Commercial
Underground Coal Gasification:
Performance and Economics

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The Exergy UCG™ (εUCG) –
the Source of Hydrocarbons from Unminable Coal:
• Indigenous and safe
• Environmentally Clean and Carbon Efficient
• Cost Competitive
• for IGCC Power Generation
• for Synthesis of Clean Fuels & Chemicals
εUCG Technology

- Large-scale coal mining technology
- Makes use of rock deformation and ground water influx
- Injection of oxygen, air, H₂O, CO₂ etc.
- Drilling of directional, inclined, vertical and other wells
- Modern technology based on 70+ years of Soviet work
- Applied in international commercial projects: the USA, Canada, New Zealand, South Africa, Australia, China, India etc.
<table>
<thead>
<tr>
<th>UCG Plant</th>
<th>Coal Rank</th>
<th>Thickness, ft.</th>
<th>Depth, ft.</th>
<th>Dip, °</th>
<th>LHV, BTU/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lisichansk</td>
<td>Bituminous</td>
<td>1.5 – 6.5</td>
<td>200 – 800</td>
<td>38 – 60</td>
<td>8,640 – 9,890</td>
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<td>Yuzhno-Abinsk</td>
<td>Bituminous</td>
<td>7 – 30</td>
<td>425 – 1250</td>
<td>35 – 70</td>
<td>12,430 – 13,200</td>
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<tr>
<td>Podmoskovnaya</td>
<td>Lignite</td>
<td>8.5</td>
<td>100 – 260</td>
<td>&lt; 1</td>
<td>5,075</td>
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<tr>
<td>Angren</td>
<td>Sub-bituminous</td>
<td>10 – 80</td>
<td>350 – 820</td>
<td>7</td>
<td>6,580</td>
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<tr>
<td>Shatskaya</td>
<td>Lignite</td>
<td>8.5</td>
<td>100 – 200</td>
<td>&lt; 1</td>
<td>4,750</td>
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<tr>
<td>Sinelnikovo</td>
<td>Lignite</td>
<td>12 – 20</td>
<td>260</td>
<td>&lt; 1</td>
<td>3,500</td>
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<tr>
<td>Chinchilla</td>
<td>Sub-bituminous</td>
<td>33</td>
<td>460</td>
<td>&lt; 1</td>
<td>9,330</td>
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<tr>
<td>Majuba</td>
<td>Bituminous</td>
<td>10 - 15</td>
<td>950</td>
<td>2-3</td>
<td>9,100</td>
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<tr>
<td>Kingaroy</td>
<td>Sub-bituminous</td>
<td>56</td>
<td>650</td>
<td>5</td>
<td>10,500</td>
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<tr>
<td>Huntly West</td>
<td>Bituminous</td>
<td>&gt;60</td>
<td>800 - 1900</td>
<td>0-35</td>
<td>10,500</td>
</tr>
<tr>
<td>CC Alberta</td>
<td>Sub-bituminous</td>
<td>25</td>
<td>450-1000</td>
<td>&lt; 1</td>
<td>8,810</td>
</tr>
</tbody>
</table>
εUCG Raw Syngas Production

- Oxidant Air/Oxygen
- UCG Module
- UCG Module
- UCG Module
- UCG Module

Raw Syngas

Main Components:
- H₂, CO, CO₂, (N₂), CH₄, H₂O, pyrolysis products

Minor Components:
- NH₃, H₂S, COS, HCN, HCl, Hg, ash

- Exploration
- Drilling
- In-seam linking
- Channel conditioning
- RM & GW Monitoring
- In-situ shift & cleanup
- Panel piping
- Well P&A
- Panel shutdown
Texas Lignite

- 35 Billion Tons of Deep Resources
  - 200 to 2,000 feet depth
  - over 5 feet seam thickness
- Wilcox Group
  - 70% of Deep Texas Lignite
  - 6,500 BTU/lb HHV
- Jackson Group
  - 30% of Deep Texas Lignite
  - 4,500 BTU/lb HHV
Evaluation Basis

• **Method:** Comparing UCG and Conventional Gasification in Texas Conditions

• **Fuel:** Texas Lignite

• **Underground Coal Gasification Technology:** The Exergy UCG™ (εUCG)

• **Conventional Coal Gasification Technology:** Generic dry feed, entrained flow - (CG)

• **Products:** Electricity, SNG, Methanol, Gasoline, Diesel, Urea, (Naphtha, Ammonia, DME, Hydrogen, Ethanol, LPG etc.)

• **Raw Gas:** εUCG raw gas was not optimized for needs of specific products (lost efficiency)

• **CO2 Capture:** 97+%v CO2 compressed to 2,100 PSIG ready for EOR
Evaluation Basis

Feedstock - Wilcox Group Texas Lignite

Geology:
- Coal seam thickness: 21 ft (7m)
- Depth to Coal: 600 ft (200 m)

Quality:
- 6,500 BTU/lb wet HHV; 10,000 BTU/lb dry HHV
- 56.2%w dry Carbon; 21.7%w dry Ash; 2.9%w dry Sulfur

Financing Conditions - Independent Power Producer (IPP)

Debt/Equity Ratio - 60 / 40 (%)  
Debt Interest - 10%

Cost of electricity for synfuel & chemicals

UCG — at cost from adjacent UCG-IGCC plant
CG — at cost from adjacent CG-IGCC plant
CG (M) — purchased at market price (Texas)

Project Size

Power Generation — nominal 300MW net
Synthesis products — equivalent of 10,000 bpd of gasoline (30 PJ/a of syngas – LHV)

CO₂ — emissions

Electricity: Removal of CO₂ to less than the California Standard, 1100 Lb/MMWh net, CO₂ EOR ready
Products: Removal of all CO₂ available, CO₂ EOR ready
Texas: εUCG vs. CG

Cost of Electricity, $/MWh Sent-Out

Market $50

$68.53

$29.93

UCG

CG

Power  Capital  O&M  Coal  Byproducts
Texas: εUCG vs. CG

*Source: NG Forecast Price - US EIA Energy Outlook 2011*
Texas: εUCG vs. CG

Cost of Methanol, $/metric tonne

Market $350 (2011)*

Market $150 (2008)*

UCG
CG
CG(M)

Methanol  Capital  O&M  Coal  Byproducts

*Source: ICIS Chemical Business
September 5-11, 2011
Texas: εUCG vs. CG

Cost of Gasoline, $/Gallon

Market $2.95 (2015)*

$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00

$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00

$0.90
$2.02
$1.91

Texas: $\epsilon$UCG vs. CG

*Source: Diesel Forecast Price - US EIA Energy Outlook 2011
Texas: εUCG vs. CG

*Source: Urea Historical Prices - Fertilizer Week July-August 2011
Texas: εUCG vs. CG

εUCG vs. CG, Cost Reduction

<table>
<thead>
<tr>
<th></th>
<th>Capital</th>
<th>O&amp;M</th>
<th>Coal</th>
<th>By-products Credit</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>39%</td>
<td>28%</td>
<td>98%</td>
<td>29%</td>
<td>56%</td>
</tr>
<tr>
<td>SNG/CH₄</td>
<td>55%</td>
<td>43%</td>
<td>98%</td>
<td>-25%</td>
<td>66%</td>
</tr>
<tr>
<td>Methanol</td>
<td>52%</td>
<td>49%</td>
<td>98%</td>
<td>-25%</td>
<td>62%</td>
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<tr>
<td>Gasoline</td>
<td>42%</td>
<td>44%</td>
<td>98%</td>
<td>-24%</td>
<td>55%</td>
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<tr>
<td>Diesel</td>
<td>36%</td>
<td>44%</td>
<td>98%</td>
<td>-15%</td>
<td>54%</td>
</tr>
<tr>
<td>Urea</td>
<td>29%</td>
<td>42%</td>
<td>98%</td>
<td>-25%</td>
<td>44%</td>
</tr>
</tbody>
</table>

CO₂ Capture (% of total Carbon in coal)

<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>SNG</th>
<th>Methanol</th>
<th>Gasoline</th>
<th>Diesel</th>
<th>Urea</th>
</tr>
</thead>
<tbody>
<tr>
<td>εUCG</td>
<td>57%</td>
<td>45%</td>
<td>43%</td>
<td>43%</td>
<td>48%</td>
<td>29%</td>
</tr>
<tr>
<td>CG</td>
<td>43%</td>
<td>56%</td>
<td>57%</td>
<td>57%</td>
<td>62%</td>
<td>39%</td>
</tr>
</tbody>
</table>
Texas: εUCG vs. CG

With the same:
Feedstock, Project location, Labor cost, Financing conditions & Market
εUCG delivers the following advantages:

• 30-55% lower capital cost
• 30-50% lower O&M cost
• 98% lower lignite cost
• 45-65% lower product costs
The Exergy UCG Technology

✓ Clean Energy from Unminable Coal
✓ Exergy- and Carbon-Efficient
✓ Cost Competitive
✓ Worldwide Applications
εUCG-IGCC Power Generation
εUCG to SNG

Coal Gasification → Gas Scrubbing → Gas Compression → Acid Gas Removal → Methanation → SNG

- CO₂ to EOR
- Trim Shift Conversion
- CO₂ Comp.
- Steam Turbine
- H₂, CO, CH₄
- Sup Steam
- BFW
- Clean Syngas
- Sulfur Recovery
- Sulfur
- Oxygen
- Ash Oil
- Wastewater Treating
- Air Separation
- Air
CG to SNG

Coal Prep. → Coal Gasification → Gas Cooling and Scrubbing → Shift Conversion → Acid Gas Removal → Methanation → SNG

- Coal
- Steam or Water
- Sat Steam
- BFW
- Sat Steam
- BFW
- CO₂ to EOR
- CO₂ Comp.
- Steam Turbine
- Sup Steam
- BFW
- H₂
- CO
- Clean Syngas
- Sat Steam

- Oxygen
- Air Separation
- Air
- Slag
- Wastewater Treating

- BFW
- Steam
- BFW

- Sulfur

ERGO EXERGY
TECHNOLOGY INCORPORATED

BLACK & VEATCH

Laurus Energy Inc.
εUCG to Urea