Carbon Capture and Sequestration: Challenges and Costs for Coal

2009 WV Energy Summit: WV’s Commitment to Energy Security
Stonewall Resort – Roanoke, WV
December 8, 2009

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Director, Systems Division
Carbon Capture and Sequestration (CCS)

An Unprecedented Challenge

Doable Today, but Costly

R&D will Reduce Costs
Carbon Capture and Sequestration (CCS)

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Doable Today, but Costly

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Today, I’m proud to announce that EPA has finalized its endangerment finding on greenhouse gas pollution, and is now authorized and obligated to take reasonable efforts to reduce greenhouse pollutants under the Clean Air Act.

Administrator Lisa P. Jackson,
Remarks on the Endangerment Finding on Greenhouse Gases,
As Prepared 12/07/2009
Waxman-Markey (HR 2454)
Unprecedented Environmental Challenge

- Passed House 6-26-09, awaiting Senate action

- Section 703 caps 2050 GHG emissions at 17% of 2005 levels
  - an 83% reduction (reiterated in 11/25/09 pre-Copenhagen White house press release)
  - CCS is essential for meeting cap

- Section 116 would amend the Clean Air Act to apply Performance Standards to **New Coal Plants** (and only to coal)
  - **EXEMPT** – if permitted before Jan-2009
    - but must still acquire emission allowances
  - **50% REDUCTION**
  - **65% REDUCTION**
  - **BEST ACHIEVABLE** – no later than 2025

\[ \sim 1,100 \text{ lb/MWh} \]
\[ \sim \text{equal to least efficient existing NGCC} \]
Coal Has Dealt with Previous Environmental Challenges

Will CO$_2$ be any different?

Changes from 1970

- NO$_x$ Emissions/kWh
  - 82%

- SO$_x$ Emissions/kWh
  - 88%

- PM10 Emissions/kWh
  - 96%

Sources: EPA National Air Pollutant Emission Trends
EIA Annual Energy Review
Pound per Pound, CO₂ Control is Unprecedented in Magnitude

- **NOₓ**: 0.01 lbs per lb of coal
- **SOₓ**: 0.05 lbs per lb of coal
- **CO₂**: 2.34 lbs per lb of coal

50-fold increase compared to SOₓ scrubbers
Annual Emissions from a Typical 500-MW Coal Plant

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New Coal Plants, Current Technology: CCS Adds over 70% to Electricity Cost

- **Supercritical PC**: $150/MWh
- **Supercritical PC w/CCS**: $86/MWh, +73%
- **IGCC w/CCS**: $150/MWh

Notes:
- IGCC and PC fired with Bituminous Coal
- CF for IGCC = 80%, PC = 85%
- 30-Year, Current-Dollar Levelized Cost of Electricity

Draft Final Results – Subject to Revision
Cost of Avoiding CO\textsubscript{2} Emissions in New Coal Plants
Compared to Supercritical PC without Capture

- **If the cost to emit CO\textsubscript{2} is…**
  - $< 90/\text{tonne}$, cheaper to pay for emissions
  - $> 90/\text{tonne}$, cheaper to avoid emissions with CCS
  - (somewhat simplified)

Notes: IGCC and PC fired with Bituminous Coal
CF for IGCC = 80%, PC/NGCC = 85%
An Unprecedented Cost for New Coal Plants

- Relating cost of avoiding CO$_2$ to the coal cost:

<table>
<thead>
<tr>
<th>2.34</th>
<th><strong>tonne CO$_2$ produced</strong></th>
<th>X</th>
<th>0.6</th>
<th><strong>tonne CO$_2$ produced</strong></th>
<th>X</th>
<th>90</th>
<th><strong>$</strong></th>
<th>avoided</th>
<th><strong>$</strong></th>
<th>126</th>
<th><strong>tonne CO$_2$</strong></th>
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</thead>
<tbody>
<tr>
<td></td>
<td><strong>tonne coal</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>coal</strong></td>
</tr>
</tbody>
</table>

Levelized cost of avoiding CO$_2$ is **$126** per tonne of coal.

2.5 to 4 times coal cost of ~$30-50/tonne.

Eliminates coal’s cost advantage?

The 0.6 factor is based on capturing 90% of produced CO$_2$ and reflects efficiency reduction inherent with CCS.
CO₂ Emissions Cost

• Under a simple, across-the-board, CO₂ emission cost...
  – Power plants would add CCS only if the CO₂ emission cost approached $90/tonne (their cost of avoiding CO₂)

• If a ~$90/tonne CO₂ cost is unacceptable, will a “price collar” be applied?
  – “price collar” being debated for proposed Kerry-Boxer Senate bill (~$30/tonne limit?)
  – if so, new plants will not include CCS, unless...

• Congress mandates CCS for new coal (a la W-M)?
  – would equate to a targeted $86/tonne cost for new coal compared to $30/tonne for other plants
What would be the effect of a $90/tonne CO₂ emissions cost? (tax or traded allowance)
Assumptions:
1. $4.50/MMBtu natural gas

Representative of delivered gas price paid by utilities (summer 2009, http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm)
PJM with CO₂ Emissions Cost

Assumptions:
1. $4.50/MMBtu natural gas
2. $90/tonne CO₂

1. Representative of delivered gas price paid by utilities (summer 2009, http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm)
PJM with CO$_2$ Emissions Cost and Coal Performance Standard

Without a CO$_2$ price collar, new coal plants that meet the W-M performance standard could be economically feasible.

- Dispatches before Gas
- 10.5% Return on Equity

Assumptions:
1. $4.50/MMBtu natural gas
2. $90/tonne CO$_2$
3. Capacity price $40/kW-yr

1. Representative of delivered gas price paid by utilities (summer 2009, http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm)
With a CO₂ price collar, new coal plants that meet the W-M performance standard could be economically unfeasible.

New Supercritical PC with 90% CCS

Less than 2% ROE

1. Representative of delivered gas price paid by utilities (summer 2009, [http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm](http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm))
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R&D will Reduce Cost of CCS for Coal Combustion

Cumulative Incorporation of Advanced PC Technologies

- Relative to a Greenfield Supercritical Pulverized Coal Plant Without Carbon Capture

* Increase in Cost of Electricity (%)

Basis:
Supercritical Air-fired PC
550 MW Net Output

CURRENT STATE
Amine Scrubbing

Supercritical Oxyfuel Cryogenic ASU

pilot scale demos planned between 2010 and 2012

ADVANCED
Ultra-Supercritical Cryogenic ASU

ADVANCED
O₂ Membrane Supercritical

ADVANCED

pilot scale demos planned between 2017 and 2025

Advanced Technologies Pathway for IGCC with Carbon Capture

Cumulative Incorporation of Advanced IGCC Technologies

<table>
<thead>
<tr>
<th>Technological Addition</th>
<th>Increase in Cost of Electricity (%)</th>
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</thead>
<tbody>
<tr>
<td>Reference</td>
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<tr>
<td>Coal Feed Pump</td>
<td>68</td>
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<tr>
<td>Adv Materials/Sensors</td>
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<tr>
<td>Warm Gas Cleanup</td>
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<td>Hydrogen Membrane</td>
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<td>1st Gen Adv H2 Turbine</td>
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<tr>
<td>Ion Transport Membrane</td>
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<tr>
<td>Next Gen Adv H2 Turbine</td>
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<td>Adv Controls/Experience</td>
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<tr>
<td>Adv. Integrated Gasification Fuel Cell</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td><strong>demonstrated at pilot scale</strong></td>
</tr>
</tbody>
</table>
|                                 | **pilot scale demos planned by 2015**

*Relative to a Greenfield Supercritical Pulverized Coal Plant Without Carbon Capture*
Conclusions

• CCS is an unprecedented challenge for coal
  – CCS needed to meet W-M’s 83% reduction by 2050
  – 50-fold increase compared to sulfur scrubbers

• CCS is doable today, but costly
  – Adds 70% to cost of electricity from new coal plants
  – CO$_2$ emission cost approaching $90/tonne needed to justify CCS
  – $90/tonne CO$_2$ emission cost could quadruple PJM electricity cost
  – Double regulatory burden for coal?
    • Performance Standard AND CO$_2$ Price Collar
    • Could make new coal plants unacceptable to developers
    • Could disproportionately impact economies of coal-reliant states

• R&D will reduce costs
  – 16% to 30% adder for CCS instead of 70% adder