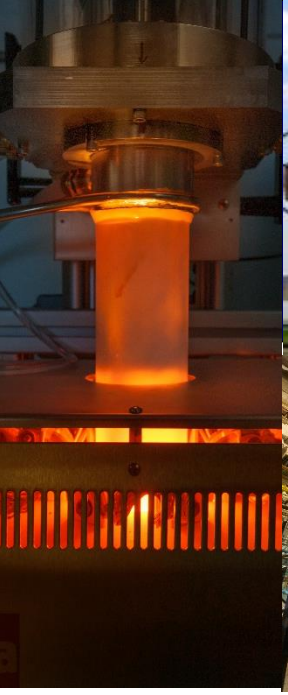
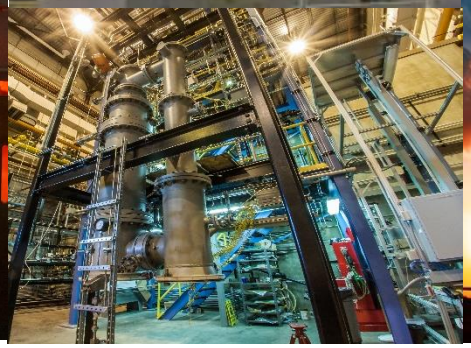





U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

Update on CCUS in the United States

Maryland Energy Administration CCUS Workshop

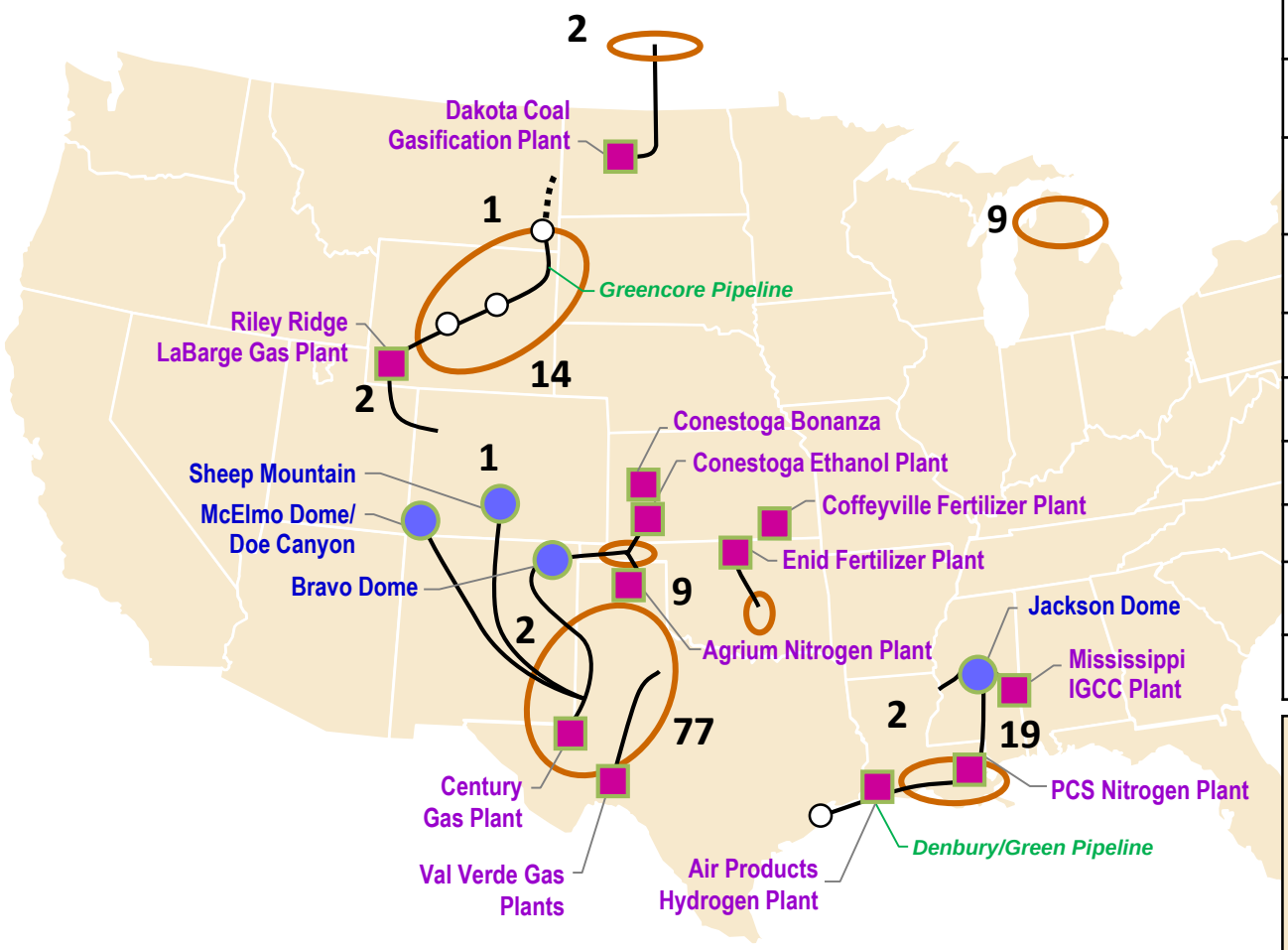
November 19, 2019

Mark Ackiewicz
Director, Division of CCUS R&D

The US: A global leader on CCUS research, development, and deployment

- **40+ year history of CO_2 utilization for enhanced oil recovery (EOR)**
- **Over 600 million tons of associated storage with EOR**
- **Over 4,000 miles of CO_2 pipelines in the United States**
- **Strong efforts in developing the human capital and enablers for CCUS deployment (scientists, engineers, trades)**
  - Broad R&D program engaging Private Industry, Universities, National Laboratories, small business, and the financial community.
- **Has successfully invested in major CCUS demonstrations**
- **Leading one of the most globally recognized and successful RD&D programs on CCUS….**
- **…And leveraging this technology, science, and knowledge with other agencies for sound policy development.**

Current CO_2-EOR Operations and CO_2 Sources (2014)



Oil Production (2014)	
CO_2-EOR Projects	136
Oil Production (MBbl/d)	300
CO_2 Supplies (2014)	
Number of Sources	17
• *Natural*	*5*
• *Industrial*	*12*
CO_2 Supply (Bcf/d)	3.5
• *Natural*	*2.8*
• *Industrial*	*0.7*

136 — No. of U.S. CO_2-EOR Projects

Natural CO_2 Source

Industrial CO_2 Source

CO_2 Pipeline

CO_2 Proposed Pipeline

Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2014 and other sources.

JAF2014.084.PPT

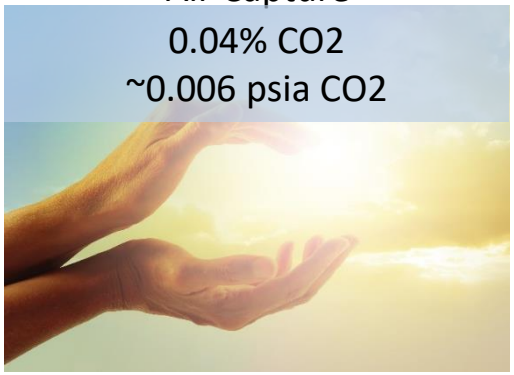
CCUS – Flexible Technology for Multiple Applications

CO_2 Source Concentration/Characteristics

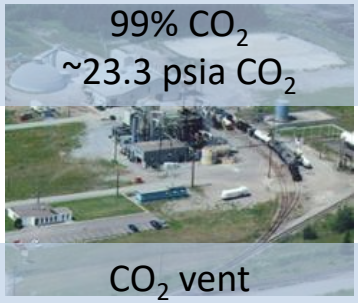
Coal Power Plant

Gas Power Plant

Air Capture

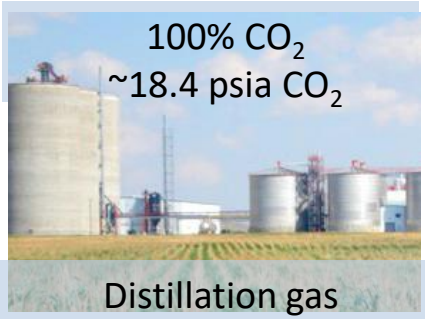


NG Processing Plant

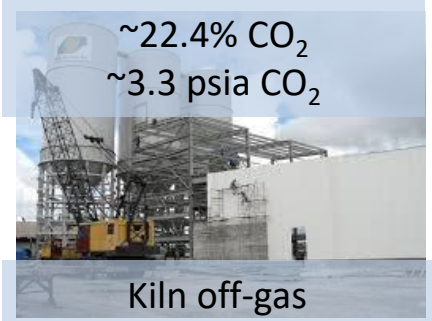


Ammonia Plant

Ethanol Plant



Cement Plant



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

High-level R&D Program Goals and Challenges

Reduce the cost of capture by 50%

- Capital cost
- Energy penalty
- Integration or process intensification

Develop viable carbon utilization alternatives Reduce capital cost

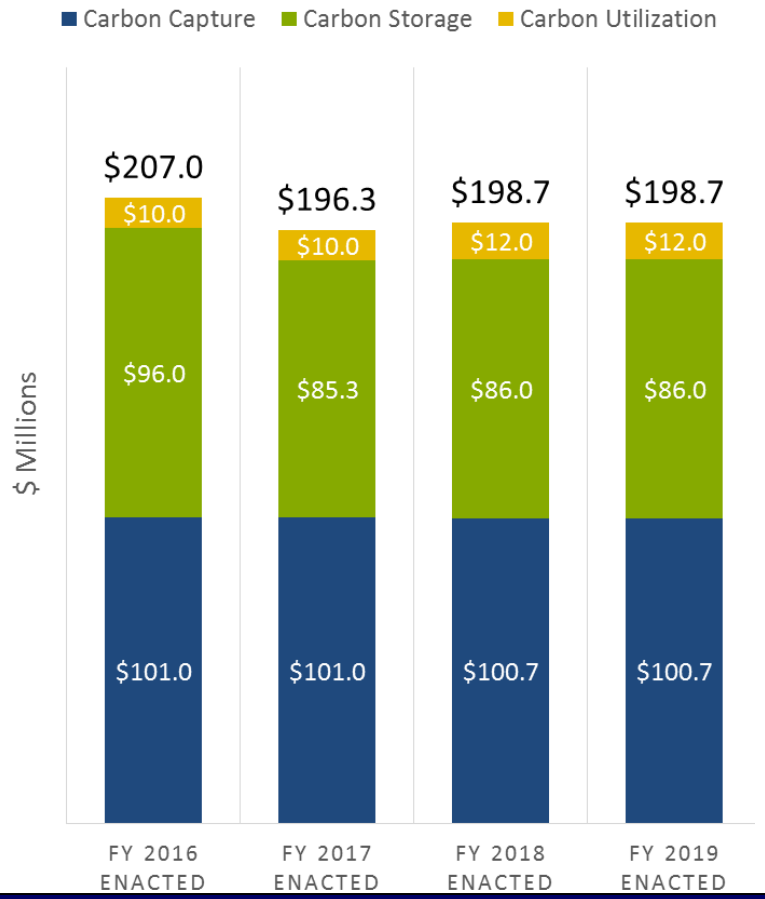
- Reduce energy requirements
- Lifecycle assessment better than existing products

Improve monitoring and simulation of the subsurface

- Higher resolution and quantification (e.g., accurate characterization of faults and fractures)
- Pressure and state of stress
- Costs/uncertainty/enabling real-time decision making

2012:$80/tonne
2016: $60
2020: $40
2030: $30

Source: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015



Major CCUS demonstration projects

Air Products Facility (Port Arthur, TX) – operations began in 2013

- Built and operated by Air Products and Chemicals Inc. at Valero Oil Refinery
- State-of-the-art system to capture CO_2 from two large **steam methane reformers**
- **Over 5.0 million metric tons of CO_2** captured and transported via pipeline to oil fields in eastern Texas for **enhanced oil recovery (EOR)** since March 2013

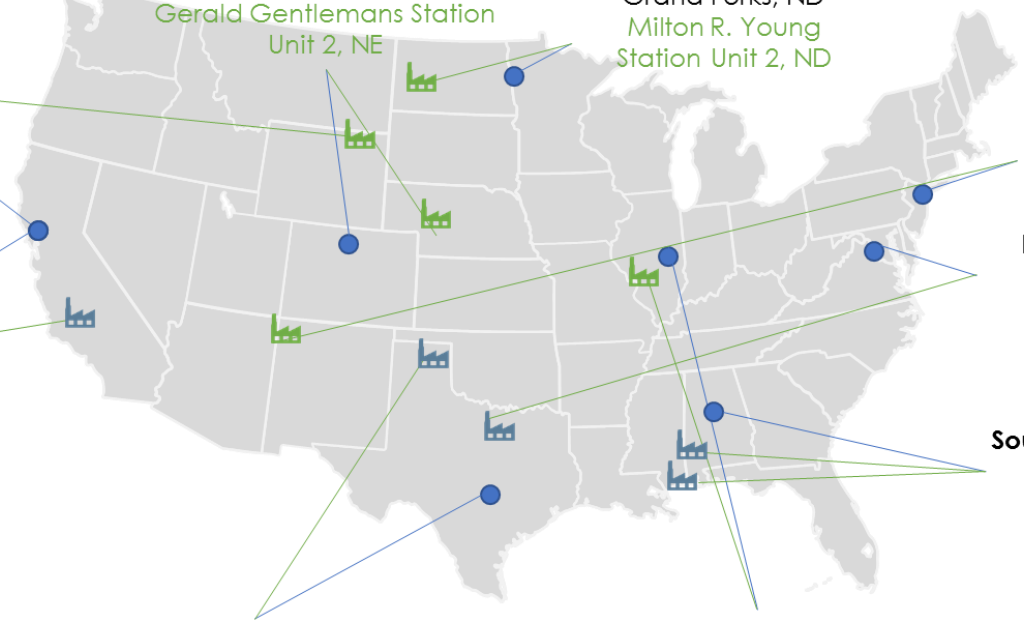
Petra Nova CCS (Thompsons, TX) – operations began in 2017

- Joint venture by NRG Energy, Inc. (USA) and JX Nippon Oil and Gas Exploration (Japan)
- Demonstrating Mitsubishi Heavy Industries' solvent technology to **capture 90% of CO_2 from 240-MW flue gas stream** (designed to capture/store 1.4 million metric tons of CO_2 per year)
- **Nearly 3.3 million metric tons of CO_2** used for **EOR** in West Ranch Oil Field in Jackson County, Texas since January 2017

ADM Ethanol Facility (Decatur, IL) – operations began in 2017

- Built and operated by Archer Daniels Midland (ADM) at its existing biofuel plant
- CO_2 from **ethanol biofuels production** captured and stored in **deep saline reservoir**
- **First-ever CCS project** to use new U.S. Environmental Protection Agency (EPA) Underground Injection **Class VI well permit,** specifically for CO_2 storage
- **1.3 million metric tons of CO_2 stored**, since April 2017

Commercial Carbon Capture FEED Study Projects $55M
DOE - 2019



Membrane Technology and Research, Inc.
Newark, CA
Basin Electric Dry Fork Station, WY

Ion Engineering LLC
Boulder, CO
Nebraska Public Power District Gerald Gentlemans Station Unit 2, NE

Minnkota Power Cooperative, Inc.
Grand Forks, ND
Milton R. Young Station Unit 2, ND

Enchant Energy LLC
New York, NY
San Juan Generating Station, NM

Bechtel National, Inc.
Reston, VA
Panda Power Funds, TX

Electric Power Research Institute, Inc.
Palo Alto, CA
Elk Hills Power Plant, CA

Southern Company Services, Inc.
Birmingham, AL
Plant Barry 6 &7 AL or Plant Daniels 3&4. MS

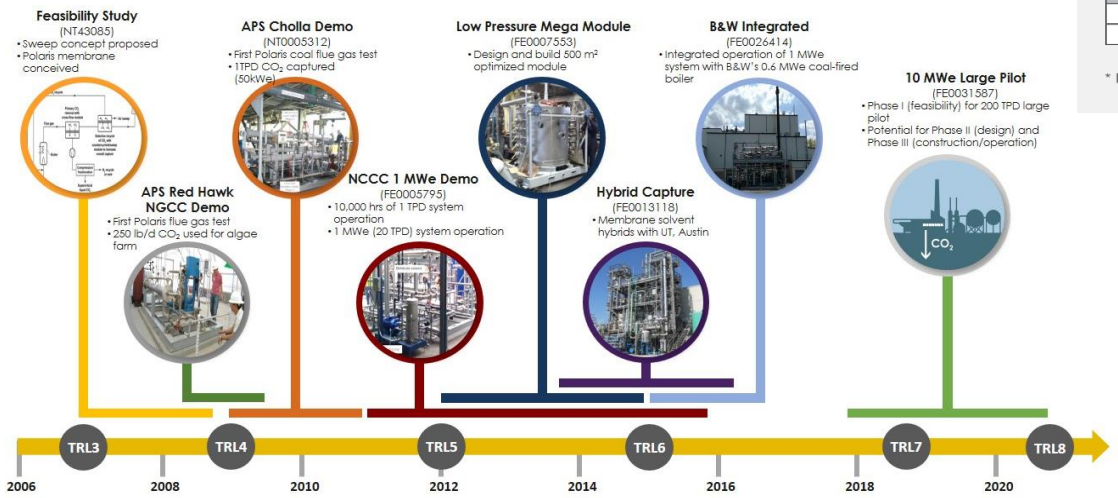
The University of Texas at Austin
Austin, TX
Golden Spread Electric Cooperative Mustang, TX

Board of Trustees of the University of Illinois
Champaign, IL
Prairie State Generating Company's Energy, IL

Natural Gas
Coal

Carbon Capture: Post-Combustion, Pre-Combustion, and Direct Air Capture - *Focus on Cost Reduction, Energy Penalty, and Integration*

Requires improvements in multiple areas



Summary of Carbon Capture R&D Program Advancement of 2nd Generation Technologies

Cost Reduction	Energy Penalty Reduction	Program Activity
$100+/tonne	30+%	180+ Projects
$41/tonne	14-15%	15 Technologies Tested at Pilot Scale

Pilot-scale Testing

TECHNOLOGY HIGHLIGHTS	Innovation Pathways	PRINCIPAL DEVELOPER
POST-COMBUSTION		
Imbedded Amine Sorbent*		ADA-ES
Low-water Amine Solvent		Fluor/MHI
Hybrid Solvent/Membrane		Gas Technology Institute
Amino-silicone Solvent*		General Electric Company
Amine/Imidazole Solvent Mixture* *(Large Pilot)*		ION Engineering
Advanced Amine Solvent Process*		Linde/BASF
Advanced Membrane Process*		MTR
Nozzle-based Solvent Contactor*		Neumann Systems Group
Mixed Salt Solvent Process*		SRI International
Carbon-based Sorbent*		SRI International
Alkalized Alumina Sorbent*		TDA Research
Optimized Amine Solvent Process		University of Kentucky
Piperazine Solvent/Flash Stripper		URS/University of Texas
PRE-COMBUSTION		
Ammonium Carbonate/Bicarbonate Solvent*		SRI International
Integrated Sorbent Process		TDA Research

Materials / Processes / Equipment

* Project Completed

Case Study of Technology Development Progression Through the Carbon Capture R&D Program – Membrane Technology Research, Inc.

Post Combustion Capture
National Carbon Capture Center - Benefits to Program

- Operated by Southern Co Services
- Hosted at Plant Gaston, AL
- DOE funds 80% of operations
- Over 100,000 test hours *(10+ years)*
- Technologies from U.S. and six other countries since 2008 founding of NCCC
- More than 50 carbon capture technologies tested
  - 30+ Post combustion
  - 20+ Pre-combustion
- Dedicated staff of plant engineers
- Standard design guidelines
- Slipstream (0.05 MWe) and Pilot (0.5 MWe) Solvent Test Units

Lab-Scale Unit

Bench-Scale Unit

Small Pilot-Scale Unit

Engineering Scale Testing of Advanced Carbon Capture Technologies

Scaling of Carbon Capture Technologies to Engineering Scales Using Existing Host Site Infrastructure

Performer	Project Title	Technology
Research Triangle Institute	Engineering Scale Testing of Transformational Non-Aqueous Solvent-Based CO_2 Capture Process at Technology Centre Mongstad (13MWe)	Non Aqueous Solvent
SRI International	Engineering Scale Demonstration of Mixed-Salt Process for CO_2 Capture (15MWe)	Physical Solvent
Membrane Technology and Research, Inc.	Scale-Up and Testing of Advanced Polaris Membrane CO_2 Capture Technology (1MWe+)	Membrane – Partial Capture
TDA Research, Inc.	Membrane-Sorbent Hybrid System for Post-combustion Carbon Capture (2MWe+)	Membrane / Sorbent – 90% capture
Fluor	Multi-component solvent test (13MWe)	Water lean solvent

- **Existing solvent units for drop-in testing**
- **Supports 4000+ hours each project**
- **Solvents go through rigorous degradation tests to support environmental permitting at SINTEF**
- **Full analytical and operations staff support**

Source: Technology Centre Mongstad

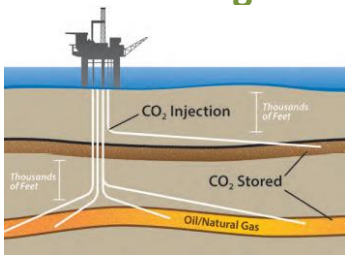
Carbon Storage Program

Improving and Optimizing Performance

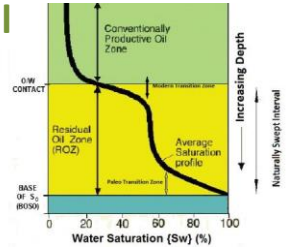
Regional Carbon Sequestration Partnerships (RCSPs)

CarbonSAFE

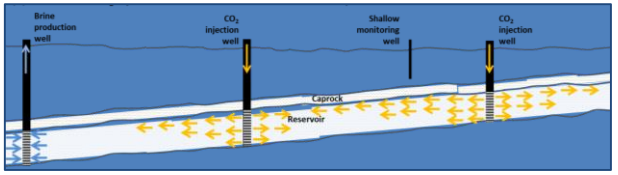
Offshore Storage



Unconventional EOR

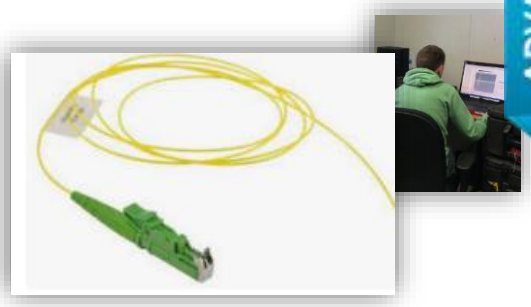


Brine Extraction Storage Tests (BEST)



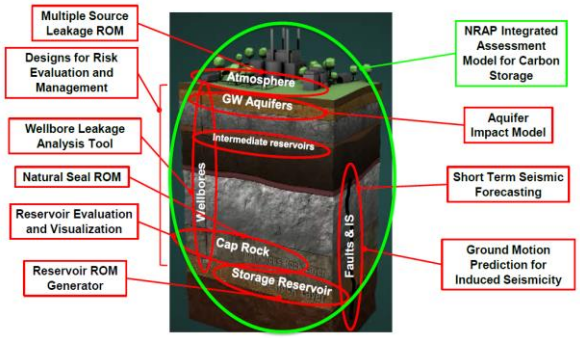
CARBON STORAGE PROGRAM

Advancing monitoring and measurement tools: improving characterization and reducing the uncertainty about the CO_2 and pressure fronts.



Fiber Optic Distributed Acoustic Sensing (DAS)

National Risk Assessment Partnership (NRAP) is developing toolsets to reduce uncertainty and quantify potential impacts related to release of CO_2 and induced seismicity

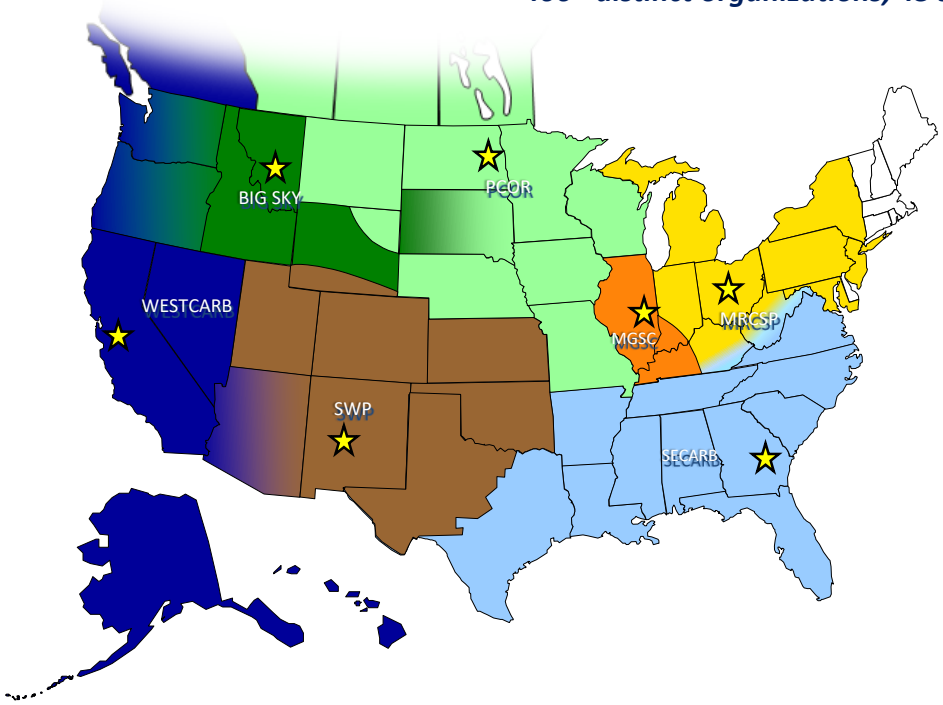


Regional Carbon Sequestration Partnerships

Developing the Infrastructure for Wide Scale Deployment

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 (2008-2018+)

6 large scale injections (over 10 million tons injected)	Commercial scale understanding and validation

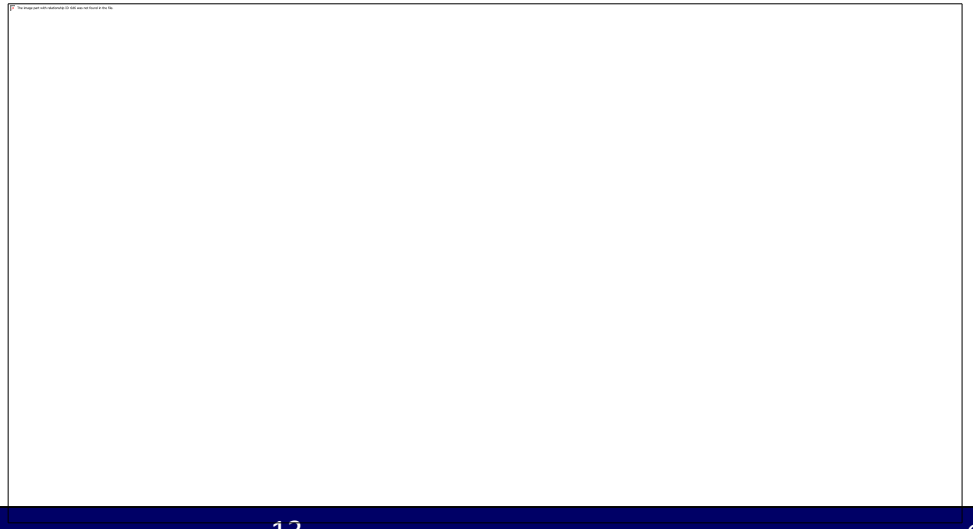
New Regional Initiative CCUS Selections

Regional Initiative to Accelerate CCUS Deployment (DE-FOA-0002000)

Projects will address key CCUS technical challenges; facilitate data collection, sharing, and analysis; evaluate regional infrastructure; and promote regional technology transfer.

- $20 million in Federal funding awarded
- Four projects selected

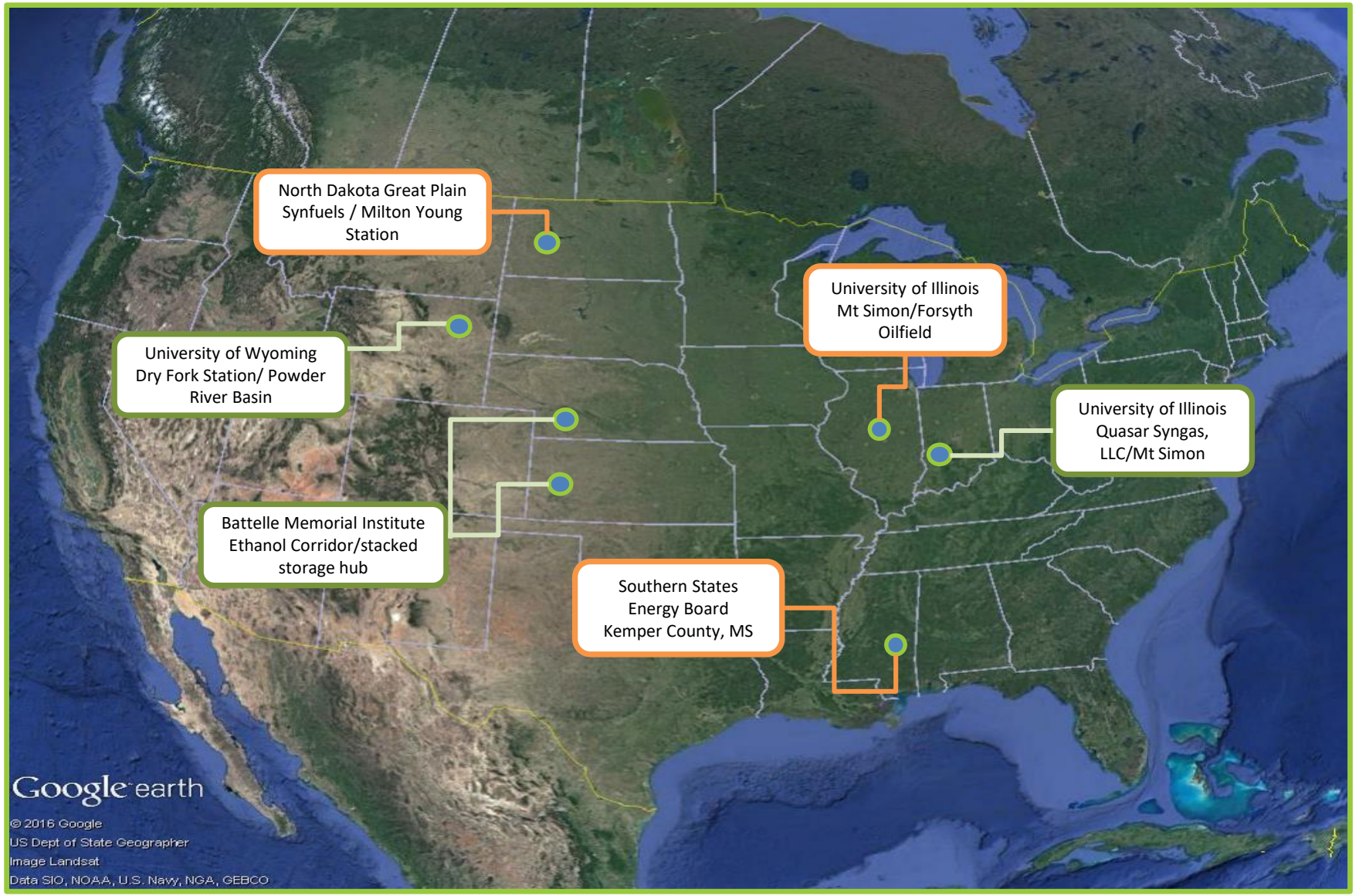
Awardee	Project
Battelle Memorial Institute	Regional Initiative to Accelerate CCUS Deployment in the Midwest and Northeastern USA
New Mexico Institute of Mining and Technology	Carbon Utilization and Storage Partnership of the Western United States
Southern States Energy Board	Southeast Regional Carbon Utilization & Storage Partnership (SECARB-USA)
University of North Dakota	Plains Carbon Dioxide Reduction (PCOR) Partnership Initiative to Accelerate CCUS Deployment



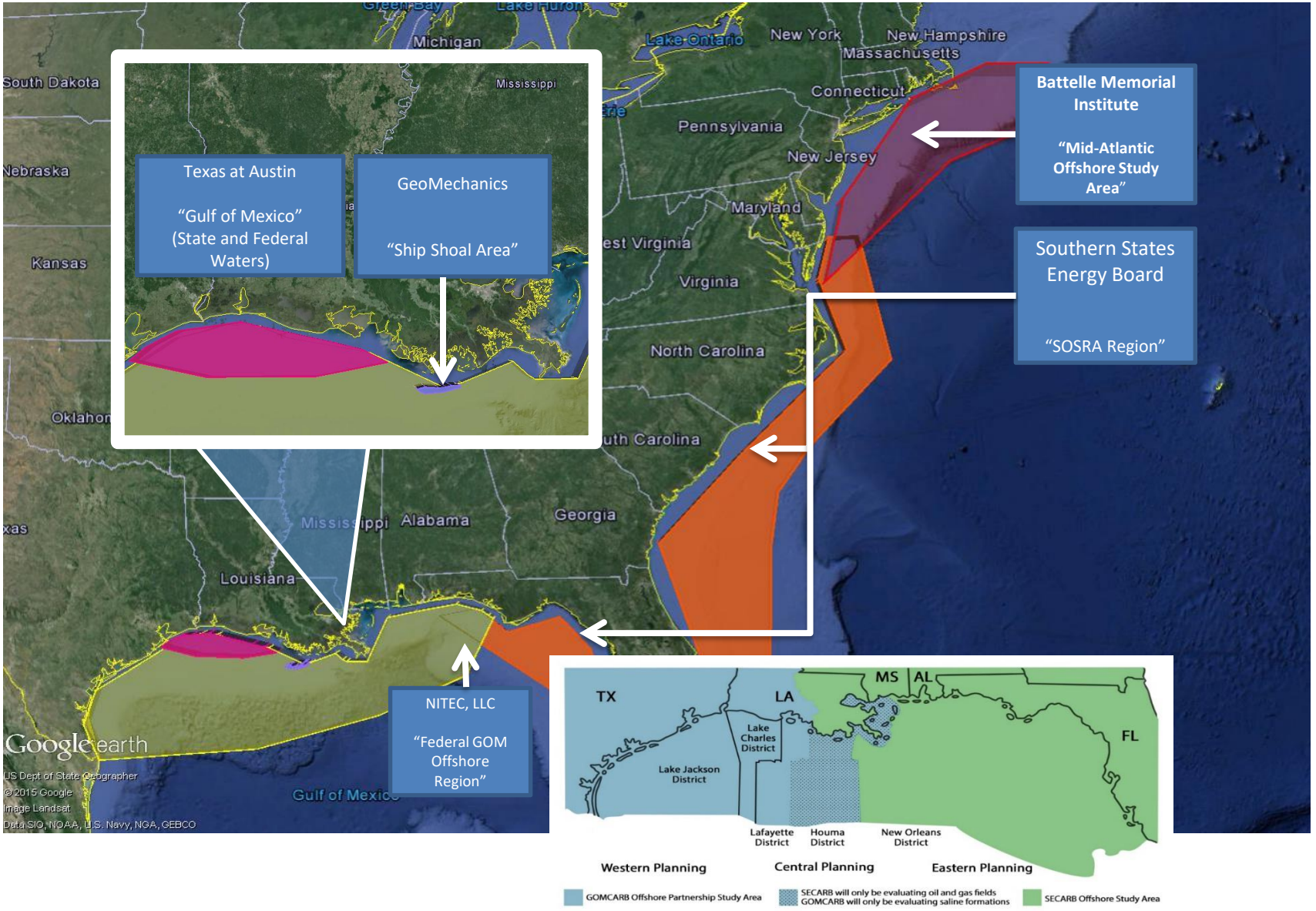
Carbon Storage Assurance Facility Enterprise (CarbonSAFE)

- Goal: Identify and certify geologic storage sites at commercial volumes (50+ million metric tons of CO_2)
- Phase I: Integrated CCS Pre-Feasibility (12-18 months) 
  - Formation of a team
  - Development of a plan encompassing technical requirements, economic feasibility and public acceptance, and
  - High-level technical evaluations of the sub-basin and potential CO_2 source(s)
- Phase II: Storage Complex Feasibility (2 years) 
  - Includes and extends the pre-feasibility work, focusing on one or multiple specific reservoirs within the defined storage complex
  - Data collection; geologic analysis; identification of contractual and regulatory requirements and development of plans to satisfy them; subsurface modeling to support geologic characterization, risk assessment, and monitoring; and public outreach
- Phase III: Site Characterization (Funding Opportunity Announcement (FOA) Released September 2019)

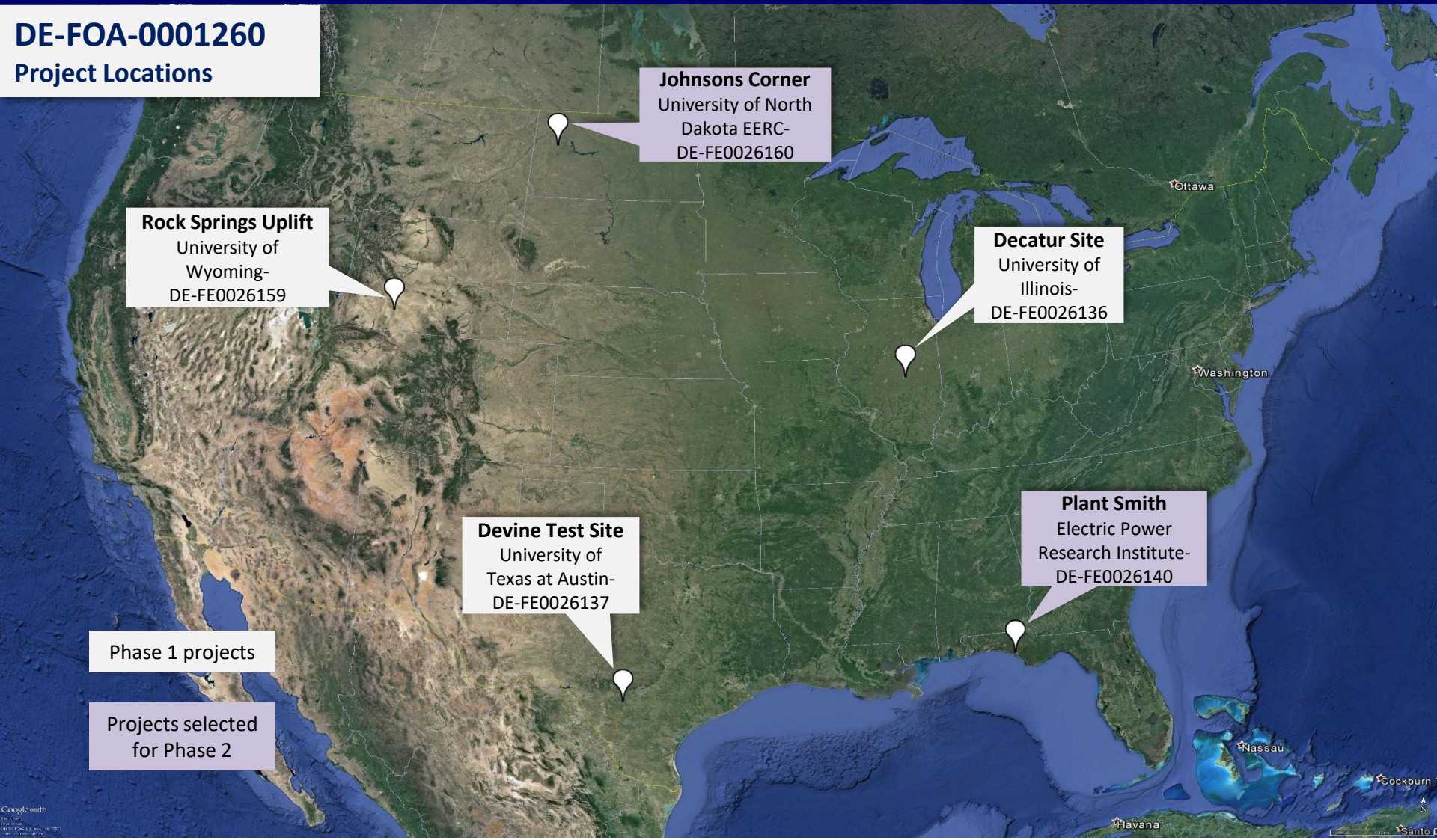
CarbonSAFE Phase II



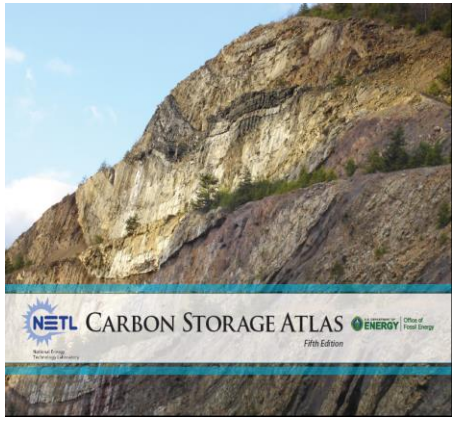
Offshore Resource Assessment Projects

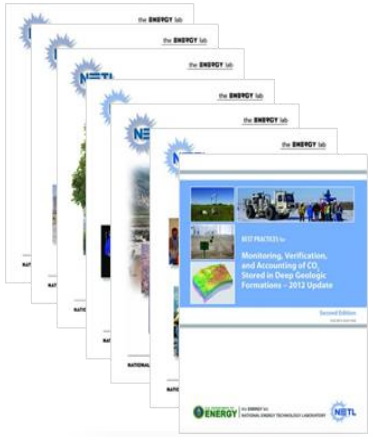


Brine Extraction Storage Test (BEST) Project Locations

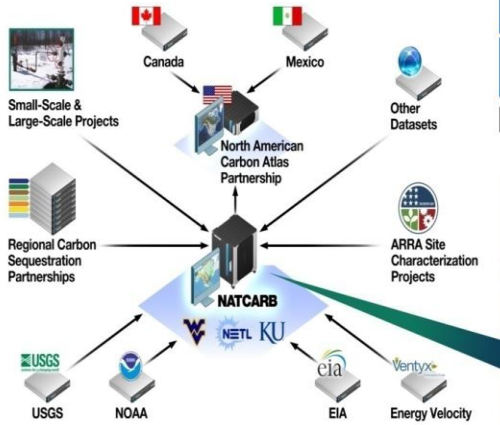


KNOWLEDGE SHARING PRODUCTS





Worldwide CCS Project Database



EDX
Energy Data eXchange

Policy Incentives for CCUS - 45Q tax credits

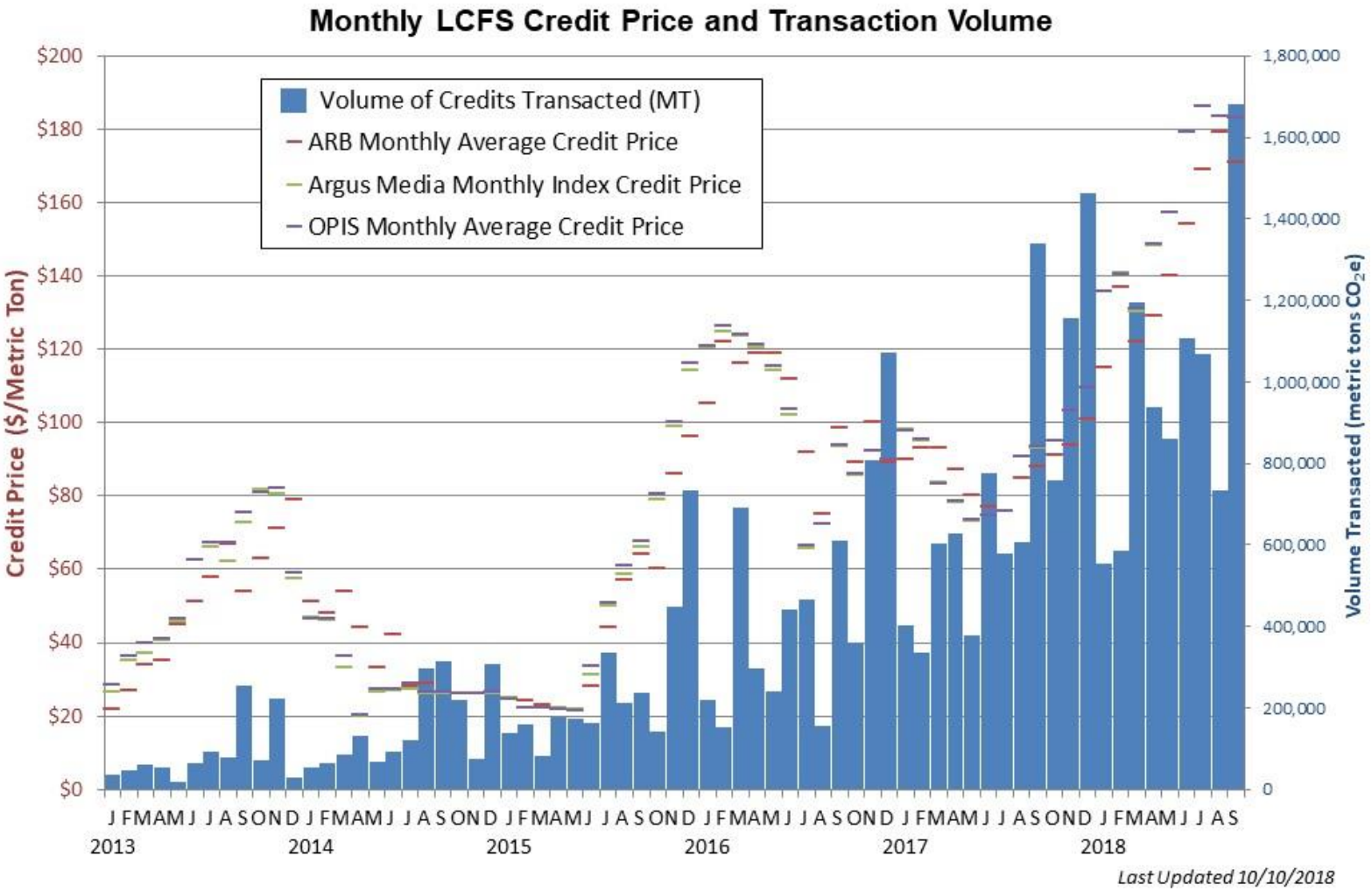
"Technology push" through R&D is matched with "market pull" through financial incentives

	Threshold by Facility Type ($ktCO_2/y$)			Credit in 2026 ($/t)
	Power Plant	Industrial Facility	Direct Air Capture	
Dedicated Storage	500	100	100	50
EOR	500	100	100	35
Utilization	25	25	25	35

Source: McCoy, 2018

- **Credit available to qualified facilities for 12 year period**
- **Defines qualified Carbon Oxides (CO or CO_2)**
- **Measured at point of capture and verified at the point of disposal/injection/use**
- **Qualified facilities:**
  - 1) Construction must begin by Jan 1, 2024;
  - 2) Original planning and design includes carbon capture equipment
- **Credit can be claimed by owner of capture equipment or transferred to disposal/use entity**

California's Low Carbon Fuel Standard



This chart tracks credit prices and transaction volumes over time. Monthly average credit prices reported by Argus Media and OPIS [used with permission] are shown along with ARB monthly average price.

Source, California ARB (2018)

Loan Programs

- **DOE Loan Guarantee Program**

  $8.5 billion in authority for fossil energy of a total of $40 billion

  Focus on bridging gap for innovative technologies to commercial market

- **USDA Rural Utility Service Loan Programs**

  Electric Infrastructure Loan Program

  - 104 loans were obligated for a total of $4,996,130,472
  - Approximately 7.6 million rural residents will receive new/improved electric facilities
  - Dollars Leveraged, $1.77 billion

  313A Loan Guarantee Program

  - 2 loans were obligated for a total of $750,000,000

  Rural Energy Savings Program (RESP)

  - 6 loans were obligated for a total of $34,200,000
  - Serving 94,228 rural residents

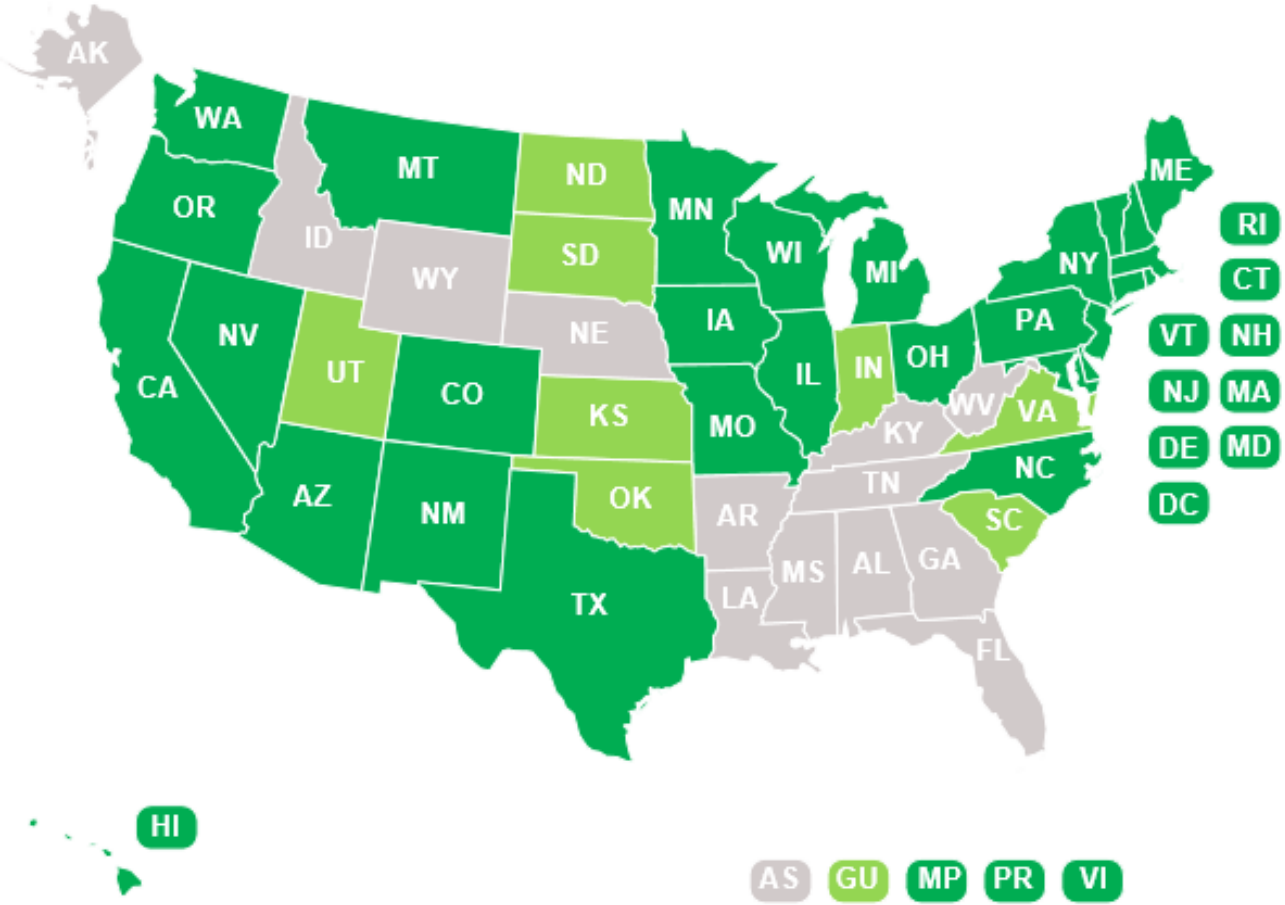
  High Energy Cost Grant (HECG) Program

  - 6 grants were obligated for a total of $11,668,431; $3.9 million non-federal match: $3.5million Denali and $400 thousand other)

State renewable portfolio or clean energy standards can include carbon capture

Source: http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx

States and territories with Renewable or Clean Energy Portfolio Standards	States and territories with a voluntary renewable energy standard or target	States and territories with no standard or target



U.S. role in multilateral CCUS partnerships

- **International Energy Agency (IEA)**
  - Working Party on Fossil Fuels (Chair)
  - Greenhouse Gas R&D Programme (GHG) *ExCo member*
  - Clean Coal Centre (CCC) *ExCo Chair*
  - CCS Unit – CCS Roadmap and International CCS Regulatory Network
- **Carbon Sequestration Leadership Forum (CSLF)**
  - *Secretariat and Policy Group Chair*
- **Clean Energy Ministerial (CEM) - CCUS Initiative**
  - *CCUS Initiative Lead*
- **Accelerating CCUS Technologies (ACT) Initiative**
- **Mission Innovation CCUS Initiative**
- **Asia Pacific Economic Cooperation Expert Group on Clean Fossil Energy (APEC EGCFE)**
  - *EGCFE Chair*
- **UN Economic Commission for Europe (UNECE)**
  - *Sustainable Energy Bureau Vice Chair*
- **Global CCS Institute**

Thank You.