Majuba Underground Coal Gasification

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Presenter: MJ BEESLAAR
Context

- Coal is the predominant natural energy resource in RSA.
- Eskom presently generates 88% of its electricity from coal.
- This predominance will decrease, with the introduction of alternative energy carriers to mitigate the impact of the continued usage of coal.
- Coal will remain a predominant, albeit reducing primary energy carrier for the foreseeable future in RSA.
- Eskom has therefore run a comprehensive Clean Coal Technology research and development program for several decades, to explore, identify and demonstrate solutions for continued coal usage.
Eskom’s Clean Coal Programme

- Improved efficiencies on conventional sub critical pulverised coal
- Supercritical pulverised coal – Medupi & Kusile
- Ultra-supercritical pulverised coal - scanning
- Fluidised Bed Combustion - pilot
- Conventional and advanced emissions control – FGD, LNB
- Surface gasifier - IGCC
- Carbon Capture and Storage – scanning, national atlas

• Underground coal gasification – IGCC

IGCC = Integrated Gasification Combined Cycle
Why UCG? Eskom Strategic Drivers

1. Security of supply
   - Baseload option

2. Clean energy
   - Lower CO2 Emissions (lower than super critical PF coal)

3. Flexibility
   - Modularity, lead time

4. Utilize Unminable Coal
   - Potentially 350GWe
   - Better utilisation than conventional mining

5. Lower cost option
   - Competitive R/MWh
The only cleaner coal-based technology is the developing ultra-supercritical PF.

UCG-IGCC Comparative Emissions

**Graph showing comparative emissions for different technologies:**
- **CO2 kg/MWh net**
- **NOx/SOx/Particulates kg/MWh net**

Technologies compared:
- Conv PF
- Super PF
- Conv IGCC
- UCG-IGCC
- Nat Gas CC

Legend:
- **CO2**
- **NOx**
- **SOx**
- **Particulates**
Resource Utilisation Efficiency

- **23.8% of coal resource utilised**
  - Thermal Efficiency
  - Mining Efficiency
  - Present: Sub-critical Power Station with Longwall U/G Mine
    - 0% Chemical Efficiency
    - 100% Mining Efficiency

- **33% of coal resource utilised**
  - Thermal Efficiency
  - Mining Efficiency
  - Potential: Ultra-supercritical or Conventional IGCC with Longwall U/G Mine
    - 0% Chemical Efficiency
    - 100% Mining Efficiency

- **36% of coal resource utilised**
  - Thermal Efficiency
  - Chemical Efficiency
  - Mining Efficiency
  - UCG-IGCC
    - 0% Chemical Efficiency
    - 100% Mining Efficiency
Coal Value Chain Reduction = Cost

Conventional mining and power station operations

- Mining
- Transport
- Beneficiation
- Mine Stockpile
- Reclaim & Transport
- Power Station Stockpile
- Reclaim & Transport
- Mill & Combust
- Emissions Cleanup
- Ash Capture & Storage

UCG mining and power station operations

- UCG Mining
- Gas Piping
- Gas Cleanup
- Gas Piping
- OCGT/CCGT
- Emissions Cleanup
Potential RSA Applications

27 Potential Sites

- RSA coal resources quoted at 194.4 Bt (1998, DME Bulletin 113)

- Eskom geological records for coal offers received but considered unminable
  = 45 Bt
  = potential for 350 GWe
  = 8 x present Eskom total capacity

- The remaining:
  194.4 Bt – mined – minable = 100 Bt?

UCG criteria: > 200m depth, > 0.4m seam, < 80% ash
UCG Technology
What is UCG?

UCG is a process where air is injected into the cavity, water enters from surrounding strata, and partial combustion and gasification take place at the coal seam face after ignition. The resulting high-pressure gas stream is returned to the surface, where the gas is dried and then combusted in a high-efficiency power station to generate electricity.

Surface Plant commercially proven with other gases – needs implementation for UCG

UCG commercially proven in Former Soviet Union (FSU) – needs proving in RSA on commercial scale.
UCG – Current World Trends

- **FSU – Uzbekistan**: Angren commercial plant refurbishing
- **New Zealand**: Solid Energy NZ starting site characterisation R&D. Eventual UCG-CCGT
- **USA**:
  - Laurus Energy investigating a 2.3 bt resource in Wyoming
  - CIRI developing a 100MW UCG-CCGT in Alaska
  - LLNL investigating the potential of UCG + H$_2$ production + CO$_2$ sequestration
- **Australia**:
  - Linc Energy Pilot plant recommissioned. Relocating to S. Australia
  - Carbon Energy 100d pilot trial successful. 20MWe pilot with CCS announced
  - Cougar Energy site characterisation successful, and 10,000 Nm3/h pilot commissioned.
• **UK**:  
  - Being investigated for coal under the Firth of Forth, Scotland  
  - Clean Coal investigating 5 North Sea coal resource sites, Scotland  
  - VP Power drilling in the Kish Basin (20km E of Bray Head, Dublin Bay), Ireland

• **India**:  
  - GAIL approved a feasibility study  
  - Abhijeet Group investigating UCG-CCGT

• **Pakistan**: approved a feasibility study for UCG-CCGT

• **China**:  
  - Historically 16 sites, typically small scale  
  - New initiatives underway for SNG and methanol, following a successful 1 month trial

• **Southern Africa**: Eskom & Sasol, with several other entrants emerging
Where is Eskom i.t.o. UCG Development?

Over 66 FSU (Former Soviet Union), 33 US and 40 other international projects. There are 5 UCG technology variations, with another 2 emerging. Sasol recently announced their UCG demonstration plant at Secunda (100km North of the Majuba site).

Eskom is presently the leading adaptor of UCG technology.
UCG Project Progress

Since Inception:

- UCG technology potential noted - April 2001
- Ergo Exergy Technologies Inc. (Canada) contracted in
- Scoping study - Nov 2002, highlighted potential at Majuba colliery
- Pre-feasibility study - Dec 2003, confirmed Majuba potential
- Detailed site characterisation study - July 2005, confirmed the potential
- 20th January 2007 – Eskom commissioned a 3-5000 Nm³/h pilot plant on Majuba coalfield
- 31st May 2007 – first electricity generated from UCG gas at Majuba
- 7km x 600mm NB steel pipeline built to link UCG with Majuba power station

Co-firing:

- Commissioning of new co-firing plant commenced 30 Jan
- Gas ready for co-firing

DRA:

- DRA design study recommended E-class GT’s (100 – 140 MW)
Indicative Developmental Approach

2002
Scoping Study

2003
Pre-feasibility Study

2005
Site Characterisation

20th January 2007
Commissioned
5000 Nm3/h pilot plant
on Majuba coalfield

To do

DRA = Decision Release Approval = Design, Engineering, Costing
ERA = Execution Release Approval = Procure, Construct and Commission
UCG Phased Development – 108MW demo

* size still being finalised. Present demo range 100-140MW. Commercial size not decided yet.

Pilot
5-15,000 Nm3/h

Demo
242,000 Nm3/h

Commercial
2,900,000 Nm3/h

Jan 2007
Jan 2014
Mar 2017

108 MW OCGT

260 MW CCGT per unit  X  multiple units

Jan 2007
Jan 2014
Mar 2017
Eskom UCG Demonstration Site

Production wells

Gas Treatment Plant

By-product handling
Demonstration plant – Conceptual design layout
What will this Demonstration plant Demonstrate?
Sustainable gas production
## By-Products

<table>
<thead>
<tr>
<th>By-Product Option</th>
<th>Perceived Risk (Low value = low risk)</th>
<th>ROI (%)</th>
<th>Jobs Created</th>
</tr>
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<tbody>
<tr>
<td>Waste Heat</td>
<td>13</td>
<td>26%</td>
<td>51</td>
</tr>
<tr>
<td>Scrap Steel</td>
<td>11</td>
<td>1,120%</td>
<td>8</td>
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<tr>
<td>Bagged Sulphur</td>
<td>21</td>
<td>84,405%</td>
<td>19</td>
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<tr>
<td>Sulphuric Acid</td>
<td>15</td>
<td>1,073%</td>
<td>25</td>
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<tr>
<td>Bulk Ammonia</td>
<td>20</td>
<td>995%</td>
<td>17</td>
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<td>Urea Plant</td>
<td>14</td>
<td>19%</td>
<td>64</td>
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<tr>
<td>Organics – Bulk Commodities</td>
<td>27</td>
<td>879%</td>
<td>55</td>
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<tr>
<td>Organics - Fuel</td>
<td>9</td>
<td>179,131%</td>
<td>17</td>
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UCG: The Challenges

- Environmental Impact Assessments
- Legislative requirements
  - Mineral & Petroleum Resources Developmental act
  - Mine Health & Safety Act etc.
- By-products
- Skills & Development
- Project accounting
- Funding going forward
UCG Demo Plant Experience for 100 – 140 MW scale as @ 2010

Compressors → Wells & Drilling → Pipeline - DX → Pipeline - TX → Water Wash Condensate Removal → Sulphur Removal

Water → UCG Technology

Gas → SCR NOX Abatement → H2S/NH3 → Flue Gas

Steam Turbine/Gen

Gas Compressor → Gas Turbine/Gen

Steam Stripping Ammonia Removal

Particulates and Oils

Condensate → Steam Turbine/Gen

H2S/NH3

Electricity

Water

Full Eng Capability

Substantial Eng Capability

Partial Eng Capability

Some Eng Capability

Limited Eng Capability

Zero Eng Capability

Electricity

Raw Water

Phenols

Phenol Recovery
UCG Conclusions

• UCG is a promising clean coal option which allows the effective extraction and use of RSA coal resources

• UCG has a role to play in the reduction of greenhouse gases and has possible potential for carbon capture and storage

• UCG is gaining momentum worldwide

• The Eskom UCG pilot has been operating reliably for 34+ months

• No environmental concerns have been noted to date

• Based on work to date, UCG appears to be a very promising, stable and viable primary energy (baseload) option with potential on multiple sites

• Eskom is embarking on commercialisation of the technology, with the first milestone being successful operation of a demonstration plant
From small beginnings to great achievements……

Thank you