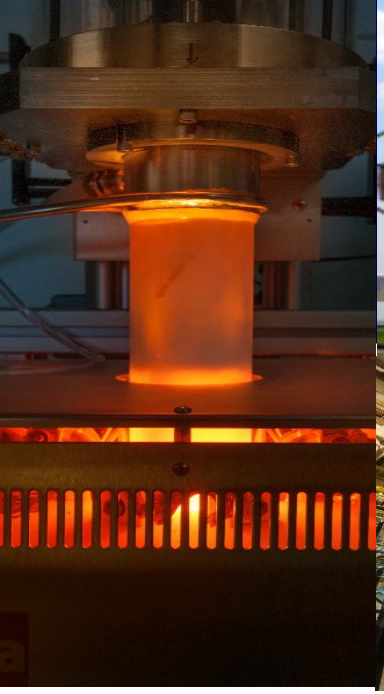

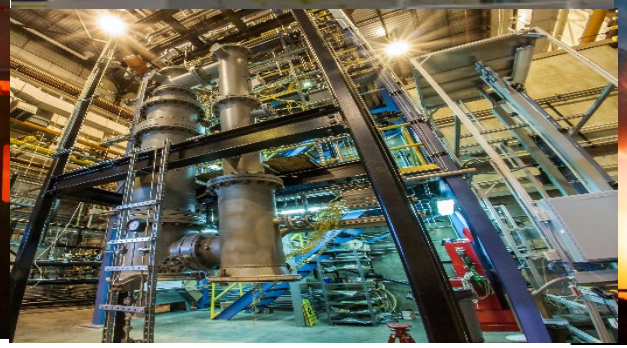


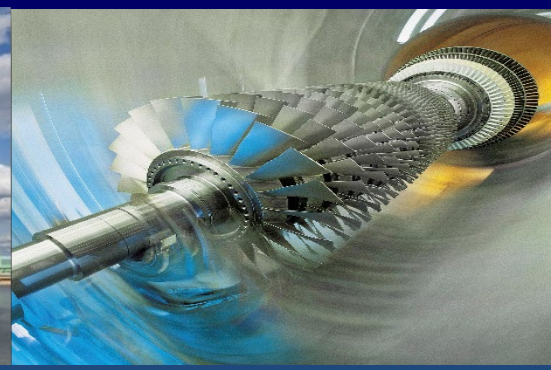

U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

GWPC Annual Forum
SAFE GEOLOGIC STORAGE OF CAPTURED CARBON DIOXIDE: TWO DECADES OF DOE'S CARBON STORAGE R&D PROGRAM IN REVIEW

September 30, 2020

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U.S. DOE Office of Fossil Energy

WHY THIS REPORT…?

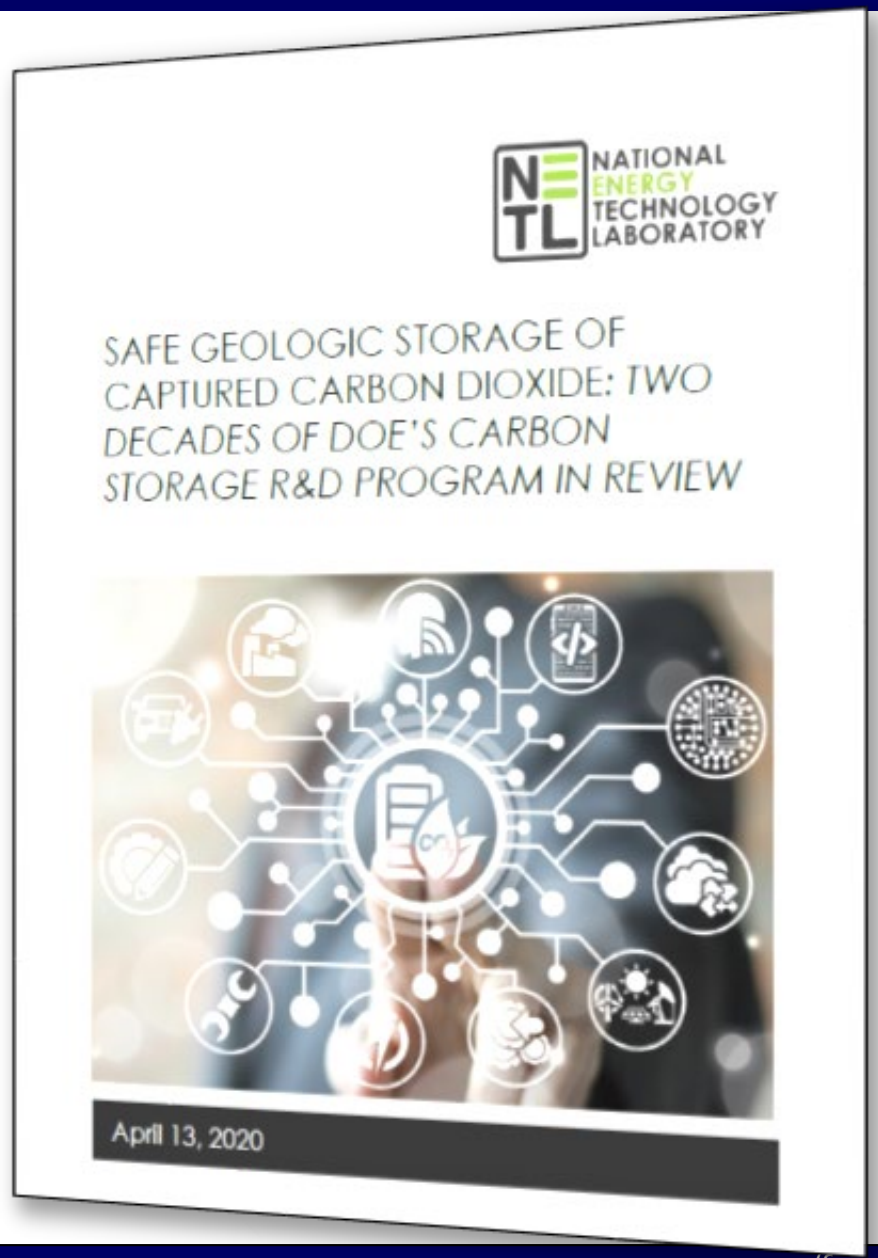
1. We observed an increased interest in CCUS after enhancement of 45Q tax credits.

2. No document existed that summarizes the years of work supported by DOE and the advancements in CCUS technologies that have been made.

3. This prompted the need to make available a brief and easily digestible report on DOE's CCUS R&D storage program activities.

    - Particularly as related to what we know about the safety and security of geologic storage of CO_2.

https://netl.doe.gov/node/9687



WHAT IS THE BASIS OF THE ASSURANCES WE CAN MAKE TODAY ABOUT THE SECURE STORAGE OF CO_2 IN DEEP GEOLOGIC RESERVOIRS?

The assurances we can make today are based on…

1. A foundation of nearly five decades of oil and gas industry experience injecting CO_2 into oil- and gas-filled formations

2. The 20 years of technology advancements made from R&D programs like DOE's Carbon Storage Program

3. Field-testing campaigns, such as the Regional Carbon Sequestration Partnerships (RCSPs), that have validated monitoring tools and strategies, and developed best practices

4. Improved understanding of the physics, chemistry, and mechanics involved throughout the life of a CCUS project, which has served as the foundation for new risk assessment and management tools

5. The growing number of CCUS demonstration and commercial projects worldwide that promote learning-by-doing

Graphic credit: UNDEERC

1. NEARLY FIVE DECADES OF OIL AND GAS INDUSTRY EXPERIENCE INJECTING CO_2 INTO OIL- AND GAS-FILLED FORMATIONS

- Geological storage of CO_2 has been a natural process in the Earth's upper crust for hundreds of millions of years.
- The concept of geologic carbon storage to reduce emissions is further supported by an industry that is already doing it.
- More than 600 million metric tons of CO_2 have been used in the southwest U.S. Permian Basin alone.
- Injection technologies for permanent geologic storage are virtually identical to those used for CO_2-EOR.

It is vitally important that the technical means exist to identify suitable sites and monitor stored CO_2 to verify secure storage

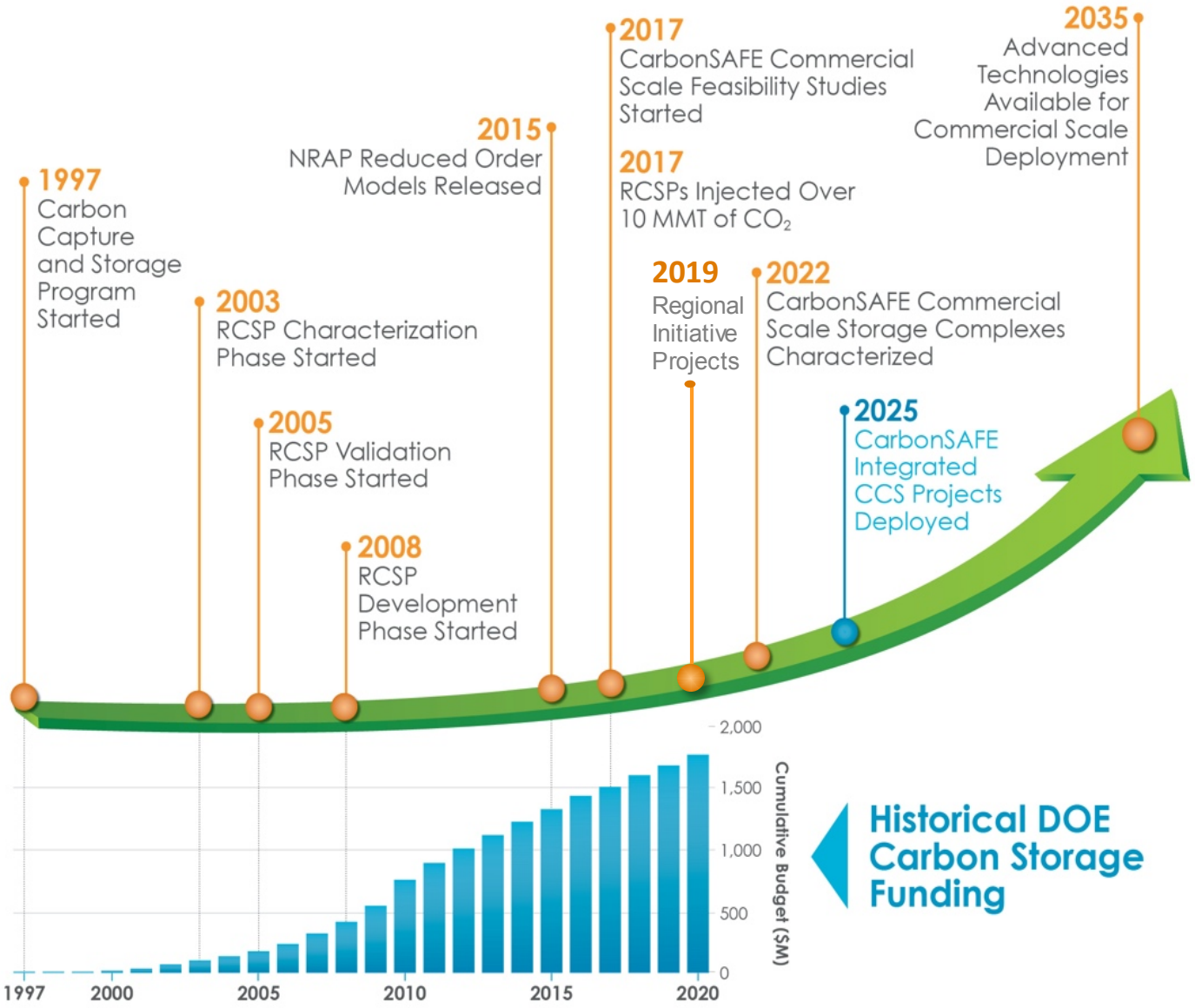
2. 20 YEARS OF TECHNOLOGY ADVANCEMENTS MADE FROM R&D PROGRAMS LIKE DOE'S CARBON STORAGE PROGRAM

Goal:

Develop technologies for commercial readiness beginning in 2025 that ensure safe, secure, efficient, and affordable CO_2 injection in diverse geologic settings

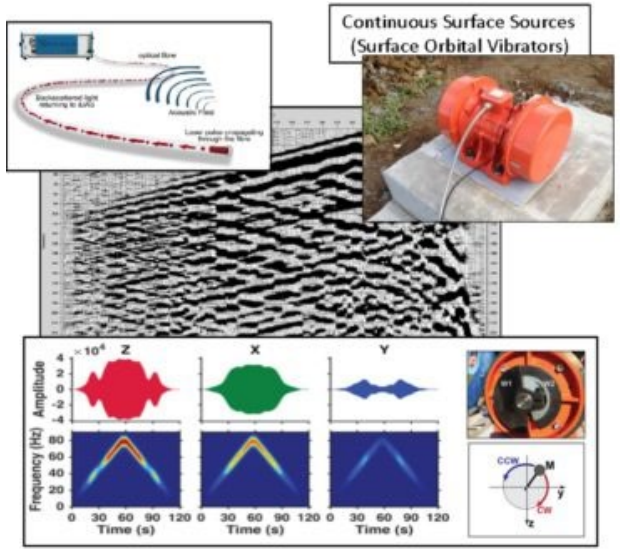
Key Objectives:

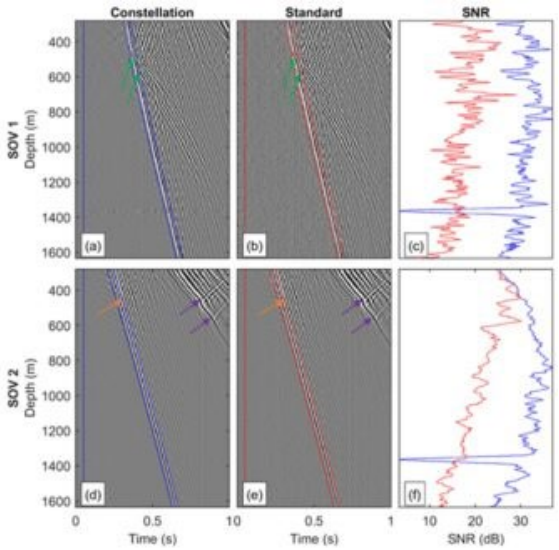
- Reduce uncertainty and risk
- Provide a field validated commercial toolbox that enables operators to operate safely and meet regulatory requirements
- Provide regulators a technical foundation for ensuring environmental protection



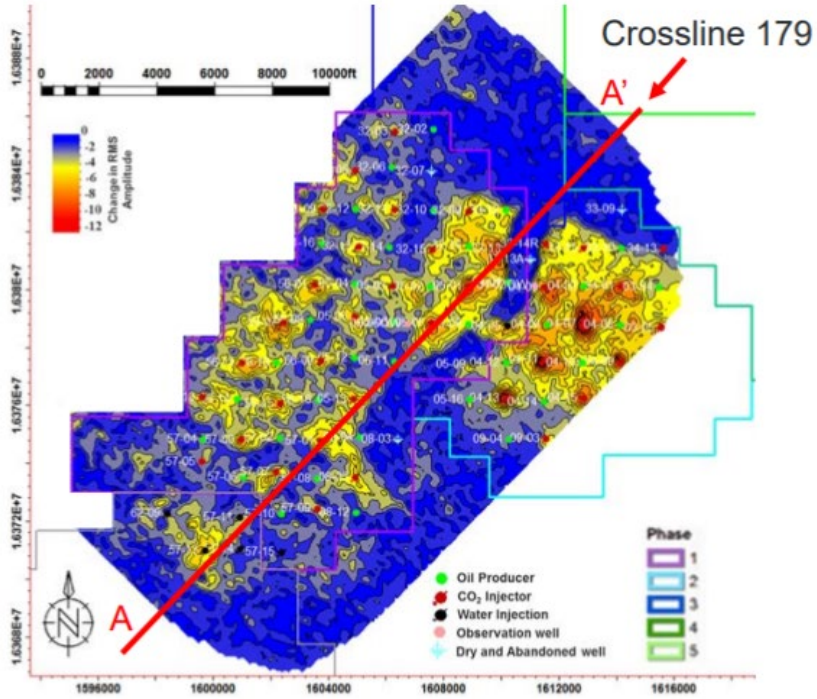
2. 20 YEARS OF TECHNOLOGY ADVANCEMENTS MADE FROM R&D PROGRAMS LIKE DOE'S CARBON STORAGE PROGRAM

Fiber optic technologies





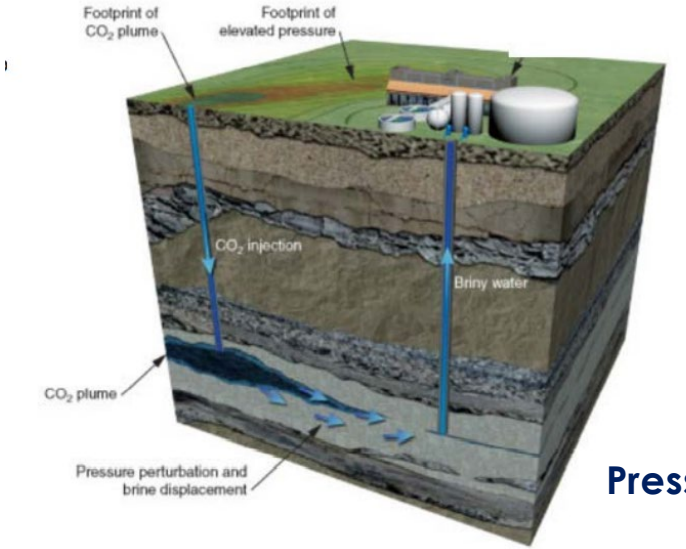
New seismic methods to track CO_2 movement



Time-lapse difference map of the reservoir displaying RMS amplitude changes.

Site screening tools

CO_2 SCREEN



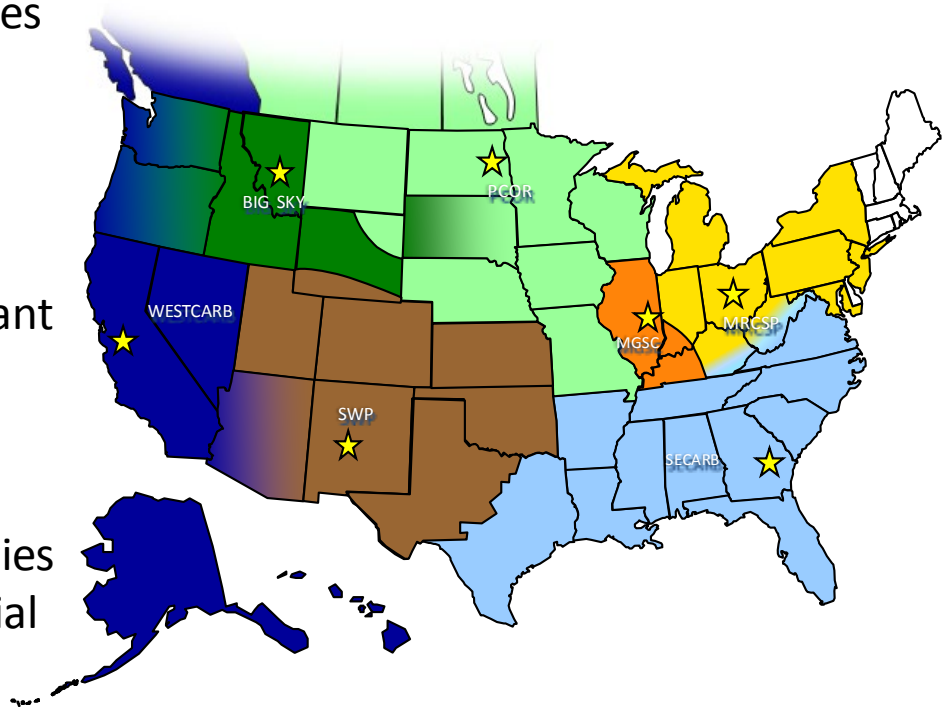
Pressure management strategies

3. FIELD-TESTING CAMPAIGNS, SUCH AS THE REGIONAL CARBON SEQUESTRATION PARTNERSHIPS HAVE VALIDATED MONITORING TOOLS AND STRATEGIES, AND DEVELOPED BEST PRACTICES

- ✓ Over 11.2 Million Tons Injected
- ✓ Established the first U.S. national network of companies and professionals focused on carbon storage
- ✓ Proved adequate large scale injectivity and available capacity in regionally important storage formations
- ✓ Contributed toward developing/evaluating innovative storage technologies for a cost-effective commercial toolbox
- ✓ Contributed to a series of best practice manuals on major topics associated with geologic storage implementation

Seven Regional Partnerships

400+ distinct organizations, 43 states, 4 Canadian Provinces



- Engage regional, state, and local governments
- Determine regional sequestration benefits
- Baseline region for sources and sinks
- Establish monitoring and verification protocols
- Validate sequestration technology and infrastructure

Characterization Phase (2003-2005)

Search of potential storage locations and CO_2 sources	Found potential for 100s of years of storage

Validation Phase (2005-2011)

20 injection tests in saline formations, depleted oil, unmineable coal seams, and basalt

Development Phase (2008-2020+)

6 large scale injections (over 11 million tons injected)	Commercial scale understanding and validation

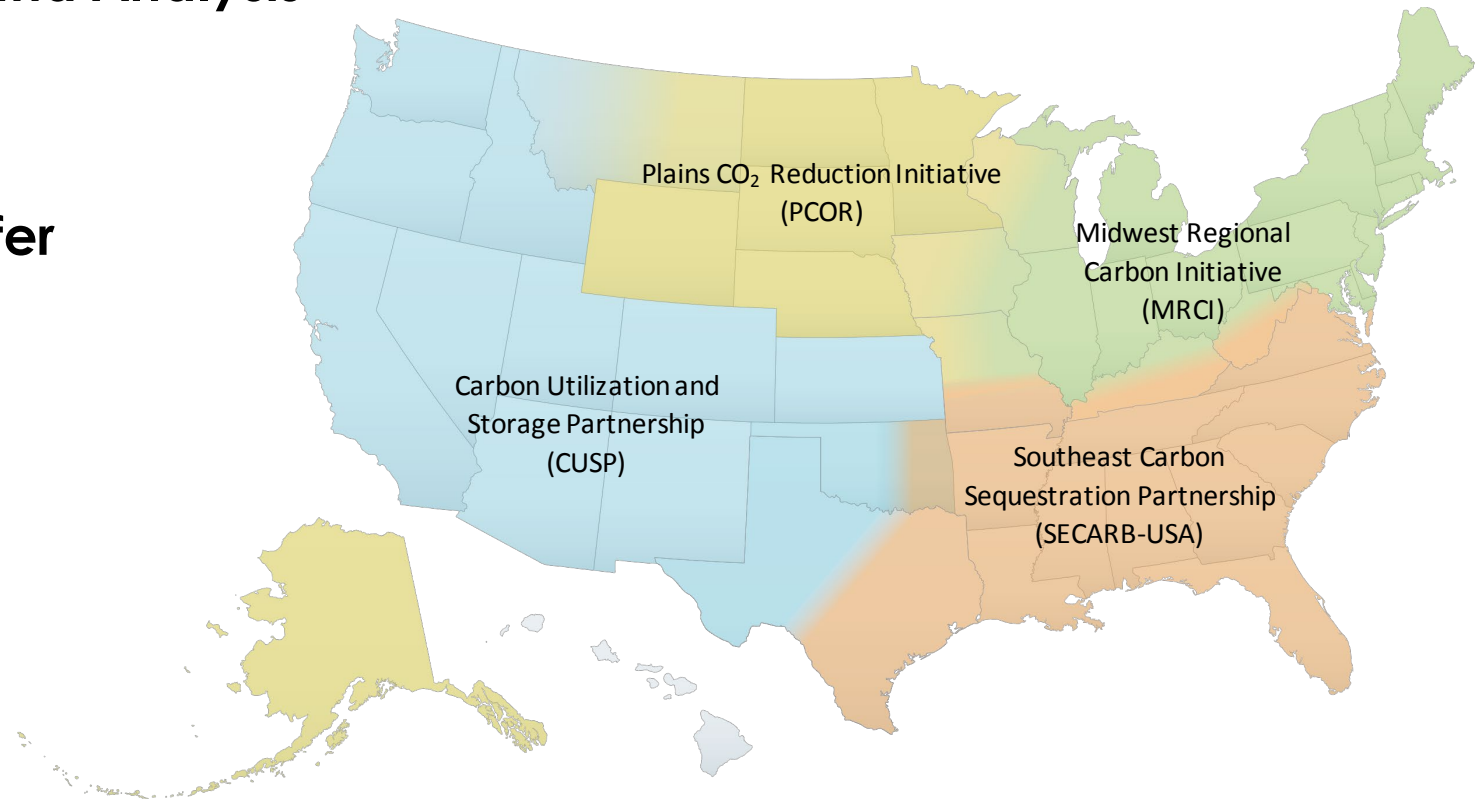
REGIONAL PARTNERSHIP PROJECTS CONTINUE…

-Addressing Key Technical Challenges

-Facilitating Data Collection, Sharing, and Analysis

-Evaluating Regional Infrastructure

-Promoting Regional Technology Transfer



Why do these projects continue to be so important?

- Established stakeholder network
- Long history on best practices development
- Wealth of data to support further research
- Experienced in public outreach and education

4. IMPROVED UNDERSTANDING OF THE PHYSICS, CHEMISTRY, AND MECHANICS, WHICH HAS SERVED AS THE FOUNDATION FOR NEW RISK ASSESSMENT AND MANAGEMENT TOOLS

NRAP leverages DOE's capabilities to quantify storage risks amidst system uncertainties, to help ensure safe and efficient storage operations throughout the lifecycle of a CCUS project.

- Primary intent is to provide key insights to inform decisions related to minimizing and mitigating risks associated with long-term storage of CO2.
- Developed a toolset for rapid, science-based quantification of key risk-related processes
- Tools are implemented in workflows for answering specific risk-mitigation questions throughout the project lifecycle
- Helps establish protocols for designing monitoring and operational strategies to minimize & mitigate risks

www.edx.netl.doe.gov/nrap

NRAP
National Risk Assessment Partnership

Technical Team

NETL National Energy Technology Laboratory
Berkeley Lab
Los Alamos National Laboratory
Lawrence Livermore National Laboratory
Pacific Northwest National Laboratory

Stakeholder Group

American Electric Power
Blue Source
bp
EPA United States Environmental Protection Agency
ExxonMobil
ieaghg
IEc
MIT
NRDC
Schlumberger
Southern States Energy Board
Stanford University
Texas Railroad Commission
USGS
The University of Utah
Wade, LLC
Whiting
Zurich

5. THE GROWING NUMBER OF CCUS DEMONSTRATION AND COMMERCIAL PROJECTS WORLDWIDE PROMOTE LEARNING-BY-DOING

Air Products Facility (Port Arthur, TX) – Began Operations 2013

- Built and operated by Air Products and Chemicals Inc. and located at Valero Oil Refinery in Port Arthur, TX
- State-of-the-art system to capture the CO_2 from two large steam methane reformers
- Captured gas transported via pipeline to oil fields in eastern Texas where it is used for EOR.
- Since 2013, the project has captured nearly seven million metric tons of CO_2.

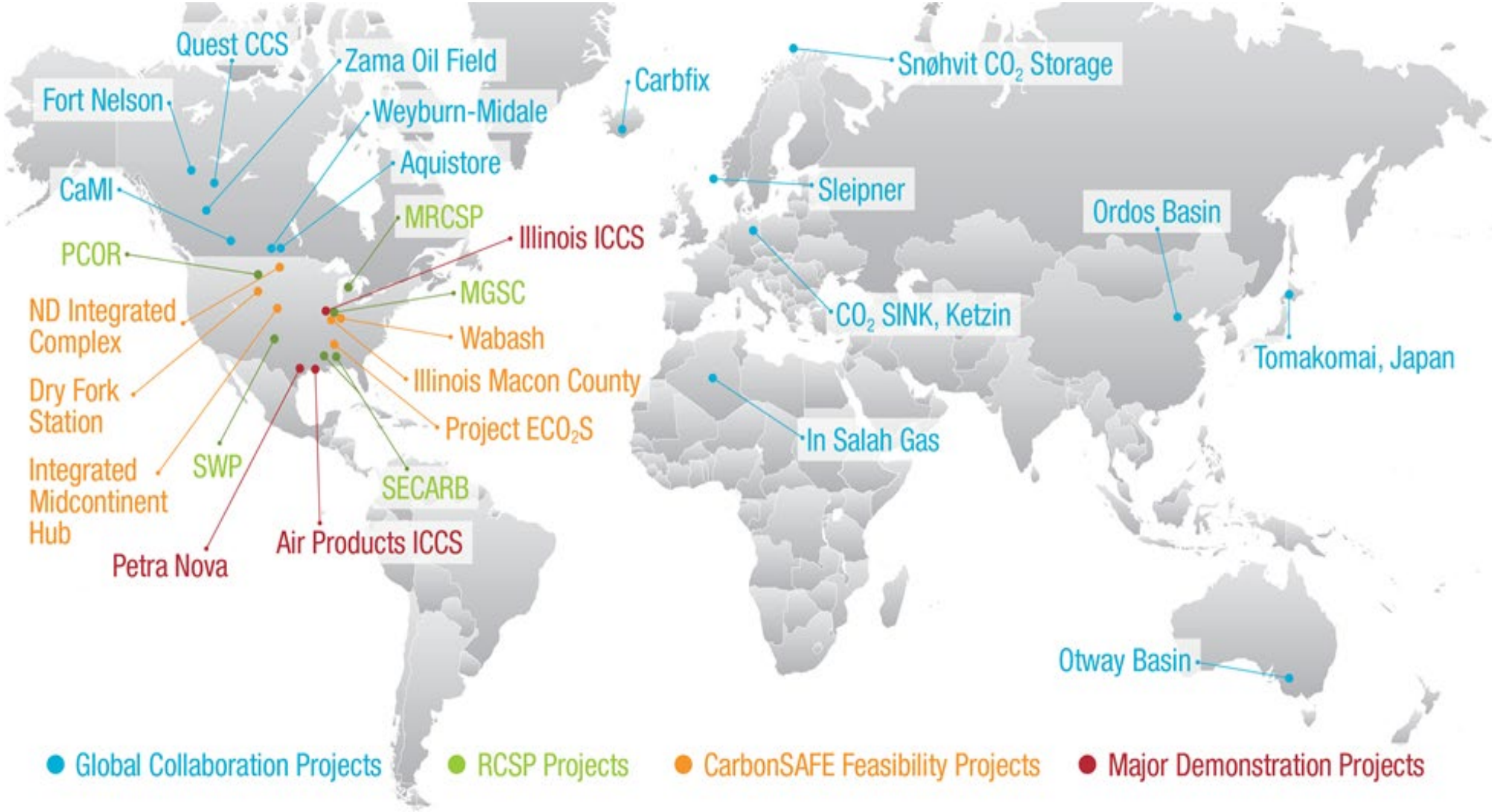
Petra Nova CCS (Thompsons, TX) – Began Operations 2017

- Joint venture by NRG Energy, Inc. and JX Nippon Oil and Gas Exploration
- Demonstrate the Mitsubishi Heavy Industries CO_2 capture technology ability to capture 90% of the CO_2 emitted from a 240-megawatt flue gas stream. (designed to capture/store 1.4 million tonnes of CO_2 per year)
- Captured CO_2 used for EOR at the West Ranch Oil Field in Jackson County, Texas, where it will remain sequestered underground

ADM Ethanol Facility (Decatur, IL) – Began Operations 2017

- Built and operated by Archer Daniels Midland (ADM) at their existing biofuel plant located in Decatur, IL
- **1 million metric tons of CO_2** as a by-product of the ethanol biofuels production process and store it in a deep saline reservoir
- First ever CCS project to use the EPA Underground Injection Class VI well permit in the United States that is specifically designed for CO_2 storage

5. THE GROWING NUMBER OF CCUS DEMONSTRATION AND COMMERCIAL PROJECTS WORLDWIDE PROMOTE LEARNING-BY-DOING



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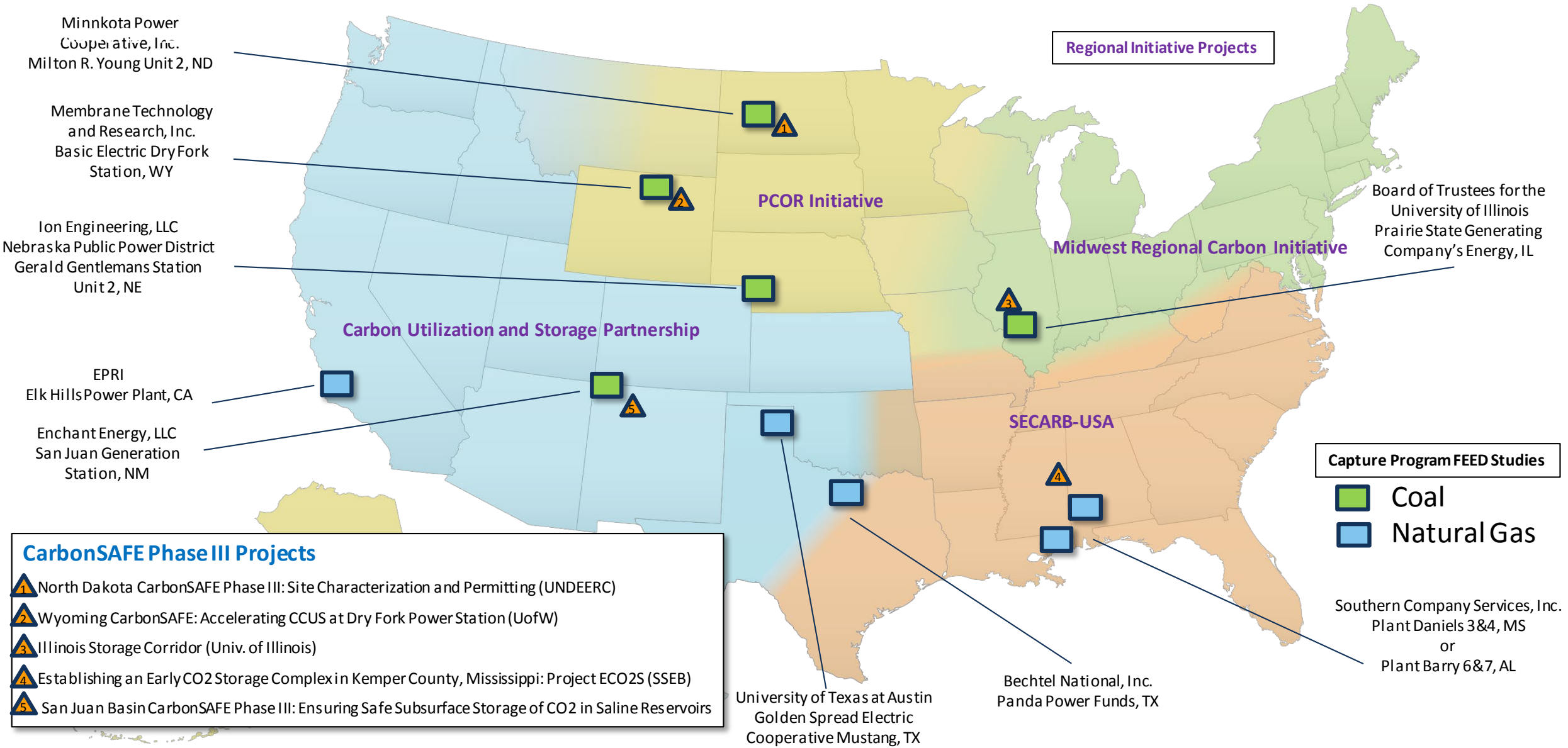

Near term focus: testing and validating technologies at scale.

- Advance technologies in our R&D pipeline that are best positioned to help enable the launch the CCUS industry by 2025

Longer term focus: develop new and transformation technologies that promote operational efficiency and enable more rapid decision making.

- Early stage R&D on artificial intelligence and machine learning approaches
- New sensing capabilities
- Autonomous monitoring systems

SMART INITIATIVE

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

Primary Goals

Real-Time Visualization

"CT" for the Subsurface

Rapid Prediction

Virtual Learning

Real-Time Forecasting

"Advanced Control Room"

https://netl.doe.gov/challenges/SMARTVisualizationPlatform

Los Alamos NATIONAL LABORATORY

BERKELEY LAB

NATIONAL ENERGY TECHNOLOGY LABORATORY

EERC

BATTELLE

THE UNIVERSITY OF UTAH®

Lawrence Livermore National Laboratory

Pacific Northwest NATIONAL LABORATORY

PennState

ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Sandia National Laboratories

OAK RIDGE National Laboratory

COLORADO SCHOOL OF MINES

BUREAU OF ECONOMIC GEOLOGY

Carnegie Mellon University

FOR MORE INFORMATION

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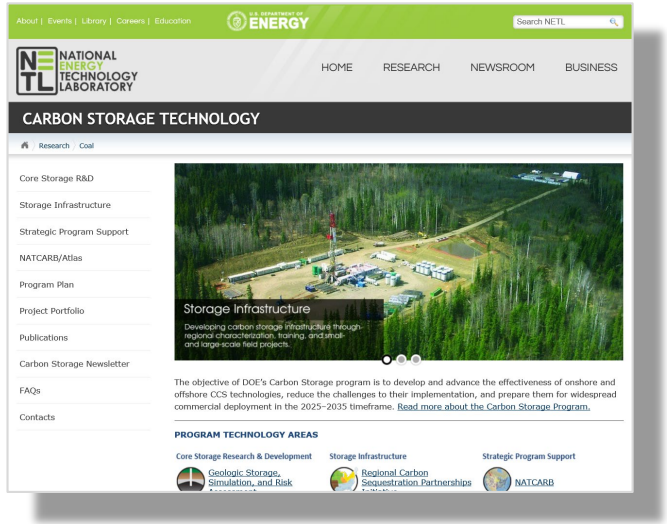

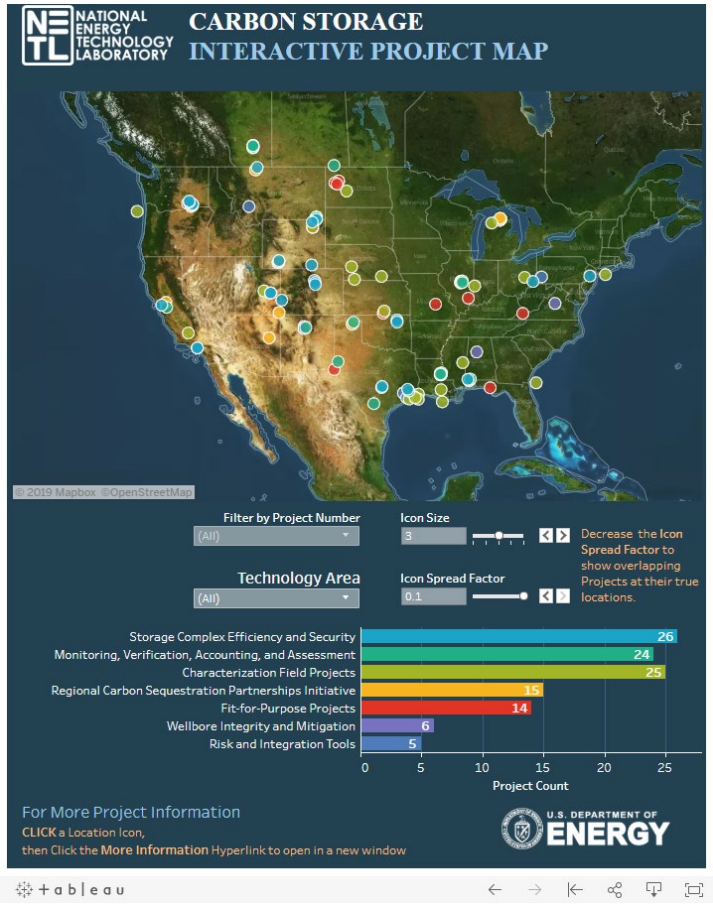

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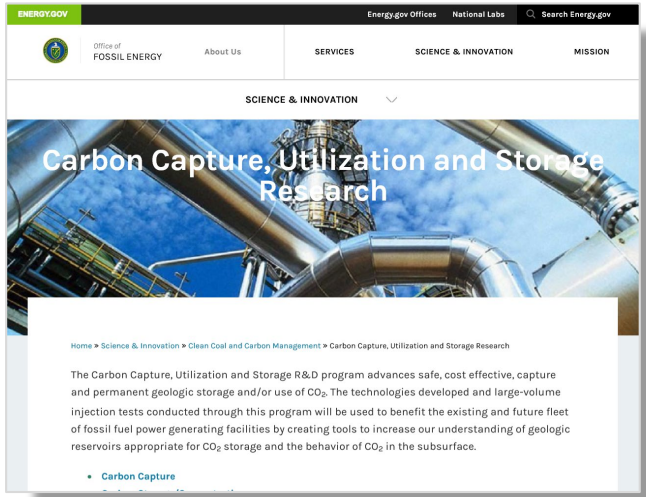

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Thank you !