

United Stated Energy Association DOE CCUS R&D Program Update

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FOSSIL ENERGY is critical in all sectors CCUS is A platform technology for many industrial sectors



EIA, Annual Energy Outlook 2017, Reference Case, https://www.eia.gov/totalenergy/data/monthly/pdf/flow/css_2017_energy.pdf

80% Fossil Energy

WHAT IS CARBON CAPTURE





Federal Government Roles in CCUS



Office of Clean Coal and Carbon Management FY 2019 Budget: \$486.2 Million

The Mission of the Office of Clean Coal and Carbon Management's R&D program is to discover and develop advanced coal technologies that ensure America's access to resilient, affordable, reliable, and near-zero emitting coal energy resources.

Our R&D is focused on the following priorities:

- 1. Advancing small-scale modular coal plants of the future, which are highly efficient and flexible, with near-zero emissions
- 2. Improving the performance, reliability, and efficiency of the existing coal-fired fleet
- 3. Reducing the cost of carbon capture
- 4. Creating new market opportunities for coal.







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 CO₂ from two large **steam methane reformers**
- 5.0 million metric tons of CO₂ 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 CO₂ from 240-MW flue gas stream (designed to capture/store 1.4 million metric tons of CO₂ per year)
- Over 3 million metric tons of CO₂ 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
- CO₂ 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 CO₂ storage
- 1.0 million metric tons of CO₂ captured, 0.8 million metric tons of we stored, since April 2017

Federal investment in DOE CCUS R&D



Carbon capture

R&D and scale-up technologies for capturing CO₂ from new and existing industrial and powerproducing plants



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



Carbon storage

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





Carbon Capture Carbon Storage Carbon Utilization

Matching "technology push" through R&D with "market pull" through financial incentives

- Tax benefits defined in "45Q" for qualified CCUS projects have been available since 2008
- The February 2018 "Bipartisan Budget Act of 2018" extended and significantly expanded the tax benefits:
 - Increased the credit amount:
 \$20/ton → up to \$50/ton for saline storage, 10/ton → up to \$35/ton for EOR
 - Expanded the qualified carbon oxides to include carbon monoxide (CO)
 - Expanded qualified uses to include CO₂ utilization other than enhanced oil or natural gas recovery
 - Lowered the qualifying threshold for the amount of CO₂ captured to allow more industries to participate in the program
 - Increased the flexibility to allow credit assignment to capture or disposal facility
 - Removed the program cap

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 (\$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)

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- Geomechanics (pressure and state of stress)
- Costs/uncertainty/enabling real-time decision making

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

2012: \$80/tonne

2016: \$60

2020: \$45

2030: \$30

Carbon Capture Activities

- \$30/tonne Transformational Carbon Capture Technologies for both pre and post combustion capture
- Direct Air Capture (leverage existing DAC projects, historical investments in post-and pre-combustion capture, and NAS study – Workshop Jul 24, 2019)
- Process development and design R&D and Carbon Capture Simulation Initiative for Industry
- Technology Validation National Carbon Capture Center and other test centers
- FEED Studies for Commercial Carbon Capture Plants (\$30+M) – Selections Pending
- Large Scale Pilots (10MWe+) 6 Technologies
 Selected







Carbon Capture: Post-Combustion, Pre-Combustion, and Direct Air Capture

Focus on Cost Reduction, Energy Penalty, and Integration



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



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
- Small (0.05MWe) and Large (0.5MWe) Solvent Test Units



Carbon Utilization

*Offset CO*₂ *capture costs + Fix CO*₂ *in stable products*

Biological Capture & Conversion

Fuels & Chemicals

Mineralization & Cements



Over 20 active projects creating products from CO₂



DAC: LEVERAGING EXISTING FE R&D TECHNOLOGIES



- Low Concentration (400ppm)
- Low efficiency 10-50%
- Large volumes of air flow
- No contaminants
- Requires low pressure drop larger machines
- Unique Material Properties Fast kinetics, low oxidation rates

- CO₂ concentrations 100-300X that of air.
- High efficiency (90+%)
- Higher pressure and temperatures
- Contaminants (SO2, NOx, particulates, etc)
- Higher pressure drops
- Unique Material Properties Low degradation rates, low heat of RX



DAC/DILUTE SOURCE CAPTURE: FE/NETL PROJECTS

\$200+/tonne



Fixed-bed laboratory unit for testing structured sorbents

https://www.netl.doe.gov/research/coal/project-information/proj?k=SC0015114

\$300+/tonne

The Ohio State University

Membranes (<1% CO₂ concentration)



Continuous membrane fabrication machine at OSU

https://www.netl.doe.gov/research/coal/projectinformation/proj?k=FE0026919



Products: Animal feeds

Test at Orlando Utilities Commission – Stanton Energy Center site Algae Cultivation to capture CO2 from Power Plants and Air \$300+/tonne

\$200+/tonne**

Carbon Engineering

Wet scrubbing air contactor (400 ppm Direct Air Capture)



Carbon Engineering's research pilot facility in Squamish, BC

https://www.netl.doe.gov/research/coal/project-information/proj?k=FE0026861



Products: Biofuels, food, & nutraceuticals

Test at NCCC



DOE Efforts in FY19 and FY20

- > Workshop for DAC R&D Priorities July 24, 2019
- Techno economic assessment (TEA) Baseline for DAC FY2019 (In progress)
- National Resources Assessment for DAC FY2020 (In progress)

Funding Opportunities

- University Coal Fossil Energy Research on Materials novel DAC materials (FY2019)
- Funding Opportunity Announcement / Lab Call (FY2020)



Carbon Storage

Improving and Optimizing Performance

Regional Carbon Sequestration Partnerships (RCSPs)

CarbonSAFE



CARBON STORAGE PROGRAM

axce 0 (5) 0 (2) (40 (5) (8) Water Saturation (Sw) (%)

Unconventional

EOR



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



ADVANCED STORAGE R&D

Wellbore Integrity and Mitigation Storage Complex Efficiency and Security Monitoring, Verification, Accounting (MVA) and Assessment

STORAGE INFRASTRUCTURE

Regional Carbon Sequestration Partnerships Initiative

Characterization Field Projects (Onshore and Offshore)

Fit-For-Purpose Projects

RISK and INTEGRATION TOOLS

Fiber Optic Distributed Acoustic Sensing (DAS)

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



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CARBONSAFE PHASE II



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Integrated portfolio consisting of:

Field Projects

- Regional Partnerships
- Unconventional EOR
- Offshore
- Brine Extraction Storage Tests
- CarbonSAFE

Advanced Storage R&D

- Monitoring and measurement technologies
- Wellbore integrity
- Modeling and simulation tools
- Risk assessment

Addressing key challenges to accelerate commercial-scale deployment....

...and sharing knowledge and information to key stakeholders.



The U.S. is THE global leader on CCUS research, development, and deployment



Modeling Impact of 45Q and R&D on CCUS Deployment





CCUS Retrofit Case Study – Benefits of 45Q and EOR

Purpose

Develop a techno-economic study of adding carbon capture, utilization and storage (CCUS) to existing coal plants

- Focus on existing energy and CO₂ markets
- Considered "what makes sense from a business perspective"

Location

Based on existing natural CO₂ resources and pipeline infrastructure

Analysis

Phase I: Assess potential carbon dioxide (CO₂) markets to support CCUS application

• Result: Colorado selected

Phase II: Techno-economic case study of adding CCUS to a representative coal plant

• Result: Comanche Generating Station selected

Phase II: Plant Analysis

Comanche Generating Station determined to have met established criteria

✓CO₂ source: coal-fired power plant (3 units)

✓ CO₂ pipeline proximity (Sheep Mountain Pipeline)

Comanche Station Snapshot

- Three coal-fired units
 - 325 MW, 335MW, 750 MW
- Owned by Xcel Energy *
- Planned retirement for Units I (2022) and II (2025)
- * Xcel Energy was not consulted or directly involved in the study



Phase II: Summary

Evaluation Scenarios

- Established costs and benefits under three scenarios
 - ➢BAU, or Business as Usual

>CEP, or Colorado Energy Plan (renewable energy incorporation, units I and II retired)

CCUS, or Carbon Capture Retrofit (no units retired)

Key Takeaways

- CCUS scenario results in similar cost of electricity (COE) and a highest percentage reduction in CO₂ emissions
- CCUS scenario results in significant positive effect on economy & jobs
- Credits from 45Q and revenues from the sale of CO₂ for EOR can offset the cost of electricity for Comanche Station, with a resulting reduction in the COE

Table EX 1: Summary of the Three Electricity Options for Colorado

	BAU	CEP	ccus
Coal Retirements	2033/2035	2022/2025	Not Retired
Resource Acquisition Period (RAP) Resource Need (MW) (by 2023)	450	775	450
Wind Additions (MW)	789 MW	1,131 MW	0
Solar Additions (MW)	322 MW	707 MW	0
Battery Storage (MW)	50 MW	275 MW	0
Generation Investment (\$M)	\$1,460	\$2,550	\$3,738
Transmission Investment (\$M)	\$175	\$204	-
Total Investment (\$M, nominal)	\$1,636	\$2,754	\$3,738
Reduction in CO ₂ Emissions in 23 Years (2020-2042) relative to Fleet- Wide 2005 Emissions	45%	52%	65%

- 40+ year history of CO₂ utilization for EOR
- Over 600 million tons of associated storage with EOR
- Over 4,000 miles of CO₂ 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 three 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, including 45Q guidance.



Thank you!

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