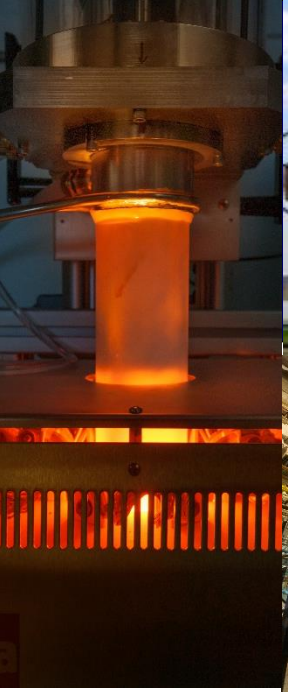
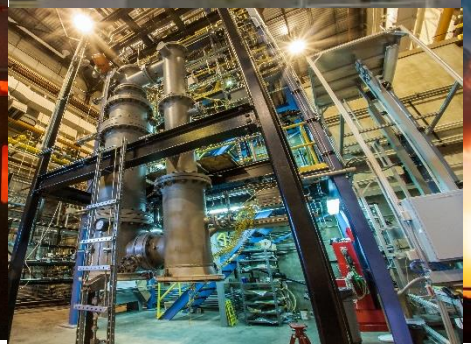





U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

# Fossil Energy R&D

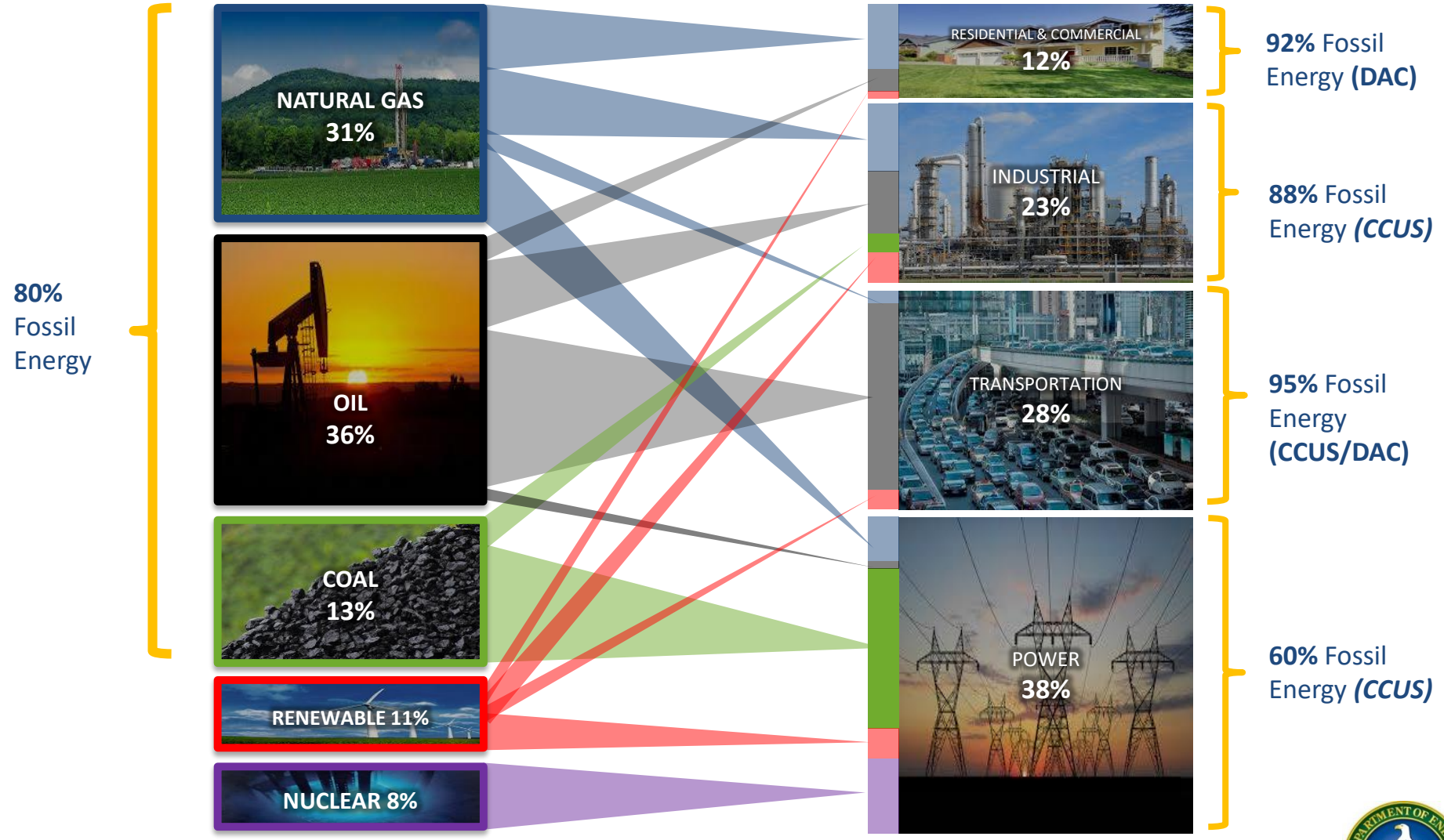
**Traci Rodosta**
Carbon Storage Technology Manager

Office of Clean Coal and Carbon Management

DOE NETL | Midland $CO_2$ Conference| December 2019

# FOSSIL ENERGY IS CRITICAL IN ALL SECTORS

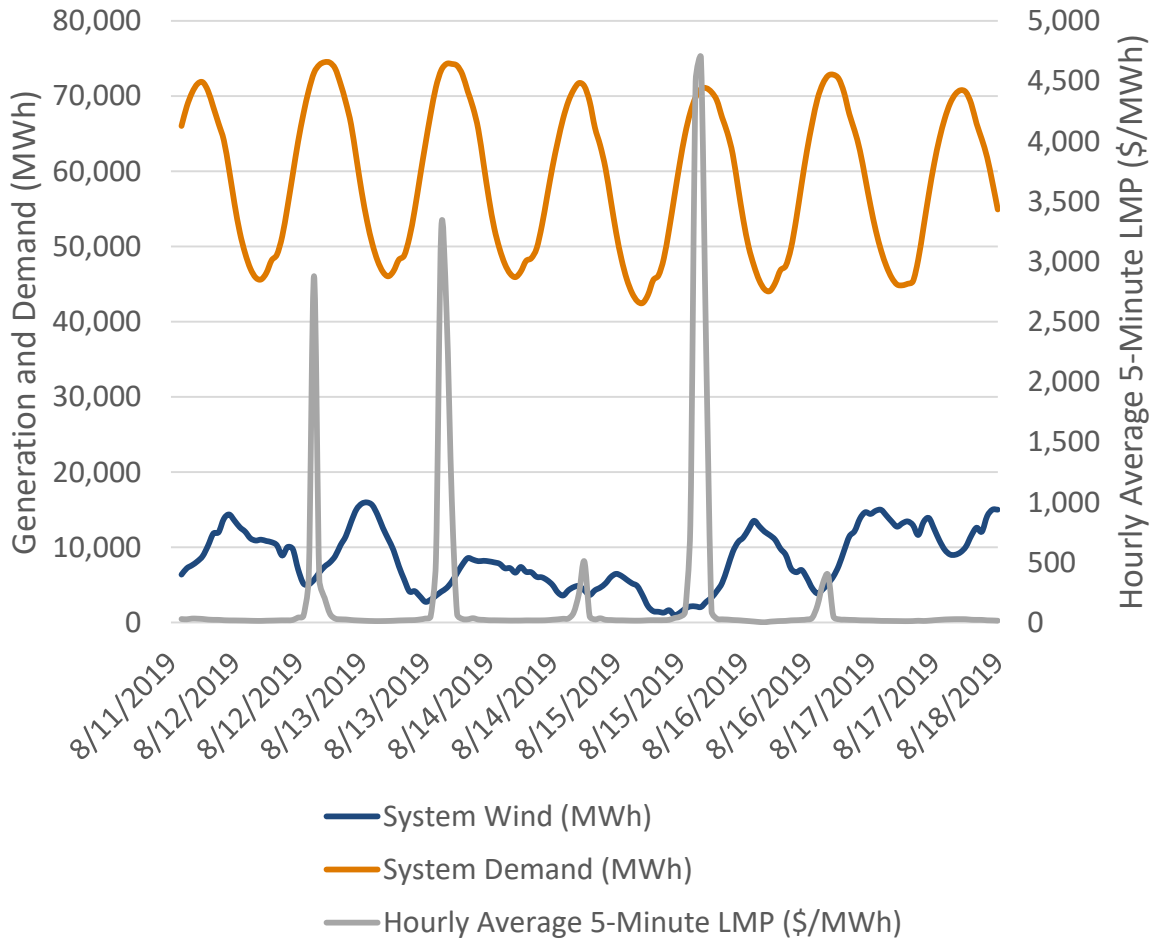
## CCUS IS A PLATFORM TECHNOLOGY FOR MANY INDUSTRIAL SECTORS




EIA, *Annual Energy Outlook 2019*, Reference Case, *https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf*

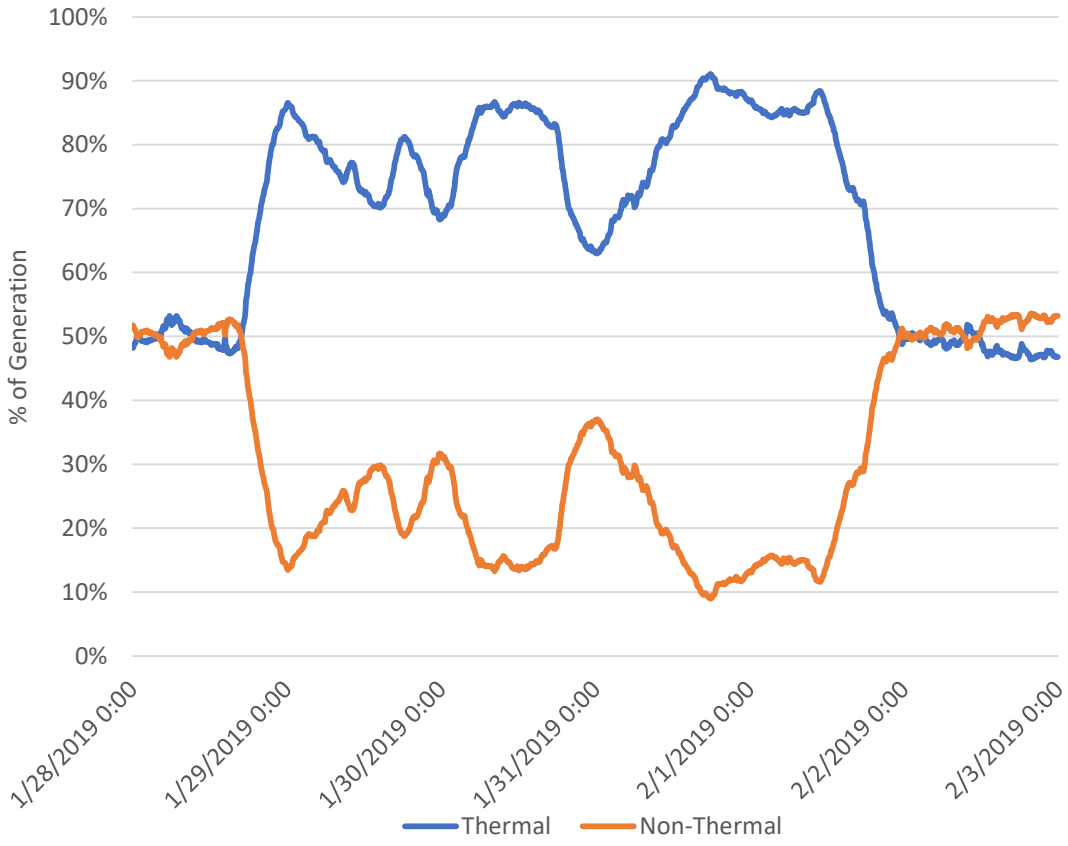
# ERCOT SYSTEM DEMAND VS. WIND OUTPUT

**Wind generation in ERCOT was not reliable during the 2019 summer peak**



# RESOURCE DRIVEN INDUCED POWER SUPPLY VOLATILITY

**Variable resources sudden loss in generation led to a spike in thermal generation during 2019 winter storm in Southwest Power Pool**




- Non-thermal output fell significantly over 12-hours
- Thermal resources in place made up for sudden loss
- Future resources to cover such an event are in doubt
- FE R&D is key to ensuring these resources are available to provide resilience and ensure a reliable power supply to consumers

# COAL R&D OVERVIEW


| Advanced Energy Systems | Crosscutting Research | $CO_2$ Capture and Utilization | $CO_2$ Storage |
|---|---|---|---|
| ***Efficiency improvements for new and existing units*** | ***Crosscutting technology development program*** | ***Reducing the cost of $CO_2$ capture for new and existing units*** | ***Safely and permanently storing $CO_2$*** |
| • Advanced energy materials<br>• Advanced gasification<br>• Solid oxide fuel cells<br>• Advanced coal processing<br>• Advanced turbines<br>• Advanced combustion<br>• Sensors and controls | • Power generation efficiency<br>• Supercritical transformational electric power<br>• Critical minerals<br>• Coal utilization science<br>• Transformational coal pilots<br>• University research<br>• SBIR/STTR*<br>• Technology Commercialization Fund (TCF)* | • Post-combustion capture<br>• Pre-combustion capture<br>• New pathways to utilize captured $CO_2$ | • Safe use and permanent storage of $CO_2$ from power generation and industry<br>• Minimizing subsurface risks (coordinated with other subsurface offices, e.g., Office of Oil and Natural Gas)<br>• $CO_2$ infrastructure analysis |

*Note: Programmatic not necessarily budgetary groupings*
**SBIR/STTR and TCF are managed under the Crosscutting Program but funded by all R&D programs*

# HIGH-LEVEL CCUS R&D PROGRAM GOALS AND CHALLENGES

**Reduce the cost of capture by 50%**

- Capital cost
- Energy penalty
- Integration or process intensification

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

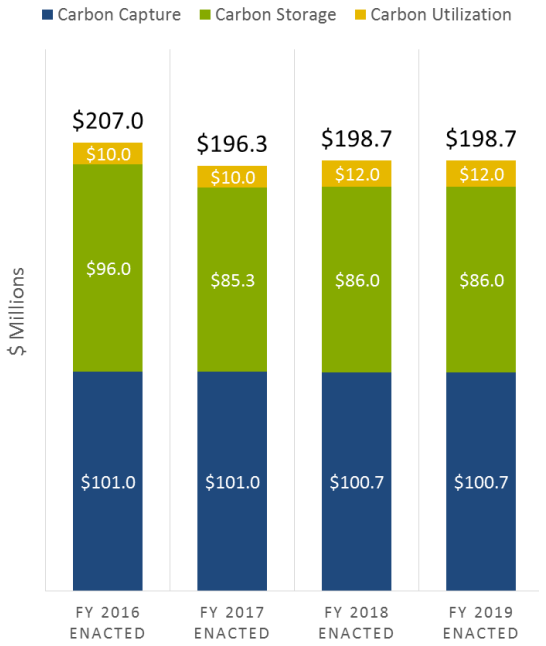
Source: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015

**Develop viable carbon utilization alternatives ($1T opportunity)**

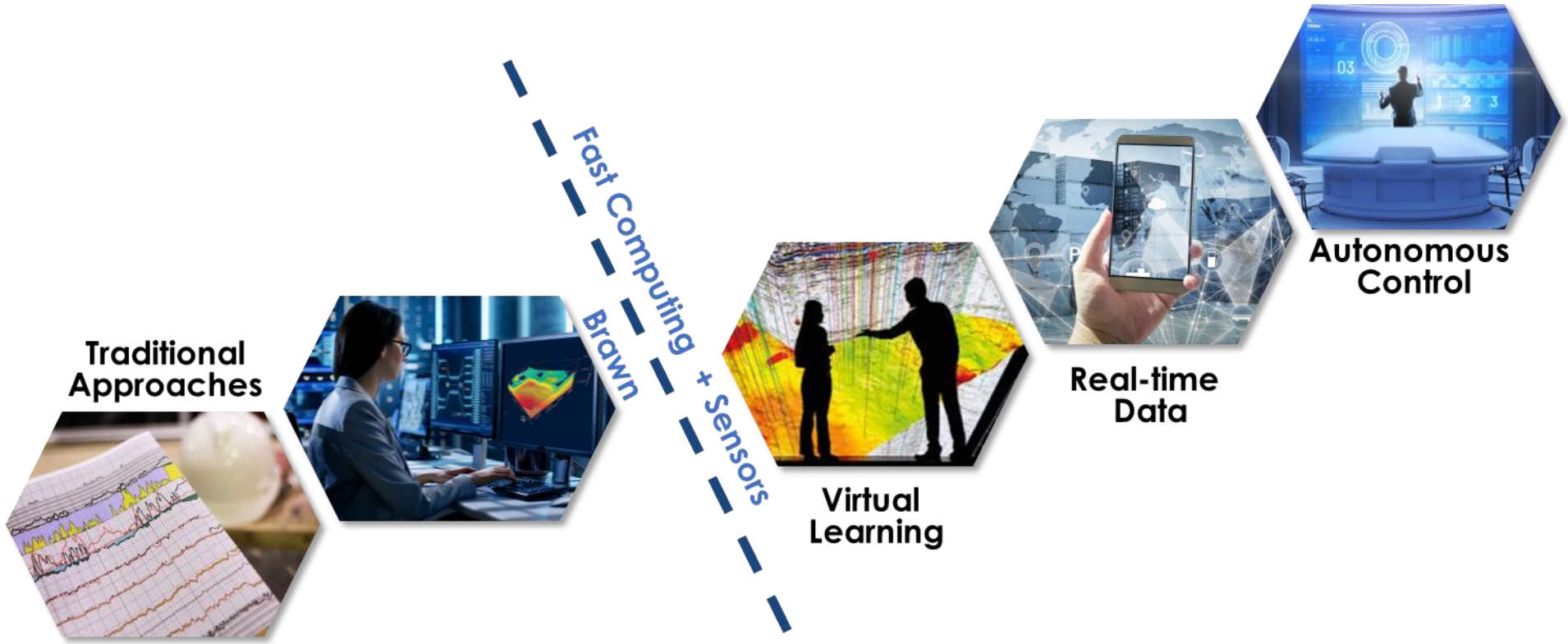
- Reduce Capital cost
- Reduce energy requirements
- Lifecycle assessment better than existing products

**Reduce the risk of geologic storage – improve monitoring and simulation**

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



# MACHINE LEARNING IN THE SUBSURFACE

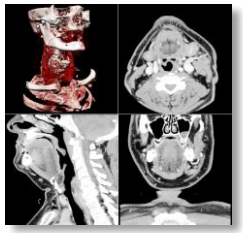


# SCIENCE-BASED MACHINE LEARNING TO ACCELERATE REAL-TIME DECISION MAKING – SMART – INITIATIVE

*FE Vision for Exploiting Machine Learning to Transform Subsurface operations*

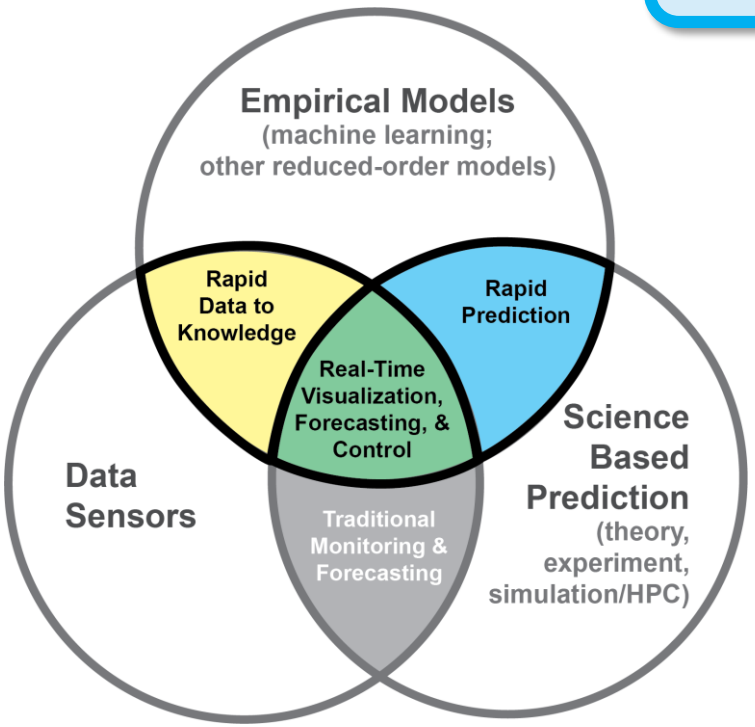
**Real-Time Visualization**

*"CT" for the Subsurface*



**Real-Time Forecasting**

*"Advanced Control Room"*


**Rapid Prediction**

*Virtual Learning*

# BRINE EXTRACTION STORAGE TEST (BEST)

## Developing and Validating Pressure Management and Plume Control Strategies

Active Reservoir Management (ARM) Test

- Reduce stress on sealing formation
- Geosteer injected fluids
- Divert pressure from leakage pathways
- Reduce area of review (AOR)
- Improve injectivity, capacity, and storage efficiency
- Validate monitoring techniques, and forecast model capabilities

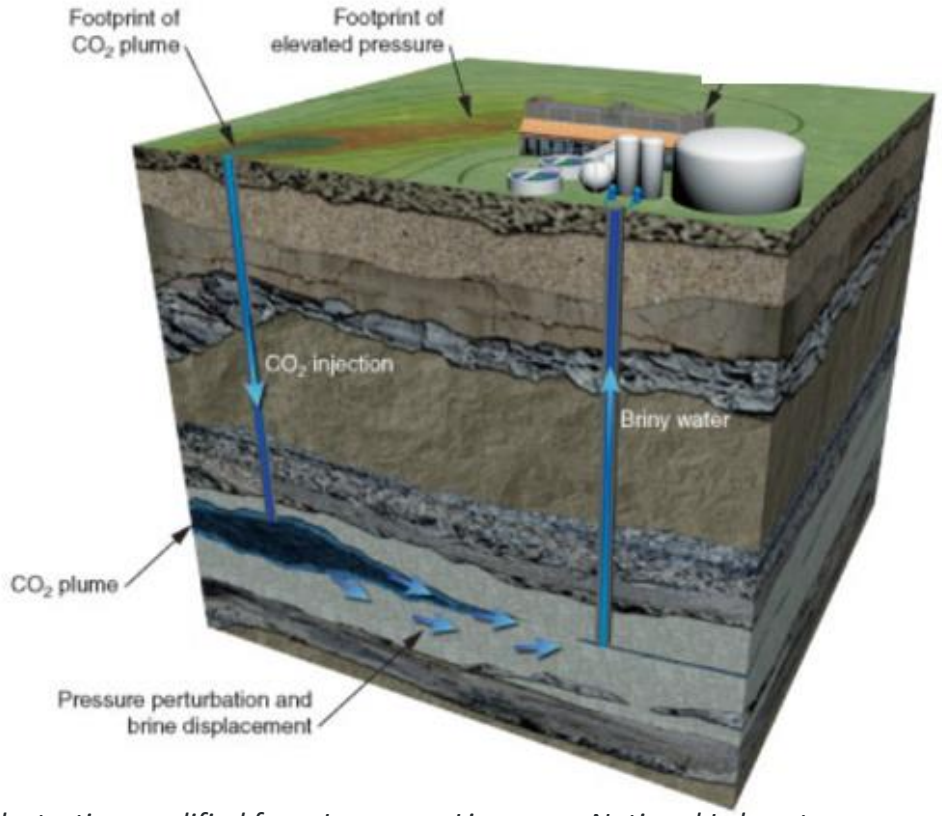
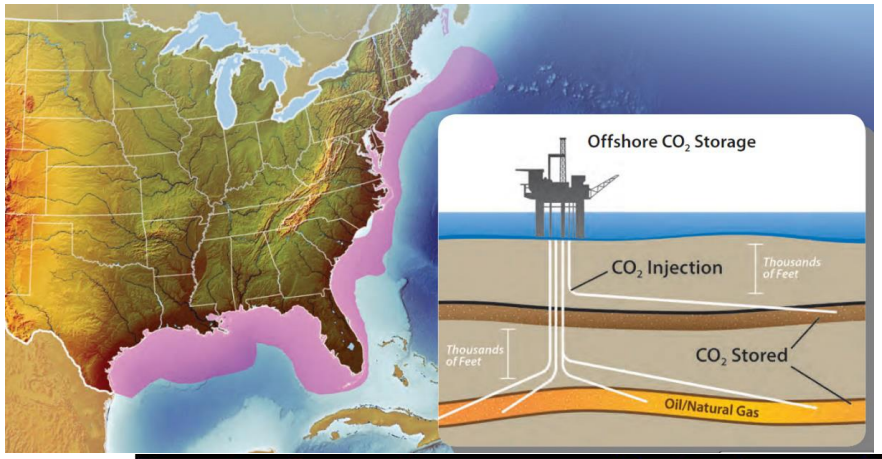
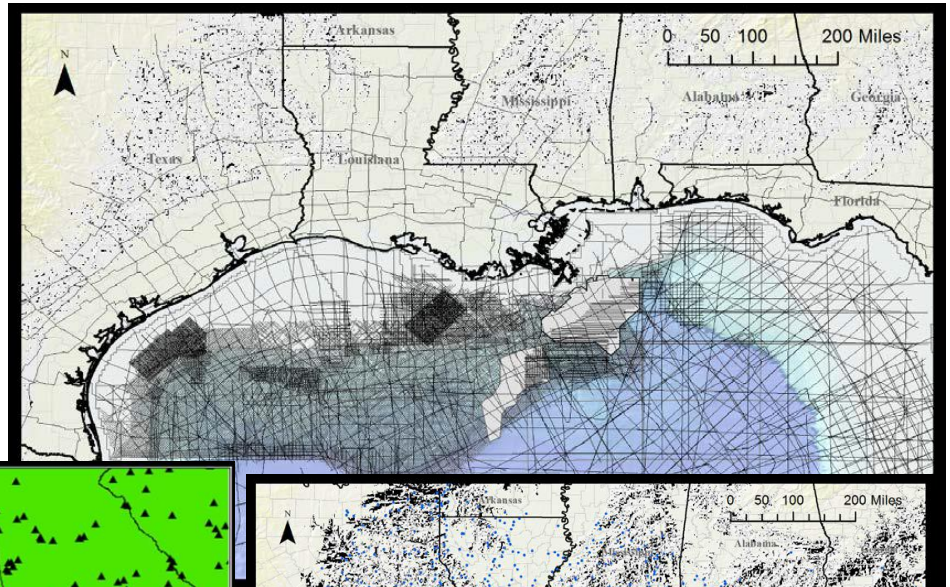
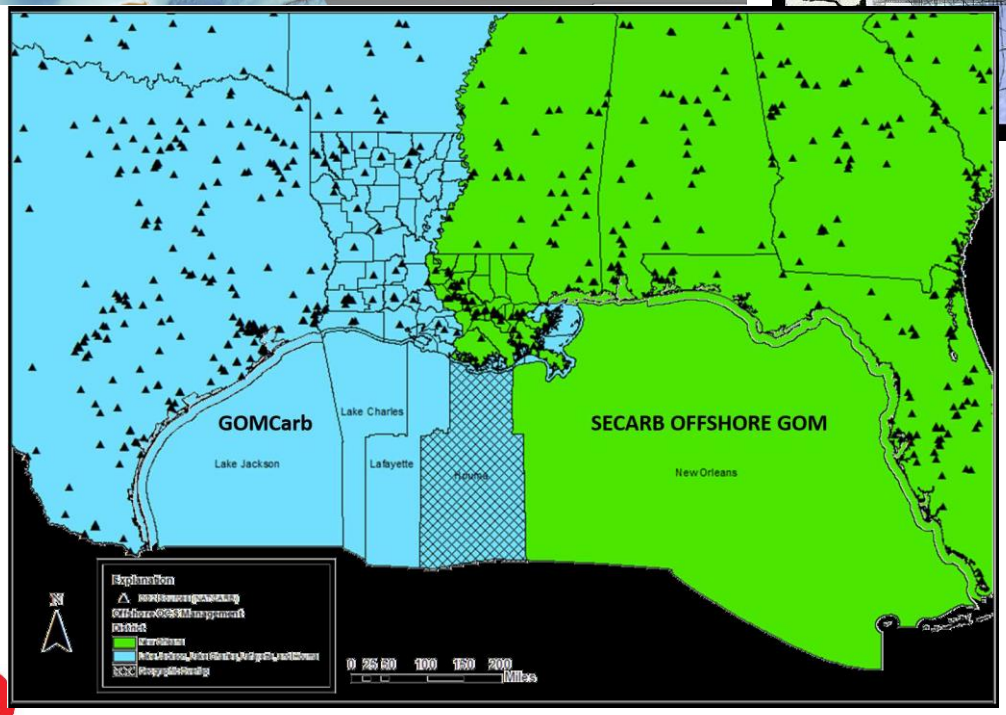


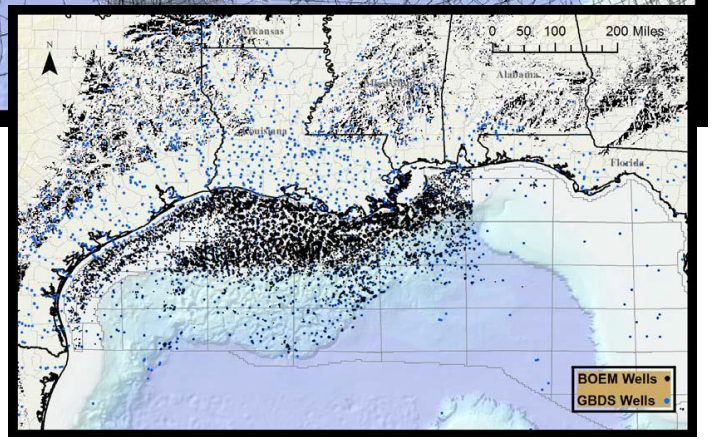

*Illustration modified from Lawrence Livermore National Laboratory*
*https://str.llnl.gov/Dec10/aines.html*

# OFFSHORE STORAGE POTENTIAL

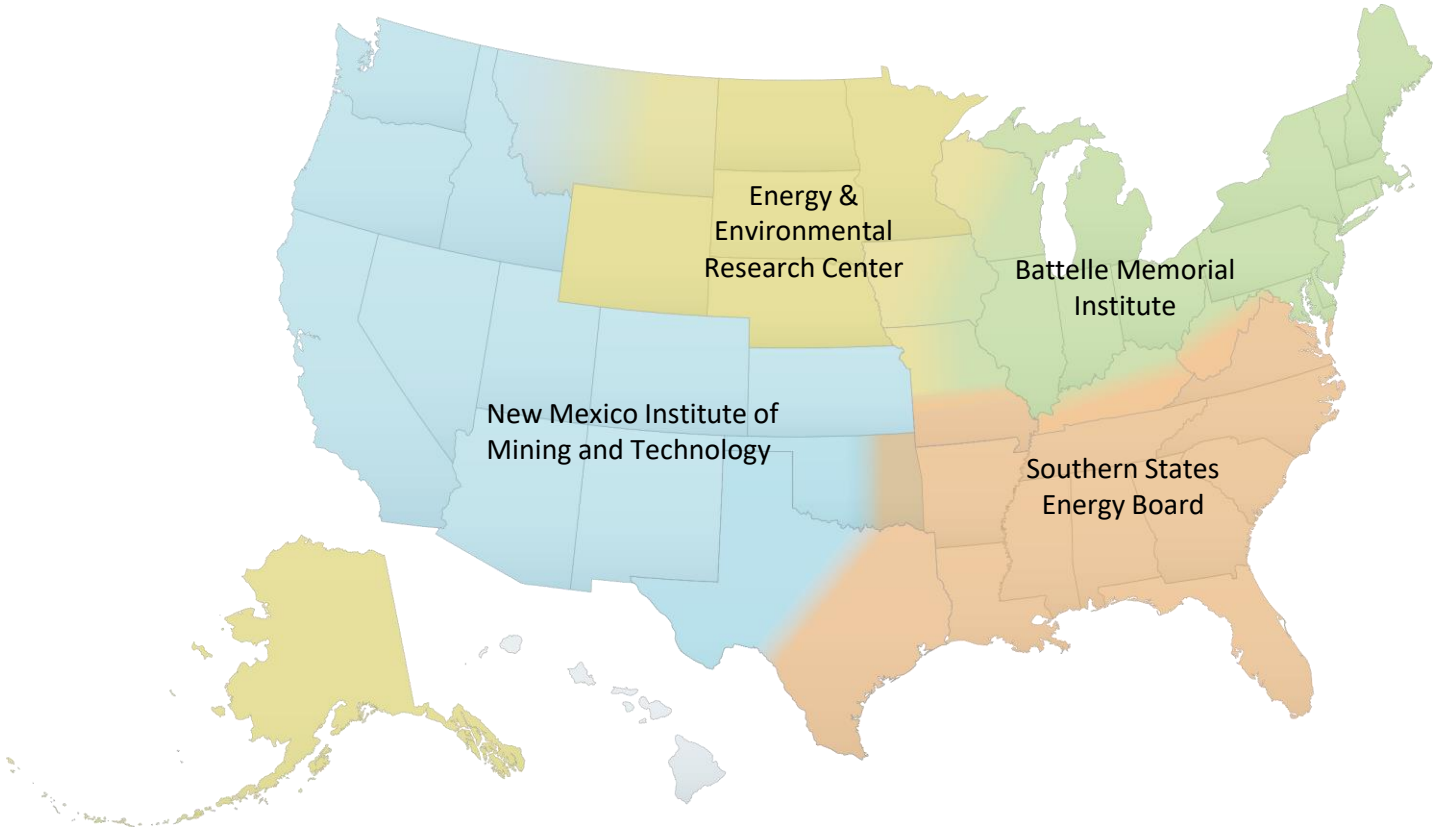


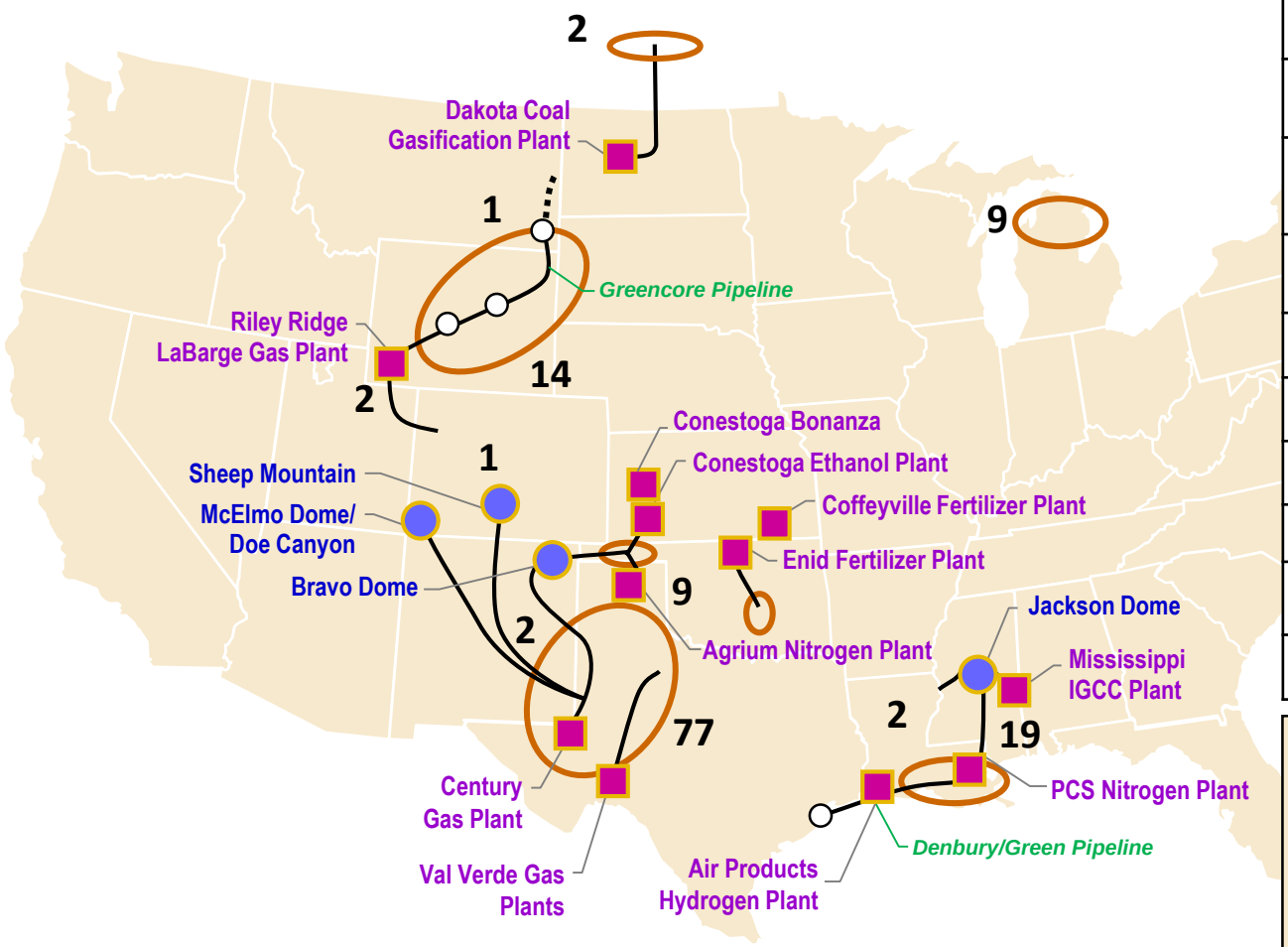



# ACCELERATING CCUS THROUGH NEW REGIONAL INITIATIVE




- **Addressing Key Technical Challenges**
- **Facilitating Data Collection, Sharing, and Analysis**
- **Evaluating Regional Infrastructure**
- **Promoting Regional Technology Transfer**

# $CO_2$-EOR Operations and $CO_2$ Sources (2014)

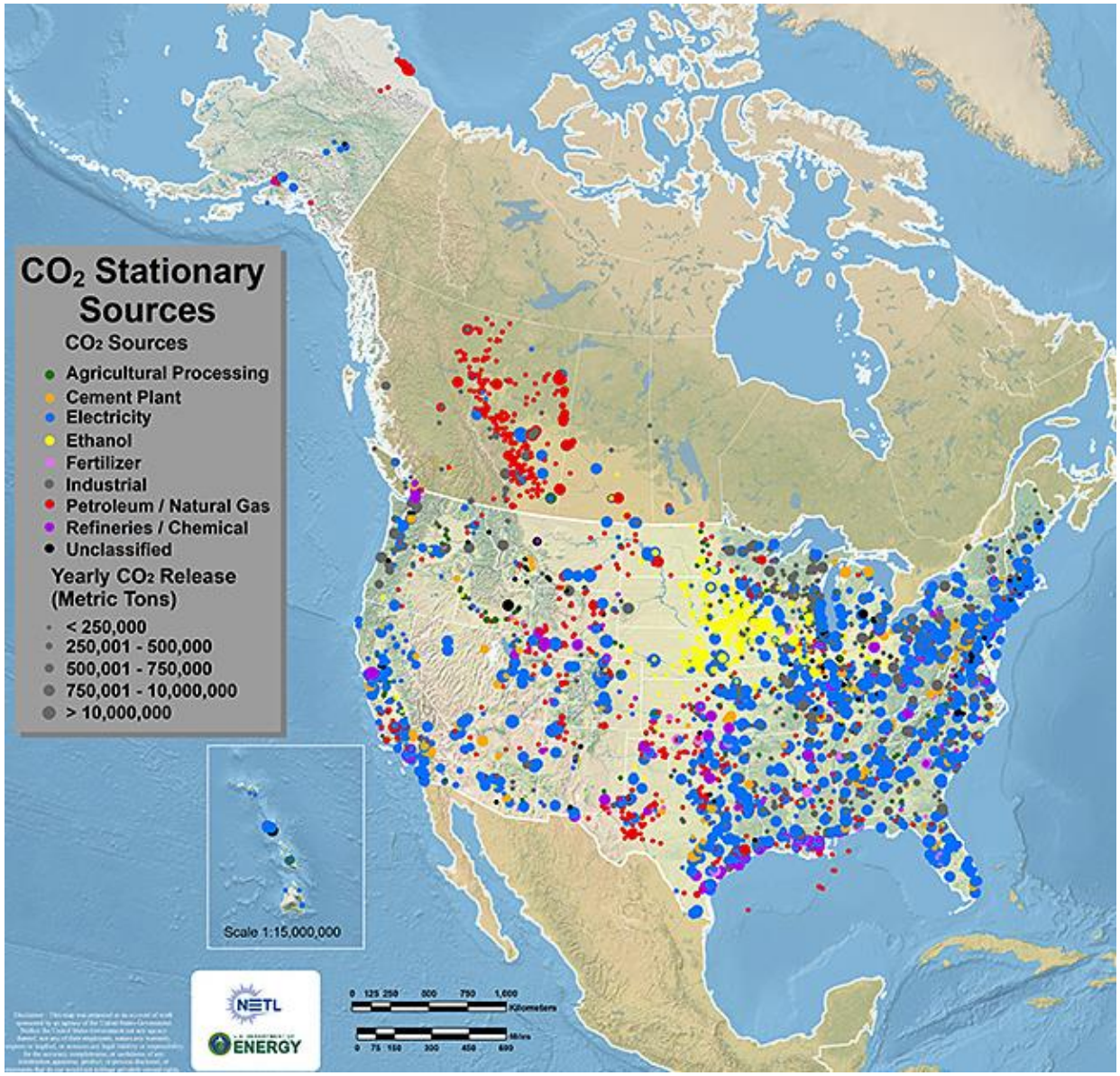



| Oil Production (2014) | |
|---|---|
| $CO_2$-EOR Projects | 136 |
| Oil Production (MBbl/d) | 300 |
| **$CO_2$ Supplies (2014)** | |
| Number of Sources | 17 |
| • *Natural* | *5* |
| • *Industrial* | *12* |
| $CO_2$ Supply (Bcf/d) | 3.5 |
| • *Natural* | *2.8* |
| • *Industrial* | *0.7* |

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.

# $CO_2$ STATIONARY SOURCES



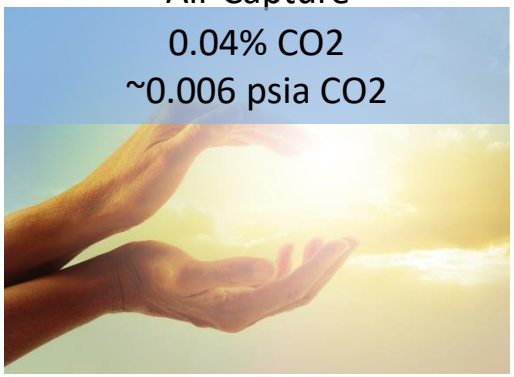
# CCUS – FLEXIBLE TECHNOLOGY FOR MULTIPLE APPLICATIONS

## $CO_2$ Source Concentration/Characteristics

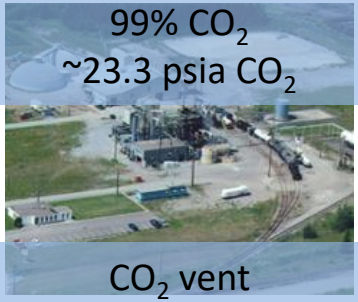
Coal Power Plant


Gas Power Plant


Air Capture

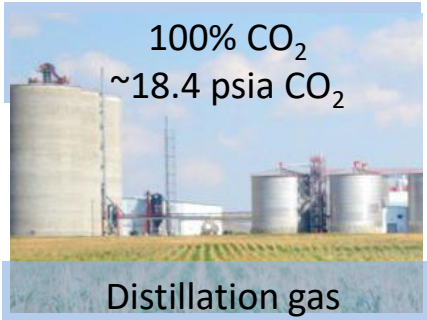



NG Processing Plant

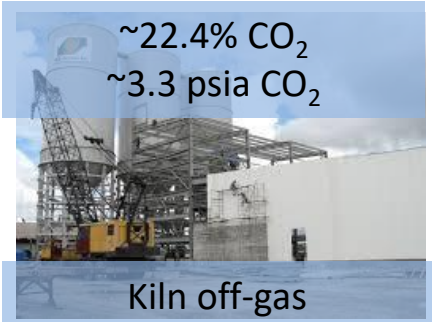



Ammonia Plant


Ethanol Plant




Cement Plant




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

# Engineering Scale Testing of Advanced Carbon Capture Technologies

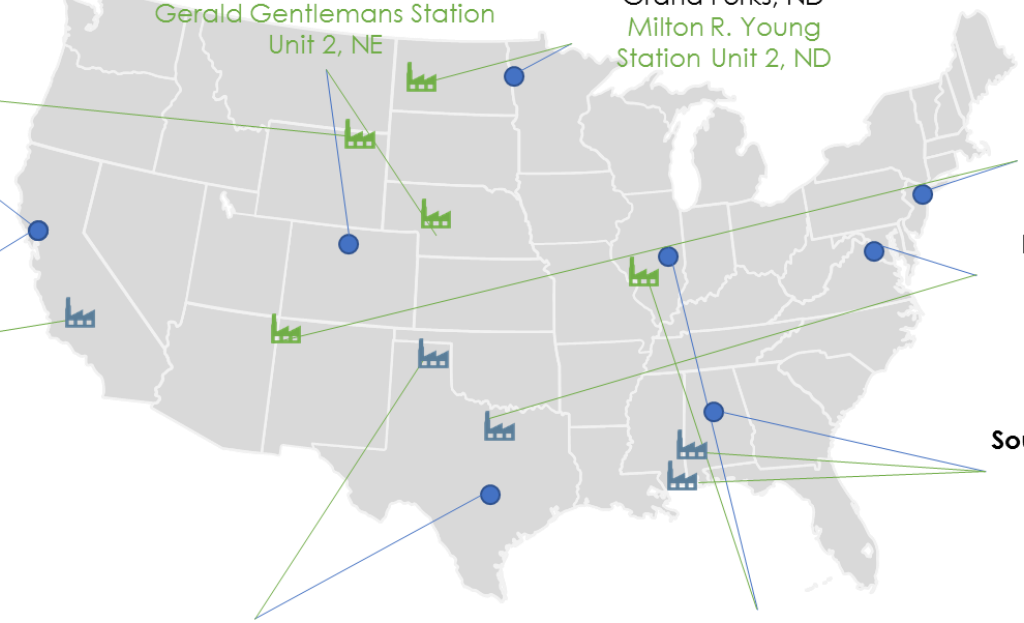
## Scaling of Carbon Capture Technologies to Engineering Scales Using Existing Host Site Infrastructure

| 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

# 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

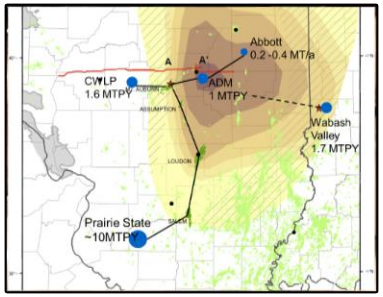
**Board of Trustees of the University of Illinois**
Champaign, IL
Prairie State Generating Company's Energy, IL

Natural Gas
Coal

# CARBON STORAGE ASSURANCE FACILITY ENTERPRISE –CARBON

## 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 $CO_2$ sources
- Thirteen projects funded

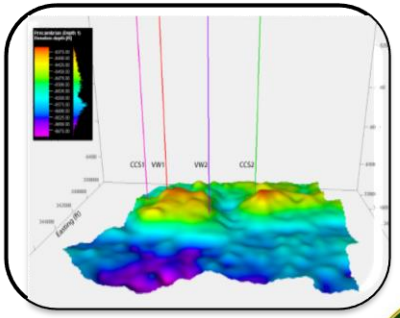



## Phase II: Storage Complex Feasibility
### 2-year initiative

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

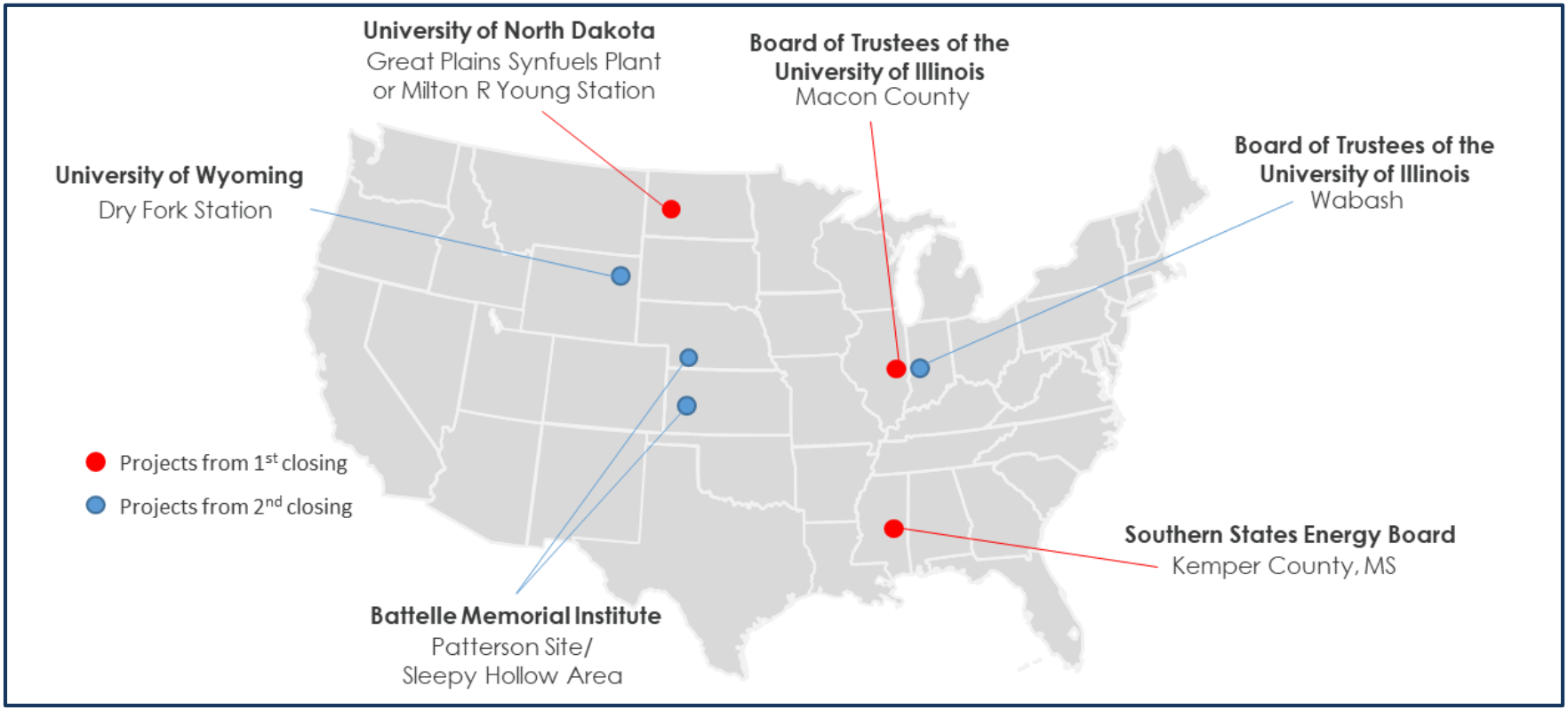
## Phase III: Site Characterization and $CO_2$ Capture Assessment
### 3-year initiative

- Detailed site characterization; obtain Underground Injection Control (UIC) Class VI Permit to construct; $CO_2$ Capture Assessment; NEPA approvals

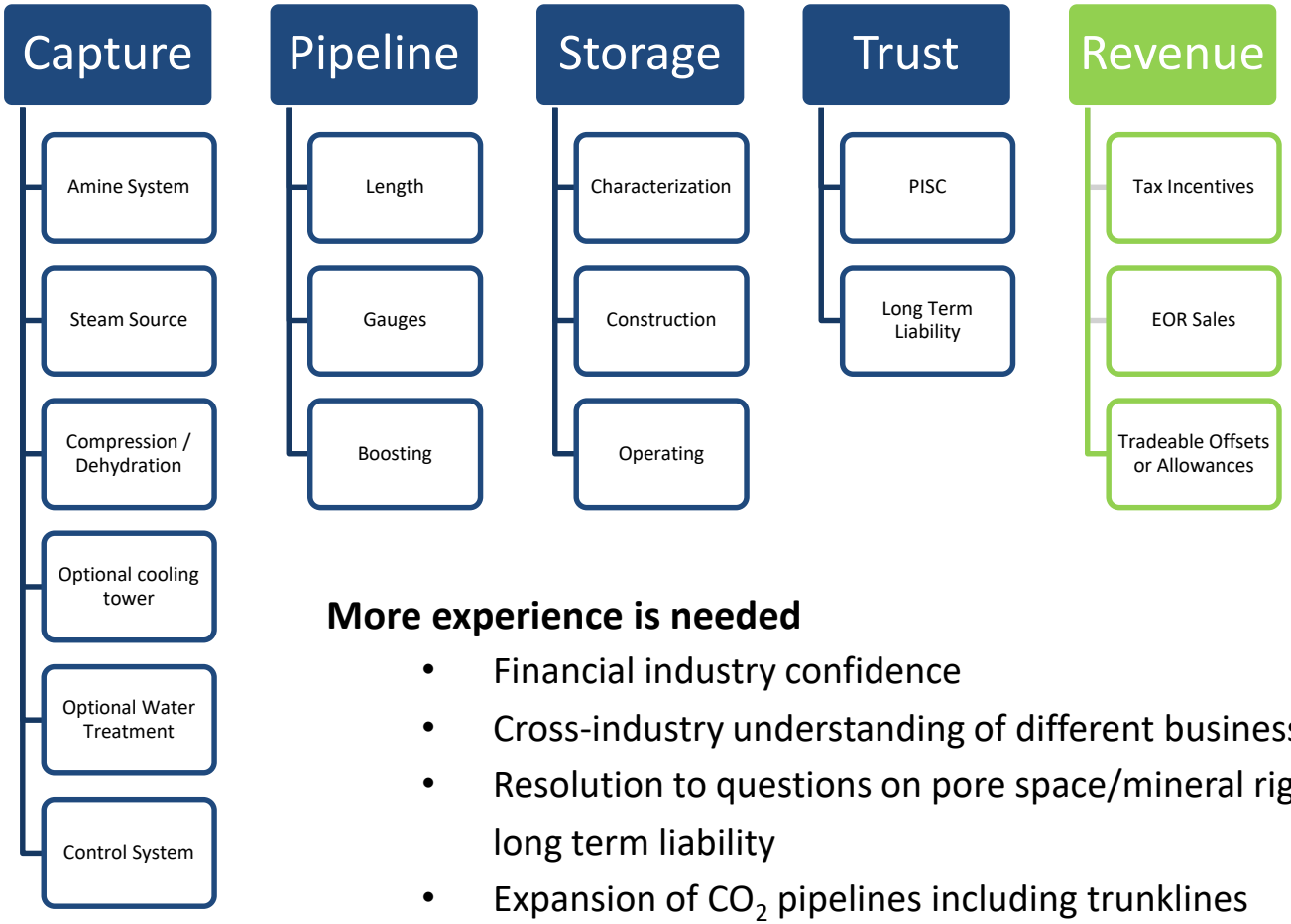


Link to Current FOA: https://netl.doe.gov/node/9138

## Reducing Risk—Increasing Certainty—Decreasing Costs



# BUSINESS CASE DEVELOPMENT




**More experience is needed**

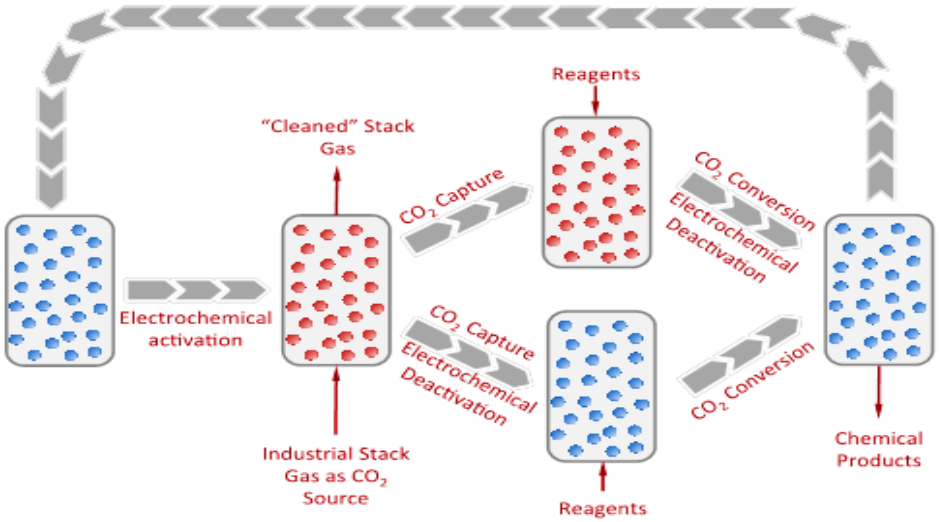
- Financial industry confidence
- Cross-industry understanding of different business models
- Resolution to questions on pore space/mineral rights and long term liability
- Expansion of $CO_2$ pipelines including trunklines
- Additional tools to help complete the CCUS toolbox
- Enabling operators to meet regulatory requirements

# CARBON UTILIZATION

OFFSET $CO_2$ CAPTURE COSTS + FIX $CO_2$ IN STABLE PRODUCTS

## Biological Capture & Conversion

## Fuels & Chemicals




## Mineralization & Cements

**24 Active Projects – Recently selected 11 lab and 4 field-scale projects**

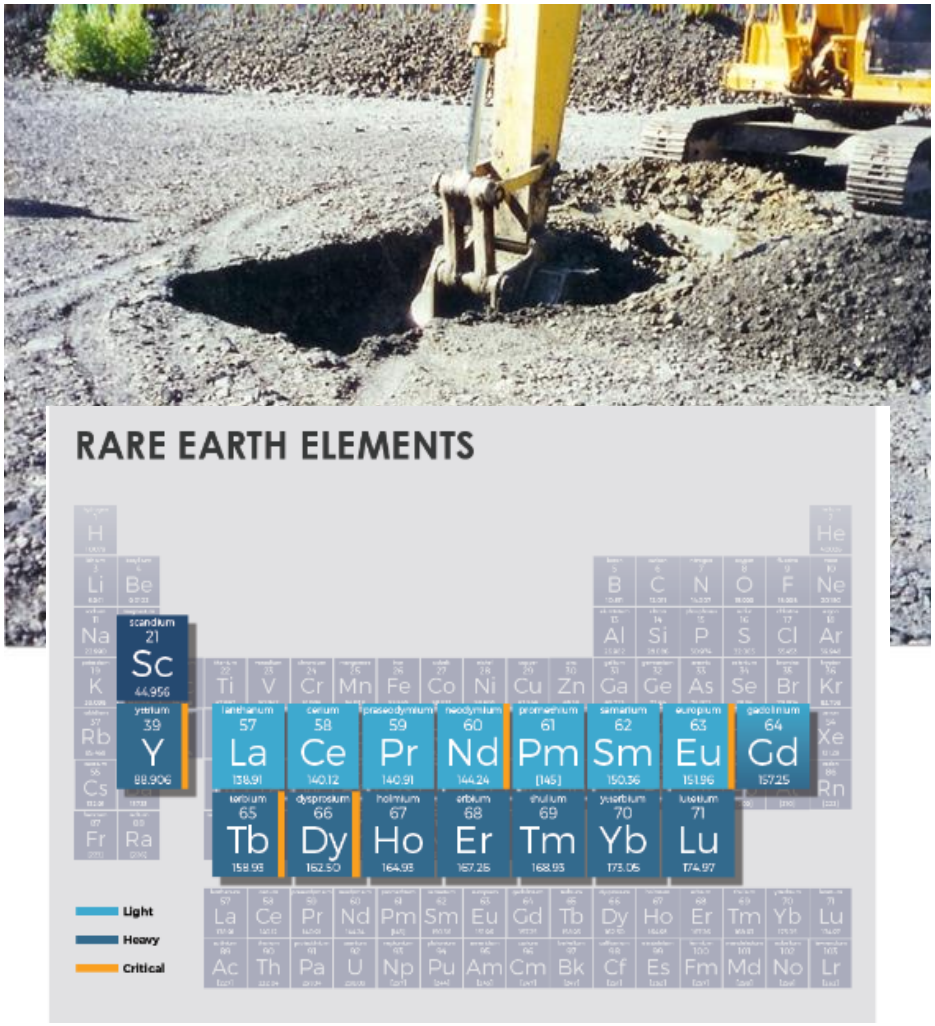
### Catalysis and Biological Pathways - Fuels and Chemicals

- Projects creating CO or direct to fuels using low-carbon energy and/or hydrogen

### Concrete: Solidia Technologies - Utilizes $CO_2$ to make cement and concrete

- Reduce carbon footprint up to 70%
- $1.9M DOE investment leveraged by industry
- Oil and Gas Climate Initiative's Climate Investment Funded and other parties

# COAL UTILIZATION – ADVANCED MATERIALS




## Critical Minerals

- Cobalt: 1,000+ PPM
- Nickel: 900+ PPM
- Manganese: 1.5+ wt%
- Rare Earths: 800+ PPM
- Zirconium: 2+ wt%
- Hafnium: 500+ ppm
- Yttrium: 1,000+ PPM
- Alumina: 30+ wt%)

## Advanced Materials

- Graphite
- Graphene
- Carbon fiber
- Coal pitch
- Needle coke

# FUTURE COMMERCIAL-SCALE DEPLOYMENT

## Integrated R&D Approach


**2017**
Large Capture Pilots Initiated

**2020**
R&D Completed for Carbon Capture 2nd Generation Technologies

**2025**
Integrated CCS Projects Deployed

**2035**
Transformational Technologies Available for Deployment

Deployments


**2017**
Initiate Storage Feasibility for Integrated CCS

**2022**
Commercial-scale Storage Complexes Characterized