Topics

• IGCC environmental performance
  – Air
  – Water
  – Wastes
• Impacts of adding CO\textsubscript{2} capture
• Hybrid IGCC configuration
• Conclusions
Permits/Permit Applications for Actual IGCC Projects

- **Excelsior Energy, Mesaba Energy Project, MN**
  - 600 MW\textsubscript{e}, No CO\textsubscript{2} Capture
  - E-Gas/MDEA

- **Taylorville Energy Center, IL**
  - 542 MW\textsubscript{e}, Hybrid
  - Siemens/Rectisol

- **Duke Energy, Edwardsport, IN**
  - 630 MW\textsubscript{e}, No CO\textsubscript{2} Capture
  - GE RQ/Selexol

- **Mississippi Power, Kemper County IGCC**
  - 582 MW\textsubscript{e}, 65% CO\textsubscript{2} Capture
  - KBR TRIG/Selexol

- **Cash Creek Generation, KY**
  - 566 MW\textsubscript{e}, Hybrid
  - GE Quench/Selexol

- **Hydrogen Energy California**
  - 250 MW\textsubscript{e}, 90% CO\textsubscript{2} Capture
  - GE Quench/Rectisol
Air Emissions
SO$_2$ Emission Rate Comparison

- **Excelsior - Mesaba-syngas**
- **Duke Edwardsport - syngas**
- **Mississippi Power - Kemper County-H2**
- **Cash Creek Generation-syngas**
- **Hydrogen Energy California-H2**
- **Cash Creek Generation Hybrid SNG**

Data from public submittals
NOx Emission Rate Comparison

- **Excelsior - Mesaba IGCC**
- **Duke Edwardsport - syngas**
- **Mississippi Power - Kemper County**
- **Cash Creek Generation**
- **Cash Creek Generation Hybrid IGCC**

Data from public submittals
Mercury Removal

- Pre-sulfided activated carbon beds
- >94% removal of vapor-phase mercury at Eastman Chemical
- Spent carbon disposed of in drums once/year
- Proposed IGCC plants will use this technology

Source: Eastman Chemical
For IGCC reference plant:

- 784 MW (gross) unit, 464 MW is from CTs and 320 MW is from the ST
- Only ~1/3 of total output is from steam turbine, so condenser cooling water make-up needs are decreased by ~2/3

No FGD system with IGCC, so no need for water to produce limestone slurry
IGCC Water Consumption

• Water requirement for slurry-feed gasifiers to produce slurry of about 65% solids that is pumped to the gasifier
• Syngas coolers have pure water needs for producing steam
• Gasification plants usually include a combined cycle power block
  – Cooling tower makeup
Raw Water Usage for Power Plants
IGCC is ~40% less than for PC

Source: U.S. DOE
Wastewater Production – Sources of Contaminants

• Ash in the feedstock
  – Slag (for high temperature gasification)
  – Bottom ash (for low temperature gasification)
  – Fly ash

• Chlorides in the raw water and feedstock

• Sulfur in the feedstock

• Compounds formed in the gasification process
  – Ammonia
  – Sulfides
  – Formates
  – Cyanides
Water and Wastewater Discharges

- IGCC design typically based on significant re-use and recycling of process water discharges
- Zero liquid discharge systems are common
  - Vapor recompression systems
  - Evaporator-crystallizers
  - Ammonium chloride brine cake for disposal
    - May be a hazardous material depending on contaminants, requiring appropriate disposal,
Solid Byproducts

• Ash is removed in molten form, then quench-cooled to form glassy, inert slag
Slag Use

- Used for making
  - Cement
  - Asphalt filler
  - Roofing shingles
  - Sand-blasting grit
Other Byproducts

• Sulfur
  – Recovered in molten form
  – Transported by rail or truck

• Sulfuric acid
  – Various concentrations can be produced, depending on local markets
  – Transported by rail or truck
CO$_2$ Capture
IGCC Reference Plant Block Flow Diagram
No CO₂ Removal
Water Shift Reaction

- Low concentration of CO$_2$ in syngas
- Must be increased for efficient removal
- By adding steam to the syngas, over a catalyst bed, the CO in the syngas is converted to CO$_2$, raising the concentration in the syngas to >50%
IGCC Reference Plant Block Flow Diagram w/Water Shift Reactor and CO₂ Capture

New items in RED
Impact of CO₂ Pipeline Specification on Sulfur Removal

• Pipeline specification for H₂S/COS may require additional capacity in acid gas removal system or CO₂ capture stage

<table>
<thead>
<tr>
<th></th>
<th>Dakota Gasification</th>
<th>FutureGen</th>
<th>Kinder Morgan</th>
<th>Hydrogen Energy CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>&gt; 95%</td>
<td>95%</td>
<td>&gt; 95%</td>
<td>&gt;97%</td>
</tr>
<tr>
<td>H₂S</td>
<td>&lt; 20,000 ppmv</td>
<td>100 ppmv</td>
<td>20 ppmw*</td>
<td>-</td>
</tr>
<tr>
<td>Total S</td>
<td>-</td>
<td>-</td>
<td>35 ppmw**</td>
<td>&lt;30 ppmv</td>
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</table>

• Options for increasing CO₂ purity include:
  - Increase pressure to improve Selexol CO₂ capture efficiency
  - Add post-capture purification of CO₂ through compression / liquefaction / gas separations / pumping
  - Use Rectisol process
What Happens When CO$_2$ Compressor or CO$_2$ Pipeline is Out of Service?

• Option 1 - CO$_2$ stream could be vented
  – CO and H$_2$S/COS in stream may require thermal oxidizer ($$$ for capital and operation)

• Option 2 - Inject CO$_2$ as diluent in CTs (instead of N$_2$)
  – need to maintain Modified Wobbe Index
    • control heating value, specific gravity and temperature of fuel/diluent mixture

• Option 3 - Shut down/bypass water shift reactor and combust “normal” syngas (with N$_2$ diluent) in CTs
  – need capability to switch from H$_2$ to syngas at full load
  – steam flow imbalances
Hybrid IGCC
Hybrid IGCC – an Option for IGCC with CO₂ Capture

• Produce syngas in gasification area
• Use water shift reaction to produce high concentrations of H₂ and CO₂
• Capture the CO₂ from the syngas
• Methanate the syngas to synthetic natural gas (SNG)
• Compress the CO₂ for sequestration or use in enhanced oil recovery
Hybrid IGCC

• Cash Creek Generation (Kentucky)
  – GE Energy quench gasification technology
  – 566 MW (net)

• Taylorville Energy Center (Illinois)
  – Siemens quench gasification technology
  – 542 MW (net)

Source: Taylorville Energy Center
Hybrid IGCC

- Overall conversion rate of coal to gaseous fuel is lower than for conventional IGCC
- Two-thirds of the carbon in the coal is removed in a concentrated CO\(_2\) stream
- Limited ability to respond to CO\(_2\) compressor or CO\(_2\) pipeline outages
  - CTs are designed for NG/SNG, but not syngas
  - CO\(_2\) capture system must stay in service
  - CO\(_2\) not viable as diluent in CT
  - CO\(_2\) stream must be vented; thermal oxidizer may be required
## Change from IGCC to Hybrid IGCC - Cash Creek Generation

<table>
<thead>
<tr>
<th></th>
<th>IGCC No CO₂ Capture</th>
<th>Hybrid IGCC w/CO₂ Capture</th>
<th>Change</th>
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<tbody>
<tr>
<td>Gasifiers</td>
<td>2 x 50% radiant quench</td>
<td>3 x 33% quench</td>
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<tr>
<td>Heat input to gasifiers</td>
<td>5,834 MMBtu/hr</td>
<td>7,393 MMBtu/hr</td>
<td>+27%</td>
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<tr>
<td>Tons coal/year</td>
<td>2.36 million</td>
<td>2.98 million</td>
<td>+26%</td>
</tr>
<tr>
<td>CTs</td>
<td>2 x 7FB @ 464 MW</td>
<td>2 x 7FA @ 376 MW</td>
<td>-19%</td>
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<tr>
<td>ST</td>
<td>306 MW</td>
<td>385 MW</td>
<td>+26%</td>
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<tr>
<td>Total gross output</td>
<td>770 MW</td>
<td>761 MW</td>
<td>-5%</td>
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<tr>
<td>Internal load</td>
<td>140 MW</td>
<td>195 MW</td>
<td>+55%</td>
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<tr>
<td>Total net output</td>
<td>630 MW</td>
<td>566 MW</td>
<td>-10%</td>
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<tr>
<td>Efficiency</td>
<td>36.8 %</td>
<td>26.1 %</td>
<td>-10.7 points or -29%</td>
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</table>
CoalFleet IGCC User Design Basis Specification (UDBS)

• Defines power company **technical requirements** for a site-specific IGCC plant; supplier alliances to propose plants that meet the UDBS

• UDBS represents **major collaborative effort**
  – All sectors of industry engaged
  – 40+ people developed UDBS
  – Approved by all CoalFleet members

• Robust, 1200-page industry-developed and tested **guideline, primer, and lessons-learned compendium**

• **Flexible**, yet promoting of standardized, optimized designs

• **Already in use** by numerous CoalFleet participants
Conclusions

• IGCC plants produce very low quantities of air pollutants.

• IGCC plants use significantly less water than traditional coal-based power generation, and can be designed to recycle the process water.

• Gasification slag and sulfur byproducts are non-hazardous and are readily marketable.

• CO$_2$ can be captured from IGCC plants using commercially proven technologies.
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