Carbon Reduction Options in Power Generation

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Detroit Branch

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Overview

- What needs to be done
- When does it need to be done
- Where does electrical generation fit
- What are the options in generation
- US Generation Fleet Characteristics
- Retrofitting Existing PC Plants
- Fleet Impact of Retrofit CO₂ Capture
- Issues Outside the Plant Gate
- Regional Considerations
What Needs to be Done about CO₂

- UK's Stern calls on 'rich' nations for 75% cut in greenhouse gases
  - September 27, 2007 (Emissions Daily) -- Sir Nicholas Stern, told US congressional staff on September 21 that the United States, EU countries and other industrialized nations should agree this year to cut emissions 75% below 1990 levels by 2050.

- What constitutes an appropriate level of GHG in the atmosphere remains open to debate, but even modest scenarios for stabilization would eventually require a reduction in worldwide GHG emissions of 50 to 90 percent below current levels. Source: “Carbon Sequestration Program Environmental Reference Document”, August 2007, DE-AT26-04NT42070 National Energy Technology Laboratory
When Should CO₂ Capture be Required

  - Recommendation #6b: Congress should act to close this potential “grandfathering” loophole before it becomes a problem for new power plants of all types that are being planned for construction. (Page 100)

  - The technology development pathways outlined in this section are intended to achieve two key targets: first, increase the efficiency of PC and IGCC baseload plants (with CO2 capture) to the 43-45% range by 2030; and second, ensure that all coal plants built after 2020 have the capability to capture and store 90% of the CO2 produced.
Carbon Dioxide Sources

- US 2005: 5945 million tonnes CO$_2$ all sectors
- Electrical generation: 2375 million tonnes
- Transportation: 1953 million tonnes
- Electric power and transportation are roughly $\frac{3}{4}$ of the total

Source: EIA Annual Energy Review 2006
Why Electricity Generation is a Target

- Transportation and coal-fired generation have similar CO$_2$ emissions
  - 1953 Million tonnes – coal 2005
  - 1944 Million tonnes – transportation sector 2005
- There are about 1500 coal-fired generators, about 240 million cars and trucks
- The average coal plant emitted 1.6 million tonnes, the average vehicle emitted 8.1 tonnes

Sources: Emissions: EIA Annual Energy Review 2006
Electricity and Transportation

US Power Plants > 100 MW

Source: EIA Website

1536 total power plants greater than 100 MW
What are the Options in Electricity

- Fuel switching
  - Substituting natural gas for coal
- Post combustion capture
  - Conventional PC with amine scrubbing of flue gas
  - Oxyfuel PC with amine scrubbing of flue gas
- Pre-combustion capture
  - IGCC
    - *FutureGen prototype*
- Chemical looping and other approaches
- Nuclear and renewables
  - These are subjects of other presentations today
Fuel Switching – Coal to Natural Gas

- Existing coal fleet has 72.2% capacity factor, 32.8% thermal efficiency
- Existing gas fleet has 23.7% capacity factor, 39% thermal efficiency
- Substituting gas for coal reduces emissions about 53%, not 70-90% needed
- *We don’t have either the gas resources or deliverability to make this substitution*
Post Combustion Capture

- Conventional PC with Scrubbing
  - Costs
  - Derating, Efficiency reduction
  - Lack of utility-scale experience

- Oxyfuel PC with Scrubbing
  - Cost, complexity
  - Air separation reduces efficiency, derates output
  - Lack of experience base
Pulverized Coal – No Capture
Current Technology
Pulverized Coal Power Plant

Orange blocks added for carbon capture

Source: Cost and Performance Baseline for Fossil Energy Plants, National Energy Technology Laboratory, April 10, 2007
Oxyfuel PC with CO₂ Capture
Oxyfuel Combustion

Oxyfuel Challenges

1. **High combustion temperatures**
   * Boiler materials of construction issues
   * Requires large amounts of flue gas recycle

2. **Cryogenic oxygen production is expensive and energy intensive**
   * Opportunity for oxygen membranes

Source: NETL Carbon Sequestration Program

*US Perspective on CO2 Capture and Separation*, Jared P. Ciferno,
April 27, 2004

Stanford University
IGCC with Carbon Capture

Orange blocks added for carbon capture

Source: Cost and Performance Baseline for Fossil Energy Plants, National Energy Technology Laboratory, April 10, 2007
Existing US IGCC Plants

Both plants were built under the Clean Coal Technology Program of DOE

Tampa Electric

Wabash River

NGCC with Carbon Capture

Source: Cost and Performance Baseline for Fossil Energy Plants, National Energy Technology Laboratory, April 10, 2007
Current Generation Capacity

- Scale of current generation fleet
  - 970+ GW capacity, 16,000+ units
  - 1500 >100 MW plants, 400+ are PC
  - Pre-combustion fleet very small
    - Wabash River, IN
    - Tampa, FL

- Oxyfuel is a possible path from PC to IGCC with CCS
  - No utility-scale currently
US Generation Fleet Characteristics

U.S. Electric Power Industry
Net Summer Generating Capacity, 2005

Source: EIA Electricity Website, http://www.eia.doe.gov/neic/brochure/elecinfocard.html
CO₂ Emission from Generation Plants

Net CO₂ Emissions for New Plants

## Plant Cost Comparison

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Avg Cost ($/kW)</th>
<th>Avg Cost w/ CO2 Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg IGCC</td>
<td>1841</td>
<td>2496</td>
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<tr>
<td>Avg IGCC w/ CO2</td>
<td>1549</td>
<td>2895</td>
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<tr>
<td>PC-Sub</td>
<td>1575</td>
<td>2870</td>
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<td>PC-Sub w/ CO2 Capture</td>
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<tr>
<td>PC-Super</td>
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<td>1172</td>
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<td>PC-Super w/ CO2 Capture</td>
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*Revised August 2007, National Energy Technology Laboratory*
Cost of Electricity Impacts

January 2007 Dollars, Coal cost $1.80/106Btu. Gas cost $6.75/106Btu

Revised August 2007, National Energy Technology Laboratory
Retrofitting an Existing PC Plant

Conesville Unit #5 studied

Subcritical steam cycle

463 MW gross, 430 MW net

Bituminous coal

ESP and wet lime FGD

Source: CO2Capture From Existing Coal-Fired Power Plants, Jared P. Ciferno -National Energy Technology Laboratory, April 2007
This type of FGD would be needed for most coals, retrofit or new.
Impacts on Net Output and CO₂ Emissions

Source: CO₂ Capture From Existing Coal-Fired Power Plants,
Jared P. Ciferno - National Energy Technology Laboratory,
April 2007

Capital costs ranged from 417 $/kW at 30% capture to 1010 $/kW at 90% capture.
Roughly 250 MW of incremental capacity needed for every 1000 MW of capacity retrofitted at 70% carbon capture

NETL and Argonne are beginning a joint study to better understand the grid-level implications of retrofitting significant levels of generation capacity with CO₂ capture

- Midwest will be initial focus
- Least-cost replacement power sources and impacts will be examined
Issues Outside the Plant Gate

- Pipeline costs, rights-of-ways, regulations
- Availability of adequate storage (sequestration) capacity
- Unsettled legal and regulatory issues
  - Who owns the CO₂
    - *Is the CO₂ a ‘waste’ or a product*
  - Who owns the mineral rights and/or property rights at the sequestration site
  - What will the monitoring requirements be
    - How long will they run
  - If cap and trade, how will the trading regimen work
  - Who owns the short-term and long-term liabilities
US Power Plants and CO₂ Pipelines

Top map from EIA website

Electric Power Plants
Min. net summer capacity of 100 megawatts
(Values below are U.S. totals)
- Natural Gas (731)
- Coal (401)
- Hydro (183)
- Petroleum (108)
- Nuclear (56)
- Wind (31)
- Wood (8)
- Geothermal (4)
- Biomass (2)
- Solar (2)
How does the Chicago FRB Region Compare to US

- States of Illinois, Indiana, Iowa, Michigan, and Wisconsin taken as surrogate for FRB region

Illinois, Indiana, Iowa, Michigan, Wisconsin

- Coal: 66%
- Petroleum: 6%
- Natural Gas: 25%
- Other Gases: 6%
- Nuclear: 0%
- Hydroelectric: 19%

US Total

- Coal: 50%
- Petroleum: 7%
- Natural Gas: 19%
- Other Gases: 0%
- Nuclear: 19%
- Hydroelectric: 3%
Regional Capacity and Generation

Illinois
- 48%
- 48%
- 4%

Indiana
- 95%
- 3%
- 2%

Regional Generation 2005

- Other Renewables
- Hydroelectric
- Nuclear
- Other Gases
- Natural Gas
- Natural Gas
- Petroleum
- Petroleum
- Coal

[Graph showing regional generation with states and energy sources represented]
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Useful URLs

www.eia.doe.gov  
www.netl.doe.gov  
www.anl.gov

Thank you for your attention