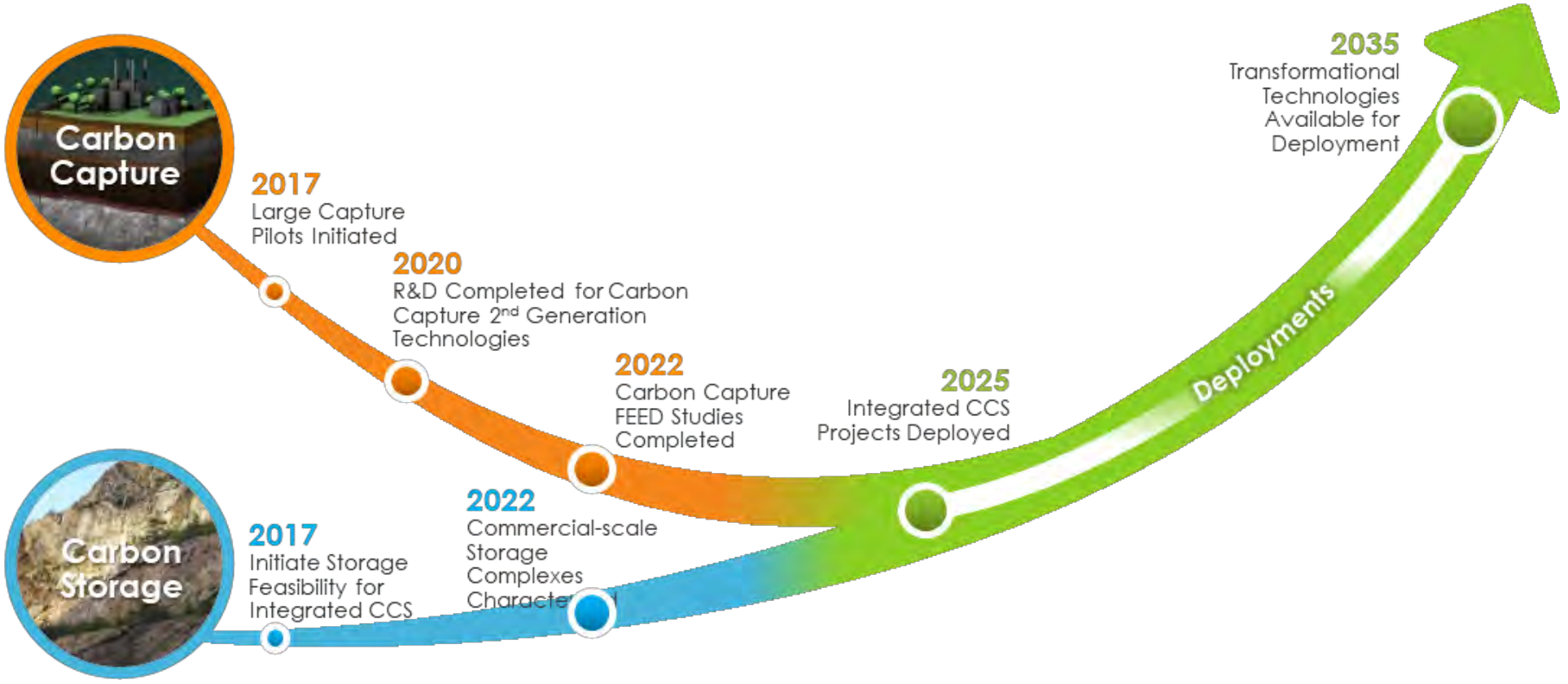
Carbon Capture Interactive Project Map

U.S. DEPARTMENT OF ENERGY



Capture & Storage…Timeline Integration



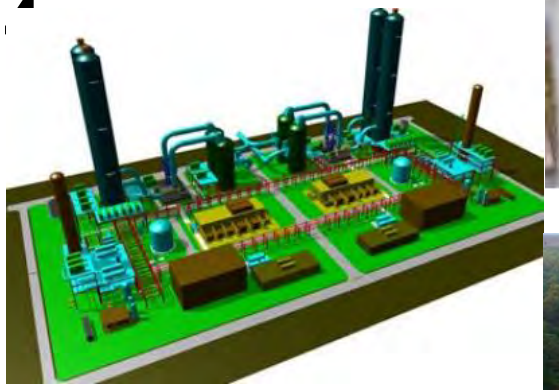
https://netl.doe.gov/2020CCUS-proceedings

Pre-Commercial.. FEEDs Studies (TRL 6+)

Carbon Capture from Natural Gas Power Plant

- **Alabama Power's Plant Barry Units 6 and 7**
  - Located in Bucks, AL
  - Natural Gas 525 MW net
- **Mississippi Power's Plant Daniel Units 3 and 4**
  - Located in Moss Point, MS
  - 525 MW net

- **Linde-BASF aqueous amine solvent-based technology**
  - BASF OASE® blue solvent
  - High-capacity structured packing
  - Fast-response reboiler design



Post-combustion capture plant (3D design)

Host Site

CO_2 Storage, Kemper County

Southern Company

2nd Generation Solvents.. Water-Lean (TRL 6)

Research Triangle Institute

Water-Lean Solvent Process

Technology Centre Mongstad (TCM)

CHALLENGE:

- Current solvent technologies: ~30% amines & ~70% water (negative energy impacts)

SOLUTION:

- Replace water (for ~5-10% total) with a hydrophobic non-aqueous solvent

SIGNIFICANT RESULTS

Techno-economic analyses indicate:

- **Reduced Capital Costs:** Smaller columns, heat exchangers, & footprint
- **Reduced Operating Costs:** Lower energy requirements

Lab/Bench Scale Development – 2009

- Proof of concept/feasibility (2009)
- Lab-scale testing (2010)
- Bench-scale testing (2014)
  - TEA ~capture cost ≤ $40/tonne

Scale-Up Testing – 2016

- SINTEF's Tiller Plant (60 kWe).. 1500+ hrs.
- NCCC (50 kWe).. 570 hrs

Large Pilot-Scale Testing – 2018

- ~12 MWe scale testing at TCM
- Additional operational testing with RTI solvent

Carbon Capture Program.. Outreach

Carbon Capture Newsletter

Carbon Capture Program R&D Compendium

Carbon Capture Program Website

Questions

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

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Carbon Storage

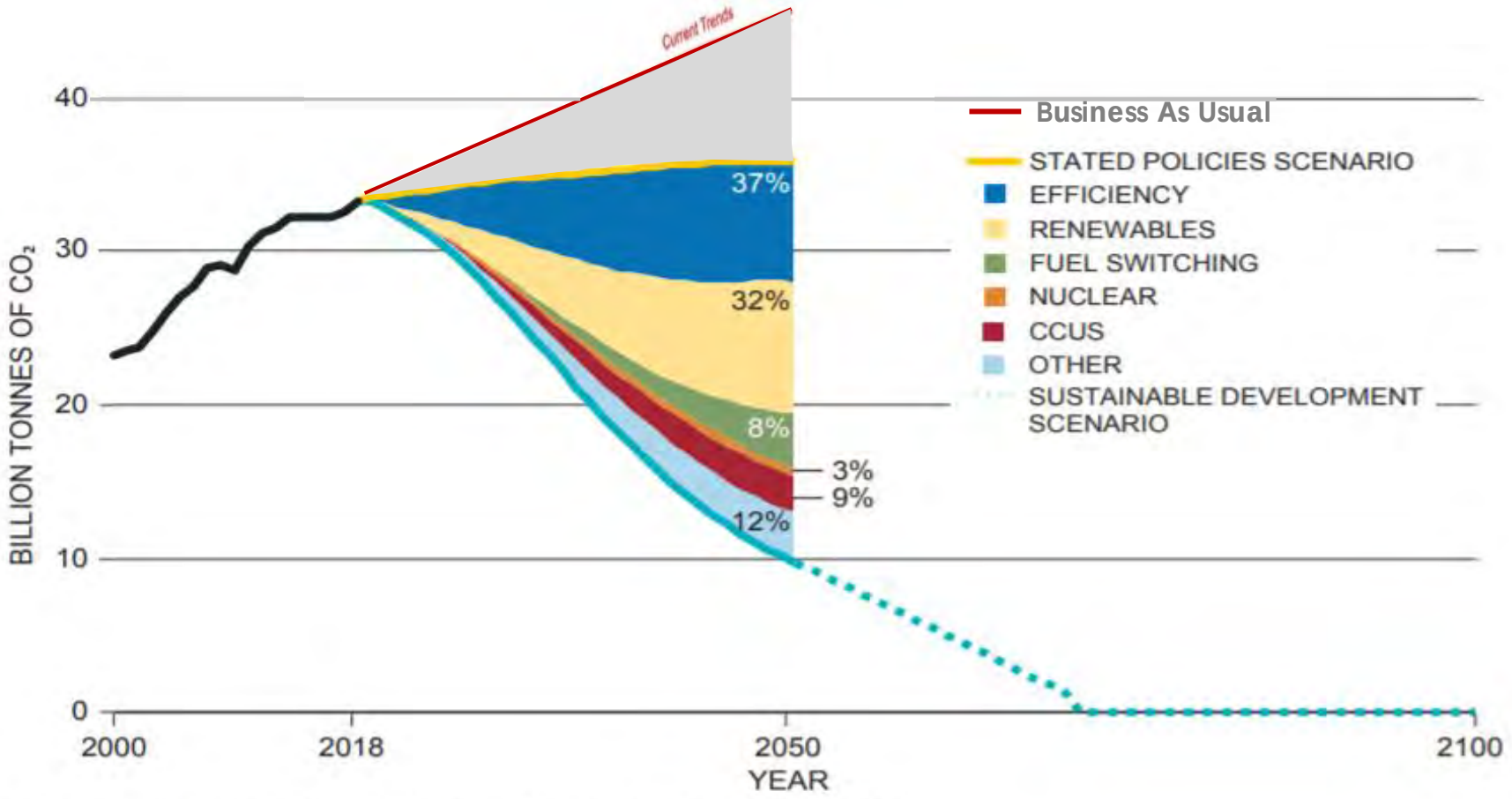
Solutions for Today | Options for Tomorrow

NATIONAL ENERGY TECHNOLOGY LABORATORY

Mark McKoy
DOE-NETL Technology Manager Carbon Storage

Why do we need CO_2 storage?

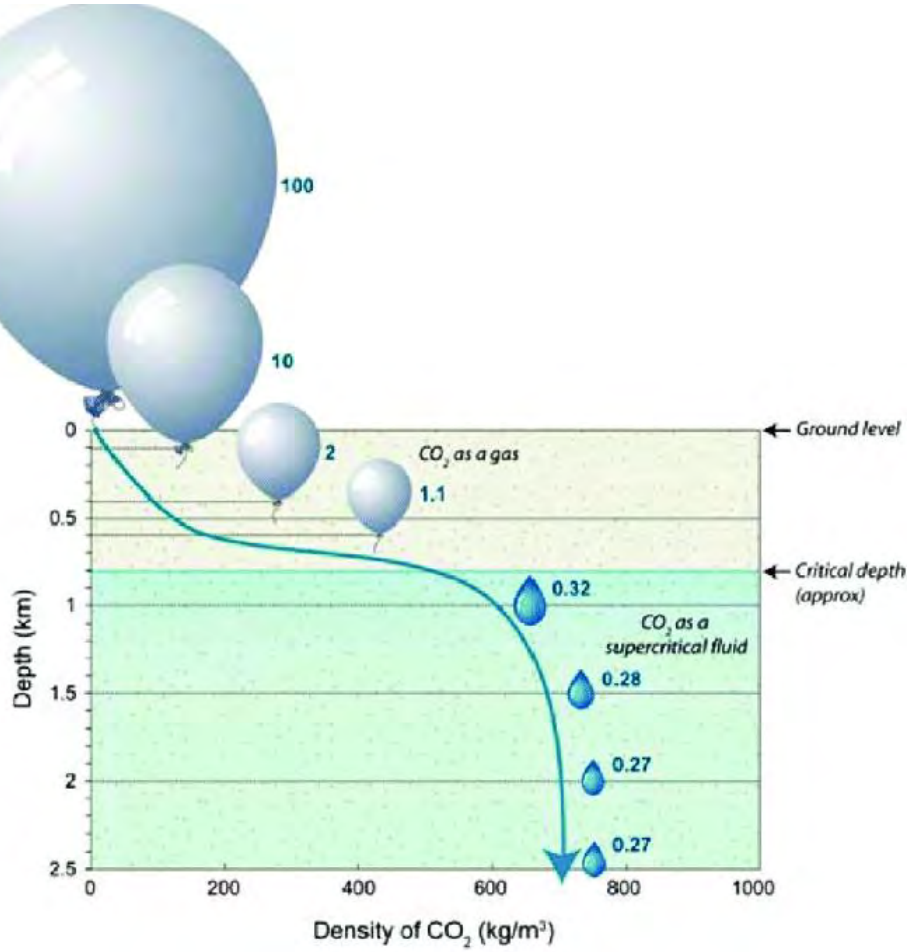
Global Emissions Projections for the IEA's Sustainable Development Scenario and Stated Policies Scenario



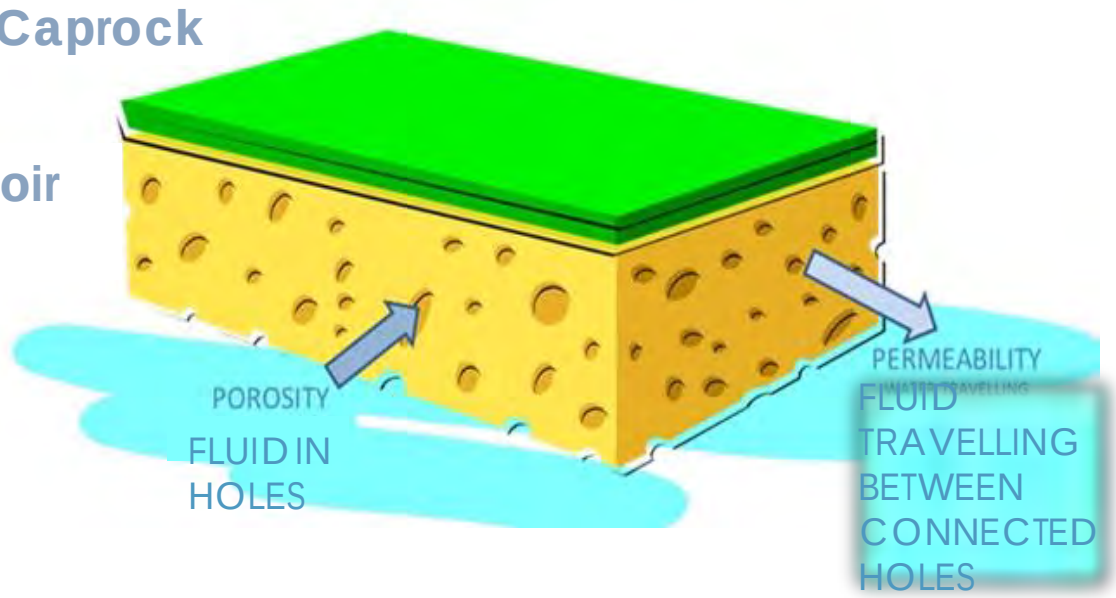
Source: Based on data from International Energy Agency, World Energy Outlook 2019.

How and Where is CO_2 Stored?

Supercritical CO_2



The reservoir as a sponge



Source: http://www.acogok.org/water/groundwater-oklahoma/aquifer-and-rock-types/

How Does the CO_2 Stay Underground?

Deep Subsurface Injection

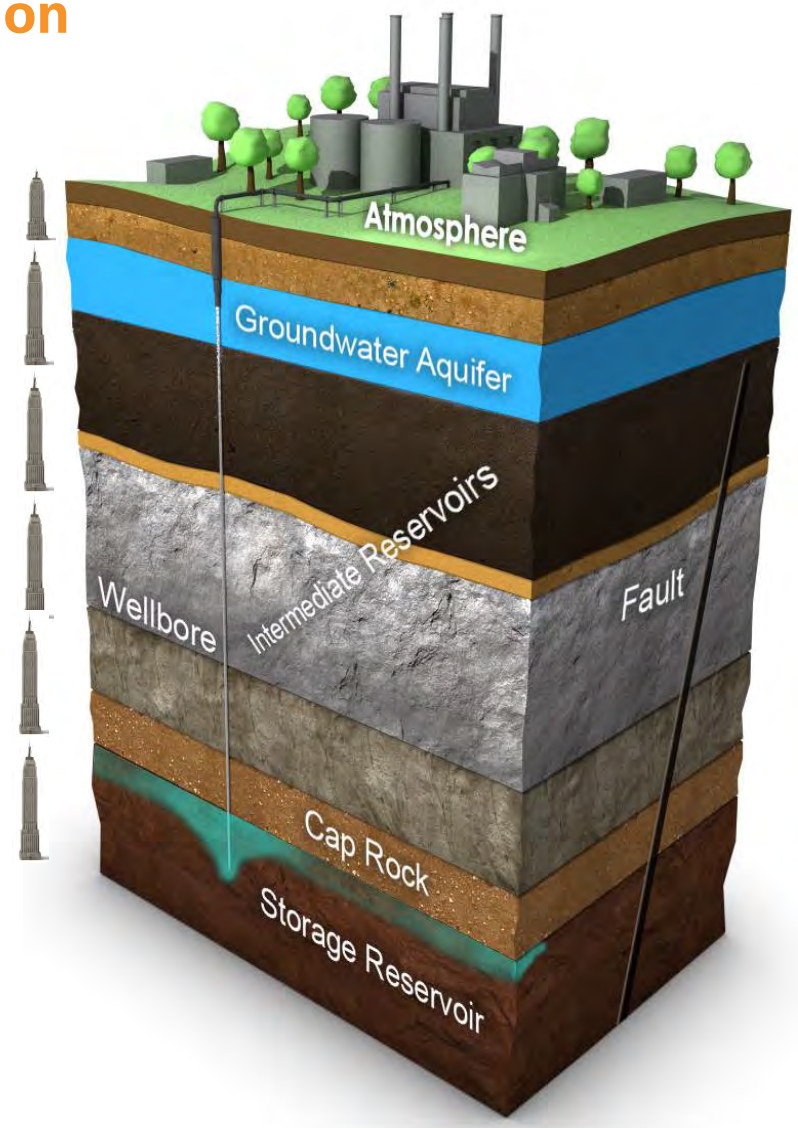
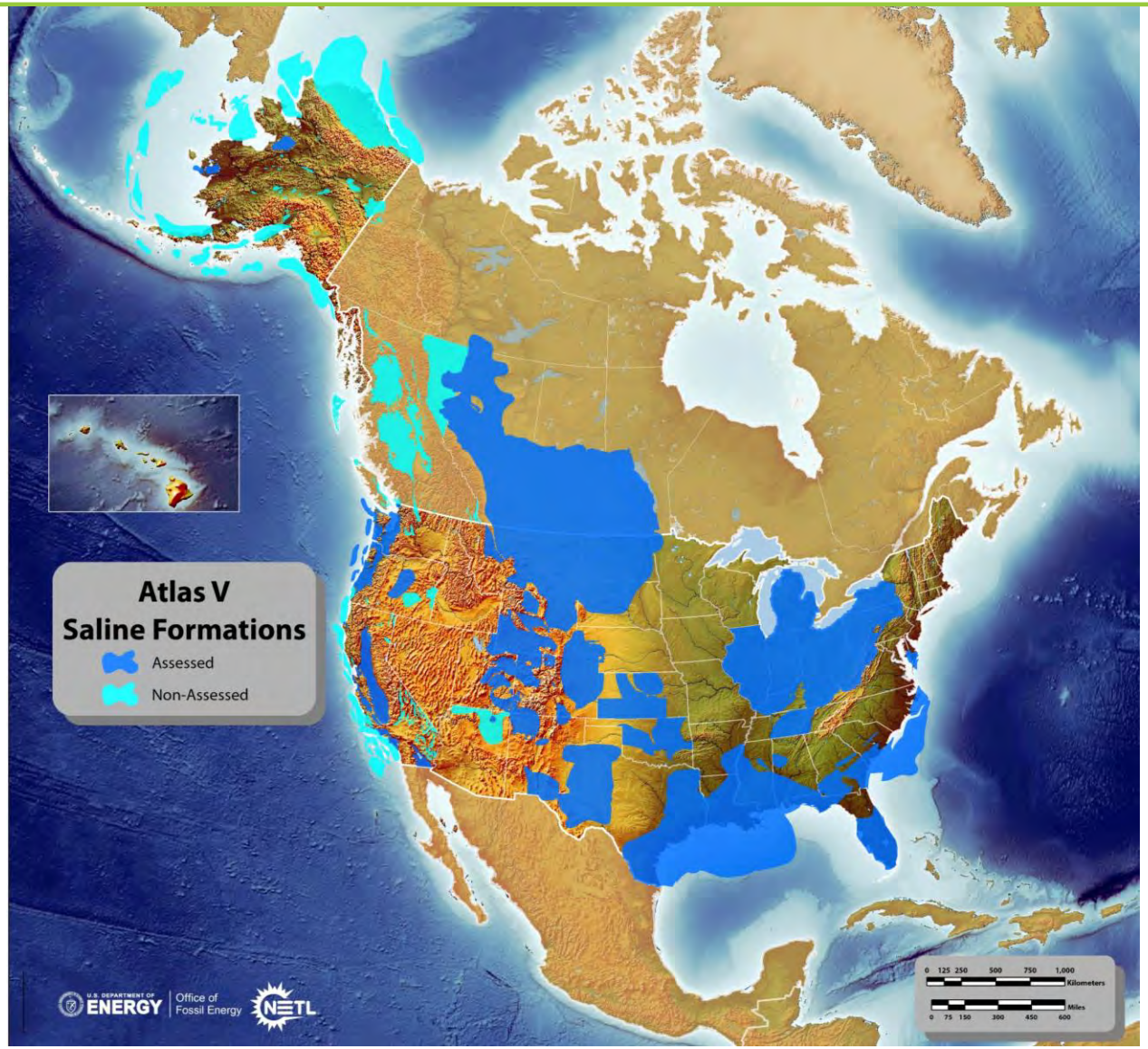


Image from National Risk Assessment Partnership (NRAP)

Where Can CO_2 Be Safely Stored?



Onshore CO_2 Volumetric Assessment

Regonal Carbon Storage Partnerships	Billion Metric Tons	
	Low	High
Oil and Natural Gas Reservoirs	**186**	**232**
Unmineable Coal	**54**	**113**
Saline Onshore	**2,379**	**21,633**

Carbon Storage Atlas V:

https://netl.doe.gov/sites/default/files/2018-10/ATLAS-V-2015.pdf

What is the DOE Role in Deploying CCUS?

Federal investment in CCUS is driven by Congressional appropriations and the **presidential administration's** clean energy goals.

E.g., The President wants to **"move ambitiously to** generate clean, American-made electricity to achieve a carbon pollution-free power **sector by 2035"**

- The President's Budget asks for and Congress appropriates funding to DOE for CCUS R&D programs.
- DOE Programs invest in the advancement of promising CCUS technologies for adoption by industry.
- DOE also partners with industry to share the risks of first-of-a-kind deployment.

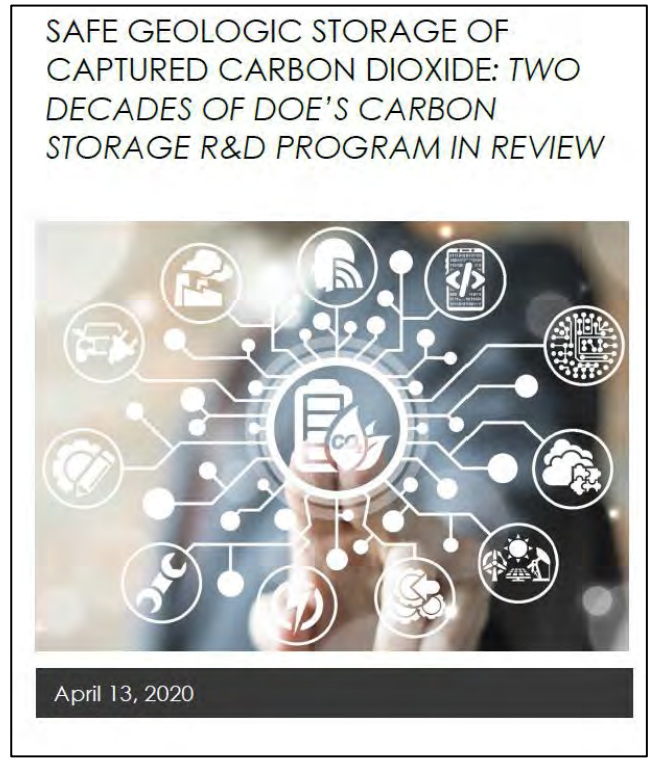
DOE's R&D programs support in-house and extramural research based on lessons learned.

Evolution of the Carbon Storage Program

Historical focus: Develop and demonstrate tools and techniques that promote safe and long-term storage

New focus: Reduce project cost and risk, supporting scale-up to commercial projects

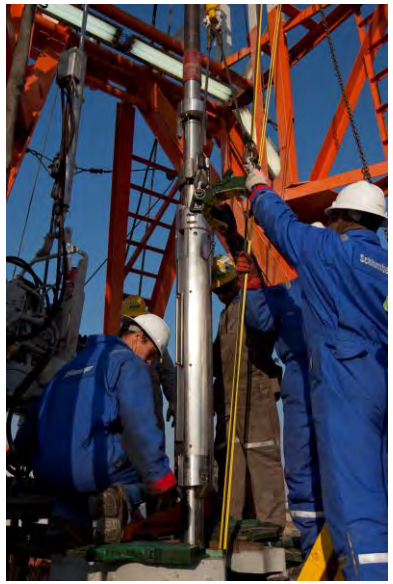
- Large-scale field projects in multiple regions
- Individual R&D projects and small-scale field projects focused on research gaps identified in large-scale field projects
- Information collection/synthesis/reporting to support further regulatory evolution, liability apportionment, and legal issues such as pore space ownership



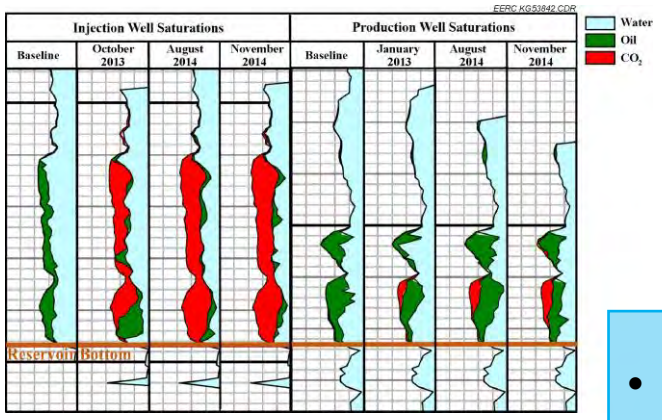
https://netl.doe.gov/sites/default/files/Safe%20Geologic%20Storage%20of%20Captured%20Carbon%20Dioxide_April%2015%202020_FINAL.pdf

Carbon Storage Program Objectives

- Individual technology R&D to fill specific technical needs as identified from previous R&D and field projects.
- Lab-scale activities prioritized based on an iterative assessment cycle with the larger field projects.

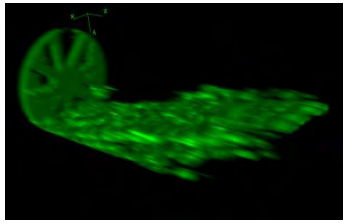


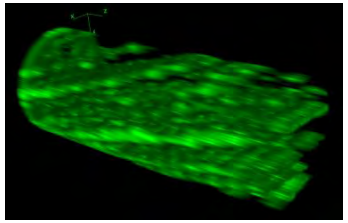
CO_2 storage well completion at the IBDP ADM Decatur, IL site



Pulsed Neutron Log (PNL) at PCOR's Bell Creek injection site

NETL-RIC: Field Sampling at Active CO_2-EOR Site





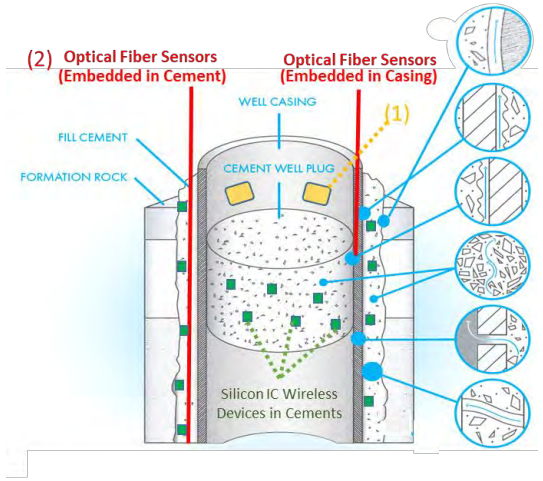
NETL-RIC: Measuring flow at geochemical conditions

- Field projects, laboratory studies
- Regional characterization
- Demonstrations: different storage complexes in various geologic settings have the capability to safely and permanently store CO_2.

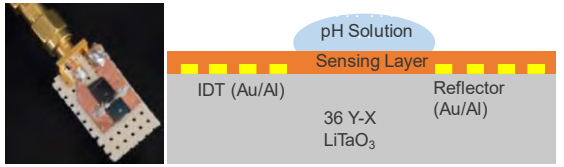
NETL's Research & Innovation Center (RIC)

- National Risk Assessment Partnership (NRAP)
- Monitoring CO_2/Brine Plumes and Ground-Water Impacts
- Reservoir Performance
- Shales as Seals and Unconventional Reservoirs
- Resource Assessments and Geospatial Resources (EDX and NATCARB)
- Crosscutting Technologies

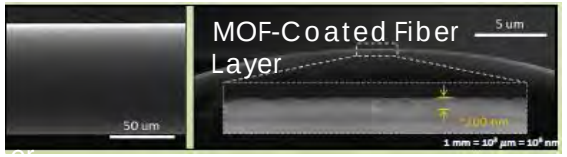
Designing and testing embedded sensors for Wellbore Integrity



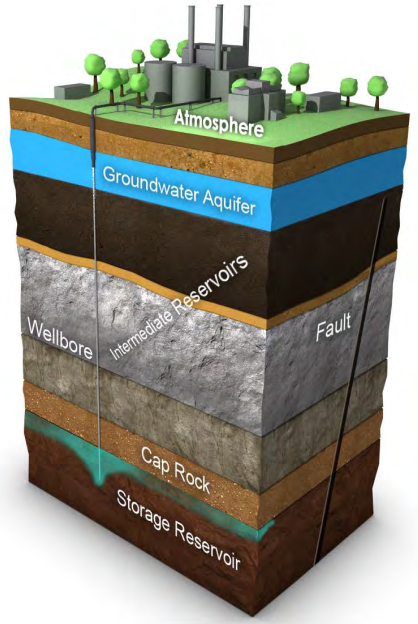
(1) SAW Sensors for Liquid Phase Applications



(2) Coated Fiber Optic Chemical Sensor



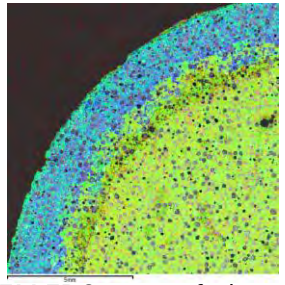
Leading development of NRAP tools to probe uncertainty in the storage system



Lab methods for complex waters

Thermo Scientific Neptune Plus MC-ICP-MS for groundwater isotopes

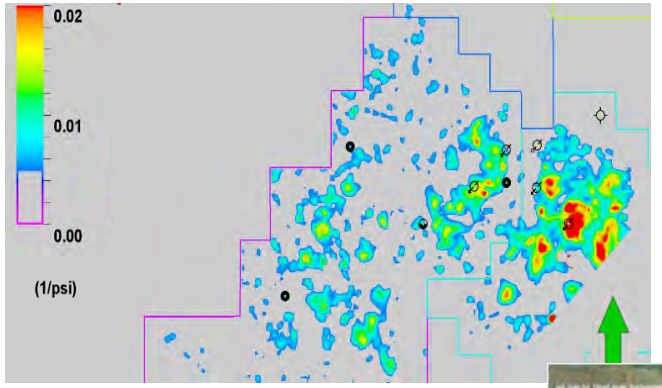
Foamed and CO_2 resistant cements



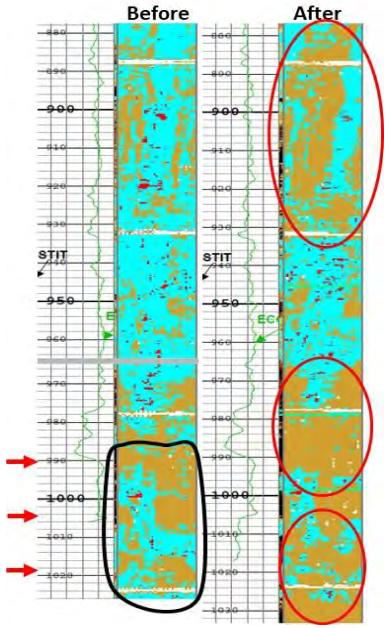
SEM-EDS map of altered cement (20% foam quality)

DOE Funded Extramural Cutting-Edge Research

- Fundamental research, technology development, field projects
  - Large-Scale Injections
  - Improved monitoring in the subsurface
  - Artificial Intelligence/Machine Learning
  - New geophysical tools and methods
  - New materials to remediate leaks

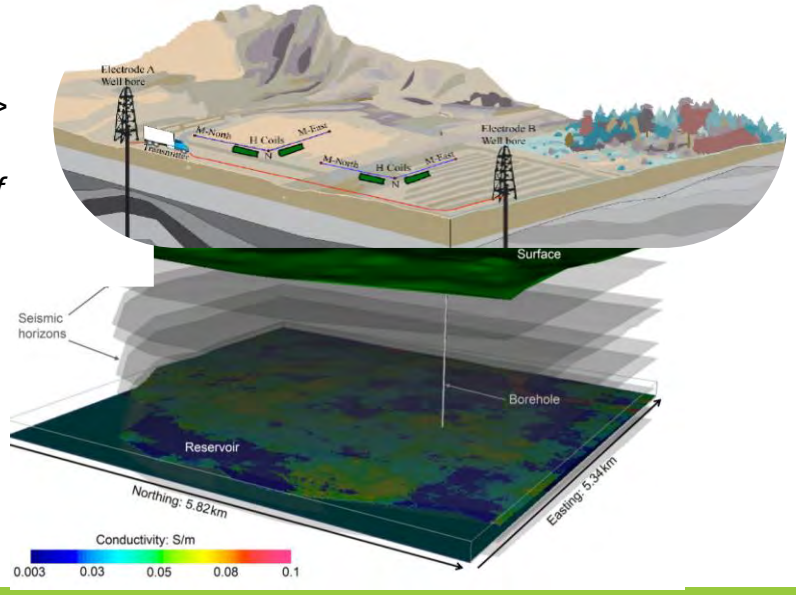


< Inversion of Time-lapse Seismic data; AVO approach *EERC*

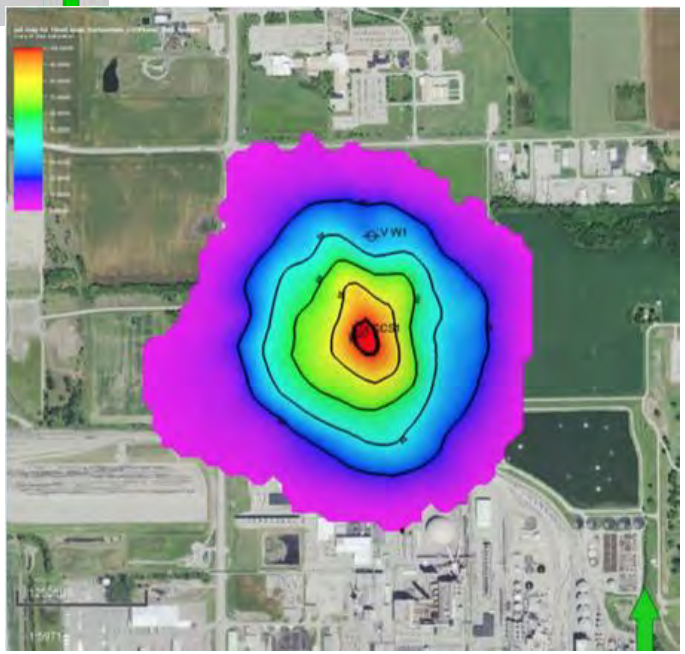


< Wellbore Remediation; *Montana State University*

Charged Wellbore Casing Controlled Source Electromagnetics > [CWC-CSEM] *Colorado School of Mines*



MGSC IBDP: Simulated Net CO_2 Saturation V



Addressing Larger-Scale Challenges

Field Projects and Studies

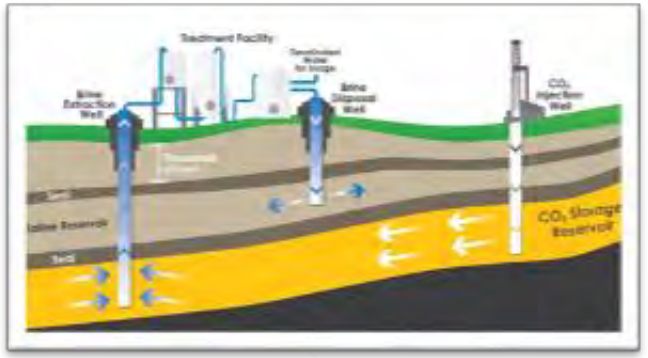
- CarbonSAFE
- Regional Carbon Sequestration Partnerships
- Regional Initiatives
- Offshore Storage Feasibility Studies
- Brine Extraction Storage Tests (BEST)
- Associated Storage Projects

Regional Carbon Sequestration Partnerships

Storage Resource Offshore

CarbonSAFE – Kemper County Facility

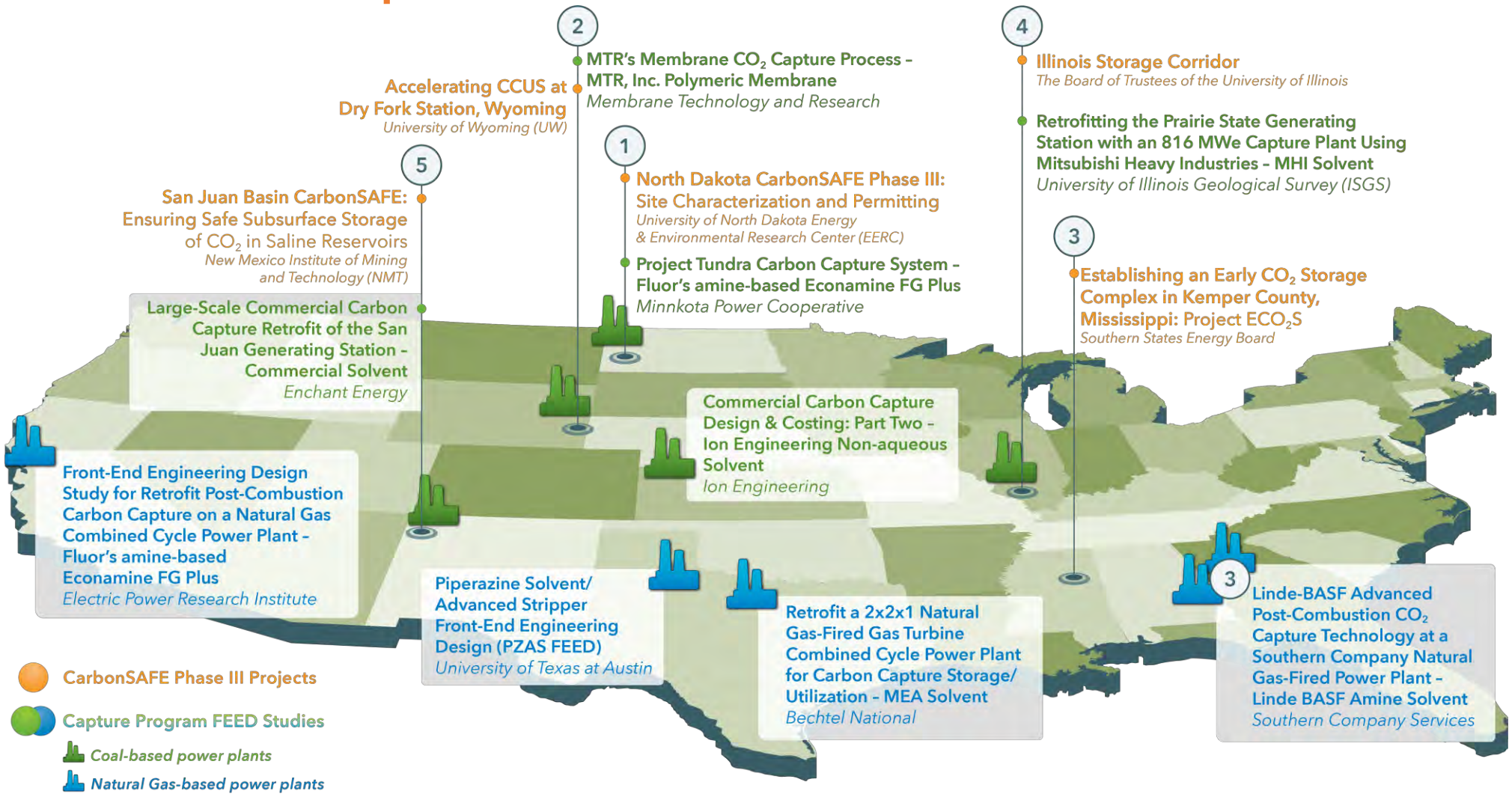
Cross Section Depicting a Brine Extraction Storage Test



Domestically, over 11 million metric tons stored since 2008 by the Storage Program (21 million metric tons domestically with the inclusion of major demonstrations)

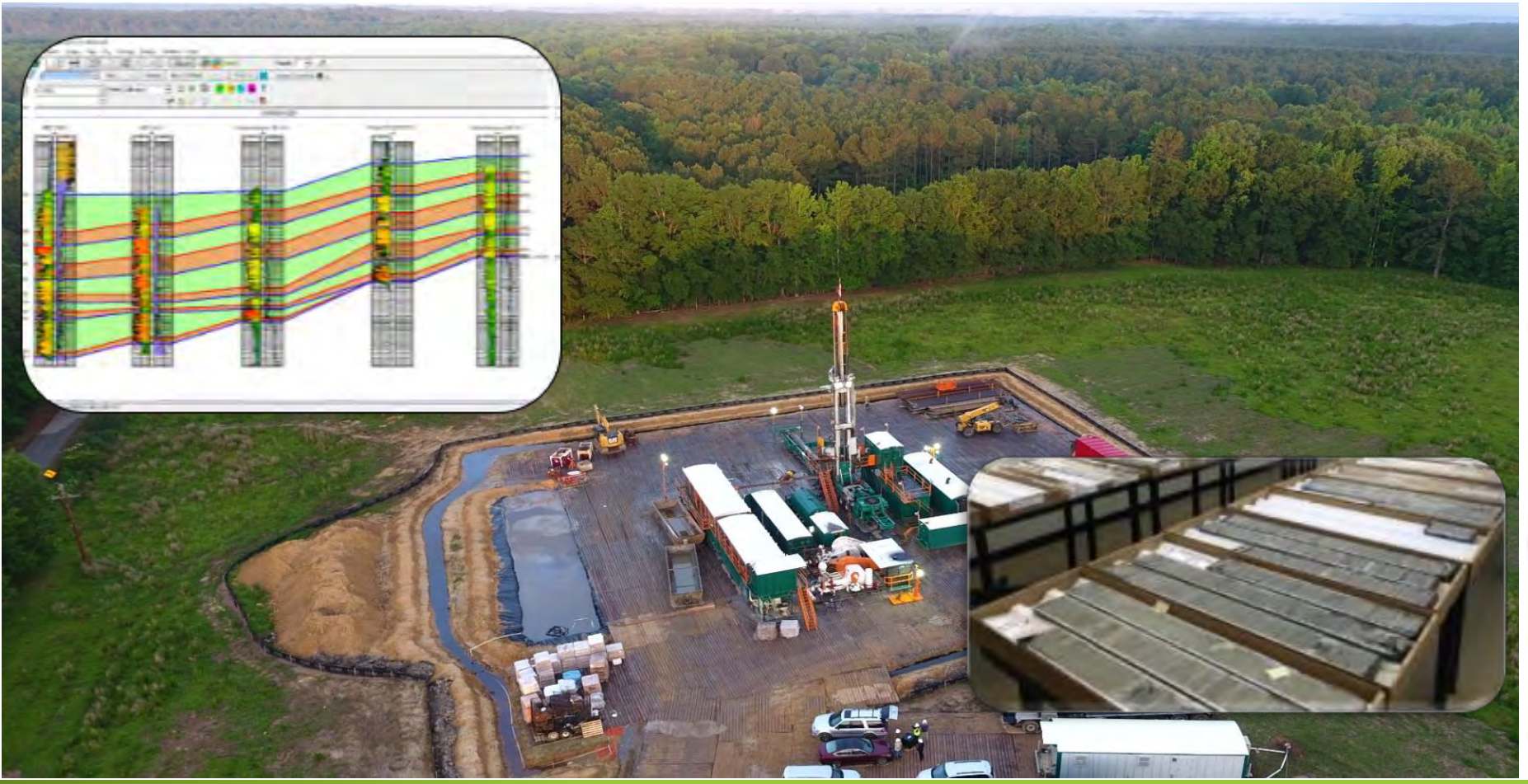
Carbon Storage Assurance Facility Enterprise

CarbonSAFE Phase III & Capture Funded FEED Studies Locations



Establishing an Early CO_2 Storage Complex in Kemper County, Mississippi: Project ECO$_2$S (DE-FE0031888)

Demonstrate that the subsurface in Kemper County can safely and permanently store commercial volumes of CO_2.



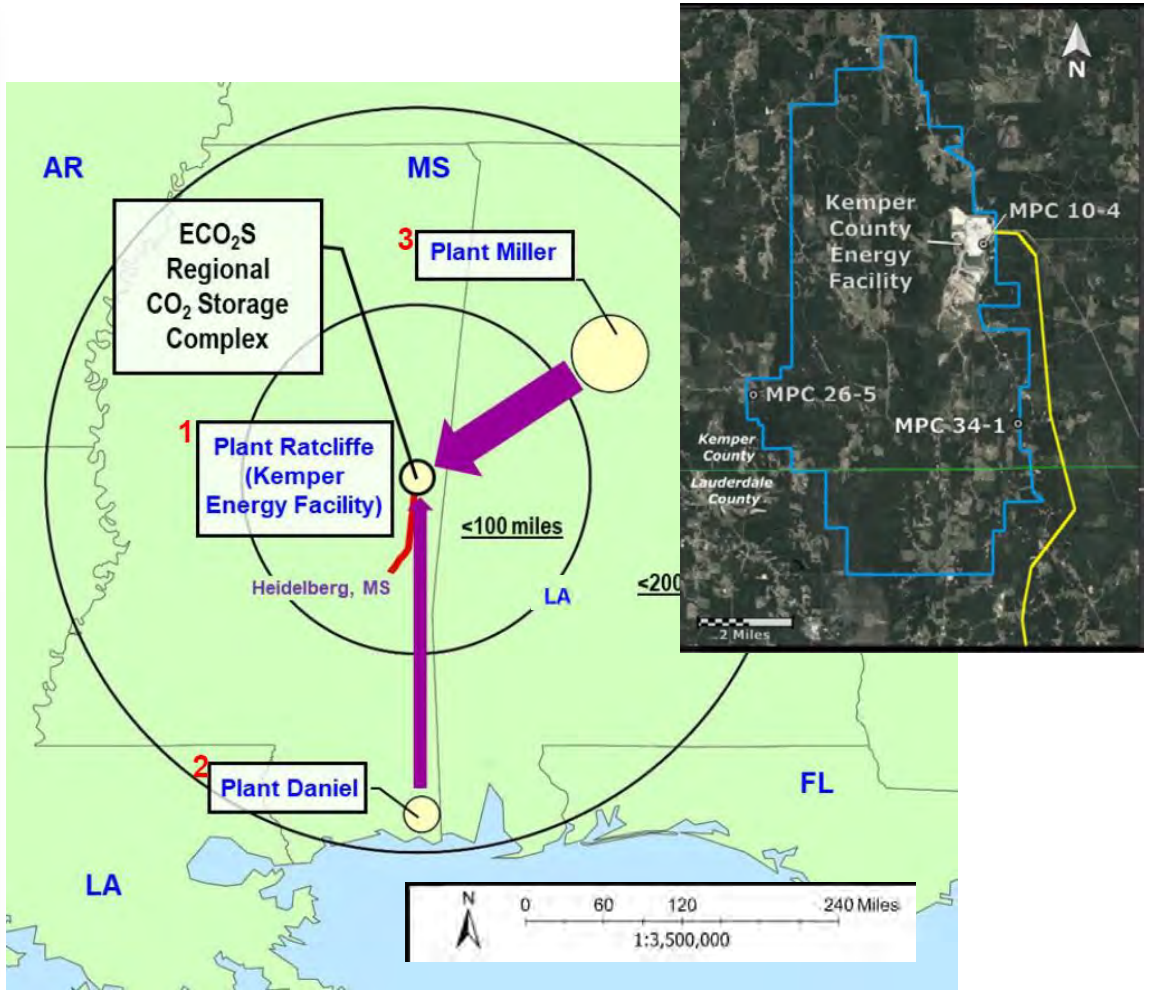
Establishing an Early CO_2 Storage Complex in Kemper County, Mississippi: Project ECO$_2$S (DE-FE0031888)

Key Project Attributes

- 22.5 MMT/year CO_2 storage combined from Southern Company's Plant Miller (coal), Plant Ratcliffe (NG) and Plant Daniel (NG)
- Excellent Geology - Stacked formations provide gigaton storage potential (900 MMT of CO_2 over 30,000-acre area)
- Strong corporate support with Southern Company

Characterization Plan

- Drill/core three characterization wells
- Perform 4-6 mi^2 3D seismic survey
- Completion, development and sampling of a deep USDW characterization and monitoring well

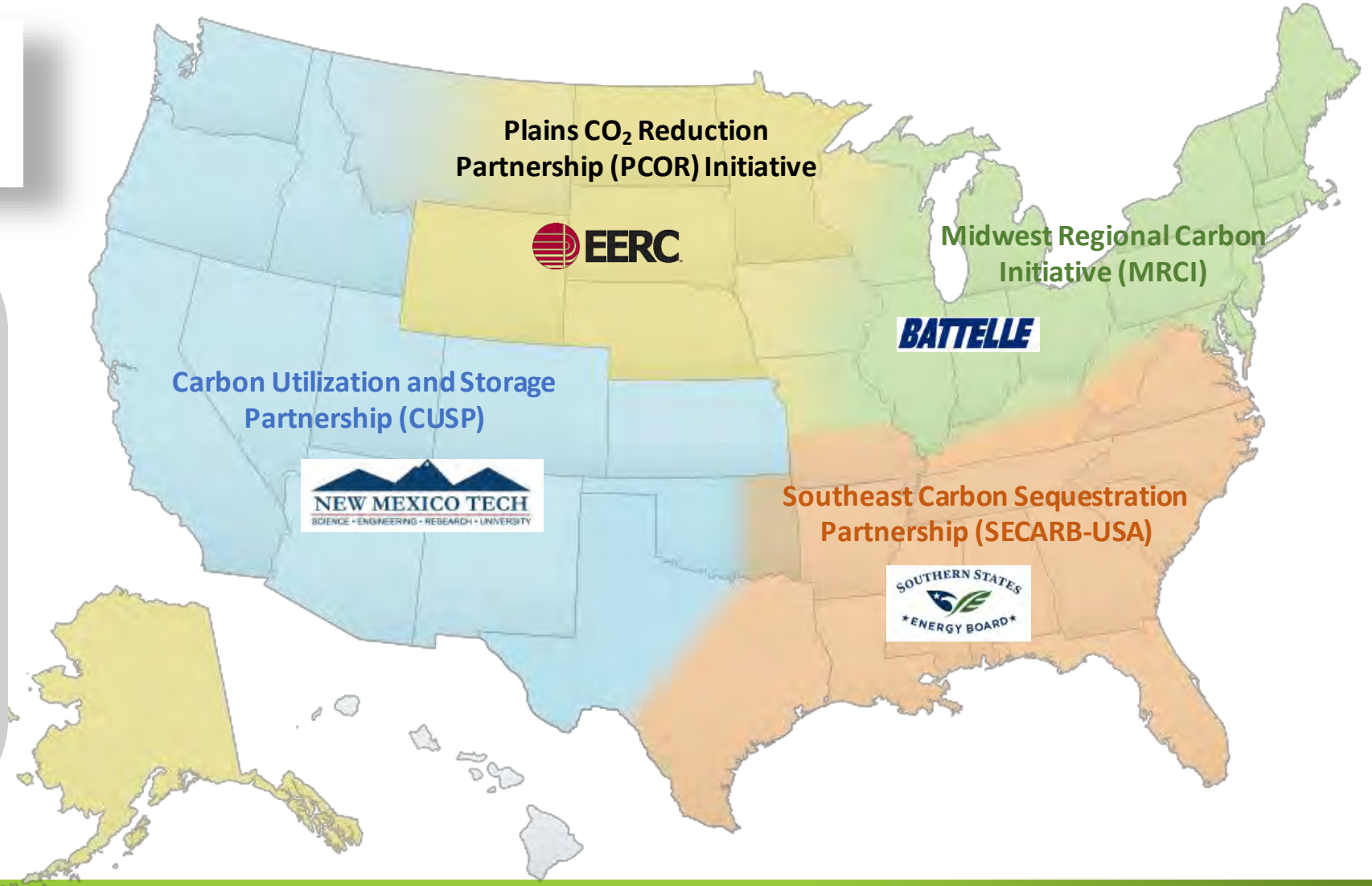


RCSPs transitioned into the Regional Initiatives

7 regional partnerships transitioned to 4 Regional Initiatives to Accelerate CCUS

Four Key Activities to accelerate CCUS Deployment

- Promote regional technology transfer
- Address certain technical challenges
- Facilitate data collection, sharing, and analysis
- Evaluate existing regional infrastructure



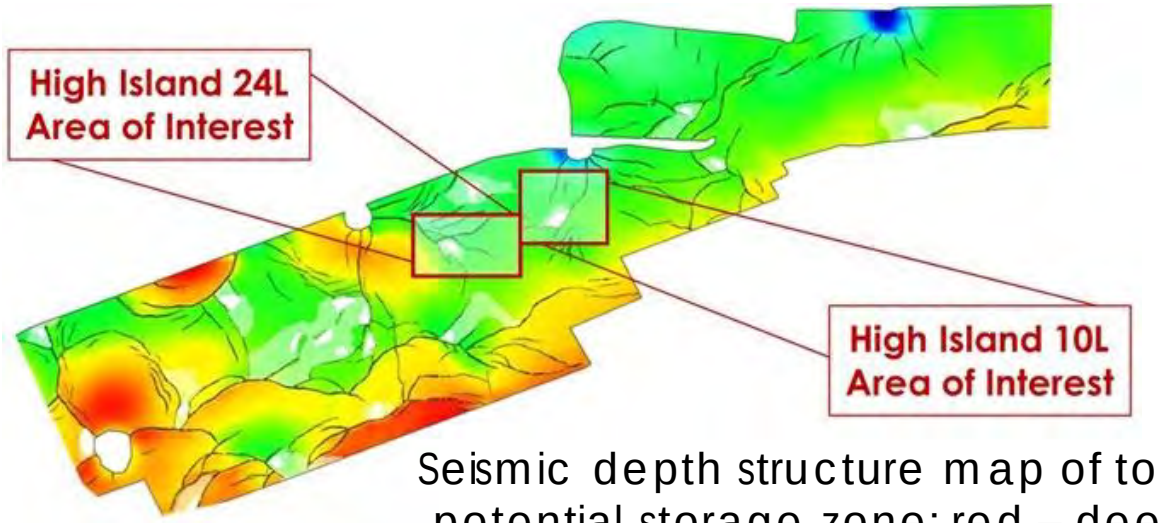
https://undeerc.org/research/carbon.html; https://www.mrcsp.org/whats-new; https://www.nmt.edu/news/2020/regional_carbon_capture_partnership.php;https://www.sseb.org/programs/secarb-usa/

Storage Resources in the Offshore Atlantic and GOM

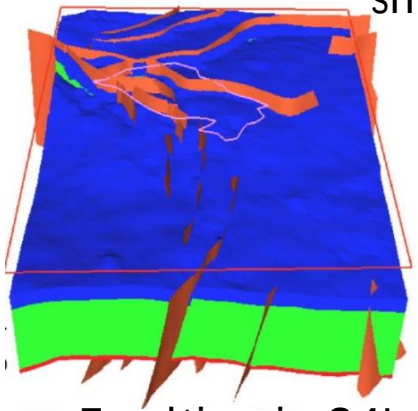
First Assessment Completed

- Regional estimates: hundreds of gigatons storage resource potential
- Initial characterization of three sites with >30Mt Storage Capacity
- Production-storage correlation determined for different reservoir types
- Several storage zones and caprocks mapped in the Atlantic Coast US

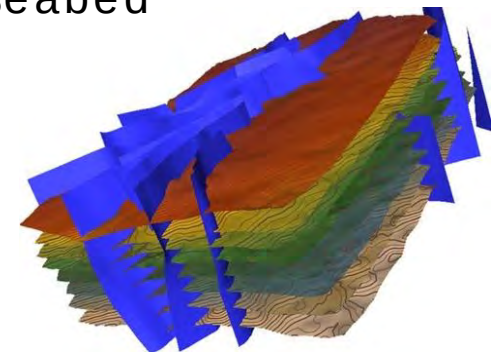
Northern GOM storage resource assessment by UT



Seismic depth structure map of top of potential storage zone; red – deeper; green - shallower below seabed



Faulting in 24L area

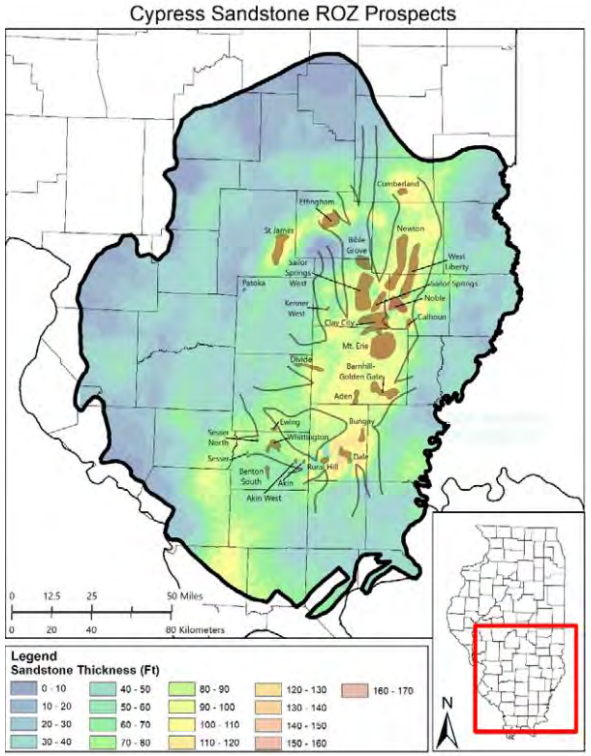


Faulting in 10L area

BEST and Associated Storage Projects

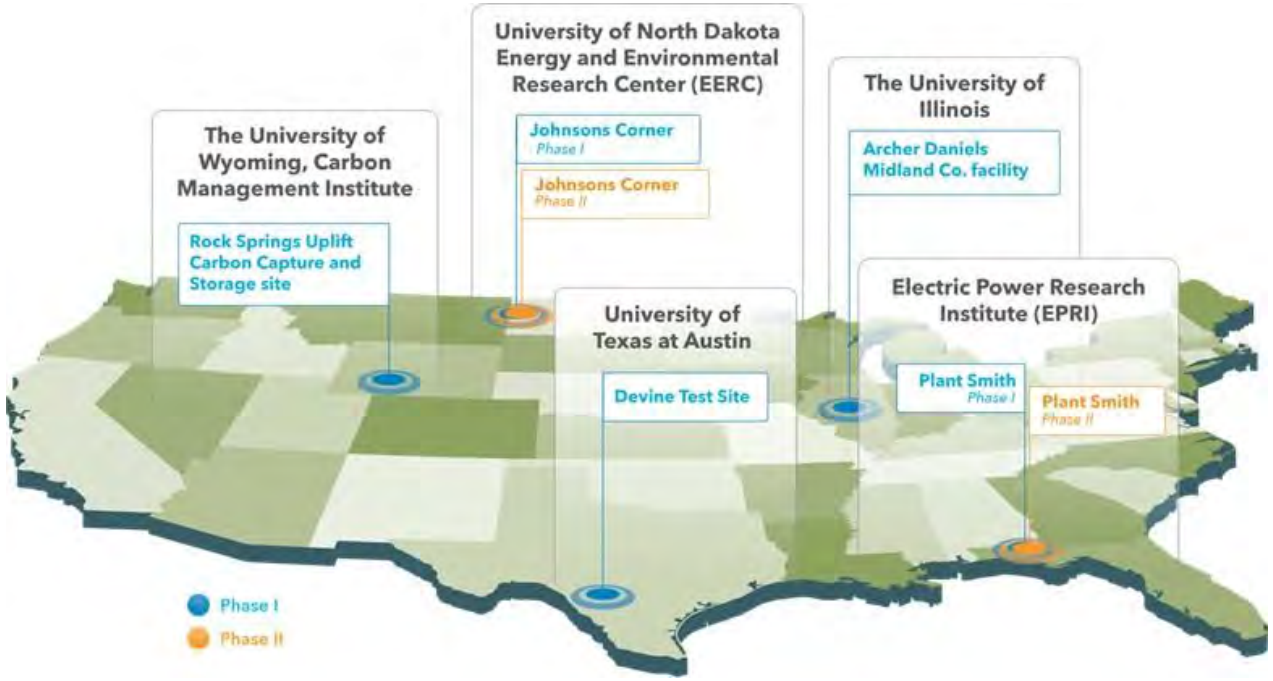
Associated Storage

Developing Technologies for Advancement of Associated Geologic Storage in Basinal Geo-laboratories (DE-FOA-0001829)



ROZ areas within the Cypress Sandstone study area by University of Illinois

Brine Extraction Storage Test (BEST)



- Focused on formations representing important potential geologic storage opportunities in the U.S.
- Injection/extraction of brine only

What jobs opportunities are involved in CCUS Deployment?

The CCUS Value Chain

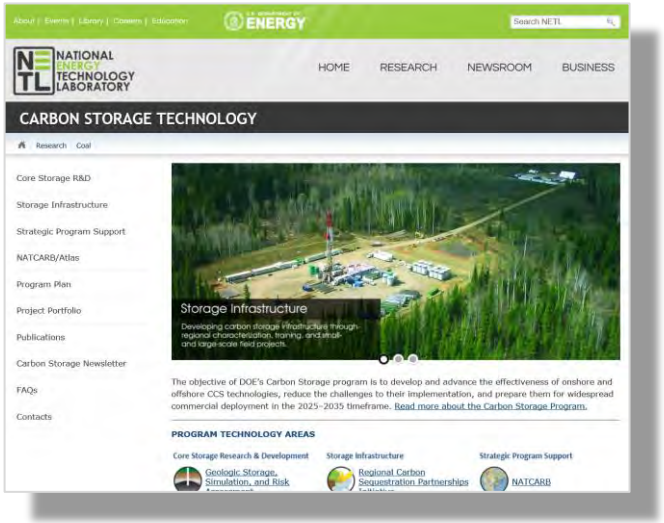
- Jobs created include:
  - Project jobs
  - Operation jobs

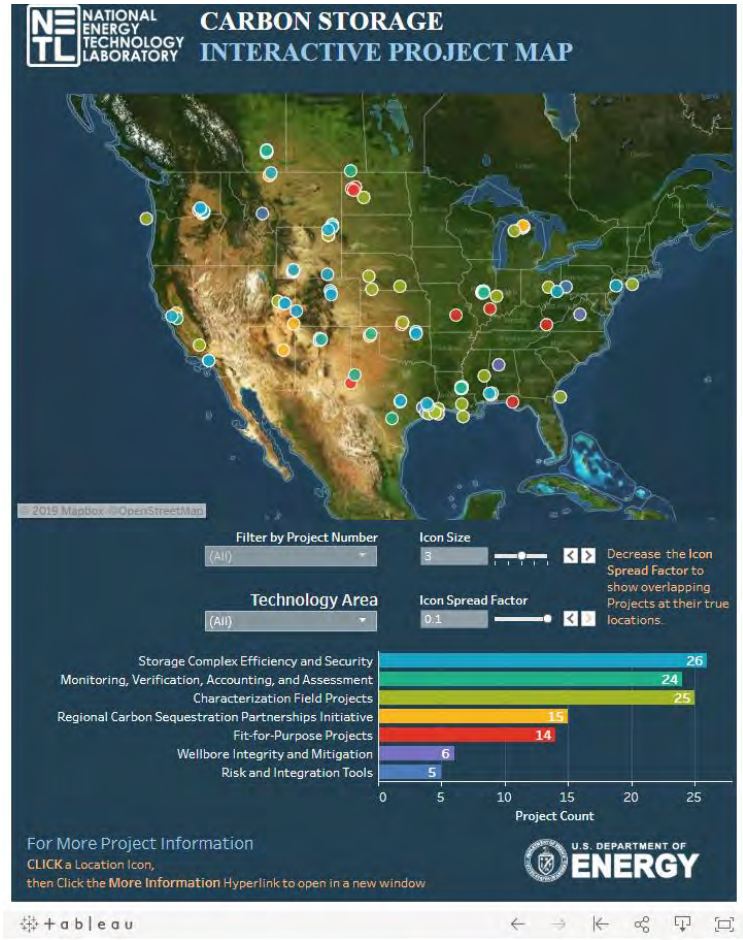
- Carbon Capture Retrofits
  - Industries
  - Power Generation
- CO_2 Transport Infrastructure
- CO_2 Storage Infrastructure

Great Plains Institute white paper on regional infrastructure for mid century decarbonization.

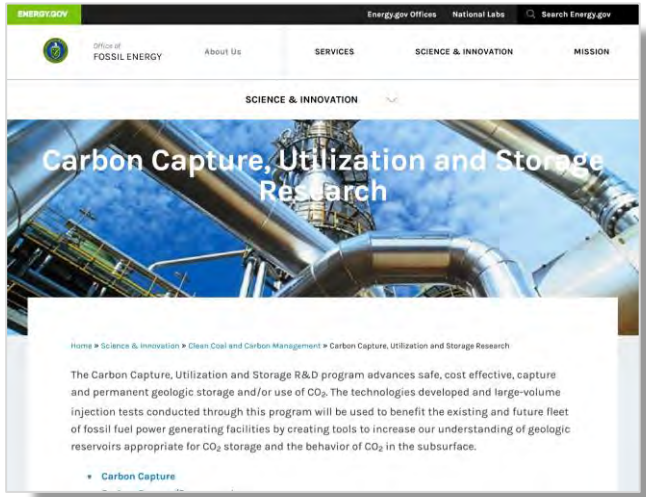
For More Information

NETL
www.netl.doe.gov





Office of Fossil Energy
www.fe.doe.gov



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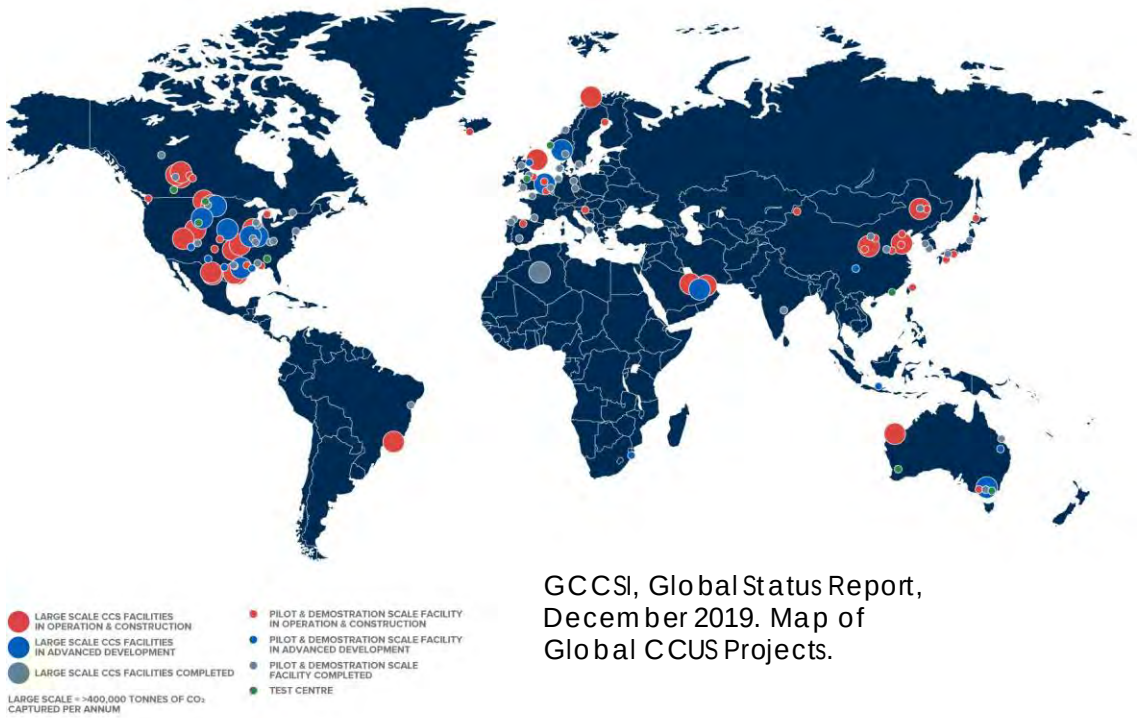
@Fossil Energy Gov

The Carbon Storage Industry

Globally, operational CCUS projects have more than tripled since 2010.

- *Globally, 21 large-scale facilities currently capture approximately 42 millions metric tons of CO_2 per year.*
- *The U.S. has 13 commercial-scale carbon capture facilities operating today, with the capacity to capture on the order of 25 million tons of CO_2 annually.* **– *Carbon Capture Coalition***



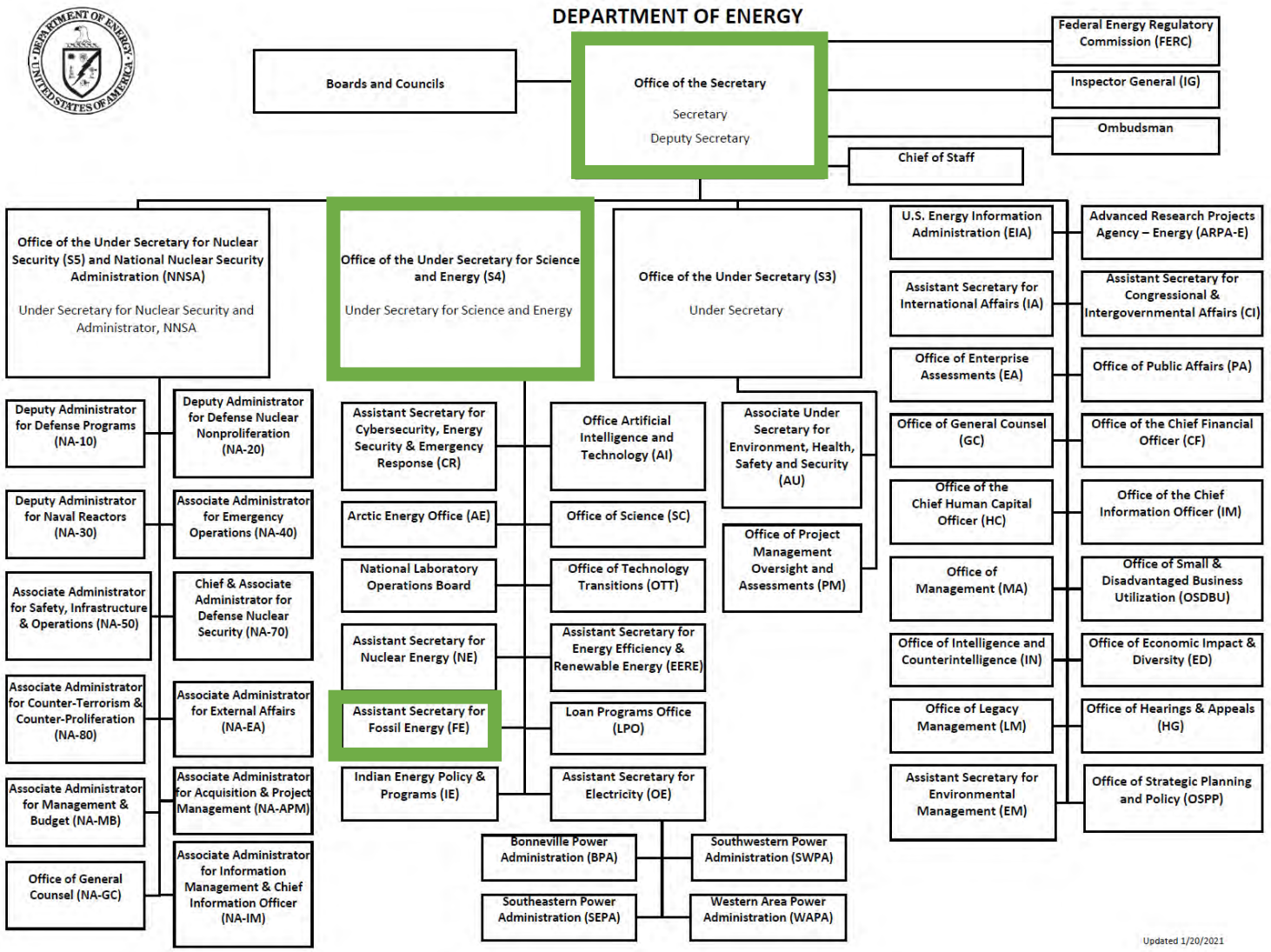
GCCSI, Global Status Report, December 2019. Map of Global CCUS Projects.

Costs are coming down/ expected to drop:

- ***"If Shell were to build a new project today, it said*** *in a release it would expect the cost to be 30* ***percent lower…" –*** *July 10, 2020 Financial Post*

In the 2020s, net-zero pathways support an annual average of ~3 million supply-side energy jobs. – *"Net-Zero America Project" Princeton University*

Department of Energy Organizational Chart



DOE National Laboratories

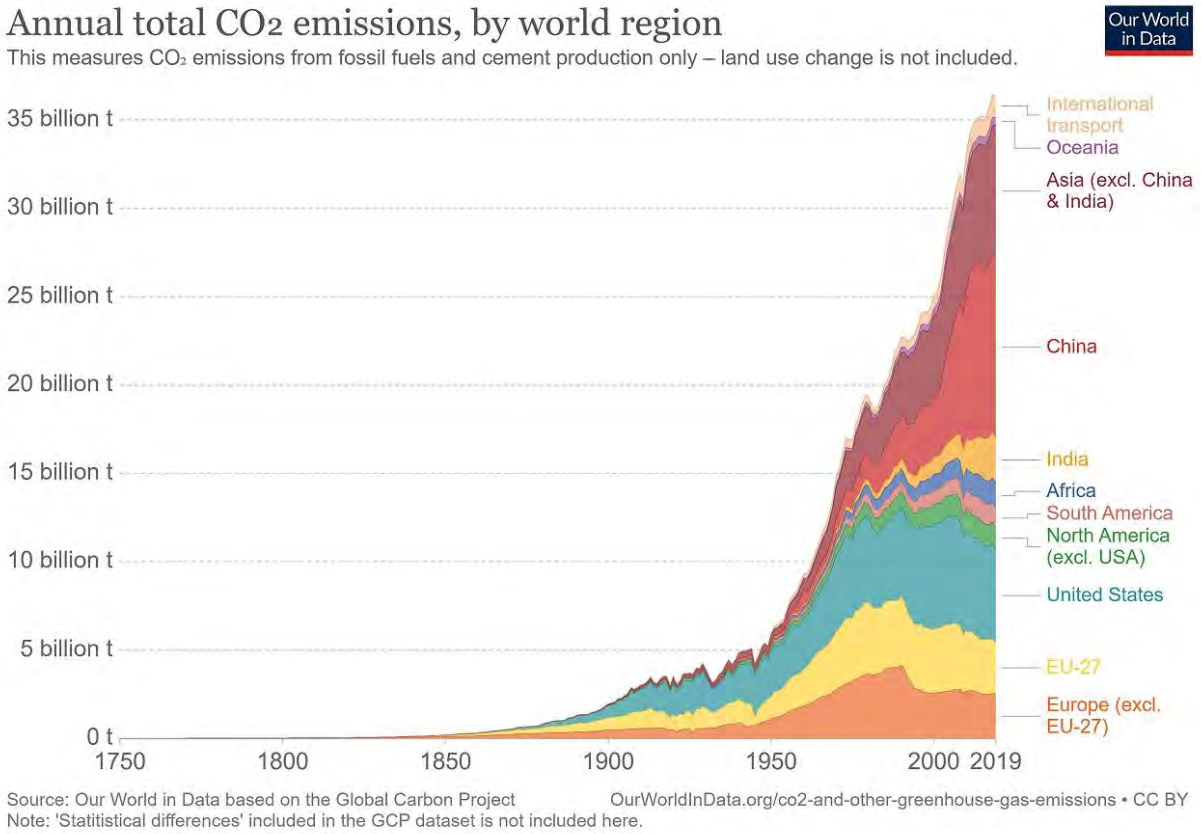
Established & Expanding Partnerships

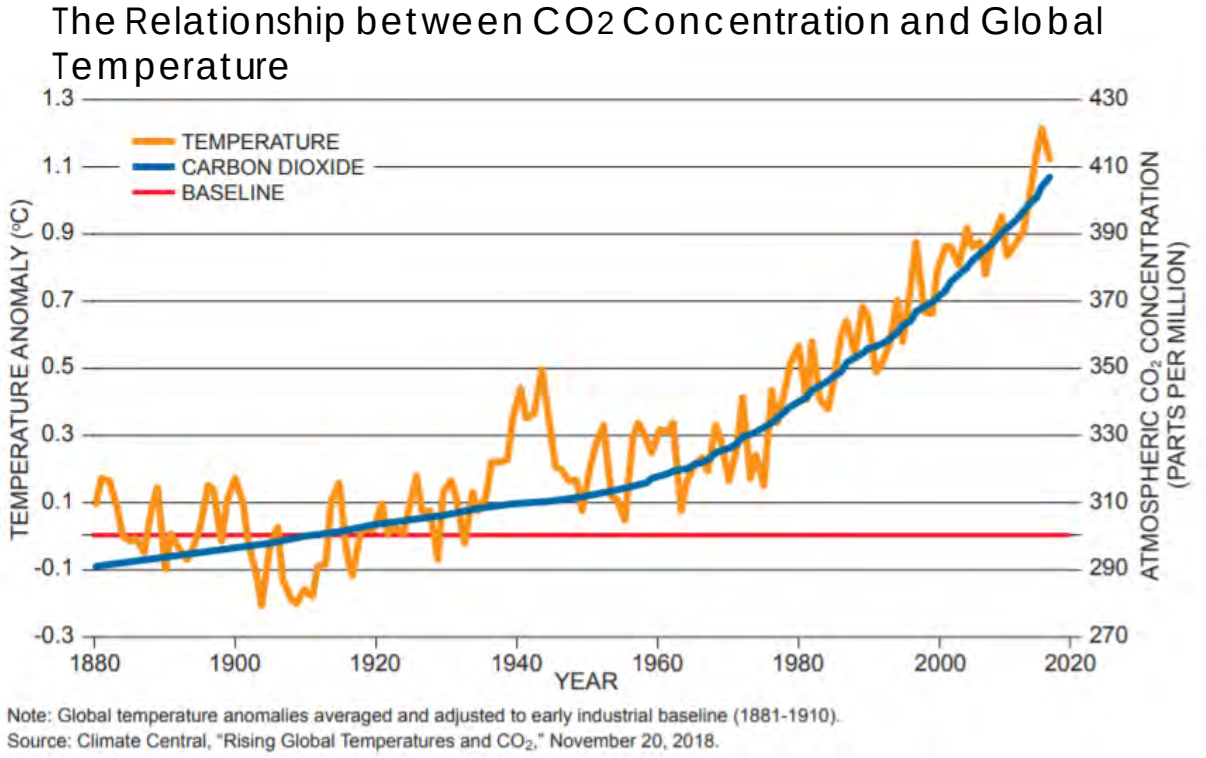
An Active Portfolio from Concept to Market Readiness

600+ partnerships with industry, academia & govt organizations

900+ research and development projects nationwide

The Challenge

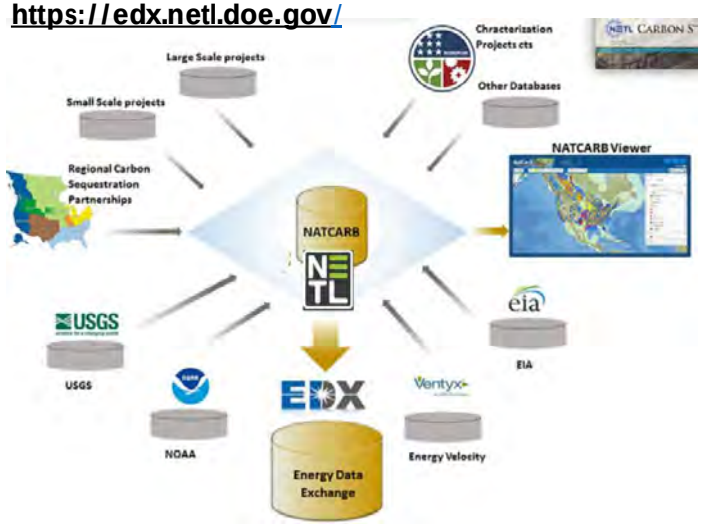


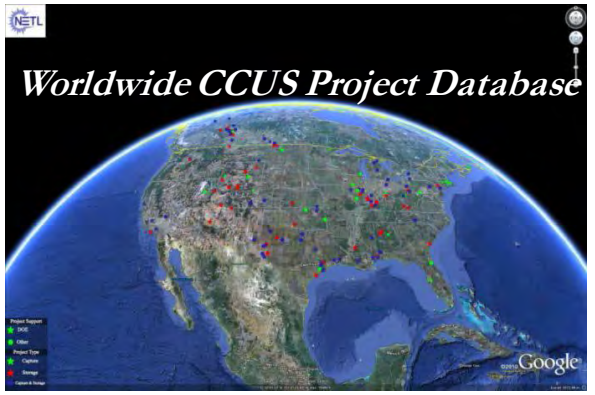


In 2019, atmospheric concentrations of CO_2 climbed to over 400 parts per million (ppm) from a pre-Industrial Revolution level of 280 ppm. High GHG levels lead to global warming.

Products from the Carbon Storage Program

https://edx.netl.doe.gov/





Thank you for your participation!

NETL Regional Workforce Initiative (RWFI) Presents

Energy 101 – Carbon Capture, Utilization and Storage

Contact us at netl.rwfi@netl.doe.gov

Also send an email to be added to E-note and further events like the next Energy 101

We welcome continued dialogue and communication

E-note and Past webinars at www.netl.doe.gov/rwfi

Today's Agenda

I. The NETL RWFI Initiative, Energy 101, Anthony Armaly, NETL RWFI Coordinator
II. Carbon Capture 101, Dan Hancu, NETL Technology Manager – Carbon Capture
III. Carbon Storage 101, Mark McKoy, NETL Technology Manager – Carbon Storage
IV. Workforce and Economic Development Online Roundtable