Outline

- Introduction
- Worldwide summary
- Former Soviet Union
- United Kingdom
- USA
- Europe
- China
- Australia
Underground coal gasification has been performed at over 50 sites worldwide since the 1930s.

Operations in the former Soviet states dominate in terms of quantities of coal gasified and the range of coal seam characteristics used.

Gasification sites over 600m deep have been used in Western Europe.
Distribution of UCG sites

- Test site
- Commercial facility
Research commenced in the 1930s with the target to demonstrate UCG in a wide range of coal seams. Large plants were under construction prior to WWII, but were abandoned. In the 1950s there was rapid expansion in use of UCG in many parts of the FSU. Most plants closed with the increasing availability of Siberian natural gas. Angren (Uzbekistan) and Yuzhno-Abinsk (Siberia) remain operational.
## Summary of coal seam characteristics at Soviet UCG sites

<table>
<thead>
<tr>
<th>Sites of UCG</th>
<th>Coal seam thickness m</th>
<th>Depth of occurrence, m</th>
<th>Angle of dip, degree</th>
<th>Technical composition of coal</th>
<th>Low heat value, as received basis, MJ/Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Moisture content as received,</td>
<td>Volatile matter (Combustible mass)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ash content, dry basis,</td>
<td></td>
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<tr>
<td>Lisichansk</td>
<td>0.44-2.0</td>
<td>60-250</td>
<td>15-50</td>
<td>12 - 15</td>
<td>7 - 17</td>
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<tr>
<td>Yuzhno-Abinskaya</td>
<td>2.2-9.0</td>
<td>50-300</td>
<td>55-65</td>
<td>2.5-8.0</td>
<td>2.3-5.2</td>
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<tr>
<td>Brown coal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angrenskaya</td>
<td>2.0-22.0</td>
<td>120-250</td>
<td>7 - 10</td>
<td>35.00</td>
<td>12.20</td>
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<tr>
<td>Podmoskovnaya</td>
<td>2.50</td>
<td>30-80</td>
<td>0-2</td>
<td>30.00</td>
<td>34.30</td>
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<tr>
<td>Shatsk</td>
<td>2.6-4.0</td>
<td>30-60</td>
<td>0-2</td>
<td>30.00</td>
<td>26.00</td>
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<tr>
<td>Sinehikovsky</td>
<td>3.5-6.0</td>
<td>80.00</td>
<td>0-2</td>
<td>55.00</td>
<td>23.80</td>
</tr>
</tbody>
</table>
FSU - Vertical wells

Air

Exhausted holes

Product
First UCG test was at Durham in 1912 and a full research programme ran from 1949-1959 to develop a commercial industry.

Commercial trials performed from 1956-1959 to develop a power generation site (unsuccessful, but the last trial performed well).

Reviews in 1964 and 1976 to decide if research should be continued.

New research programme started in 1999.
Blindhole layout gave the best performance during the experimental trials.

Problems were experienced with the injection pipes failing during operation.
Final commercial design and cavity formed in trial
New research programme commenced in 1999 to evaluate the potential of UCG to replace North Sea natural gas.

Most research has been on site selection, drilling technology, cost evaluation and environmental criteria.

Drilling and in-situ gasification trials have been delayed and now require industry support.

A feasibility analysis has been produced for a proposed site at the Firth of Forth.
History of UCG in the U.S.A

By

Burl E. Davis

Carbon Energy Associate
### U.S. Department of Energy Programs

<table>
<thead>
<tr>
<th>Date</th>
<th>Organ.</th>
<th>Location</th>
<th>Process Config.</th>
<th>Coal Rank</th>
<th>Seam Thick</th>
<th>Seam Depth</th>
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</thead>
<tbody>
<tr>
<td>1971-1981</td>
<td>Laramie ETC</td>
<td>Hanna, Wy.</td>
<td>LVW-RCL</td>
<td>Sub.</td>
<td>7M</td>
<td>80M</td>
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<tr>
<td>1972-1982</td>
<td>Lawrence Livermore</td>
<td>Hoe Creek.</td>
<td>LVW-RCL</td>
<td>Sub.</td>
<td>5M</td>
<td>30M</td>
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<tr>
<td>1977-1980</td>
<td>Morgantown</td>
<td>Pricetown WV</td>
<td>LVW-drilled link.</td>
<td>Bit.</td>
<td>3m</td>
<td>300m</td>
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<tr>
<td>1976-1982</td>
<td>Gulf /DOE</td>
<td>Rawlins</td>
<td>SDB</td>
<td>Sub.</td>
<td>7m</td>
<td>120-200m</td>
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<tr>
<td>1981-1985</td>
<td>Lawrence Livermore</td>
<td>Centralia, Wash.</td>
<td>CRIP</td>
<td>Sub.</td>
<td>6-8m</td>
<td>20-50m</td>
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<tr>
<td>1986-1993</td>
<td>Ind.Cons/D OE</td>
<td>Hanna, WY</td>
<td>LVW-CRIP</td>
<td>Sub.</td>
<td>7m</td>
<td>75m</td>
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</table>
## U. S. Industrial UCG Projects

<table>
<thead>
<tr>
<th>Date</th>
<th>Organization</th>
<th>Location</th>
<th>Proc. Config.</th>
<th>Coal Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978-80</td>
<td>Texas A&amp;M</td>
<td>Rockdale TX</td>
<td>LVW-RCL</td>
<td>Lignite</td>
</tr>
<tr>
<td>1976-80</td>
<td>Texas Utilities</td>
<td>Tennessee Colony</td>
<td>LVW</td>
<td>Lignite</td>
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<tr>
<td>1977-82</td>
<td>ARCO</td>
<td>Rocky Hill WY</td>
<td>LVW-RCL</td>
<td>Sub.</td>
</tr>
</tbody>
</table>
Linked Vertical Wells

Steam/Oxygen

Fuel Gas or Synthesis Gas

Sandstone

Shale

Coal

Reactor
Hoe Creek Findings

Directional Drilling as the primary method of linking.

Importance of maintaining gas flow low in the seam.
Linear CRIP Configuration
Rocky Mountain 1

• Operation of parallel reactors
  – LVW
  – CRIP
• Steam/Oxygen
• Slip Stream Catalyst Test
• Full Environmental Compliance
CRIP

Steam/Oxygen

Fuel Gas or Synthesis Gas

Shale

Sandstone

Shale

Coal
Test Results

• LVW
  – 65 Days to Burnout
  – Second Injection Well
  – 70-100 Tons/day
  – HHV 230-280 Btu/scf

• CRIP
  – 90 Days of Operation
  – 4 Reactors
  – 70-200 Tons/day
  – HHV 250-320 Btu/scf
CRIP Reactor Development
(Plan View)

50 M

200 M
Rawlins

- Two Tests
- Gulf Oil Cost Shared Contract
- Subbituminous Coal
- 7-8 Meters Thick
- Seam Dip 60°
- Full Environmental Compliance
Steeply Dipping Beds

Underground Coal Gasification
Steeply Dipping Beds
SDB Reactor Development

150 M

30 Meters
Horizontal vs. Dipping

- **Horizontal**
  - Large Resource
  - 75-80% Thermal Efficiency
  - 0.4 O₂/1 coal

- **Dipping**
  - Limited Resource
  - 82-88% Thermal Efficiency
  - 0.2 O₂/1 coal
UCG to Ammonia

- Raw Product Gas
- O2+Steam
- Solids Removal
- Scrubber
- Reformer
- Shift
- Acid Gas Removal
- Ammonia
- Ammonia Synthesis

Rawlins Clean Coal Technology
Coal to Ammonia Facility
Conclusions

Each DOE UCG Program contributed to the evolution of UCG Technology

Results were published and available to other workers in the field

Virtually all of the technology is considered a the public domain
Experimental trials have been held intermittently since 1948 in Western Europe in deep coals.

Recent notable trials have been at:
- Thulin (1982-84 and 1985-86) in Belgium
- Alcorisa (1997) in Spain

The recent trials have benefited from the use of CRIP technology as this is more suited to use in deep coal seams than vertical wells.
EU - Spanish Test Site
EU – Spanish CRIP progress

Diagram:

- **a** - Start of the gasification
- **b** - After 2-3 days
- **c** - After 5 days

- Injection well
- Recovery well
- Clayey sand
- Coal seam
- Limestone
- Cavity
- Accumulation of rubbles
- Water influx
- Coal seam ~2m thick at ~600m
- Oxygen and liquid water injection
- Operations hampered by high water production (wet sand overburden)
- Injection well failed structurally
- Construction and operation problems relating to poor site characterisation and selection
China has developed a different technique using mined tunnels and has demonstrated it at least 12 sites since 1995.

Air and steam are used, sometimes in stages, to produce either fuel gas, synthesis gas or hydrogen.

While high quality gas can be produced using the technique, the economics are difficult to evaluate because most plants receive 5-year grants to aid construction and none have been expanded after the 5-year period.
China – Tunnel technique

Steam, Air, Flame front movement, Product, Mined tunnels
Product gas from China’s UCG sites has been used for various purposes, including:

- Domestic fuel gas
- Coal-fired boilers
- Pottery kilns
- Ammonia synthesis
Trial operated at Chinchilla from 1999 to 2002

Over 30,000 tonnes of coal used in 2 gasifiers

10m thick seam at 130m depth using a modified vertical wells technique
Linc Energy had a successful share offering earlier in 2006, raising $22 million. Development of a small liquid synthesis plant is planned at the same site as the earlier demonstration with the support of Syntroleum, a Fischer-Tropsch technology provider.
The End