CCS Demonstrations Status & Lessons Learned

Michael K. Knaggs
Associate Director, Strategic Partnerships
NETL’s New Organizational Structure

**Office of the Director**
*Dr. Grace M. Bochenek, Director*

Associate Deputy for Business Transformation – Scott Klara
Congressional Relations & Public Affairs

**Office of Chief Counsel**
*R. Paul Detwiler, Chief Counsel*

**Science & Technology**
Strategic Plans & Programs
*Dr. Cynthia Powell, Deputy Director & Chief Technology Officer*

- **Strategic Planning:**
  - Effective Resource Development
  - Efficient Energy Conversion
  - Environmental Sustainability

- **Strategic Partnerships:**
  - University/Natl Lab
  - Industrial/Tech Transfer
  - Global
  - State/Local

**Laboratory Operations Center**
*Susan Malie, Deputy Director & Chief Operating Officer (Acting)*

**Research & Innovation Center**
*Dr. Bryan Morreale, Executive Director (Acting)*

**Technology Development & Integration Center**
*Dr. Sean Plasynski, Executive Director*

**Finance & Acquisition Center**
*James Wilson, Executive Director & Chief Financial Officer*

**Office of S&T Career Management**
*Director*
Major CCS Demonstration Projects

Project Locations & Cost Share

- **Summit TX Clean Energy**
  - Commercial Demo of Adv. IGCC w/ Full Carbon Capture; EOR in Permian Basin
  - ~$3.2B – Total; $346M – DOE
  - EOR – ~1.71 MMTPY; late 2018 start

- **HECA**
  - Commercial Demo of Advanced IGCC w/ Full Carbon Capture
  - ~$5B – Total; $286M – DOE
  - EOR or saline – ~2.5 MMTPY; TBD start

- **Petra Nova**
  - W.A. Parish Generating Station
  - Post Combustion CO₂ Capture
  - $1B – Total; $167M – DOE
  - EOR – ~1.4 MMTPY; early 2017 start

- **Southern Company**
  - Kemper County IGCC Project
  - Transport Gasifier w/ Carbon Capture
  - ~$6.9B – Total; $270M – DOE
  - EOR – ~3.0 MMTPY; 3rd Qtr 2016 start

- **Air Products & Chemicals, Inc.**
  - CO₂ Capture from Steam Methane Reformers
  - EOR in Eastern TX Oilfields
  - $431M – Total; $284M – DOE
  - EOR – ~0.93 MM TPY; started December 2012; 2.7 MMT stored as of March 2016

- **Archer Daniels Midland**
  - CO₂ Capture from Ethanol Plant
  - CO₂ Stored in Saline Reservoir
  - $208M – Total; $141M – DOE
  - Saline – ~0.9 MM TPY; 2016 start

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**Project Details**

- **Kemper County IGCC Project**
  - Transport Gasifier w/ Carbon Capture
  - ~$6.9B – Total; $270M – DOE
  - EOR – ~3.0 MMTPY; 3rd Qtr 2016 start

- **W.A. Parish Generating Station**
  - Post Combustion CO₂ Capture
  - $1B – Total; $167M – DOE
  - EOR – ~1.4 MMTPY; early 2017 start

- **Dow Chemical**
  - Commercial Demonstration of Advanced IGCC w/ Full Carbon Capture
  - ~$5B – Total; $269M – DOE
  - EOR or saline – ~2.5 MMTPY; TBD start

- **Summit Texas Clean Energy**
  - Commercial Demo of Adv. IGCC w/ Full Carbon Capture; EOR in Permian Basin
  - ~$3.2B – Total; $346M – DOE
  - EOR – ~1.71 MMTPY; late 2018 start

- **Air Products & Chemicals, Inc.**
  - CO₂ Capture from Steam Methane Reformers
  - EOR in Eastern TX Oilfields
  - $431M – Total; $284M – DOE
  - EOR – ~0.93 MM TPY; started December 2012; 2.7 MMT stored as of March 2016

- **Archer Daniels Midland**
  - CO₂ Capture from Ethanol Plant
  - CO₂ Stored in Saline Reservoir
  - $208M – Total; $141M – DOE
  - Saline – ~0.9 MM TPY; 2016 start
Southern Company Services, Inc. CCPI-2
*Kemper County Advanced IGCC with CO₂ Capture*

- Kemper County, MS
- 582 MWe (net) with duct firing; 2 TRIG™ gasifiers, 2 Siemens combustion turbines, 1 Toshiba steam turbine
- Fuel: Mississippi lignite
- 67+% CO₂ capture (Selexol® process); 3,000,000 tons CO₂/year
- EOR: Denbury Onshore LLC, Treetop Midstream Services LLC
- Total DOE CCPI Project: $2.01 B; DOE Share: $270 MM (13%)
- Total estimated project cost: ~$ 6.88B

**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
- Operations: 3rd Qtr 2016

**Status**
- Plant construction >99% complete
- Peak construction labor 6,121
- Lignite mine in commercial operation: June 2013
- Combined cycle commercial operation on natural gas: Aug. 2014
- Gasifier “First Fire” of natural gas startup pilot burners: Mar 2015
Kemper County IGCC Project

Liberty Mine

Lignite Storage Dome

Ash Management Area

Gasification Area

Gas Cleanup Area

Combined Cycle Area

Treated Effluent Reservoir

Water Treatment Area
Kemper County IGCC Project
Construction Progress

Selexol unit (acid gas removal)

Entire plant from south

Sulfuric acid production unit

Lignite delivery facility
CCPI-3 Texas Clean Energy Project
Advanced IGCC-Polygen

- Penwell, Ector County, TX (greenfield)
- \( \sim 445 \text{ MW}_{\text{th}} \) (syngas); \( \sim 405 \text{ MW}_e \) (CC plant);
  \( \sim 205 \text{ MW}_e \) (net) to utility grid
  - 1x 100% Siemens SFG-850 gasifier
  - 1 x 1 CC Siemens high-H\(_2\) SGT6-8000H & SST-900RH w/HRSG
- Fuel: PRB sub-bituminous coal
- > 90% CO\(_2\) capture from syngas: \( \sim 2.25 \text{ MMtpy} \) CO\(_2\)
  (90% carbon capture from total plant)
  - \( \sim 1.71 \text{ MMTPY} \) to EOR (Permian Basin); \( \sim 0.54 \text{ MMtpy} \) to Urea
  - 3-stage Water Gas Shift; Linde Rectisol\textsuperscript{®} Wash AGR
- \( \sim 0.700 \text{ MMtpy} \) granulated Urea fertilizer
- ZLD; 30% less water use through air-cooling of CC plant
- Total DOE Project: $1.727 B; DOE Share: $346 MM (20%)
- Total estimated project cost: \( \sim 3.2B \) (all in)

**Key Dates**
- Project Awarded: January 2010
- Air Permit: December 2010
- NEPA Record of Decision: Sept. 2011

**Status**
- Urea contract in-place
- Off-takers for CO\(_2\) & power are engaged
- China Eximbank MOU for debt financing
- Currently finalizing EPC contracts

NOTE: All tons are metric tons
MMtpy \( \rightarrow \) million metric tons per year
Hydrogen Energy California

Advanced IGCC-Polygen

• Kern County, CA (greenfield)
• Up to 300 MWe (net) with load following;
  1.0 MMT/yr urea/UAN
  – MHI oxygen-blown gasifier (1 x 100%)
  – MHI G-class air cooled combustion turbine (1)
• Fuel: Sub-bituminous coal/petcoke
• 90% CO₂ capture – 3,020,000 tonnes CO₂/year
  – 2.57 MM tonnes EOR; 0.45 MM Urea production
  – 2-stage Water Gas Shift, Linde Rectisol ® AGR
• EOR: Elk Hills oil field
• Saline: At or near power plant site
• Use of brackish water for power production; ZLD
• Total DOE Project: $4.028 B; DOE Share $408 MM (10%)
• Total Plant Cost: ~$5 B

Key Dates
- Project Awarded: Sept. 2009
- New Owner, SCS Energy: Sept. 2011
- Financial Close: TBD
- Construction: TBD
- Start of Operation: TBD

Status
- FEED completion: April 2013
- Draft PSA/EIS: June 2013
- Final Determination of Compliance (air permit): July 2013
- Power/Fertilizer/CO₂/EPC discussions in progress
Petra Nova – NRG W.A. Parish CCPI-3
Advanced Post Combustion CO₂ Capture

- Thompsons, TX (near Houston)
- 240 MWe slipstream at NRG Energy’s W.A. Parish power plant (originally 60 MWe)
- Fuel: PRB sub-bituminous coal
- 90% CO₂ capture (KM CDR Process®) 1,400,000 tonnes CO₂/year
- EOR: Hilcorp West Ranch oil field
- Total Project Cost: ~$1 billion
  DOE Share: $167 million

Key Dates
- Project Awarded: May 2010
- Air Permit: December 2012
- NEPA Record of Decision: May 2013
- Financial Close: July 2014
- Construction: March 2014 (LNTP);
  July 2014 (NTP)
- Operation: January 2017

Status
- Foundations completed for quencher, absorber, regenerator, compressor & HRSG. Cooling tower complete
- Construction in progress on quencher, absorber, & HRSG
- Pipeline mechanically complete, hydro-test completed
- Regenerator & compressor delivered to site and installed
- Overall EPC effort: 87% complete (1/31/16)
- Construction: 67% complete (1/31/16)
Air Products & Chemicals, Inc. ICCS Area 1
*Steam Methane Reforming with CO$_2$ Capture*

- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90%+ CO$_2$ capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding \( \approx 925,000 \) tonnes CO$_2$/year
- \( \approx 30 \) MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and compression equipment
- CO$_2$ to Denbury “Green” pipeline for EOR in Texas at West Hastings oil field
- Total Project: $431$ MM; DOE Share: $284$ MM (66%)

**Key Dates**
- Phase 2 Awarded: June 15, 2010
- FEED completed: Nov. 2010
- Permit By Rule (PBR) and Standard Air Permits issued: May 2011
- NEPA FONSI: July 2011
- Construction started: Aug. 2011

**Status**
- PA-1 initiated operation: March 3, 2013
- PA-2 initiated operation: Dec. 16, 2012
- Full capacity achieved: April 2013
- Has operated at >100% of design when necessary
- 1 MM tonnes CO$_2$ delivered as of 4/24/14
- 2 MM tonnes CO$_2$ delivered as of 5/15/15
- 2.72 MM tonnes CO$_2$ delivered as of 3/7/16
Archer Daniels Midland Company ICCS Area 1

CO₂ Capture from Biofuel Plant

- Decatur, IL
- CO₂ (>99% purity) is a by-product from production of fuel-grade ethanol via anaerobic fermentation
- Up to 90% CO₂ capture, dehydration (via triethylene glycol) & compression
- ~900,000 tonnes CO₂ /year
- Sequestration in Mt. Simon Sandstone saline fm.
- Total Project: $208 MM; DOE Share: $141 MM (68%)

Key Dates
- Phase 2 Awarded: June 15, 2010
- FEED Completed: April 2011
- NEPA FONSI: April 2011
- Construction started: May 2011
- UIC Class VI Injection Well Permit: Sept. 2014; UIC Class VI Operating Permit: 2016
- Sequestration start: 2016

Status
- Construction >99% complete Mar. 2016
- Two monitoring wells drilled: Nov. 2012
- New Hans substation energized: Nov. 2014
- Commissioning compression and dehydration system completed: Sept. 2015
- Injection well drilled and completed: Sept. 2015
ADM - Successful CCS Demonstrations Providing Foundation for Future Commercial Projects

Location
Archer Daniels Midland Company, Decatur, Illinois

Regional Carbon Sequestration Partnership:
Midwest Geological Sequestration Consortium
Illinois Basin – Decatur Project (IBDP)
(Large-scale 3-year field test completed 2011-2014; post-injection monitoring in progress)

Industrial Carbon Capture and Storage
Illinois Industrial Carbon Capture and Storage (IL-ICCS) Project – 2009 Recovery Act Project
(Commercial-scale demonstration with EPA’s first Class VI injection well operating permit, storage to begin in 2016)
DOE’s Major Demonstrations Program
A History of Innovative Projects

Industry / Government Partnership

Clean Coal Technology Demonstration Program (CCTDP) 1985 - 2006

Power Plant Improvement Initiative (PPII) 2001 - 2009

Clean Coal Power Initiative (CCPI) 2002 – 2016+

Industrial Carbon Capture & Sequestration (ICCS) 2009 – 2016+

CCPI Round 1 – 2002
Advanced Coal Technologies for Efficiency, Environmental, and Economic Improvements

CCPI Round 2 – 2004
Advanced Gasification Technology, and Advanced Clean-up Systems (incl. Hg)

CCPI Round 3a – 2008
CCS Technologies

CCPI Round 3b – 2009
CCS Technologies with ARRA Funds

What's Next?
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Lessons Learned – Major Demonstrations

• A multi-award, multi-FOA ‘down-select’ approach may be optimal:
  o Pre-FEED awards → fewer FEED awards → fewer construction/operation awards
  o Multiple, discrete, sequential awards allow work scope and budgets to be well-defined and better managed
  o Allows DOE to respond to changes in market/business environment
  o Each step might be full-and-open competition FOA soliciting proposals from existing projects plus new ones (or ones unsuccessful in an earlier round)
  o Allow low recipient cost shares for the pre-FEED and FEED awards

• Encourage recipients to identify and address fundamental issues related to CCS deployment in their state or region
  o UIC Class VI permits
  o Whether or not the state asks for primacy from the U.S. EPA
  o Pore space ownership
  o Premium electricity rates or line charges to recover CCS costs
  o Unique tax treatments to help the business case for commercial CCS projects
  o State or other entity assuming risk of long-term storage liability for CCS projects

• Incorporation of CO₂ storage alternatives to facilitate projects proceeding into construction while UIC Class VI permits are being processed
For Additional Information

NETL
www.netl.doe.gov