Overview of the DOE CCUS R&D Program

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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?”
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

<table>
<thead>
<tr>
<th></th>
<th>FY 2016</th>
<th>FY 2017</th>
<th>FY 2018</th>
<th>FY 2019</th>
<th>FY 2020</th>
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</thead>
<tbody>
<tr>
<td>Carbon Capture</td>
<td>101.0</td>
<td>101.0</td>
<td>100.7</td>
<td>100.7</td>
<td>117.8</td>
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<tr>
<td>Carbon Storage</td>
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<td>85.3</td>
<td>86.0</td>
<td>86.0</td>
<td>79.0</td>
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<tr>
<td>Carbon Utilization</td>
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<td>10.0</td>
<td>12.0</td>
<td>12.0</td>
<td>21.0</td>
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</table>

$ millions
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

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/NELT-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)
### CAPTURE FEED Studies Selections in September 2019

Nine projects selected ($55.4M total)

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

<table>
<thead>
<tr>
<th>Awardee</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bechtel National</td>
<td>FEED Study for Retrofitting a 2x2x1 Natural Gas-Fired Gas Turbine Combined Cycle Power Plant for Carbon Capture Storage/Utilization – MEA Solvent</td>
</tr>
<tr>
<td>The Board of Trustees of the University of Illinois</td>
<td>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</td>
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<tr>
<td>Electric Power Research Institute</td>
<td>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</td>
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<tr>
<td>Enchant Energy</td>
<td>Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station – Commercial Solvent</td>
</tr>
<tr>
<td>Membrane Technology and Research Inc.</td>
<td>Commercial-Scale Front-End Engineering Study for MTR’s Membrane CO(_2) Capture Process – MTR, Inc Polymeric Membrane</td>
</tr>
<tr>
<td>Minnkota Power Cooperative Inc.</td>
<td>Front-End Engineering &amp; Design: Project Tundra Carbon Capture System – Fluor’s amine-based Econamine FG Plus</td>
</tr>
<tr>
<td>Southern Company Services</td>
<td>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</td>
</tr>
<tr>
<td>The University of Texas at Austin</td>
<td>Piperazine Solvent/Advanced Stripper Front-End Engineering Design (PZAS FEED)</td>
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</table>
Carbon Utilization R&D – Creating Value from CO$_2$

- 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)

CarbonSAFE

Offshore Storage

Unconventional EOR

Brine Extraction Storage Tests (BEST)

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

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
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”
Carbon Storage Assurance Facility Enterprise (CarbonSAFE)

- 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

Membrane Technology and Research, Inc.,
Basic Electric Dry Fork Station, WY

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

Ion Clean Energy Systems, Nebraska
Public Power District,
Gerald Gentleman Station, NE

Electric Power Research Institute, Elk Hills Power Plant, CA

Enchant Energy, LLC
San Juan Generation Station, NM

Carbon Utilization and Storage Partnership

PCOR Initiative

Midwest Regional Carbon Initiative

SECARB-USA

CarbonSAFE Phase III Projects (Awards Pending)

North Dakota CarbonSAFE Phase III: Site Characterization and Permitting (UNDEERC)

Wyoming CarbonSAFE: Accelerating CCUS at Dry Fork Power Station (UofW)

Illinois Storage Corridor (Univ. of Illinois)

Establishing an Early CO2 Storage Complex in Kemper County, Mississippi: Project ECO2S (SSEB)

San Juan Basin CarbonSAFE Phase III: Ensuring Safe Subsurface Storage of CO2 in Saline Reservoirs

Capture Program FEED Studies

Coal

Natural Gas

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

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

Bechtel National, Inc.,
Panda Power Funds, TX

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

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

- Annual Carbon Storage Meeting
- RCSP Working Groups
- Domestic Collaborations
- International Collaborations
- Technical Workshops

Worldwide CCS Project Database

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

CCUS Applications for Industrial and Natural Gas

CCUS Enabling Low- or Carbon-Free Hydrogen Production
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

www.energy.gov/fe

https://www.netl.doe.gov

facebook.com/FossilEnergy

twitter.com/fossilenergygov