THE COAL RESEARCH FORUM

19th ANNUAL MEETING

“CURRENT DEVELOPMENT IN COAL RESEARCH”

“IGSC – A PRESSURISED OXYFUEL CYCLE THAT USES WATER AS A COOLANT”

10TH APRIL 2008
The Original CES Cycle Concept

- **O₂**
- **Fuel**
- **Gas Generator**
- **Recycle Water**
- **CO₂ Recovery**
- **Cond.**
- **HX**
- **Elect Gen.**
- **Multi-stage Turbines**
- **Direct Sales**
- **EOR, ECBM, or Sequestration**
- **Excess Water**

*CH₄, CO, H₂, etc.*
20 MW_th GAS GENERATOR - 2
20 MW$_{th}$ GAS GENERATOR - 3
200 MW$_{th}$ GAS GENERATOR
IGSC Project Development – List of Cases

- DEVELOPMENT
  - Mark 1
  - Mark 2
  - Mark 3

- BASE - For the Review Report

- UTILITY – For New Power Stations

- RETROFIT – For Existing Power Stations

- INDUSTRIAL – Also for a Hatfield Demo Plant
The IGSC Flowscheme
(Brayton and Rankine Cycle)

- Coal
- Water Quench Gasifier
- Slag
- Oxygen
- Total Combustion
- Fired Expander
- Water Saturated Syngas
- HRSG
- HP Steam
- LP Steam
- CO₂ Separation
- CO₂ (and SO₂)
- Recycle of Hot Water

- Steam Turbine

- Recycle of Hot Water
IGSC – 1200 MW Utility Case

Oxygen

Coal

Quench Gasifier

24 CES Burners around Circumference

Fired Expander

V94.3A Gas Turbine Expander

HRSG

Main Steam Turbine

LP Steam Generator

Electricity

Clean Condensate

CO₂ (and SO₂)

Surplus Water

BFW

Electricity

Water

Slag
Siemens SGT5-4000F (V94.3A)
Gas Turbine Combustion Chamber
CO₂ Removal/LP Steam Generation

Steam & CO₂

LP Steam

Desaturator

CO₂

To Sulphur Recovery

SO₂ Scrubber

Water Recycle to Combustion

LP Steam

Boiler

BFW

LP Steam

Boiler
Typical Sensitivity to Desaturator Pressure

Efficiency vs Desaturator Pressure

Efficiency

Pressure bara
# New Power Plant Options with CCS - 1

<table>
<thead>
<tr>
<th></th>
<th>Pre-Combustion IGCC</th>
<th>Post Combustion Oxyfuel</th>
<th>Flue Gas Scrubbing not Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO2 Recycle</td>
<td>IGSC Water Recycle</td>
<td></td>
</tr>
<tr>
<td><strong>Coal Preparation</strong></td>
<td>Grind to 200 mesh</td>
<td>Grind to 200 mesh</td>
<td>Grind to 200 mesh Wet or dry feed</td>
</tr>
<tr>
<td><strong>ASU</strong></td>
<td>40%</td>
<td>100%</td>
<td>100% 95% Oxygen</td>
</tr>
<tr>
<td><strong>Energy Conversion</strong></td>
<td>Gasification GT Combustors</td>
<td>Coal Combustion</td>
<td>Gasification CES Burners Total Combustion</td>
</tr>
<tr>
<td><strong>Shift System</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Heat Recovery</strong></td>
<td>Steam Raising</td>
<td>Steam Raising</td>
<td>Steam Raising</td>
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<tr>
<td><strong>Acid Gas Removal</strong></td>
<td>Two Stage</td>
<td>Sulphur Scrubber</td>
<td>Optional (from CO2)</td>
</tr>
<tr>
<td><strong>CO2 Compression</strong></td>
<td>From Atmospheric</td>
<td>From Atmospheric</td>
<td>From 10 bar 100 bar export</td>
</tr>
<tr>
<td><strong>Power Generation</strong></td>
<td>Gas plus Steam Turbine</td>
<td>Steam Turbine</td>
<td>Fired Expander plus Steam Turbine</td>
</tr>
<tr>
<td><strong>Stack</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>“Standard” Unit Size</strong></td>
<td>c550 MW</td>
<td>c500 MW</td>
<td>300-500 MW</td>
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</tbody>
</table>
### New Power Plant Options with CCS - 2

<table>
<thead>
<tr>
<th></th>
<th>Pre-Combustion IGCC</th>
<th>Post Combustion Oxyfuel</th>
<th>Flue Gas Scrubbing not Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ Recycle</strong></td>
<td></td>
<td>CO₂ Recycle</td>
<td>IGSC Water Recycle</td>
</tr>
<tr>
<td><strong>Available</strong></td>
<td>Now</td>
<td>Burner development In hand</td>
<td>Fired Expander development in hand</td>
</tr>
<tr>
<td><strong>Suitability for Retrofit</strong></td>
<td>Only if Shift already fitted</td>
<td>Any Steam Turbine</td>
<td>Any Steam Turbine</td>
</tr>
<tr>
<td><strong>Capture Capability</strong></td>
<td>90%</td>
<td>Near 100%</td>
<td>Near 100%</td>
</tr>
<tr>
<td><strong>CO₂ Purity</strong></td>
<td>97%</td>
<td>90%</td>
<td>92%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impurities mainly argon and nitrogen</td>
</tr>
<tr>
<td><strong>Water Consumption</strong></td>
<td>Loss up Stack</td>
<td>Blowdowns and FGD Discharge loss</td>
<td>Blowdowns Only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxyfuel and IGSC retain water from fuel hydrogen</td>
</tr>
<tr>
<td><strong>Intrinsic By-Products</strong></td>
<td>Sulphur</td>
<td>Sulphur Compounds</td>
<td>None</td>
</tr>
<tr>
<td><strong>Possible By-Products</strong></td>
<td>Hydrogen</td>
<td>Gypsum</td>
<td>Sulphur Compounds</td>
</tr>
<tr>
<td><strong>Solid Effluent</strong></td>
<td>Non-Leaching Slag</td>
<td>Ash</td>
<td>Non-Leaching Slag</td>
</tr>
<tr>
<td><strong>Liquid Effluent</strong></td>
<td>Quench, Boiler blowdowns</td>
<td>Boiler blowdown, Acid Condensate</td>
<td>Quench, Boiler blowdowns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxyfuel and IGSC Retain Water from Fuel Hydrogen</td>
</tr>
<tr>
<td><strong>Gaseous Effluent</strong></td>
<td>SOₓ &amp; NOₓ in Gas Turbine Exhaust</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
IGSC – Generic Flowscheme

- Oxygen
- Coal
- Slag
- Water
- BFW
- HRSG
- Quench Gasifier
- Fired Expander
- Retrofit or New Steam Turbine

Electricity
Clean Condensate
CO2 (and SO2)
Surplus Water
Cycle Advantages

• ALL COMMERICALLY PROVEN EQUIPMENT WITH THE EXCEPTION OF THE FIRED EXPANDER

• SUITABLE FOR RETROFITTING EXISTING SINGLE CYCLE POWER STATIONS

• ROBUST AND STABLE OPERATION

• NO MAINSTREAM SULPHUR REMOVAL (SO₂ CAN BE REMOVED FROM PRODUCT CO₂)

• EASY START-UP AND SHUT-DOWN USING NATURAL GAS

• SIGNIFICANT PRODUCTION OF SURPLUS WATER

• DEMONSTRATION UNIT BEING PLANNED FOR HATFIELD IGCC SITE
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