Global Outlook for Coal-Based Power Generation: Implications for Developing Countries

Edward S. Rubin
Department of Engineering and Public Policy
Department of Mechanical Engineering
Carnegie Mellon University
Pittsburgh, Pennsylvania

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Outline of Talk

- Global energy demand, coal use and CO$_2$ emissions
- The needs of climate change mitigation
- Past trends in “clean coal technology”
- Status and outlook for CO$_2$ capture & storage (CCS)
- The role of CCS in developing countries
Outlook for World Energy Use
(reference case scenario)

Source: USDOE-EIA, 2008

50% increase

World Electricity Generation
(reference case scenario)

Source: USDOE-EIA, 2008

E.S. Rubin, Carnegie Mellon
World Coal Consumption
(reference case scenario)

Source: USDOE-EIA, 2008

CO₂ Emissions from Coal Combustion
(reference case scenario)

Source: USDOE-EIA, 2008
Avoiding Serious Climate Impacts Requires Large Reductions in CO₂

The most recent IPCC assessment indicates potentially serious impacts for more that a 2°C rise in average global temperature

<table>
<thead>
<tr>
<th>Atmospheric stabilization CO₂-equiv (ppm) (2005=375 ppm)</th>
<th>Global avg. temperature increase over pre-industrial</th>
<th>Required year for peak global CO₂ emissions</th>
<th>Required change in global CO₂ emissions from 2000 to 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>445 – 490</td>
<td>2.0 – 2.4 °C</td>
<td>2000–2015</td>
<td>-85% to -50%</td>
</tr>
<tr>
<td>535 – 590</td>
<td>2.8 – 3.2 °C</td>
<td>2010–2030</td>
<td>-30% to +5%</td>
</tr>
<tr>
<td>710 – 855</td>
<td>4.0 – 4.9 °C</td>
<td>2050–2080</td>
<td>+25% to +85%</td>
</tr>
</tbody>
</table>

Source: IPCC, 2007

Lower stabilization levels require earlier action to reduce emissions

The Potential of Clean Coal Technology

- The term “clean coal technology” was coined in the 1980’s to describe new PC and IGCC power plants with low levels of particulate, SO₂ and NOₓ emissions
- Here are the trends for new U.S. power plants:
The Potential of Clean Coal Technology (2)

- Increasingly, “clean coal” also means low emissions of CO\textsubscript{2}—both from improved power plant efficiency (e.g., use of supercritical vs. subcritical boilers), and also from the use of CO\textsubscript{2} capture and storage (CCS).

CCS is a key element of cost-effective global energy strategies

Source: IPCC, 2007
Key Messages

• Coal-based power plants will continue to provide the major share of electricity demand for decades to come, especially in emerging economies
• Large reductions in CO₂ emissions from coal plants are needed to avoid serious impacts of climate change
• Only CCS has promise to reconcile continued use of coal with climate change mitigation

Status of CCS Technology

• CO₂ capture technologies are commercial and widely used in industrial processes, mainly in the petroleum and petrochemical industries (e.g., for ammonia production and processing of natural gas)
• CO₂ capture also has been applied to several gas-fired and coal-fired boilers (to produce commodity CO₂ for sale), but at scales that are small compared to a large modern power plant
• Integration of CO₂ capture, transport and geologic sequestration has been demonstrated in several industrial applications, but not yet at an electric power plant
Three Current CCS Projects

- Weyburn (Canada)
- Sleipner (Norway)
- In Salah (Algeria)

Estimated Increase in New Plant Costs with Current CCS Technology

<table>
<thead>
<tr>
<th>Incremental Cost of CCS Relative to a Similar Plant without CCS based on bituminous coals</th>
<th>Supercritical Pulverized Coal Plant</th>
<th>Integrated Gasification Combined Cycle Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in capital cost ($/kW) and total generation cost ($/MWh) (w/ deep aquifer storage)</td>
<td>~ 70%</td>
<td>~ 40%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost of CO₂ avoided (US costs)</th>
<th>~ $70 /tCO₂</th>
<th>~ $40 /tCO₂*</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Deep aquifer storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Enhanced oil recovery + storage</td>
<td></td>
<td></td>
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</tbody>
</table>

* ~$55/t relative to a SCPC plant. Different choices of reference plant have different avoidance costs.

Source: Based on IPCC, 2005; Rubin et al, 2007; DOE, 2007

Costs vary widely for different assumptions and circumstances
Barriers to CCS Deployment

- No requirement for large reductions in CO₂ emissions
- High cost of current technology
- Lack of experience in power plant applications
- Lack of regulations for large-scale geological sequestration
- Unresolved legal issues (e.g., long-term liabilities)
- Uncertainties about public acceptance

*These barriers do not apply in all countries*

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Full-Scale Projects Are Needed to...

- Establish the *reliability* and true cost of CCS in commercial power plant applications
  - For different technologies, coal types, and geological settings
- Help establish legal and regulatory requirements for geological sequestration at large scales
- Reduce future cost of CCS via learning-by-doing plus sustained R&D
Potential Cost Reductions for CCS

Many Government Programs and Public-Private Partnerships Are Already In Place

Some of the government programs supporting CCS:

- Australia
- Canada
- China
- European Union
- United Kingdom
- United States

Funding levels and scale of projects vary widely
### Current Activity

A variety of CCS projects are proposed or planned in different parts of the world.

#### Project Name

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Location</th>
<th>Feedstock</th>
<th>Size MW</th>
<th>Capture Process</th>
<th>CO2 Fate</th>
<th>Start-up</th>
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</thead>
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<tr>
<td>Total Laxi</td>
<td>France</td>
<td>Oil</td>
<td>35</td>
<td>Day</td>
<td>Seq</td>
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<tr>
<td>Southern Completion</td>
<td>Germany</td>
<td>Coal</td>
<td>30/300/1000</td>
<td>Day</td>
<td>Undecided</td>
<td>2009</td>
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<tr>
<td>AGP Emsland Moorsbiener</td>
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<td>50</td>
<td>Post</td>
<td>Seq</td>
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<tr>
<td>Columbia Oxy Fuel</td>
<td>Australia</td>
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<td>75</td>
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<tr>
<td>GreenGen</td>
<td>China</td>
<td>Coal</td>
<td>25/300</td>
<td>Pre</td>
<td>Seq</td>
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<td>Homemade</td>
<td>USA</td>
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<td>Dec</td>
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<td>China</td>
<td>Coal</td>
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<td>Jangsz House</td>
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<td>Post</td>
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<td>Sweden</td>
<td>Oil</td>
<td>5</td>
<td>Post</td>
<td>Undecided</td>
<td></td>
</tr>
</tbody>
</table>

Source: MIT, 2008

### Existing/Proposed CO2 Storage Sites

- **Sites currently injecting CO2**
- **Planned CCS sites (at least 700,000 t CO2/yr)**
- **Sites which have been cancelled or have completed injection**
The GreenGen Project
(Tianjin, China)


Financing large-scale CCS projects has been a major hurdle

Options for financing early CCS projects (in U.S. and other industrial countries):

- Expand traditional “technology policy” options (e.g., tax credits, loans, subsidies, etc.)
- Adopt sufficiently stringency cap-and-trade program w/ CCS bonus allowances and/or a tech. fund (e.g., from auction of allowances)
- Establish a CCS Trust Fund with fees used to pay full added cost of early CCS projects
- Set new regulations requiring CCS
CCS and Developing Countries

• CCS projects in developing countries can contribute significantly to the worldwide need for large-scale demonstrations at coal-based power plants

• Current government and industry programs need to aggressively pursue additional options to raise roughly $1–2 billion/yr to support early CCS projects

• The World Bank potentially can contribute to this effort, in conjunction with other international programs, via its Clean Technology Fund and other mechanisms

• The sooner countries take action, the better our chances of avoiding serious impacts of global climate change

Thank You

rubin@cmu.edu