Options and Issues for CO$_2$ Capture and Storage

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April 3, 2009
CO₂ Capture in Coal Power Systems

**Postcombustion (PC)**
- Coal
- Air
- Power & Heat
- CO₂ Separation
- N₂
- O₂
- CO₂

**Precombustion (IGCC)**
- Coal
- Air/O₂
- Gasification
- Shift, Gas Cleanup + CO₂ Separation
- Steam
- H₂
- Power & Heat
- CO₂

**Oxyfuel Combustion**
- Air
- Air Separation
- N₂
- O₂
- CO₂
- Power & Heat

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Opportunity and Issues

Opportunities

• Global interest in demonstrating CO2 Capture and Storage (CCS)
• US Stimulus funding for CCS~ $3.4B
• Europe, Australia, China, Japan all putting money and effort into developing options

Issues

• Cost and Energy Use of Capture
• Technology of storage
• Assurance and legal/siting issues for storage
New Technology Deployment Curve for Coal

Not All Technologies at the Same Level of Maturity.
EPRI PC and IGCC Capital Cost Estimates
With and Without CO₂ Capture (Sub-Bituminous PRB Coal)

CURRENT TECHNOLOGY

No Capture  Retrofit Capture  New Capture

IGCC and CCS cases have +10% contingency for first-of-a-kind
With Current Technology CO₂ Capture Costly
No Clear Winners in Current Designs

- COE Includes $10/tonne for CO₂ Transportation and Sequestration
- IGCC & CCS include 10% TPC contingency for first-of-a-kind

Illinois #6 Bituminous
PRB (Western Sub Bituminous Coal)

30-Yr levelized COE, $/MWh (Constant 2007$)

- No Capture
- Retrofit-Capture
- New Capture

Installed Later

MEA- installed initially

Supercritical PC
GE Total Quench
Average IGCC
Ultrasupercritical PC
ConocoPhillips E-Gas
Average IGCC
Cost & Performance Penalties for CO₂ Capture
(based on retrofit of existing PC or IGCC plant – today’s technology)

PC = Pulverized fuel
IGCC = Integrated Gasification combined Cycle
Bit = Bituminous
Subbit = Subbituminous
Shell = Shell
E-Gas = Conoco Phillips
GE Q = GE Quench
GE RQ = GE Radiant Quench

Increase in Capital Cost ($/kW)

Reduction in Net Power Output

PC-Subbit
PC-Bit

IGCC Shell-Bit
IGCC Shell-Subbit
IGCC E-Gas-Subbit
IGCC E-Gas-Bit
IGCC GE RQ-Bit
IGCC GE Q-Bit

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CO2 Capture
Typical Solvent-based Process

Flue Gas from FGD
Chilled Water
Gas Cooling and Cleaning
Cooled Flue Gas
CO2 Absorber
Reagent
CO2 Regenerator
Clean CO2 to Storage
Gas to Stack

Graphics courtesy of Alstom
EPRI Finding Many Process Being Developed for Post-Combustion CO$_2$ Capture

~ 30 processes found 2/07 (Report #1012796)
> 75 processes now (Report #1016995)

Goal: 10% Energy Penalty (stretch), ≤ 20% COE Increase
Demonstrations of CCS and Related Technology

Idea → Lab/Pilot → Demonstration
Examples of CCS Demonstrations and Commercial IGCC/CCS Units Planned

- RWE (Germany) Goldenbergwerk 450MWe
- GreenGen (China)
- ZeroGen (Australia)
- Southern Calif Edison (USA) Utah 600+ MW 90% capture
- FutureGen (USA) original
- BP/Rio Tinto (HE) 300 MW+ unit planned near Bakersfield CA (USA) 90% capture
- Duke Edwardsport (USA) 600+MW IGCC construction now plans partial CCS
- Mississippi Power (USA) 600+MW IGCC brown coal/lignite partial CCS FEED
- Polk Tampa new slipstream demonstration planned of CCS
Examples of Demonstrations Oxy-Fuel/ Oxy-Combustion

- Oxy-fuel/ Oxy Combustion
  - Vattenfall Schwarze Pumpe
    Germany 30 MWt (~ 10 MWe) operating in test mode 2008
  - B&W USA 30 MWt (~ 10 MWe) operating in test mode 2007-8. B&W looking at larger proposal
  - Callide oxyfuel – ~30 MWe in Queensland Australia in operation 2010 injection 2011
  - Jamestown (USA) announced ~ 50 MWe CCPI proposal
Examples of Planned Demonstrations of Pulverized Fuel with CCS

- PF/CCS Chilled ammonia (Ammonia Absorption/Stripping)
  - AEP (USA) ~ 200+ MWe Northeastern or Mountaineer plant EOR possible after 20 MW demo with EPRI/Alstom
  - TransAlta (Canada) announces large scale installation
  - Follow-on to Mummorah PCC in NSW?
- PowerSpan ECO₂™ (Ammonia Absorption/Stripping)
  - Basin (USA) Electric adds lignite unit 120 MWe EOR and saline storage
- Polish Alstom Amine (with Dow) Elektrownia Bełchatów. (Pilot first)
- Advanced Amine Southern Co site 25 MW (Pilot first) saline storage managed by EPRI in demo
- China TPRI Amine 20 MW in Shanghai operating April 2010
Chilled Ammonia Pilot Plant at We Energies

- Alstom and more than 37 U.S. and international utilities funding this project
- Designed to capture up to 15,000 tons/year of CO$_2$
- Testing to continue through 2008 – mid 2009 to establish process performance and measure energy consumption
- Develop techno-economic analysis to scale the system for commercial applications

We Energies Pleasant Prairie Power Plant (P4)
### BOD-Approved Generation Demo Projects

Three project groups comprise six projects:

<table>
<thead>
<tr>
<th>Description</th>
<th>Size</th>
<th>Estimated/Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC with CCS: AEP</td>
<td>20 MW</td>
<td>$130M</td>
</tr>
<tr>
<td>PC with CCS: Southern Co.</td>
<td>25 MW</td>
<td>$150M</td>
</tr>
<tr>
<td>ITM for Low Cost Oxygen Production</td>
<td>150 tons O₂/day</td>
<td>$75M</td>
</tr>
<tr>
<td>IGCC with CCS Project 1 (Tampa Electric)</td>
<td>300,000 tons CO₂/year</td>
<td>$210M</td>
</tr>
<tr>
<td>IGCC with CCS Project 2 (Duke Energy)</td>
<td>1M tons CO₂/year</td>
<td>$200M</td>
</tr>
<tr>
<td>IGCC with CCS Project 3 (SCE)</td>
<td>3.5M tons CO₂/year</td>
<td>$250M</td>
</tr>
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Current Generation Demonstrations Funders

- AECC
- AEP Service Corp.
- Ameren Services Co.
- Buckeye Power, Inc.
- Duke Energy Corp.
- ENEL (Italy)
- Entergy Services, Inc.
- Great Plains Energy
- Oglethorpe Power Corp.
- Salt River Project
- Sierra Pacific / NV Energy
- Southern Co. Services, Inc.
- Stanwell (Australia)
- Tri-State G&T Assoc., Inc.
- We Energies

Over 1/3 of the installed coal capacity in the U.S. plus two internationals to date

Over $38M raised so far
Is CO₂ Pipeline for EOR Experience Applicable to CCS or Manageable? Knowledge is the Key

>4500 km of CO₂ Pipe in US Today…550,000 for Natural Gas
Summary…

• Looking ahead … more will need to be done to validate the CO₂ Capture, Transport and Storage technologies on a larger scale – must start now

• Many organizations support large scale demonstrations…. “Without so-called carbon capture and storage, or CCS technologies, emissions reductions in developing nations such as China and India are impossible”- IEA Executive Director Nobuo Tanaka 24 November 2008

• EPRI’s role is to collaboratively help coordinate and facilitate Industry projects and help accelerate their introduction into the marketplace
Together…Shaping the Future of Electricity