CCS challenges and opportunities for China

Dr Andrew J Minchener OBE
A source of unbiased information on the sustainable use of coal world-wide
Structure of presentation

• Coal in China
• CO₂ issues
• Status of CCS in China
• Larger scale CCS industrial activities for combustion based applications
• CCS for gasification options
  • IGCC
  • Non power gasification initiatives
    • Gasifier technology options
    • Chemical product issues
    • CO₂ capture opportunities
    • Chinese CCS demonstration initiatives in this sector
    • Techno-economic comparisons
    • Current demonstration prospects in China
• The way forward
Coal and China
Unlike OECD countries, coal use in China is spread across many sectors. Power generation is the largest user of coal and its proportion of a growing total will rise in future.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Coal use (Mt)</th>
<th>Proportion of coal use (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation</td>
<td>1765</td>
<td>54.8</td>
</tr>
<tr>
<td>Iron &amp; steel</td>
<td>515</td>
<td>16.0</td>
</tr>
<tr>
<td>Building materials</td>
<td>515</td>
<td>16.0</td>
</tr>
<tr>
<td>Chemicals</td>
<td>171</td>
<td>5.3</td>
</tr>
<tr>
<td>Others</td>
<td>245</td>
<td>7.6</td>
</tr>
<tr>
<td>Export</td>
<td>10</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Geographical spread of Chinese coal resources
China’s energy and environmental policy initiatives within the 12th Five Year Plan (2011-2015)

GDP is expected to grow by 7 percent annually on average

- Energy consumption per unit of GDP to be cut by 16 percent from 2010 levels
- \( \text{SO}_2 \) and \( \text{NOx} \) emissions to be cut by 8 percent and 10 percent respectively from 2010 levels
- \( \text{CO}_2 \) emissions per unit of GDP to be cut by 17 percent from 2010 levels
- Non-fossil fuel use to account for 11.4 percent of primary energy consumption;
- Expenditure on R&D to account for 2.2 percent GDP
In the near term, coal use will continue to dominate the power generation sector, with its capacity rising from ~700 GWe (2010) to ~935 GWe (2015).

In 2010, CO₂ emissions were 8.3 Gt with those from coal in excess of 6Gt.

Studies indicate that absolute CO₂ emissions will rise but at decreasing rates.

With further introduction of low/zero carbon technologies, emissions may reach a plateau by about 2030.

CCS will be required if emissions are to subsequently decline.

Ref: UNDP
Does not feature in the economic goals of 12th FYP but is included as a high technological priority within the R&D programme

- CO₂ capture, utilisation and storage technologies, namely through the development of key technologies and measures for capturing, utilising and storing CO₂;
- the design of a technology roadmap for CO₂ capture, utilisation and storage;
- the implementation of capacity building;
- the establishment of an engineering and technical demonstration project.

Mixture of domestic R&D programmes plus larger scale industrial trials and significant international cooperation for capacity building
Coal fired power generation development in China

• Coal based power generation is mostly (90%) based on pulverised coal combustion (which is also the primary technique for use in cement manufacture)

• Alternative technology for power generation (10%) is circulating fluidised bed combustion, which is mostly used for low grade and variable quality coals

• Integrated gasification combined cycle is a further longer term possibility but has yet to be demonstrated in China
In 2010, Huaneng established a post-combustion capture unit on the 2x660 MWe Shidongkou No. 2 Power Plant in Shanghai, which can remove 120,000 tonnes of CO₂ each year.

The CO₂ is sold to the food and beverage industries.
Greengen IGCC CCS project

- High-efficiency, coal-based IGCC polygeneration system and efficient treatment of pollutants with near-zero emissions of CO₂.
- Phase 1 is to prove the scale-up of the Chinese gasifier.
- Phase 2 aims to improve the IGCC polygeneration technology, and to determine how best to take forward the fuel cell power generation technology, and to produce up to 30-60,000 tonnes/year of CO₂ for EOR trials.
- Phase 3 will comprise a 400 MWe demonstration of the overall concept.

Greengen demonstration project needs to be a success if IGCC is to have a significant chance of successful deployment in China.
### Overview of non-power coal gasifier deployment in China in 2011

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Coal gasification projects</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operational</td>
<td>Design/construct</td>
<td>Total</td>
</tr>
<tr>
<td>GE</td>
<td>27</td>
<td>10</td>
<td>37</td>
</tr>
<tr>
<td>Shell</td>
<td>14</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Siemens</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sasol Lurgi</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>GTI U-Gas</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>ECUST</td>
<td>8</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>TPRI</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>CACG</td>
<td>3</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Tsinghua U</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>ICC-CAS</td>
<td>3</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>63</strong></td>
<td><strong>53</strong></td>
<td><strong>116</strong></td>
</tr>
</tbody>
</table>
CCS potential in the coal to chemicals sector

- There is a growth in scale and extent of application in the coal to chemicals sector, with the opportunity to capture CO$_2$ at relatively low cost.

- So, there is potential for some early CCS demonstrations and commercial prototypes, probably for EOR applications.
CCS opportunities for the modern coal to chemicals sector in China
The first major coal gasifier CCS trial in China is underway at the Shenhua Direct Coal to Liquids (CTL) Demonstration Plant, close to Erdos, Inner Mongolia Autonomous Region.

Aim is to remove up to 100,000 tonnes/year of CO$_2$ from the waste stream and transport it for storage in a nearby aquifer.
Shenhua site for CCS
CO₂ capture from coal power plants

(China-UK NZEC www.nzec.info)

Technology maturity

- Solvent processes for post-combustion capture established in other applications
- Pre-combustion capture technology has been demonstrated at scale but not on a coal IGCC
- Oxyfuel combustion has potential but development is at an early stage
- Other methods of post-combustion capture at R&D stage

Comparative costs of electricity generation for China

- Pulverised-coal plant with MEA capture and IGCC with capture plus transport and storage are 493 RMB per MWh and 440 RMB per MWh respectively
- Increased costs of each option about 200 RMB per MWh compared to a PC plant without CCS
- Cost of avoided emissions is about 280 RMB per tonne of CO₂ avoided compared with the PC base-case
## Impact of CO$_2$ capture on Chinese coal power plants

(NZEC Case studies – New build plant)

<table>
<thead>
<tr>
<th></th>
<th>Net Efficiency (% lhv)</th>
<th>Capture Efficiency Penalty % points</th>
<th>CO$_2$ Emissions g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Plant: Advanced Supercritical (no Capture)</td>
<td>43.9</td>
<td>-</td>
<td>797</td>
</tr>
<tr>
<td><strong>Capture Cases:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Combustion MEA</td>
<td>33.1</td>
<td>10.8</td>
<td>106</td>
</tr>
<tr>
<td>Post-Combustion Ammonia</td>
<td>35.7</td>
<td>8.2</td>
<td>98</td>
</tr>
<tr>
<td>Pre-Combustion/IGCC</td>
<td>36.8</td>
<td>7.1</td>
<td>95</td>
</tr>
</tbody>
</table>
International cooperation on CCS is important for China

Considerable international cooperation in China on all aspects of CCS through:

- membership of international organizations (GCCSI, CSLF, APP)
- bilateral agreements with many nations
- multilateral agreements
- academic cooperation, with financial support from various funding bodies; and
- industrial cooperation, either with or without government financial support

These cooperative activities have increased Chinese capacity and raised awareness of CCS among many stakeholders. Chinese enterprises have taken this forward at industrial scale to achieve very important results.

Further such engagement is needed, not just to take forward the development work but also to establish demonstration and deployment in China.
China appears to recognise that it should host certain CCS demonstration projects, both as showcases for its technology developments and also as a key step on the pathway towards commercial deployment. Aims would be to:

- establish the technology, including process integration and optimisation, at a scale that is large enough to allow subsequent plants to be built with confidence at commercial scale;
- prove that CCS works and is safe, thereby building public confidence; and
- accelerate technology development in order to gain experience that will lead to subsequent cost reduction on larger scale plan.
The rationale and choices for demonstration projects in China are strategic considerations. Options might include:

- 1Mt/year CO$_2$ capture and EOR project using a modern coal power plant with post-combustion capture (Huaneng)
- 400MWe IGCC with full CO$_2$ capture and EOR (Greengen)
- 1-3 Mt/year CO$_2$ capture and aquifer storage project at a large coal to oil plant (Shenhua).
- 1Mt/year CO$_2$ EOR trial in the Jilin Oilfield (PetroChina)
- CCS cluster using various coal to chemicals plants in a specific region
Focus on technologies to reduce both GHG and non-GHG (NOx, SO₂, PM) emissions.

**Technologies for cleaner coal generation**

1. **Reducing coal consumption**
   - Mill
   - Coal
   - Boiler
   - Water
   - Steam
   - Condenser
   - Turbine
   - Water

2. **Reducing non-GHG emissions**
   - De-NOx
   - Flue gas
   - De-S
   - ESP
   - Pollutants to be reduced: • SO₂, NOx, • Particulate matter

3. **Carbon Capture and Storage**
   - CO₂ Capture
   - CO₂ Storage
   - N₂, H₂O

Technologies needed for both conventional gas clean-up as well as CCS
China – the future?

Needs to pursue a low carbon development path with Chinese characteristics, with clearly defined targets and priority actions

– Reduction in energy use per unit of GDP, with consequent reduction in CO₂ emissions

Recognition that China can fulfil a leadership role in clean coal technology with carbon capture and storage

– China already a growing provider of equipment and know-how in power generation, both domestically and overseas
– Tremendous scope to build on the base to integrate CCS techniques as necessary
– Build on joint ventures and licensing arrangements already in place

It is essential that the rest of the international community continues to work with and support China to ensure CCS is established on a viable global basis
Thank you for your attention!

andrew@minchener.fsnet.co.uk