U.S. Department of Energy
Carbon Capture and Sequestration

CCUS Major Demonstrations Program Overview

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**U.S. DOE CCS Major Demonstration Projects**

- **Archer Daniels Midland (ADM)**
  - CO₂ Capture from Ethanol Plant
  - CO₂ Stored in Saline Reservoir
  - SALINE – ~0.9 MM TPY;
  - Started Operations: April 2017

- **Southern Company**
  - Kemper County IGCC Project
  - Transport Gasifier w/ Carbon Capture
  - Startup Suspended: June 2017

- **Petra Nova**
  - W.A. Parish Generating Station
  - Post Combustion CO₂ Capture
  - EOR – ~1.4 MM TPY;
  - Started Operations: January 2017

- **Air Products and Chemicals, Inc.**
  - CO₂ Capture from Steam Methane Reformers
  - EOR in Eastern TX Oilfields
  - Over 3.7 MMT already stored as of May 2017!
  - Started Operations: March 2013
Petra Nova – NRG Energy W.A. Parish, CCPI-3

Advanced Post Combustion CO₂ Capture

• Project at NRG’s W.A. Parish power plant near Houston TX
• Retrofit of Existing Coal Plant to process flue gas from W.A. Parish Unit 8 - Post-Combustion CO₂ capture
• World’s largest post-combustion CO₂ capture system
• Project was completed On-Budget and On-Schedule
• Delivering and permanently storing around 1.4 million metric tons of CO₂ per year for EOR.
• 240 MWe slipstream scaled up to improve project economics
• 90% CO₂ capture from supplied flue gas (KM CDR Process®)
• Technology applicable to retrofit of existing coal plants
• EOR at the Hilcorp West Ranch oil field.
• Total Project Cost: ~$1 billion (DOE Cost Share: $190 MM)
  — NRG Equity - $300 million
  — JX Nippon Equity – $300 million
  — JBIC Project Financing - $250 million
  — MHI – Technology Provider

Key Dates:
- Project Awarded: May 2010
- NEPA Record of Decision: May 2013
- Financial Close: July 2014
- Construction Complete: December 2016
- Construction Completed On-Budget and On-Schedule
- Started Operations: January 10, 2017
- Ribbon Cutting Ceremony: April 13, 2017

Petra Nova project “...demonstrates that clean coal technologies can have a meaningful and positive impact on the Nation’s energy security and economic growth.”

U.S. DOE Secretary Rick Perry, April 13, 2017
Air Products & Chemicals Inc., ICCS Area 1

Steam Methane Reforming with CO$_2$ Capture

- Built and operated by Air Products and Chemicals Inc. and located at Valero Oil Refinery in Port Arthur, TX.
- CO$_2$ capture added to 2 existing Steam-Methane Reformers (SMRs) used for Hydrogen Production
- Project achieves 90+% CO$_2$ capture using Vacuum Swing Adsorption (VSA) for CO$_2$ separation
- Capturing ~925,000 tonnes CO$_2$/year
- ~30 MWe cogeneration unit makeup steam to SMRs and power to VSA and Compressors
- CO$_2$ to Denbury “Green” pipeline for EOR in Texas at the West Hastings oil field
- Total Project cost: $431 MM;
- DOE Share: $284 MM (66%)
- Project was executed on time and under budget
- Project has operated >100% of design when needed

Key Dates:
- Phase 2 Awarded: June 15, 2010
- Construction started: Aug. 2011
- Started Operations: March 2013
- 1 MM Tons of CO$_2$ delivered Apr 2014
- 2 MM Tons of CO$_2$ delivered May 2015
- 3 MM Tons of CO$_2$ delivered May 2016
- 4 MM Tons of CO$_2$ expected Sep. 2017
Archer Daniels Midland Co., ICCS Area 1
CO₂ Capture from Biofuel Plant

- CCS project built and operated by Archer Daniels Midland (ADM) at their existing biofuel plant
- located in Decatur, IL
- CO₂ is a direct by-product from production of fuel-grade ethanol via anaerobic fermentation
- Up to 90% CO₂ capture (with >99% CO2 purity), dehydration (via tri-ethylene glycol) & compression
- ~900,000 tonnes CO₂/year captured and stored
- CO₂ Sequestration in Mt. Simon Sandstone deep saline formation.
- ADM is the first project to use the new EPA UIC Class VI well permit for CO₂ sequestration
- Total Project Cost: $208 MM
- DOE Cost Share: $141 MM (68%)

Key Dates:
- FEED Completed: April 2011
- Construction started: May 2011
- Two monitoring wells drilled: Nov. 2012
- UIC Class VI Injection Well Permit: Sept. 2014;
- Injection well drilled and completed: Sept. 2015
- Construction complete Apr. 2016
- Started Commercial Operations: April 7, 2017
- Project Opening Ceremony: September 22 2017
Kemper County – Southern Company Services, Inc., CCPI-2
Advanced IGCC with CO₂ Capture

Project Background:
- New Built Coal Plant In Kemper County, MS
- First Base Load Unit Built in 30 years and Located Away from the Coast after Hurricane Katrina
- Mississippi Power is a PSC Regulated Utility
- Generation: 582 MWe (net) with duct firing
- 2 TRIG™ gasifiers developed by Southern Co. and KBR
- Fuel: Local Mississippi Lignite
- 67+% CO₂ capture (Selexol® process)
- ~3,000,000 metric tons CO₂/year
- EOR: Denbury Onshore LLC

Current Status:
- Over 200 days of gasifier operation accomplished before start-up operations were suspended.
- Plant will continue to produce electricity using Natural Gas
- Negotiations with Mississippi PSC continuing

Key Dates:
- Project Awarded: Jan. 30, 2006
- Project moved to MS: Dec. 5, 2008
- NEPA Record of Decision: Aug. 19, 2010
- Initiate excavation work: Sept. 27, 2010
- CC operation on Nat Gas: August 2014
- First Syngas production initiated: July 14, 2016
- Project Startup Suspended: June 28, 2017
Today’s Challenges - Natural Gas a Key Factor in Projected Future US Energy Mix

Source: EIA Annual Energy Outlook 2017
U.S. DOE FE is Advancing Clean Coal Technologies

Making Coal Plants More Efficient
- Increase Efficiency at Existing U.S. Coal Plants
- Advanced Turbines,
- Advanced Combustion,
- Fuel Cells,
- 2nd Gen Materials, Sensors, Modeling Technologies
- Supercritical CO2 Research,
- Coal Based Rare Earth Elements (RRE)

Capturing More CO2
- Cost-effective carbon capture for new and existing power plants

Turning CO2 into Valuable Products
- New pathways CO2 Utilization

CO2 Utilization
- Safe use and permanent storage of CO2 from power generation and industry

Crosscutting technology development program

Bringing it All Together

Making Coal Plants More Efficient
U.S. DOE Helping to Identify Efficiency Improvements at Existing U.S. Coal Power Plants

- U.S. coal power plants represent ~30% of all U.S. power generation
- Coal is a critical part of U.S. power generation fuel diversity
- Coal plants are competing with low cost Natural Gas
- DOE is helping U.S. coal power plants to improve their thermal efficiency (Plant Heat Rate)
  - Increase Boiler Efficiency
  - Examine Potential Turbine Enhancements/Retrofits
  - Efficiency Enhancements of Condensers, Pumps, Fans, Heaters and Other Equipment
  - Investigate Coal Beneficiation Options (Fuel Delivery and Pre-Processing of Coal to Enhance Coal Quality)
  - Identify New Economic Opportunities (ex. CO₂ for EOR potential, REE extraction, etc.)
  - Operational Improvements (ex. Plant Cycling, Control Systems, etc.)

- Plant efficiency improvements translate to overall lower emissions (including CO₂, SO₂, NOx, Hg)
- Heat Rate improvements allow the coal plants to be more economical and more competitive with other fuels.
U.S. DOE Transformative R&D: Supercritical Carbon Dioxide (sCO2)

**Supercritical CO$_2$:** A highly efficient working fluid

- Higher thermal efficiencies, smaller physical footprint, and lower capital costs
  - (than conventional steam-based power generation)

**Diverse fuel/heat sources**

- COAL
- SOLAR
- WASTE MFG. HEAT
- NATURAL GAS
- NUCLEAR

**Cleaner, more efficient and affordable electricity**
Coal-Based Rare Earth Elements (REE’s)

Objectives:
• Establishment of the Economic Production of REE’s from Coal and Coal Byproducts
• Identify Highest Rare Earth Content Materials in the U.S. Coal Value Chain
• Ore-Specific Plant Designs for these Materials
• Financial Projections for Rare Earth Production from these Materials
• Economic U.S. Rare Earth Production Opportunities

Strategies:
• Engagement of U.S. Technical Resources, Including Industry and Academia
• Where Required, Technology Development

Future Directions:
• Expanded Search for High Rare Earth Assays
• Pilot-Scale Operations
U.S. DOE National Carbon Capture Center (NCCC)

- Operated by Southern Co. Services
- Hosted at Plant Gaston, AL
- DOE funds 80% of operations
- Over 91,000 test hours
- Technologies from U.S. and six other countries since 2008 founding of NCCC
- More than 40 carbon capture technologies tested
  - 20+ Post combustion
  - 20+ Pre-combustion
- Dedicated staff of plant engineers
- Standard design guidelines
- Small and Large Solvent Test Units
- 90+% of US developers opt for NCCC
Potential Policy Incentives for CCUS

• Tax and financial incentives to support CCUS deployment are currently under consideration
• The tools under consideration include:
  – Incentives for CO₂ storage-EOR including expansions of the existing 45Q tax credit provisions
  – Investment tax credits (ITCs)
  – CO₂ price stabilization and market creation
  – Master Limited Partnerships (MLPs)
  – Private Activity Bonds (PABs)
• Diverse stakeholder support for proposed CCUS legislation
Sample of State CCUS Policies

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**Liability:** How long the operator is responsible for the site post closure.

**Storage Fund:** A fund established for the long-term management and monitoring of CCS storage sites

**Pore Space:** Who owns the pore space into which the CO₂ is injected

**CO₂ Owner:** Post-Injection owner of CO₂

**Unitization:** Minimum % of landowners which must agree to project

**Primacy:** CCS rights granted to mineral rights holders

**Inter-state boundary issues.**
Potential CO$_2$ Utilization - Oil and Gas Fields

Source: Workshop on Siting and Regulating Carbon Capture and Storage (CCS) Infrastructure, April 8, 2016
Coal and CCUS Activities in the U.S. – Historically Focused on Technology Development and Market Mechanisms

**DOE Technology Push**

- Develop new coal power plant technologies
- Improve efficiency at existing coal plant
- CO₂ R&D focused on: cost (capture) and confidence (storage)
- Demos (integration and learning)

**Market Pull**

- Existing Market Mechanisms: Enhanced Oil Recovery (EOR)
  - 65 million tons per year of CO₂ to produce nearly 300,000 barrels of oil per day.
- Regulatory Framework
- Financing (Tax Credits and Loan Guarantees)
For More Information

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