Reducing CO$_2$ Emission by Hydrogen IGCC Power Plants

Robert M. Jones, GE Power Systems
Joachim Wolff, Uhde GmbH (Speaker)
Increasing Environmental Benefit of IGCC

1. Carbon Sequestration
2. Design Philosophy
3. Gasification, Gas Treatment & Gas Turbine
4. Performance Data
5. Outlook
**Carbon Sequestration and Enhanced Oil Recovery**

**Total CO₂ Emission ~ 28,000 mmst**  
(Year 2000)

**World CO₂ - Emission (Year 2000)**  
from Consumption of

**Coal**  
2,632 mmst  
(Carbon Equivalent)

**Petroleum**  
2,985 mmst  
(Carbon Equivalent)

<table>
<thead>
<tr>
<th>Model</th>
<th>NG-SC</th>
<th>Syngas-SC</th>
<th>Net-IGCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>6FA</td>
<td>70</td>
<td>90</td>
<td>126</td>
</tr>
<tr>
<td>7FA</td>
<td>172</td>
<td>197</td>
<td>280</td>
</tr>
<tr>
<td>9EC</td>
<td>170</td>
<td>215</td>
<td>300</td>
</tr>
<tr>
<td>9FA</td>
<td>256</td>
<td>286</td>
<td>420</td>
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</tbody>
</table>

All Units MW

A company of ThyssenKrupp Technologies

**Hydrogen IGCC**

GE Power Systems
Carbon Sequestration and Enhanced Oil Recovery

- Sequestration of CO₂ in Depleted Natural Gas Fields
- CO₂ and other Gases for Enhancing of Oil Wells (EOR)

Application: Uhde’s Morphysorb Technology used in the Kwoen Plant of Duke Energy - Canada

Acid Gas Storage - 200 bscf
Acid Gas - 90 mmscfd
Feed Gas - 300 mmscfd

Local Situation - Limited Application
Hydrogen IGCC

**Design Philosophy**

- Use Proven Commercial Technologies
- Meet the Best Available Control Technology
- Removal of Bulk CO₂ to limit Cost Impact
- Integrated IGCC Concept to meet GT Requirements
- Minimise Utility Consumption

Best Available Control Technology:
- Current IGCC BACT: 15-25 ppm NOₓ
- Near Future IGCC BACT: 9-15 ppm NOₓ
- Long Term IGCC BACT: <9 ppm NOₓ

* Module - one GE GT 7FA

* Shell (COAL) Gasification Process
Shell Gasification Process

High on-stream factors based on new developments

- Co-annular Burner with Removable Auxiliary Burner
- Soot Ash Removal Units (Soot Filtration and optional Soot Work-off)
- Modular Safeguarding and Control System

* Fuel Flexibility and low Soot Make
* Improving Safety, Reliability and On-stream Time
* High Degree of Automation/Less Operator Involvement

<table>
<thead>
<tr>
<th>Visbreaker Residue</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity @ 59 F</td>
<td>1.11</td>
</tr>
<tr>
<td>C/H Ratio, wt</td>
<td>9.5</td>
</tr>
<tr>
<td>Sulphur, % wt</td>
<td>3.54</td>
</tr>
<tr>
<td>Ash, % wt</td>
<td>0.06</td>
</tr>
<tr>
<td>Heating value, BTU/lb dry (LHV)</td>
<td>16,896</td>
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</tbody>
</table>
Shell Coal Gasification Process

Basic Concept of the **reliable** SCGP-Gasifier

- Slagging, Oxygen Blown, Entrained Flow
- Internal Membrane Wall
- Multiple Opposed Burner
- Dry Feeding System

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Petroleum Coke</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/H Ratio, wt</td>
<td>16.2</td>
<td>27.7</td>
</tr>
<tr>
<td>Sulphur, % wt</td>
<td>2.69</td>
<td>7.00</td>
</tr>
<tr>
<td>Ash, % wt</td>
<td>11.30</td>
<td>0.14</td>
</tr>
<tr>
<td>Heating value, BTU/lb dry (LHV)</td>
<td>12,080</td>
<td>14,355</td>
</tr>
</tbody>
</table>
Syngas Treatment

Standard Concept for Power (IGCC)

- COS Hydrolysis

- Selective H₂S Removal based on MDEA Process (Limiting Co-Absorption of CO₂)

Included
* Claus Plant
* Tailgas Treatment
(Hydrogenation and H₂S Recycle)
Syngas Treatment

Standard Concept for CO$_2$ Removal/Power (Hydrogen IGCC)

- Single stage CO-Shift (incl. COS Hydrolysis)
- CO$_2$ & H$_2$S Removal based on physical Solvent Genosorb® 1753

Genosorb® 1753 (Tetraethylene glycol dimethyl ether) - Clariant
Applications:
OMV, NEAG, Wintershall, DSM, Turkish Petrol, Laholm

Excluded
* Claus Plant
* Tailgas Treatment
General Electric Gas Turbine Technology

Proven Technology with following Track Record

- 499,100 fired Hours of Syngas Experience
- 12 Plants in operational Phase
- Heating Value Range from 193 to 318 Btu/SCF
- Hydrogen in the Fuel Gas from 8.6 to 61.9%

Successful **Full-Scale** Lab Testing of Hydrogen Fuel Gas: 46.8 % Hydrogen, 40.8 % Nitrogen, 10.4 % Water

**Full-Scale** Combustion System Testing
53.6% - 89.2 % Hydrogen (Balance Nitrogen, Saturation case to case)
## Performance Data

### GT-Feed Composition

<table>
<thead>
<tr>
<th></th>
<th>Residue</th>
<th>Coal</th>
<th>Coke</th>
<th>H₂-Residue</th>
<th>H₂-Coal</th>
<th>H₂-Coke</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>%Vol</td>
<td>49.45</td>
<td>52.94</td>
<td>56.58</td>
<td>8.33</td>
<td>9.52</td>
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<tr>
<td>CO₂</td>
<td>%Vol</td>
<td>4.33</td>
<td>2.32</td>
<td>2.08</td>
<td>2.99</td>
<td>3.23</td>
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<tr>
<td>H₂</td>
<td>%Vol</td>
<td>44.34</td>
<td>25.59</td>
<td>19.47</td>
<td>62.34</td>
<td>61.76</td>
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<tr>
<td>H₂O</td>
<td>%Vol</td>
<td>0.10</td>
<td>11.50</td>
<td>11.50</td>
<td>25.10</td>
<td>19.22</td>
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<tr>
<td>N₂</td>
<td>%Vol</td>
<td>0.63</td>
<td>6.86</td>
<td>9.46</td>
<td>0.48</td>
<td>5.59</td>
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<tr>
<td>CH₄</td>
<td>%Vol</td>
<td>0.36</td>
<td>0.01</td>
<td>0.01</td>
<td>0.23</td>
<td>0.01</td>
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<tr>
<td>Ar</td>
<td>%Vol</td>
<td>0.79</td>
<td>0.77</td>
<td>0.89</td>
<td>0.52</td>
<td>0.68</td>
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### Diluent Injection and Composition

<table>
<thead>
<tr>
<th></th>
<th>%Vol</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>H₂O</td>
<td></td>
<td>29.12</td>
<td>15.00</td>
<td>15.00</td>
<td>0.00</td>
<td>1.01</td>
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<tr>
<td>N₂</td>
<td></td>
<td>69.46</td>
<td>84.24</td>
<td>84.25</td>
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<td>97.01</td>
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<tr>
<td>O₂</td>
<td></td>
<td>0.21</td>
<td>0.43</td>
<td>0.43</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Ar</td>
<td></td>
<td>1.20</td>
<td>0.34</td>
<td>0.32</td>
<td>1.70</td>
<td>1.68</td>
</tr>
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### Air Extraction

<table>
<thead>
<tr>
<th>Integration</th>
<th>%</th>
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<tr>
<td></td>
<td>50</td>
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### Performance Data

<table>
<thead>
<tr>
<th></th>
<th>Residue</th>
<th>Coal</th>
<th>Coke</th>
<th>H₂-Residue</th>
<th>H₂-Coal</th>
<th>H₂-Coke</th>
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</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>MW</td>
<td>197.0</td>
<td>197.0</td>
<td>197.0</td>
<td>197.0</td>
<td>197.0</td>
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<tr>
<td>Steam Turbine</td>
<td>MW</td>
<td>109.5</td>
<td>130.3</td>
<td>146.7</td>
<td>94.5</td>
<td>114.3</td>
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<tr>
<td>Expander</td>
<td>MW</td>
<td>5.3</td>
<td>-</td>
<td>-</td>
<td>5.3</td>
<td>-</td>
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<tr>
<td>Consumption</td>
<td>MW</td>
<td>34.4</td>
<td>50.1</td>
<td>58.7</td>
<td>45.9</td>
<td>62.2</td>
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<tr>
<td>Net Output</td>
<td>MW</td>
<td>277.4</td>
<td>277.2</td>
<td>285.0</td>
<td>250.9</td>
<td>249.1</td>
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<tr>
<td><strong>By-products</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>lb/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>281,700</td>
<td>369,300</td>
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<tr>
<td>H₂S</td>
<td>lb/h</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4,750</td>
<td>5,500</td>
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<tr>
<td>Sulphur</td>
<td>STPD</td>
<td>56.7</td>
<td>58.4</td>
<td>136.2</td>
<td>-</td>
<td>-</td>
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</table>
# Performance Data

## Additional Hydrogen Production

### Maximum Size Gasifier

<table>
<thead>
<tr>
<th></th>
<th>Residue</th>
<th>Coal</th>
<th>Coke</th>
<th>H$_2$-Residue</th>
<th>H$_2$-Coal</th>
<th>H$_2$-Coke</th>
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</thead>
<tbody>
<tr>
<td>Quantity of Gasifier</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Quantity of ASU</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Quantity of GT</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Feedstock flow rate</td>
<td>31.3</td>
<td>90.9</td>
<td>77.7</td>
<td>31.8</td>
<td>95.4</td>
<td>83.8</td>
</tr>
<tr>
<td>(st/h dry)</td>
<td>(62.6)</td>
<td></td>
<td></td>
<td>(63.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. feedstock</td>
<td>55</td>
<td>150</td>
<td>125</td>
<td>55</td>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>flow rate (st/h dry)</td>
<td>(110)</td>
<td></td>
<td></td>
<td>(110)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cost Impact (Specific Investment Cost)

- Residue Gasification: +10%  
- Solid Gasification: +20%

Note: Acid Gas Compression Excluded!

Note:
- Higher Feedstock Consumption
- Higher Internal Power Consumption
  * ASU
  * Gas Treatment
- Nitrogen Return
  * Low Level Heat
  * Power Consumption
Outlook

Substantial Reduction of CO$_2$ - 70 %
* Use of CO$_2$ for EOR (or similar)
* Use of CO$_2$ for other purposes

Increase of Water Consumption
Residue 65%
Solid 120%

H$_2$S Removal
* EOR (minor)
* Production of Sulphur
Outlook

Plant Size to meet Customer Requirements

- Full Size Gasifier to Produce Syngas for other Purposes
  * Hydrogen
  * Fuel Gas
  * Duct Firing

- Higher Power Output of Gas Turbine

- More Modules with Optimised Quantity of Gasifiers

7FA Natural Gas
150-172 MW ISO

Year 1995
7FA IGCC
192 MW ISO

- IGCC Combustor
- Modified Turbine Nozzle

Year 2000
7FA+e IGCC
197 MW ISO

- Higher Firing Temperature
- Increased Pressure Ratio

Year 2004
7FA Advanced IGCC
211 MW ISO

- Higher Torque Rotor
- Combustor Developments

Hydrogen IGCC

GE Power Systems
Outlook

**No Nitrogen Return (Study Case - No GE Product Capability)**

+ Less Internal Power Consumption (Nitrogen Compression)
+ Optimisation of Low Level Heat Utilisation
- Lower Firing Temperature
- Higher Water Consumption

**Increasing GT Flexibility regarding**
Fuel Gas Heating Value from 200 Btu/SCF to 150 Btu/SCF

Plant Design with later Option for CO₂ Removal