BIA 25 -- TRIBAL PROVIDERS CONFERENCE
CLEAN COAL AND WASTE TO ENERGY SESSION
ANCHORAGE, ALASKA

John M. Panek
Office Of Strategic Planning and
Global Engagement

DECEMBER 2015
The Energy Challenge

Goals for Energy Systems

1. Economic security – cost efficient energy systems
2. Energy security – energy systems that have multiple supply options and are robust and resilient
3. Environmental security – much lower emissions of greenhouse gases and other pollutants

Opportunity
Create and manage linked, complex systems that deal with all three challenges
CCS Will Be Required To Meet Our Global Carbon Emission Reduction Goals

CCS Activities in the U.S. – Focused on Technology Development and Market Mechanisms

**Technology Push**

- R&D focused on: cost (capture) and confidence (storage)
- Demos (integration and learning)
CCS Activities in the U.S. – Focused on Technology Development and Market Mechanisms

**Market Pull**

Domestic Oil Supplies and CO₂ Demand (Storage) Volumes from “Next Generation” CO₂-EOR Technology

- **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**
Early CCS Projects

Sleipner (Source: Statoil)

Great Plains Synfuels (Source: Dakota Gasification)

Boundary Dam (Source: SaskPower)

Kemper (Source: IEA)

Decatur (Source: US DOE)

Port Arthur (Source: Air Products)

Peterhead (Source: Shell)

Gorgon (Source: Chevron)

Scotford Upgrader (Source: Shell)
REALIZING THE PROMISE OF CLEAN COAL

• Clean Coal Research
• Carbon Capture and Storage Research

• Petroleum Reserves
• Heating Oil Reserves

• Oil and Gas Research

(The Office of Fossil Energy regulates natural gas and LNG imports and exports under Section 3 of the Natural Gas Act of 1938.)
FE is Advancing Coal Towards a Low-Carbon Future

Making Coal Plants More Efficient
Gasification, Advanced Turbines, Advanced Combustion, CBTL, and Fuel Cells

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

Turning CO₂ into Valuable Products
New pathways to utilize captured CO₂

Storing CO₂ Underground
Safe, permanent storage of CO₂ from power generation and industry

Bringing it All Together
Crosscutting technology development program
A technology pipeline for affordable CCS
Clean Coal RD&D Progress
Performance Improvement is Driving Cost Reductions

Relative to Supercritical PC Plant w/o Capture (39.3% HHV efficiency)

Power Generation Penalty [% of Plant Output]

$150+/tonne (NOAK)

~ $60/tonne (NOAK)

< $40/tonne (NOAK)

"2005" "2012" "2020"

Costs of capturing CO₂ from greenfield plants, excluding CO₂ transport and storage, expressed in 2011 dollars
CO₂ Capture
Requires Multiple Technologies and Multiple Scientific and Engineering Disciplines

Technology Areas
- Post–Combustion Capture
- Pre–Combustion Capture
- Oxy–Combustion Capture

Key Technologies
- Solvents
- Sorbents
- Membranes
- Novel/Hybrid Concepts

Primary pathway to steep cost reductions
CO₂ Capture from Industrial Sources

- Globally, industry accounts for 40% of energy-related CO₂ emissions - mostly in developing countries
- Many industrial facilities are large point sources
- In some plants, CO₂ is already being captured in order to produce the desired product (e.g., H₂/Ammonia), and additional capture cost is minimal
- CO₂ concentration in treated stream may be high or nearly pure
- Often located near potential storage sites
- ICCS technology is applicable to coal-fired power generation

Hanson Permanente Cement Kiln, Los Altos, CA, 2008
Discovering, Characterizing, and Predicting
Efficiently and accurately locate target geophysical and geochemical responses, finding more viable and low-risk resource, and quantitatively infer their evolution under future engineered conditions

Accessing
Safe and cost-effective drilling, with reservoir integrity

Engineering
Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

Sustaining
Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex system evolution

Monitoring
Improve observational methods and advance understanding of multi-scale complexities through system lifetimes
Regional Carbon Sequestration Partnerships

*Developing the Infrastructure for Wide Scale Deployment*

Seven Regional Partnerships

*400+ distinct organizations, 43 states, 4 Canadian Provinces*

- Engage regional, state, and local governments
- Determine regional sequestration benefits
- Baseline region for sources and sinks
- Establish monitoring and verification protocols
- Validate sequestration technology and infrastructure

**Characterization Phase (2003-2005)**

- Search of potential storage locations and CO₂ sources
- Found potential for 100s of years of storage

**Validation Phase (2005-2011)**

- 20 injection tests in saline formations, depleted oil, unmineable coal seams, and basalt

**Development Phase (2008-2018+)**

- 8 large scale injections (over 1 million tons each)
- Commercial scale understanding and validation
**RCSP Phase III: Development Phase**

*Large-Scale Geologic Tests*

- **Midwest Regional Carbon Sequestration Partnership**
  - **Michigan Basin Project**
  - 314,000 metric tons

- **Midwest Geological Sequestration Consortium**
  - **Illinois Basin Decatur Project**
  - 999,216 metric tons

- **Plains CO₂ Reduction Partnership**
  - **Fort Nelson Project**
  - Injection TBD

- **Southeast Regional Carbon Sequestration Partnership**
  - **Cranfield Project**
  - 4,699,000 metric tons

- **Southeast Regional Carbon Sequestration Partnership**
  - **Citronelle Project**
  - 114,391 metric tons

- **Southwest Regional Carbon Sequestration Partnership**
  - **Farnsworth Unit – Ochiltree Project**
  - 229,000 metric tons

- **Plains CO₂ Reduction Partnership**
  - **Bell Creek Field Project**
  - 1,660,000 metric tons

- **Big Sky Carbon Sequestration Partnership**
  - **Kevin Dome Project**
  - Injection 2015 (planned)

*Injection volumes updated as of March 2015*
North American Carbon Storage Atlas

V

• Provides overview of DOE’s Carbon Capture and Storage Activities

• Highlights from carbon storage research and analyses conducted at the National Energy Technology Laboratory

• Summarizes knowledge sharing efforts to Stakeholders

www.netl.doe.gov/research/coal/carbon-storage/natcarb-atlas
# Capturing and Sharing Knowledge

## Best Practices Manual

<table>
<thead>
<tr>
<th>Area</th>
<th>Version 1 (P--II)</th>
<th>Version 2 (P--III)</th>
<th>Final Version (Post-Injection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring, Verification and Accounting</td>
<td>2012</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Public Outreach and Education</td>
<td>2009</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Site Characterization</td>
<td>2010</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Geologic Storage Formation Classification</td>
<td>2010</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Simulation and Risk Assessment</td>
<td>2010</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Carbon Storage Systems and Well Management Activities</td>
<td>2011</td>
<td>2016</td>
<td>2020</td>
</tr>
</tbody>
</table>
Carbon Capture and Storage

- Capture with solvents well demonstrated
- 2nd generation demonstrations
- Reduce energy penalties and costs of components, materials, chemistries, separations, integrated plant designs
- Storage in a variety of subsurface geologic settings
- Demonstrate for post-combustion retrofits, natural gas generation

Southern Company Kemper Project, IGCC + CC + EOR
Credit: Mississippi Power
Major CCS 1st Gen Demonstration Projects

Project Locations & Cost Share

Clean Coal Power Initiative

ICCS Area 1

- **Summit TX Clean Energy**
  - Commercial Demo of Advanced IGCC w/ Full Carbon Capture
  - $1.7B – Total, $450M – DOE
  - EOR – ~2.2M MTPY 2018 start

- **Petra Nova (formerly NRG)**
  - W.A. Parish Generating Station
  - Post Combustion CO₂ Capture
  - $775 M – Total
  - $167M – DOE
  - EOR – ~1.4M MTPY 2017 start

- **Southern Company**
  - Kemper County IGCC Project
  - Transport Gasifier w/ Carbon Capture
  - $4.12B – Total, $270M – DOE
  - EOR – ~3.0M MTPY 2015/2016 start

- **Archer Daniels Midland**
  - CO₂ Capture from Ethanol Plant
  - CO₂ Stored in Saline Reservoir
  - $208M – Total, $141M – DOE
  - SALINE – ~0.9M MTPY 2015 start

- **HECA**
  - Commercial Demo of Advanced IGCC w/ Full Carbon Capture
  - $4B – Total, $408M – DOE
  - EOR – ~2.6M MTPY 2019 start

- **Air Products and Chemicals, Inc.**
  - CO₂ Capture from Steam Methane Reformers
  - EOR in Eastern TX Oilfields
  - $431M – Total, $284M – DOE
  - EOR – ~0.93M MTPY 2012 start
Archer Daniels Midland (ADM) ICCS Demonstration

Project Background

- Decatur, IL
- Corn to Ethanol Biofuel plant with CO₂ Geologic Storage
- CO₂ >99% purity from fermentation reactors (dehydration & compression); ~900,000 tonnes CO₂/year
- Total Project: $208 million; DOE share: $141 million

Current Project Status

- Drilled the monitoring and geophysical wells (Nov 2012)
- Injection well was drilled to a total depth of 7192 feet (May 28, 2015)
- Working towards
- EPA authorization for injection and begin CO₂ sequestration (Nov 2015)
- CCS in operation Apr/May 2016
Archer Daniels Midland (ADM) Ethanol Facility

Decatur, IL
ADM 2013

CO₂ Pipe to Injection Well
Compression Facility
Air Products ICCS Demonstration

Project Background

- Port Arthur, TX
- Hydrogen production plant at Valero Refinery
- 90%+ CO₂ capture (Vacuum Swing Adsorption) ~925,000 tonnes CO₂/year sent through Denbury “Green” pipeline to West Hastings oil field
- Total Project: $431 million; DOE share: $284 million

Current Project Status

- In operation since December 2012
- Successfully captured and delivered over 2,000,000 metric tons of CO₂
- Project has been a successful demonstration of ICCS for EOR in production for over two years
Air Products ICCS Demonstration

Port Arthur, TX

Air Products

Co-Gen Unit

Existing SMR

CO₂ Compressor & TEG Unit

CO₂ Surge Tanks

Blowers

VSA Vessels
Wide-Ranging Partnerships At Home and Around the World
Cooperation and Collaboration is Critically Important
International partnerships required

Many platforms (WEC, APEC, etc.)

**CSLF: Multinational platform**
- 22 countries + E.C.
- 12 years in practice
- Productive technical and policy working groups
  - Potential to showcase global large scale CCS projects

**Partnerships in Commerce**
- Joint ventures
- International investment
- “Showcase” projects

**Accelerated Deployment**
- Data sharing
- International Science Projects
**Mission**

An international initiative focused on improved cost-effective technologies for the separation and capture of carbon dioxide for its utilization and long-term safe storage

**Purpose**

Make technologies broadly available internationally; Identify and address wider issues

**23 members**

- Australia
- Brazil
- Canada
- China
- European Union
- France
- Germany
- Greece
- India
- Italy
- Japan
- Mexico
- Netherlands
- New Zealand
- Norway
- Poland
- Russia
- Saudi Arabia
- South Africa
- United Arab Emirates
- United Kingdom
- United States
- United States
- United Kingdom
- United States
- United Kingdom
The Next Decade of Projects: Policy Infrastructure

- Quest (CAN)
- White Rose Peterhead (UK)
- Uthmaniyah (KSA)
- Lula (BRA)
- GreenGen (PRC)
- Shengli Y anchang
- ESI (UAE)
- Gorgon (AUS)

Pure CO₂ Sources >95% (kt CO₂ per year)
- 0 - 250
- 250 - 500
- 500 - 1000
Technology Informs Policy

• **Technology Development**
  – Informs state, industry, regulatory, and governmental leaders on the current technical “state of the art” fossil based technologies.
  – Provide high-level information on the general direction of R&D initiatives on many fossil energy component technologies.

• **EPA’s Clean Power Plan (111(d))**
  – Fossil Energy, through its National Laboratory, has access to tools and analysis capabilities that can help States examine their options on Greenhouse Gas mitigation and fossil resource use.
  – Provide technical expertise and speakers at meetings to discuss energy technologies and policies that can be used to help States mitigate Greenhouse Gas emissions.

• **Education/Information**
  – FE has access to significant amounts of information and educational material on a variety of coal and fossil issues ranging from electricity to fuels. These include topics like: Carbon Capture & Storage (CCS), Turbines, Gasification, Fuel Cells, Fuels, Crosscutting Research, Major Demonstration projects, etc.
Key unit of innovation – global engines of discovery

The next decade of projects = policy infrastructure
For More Information...

www.fossil.energy.gov

facebook.com/FossilEnergy
twitter.com/fossilenergygov