



U.S. DEPARTMENT OF
ENERGY

Office of
Fossil Energy

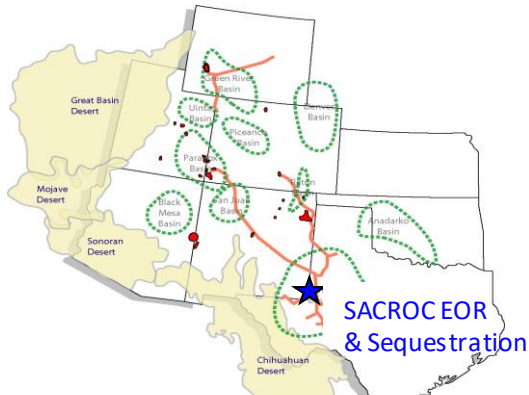


Overview of the DOE CCUS R&D Program

August 17, 2020

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Director, Division of
Emissions Controls and
CCUS R&D

Before looking ahead, let's review the journey so far



Enhanced Oil Recovery - US

- First US patent for CO₂ EOR issued in 1952
- First field test in 1964
- First commercial project (SACROC) in 1972



Sleipner Project- Norway

- CO₂ removed from natural gas produced on production platform in North Sea
- Injection into saline reservoir under sea
- Started 1996



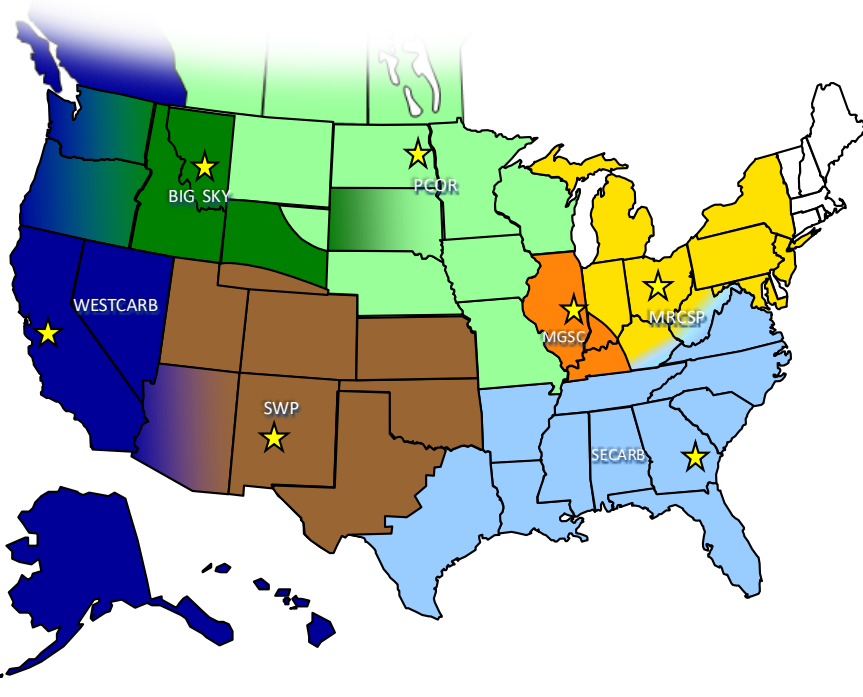
Weyburn – Saskatchewan

- EOR project with 50 wells
- Uses CO₂ from coal gasification plant
- Started 2000

Domestically, over 23 million metric tons injected since 2008 in DOE projects

Seven Regional Partnerships

*400+ distinct organizations, 43 states, 4
Canadian Provinces*



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



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

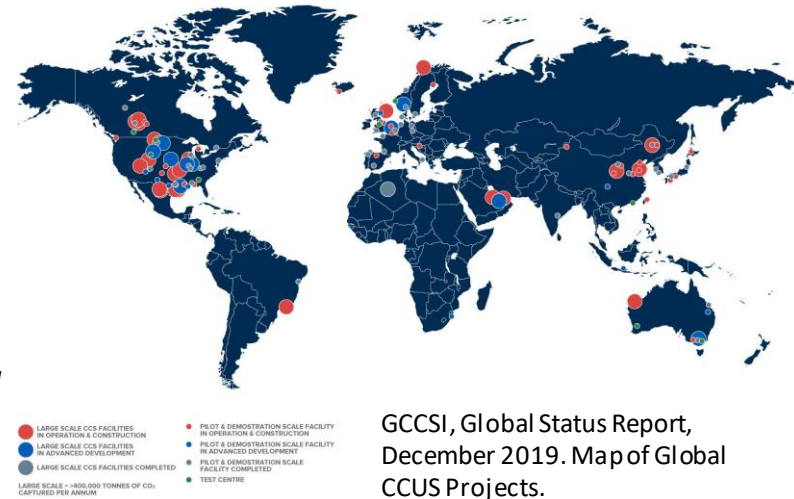


ADM Ethanol Facility (Decatur, IL) – Operations began in 2017



Interesting Facts/Observations

- Globally, operational CCUS projects **more than triple** since 2010.
 - ~10 million metric tons per year to 35-40 million metric tons per year.
- 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](#)
 - New technologies are showing potential – GCCSI Global Status Report
- Project pipeline is replenishing
 - DOE Integrated Projects
 - Globally as well... Northern Lights, Porthos, UK
- Question shifting from “Why we need it” to “What do we need to do to scale and how do we implement?”



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



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



April 13, 2020



Federal investment in DOE CCUS R&D



Carbon capture

R&D and scale-up technologies for capturing CO₂ from new and existing industrial and power-producing plants, and direct air capture



CO₂ utilization

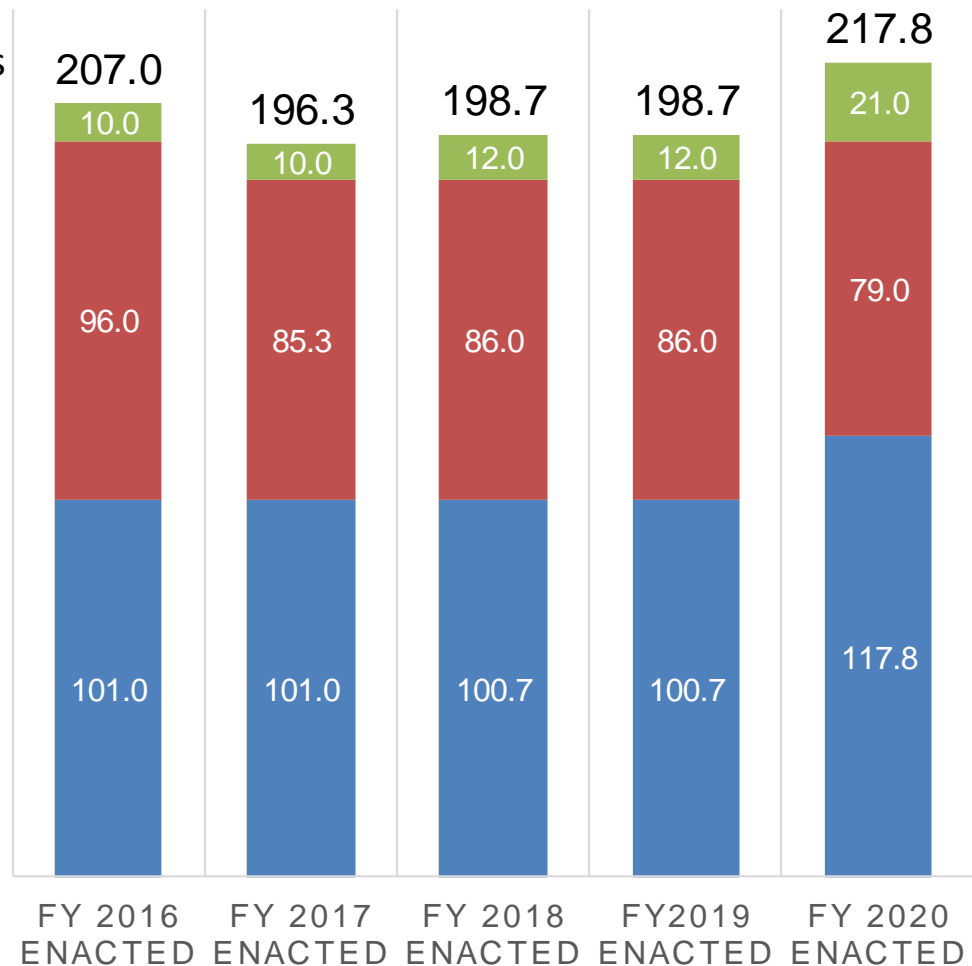
R&D and technologies to convert CO₂ to value-added products



Carbon storage

Safe, cost- effective, and permanent geologic storage of CO₂

\$ millions



■ Carbon Capture ■ Carbon Storage ■ Carbon Utilization



CCUS R&D Program Goals and Challenges

Reduce the cost of capture by 50%

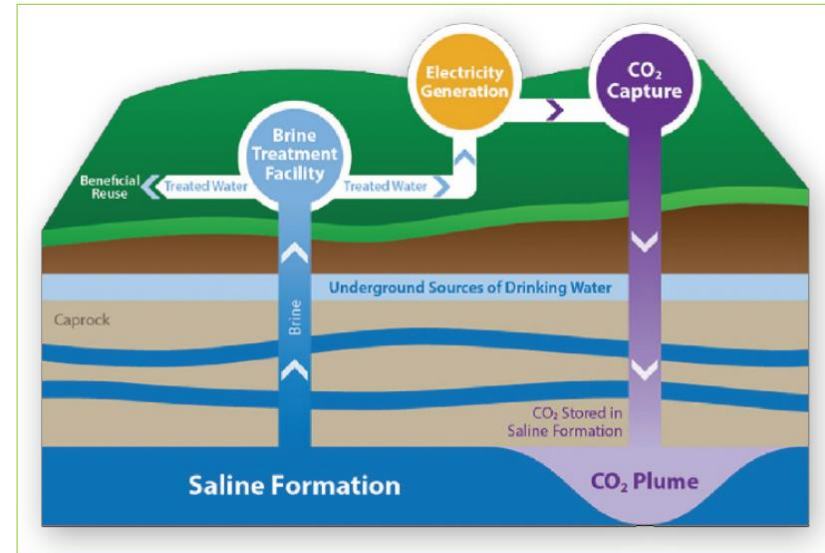
- Capital cost
- Energy penalty
- Integration or process intensification

Develop viable carbon utilization alternatives

- Reduce capital cost
- Reduce energy requirements
- Lifecycle assessment better than existing products

Optimize geologic storage operations

- Higher resolution and quantification (e.g., improve characterization of faults and fractures)
- Geomechanics (pressure and state of stress)
- Enabling real-time decision making



Sources: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015; NETL Cost and Performance Baseline for Fossil Energy Plants, September 2019.

Carbon Capture Program – Evolving and Expanding

Leveraging R&D for multiple applications

Coal Power Plant

11-14% CO₂



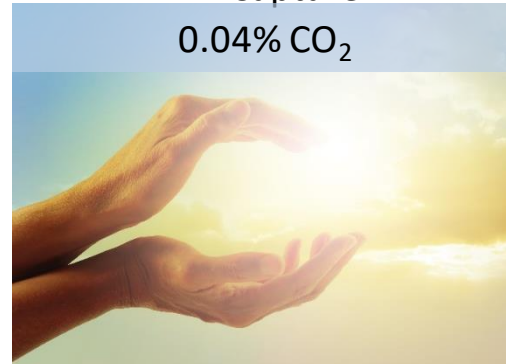
Gas Power Plant

4-6% CO₂



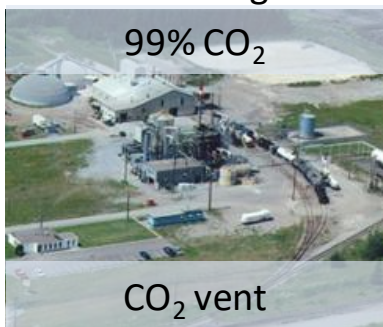
Air Capture

0.04% CO₂



NG Processing Plant

99% CO₂



CO₂ vent

Ammonia Plant

99% CO₂



Stripping vent

Ethanol Plant

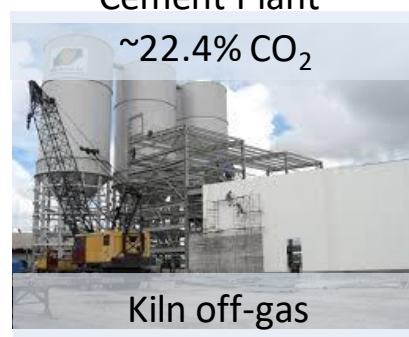
100% CO₂



Distillation gas

Cement Plant

~22.4% CO₂



Kiln off-gas

Cost of Capturing CO₂ from Industrial Sources, January 10, 2014, DOE/NETL-2013/1602

FY2020 FOAs: DAC, Engineering Studies for Industrial Sources, Small Pilots for Coal and Natural Gas



National Carbon Capture Center - Benefits to Program

- Operated by Southern Co. Services
- Hosted at Plant Gaston, AL
- Facility capable of testing on coal and natural gas streams – capture and utilization technologies
- 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
- International partners – Total (France)

Lab-Scale Unit



Bench-Scale Unit












Small Pilot-Scale Unit



CAPTURE FEED Studies Selections in September 2019

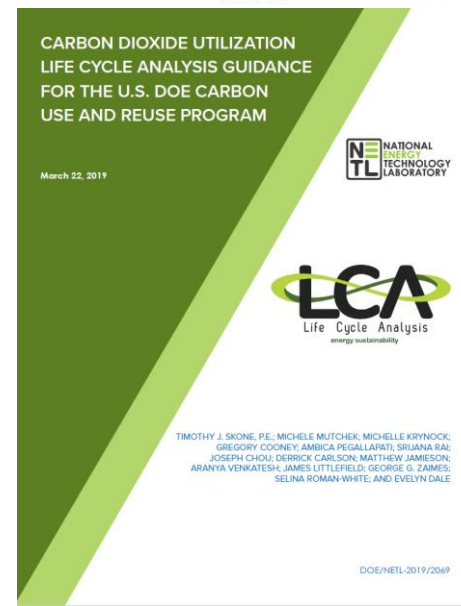
Nine projects selected (\$55.4M total)

Projects will support FEED studies for commercial-scale carbon capture systems

| | Awardee | Project |
|---|---|---|
|  | Bechtel National | FEED Study for Retrofitting a 2x2x1 Natural Gas-Fired Gas Turbine Combined Cycle Power Plant for Carbon Capture Storage/Utilization – MEA Solvent |
|  | The Board of Trustees of the University of Illinois | Full-Scale FEED Study for Retrofitting the Prairie State Generating Station with an 816 MWe Capture Plant Using Mitsubishi Heavy Industries of America Post-Combustion CO ₂ Capture Technology – MHI Solvent |
|  | Electric Power Research Institute | Front End Engineering Design Study for Retrofit Post-Combustion Carbon Capture on a Natural Gas Combined Cycle Power Plant – Fluor's amine-based Econamine FG Plus |
|  | Enchant Energy | Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station – Commercial Solvent |
|  | Ion Engineering | Commercial Carbon Capture Design & Costing: Part Two – Ion Engineering Non-aqueous Solvent |
|  | Membrane Technology and Research Inc. | Commercial-Scale Front-End Engineering Study for MTR's Membrane CO ₂ Capture Process – MTR, Inc Polymeric Membrane |
|  | Minnkota Power Cooperative Inc. | Front-End Engineering & Design: Project Tundra Carbon Capture System – Fluor's amine-based Econamine FG Plus |
|  | Southern Company Services | Front End Engineering Design of Linde-BASF Advanced Post-Combustion CO ₂ Capture Technology at a Southern Company Natural Gas-Fired Power Plant – Linde BASF amine Solvent |
|  | The University of Texas at Austin | Piperazine Solvent/Advanced Stripper Front-End Engineering Design (PZAS FEED) |

Carbon Utilization R&D – Creating Value from CO₂

- Technical Focus Areas
 - Mineralization concepts – advanced cements, curing, and composites
 - Thermochemical and Electrochemical Pathways – conversion to chemicals, fuels, and advanced materials (Carbon fiber)
 - Biological approaches Algae – Open ponds and photo bioreactors – integration with plants
- Life cycle critical to assessing benefits of conversion
- 11 new projects, \$17 million investment in FY2020



Carbon Storage Program

Improving and Optimizing Performance

Regional Carbon Sequestration Partnerships (RCSPs)



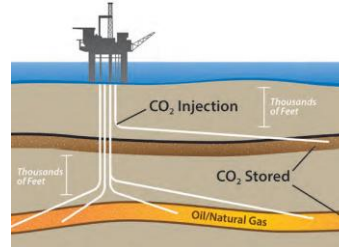
Advancing monitoring and measurement tools: improving characterization and reducing the uncertainty about the CO₂ and pressure fronts.



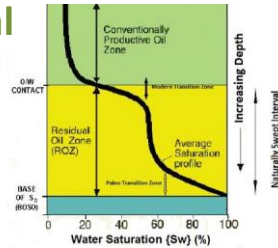
CarbonSAFE



Offshore Storage



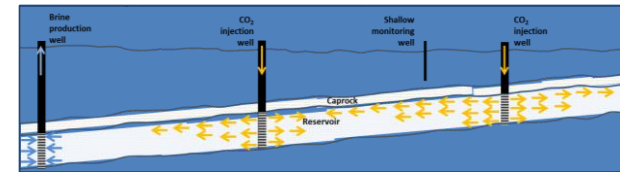
Unconventional EOR



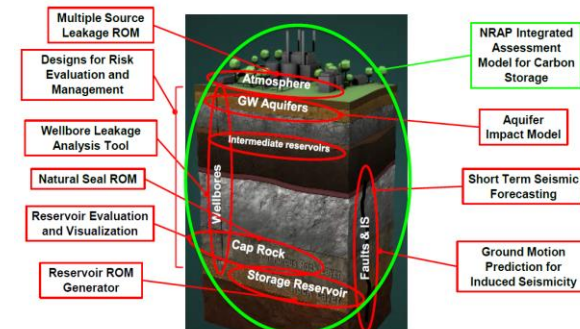
CARBON STORAGE PROGRAM



Brine Extraction Storage Tests (BEST)



National Risk Assessment Partnership (NRAP) is developing toolsets to reduce uncertainty and quantify potential impacts related to release of CO₂ and induced seismicity



Fiber Optic Distributed Acoustic Sensing (DAS)



Office of Clean Coal and Carbon Management

SMART Initiative

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

Primary Goals

Real-Time Visualization

"CT" for the Subsurface

Rapid Prediction

Virtual Learning

Real-Time Forecasting

"Advanced Control Room"



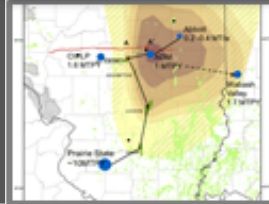
Carbon Storage Assurance Facility Enterprise (CarbonSAFE)



Phase I: Integrated CCS Pre-Feasibility 18-month initiative

- Formation of a team; development of a feasibility plan; and high-level technical evaluation of the sub-basin and potential CO₂ sources
- Thirteen projects funded

Complete



Phase II: Storage Complex Feasibility 2-year initiative

- Data collection; geologic analysis; analysis of contractual and regulatory requirements; subsurface modeling; risk assessment; evaluate monitoring requirements; and public outreach
- Six projects funded

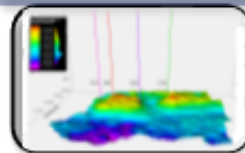
Active



Phase III: Site Characterization and CO₂ Capture Assessment 3-year initiative

- Detailed site characterization; obtain Underground Injection Control (UIC) Class VI Permit to construct; CO₂ Capture Assessment; NEPA approvals

Selections Announced



Phase IV: Permitting and Construction of Storage Complex 2.5-year initiative

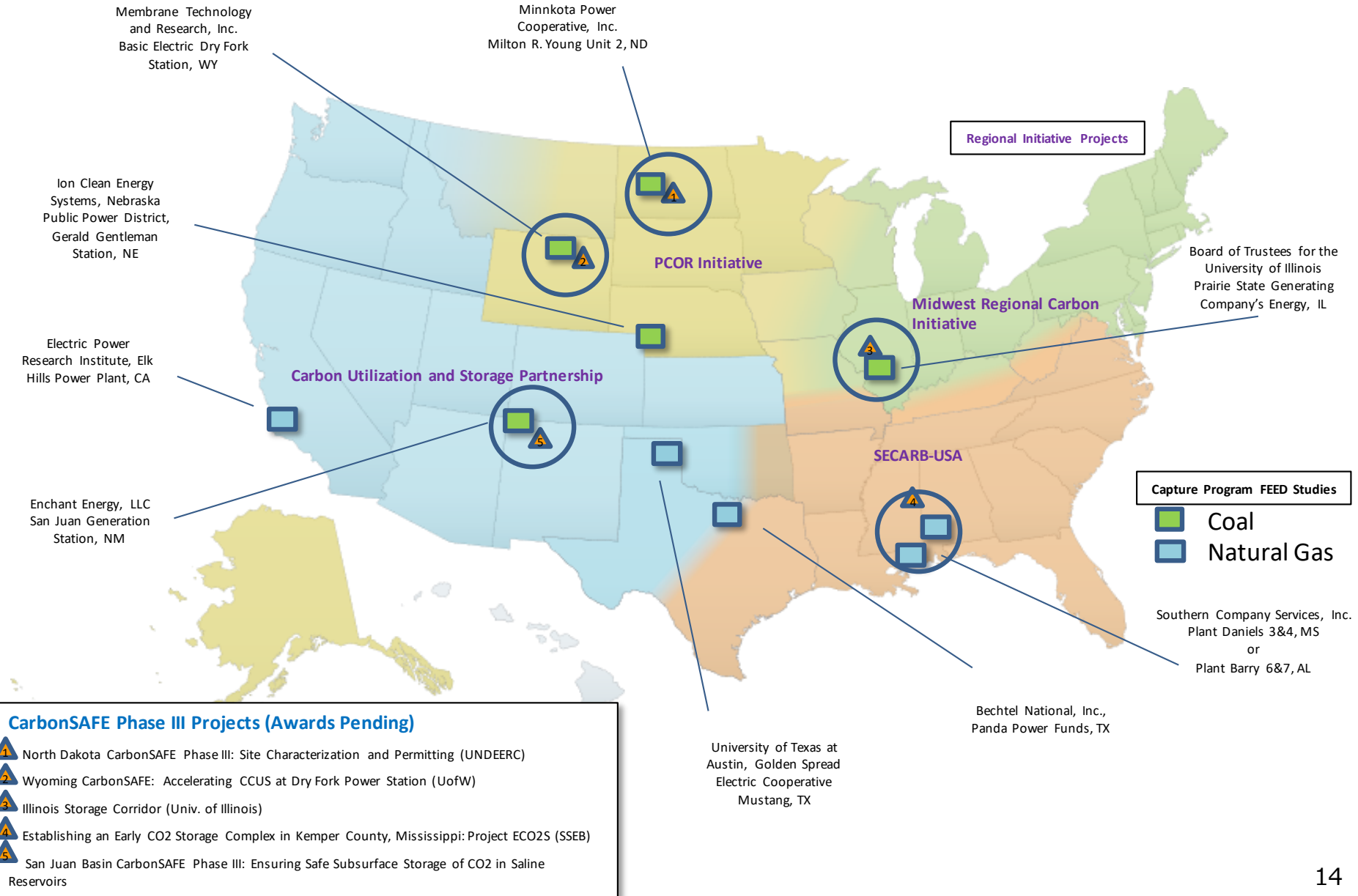
- Obtain UIC Class VI permit to inject; drill and complete injection and monitoring wells; develop risk and mitigation plans
- Subject to future funding

Future Funding



- CarbonSAFE was conceived to address the knowledge gaps associated with the development of a commercial-scale (50+ million metric tons CO₂) storage complex.
- CarbonSAFE projects were envisioned as staged efforts to develop an integrated CCS storage complex constructed and permitted for operation in the 2025–30 timeframe.
- 13 pre-feasibility projects (Phase I) were selected November, 2016; \$15M total DOE funding.
- 6 feasibility projects (Phase II) are currently active; \$60M total DOE funding.
- Five Phase III projects announced on April 24, 2020.
- Continuation to the fourth and final phase depends on future appropriation of funding.

STORAGE PROGRAM FIELD INITIATIVES AND CAPTURE PROGRAM FEED STUDIES



Cooperation is Critical to Advancing CCUS Globally

U.S. is leading the world with an integrated technical, policy, and regulatory approach

Multilateral Partnerships

International Energy Agency (IEA)

- Working Party on Fossil Fuels (WPFF)
- Greenhouse Gas R&D Programme (GHG)
- Clean Coal Centre (CCC)
- CCS Unit – CCS Roadmap and International CCS Regulatory Network

Carbon Sequestration Leadership Forum (CSLF)

Clean Energy Ministerial (CEM) – CCUS Initiative

Mission Innovation CCUS Initiative

APEC Expert Group on Clean Fossil Energy (APEC EGCFE)

UN Economic Commission for Europe (UNECE)

Accelerating CCS Technologies (ACT) initiative

Global CCS Institute



MISSION INNOVATION
Accelerating the Clean Energy Revolution



Select Bilateral Partnerships

Japan

- Japan-U.S. Strategic Energy Partnership (JUSEP)
- Memorandum of Cooperation on CCUS

China

- Fossil Energy Protocol
- CCUS Initiative
- Advanced Combustion Technology Consortium

Norway

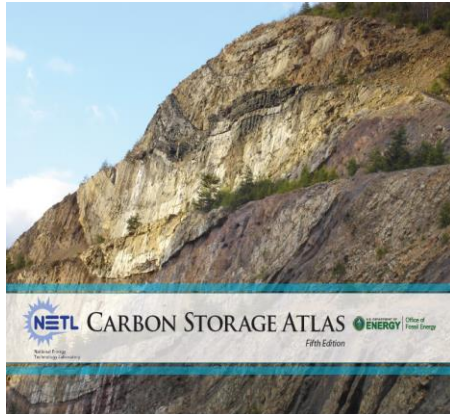
- Memorandum of Understanding on CCUS

India

- Strategic Energy Partnership's Power & Energy Efficiency Pillar
- Partnership to Advance Clean Energy Research (PACE-R)

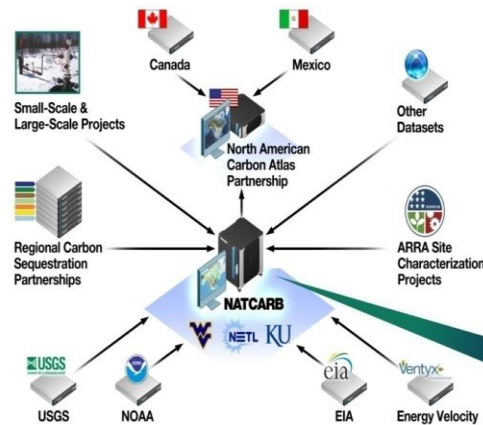
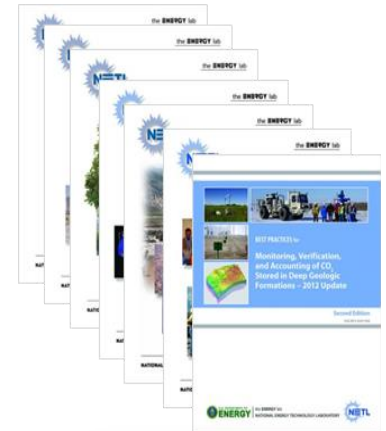


KNOWLEDGE SHARING PRODUCTS



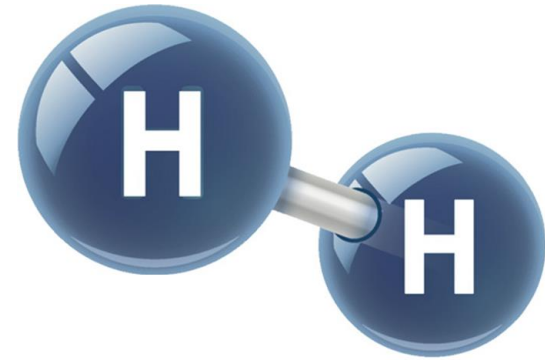
<https://netl.doe.gov/coal/carbon-storage/strategic-program-support/natcarb-atlas>

Worldwide CCS Project Database

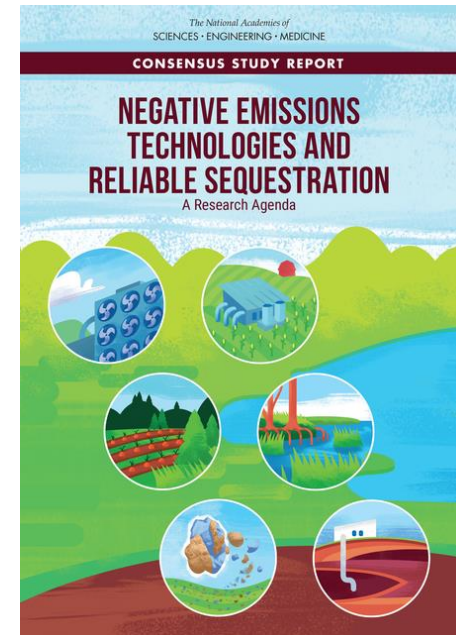


Opportunities Ahead

CCUS Enabling Low- or Carbon-Free Hydrogen Production



CCUS Applications for Industrial and Natural Gas



Some Final Observations

- Much progress made over the past 20 years...
 - Significantly increased our scientific, technical, and economic understanding throughout the CCUS value chain
 - Driving down costs
- Exciting time for the CCUS community with growing interest, and hopefully, optimism:
 - Multiple government and multilateral initiatives underway
 - Large-scale project pipeline is replenishing
 - 45Q tax credits and other policy mechanisms

For More Information



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