NARUC Winter Committee Meetings
Subcommittee on Clean Coal

Opportunities for CCS from the Coal Utilization Research Council (CURC) Perspective

Renaissance Washington Hotel
Washington, DC
Ben Yamagata
Executive Director
Coal Utilization Research Council
# CURC 2014 Members

<table>
<thead>
<tr>
<th>ADA-Environmental Solutions</th>
<th>FutureGen Industrial Alliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerojet Rocketdyne, Inc.</td>
<td>The Greater Pittsburgh Chamber of Commerce</td>
</tr>
<tr>
<td>Air Products and Chemicals</td>
<td>Illinois Coal Association</td>
</tr>
<tr>
<td>Alpha Natural Resources</td>
<td>Illinois Department of Commerce and Economic Opportunity</td>
</tr>
<tr>
<td>Alstom Power, Inc.</td>
<td>Kentucky Coal Association</td>
</tr>
<tr>
<td>American Coal Council</td>
<td>Kentucky Energy and Environment Cabinet</td>
</tr>
<tr>
<td>American Coalition for Clean Coal Electricity (ACCCE)</td>
<td>LG&amp;E Energy</td>
</tr>
<tr>
<td>American Electric Power</td>
<td>Lehigh University</td>
</tr>
<tr>
<td>Anglo American Thermal Coal</td>
<td>The Linde Group</td>
</tr>
<tr>
<td>Arch Coal, Inc.*</td>
<td>Mitsubishi Heavy Industries America</td>
</tr>
<tr>
<td>The Babcock &amp; Wilcox Company</td>
<td>National Rural Electric Cooperative Association (NRECA)</td>
</tr>
<tr>
<td>Caterpillar Global Mining</td>
<td>Ohio State University</td>
</tr>
<tr>
<td>Center for Coal Technology Research at Purdue University</td>
<td>Peabody Energy</td>
</tr>
<tr>
<td>CONSOL Energy, Inc.</td>
<td>Pennsylvania Coal Alliance</td>
</tr>
<tr>
<td>Duke Energy</td>
<td>Penn State University</td>
</tr>
<tr>
<td>Edison Electric Institute (EEI)</td>
<td>Schlumberger Carbon Services</td>
</tr>
<tr>
<td>Electric Power Research Institute (EPRI)</td>
<td>Southern Company</td>
</tr>
<tr>
<td>Energy Industries of Ohio</td>
<td>Southern Illinois University</td>
</tr>
</tbody>
</table>

**State of Ohio, Air Quality Development Authority**

**Tri-State Generation & Transmission Association**

United Mine Workers of America

University of Kentucky

University of North Dakota’s Energy & Environmental Research Center

University of Utah

University of Wyoming

West Virginia Coal Association

West Virginia University

Western Research Institute

Wyoming Mining Association

Companies in red indicate 2014 Steering Committee Members
What is CURC?

More information: www.coal.org

Coal Utilization Research Council

Based in Washington D.C. & organized in 1997

50 members – coal producers, utilities, equipment suppliers, states & universities

Focused upon coal related technology development and use as well as CCUS
It’s more complicated than just “Plugging into an electrical outlet”
Announced & Planned Coal Retirements: 2010-2020

<table>
<thead>
<tr>
<th>CURRENT US coal fleet</th>
<th>MATS Mercury</th>
<th>EPA proposed §111(d) rule</th>
<th>Total US coal fleet capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014: 310 GWs</td>
<td></td>
<td></td>
<td>310 GWs</td>
</tr>
<tr>
<td>2016-2020: 50-54 GWs</td>
<td>256 -260 GWs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020-2030: EPA scenario 49 GWs</td>
<td>207 -211 GWs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Within the next 15 years, US retires 1/3rd of the US Coal Fleet
Technology Developed to Address other Environmental Concerns

With the application of new technologies developed in partnership between DOE and the private sector, the U.S. is significantly reducing criteria emissions
(particulate matter, sulfur dioxide, carbon monoxide, lead, ozone, and nitrogen oxides)

1990 SO₂ Concentrations

2009 SO₂ concentrations

Source: CASTNET

USEPA/CAMD 08/09/06

Source: CASTNET

USEPA/CAMD 07/26/10
Current Technology Levelized Cost of Electricity for a New Electric Generating Unit Commencing Operation in 2018
(Based on EIA/AEO 2013er)

Source: CURC analysis of EIA AEO 2013er
CCS Projects in US and Europe

Map Key

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>🚶️</td>
<td>Power Plant CCS Projects</td>
</tr>
<tr>
<td>🏛️</td>
<td>Pilot CCS Projects</td>
</tr>
<tr>
<td>🛡️</td>
<td>Commercial EOR Projects</td>
</tr>
<tr>
<td>🏝️</td>
<td>Non-Power CCS Projects</td>
</tr>
</tbody>
</table>

Source: Carbon Capture & Sequestration Technologies@MIT
Major U.S./Canada Demonstrations

**SaskPower Boundary Dam**
- Post Combustion CO₂ Capture & EOR
- 139 MW gross (110 MW net) Retrofit
- ~$1.24B Total; ~$240 M Canada Gov’t
- FINAL Cost/kW = $1.35B/110MW = $12,300/kW
- EOR – 1.0M TPY Oct 2014 start-up

**FutureGen 2.0**
- Large-Scale Testing of Oxy-Combustion w/ CO₂ Capture & Sequestration in Saline Formation
- ~$1.3B Total; ~$1.0B DOE
- SALINE – 1.3M TPY 2016 start

**Summit TX Clean Energy**
- Commercial Demo of Advanced IGCC w/ Full Carbon Capture
- ~$1.7B Total; $450M DOE
- EOR – 3M TPY 2014 start

**Hydrogen Energy California**
- Commercial Demo of Advanced IGCC w/ Full Carbon Capture
- ~$4B Total; $408M DOE
- EOR – 3M TPY 2018 start

**NRG**
- W.A. Parish Generating Station
- Post Combustion CO₂ Capture
- 250 MW slip stream from 610 MW unit
- $339M Total; $167M DOE
- Total Est. cost $1.0B
- EOR for TX oilfield owned by NRG
- EOR – 1.4M TPY end of 2016 est. start

**Air Products and Chemicals, Inc.**
- CO₂ Capture from Steam Methane Reformers
  - EOR in Eastern TX Oilfields
  - $368M – private, $284M – DOE (??)
  - In operation

**Archer Daniels Midland**
- CO₂ Capture from Ethanol Plant
  - CO₂ Stored in Saline Reservoir
  - $208M Total; $141M DOE
  - SALINE – ~1 M TPY 2011 start

**Southern Company**
- Kemper County IGCC Project
  - IGCC-Transport Gasifier w/ Carbon Capture
  - ~$2.67B Total; $270M DOE
  - Est.’d @ $5.596B (July 2014) $6.17B (Feb. 2015)
  - 524 MW on syngas (582 MW peak)
  - Adjusted for 90% capture = $11,900/kW
  - EOR – 3 M TPY 2014 start (new start date is 2016)

**Leucadia Energy**
- CO₂ Capture from Methanol Plant
  - CO₂ Stored in Saline Reservoir
  - $436M Total; $261M DOE
  - Project cancelled in October 2014

Source: U.S. DOE NETL 2013; reference to Canadian project from SaskPower presentation to CURC, October, 2013
Independent of a climate driver, less CO₂ is emitted as a result of increased power generation efficiency, and less coal is used for the same unit of power output.

Reduced emissions of traditional air pollutants, reduced water use and consumption, and reduced CO₂ emissions.

**2010 “State of the Art” Baseline Data**

Reductions reflect a range of values for both PC and IGCC technology changes after 2010, but the reductions in 2010 are very significant:

- **CO₂**: 0% (no carbon controls in use)
- **NOx and SO₂**: 90 - 99% reduction
- **PM**: 99.6% reduction
- **Mercury**: 90% reduction
- **Water Withdrawal Reduction** (as a result of cooling towers): 98%
Successful Technology Development Results in Coal-fueled Electricity Cost-Competitive with Low Carbon Alternatives

Slightly larger cost reductions are possibly by 2035 if RD&D is successful on emerging “transformational” power concepts.
The Success of CCS depends upon --

- **Adequate Time** –
  - Next 10 years are crucial

- **Financial support**
  - Majority of funding must be public monies

- **Regulatory support**
  - Accommodate time needed for RD&D

- **Support from legislators, regulators, the public**
3-Part Technology Program: Coal from 2015 to 2050 & Beyond

Efficiency, reliability, and flexibility of the existing coal fleet

Support coal-fueled facilities (CTL, SNG, chemicals, electricity) and spur the development of CO2 capture through enhanced oil recovery

Support Investments in RD&D Today:
- Improve today’s coal-use technologies (target costs & performance)
- Develop “transformational” technologies and create new ways to use coal

Near Term Program: Existing Coal Fleet

Mid-Term Program: New & retrofitted coal with CCS CO2 use for EOR +

Long-Term Program: Transformational technologies for the future
Thank You

CURC
COAL UTILIZATION RESEARCH COUNCIL
www.coal.org