POWER GENERATION WITH UCG

Economics of power generation with UCG

A Presentation by NTPC
POWER GENERATION WITH UCG

CONTENTS OF PRESENTATION

• NTPC IN POWER GENERATION
• GASIFICATION OF COAL
• IGCC POWER PLANT
• UCG BASED IGCC
• ECONOMICS OF POWER GENERATION
• ISSUES RELATED WITH UCG FOR POWER GENERATION
POWER GENERATION WITH UCG

• NTPC’s present installed capacity is 26,404 MW.
• Consists of 14 coal based and 7 Gas based and 4 JVs stations.
• Comprising 72 thermal units of 60 / 110 / 200 / 210 / 500 MW rating.
• 22 Gas Turbine units/10 Steam Turbines in combined cycle mode.
• Construction 4000 MW thermal plants and Hydro stations
• Venturing in to Nuclear field/Mining of coal
• Target of 51000 MW installed capacity by 2012
POWER GENERATION WITH UCG
POWER GENERATION WITH UCG

NTPC OPERATING PERFORMANCE PLF OF NTPC STATION Vs ALL INDIA

ALL INDIA PLF NTPC PLF

UCG FOR POWER GENERATION
POWER GENERATION WITH UCG
POWER GENERATION WITH UCG

GROWTH OF NTPC INSTALLED CAPACITY & GENERATION

23,749 MW (as on 31.03.2005)

159 BU's (for the year 2004-2005)

UCG FOR POWER GENERATION
POWER GENERATION WITH UCG

GASIFICATION OF COAL
An Indian perspective
What is UCG

• Underground coal gasification (UCG) utilizes coal without mining it.
• UCG can provide energy from coal seams where traditional mining methods are either impossible or uneconomical.
• It can be used to exploit the off-shore coal reserve which is unsuitable for utilization by conventional mining.
• Hence it may be used for coal deep under ground.
• Gas may be used for - industrial heating, power generation, production of hydrogen, synthetic natural gas, liquid fuel or other chemicals.
Gasification

Conversion of Coal to Fuel Gas (Syngas) by Reaction in Oxygen deficit environment and in presence of steam

Gasification is slow reaction and require high temperature and more reaction time

UCG FOR POWER GENERATION
Definition and Process

Process for in-situ conversion of coal in the mine to combustible gas

• Air or oxygen is injected inside the coal mine

• Coal is ignited in-situ itself

• Fuel gas is produced by providing steam along with oxidizer

• Syngas produced contains CO, H₂, CH₄, CO₂, H₂O, N₂.
POWER GENERATION WITH UCG
Advantages of UCG

- Process of Mining is eliminated
- Loss of methane during mining and transportation is avoided
- No ash or coal handling at surface.
- Adjacent strata and cavity are potential Sequestration locations.
- Syngas suitable for high-efficiency power generation.
- High-pressure syngas can be easily treated.
- CO$_2$ capture and sequestration facilitated.
- Syngas is source of hydrogen, liquid fuel, and chemicals
# UCG Global Status

## Major International Field Trials & Schemes

<table>
<thead>
<tr>
<th>Country</th>
<th>Max. Depth</th>
<th>Coal</th>
<th>Oxidant</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>1200 m</td>
<td>Anthracite</td>
<td>Air</td>
</tr>
<tr>
<td>Belgium</td>
<td>866 m</td>
<td>Anthracite</td>
<td>Air/ O2/Foamy water</td>
</tr>
<tr>
<td>USSR</td>
<td>150 m</td>
<td>Lignite</td>
<td>Air</td>
</tr>
<tr>
<td>Australia</td>
<td>100 m</td>
<td>Lignite</td>
<td>Air/ Steam</td>
</tr>
</tbody>
</table>

Chinchilla (Australia) was operated at large scale > 200 MWe and a recent pilot project (1999-2003) was successful and commercially available.

Russian experience equivalent to about 200 Mwe.
Vertical wells coupled generally with air pressurization to open up an internal pathway. It is suitable for young coal only.

Man-built galleries in the coal seam as the gasification channels and boreholes are constructed to communicate with the surface.

Create dedicated inseam boreholes, using drilling and completion technology, adapted from oil and gas Production. It uses CRIP and O2.

UGC Technology World Wide

Russian

Chinese

European
Indian Coal Reserves

**TYPE-WISE CATEGORISED RESOURCE OF INDIAN COAL**
(As on 01-01-2004)

- **Proved**
- **Indicated**
- **Inferred**

Coal for Power Generation

Annual consumption ~ 0.5

UCG FOR POWER GENERATION
POWER GENERATION WITH UCG

DEPTH-WISE AND CATEGORY-WISE RESOURCE OF INDIAN COAL
(As on 01-01-2004)

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Proved</th>
<th>Indicated</th>
<th>Inferred</th>
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<tbody>
<tr>
<td>0-300m</td>
<td>69.79</td>
<td>66.75</td>
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<tr>
<td>0-600m</td>
<td>15.22</td>
<td>13.71</td>
<td>0.50</td>
</tr>
<tr>
<td>300m-600m</td>
<td>6.46</td>
<td>38.31</td>
<td>17.06</td>
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<tr>
<td>600m-1200m</td>
<td>1.67</td>
<td>10.60</td>
<td>5.61</td>
</tr>
</tbody>
</table>

UCG FOR POWER GENERATION
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RESOURCE OF COAL IN MAJOR INDIAN COALFIELDS
(As on 01-01-2004)

- Medium depth UCG
- High depth UCG

UCG FOR POWER GENERATION
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PROVEN NON COKING COAL RESERVE AT 300-1200 m DEPTH (In Billion Tons)

- Godavri Valley: 2.75
- Kamptee: 0.073
- Kusaga: 0.025
- Singrauli: 0.079
- Pathakhera: 0.03
- Mankum: 0.125
- South Karanpura: 0.159
- North Karanpura: 0.277
- Jharia: 0.5
- Raniganj: 0.106
- Raniganj (WB): 1.62

Coal Required by 100MW plant for 30 years: 0.015 billion Tons
POWER GENERATION WITH UCG

• Proven Non Coking Coal Reserve at 0-600m depth (In billion Tons)

- Singrauli: 0.128
- Pathakhera: 1.268
- South Karanpura: 1.27
- Jharia: 5.6
**UCG Potential in India**

Total Coal Resources in India 460 billion Ton
( up to a depth of 1500 m)

Of which, below more than 300 m depth 315 billion Ton

**Target coal for underground gasification because of**
- favorable geographical set up,
- thickness of coal seams,
- optimum rank,
- maturity and
- low sulfur
UCG Potential in India

Potential Areas in India:

- Mehsana
- Gondwana coal area

About 70 billion ton of coal at Mehsana is available for underground gasification

May result in 15000 billion m$^3$ equivalent of NG

Present gas production
32 billion m$^3$
POWER GENERATION WITH UCG

IGCC POWER PLANT
IGCC: Opportunity to utilize coal in high efficiency combined cycle

- IGCC is gasification of coal and then its use in combined cycle

- Due to higher efficiency, suitability for carbon capture and ease of capturing other pollutant IGCC is promising technology.

- With high natural gas prices and pressure for reduction of emission of greenhouse gases, IGCC with carbon capture seems to be a favorable option for fossil fuel based power generation.

- UCG is coal gasification without Gasifiers

- IGCC considered for Power generation with ICG
IGCC SCHEMATIC

UCG FOR POWER GENERATION
Types of Gasifier

**Entrained flow gasifier**

- Texaco: Commercial
- E Gas: Commercial
- Shell: Commercial
- Noell: Commercial
- Prenflo: Commercial
- Mitsubishi: Pilot

Suitable for Pet Coke and Low Ash Coal

**Moving bed gasifier**

- Lurgi: Commercial
- BGL: Demo

Suitable for Reactive Coal, both Low and High Ash Coal

**Fluidized bed gasifier**

- U-Gas: Pilot
- KBR: Pilot
- KRW: Demo
- BHEL: Pilot
- HT Winkler: Demo

Suitable for Reactive Coal, both Low and High Ash Coal

UCG FOR POWER GENERATION
IGCC is expected to give higher efficiency and lower water consumption than PC pant.

**Plant Efficiencies for 2x 500MW Plant**

**Water Consumption for 2x500MW Plant**

Solid bars - Washed coal, coloured bar – ROM coal

IGCC has major advantage in reducing pollutant like SOx and heavy metal. Because of lower volume of syngas carbon capture is economical.

UCG FOR POWER GENERATION
EXPECTED TRENDS FOR FUTURE CAPITAL COST

COST (US $ / kW)

10000

1000

100

TIMELINE (CALENDAR YEAR)

1980 1990 2000 2010

KEY TO COMPETITIVENESS
HIGHER CAPITAL COST MUST BE COMPENSATED BY INCREASED EFFICIENCY TO MAINTAIN SAME COG

UCG FOR POWER GENERATION
IGCC for India needs Indian Coal Specific Development

- Selection and design of gasifier is coal dependent
  - Entrained bed gasifier suitable for low ash coal
  - Moving bed gasifier has not been used in IGCC. It is not good at handling fines in coal. Tar and phenol are difficult to handle
  - Fluidized bed gasifiers are limited to pilot scale. It is suitable for high ash coal but further development are required.
- Penalty for cold gas cleanup is comparatively high for air blown fluidized bed gasifier
  - Hot gas particulate cleaning, desulphurization and alkali cleaning is key to utilizing full potential of IGCC
  - These technologies are still under development around the world
- Gas turbine combustor for low Btu gas from fluidized bed gasifier need to be fully developed/tested

High temperature Fluidized bed gasifier, Hot gas cleanup and Low BTU Combustor are required for Indian Coal based IGCC
For high ash Indian Coal IGCC Efficiency is comparatively low

<table>
<thead>
<tr>
<th>Parameter</th>
<th>660 MW Super Critical</th>
<th>500 MW Sub Critical</th>
<th>100 MW IGCC</th>
<th>500 MW IGCC (Expected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross efficiency</td>
<td>38.9</td>
<td>38</td>
<td>37 to 40%</td>
<td>40 to 43%</td>
</tr>
<tr>
<td>Auxiliary Power</td>
<td>7-8%</td>
<td>7-8%</td>
<td>13-20%</td>
<td>13-20%</td>
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<tr>
<td>Net efficiency</td>
<td>35.9</td>
<td>35</td>
<td>30 to 33%</td>
<td>36 to 37%</td>
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<tr>
<td>Capital Cost (Crores Per MW)</td>
<td>4.5</td>
<td>4.5</td>
<td>8 - 9</td>
<td>7 - 8</td>
</tr>
</tbody>
</table>

Capital Cost High due to cost of development, additional systems etc.
IGCC Scenario for India

- Environmental regulations are going to be stricter in coming years

- Deregulation of power market will require induction of Advanced Technologies at competitive price in future projects

- Super critical/ Ultra-supercritical PC fired plants at present appear to be the most commercially used and viable option for power generation using coal

- With development of higher size CFBC boilers, this technology is expected to be more popular in future.

- IGCC will become cost effective with development of high capacity plants, for more stringent environmental norms, carbon sequestration and also when water consumption becomes a major issue

- Development of IGCC should be perused toward improving efficiency and reliability.

Coal will Remain Main Stay for Indian Power Generation in future
POWER GENERATION WITH UCG

UCG Based IGCC
UCG Product

Power & Steam

Coal

Gasification

Iron Reduction

Fuel/Town Gas

Ammonia & Urea

Dimethyl ether

Ethylene & Propylene

Oxo Chemical

Polyol

Synthetic Gas

Synthetic Nat. gas

Naphtha

Liquefied

Waxes

Diesel/Kero

Methanol

Methyl Acetate

Acetic Anhydride

Acetic acid

FT Liquid
POWER GENERATION WITH UCG
Environmental concerns of UCG

• There is possibility of leaching of organic substance, which is very likely to be extracted and transferred into the underground water. Phenol is the most obvious organic pollutant due to its relatively high water solubility.

• The concentration of inorganic salt near the gasification zone is likely to increase due to water vaporization in high temperature zone or solubility improvement in existence of CO2.

• Dissolving of gas such as H2, CH4, CO2, H2S, and NH3 in underground water.

• Leaching of heavy metals (Hg, As, Pb, Cr, Cd) may influence the quality of underground water.
CO2 emission in T/MWhr

- Coal Modern Steam plant
- Coal Surface Gasification
- UCG Gas Combined Cycle
- UCG with CO2 Separation
- Natural Gas Combined Cycle
Indian Effort

- GAIL is prospecting coal and lignite deposits for underground coal gasification (UCG) projects in India along with Ergo Exergy. The design of pilot and commercial UCG plants, their construction, commissioning, operation and maintenance will also be carried out jointly. The companies will cooperate for methods of gas clean-up, safety and environmental engineering of these plants. GAIL plans to set-up 70-80 mw power plants at the pitheads.

- ONGC is perusing UCG in collaboration with CIL. ONGC have identified NMRC-Skochinsky Institute of Mining, Russia, as a consultant for the UCG application. ONGC plans to drill 100 wells and use enriched air to generate 1.5 mm scmd of gas. The ultimate aim is to set up a 200-mw power unit.
Pakri Barwadih Mine Survey

- Mine is spread over an area of 40 sq. km
- Mine survey report has been prepared by CMPDI
- Mine survey has been done up to the depth of 300m
- Estimate reserve of coal is 1400 million Tons
- 400 million Tons is recoverable
- Water bearing horizons observed between the coal seams also.
- Coal seams separated by shale and sand stone
- MECON is currently preparing the mine planning and Feasibility report for this mine
- More detailed mine survey up to greater depth (say 600 m) is required for UCG
Seams Suitable for Open Cast Mining

<table>
<thead>
<tr>
<th>Seam</th>
<th>Thickness (m)</th>
<th>Grade</th>
<th>M%</th>
<th>Ash %</th>
<th>VM%</th>
<th>GCV (k.Cal/kg.)</th>
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</thead>
<tbody>
<tr>
<td>V Top</td>
<td>1.5</td>
<td>D-G</td>
<td>3.5-6.8</td>
<td>22.4-52.2</td>
<td>17.8-22.3</td>
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<td>B-G</td>
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<td>15.7-48.7</td>
<td>20.1-21.9</td>
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<td>V. Comb.</td>
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<td>C</td>
<td>3.7-7.0</td>
<td>17.9-51.8</td>
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<td>IV A</td>
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<td>D-G</td>
<td>3.4-5.2</td>
<td>25.2-49.9</td>
<td>18.5-19.6</td>
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<td>1.25</td>
<td>E-G</td>
<td>3.1-5.8</td>
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<td>C-G</td>
<td>3.7-5.3</td>
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<td>B-G</td>
<td>2.8-5.7</td>
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<td>D-F</td>
<td>3.4-5.8</td>
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<td>4037-5529</td>
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<td>II Top</td>
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Seams not Suitable for Open Cast mining

<table>
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<tr>
<th>Seams</th>
<th>Grade</th>
<th>Ratio 1</th>
<th>Ratio 2</th>
<th>Ratio 3</th>
<th>Ratio 4</th>
<th>Ratio 5</th>
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<tbody>
<tr>
<td>I Top</td>
<td>2.5</td>
<td>B-G</td>
<td>1.5-4.0</td>
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<td>C</td>
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<td>3603-7213</td>
<td></td>
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</table>
Suitability of Pakri Barwardi for UCG

• Coal Available up to the depth 600m.
• Present Open Cast mining Limit 200m
• Proposed Open Cast mining Limit 320m
• Grade of Coal E and F Grade hence not economical for Underground Mining
• Water Table depth 60 to 70 m
• So Coal available below 400 m may be available for UCG
• At this depth Rock is generally hard and not permeable.
• Chances of pollution aquifers is little at this depth
Suitability of Pakri Barwadih

- Top four seam of Barakar formation are economically recoverable by open cast mining
- Bottom seam of Barakar formation and all the seams of Karharbari formation may be available for UCG
- European technique involving in seam drilling appears to be more suitable technique
- Many of the seams have depth of less than 1.5 m. These seams may not be viable.
- Seams separated by shale and sand stone are not suitable for UCG.
# Expertise Requirement for UCG – A Review

<table>
<thead>
<tr>
<th>Expertise</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Cycle</td>
<td>Available within NTPC</td>
</tr>
<tr>
<td>Geology &amp; hydrogeology</td>
<td>Not available within NTPC</td>
</tr>
<tr>
<td>Mining</td>
<td>Not available within NTPC (Coal Industry)</td>
</tr>
<tr>
<td>Drilling and exploration</td>
<td>Not available within NTPC (Oil and Gas Industry)</td>
</tr>
<tr>
<td>The chemistry and thermodynamics of the gasification</td>
<td>Some Knowledge base generated during IGCC study</td>
</tr>
</tbody>
</table>
POWER GENERATION WITH UCG

Economics of UCG Power Generation
Estimate of UCG Power Cost
(Data available – Is it applicable to Indian Mines/Coal/Conditions?)

UCG FOR POWER GENERATION
Estimate of UCG Cost

• Large-scale UCG with power generation (300MWe) undertaken remote from the gasification site has a generation cost comparable to, and possibly less than, Integrated Gasification Combined Cycle (IGCC) technologies. However, small scale developments (~50MWe) are not likely to be economically viable as standalone project.

• UCG with CCS has a power generation and capture cost which lies between the two estimates for IGCC with CCS and is comparable with gas turbine combined cycle (GTCC) with CCS. This assessment assumes post-gasification capture.

Source: dti(UK) internet site
Cost Estimate for 100 MW UCG IGCC
(Indian conditions)

• Total field cost for UCG IGCC power plant is CC plus additional cost for underground gasifier and piping network for supply of gas
• Cost of fuel depend on UCG cost
• Cost saving due to elimination of gasifier
• Additional cost for underground gasifier and piping network for supply of gas
• There is saving due to elimination of mining and coal transportation.
UCG – Gas Quality for power generation

- Calorific value of gas form UCG with oxygen as oxidant is in the range of 700 to 850 kcal/NM³ which may not be suitable for firing in gas turbine as calorific value in the range of 1000 Kcal/Nm³ is considered as minimum requirement for gas turbine and it would be safer to keep design value of syngas CV in the range of 1300 KCal Nm³.

- Calorific value of about 1500 Kcal/Nm³ has been obtained in UCG with oxidant having 65% O₂. So UCG with suitably enriched oxidant may provide the gas with desired CV.

- Syngas from UCG enriched with oxidant is technically viable for power generation.
Economics of UCG for Power Generation

- Assumptions made in Techno economics study:
  - 100 MW pit head power station with base load operation
  - 15 years plant life & plant cost estimated based on data
  - Coal with GCV of 3300 Kcal/Kg with 2m seam depth
  - Efficiencies of technology based on data available
  - Fuel cost escalation of 3% for UCG against 7% for others
  - Aux.power 15% for UCG & 7.5% for PC Boilers
  - Plant Load Factor of 80% & Financial parameters as per data
## Cost of 100 MW IGCC Plant (Rs Crores)

<table>
<thead>
<tr>
<th>Description</th>
<th>IGCC</th>
<th>UCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Block (Combined Cycle) cost</td>
<td>365</td>
<td>365</td>
</tr>
<tr>
<td>Gasifier and particulate cleaning</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Coal &amp; Ash Handling Plants</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Acid Gas removal and sulfur recovery</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>BOP Mech/Elect/Civil</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>Land/ Site development/Erection &amp; Commissioning/Taxes/Duties</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>850</strong></td>
<td><strong>640</strong></td>
</tr>
</tbody>
</table>
Cost of Generation from UCG

- Cost of drilling and boring for 500m x 500m panel is about £9.6 million (Rs.76.8 Crores for Rs.80 per £). Other costs associated with underground coal gasification has not been accounted in this analysis.

- For seam thickness of 2m, a 500m x 500m panel will contain about 0.5 million Ton of coal. It translates into drilling cost of Rs. 1920 per Ton of coal. Including royalty of Rs. 65 per Ton, cost of coal extraction by UCG will be Rs.1985 per Ton against pit head coal price of about Rs.550.

- Based on above cost and 12% auxiliary power consumption in gasification process, cost of syngas from works out to about $8.5/MBtu at the pit head.

- Unaccounted cost of piping network and cost other than that of drilling will further add to the above costs.

- Gasification efficiency in UCG is about 50%, hence overall efficiency of UCG assuming 50% combined cycle efficiency and 15% auxiliary power consumption works out as 21.5%

- Based on cost of Rs.1985/Ton of coal, net efficiency of 21.5% and capital cost of cost 6.4 Cr. Per MW, cost of generation from UCG comes about Rs 4.10 assuming 15 years plant life, PLF of 80% and 2.5% O&M cost (Possible only when technology becomes mature).

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Thicker coal seams with lower ash, reduction in drilling cost and higher gasification efficiency will improve the economics of UCG.

UCG FOR POWER
GENERATION
COG for UCG vs. other Technology

• Conventional PC fired plant cost about Rs. 4.5 Crores per MW, has net efficiency of about 35% with pithead coal cost of about Rs. 550/T which gives cost of generation of Rs2.00/KWhr assuming PLF of 80% and 25 years plant life.

• Assuming 15 years plant life, PLF of 80% and 2.5% O&M cost, cost of generation from IGCC is expected to be around Rs 3.00/KWhr

• Based on coal cost of Rs.1985/T, net efficiency of 21.5% and capital cost of cost 6.4 Cr. Per MW, cost of generation from UCG comes about Rs 4.10 assuming 15 years plant life, PLF of 80% and 2.5% O&M cost (Possible only when technology becomes mature).

• Thus Conventional PC plant has significant cost advantage over other two technology

• IGCC has significant cost advantage over UCG if seam available for UCG is of about 2 m thick and CV of inseam coal is about 3300 kCal/kg. UCG cost will become comparable to IGCC if Seam thickness is more and CV of coal is higher
100 MW CAPACITY POWER PLANT
A TECHNOLOGY COMPARISON

Comparison of Efficiency

Efficiency (%)

Technology

PCB  IGCC  UCG

UCG FOR POWER GENERATION
100 MW CAPACITY POWER PLANT
A TECHNOLOGY COMPARISON

Comparison of Capital Cost

Capital cost (Rs Crores)

<table>
<thead>
<tr>
<th>Technology</th>
<th>PCB</th>
<th>IGCC</th>
<th>UCG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400</td>
<td>800</td>
<td>600</td>
</tr>
</tbody>
</table>

UCG FOR POWER GENERATION
Comparison of COG

- PCB
- IGCC
- UCG

COG (Rs/KWhr)

Technology

UCG FOR POWER GENERATION
100 MW CAPACITY POWER PLANT
A TECHNOLOGY COMPARISON

Comparison of Fuel cost

- Fuel cost (Rs/Ton of coal)
- Technology: PCB, IGCC, UCG
- Series 1

UCG FOR POWER GENERATION
Economics of UCG for Power Generation

UCG Feasibility

COG versus Capital Cost

UCG FOR POWER GENERATION
Economics of UCG for Power Generation

UCG Feasibility

![Chart showing COG versus GCV of coal](chart.png)
Economics of UCG for Power Generation

UCG Feasibility

![COG versus Fuel Cost Diagram]

UCG FOR POWER GENERATION
Economics of UCG for Power Generation

UCG Feasibility

UCG FOR POWER GENERATION
Economics of UCG for Power Generation

UCG Feasibility

COG vers Gross Efficiency

UCG FOR POWER GENERATION
Drilling and Boring cost for 500 m x 500 m panel

<table>
<thead>
<tr>
<th>Plant Item</th>
<th>Cost (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration cost and monitoring cost (seismic, borehole and monitoring well)</td>
<td>0.3</td>
</tr>
<tr>
<td>Vertical production well to seam (1 per panel)</td>
<td>0.6</td>
</tr>
<tr>
<td>Vertical Injection wells (4 per panel)</td>
<td>2.4</td>
</tr>
<tr>
<td>Well site preparation (5x£50,000)</td>
<td>0.3</td>
</tr>
<tr>
<td>Inseam production wells (4x250m @£200/m)</td>
<td>0.2</td>
</tr>
<tr>
<td>Inseam injection wells (32x250m @£200/m)</td>
<td>1.6</td>
</tr>
<tr>
<td>Precise steering intersects (32 per panel @ £50,000 each)</td>
<td>1.6</td>
</tr>
<tr>
<td>Well completions (28@£50,000 each)</td>
<td>1.4</td>
</tr>
<tr>
<td>Drainage well</td>
<td>0.6</td>
</tr>
<tr>
<td>Monitoring well (1 per panel)</td>
<td>0.6</td>
</tr>
<tr>
<td>TOTAL development cost per panel</td>
<td>9.6</td>
</tr>
</tbody>
</table>
One Panel of UCG

- Gasification channels
- Single Production Well
- One of four injection wells
- Channel pattern repeated in each quadrant

Dimensions: 500m x 500m
POWER GENERATION WITH UCG

Issues related with UCG Power Generation
Issues related to UCG for Power

• Uninterrupted supply of syngas from UCG for IGCC
• Maintaining the syngas quality on continuous basis
• Removal of impurities from syngas
• Environmental impact of UCG
• Development of efficient GT for low HV syngas burning
• Overall design/development of UCG + Power Block
Road Map

- Framing of regulations pertaining to UCG.
- Estimate coal reserves for UCG
- Selection of mine based on existing geological survey.
- Mapping and assessment of the mine suitability for UCG.
- Establish cost parameters for the process to be competitive.
- Comparison of UCG with other Technologies
- Identification of Competing UCG Technology
  - Syngas quality and availability on continuous basis
  - Addressing of Environmental concerns
  - Identification of economic power plant capacity
  - Removal of impurities from syngas
- UCG Technology Selection
- Examine the implications of burning UCG gas in gas turbines
- Identify a semi-commercial site.
- Development of a pilot UCG for firsthand experience with the technology and realistic cost assessment.
POWER GENERATION WITH UCG

Thank You

Prepared by : Project Engineering Group/NTPC