The Future of Clean Coal
National Conference of State Legislatures
Energy Supply Task Force

Doug Middleton
Office of Clean Coal & Carbon Management
Tuesday December 9, 2014
“The Climate”

Graphic: Center for Climate Systems Modeling - 2014 ETH Zurich
## Electric Utility Sector & EPA Regs

<table>
<thead>
<tr>
<th>Issue</th>
<th>Federal Regulation/Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air</strong></td>
<td></td>
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</tbody>
</table>
| SO\textsubscript{x} & NO\textsubscript{x} crossing state lines | **Cross-State Air Pollution Rule (CSAPR)** Finalized 7.7.2011; 12.30.2011, DC Circuit stay of CSAPR (CAIR in effect); 8.21.2012, DC Circuit decision vacating CSAPR; SCOTUS overturned, EPA Review Pending  
**Compliance: Unknown** |
| Mercury and Hazardous Air Pollutants (HAPs) | **Mercury and Air Toxics Standards (MATS) Rule for Electric Generation Units** Finalized 12.16.2011 – Pending SCOTUS Review  
**Compliance: ~2015** |
| GHG emissions | **GHG New Source Performance Standards (NSPS)** New rule proposed 9.20.2013  
**Existing GHG Regulation** Proposed rule delivered 6.2014; final rule expected 6.2015 (under Presidential Memorandum) |
| **Waste** |  |
| Coal Combustion Residuals (e.g., coal ash, boiler slag) | **Coal Combustion Residuals (CCR) Rule** Proposed rule 6.10.2010; Final rule expected 12.2014 (court memorandum)  
**Compliance: Unknown** |
| **Water** |  |
| Cooling Water Intake Structures – impact on aquatic life | **CWA §316(b) Rule** Final rule delivered 5.2014 (settlement agreement)  
**Compliance: Within 8 Years** |
| Surface water discharges; Surface impoundments | **Steam Electric Effluent Limitations Guidelines** Proposed rule 11.2012; final rule expected 9.2015 (settlement agreement)  
**Compliance: Unknown** |

- Near-term (through 2015-2016) Compliance Horizon for EPA regulations may create potential localized reliability issues
- Local reliability issues can be managed with timely notice and coordination on retirement and retrofit decisions
- States and regions will play a valuable role in addressing EPA regulation impacts
- Non-transmission alternatives can help alleviate reliability impacts when/where available
- EPA regulations are only one aspect impacting the future of our electricity system
EPA Regs Compliance Horizon

### 2010
- **316(b) Prop Rule 4.20.2011**

### 2011
- **MATS Prop Rule 3.16.2011**
  - **MATS Final Rule 12.16.2011**
  - Compliance within 3 years of effective date + 1 add’l year if granted by permitting authority
  - **MATS: EPA Enforcement Policy Memorandum; Presidential Memorandum; FERC Policy Statement**
  - **EPA finalized its reconsideration of MATS for new sources on 3.28.2013; only impacts new sources to be built in the future.**

### 2012
- **CSAPR Prop Rule 4.26.2010**
  - **CSAPR Final Rule 7.7.2011**
  - CAIR in effect; CSAPR Compliance Currently Unknown; pending SCOTUS review

### 2013
- **EGU GHG NSPS Prop Rule 3.27.2012**
  - **EGU GHG NSPS Final Rule 9.20.2013**
  - **Technically in Effect**

### 2014
- **EGU GHG NSPS Final Rule 2013-2014**
  - **Existing EGU GHG Final Rule 6.2015**

### 2015
- **Existing EGU GHG Final Rule 6.2015**

### 2016
- **CCR Final Rule 12.2014??**

### 2021
- **Compliance Currently Unknown**

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**CCRs Propane Compliance Horizon**

- **CCR Prop Rule 6.21.2010**

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**EPA Regs Compliance Horizon**

- **Compliance within 8 years of effective date**
- **Compliance Currently Unknown**
- **Eff Guide Prop Rule 6.7.2013**
- **Eff Guide Final Rule 9.2015**
- **For Reliability Critical Units**

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**Provisions**

- **Prop Rule 6.7.2013**
  - **Prop Rule 6.2014**
  - **Prop Rule 6.2015**

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**EPA is reviewing the opinion**

- **CSAPR: 4.29.2014 opinion vacating CSAPR overturned by Supreme Court; EPA is reviewing the opinion**

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**PM directs EPA to issue new proposed EGU GHG NSPS by 9.20.2013 and a final rule “in a timely fashion after considering all public comments, as appropriate”**

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**PM directs EPA to issue proposed existing source EGU GHG rule by 6.2014 and a final rule by 6.2015.**
This is a time of fossil energy abundance

In coal, oil and gas
Supports economic growth
Creates jobs and wealth

*Once in a generation opportunity to build*
Future of Fossil Energy Demand and Generation

• Fossil fuel use still robust, accounts for 75% of global primary energy demand in 2035

• Even with robust natural gas growth, coal is still a major source of global energy demand and domestic electricity generation

• Fossil Energy remains dominant share (68%) of United States electricity generation in 2040

• With this continued use and growth is a need to address CO2 emissions
Carbon Emissions Lock-In
Coal Plants Built Post-2000

• Domestically
  – Over 40 coal plants (21 GW) built since 2000
  – Using a triangle distribution for the capacity factor of the plants
    • Over 1000 iterations
  – 90% confidence interval has emissions between 100 and 160 million tons of CO₂ per year

• China
  – Over 600 GW of coal built since 2000
  – Using a triangle distribution for the capacity factor of the plants
    • Over 1000 iterations
  – 90% confidence interval has emissions between 2.4 and 3.8 billion tons of CO₂ per year

• 10 Large Coal Users
  – Over 850 GW of coal built since 2000
  – Using a triangle distribution for the capacity factor of the plants
    • Over 1000 iterations
  – 90% confidence interval has emissions between 3.5 and 5.7 billion tons of CO₂ per year
The “Solution”

Graphic: lilpickmeup.com
DOE/FE’s Top Clean Coal and CCS priorities

Success of the major demonstrations
• Serial #1 in operation 2013-2018
• A deep and rich set of public learning

Reimagining the coal and CCS RD&D portfolio
• Advanced combustion
• Capture and storage: incl. footprint reduction
• 2nd generation large pilots

International Partnerships
• Asia, Europe and other key countries

NEW MODE: DELIVERING SOLUTIONS
Success of the Major Demonstrations

Graphic: linkedin.com
DOE CCUS Demonstration Projects

*Focus – Large-scale commercial demonstration of CCUS integrated with coal power generation and industrial sources.*

- **FutureGen 2.0**
  - Oxy-combustion with CO₂ capture and saline storage
  - $1.05 Billion - DOE
  - $1.8 Billion - Total

- **Summit Texas Clean Energy**
  - IGCC with EOR
  - $450 Million - DOE
  - $1.7 Billion - Total

- **Petra Nova Parish Holdings**
  - Post Combustion with CO₂ Capture with EOR
  - $167 Million – DOE
  - $775 Million - Total

- **Southern Company Services**
  - IGCC-Transport Gasifier w/CO₂ pipeline
  - $270 Million - DOE
  - $2.02 Billion - Total

- **Air Products**
  - CO₂ Capture from Steam
  - Methane Reformers with EOR
  - $284 Million - DOE
  - $431 Million - Total

- **Leucadia**
  - CO₂ Capture from Methanol with EOR
  - $261 Million - DOE
  - $436 Million - Total

- **Archer Daniels Midland**
  - CO₂ Capture from Ethanol w/ saline storage
  - $141 Million - DOE
  - $208 Million - Total

- **Hydrogen Energy California**
  - IGCC with EOR
  - $408 Million - DOE
  - $4.0 Billion - Total
Port Arthur, TX: 1.1 M tons/y CO2
Air Products, 2013

Existing SMR
Co-Gen Unit

CO₂ Compressor &
TEG Unit

CO₂ Surge
Tanks

Blowers

VS/SAx vessels

Operational! 1.4M tons stored so far
Kemper County, MS: 2.7M tons/y CO2
Southern Co., 2013
(Anticipated start mid-2015)
Decatur, IL
ADM 2013
300,000 tons/y today;
Over 900,000 tons to date
1 M tons/y shortly

CO₂ Pipe to Injection Well

Final class VI permit
Skyonic “Skymine” Project, San Antonio, TX
Operational !!

75,000 tons/y CO2 captured - >200,000 tons avoided
Boundary Dam: 1.1M tons/y CO2
Saskpower, Saskatchewan

Operational last month
W.A. Parrish, TX: 1.4M tons/y CO2
NRG/PetraNova project

Broke Ground Sept. 5th! Operational in 2016
North America and China dominate large-scale CCS project activity

<table>
<thead>
<tr>
<th>Region</th>
<th>Early Planning</th>
<th>Advanced Planning</th>
<th>Construction</th>
<th>Operation</th>
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<td><strong>14</strong></td>
<td><strong>9</strong></td>
<td><strong>13</strong></td>
<td><strong>55</strong></td>
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</table>
Continued Research and Development

Graphic: finavista.eu
Office of Clean Coal: Program Summary

**CO₂ Capture and Compression ~ $80 Million**

Cost effective capture for new and existing plants

Major Goals:
- 2016: complete 2ⁿᵈ gen field tests (~1.0 MW scale)
- 2020: complete 2ⁿᵈ gen pilot tests (10 to 25 MW)
- 2025: complete transformational tech. field tests (~1.0 MW)

**CO₂ Storage ~ $80 Million**

Safe, permanent storage of CO₂ from power and industry

Major Goals:
- 2020: technologies and tools available to measure and account for 99% of injected CO₂
- 2020: CCS best practices and protocols completed based upon RCSP Phase III activities

**Advanced Energy Systems ~ $50 Million**

Gasification, Adv Turbines, Adv Combustion, CBTL, and fuel cells

Major Goals:
- 2016: Complete Warm Gas Cleanup demo.
- 2025: 20-30% Reduction in Combined Cycle Capital Cost (2ⁿᵈ gen)
- 2025: Advanced combustion ready for pilot scale operation

**Cross-Cutting Research ~ $35 Million**

Crosscutting technology development program

Major Goals:
- 2016: advance 2ⁿᵈ gen materials, sensors, modeling technologies to applied programs
- 2020: develop distributed communication sensor networks (transformational tech.)
Reimagining our RD&D portfolio

Advanced combustion
• Materials and manufacturing
• Advanced cycles (e.g., PGC, sCO2)

Capture and Storage
• Advanced simulation (NRAP and CCSI)
• Functionalized discovery
• Mastery of the subsurface

Accelerated 2\textsuperscript{nd} Gen pilots
• Computational design
• International sharing
National Carbon Capture Center (NCCC)

**Goal**
Test technologies under realistic conditions to reduce the cost of CO$_2$ capture

**Advantages**
- National resource to validate performance and operations
- Consistent testing procedures and data
- Very good safety and environmental record
- Platform for international partnership and sharing

**Status**
- New 5 year commitment to operator (Southern Company)
- >20 technologies tested
- 100’s of technologies screened
2nd Generation Projects

Graphic: www.facilityservicesnow.com
Coal gasification will have a major role

Coal remains cheap and abundant
• Prices generally low to very low
• Gas prices high in much of the world

Gasification can support polygeneration
• Power (IGCC)
• SNG, chemicals (e.g., methanol)

Well configured for CCS and CCUS
• By-product: lowest price for industrial CCS
• Pre-combustion: lowest cost for power CCS

Many technology pathways and improvements
Texas Clean Energy Project
Summit Annual Revenues (30-yr avg)

- Urea: 59.85%
- Carbon Dioxide: 18.81%
- Power: 18.81%
- Argon: 1.72%
- Brine Water: 0.69%
- Slag: 0.43%
- Nitrogen: 0.21%
- Sulfuric Acid: 0.18%
Funding CCS Projects in the United States...

**American Reinvestment and Recovery Act (ARRA):**
- $1 Billion, FutureGen 2.0
- $1.52 Billion, Industrial CCS Applications
- $800 Million, CCPI Round 3 Expansion
- $100 Million, Training, Research, and Program Direction

**U.S. DOE Office of Fossil Energy**
- $25 Million, requested for Natural Gas CCS demonstration in FY 2015
- Next round of major demonstrations???

**Loan Guarantees**
$8 Billion available for Advanced Fossil Projects
- Will guarantee up to 80% of the project cost
- First round of applications submitted April, 2014

**Tax Credits: Investment and Production**
- $20 per ton for Saline Storage
- $10 per ton for EOR
State Incentives for CCS

- Financial Support
- Tax Incentives
- Off-take Agreements
- Utility Cost Recovery Mechanisms
- CCS Eligibility in Portfolio Standards
- Liability Assumptions for Stored Carbon
Clean Coal deployment: most urgent and important

Not just about cost
• Costs are higher than dirty coal plants
• Costs are lower than many clean energy alternatives

Not just about technology
• Many technologies are well demonstrated
• Improvement potential is very large

Could finance many ways
• Rate recovery; feed-in tariffs; direct grants
• Clean energy portfolios; tax-free debt financing; others

Financing is the priority action
The State, Local and Tribal Technical Assistance Gateway provides access to DOE's technical assistance and cooperative activities with state, local, and tribal officials. Through its program and staff offices, DOE has engaged extensively with various levels of state, local, and tribal governments, providing technical assistance on a range of energy issues. Our existing technical assistance and other activities, as well as relevant information offered by other federal agencies, are provided below by program or topic.

If you're a state, local, or tribal official, or a representative from an organization of such officials, with a specific question or need for assistance, email us and we'll work collaboratively across the DOE to address your inquiry. Responses could include access to DOE and national laboratory experts, ongoing cooperative activities with national state, local, regional, and tribal associations and external subject matter experts, and existing and new materials including guides, toolkits, webinars, and data. Any technical assistance provided will depend on the inquiry and the availability of DOE resources.
EXTRA SLIDES
IGCC Demonstration Project Summary

Southern Company CCPI-2 IGCC; EOR
- Kemper County, MS
- 582 MW (net) 2 TRIG™ gasifiers, 2 combustion turbines, 1 steam turbine
- 67% CO₂ capture (Selexol® process); ~3,000,000 tonnes CO₂/year
- Plant >88% complete. Peak construction labor - 6,121
- Operations: 2015
- Total project: $2.02 billion; DOE share: $270 million

Summit Texas Clean Energy CCPI-3 IGCC Polygen; EOR
- Penwell, Ector County, TX
- 600 MW (syngas); 400 MW (gross) power block; 200 MW (net) to electric grid
  0.9 MM tonnes/yr urea
- 90% CO₂ capture (Rectisol®) ~2,630,000 tonnes CO₂/year (2.0 MMT to EOR, 0.63 MMT to urea)
- EOR: Permian basin oil fields
- Operations: September 2019
- Total project: $1.7 billion; DOE share: $450 million

Hydrogen Energy California (HECA) CCPI-3 IGCC Polygen; EOR
- Kern county, CA
- 300 MW (net), 1. MMT/yr Urea/UAN
- 90% CO₂ capture (Rectisol®) ~3,020,000 tonnes CO₂/year (2.57 MMT to EOR, 0.45 MMT to urea)
  EOR: Oxy Elk Hills oil field (in negotiation)
- Operations: December 2020
- Total project: $4 billion. DOE share: $408 million

Note: Total project costs are for the DOE defined portion of the project.
Combustion Demonstration Project Summary

**Petra Nova - W. A. Parish CCPI-3 Post Combustion Capture; EOR**
- Thompsons, TX (near Houston)
- 240 MWe flue gas slipstream
- 90% CO₂ capture (KM CDR process); ~1,400,000 tonnes CO₂/year
- EOR: Hilcorp West Ranch oil field
- Operations: April 2017
- Total Project: $472 million; DOE share: $167 million

**FutureGen 2.0 Oxy-combustion; Geologic Storage**
- Meredosia, IL (plant site) and Morgan County, IL (storage site)
- 167 MWe (gross)
- 90+% CO₂ capture (cryogenic separation); ~1,000,000 tonnes CO₂/year
- Geologic Storage: Mount Simon saline reservoir, ~30 miles east of plant
- Operations: September 2017
- Total Project: $1.77 billion; DOE share: $1.05 billion

Note: Total project costs are for the DOE defined portion of the project.
ICCS Demonstration Project Summary

**Air Products Industrial Capture; EOR**
- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90%+ CO\textsubscript{2} capture (Vacuum Swing Adsorption); \sim925,000 tonnes CO\textsubscript{2}/year
- EOR: Denbury West Hastings oil field
- Total Project: \$431 million; DOE share: \$284 million
- Operations: December 2012 (Project executed under budget)
- 1,150,000 tonnes delivered as of 6/25/14

**Archer Daniels Midland (ADM) Biofuel; Geologic Storage**
- Decatur, IL
- CO\textsubscript{2} >99% purity from fermentation reactors (dehydration & compression); \sim900,000 tonnes CO\textsubscript{2}/year
- Geologic Storage: Mt Simon saline reservoir
- Plant \sim64% complete
- Operations: March 2015
- Total Project: \$208 million; DOE share: \$141 million

**Leucadia Petcoke to Methanol & Hydrogen; EOR**
- Lake Charles, LA
- 700 MM gal/yr methanol, 110 MMscfd Hydrogen
- 89% CO\textsubscript{2} capture (Rectisol®); 4,500,000 tonnes CO\textsubscript{2}/year
- EOR: Denbury West Hastings oil field
- Operations: 2018
- Total Project: \$436 million; DOE share: \$261 million

Note: Total project costs are for the DOE defined portion of the project.
DOE CCUS Demonstration Projects
Funding Sources

<table>
<thead>
<tr>
<th>Project</th>
<th>Total Project Cost (Millions)</th>
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<tbody>
<tr>
<td>HECA</td>
<td>$4,000.00</td>
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<tr>
<td>Summit</td>
<td>$2,000.00</td>
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<tr>
<td>Petra Nova</td>
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<td>Air Products</td>
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<td>Leucadia</td>
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<tr>
<td>FuterGen 2.0</td>
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<tr>
<td>Archer Daniels</td>
<td>$500.00</td>
</tr>
<tr>
<td>Kemper</td>
<td>$2,000.00</td>
</tr>
</tbody>
</table>

- **DOE Funding**
- **Industry Funding**
## Texas Clean Energy Project
### A breakdown of the financing

**Project Details**
- Advanced Integrated Gasification Combined Cycle
  - Poly-generation with Enhanced Oil Recovery
- 90% CO₂ capture ~ 2.7 million tons of CO₂ per year
- CO₂ used for EOR in the Permian Basin oilfields

**Plant Production Details**
- 400 MW of gross power
  - 160 MW net available for sale to the power grid.
- 2.2 million tons of CO₂ per year for EOR
- 720 thousand tons of Urea per year

### Project Funding
- Foreign Investment
  - MOU signed by representatives of Summit, Sinopec Engineering Group, and The Export-Import Band of China
    - Pending a possible $ 1 billion foreign investment Sinopec Engineering Group and China’s state-owned Export-Import Bank (Chexim)
- Total Funding Breakdown
  - $ 1.3 billion in debt financing in the form of bonds and bank loans
  - $ 845 million from equity and tax equity
  - $ 450 million in DOE Clean Coal Power Initiative funding
- Federal Tax Incentives – Long-term benefits totaling $1.49 billion
  - $ 313 million – Advanced Coal Program Investment Tax Credit
  - $ 253 million – Total available Carbon Sequestration Tax Credits over the first 10 years
  - $ 925 million – estimated MACRS accelerated depreciation tax benefits over the first 5 years
Summit Texas Clean Energy
Advanced Polygeneration

- New business model in US
- Key partners:
  - Siemens, Linde
  - HQC/PetroChina
  - China ExIm Bank
  - CPS; Whiting; CHS Inc.
- 200 MW (net) to grid
- 0.65 MMT/y urea
- One Siemens SFG-850 Gasifier
- Fuel: PRB sub bituminous coal
- 90% CO₂ capture – ~2.15MMT/y
- Total Plant Cost ~$2-3 B
Loan Program Office Project Development Financing
LPO Advanced Fossil Energy Solicitation
$8 billion in loan guarantees

**CARBON CAPTURE**
- From traditional coal or NG generation
- Saline formations or EOR

**ADVANCED RESOURCE DEVELOPMENT**
- ECBM, UCG, novel oil and gas drilling
- Use of co-produced waste gases vs. flaring

**LOW CARBON POWER SYSTEMS**
- Oxycombustion, chemical looping
- Syngas-, H₂, or NG-based fuel cells

**EFFICIENCY IMPROVEMENTS**
- CHP and waste-heat recovery
- High-T or high-efficiency cycles
Regional analysis – North America

- Over half the large-scale projects in operation or under construction are in North America.

- All large-scale CCS projects in the power sector in operation or under construction are in North America.

- CO$_2$-EOR providing significant business case support.

- Current project portfolio benefitted from public funding programs initiated in the previous decade.

- Present regulatory action on emissions standards must be supported by other policy actions and incentives to drive CCS deployment.

- US DOE supports an extensive R&D program into CCS technologies.

- Brazil has plans to expand its offshore CO$_2$-EOR program and Mexico is advancing CCUS pilot projects and regulatory frameworks.
China follows the US as the most active country in CCS/CCUS – similar to the US, considerable impetus comes from EOR.

The world’s largest dedicated geological storage project – the Gorgon Carbon Dioxide Injection Project – is planned to be operational in 2016.

Japan and Korea have substantial CCS activities at lesser scale:

- In Japan, the Tomakomai, Osaki CoolGen and COURSE 50 projects are testing a range of CCS technologies
- In Korea, KEPCO is testing advanced capture technologies at the Boryeong and Hadong thermal power stations.

A key focus is increasing knowledge of storage potential in the region.

Legal and regulatory advances are required in some jurisdictions to enable greater use of geological storage options.
CCS ambition in Europe has been significantly curtailed since the start of this decade.

Recognition of CCS in the October 2014 European Council conclusions is a positive sign of support.

CCS projects in the UK are progressing and policy makers are developing mechanisms to support CCS in the power and industrial sectors.

European projects in development planning are important contributors to a global portfolio – all are in the power sector and plan to use offshore geological storage.

The Dutch ROAD project is critical for CCS in mainland Europe.
Regional analysis – Gulf Cooperation Council (GCC)

- GCC countries are at an early stage of CCS/CCUS deployment.

- Nevertheless, Saudi Arabia and the United Arab Emirates (UAE) have significant projects.

- The UAE hosts the world’s first CCS/CCUS project in the iron and steel sector.

- The present focus of CCS/CCUS activity is validating large-scale projects under local conditions and supporting R&D activities.

- Confidence gained from these programs is the key driver for longer term deployment.
This year’s report:

- Provides a comprehensive overview of global and regional developments in large-scale CCS projects, in CCS technologies and in the policy, legal and regulatory environment.

- Introduces and links to project descriptions for over 30 lesser scale ‘notable’ CCS projects.

- Sets out a number of recommendations for decision makers.
Large integrated projects world-wide matter for deployment

Data from Global CCS Institute
Actual and expected operation dates for CCS projects in ‘Operate’, ‘Execute’ and ‘Define’ stages

CCS projects in the power and industrial sectors and projects utilising dedicated geologic storage options becoming more important.
Carbon Sequestration Leadership Forum: the global marquis platform for CCS partnership

CSLF: Multinational platform
- 22 countries + E.C.
- 11 years in practice
- Productive technical and policy working groups

Pending actions
- Data sharing
- International Science Projects

Pending meetings
- 22 countries + E.C.
- 11 years in practice
- Productive technical and policy working groups
In summary:

- DOE’s R&D is focused on reducing CCS costs
- Large scale demos are being built - must continue
- International acceptance of CCS

- US: Strong regulatory basis for CCS
- New regulations providing a policy push
- R&D and incentives will provide a technology pull!