UCG APPLICATION OPPORTUNITIES FOR THE POLYGENERATION OF POWER AND FUELS

JF Brand\textsuperscript{2,3} and JC van Dyk\textsuperscript{1,3},
\textsuperscript{1}African Carbon Energy, email: johan.vandyk@africary.com
\textsuperscript{2}African Carbon Energy, email: johan.brand@africary.com
\textsuperscript{3}North-West University, South-Africa
UNDERGROUND COAL GASIFICATION (UCG)

.....is a mining process which converts unmined coal into syngas.

UCG is an in-situ gasification process carried out in deep coal seams by injecting oxygen (and reagents like steam and CO₂) via an injection well, into the coal and bringing the resulting syngas to the surface via a production well.

Underground Coal Gasification is a cost-effective environmental friendly CLEAN COAL solution for resource recovery in areas beyond the technical and economic confines of conventional mining with numerous environmental benefits over conventional coal mining.
UCG Polygeneration

.....is combining the reduced cost and environmental impacts of UCG with the production of Electricity and Liquid Fuels.

UCG allows for the implementation of 2 different gasifiers that can operate on vastly different operating regimes and produce 2 different types of syngas: $\text{H}_2$-Rich for FT and CO-Rich for PowerGen.
# Typical dry-Syngas compositions (mol%)

<table>
<thead>
<tr>
<th></th>
<th>H2-Rich</th>
<th>CO-Rich</th>
<th>Mix for FT</th>
<th>Mix for Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>46.2%</td>
<td>36.1%</td>
<td>57%</td>
<td>25%</td>
</tr>
<tr>
<td>CO</td>
<td>29.5%</td>
<td>48.1%</td>
<td>28%</td>
<td>52%</td>
</tr>
<tr>
<td>CO2</td>
<td>10.3%</td>
<td>7.6%</td>
<td>0%</td>
<td>16%</td>
</tr>
<tr>
<td>CH4</td>
<td>13.2%</td>
<td>7.3%</td>
<td>14%</td>
<td>5%</td>
</tr>
<tr>
<td>C2H4</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>N2</td>
<td>0.6%</td>
<td>0.6%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>O2</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>H2O</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>H2S + COS</td>
<td>0.2%</td>
<td>0.3%</td>
<td>&lt;0.1 ppm</td>
<td>&lt;50 ppm</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
IMPORTANCE OF STUDY

When comparing UCG-Polygeneration with other CTL technologies we find that:

- Provides >25% CO$_2$ sequestration by recycling captured CO$_2$ as gasification agent
- Polygeneration requires 50% less water than conventional mining and surface gasification
- 2 UCG gasifiers, each running on different agent, can supply:
  - 2,000 bbl/day and 15 MW$_e$; OR
  - 1,400 bbl/day and 75 MW$_e$
- Modular design allows for quick (24 months) implementation
- Opportunity for other clean fuels like Hydrogen / LNG
- Opportunity for Fertilizers / Chemicals
- Low cost and low complexity per UCG Module provide the least financial and project risk and removes the difficulties of Mega-project cost and schedule overruns
- UCG has the potential to access the vast energy reserves locked in coal deposits that are uneconomic to mine using current technology and simultaneously provides the best pressure envelope for gasification.
Positive Environmental Impact

UCG does mining, gasification and ash management all in 1-step process

- no noise,
- no dust,
- no ash, no particulate matter
- no blasting,
- no coal transport,
- no waste, no AMD,

UCG offers energy efficiency improvements and low-impact on the environment and continued agriculture and possibly fertiliser from future polygen production

- Highest coal utilization, lowest emissions, cleanest and safest mining method
Africary has signed agreement with CGTL to perform a CTL study for 2,000 bbl/day.
CompactGTL’s Demonstration Plant, Aracaju, Brazil

- First modular fully integrated small scale GTL plant in the world

- Technology successfully completed testing by Petrobras and approved for commercial use in 2011
Positive Economic Impact

UCG-Polygeneration cost benefits are:
- Modular design reduce complexity
- Quick (24 months) implementation
- Production can be scaled between electricity and liquid fuels
- The SA economy has huge demand for LPG, LNG and Hydrogen as alternative fuels

The South African Basic Fuel Price (BFP) is ~ R6.00 per litre or about $60-70 / bbl and provides a hedge against the USD oil price

- Naphtha production is discouraged with almost no market / demand

http://www.sapia.org.za/
The economics – Max Fuels

UCG-Polygeneration with several products:

- Oxygen requires 8 MWe and is incorporated in the Own Use.
- The main sellable product is Ultra Low Sulphur Diesel
- LNG/CNG production has a price premium, due to lower fuel taxes
- Production can be scaled between electricity and liquid fuels, but in this case Electricity is minimized and is operated on tail and waste gas streams
- Hydrogen is priced at $10/kg

- Naphtha production to be sold as Illuminating Paraffin.
The Economics – Max Fuels

### CAPEX

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit</th>
<th>Exchange rate</th>
<th>(million)</th>
<th>Gross annual profit (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASU</td>
<td>13</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
<td>13.20</td>
<td>R/$</td>
<td>R 341</td>
</tr>
<tr>
<td>UCG</td>
<td>15</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
<td>13.20</td>
<td>R/$</td>
<td>R 379</td>
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<tr>
<td>Shift + AGR</td>
<td>30</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
<td>13.20</td>
<td>R/$</td>
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<tr>
<td>FT + Refining</td>
<td>50</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
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<td>R/$</td>
<td>R 1 364</td>
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<td>LNG + storage</td>
<td>680</td>
<td>$/tpa</td>
<td>70 000</td>
<td>t/a</td>
<td>13.20</td>
<td>R/$</td>
<td>R 632</td>
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<tr>
<td>H2 PSA + Compression</td>
<td>5</td>
<td>Euro</td>
<td>580</td>
<td>kg/hr</td>
<td>15.50</td>
<td>R/$</td>
<td>R 78</td>
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<td>Power Gen</td>
<td>650</td>
<td>Euro/kW</td>
<td>27 000</td>
<td>kW</td>
<td>13.20</td>
<td>R/Euro</td>
<td>R 373</td>
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<tr>
<td>OBL</td>
<td>12</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
<td>13.20</td>
<td>R/$</td>
<td>R 300</td>
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<tr>
<td>Indirect and General</td>
<td>19</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
<td>13.20</td>
<td>R/$</td>
<td>R 500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>R 4 658</strong> [R$350m]</td>
</tr>
</tbody>
</table>

### OPEX

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit</th>
<th>Exchange rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Processing + FT</td>
<td>15</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
<td>13.20</td>
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<tr>
<td>Powergen excluding fuel</td>
<td>15</td>
<td>$/MW</td>
<td>27</td>
<td>kW</td>
<td>13.20</td>
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<tr>
<td>Overheads</td>
<td>5</td>
<td>$/bbl</td>
<td>1 950</td>
<td>bbl/day</td>
<td>13.20</td>
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<tr>
<td>Capital and Interest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>R 758</strong> [R$75m]</td>
</tr>
</tbody>
</table>

Opex includes a 10 year payment at 10% interest
Preliminary financials supports a UCG polygeneration detail study
Location of Theunissen UCG 16 tcf exploration and production (E&P) Facility
The CTL Project Status

- Step 1: Purchased UCG coal 2012: 1 billion ton Resource
- Step 2: Approved Mining Right Application in 2016
- Step 3: Measured 3.7 mT and obtain surface rights (600 ha)
- Step 4: Market: Domestic Gas-IPP program + ULSD + LNG
  - Step 5: Environmental Approval – completed if power is approved (half way)
  - Step 6: Designed and finalize PFS and BFS engineering for UCG & 30MW & 1,950 bbl/day
  - Step 7: Financial assessment and then Bankable Feasibility Study
  - Step 8: IDC project support
  - Step 9: EPC and O&M service level agreements
  - Step 10: Offtake Agreements