Current Development Situation of China Clean Coal Industry and Technology

The clean coal theme expert group in 863 Program of Ministry of Science & Technology

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Ⅰ. The Development Tendency of China Coal Utilization

Ⅱ. Current Situation of China Clean Coal Industry and Technology

Ⅲ. Comparison between the Domestic and Foreign Technologies of Coal Development and Utilization

Ⅳ. Outlook and Discussion
In terms of the basic reserve, coal is the main body of China fossil energy, covering over 96%. Oil, coal and natural gas account for about 90% of the total production of China primary energy. In the yield of China three major fossil energies, the coal yield covers more than 85% of the fossil energy yield.
Coal Exerting Prominent Effect on Supporting China Economic Society and Energy Development

Coal is an important support for the rapid development of national economy

✓ In China, 76% of the electric power fuel, 86% of the steel energy, 79% of the building material energy, and 50% of the chemical materials come from coal. During the 11th Five-Year Plan, coal had a contribution rate of 15% to GDP.

Coal is an important guarantee for the national energy security.

✓ The coal consumption covers more than 70% of the total consumption of China primary energy. Coal can not only be translated into clean electric power, but also can produce clean gas and fluid fuel as well as chemicals.

Coal has an increasingly prominent effect on the maintenance of social stability and development

✓ At present, the total number of employees in the coal industry is above 5.5 million. The westward movement of coal development provides historical opportunity for the great-leap-forward development of central and western regions.
Before 2030, the Position of Coal as a Principal Energy won't Change in China

- In a comparatively long period from now on, the consumption of coal in China will still continuously increase, peak at around 4.5 billion tons.
- By 2030, it is estimated that the consumption of coal in China will still cover more than 55% of the total amount of primary energy.
The Severe Reality Requiring Accelerating and Promoting the Development of Clean Coal Technology

The confronting problems and challenges of coal development:

- **Resource**
  - Uneven distribution, reversal of coal and water

- **Mining**
  - Ecological damage and severe security issue

- **Transmission and distribution**
  - Increasing haul distance and extensive supply

- **Supply and demand**
  - Excessively fast growth, conflicts outburst

- **Utilization**
  - Lag in technology, low energy efficiency

- **Environment**
  - Heavy pollution, pressure on emission reduction
| Scientific and technological driven | The coal development transforms from element-dominated driven to scientific and technological driven mode. |
| Scientific development | The coal development transforms from plan production according to demand towards the scientific development mode. |
| Comprehensive improvement of quality | Coal supply transforms from extensive supply to need-gearing distribution mode after the improvement of quality. |
| Advanced electricity generation | The coal-fired power generation transforms from partial leading to overall energy conservation and environment protection. |
| Conversion and upgrade | Coal chemical industry transforms from low efficiency and high pollution to high efficiency, clean and water saving. |
| Optimization of transportation | The coal transportation transforms from single coal transportation to the simultaneous transportation of coal and electricity. |
| Energy saving and cost reducing | The high energy-consuming industry transforms from sin intensive structure, technology and management. |
Clean, High-efficient and Sustainable Coal Development Measures

I. The strategic westward movement of coal development is the inexorable trend, and to optimize the layout is the urgent affair.

II. Only when scientific energy-generation is vigorously carried out, can the transition of coal development mode be realized.

III. Comprehensive improvement of quality and using according to quality are important approaches to improve the utilization efficiency of coal.

IV. Simultaneous transportation of coal and electricity must be adhered to solve the long-distance coal transportation problem in the future.

V. Gradually decrease the proportion of coal combustion, increase the rate of coal gasification and promote the hierarchical conversion.

VI. Accelerating the development of advanced coal-fired power generation technology is imperative.

VII. Adjust the structure of coal chemical industry and orderly develop the modern coal chemical industry.

VIII. The energy efficiency of poly-generation has evident advantages, so the project demonstration should be launched as soon as possible.

IX. To realize the emission reduction target of pollutant and greenhouse gas, the first thing is to control the total amount of coal consumption.

X. Excavate the energy-saving potential of high energy consumption industry in terms of structure, technology and management.
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Ultra-supercritical Electricity Generation Technology

In 1992, the first supercritical unit was established in Shanghai.

In 2006, the first 100MW ultra-supercritical unit was established in Yuhuan, Jiangsu.

Up to January, 2013, 59 100MW ultra-supercritical units have gone into production, which is more than the sum total of other countries.

Coal-fired electricity generation technology of China realizes the great-leap-forward development from the subcritical to the ultra-supercritical, with the main units being above 600MW, the total installed capacity being 100 million KW, which saves about 22 million tons of coal every year.

The technological level, development speed and installed capacity have leaped to the world No.1, and export to foreign countries has been made.
Air-cooled Electricity Generation Technology

In 2004, large-scale air-cooled unit technology was broken through and 600MW grade unit was established.

In 2008, the project of "the research & development and industrial demonstration of 1000MW air-cooled unit packaged technology" was launched, and the world first 1000MW-grade ultra-supercritical air-cooled unit was established.

By the end of 2013, the total installed capacity of air-cooled unit with our country's proprietary intellectual property rights has reached 66 million KW; the annual water-saving amount is about 1.1 billion tons if calculated by the yearly operation time of 5,000 hours.

Break through the restriction of water resource shortage on the development of electric power industry and meet the demand of energy industry layout.

Some products are also exported to foreign countries and participate in the international competition.
Large-scale Circulating Fluidized Bed Combustion Technology

At the beginning of the 1980s, circulating fluidized bed boilers came into use in domestic.

By the end of the 1980s, the domestic 50-100MW units reached the advanced level.

Between 2006 and 2008, the domestic 200-300MW circulating fluidized bed boilers were put into operation.

Independently developed, designed and manufactured 600MW supercritical circulating fluidized bed coal firing demonstration project boilers were put into commercial operation in July, 2011.

At present, there are 2130 sets of 35-480t/h circulating fluidized bed boilers in domestic, among which 2013 are of 35-310t/h, and 150 are of 410-490t/h (including those under construction).

The national total installed capacity is more than 40,000MW.
The Industry Demonstration of China Major Modern Coal Chemical Industry

- 5 demonstration projects of coal-to-oil have been established and put into operation with the total capacity of 1.68 million tons per year.

- 4 0.6 million-ton coal-to-olefin large scale projects have been established, together with 3 methanol-to-olefin large scale projects have been established, together with 3 methanol-to-olefin large scale projects.

- 4 coal-to-natural-gas demonstration projects were basically established, with the total capacity of 15.1 billion cubic meters per year.

- 1 coal-to-ethylene-glycol demonstration project is established, with the capacity of 0.2 million tons per year.

Legend:
- Coal to oil
- Coal to olefin
- Coal to natural gas
- Coal to ethylene glycol
- Completed in construction and put into production
- Soon be constructed and put into operation or under construction
In 2003, the pilot test device of 100kg/d was established, and the development of Shenhua processing and catalyst was carried out.

In 2004, the pilot plant of 6t/d was established with accumulative operation of 5,000h.

In 2008, the industrial demonstration device of 6000t/d was established which is first set of coal liquefaction large-scale industrialization device worldwide; it was put into commercial operation in 2011, with the profit of 406 million yuan in the current year.

**Product program of demonstration project**

<table>
<thead>
<tr>
<th>Product</th>
<th>Ten thousand tons per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG</td>
<td>10.21</td>
</tr>
<tr>
<td>Naphtha</td>
<td>24.99</td>
</tr>
<tr>
<td>Diesel</td>
<td>71.46</td>
</tr>
<tr>
<td>Phenol</td>
<td>0.36</td>
</tr>
<tr>
<td>Total</td>
<td>107.02</td>
</tr>
</tbody>
</table>
Technology of coal indirect liquefaction

At the end of last century, Shanxi Institute of Coal Chemistry, Chinese Academy of Sciences, completed the pilot plant test of thousand-ton fixed bed processing and completed the pilot plant test of thousand-ton slurry bed in 2004.

By using the synthetic oil technology of Chinese Academy of Sciences, Shenhua Group, Lu'an Group and Yitai Group complete the establishment and experiment of 200-thousand-ton coal indirect liquefaction industrial demonstration device, adopting slurry bed reactor and iron-based catalyst, respectively.

At present, it is planned to establish the 4-million-ton commercialized device at Shenhua Ningxia Coal Group.

Yankuang group has completed the pilot plant test with oil-producing of 10,000t/a and the industrialized demonstration factory with oil-producing of 1 million t/a is also on the course of construction, adopting slurry bed reactor and iron-based catalyst.

At present, China's technology of coal indirect liquefaction has been equipped with industrialization conditions.
The First Coal-to-Olefin Demonstration Project in the World

At present, four sets of industrial devices have been established and they are Shenhua Baotou 0.6 million tons per year (MTO), Shenhua Ningxia Coal 0.52 million tons per year (MTP), Datang Duolun 0.46 million tons per year (MTP) and Zhongyuan petrochemistry 0.2 million tons per year (MTO).

Shenhua Baotou coal-to-olefin project is the world first established large-scale coal-to-olefin device, with the core production technology adopting the methanol-to-olefin processing (DMTO) with proprietary intellectual property rights of China.

- Be build and put into operation in 2010
- Entering commercial operation in 2011
  - 318 day of accumulative operation
  - Processing 2.666 million tons of gasified raw coal
  - Producing 1.641 million tons of the intermediate product of methyl alcohol
  - Producing 0.51 million tons of polyolefin
  - The total amount of C4 and C5 is 0.117 million tons
  - Realizing 5.63 billion yuan of accumulative operational income
  - Realizing nearly 1 billion profit
CCUS Industrial Demonstration Project Booming Nationwide

- At present, China has implemented the most CCUS industrial demonstration projects in the world.
- At present, China has been in the most leading edge on the world development and promotion CCUS technology.
- China's efforts of developing CCUS will exert huge effect on the world coping with the climatic change.
<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Project name</th>
<th>Type</th>
<th>[place]</th>
<th>Scale (ton CO₂ per year)</th>
<th>Start time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Huaneng Gaobeidian post-carbon-capture project</td>
<td>Smoke gas capture of the power plants</td>
<td>Beijing</td>
<td>3000</td>
<td>2008</td>
</tr>
<tr>
<td>2</td>
<td>Huaneng Shidongkou post-carbon-capture project</td>
<td>Smoke gas capture of the power plants</td>
<td>Shanghai</td>
<td>100,000</td>
<td>2010</td>
</tr>
<tr>
<td>3</td>
<td>China Power Investment Corporation Shuanghuai post-carbon-capture project</td>
<td>Smoke gas capture of the power plants</td>
<td>Chongqing</td>
<td>10,000</td>
<td>2010</td>
</tr>
<tr>
<td>4</td>
<td>Pre-carbon-capture project of the Advanced Energy &amp; Power Center in Chinese Academy of Sciences</td>
<td>Carbon-capture in coal gas before the combustion</td>
<td>Jiangsu</td>
<td>~10,000</td>
<td>2013</td>
</tr>
<tr>
<td>5</td>
<td>Oxygen enrichment carbon-capture project in Huazhong University of Science and Technology</td>
<td>Carbon-capture in the process of oxygen enrichment combustion</td>
<td>Hubei</td>
<td>100,000</td>
<td>2013</td>
</tr>
<tr>
<td>6</td>
<td>Displacement of reservoir oil demonstration project of China National Petroleum Corporation Jilin Oil Field</td>
<td>displacement of reservoir oil by CO₂ + storage of coal bed</td>
<td>Jilin</td>
<td>300,000 – 1,000,000</td>
<td>1997</td>
</tr>
<tr>
<td>7</td>
<td>The demonstration project of coalbed methane replacement in China United Coalbed Methane Company</td>
<td>CO₂ coalbed methane replacement + storage of coalbed</td>
<td>Shanxi</td>
<td>~1900</td>
<td>2005</td>
</tr>
<tr>
<td>8</td>
<td>The integrated demonstration of carbon-capture and displacement of reservoir oil in Shengli Oil Field owned power plant</td>
<td>Exhaust gas capture of the power plant + displacement of reservoir oil</td>
<td>Shandong</td>
<td>30,000</td>
<td>2010</td>
</tr>
<tr>
<td>9</td>
<td>CO₂ utilization demonstration project of ENN</td>
<td>Cultivate microalgae with CO₂-containing waste gas and generate biodiesel</td>
<td>Neimeng</td>
<td>20,000</td>
<td>2010</td>
</tr>
<tr>
<td>10</td>
<td>Huaneng green coal power IGCC carbon-capture + displacement of reservoir oil/ storage integrated demonstration</td>
<td>The carbon-capture before the combustion of coal-based fuel gas + displacement of reservoir oil</td>
<td>Tianjin</td>
<td>60,000 – 100,000</td>
<td>2012</td>
</tr>
<tr>
<td>11</td>
<td>Shenhua coal-to-oil carbon-capture + storage integrated demonstration</td>
<td>The carbon-capture of high-carbon-containing waste gas from chemical plants + storage of salty water layer</td>
<td>Neimeng</td>
<td>100,000</td>
<td>2011</td>
</tr>
</tbody>
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## Technology of Coal-fired Power Generation

<table>
<thead>
<tr>
<th>Coal-fired proportion</th>
<th>Ultrasupercritical</th>
<th>Circulating fluidized bed</th>
<th>IGCC</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Features</td>
<td>Number of power stations of pure electricity generation that are on active service</td>
<td>Features</td>
</tr>
<tr>
<td>China</td>
<td>50%</td>
<td>59</td>
<td>1 under construction</td>
<td>The one with the fastest development, lacking of high-temperature material technology</td>
</tr>
<tr>
<td>The United States</td>
<td>90%</td>
<td>3</td>
<td>2</td>
<td>The earliest one to be developed, with the focus on ultra-supercritical</td>
</tr>
<tr>
<td>Japan</td>
<td>50%</td>
<td>27</td>
<td>1</td>
<td>Mature technology, with the focus on high-temperature material</td>
</tr>
<tr>
<td>German</td>
<td>80%</td>
<td>23</td>
<td>The only lignite ultra-supercritical</td>
<td>The first one in the world</td>
</tr>
<tr>
<td>Others</td>
<td>60%</td>
<td>9</td>
<td>2</td>
<td>French Alstom Company: 300MW/ supercritical 600 MW</td>
</tr>
</tbody>
</table>

At present, countries like China, EU, US and Japan are carrying out the research and development of ultra-supercritical unit that is above 700℃

Circulating fluidized bed electricity generation technology is developing towards the supercritical, the large-scale, multi-fuel combustion and oxygen enrichment combustion

Increasing the availability ratio, decreasing the investment cost and power generation cost are the main attack direction of the development of IGCC technology
## Technology of Coal Chemical Industry

<table>
<thead>
<tr>
<th></th>
<th>Proportion of coal conversion</th>
<th>Coal to liquid fuel</th>
<th>Coal gas</th>
<th>Coal to chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Direct liquefaction</td>
<td>MTG</td>
<td>Methyl alcohol</td>
</tr>
<tr>
<td>China</td>
<td>20%</td>
<td>1 set 1.08 million tons</td>
<td>3 sets 0.4 million tons</td>
<td>4 sets 15.1 billion cubic meters</td>
</tr>
<tr>
<td>The United States</td>
<td>Low</td>
<td></td>
<td></td>
<td>1 set 1.6 billion cubic meters</td>
</tr>
<tr>
<td>South Africa</td>
<td>High</td>
<td>3 sets 7.6 million tons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>——</td>
<td></td>
<td></td>
<td>1 set 0.5 million tons</td>
</tr>
</tbody>
</table>

In foreign countries, there are industrial experiments or demonstrations on various fields of coal conversion, and technological reserve on the industrialized technology is completed and in continuous development.

China takes the lead in realizing large-scale industrialization on the direct liquefaction and coal-to-olefin.

China has reached the world advanced level on the key processing like coal-to- liquid-fuel and coal-to-chemicals, catalyst, equipment and systematical technology, engineering technology, etc.
### Coal Poly-generation System

<table>
<thead>
<tr>
<th>Country</th>
<th>Poly-generation scientific plan and demonstration project</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Yankuang Group put forward the IGCC-based methyl-alcohol-electricity cogeneration system in 2003, which has been put into operation. Taiyuan University of Technology put forward &quot;dual gas resource&quot; poly-generation mode and has completed the pilot plant test. Zhejiang University put forward the coal grading conversion comprehensive utilization system with the pyrolysis and gasification of coal as the core.</td>
</tr>
<tr>
<td>The United States</td>
<td>“Vision 21” poly-generation system in 1998, the poly-generation “FutureGen” project at the beginning of 2003. From 1995, commercial demonstration factories of the liquid-phase reactor technology of methyl alcohol (LPMEOHTM) and the liquid-phase reactor technology of dimethyl ether (LPDME)</td>
</tr>
<tr>
<td>Holland</td>
<td>Shell Company put forward Syngas Park poly-generation system</td>
</tr>
<tr>
<td>Japan</td>
<td>In 1998, the EAGLE cogeneration plan was proposed.</td>
</tr>
</tbody>
</table>

**On the whole,** China poly-generation system has entered the early phrase of demonstration.

Innovate and optimize the coal-based poly-generation unit technology and extensive technology, carry out the demonstration of unit technology, and cultivate the coal chemical industry and poly-generation device manufacturing industry is the key direction of coal-based poly-generation system.
## The Capture, Utilization and Storage Technology of CO₂

<table>
<thead>
<tr>
<th></th>
<th>Emission amount (100 million tons)</th>
<th>CO₂ capture technology</th>
<th>CO₂ utilization technology</th>
<th>CO₂ storage technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>79</td>
<td>The difference is not big and 100,000-ton-per-year industrial demonstration has been carried out.</td>
<td>CO₂-displacing-oil experiment has been carried out CO₂-displacing-coalbed-methane single well experiment has been carried out CO₂ chemical industry and biological utilization technology are in the stage of research and development</td>
<td>Salty water layer storage demonstration with a scale of 100,000 t/a is carried out and the initial comment on the geological storage potential of CO₂ has been launched out</td>
</tr>
<tr>
<td>The United States</td>
<td>56</td>
<td>30MW oxygen enriched combustion device began to operate in 2007</td>
<td>The technology of displacement of reservoir oil by CO₂ is mature and gets wide application, CO₂ synthesizing degradable copolymeric plastics, CO₂ synthesizing carbonic ester chemicals, etc.</td>
<td>With years of the international project practice experience on storage the seabed salty water layer</td>
</tr>
<tr>
<td>Japan</td>
<td>12</td>
<td>IGCC tests the CO₂ capture system</td>
<td>Synthesizing methyl alcohol with CO₂, biological utilization of CO₂, etc.</td>
<td>--</td>
</tr>
</tbody>
</table>

**Viewed from the world scope,** CCUS technology has attracted much attention, but it is still in the stage of development and demonstration.  
**The key direction of CCUS technological development** is to develop large-scale low-energy, low-cost capture technology and storage technology that is safe in a long term.
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The Comparatively Large Difference between US and China on the Energy Consumption Structure

US energy consumption structure (2013)

- Oil: 37%
- Natural Gas: 30%
- Coal: 20%
- Nuclear Energy: 8%
- Hydroelectric: 3%
- Renewables: 2%

China energy consumption structure (2013)

- Oil: 18%
- Natural Gas: 5%
- Coal: 67%
- Nuclear Energy: 1%
- Hydroelectric: 7%
- Renewables: 2%

Data source: BP energy statistics yearbook 2014

- US and China are both leading coal country (US ascertained reserves rank NO.1, China NO.3).
- Different to the coal-dominant energy structure of China, coal ranks only NO.3 in US energy consumption structure.
- Technology of clean coal utilization has huge potential in the US future energy development.
Greenhouse Gas Emission Reduction as the Important Factor Used to Promote the Development of Clean Coal in the Future.

During the last 4 decades, the total amount of coal consumption in US hasn't changed much, and has slightly decreased in the recent years.

The total amount of China coal consumption increased rapidly in the last 10 years.

The changing curve of CO2 emission and coal consumption amount of the two countries are basically similar, which indicates that CO2 emission has great relation with the coal consumption amount.

Under the current pressure of greenhouse gas emissions reduction, China and US must develop clean and low-carbon coal development and utilization technology in order to increase coal consumption amount.
Developing Clean Coal Technology as an Important Approach to Realize the "Energy Independence" of China and US

It needs to give sufficient attention to coal in the fairly long period of the future to truly realize the "energy independence" of China and US.

Important fields and development suggestions for Chinese and American technological development of clean coal.

- Advanced coal-fired power generation technology: ultra-supercritical electricity generation, ultra-temperature electricity generation, ultra-clean coal-fired electricity generation, etc.
- Modern coal chemical industry technology: coal to clean fluid, gas fuel, coal to olefin, etc.
- Advanced environmental protection technology: desulfurization technology, denitrification technology, technology of removing heavy metal, etc.
Thank you