R&D needs for future clean utilisation of coal in India

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Why is coal important for India?

- Installed power generation (as of June 2010)
  - 162,366 MW
  - 78,000 MW of additional capacity by 2012
  - Expected to rise to 950,000 MW by 2030

- 70% of that from thermal power plants

- 50% of India’s primary commercial energy is drawn from coal
  - 72% power (86000MW)
  - 5% steel
  - 4% cement
  - 19% others
Where are our priorities?

- The demand and supply gap is around 10%
- 400 million Indians lose electricity during power cuts
- 80% of the villages have electric poles, with not more than 50% access as against 93% access in urban households
- Over 35.5% of population live without any electricity.
What alternates do we have?

• Nuclear, hydro, renewables
  – Nuclear and hydro have their limitations to rate of expansion
  – Renewables ----how much and how soon?
    • Decentralised power for remote areas!
      – Micro and mini grids
    • 10% contribution from renewables
    • Extensive promotion for R&D

• So, Coal, oil, gas???
India has more than 250 billion tonnes of coal.

The main coal states are Andhra Pradesh, Chattisgarh, Jharkhand, Orissa and West Bengal.

A significant fraction of this coal is at depths larger than 300 m.

Indian coals are of low rank (sub-bituminous and lignite); with high ash content (upto 40%).
Steps to be taken

- Efficiency improvement in old power plants where the efficiencies are as low as 25-30%
- Reduce transmission and distribution losses

- Use clean coal technologies for new power plants
  - Evaluate the relative merits and applicability to Indian coals
- With or without CCS?
- Cannot ignore the coal used for thermal applications, where again simpler clean coal technologies can be used
Clean coal technologies (CCT) for power generation

1. Pressurised Pulverised coal combustion (PCC)
2. Supercritical and Ultra Supercritical Pulverised coal combustion
3. Integrated gasification combined cycle (IGCC)
4. Oxy-fuel combustion
5. Underground coal gasification

What is the basic principle of operation?
Why are these techniques considered ‘clean’?
What are the technological & other challenges?
Is it a suitable technique for India?
e.g., Supercritical and ultra supercritical boilers
<table>
<thead>
<tr>
<th>Technology</th>
<th>Efficiency without capture</th>
<th>With capture</th>
<th>R &amp;D requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercritical boilers</td>
<td>40%</td>
<td>31%</td>
<td>No reboiler, once-through boiler, wall thickness, materials, water chemistry, and if T &gt; 670C, nickel alloys, material development Heat transfer, materials, water chemistry</td>
</tr>
<tr>
<td>IGCC</td>
<td>40%</td>
<td>34%</td>
<td>Inherent CO2 capture but gasification still not demonstrated effectively for Indian coals</td>
</tr>
<tr>
<td>Subcritical</td>
<td>33%</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>NG-CC</td>
<td>50%</td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>Oxy fuel combustion</td>
<td></td>
<td></td>
<td>Higher flame temperatures, oxygen separation plant costs appx 25% of the plant cost Indian coals have not been found to have good ash flowability after melting, combustion characteristics of Indian coal at high temperatures, Nox emissions, heat transfer and materials.</td>
</tr>
</tbody>
</table>
IGCC vs UCG-CC

**IGCC**
- Surface gasification integrated with combined cycle
- Mining and Surface transportation of coal required
- High gross efficiency
- Technology yet not available for high ash coal

**UCG-CC**
- In-situ coal gasification with surface combined cycle
- Ash handling will not be required
- No mining and transportation required
- Lesser control
- Less data available for model verification
- Low coal utilisation

NTPC [3] analysis for 100MW power plant for Coal GCV -3300kcal/kg, thickness 2m

Capital cost (Rs) – 850 cores (IGCC), 640 (UCG-CC)

Cost of generation (Rs/kWh) – 2.6 (IGCC), 3.6 (UCG-CC)

For thickness >2m COG is expected to be comparable
UCG in India

- UCG activity in India – ONGC, GAIL, Reliance, etc.
- Governmental policies promoting UCG are expected in the coming year
- This study of Indian coal mines indicates potential of UCG for the future
- Depth-wise distribution of coal reserves in India are shown below

- >30% of Indian reserves are candidates for UCG
- High ash coals and lignites are also suitable for UCG
- There is a possibility of CO₂ sequestration in the UCG cavity

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Proved Reserve</th>
<th>Indicated Reserve</th>
<th>Inferred Reserve</th>
<th>Total Reserve</th>
<th>% Total Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-300</td>
<td>54627.35</td>
<td>54242.51</td>
<td>20519.91</td>
<td>129389.77</td>
<td>62.74</td>
</tr>
<tr>
<td>300-600</td>
<td>18929.82</td>
<td>25694.76</td>
<td>17384.94</td>
<td>62009.52</td>
<td>30.07</td>
</tr>
<tr>
<td>600-1200</td>
<td>1560.58</td>
<td>9141.99</td>
<td>4137.64</td>
<td>14840.21</td>
<td>7.19</td>
</tr>
<tr>
<td>Total</td>
<td>75117.75</td>
<td>89079.26</td>
<td>42042.49</td>
<td>206239.50</td>
<td>100</td>
</tr>
</tbody>
</table>

Underground coal gasification can be a prominent clean coal technology for India
Underground coal gasification

- Underground coal gasification (UCG) is the in-situ conversion of coal into combustible gases.
- Underground coal gasification (UCG) is a complex process which involves chemical reactions, heat and mass transfer, complex flow dynamics and growing cavity dimensions.

Advantages over conventional process are:
- Low dust and noise
- No ash handling at power stations
- No coal stocking and transportation
- Larger coal resource exploitation
- Converts sulphur (S) to H₂S and nitrogen (N) to NH₃ instead of SO₂ and NOₓ

Disadvantages:
- Surface subsidence
- Aquifer water contamination
Major issues in UCG

- UCG requires understanding of various aspects of the selected site
  - Geo-hydrological studies are required
  - Knowledge of coal chemistry and thermodynamics is vital
- Site selection for UCG has to be made considering all these factors
- Choice of a suitable drilling technique will ensure good connectivity between the injection and production wells
  - The techniques currently employed are: Directional drilling; Controlled Retractable Injection Procedure (CRIP); Man-build galleries
- Use of the UCG product gas should be known for design purposes
  - Both electricity generation and chemical synthesis (from syngas) applications are possible
- Environmental and safety concerns related to UCG are of primary importance
  - Groundwater contamination; Surface subsidence; and CO₂ emissions have to be evaluated in depth
Coal Gasification for thermal energy purposes-- India Perspective
Application characterisation of coal gasifiers for medium scale operation

- Medium scale coal based gasifier for process industries wherein thermal requirement is required at one location
- Medium scale coal based gasifier for process industries where thermal heat is required at various locations in an industry complex (6-50MWth)
- Medium and small scale gasifiers for captive power generation
- Small scale gasifiers for process heat (1-2Mth)
Potential applications for small and medium scale coal gasifiers – an overview

• 30% of total energy consumed in Indian Industry is through in-house power generation
• 40% use diesel and 15% use gas/naptha as fuel
• The share of energy from CPP is about 8% average
• Large amount of furnace oil/coal is used for thermal applications in industries like cement, steel, refractory, glass, aluminium, etc.
Centralised Coal Gasification Facility for a cluster of Steel Re-rolling Mills—A concept

- There are 120 steel re-rolling mills in Raipur and total of 1200 such mills are reported in India
- In Raipur, 15-20 are oil-fired, rest all are coal-fired furnaces—but of only 2-5 tonnes per hour steel outputs
- They use lump coal, fired on grate, having 5000-5500 kcal/kg as CV
- Average thermal energy input to oil fired furnaces is about 1800 MJ/tonne of steel while that for coal fired furnaces is about 2700 MJ/tonne of steel
By converting solid coal fired furnaces into coal-gas firing, efficiency improvement is possible as

- Excess air can be reduced
- Preheat of air up to 400°C is possible
- Better furnace instrumentation is possible
- Therefore, it is seen that thermal energy can be reduced to 1600MJ/kg of steel
Contd:

• With gasifier efficiency of 75%, energy input reduction of about 22% is possible
• \( \text{CO}_2 \) emissions will reduce
• Particulates will also reduce
R & D requirements

• The major need of the hour is a cost effective and technically feasible gas cleaning/conditioning system for medium and small gasifiers
• The unit sizes are limited and need to be expanded
• Acceptable coal particle size is an issue in this scale of operation
• Almost all gasifiers in this range including the Chinese ones are Updraft type. Upgrading of technology is essential.
Conclusions

• There is a need for simultaneous progress in both large scale technologies for power generation, as well as medium to small gasifiers to cater to the industries which are more in numbers.

• Collaborations are essential in understanding the behaviour of the Indian coals in the clean coal technologies already being researched/developed upon. The load variations are different, PLF are different in India.

• Renewable mix is important, and Co-firing is another technology which is highly neglected.

• India is already going ahead with Supercritical technology but no research base is created, specially within the research and academic institutions.

• Underground Coal Gasification is an option with very high probability of success in using the Indian coals.

• R& D in CCS is to be ongoing at global collaborative levels.