WP2 – Future Energy Technology Perspectives

2.2 Coal Technology Assessment

Ma Linwei

Tsinghua-BP Clean Energy Research & Education Center,

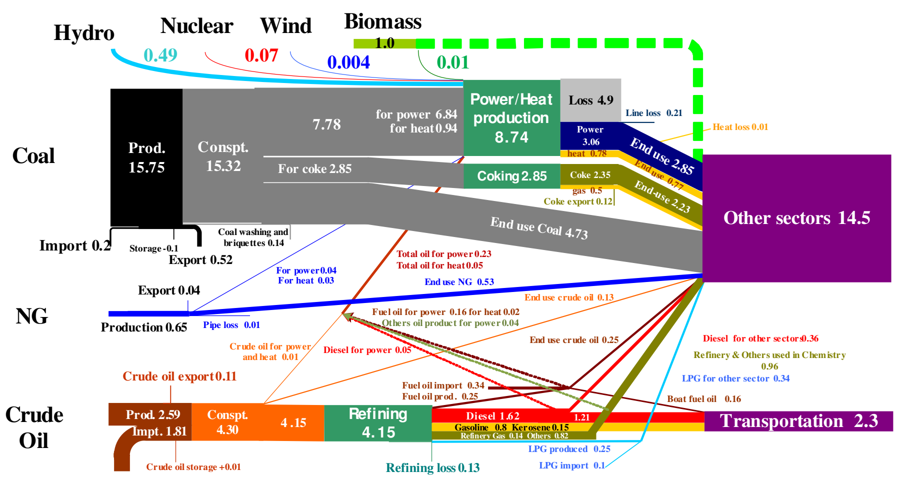
Tsinghua University, Beijing 100084, China

1 Overview of coal-based Energy Conversion Technologies in China

Coal is the dominant primary energy in China and very likely to continue to dominate in the near future. Figure 1 shows China's energy flowchart based on calorific value in 2005, which illustrates coal was the main primary energy, the major energy resource for power generation and the main end-use fuel for non-transportation sectors. As a cheap, abundant energy resource with an established infrastructure, coal remains the main option for satisfying the rapidly increasing energy demand seen in China in recent years. However, the continuous and large-scale use of coal has put significant pressure on China's ambitions for environmental protection, worker safety and GHG mitigation in particular in the form of CO_2 emissions.

From 2005 to 2008, the total coal consumption increased from 2.17 billion tonnes to 2.74 billion tonnes (a 26% increase), and the fraction of coal in total primary energy consumption kept about 70%.

Figure 1 Energy flowchart of China in 2005



Unit: 100 million tce
Data source: Statistics Yearbook of China Energy 2006

Coal use in China can be classified into three kinds of technical method:
1) Coal power generation;
2) Distributed coal combustion, mainly are domestic and industry boilers;
3) Coal chemical production, such as coking, gasification and liquefaction.

As shown in Figure 2 and Figure 3, from 1985-2007, the fraction of coal for power generation and chemical production increased dramatically while the distributed coal combustion (final consumption plus heating) keep relatively stable. In 2007, the distribution of coal use was 50% for power generation, 31% for distributed boilers and 17% for chemical production.

Figure 2 Coal consumption in China from 1985 to 2007

(Source: China Energy Statistical Yearbook 2008)

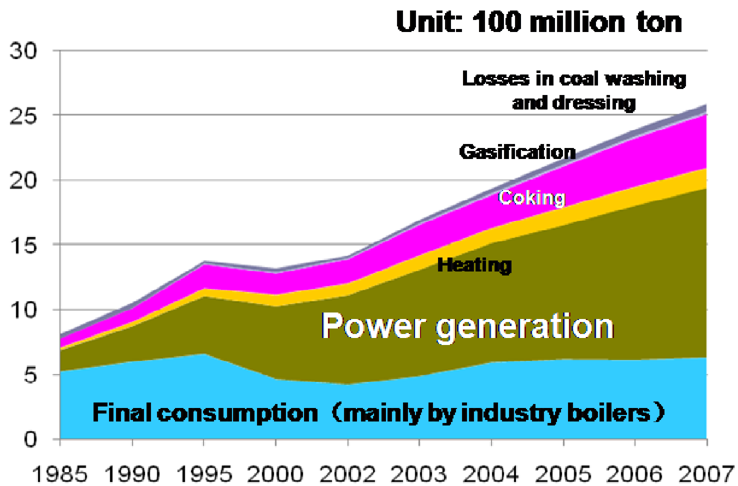
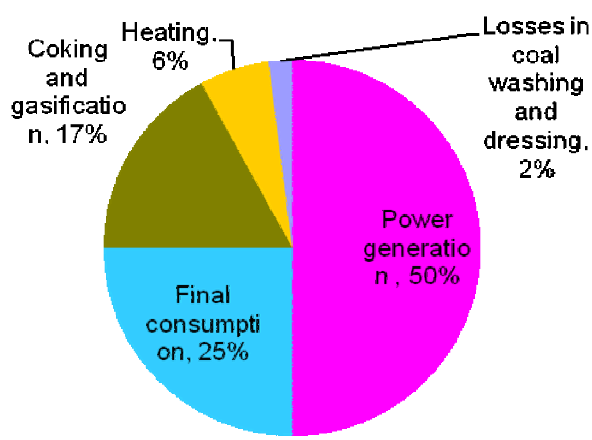


Figure 3 Coal utilization in 2007 (physical coal)

(Source: China Energy Statistical Yearbook 2008)



As this study is mainly focused on incremental coal energy conversion technologies, the research scope only includes coal power generation, coal gasification and coal liquefaction. Coking and distributed coal combustion is excluded because the former is non-energy conversion (coke is used in steel industry as material) and the latter seems not to be an incremental coal use.

2 Coal power generation technologies

4.4 Total installed power capacity

Coal power has contributed 90-96% of electricity generation in total thermal power generation (coal power, oil power and natural gas power) in recent years. The statistics of thermal power capacity are therefore a good candidate for the study of coal power capacity. The total installed power capacity and annual electricity generation of thermal power is listed in Table 1.

In recent years, the total power capacity and electricity generation is increasing rapidly but the proportion of thermal power in total power generation in China begins to decrease after 2006. In 2008, the total installed thermal power capacity is 601.3 GW and the total electricity generation is 2779.3 TWh, which contributes 77.8% and 81% in total power generation of China.

Table 1 Installed capacity and electricity generation of thermal power in China (2003-2008)

Items	Year	2003	2004	2005	2006	2007	2008
Power capacity	Thermal power (GW)	289.8	329.5	391.4	484.1	554.4	601.3
	Proportion in total capacity (%)	74	74.5	75.7	77.8	77.7	75.9
	New added thermal power(GW)	24.2	39.7	61.9	92.7	70.4	46.9
	Increased ratio (%)	9.12	77.7	18.8	23.0	14.5	8.15
Electricity generation	Thermal power(TWh)	1579	1807.3	2018	2357.3	2698	2779.3
	Proportion in total electricity generation (%)	82.9	82.6	81.5	83.2	82.9	81

(Source: Electric Reliability Indicators released 2008. State Electricity Regulatory Commission of P.R China, China Electricity Council, 2008)

4.5 Unit Scale Distribution and Power Efficiency

Coal power supply efficiency (normally expressed as coal equivalent consumption per kWh supplied to power grid) is closely related to unit scale. Lager units tend to have higher efficiencies because the technology is more advanced and energy loss will become lower as unit size increased. Table 2 shows the coal consumption of power supply for various unit sizes.

Table 2 Coal consumption of power supply vs. unit size in China in 2006

Unit Size MW	**Coal consumption of power supply ce/kWh**
6	600
12	550
25	500
50	440
100	410
300	340
600	299
600	292
1000	285.6

Source: Asian Development Bank (ADB)

So the main way to increase power efficiency has been to increase the number of larger units overall while decreasing the number of smaller units. This approach has been supported by the Chinese government, which encourages the deployment of larger scale and more efficient plants while shutting down smaller scale and less efficient ones.

Government Policy I

The “Decision for enhancing energy saving by State Council” (State Council [2006], No.28) forces the following power units burning coal/oil and within big power grid to shut down during the period 2006-2010:

- Conventional power unit scale smaller than 50MW;
- Conventional power unit scale smaller than 100MW older than 20 years;
- All kinds of power units smaller than 200MW and older than it’s official life time;
- Coal power units with coal consumption per kWh 10% higher than province or city average level, or 15% higher than national average level;
- All kinds of units, which cannot meet the national environmental emission standard;
- Other power units are to be shut down with reference to corresponding laws, regulations and policies given out by other departments of the State Council.

Figure 4 illustrates the transition from smaller scale units to larger scale units for the years from 2003 to 2007. As calculated, in 2004-2007, power medium scale units (i.e. units larger than 300MW and smaller than 599MW) took 36.7% and large-scale units (i.e. units larger than 600MW) take 53.5% of the newly installed coal power capacity. In 2007, a total capacity of 12GW was shut down, which is illustrated on a map of China in Figure 5 (data modified referring to Statistical Report of China Power Industry in 2009).

Figure 4: Unit scale distribution of thermal power capacity in China from 2003-2007

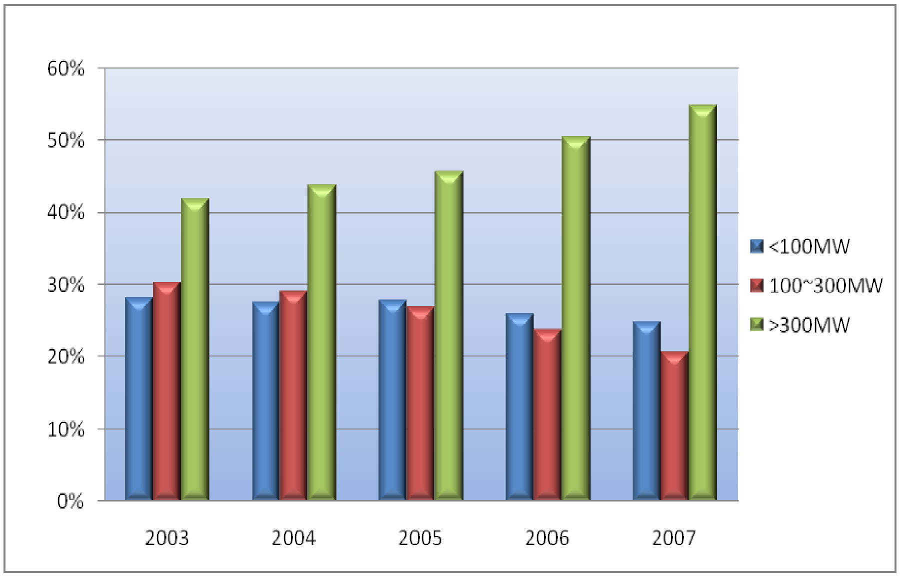
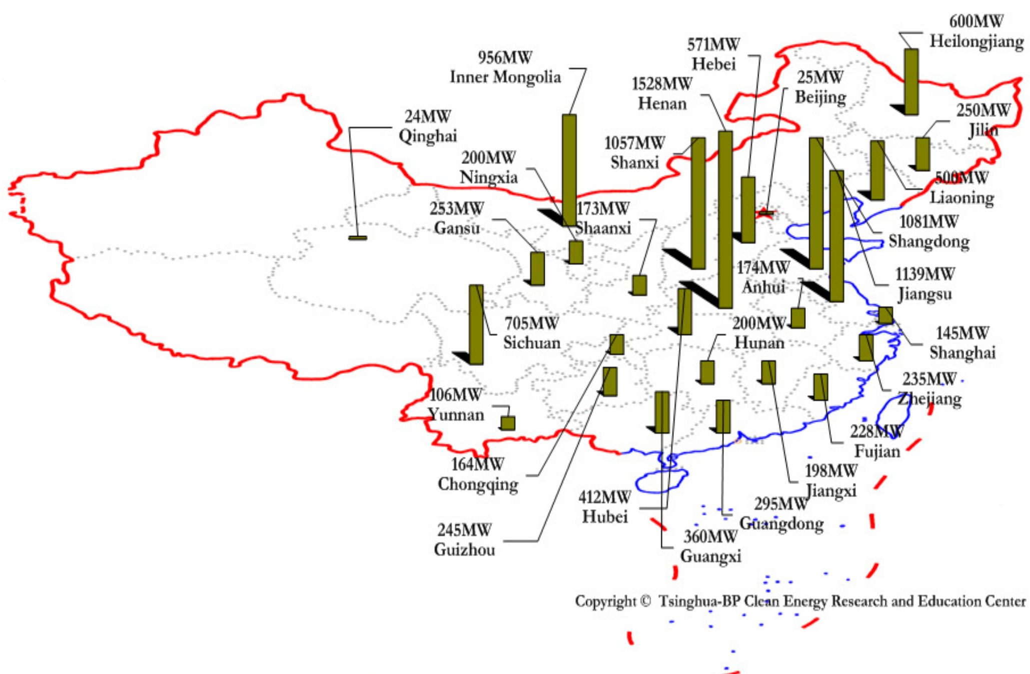
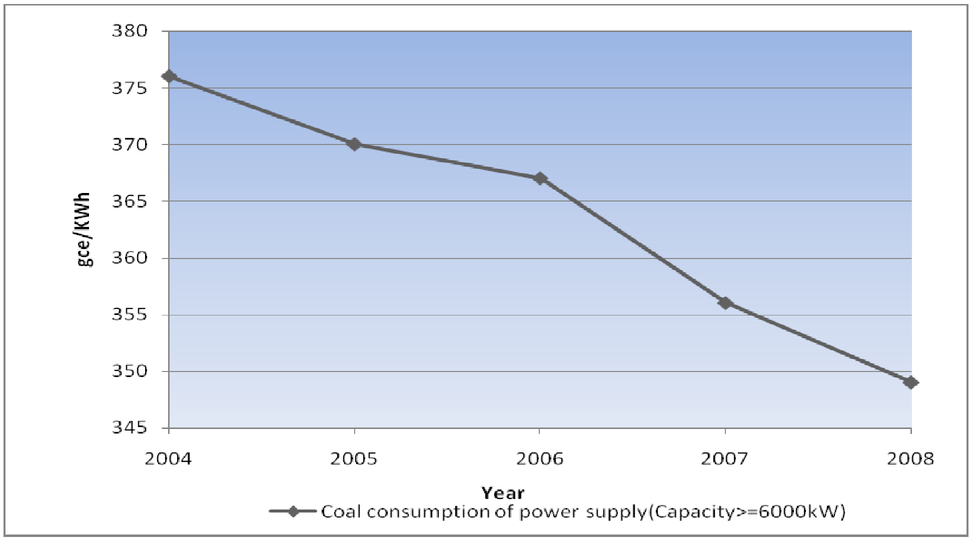


Figure 5 Regional distribution of shut down power capacity in 2007



The thermal power supply efficiency in China has continuously improved in recent years. Figure 6 shows coal consumption of power supply of China thermal power from 2004 to 2008.

Figure 6 Coal consumption of thermal power supply from 2004 to 2008 (only calculates unit size larger than 6MW)

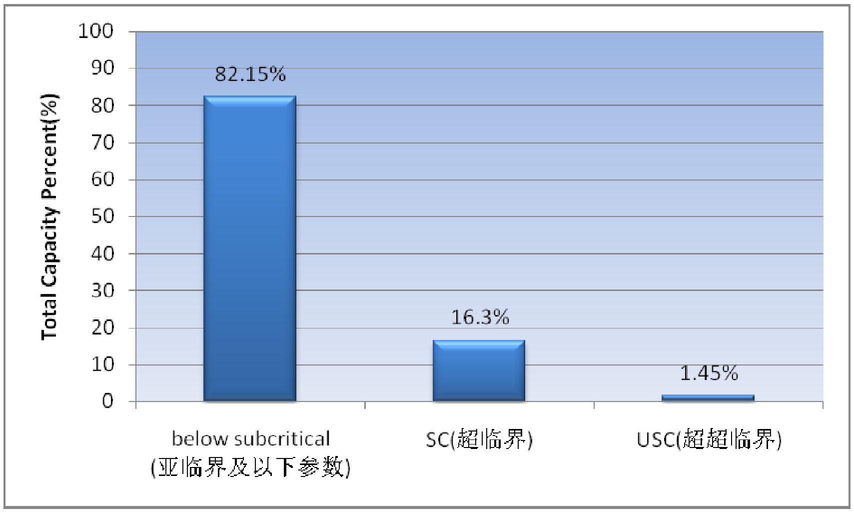


Source: China Electricity Council, the National Electricity Industry Statistics Express (2003-2008). 2009

4.6 Super-Critical (SC) and Ultra-Super-Critical (USC) Technologies

After 2003, the Chinese power sector introduced Super-Critical (SC) and Ultra-Super-critical (USC) coal combustion technology to optimize the unit scale distribution, improve efficiency and lower emissions. Now China has built the capacity to design, construct and operate 600MW SC, and the capacity to construct and operate 1000MW USC. Though below subcritical technology is still dominant in the total power capacity, SC and USC has become the main fleet of newly installed power capacity. Figure 7 shows the technology capacity distribution of total thermal power capacity in China in 2007. Below subcritical technology makes up 82.15%, SC 16.3% and USC only 1.45% of total thermal power capacity. But up to the end of 2007, there are totally 120 SC/USC units installed, 100 SC/USC units in construction and 90 SC/USC units ordered. And in total at end of 2008, over 300GWe of SC/USC units have been either installed, under construction or are at design stage. The impact of advanced technologies is growing rapidly each year. Figure 8 and Figure 9 show the regional distribution of SC and USC units in China in 2007.

Figure 7 Technology distribution of thermal power capacity in 2007 in China



Source: China Electricity Council, China Electricity Market Association

Figure 8: Regional distribution of SC unit in China in 2007

Province	Total Capacity (MW)	No. of Units X Capacity (MW)
Tianjin	1000	2x500
Shanxi	1200	2x600
Inner Mongolia	1000	2x500
Liaoning	2240	2x800+2x320
Heilongjiang	1200	2x600
Shanghai	3000	2x900+2x600
Jiangsu	4370	2x650+1x630+3x600+2x320
Zhejiang	1800	3x600
Anhui	2400	4x600
Fujian	6000	10x600
Shandong	670	1x670
Henan	4200	7x600
Hubei	1200	2x600
Hunan	2400	4x600
Guangdong	4200	7x600
Guangxi	1800	3x600

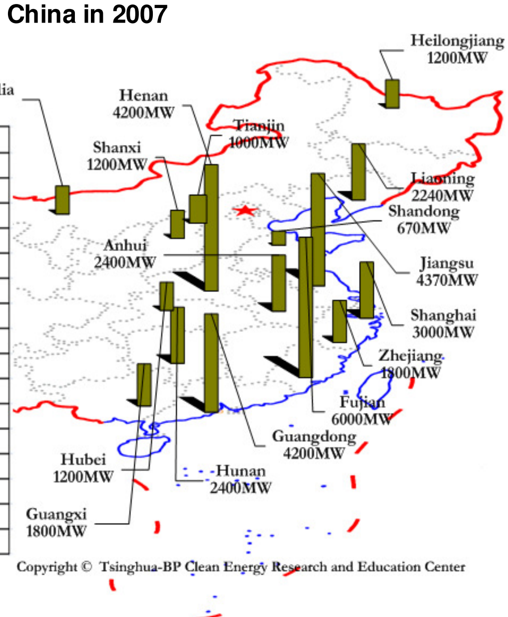
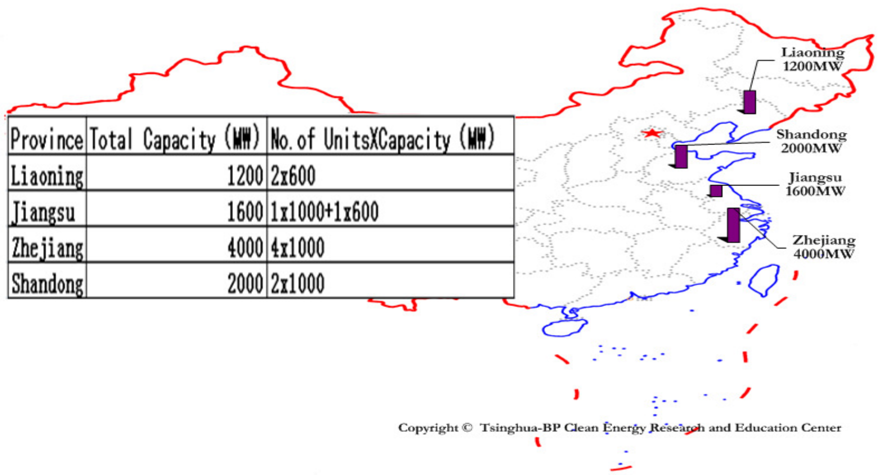


Figure 9: Regional distribution of USC unit in China in 2007



Province	Total Capacity (MW)	No. of UnitsXCapacity (MW)
Liaoning	1200	2x600
Jiangsu	1600	1x1000+1x600
Zhejiang	4000	4x1000
Shandong	2000	2x1000

According to national industry policy, 600MW SC and 1000MW USC units will become the standard in the coming years. On average, the coal consumption per kWh of a 1000MW USC unit is 10 gce lower than 600MW SC unit while the thermal efficiency is 4% higher. For example, the newly built four 1000MW USC units at Yuhuan power plant[1] has a 283.2 gce/kWh coal consumption rate and over 45% thermal efficiency.

Government Policy II

Following the policy of the National Development and Reform Commission (NDRC) newly built coal power units larger than 600MW shall all reach the efficiency level of USC.

In addition to USC and SC technologies Circulating Fluidized Bed Combustion technology (CFBC) is an important supplementing technology, which has the ability to remove sulfur at low cost while burning on a low-grade fuel. The development of CFBC technology in China is now the most advanced in the world. Up to 2007, there are totally 2,641 CFBC boilers installed, including 8 power units at 300MW scale. And now there are attempts to build a 600MW CFBC plant incorporating super critical steam conditions. This would be the world's largest of its kind and with a power efficiency expected to be 43%. In Shichuan province, a demonstration project of 600MW CFBC has entered the final stage of project designing and started the early construction at Baima power plant which has already built a 300MW CFBC unit. Table 3 shows some further information about the development of SC, USC and CFBC in China.

[1] Owned by Huaneng Power Company

Table 3 The development of SC, USC and CFBC technologies in China

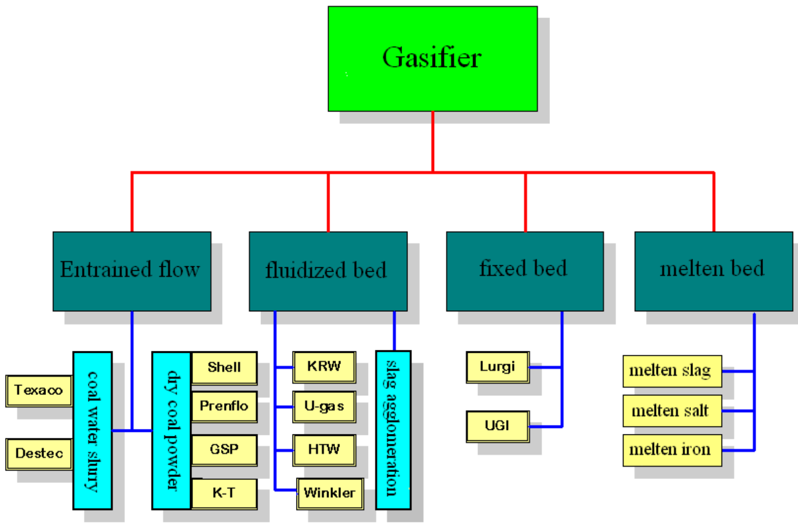
SC and USC	Up to 2007, 120 units have been built, 100 600MW SC units are in construction and 90 units are ordered. 8 1000MW USC units have been built and 50 units are ordered.
CFBC	For 35-75t/h scale, more than 500 units are in operation; 20 units for 130t/h scale; 2 for 240t/h and 2 for 410t/h, 23 for 150MW CFBC. Up to Aug. 2007, 8 300MW CFB has been built.

Source: 1) Wang Dazhong. China Energy Science and Technology Perspective in 21 Century. Tsinghua University Press, 2007.11; 2) Wang Qingyi. 2008 China Energy Statistics.

3 Coal Gasification Technologies

Coal Gasification Technologies ("gasifiers") fall into four major categories as illustrated in Figure 10.

Figure 10: Categories of main gasification technologies



- Entrained flow gasifiers
    - Coal water slurry: GE/Texaco gasifier for example
    - Dry coal powder: Shell gasifier and SIEMENS/GSP gasifier for example
- Fluidized bed gasifiers, KRW gasifier and U-gas gasifier for example
- Moving bed gasifiers, Lurgi gasifer for example
- Molten bed gasifiers

Entrained flow coal gasification technology has become the most promising technology while other kinds of gasification technologies develop only slowly. Fixed bed coal gasification technology is still the major existing technology in the coal chemical industry in China but it is becoming a comparably backward technology. This study mainly focuses on the current deployment of some existing coal gasification technologies in China. It includes technologies developed outside and inside of China as shown in Table 4.

Table 4: Gasification technologies considered

Technologies Developed Outside China
Shell gasifier (in operation)
GE/Texaco gasifier (in operation)
SIEMENS/GSP gasifier (under construction[2])
Technologies Developed in China
Ash agglomerating fluidized bed coal gasification technology (in operation)
Two-stage entrained flow gasification technology (in operation)
Two-stage Dry Feed Entrained Flow Gasification Technology (under construction)
Coal Water Slurry (CWS) gasification with opposed multi-burner technology (in operation)

4.1 Technologies Developed Outside China

Shell gasifiers

The Shell gasifier technology is built on the Koppers-Topzek (K-T) gasifier, which was originally designed as a cooperative project between Shell and Koppers. Shell later developed the Shell gasifier independently of Koppers. China has deployed a number of 1000t/d and 2000t/d sized Shell gasification devices while others will soon be in trial operation. Table 5 documents some recent installations of Shell gasifiers in China. As of now Shell has some 19 licenses issued in China.

Table 5: Recent installations of Shell gasifiers in China

Developer	Location	Feedstock input (t/d)	Product	Completed
Shuang'huan Chemistry	Hubei Yingcheng	900	ammonia	2004
Liuzhou Chemical Industry	Guangxi Liuzhou	1200	fertilizer	2005
Kaixiang Chemical Industry Corporation	Henan	2000	methanol	2004
CNPC-Shell	Hunan Yueyang	2000	ammonia	2005
CNPC	Hubei Zhijiang	2000	ammonia	2005
CNPC	Anhui Anqing	2000	ammonia	2005
Dahua Group	Liaoning Dalian	1100	methanol	2004
Yuntianhua Group	Yunnan Anning	2700	ammonia	2006
Yunzhanhua Group	Yunnan Qujing	2100	ammonia	2006
Shenhua Group	Inner Mongolia	2×2200	H_2	2004
Zhongyuan Dahua Group	Henan Puyang	1800	methanol	
Yongcheng Coal Power Group	Henan Yongcheng	2100	methanol	2004

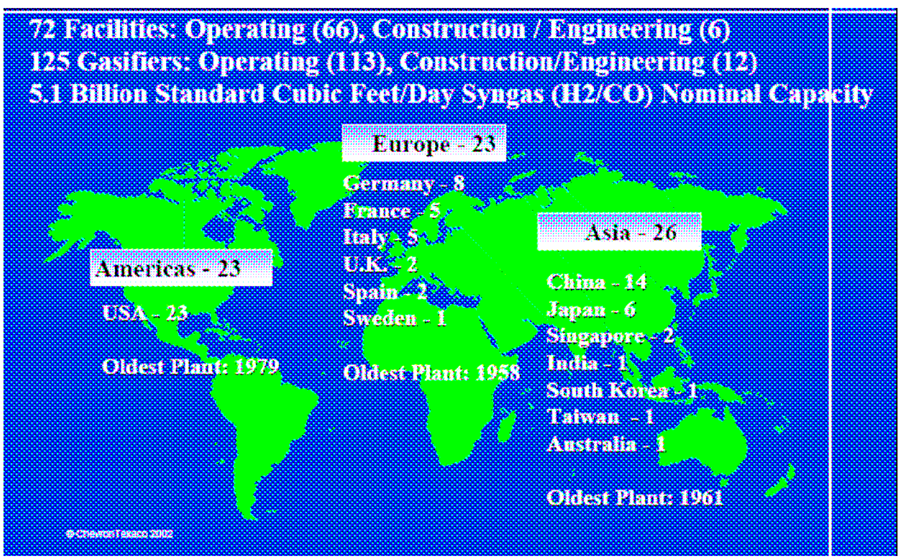
[2] The first units (7 @500MW) of this technology are under construction/being installed

Tianjin Huan'Bo'Hai Chemical Industry Corporation	Tianjin	2×2200	ammonia &methanol	2006
Datang International Power Corporation	Inner Mongolia Xi'Lin'Hao'Te	3×4000	methanol	2005
Tianfu Chemical Industry Corporation	Guizhou Fuquan	2000	ammonia &methanol	2008
Hebi Coal Power Coeporation	Henan Hebi	2700	methanol	2007

GE/Texaco gasifiers

The GE/Texaco gasifier is a mature second-generation entrained flow type gasifier, which is developed by Texaco Development Corporation of Texaco Petroleum Corporation, now owned by GE. Figure 11 shows the global location of GE/Texaco gasifiers either under operation or under construction, and the actual number should be much more than that. In fact, latest figures suggest GE have sold around 33 licenses in China.

Figure 11: Application of GE/Texaco Gasifiers and their locations



SIEMENS/GSP gasifier

The SIEMENS/GSP gasifier technology is a medium to large sized gasification technology developed in former East Germany during the 1970s. Today several gasifiers have been or will be installed in China, as listed below:

- The Ningmei Group is currently installing five 500MW gasifiers for its coal to olefin project in Ningxia Autoministration Region. Two have been completed manufacturing while three are under construction;
- In January 2008 the Lanhua Group of Shanxi Province signed a contract to apply two gasifiers;
- The Linggu Chemical Industry Corporation of Jiangsu Province currently installs the

gasification technology for its 300,000t/a ammonia synthesizing project;

- The Huaihua Group of Anhui Group completed a primary technology review for the installation of the gasification technology for its 300,000t/a ammonia synthesizing project;

4.2 Technologies Developed in China

Ash agglomerating fluidized bed coal gasification technology

The ash agglomerating fluidized bed coal gasification technology was developed by the Institute of Coal Chemistry and China Academy of Science (ICCCAS), and owned by ICCCAS and the Shanxi Qinneng Tianji S&T Stock Corporation. Installed projects are listed as follows as well as in Table 6:

- The Shanxi Qinjin Coal Gasification Engineering Facility Corporation cooperated with the Shanxi Chenggu Fertilizer Corporation in setting up a demonstration ammonia synthesizing facility (with a feedstock input of 100t/d), which was put into commercial operation in 2002;
- In 2005 the Shandong Feicheng A'si'de Chemical Industry Corporation used this technology for its aim to use local low-quality coal to replace the expensive anthracite of Shanxi.

Table 6: Installed ash agglomerating fluidized bed coal gasification technologies in China

Developer	Pressure (Mpa)	Products	Number of Gasifiers	Sign date	Status
Tianjin Alkali Industry	0.05	Ammonia	2	June 2003	Commercial
Tianji Luhua	0.08	Methanol	2	October 2004	Commercial
Taihua Group	0.06	Ammonia	1	December 2004	Commercial
Fengxi Group	1	Ammonia	1	Apr-05	Demonstration
Yulin Coal Chemistry S&T	1	Methanol	1	May 2005	Commercial

Two-Stage Entrained Flow Gasification Technology

The two-stage entrained flow gasification technology was developed by the Department of Thermal Engineering at Tsinghua University.

In 2003 the Shanxi Fengxi Fertilizer Group set up two industrial producing facilities using the technology with a feedstock input for each facility of 500t/d;

Two-Stage Dry Feed Entrained Flow Gasification Technology

This technology was originally developed by Xi'an Thermal Power Research Institute (TPRI). Together with a waste-heat boiler a gasifier with a 2000t/d throughput will be applied to the Green Coal-Electric ("GreenGen") Project, which is currently set up by the Huaneng Group in

2009. Figure 12 shows a model of the project. Prior to GreenGen the largest demonstration of this technology was a 36-40 t/d pilot built in 2004.

Figure 12: GreenGen Demonstration Project Plan of Huanneg Group

Coal Water Slurry (CWS) gasification with opposed multi-burner technology

The CWS gasification with opposed multi-burner technology was developed by the East China University of Science and Technology. ECUST has deployed this technology in a number of projects, as listed as Table 7.

Table 7: Engineering activities of the opposed multi-burners gasifier by ECUST[3]

Developer	Number of Gasifiers	Pressure (M/a)	Feedstock (t/d)	Product	Completed
Yankuang Guotai	2	4	1150	methanol/ power	2005
Hualu Hengsheng	1	6.5	750	ammonia	2005
Yankuang Guotai	1	4	1150	methanol	2007
Yankuang Luhua	1	4	1150	ammonia	2007
Tengzhou Fenghuang	3	6.5	1150	ammonia/ methanol	2008
Jiangsu Linggu	2	4	1800	ammonia	2009
Jiangsu Suopu	3	6.5	1500	methanol /acetic acid	2009
Shenhua Ningmei	3	4	1900	DME	2009

[3] http://icct.ecust.edu.cn/list.php?id=42&newsid=158

Ningbo Wanhua	3	6.5	1000	methanol/ ammonia/ CO, etc.	2010
Huadian Banshan	1	4	2000	IGCC	2010
Shandong Jiutai	6	6.5	2000	methanol	2010
Anhui Huayi	3	6.5	1500	methanol	2010

4.3 Integrated Gasification Combined Cycle (IGCC) and Poly-Generation (PG)

- Coal gasification technologies can also be applied to Integrated Coal Gasification Combined Cycle (IGCC) plants to generate power as well as to poly-generation plants based on coal gasification. In China there were more than 10 IGCC and poly-generation projects planned in 2007. However up to now, no IGCC plant has been built and as of July 2009, only GreenGen's IGCC project (in Tianjin) has got NDRC's approval to go ahead. The planning period for this 250MW demonstration plant was scheduled from 2006 to 2009 and included a dry-coal-powder compression gasification system (with a feedstock capable of 2000 tonnes/day), a syngas purification device and a low-heating value gas turbine. As for a second stage it was planned to improve the IGCC poly-generation technology to evaluate the technical and economic aspects of a gasifier capable of using a feedstock of 3,500 tonnes per day (or, alternatively, 2×2,000 tonnes per day) for the operation of a 400 MW IGCC power plant.

4 Coal Liquefaction Technologies

The main sub-divisions of coal liquefaction include:

- Direct coal to liquids (DCL),
- Indirect coal to liquids (ICL)
- Coal to Methanol (CM)
- Coal to Dimethyl Ether (CDME)

It should be mentioned methanol and DME are traditionally used as chemicals but in recent years much attention has been put to use then as liquid fuel for domestic or transportation sectors.

4.1 Direct Coal to Liquids (DCL)

Data from ASIACHEM indicate that Direct Coal to Liquid (DCL) is the most efficient method of coal liquefaction developed to date. The technology is able to achieve a liquid yield rate of over 70% (based on waterless and ashless coal) and a total thermal efficiency at 60%-70% can be obtained.[4] But it is also the most difficult technology for coal liquefaction. Shenhua completed the construction of the first direct coal liquefaction (DCL) train for the SH-1 plant in Erdos, Inner Mongolia. This, the world's first commercial DCL facility, began operation in December 2008 after four years of construction.

- It will use 7,000 t/d of sub-bituminous coal. The $1.5 billion line will produce 1.08 million tonnes per year (t/y) of mostly diesel from 3.45 million t/y of coal.
- The coal liquefaction reactor in the project was fabricated by China First Heavy Industries.
- The hydrogen unit, using Shell gasification technology, consists of two series with identical design capacity of 313t/d hydrogen output.
- Shenhua DCL project uses #863 high efficiency catalyst in the liquefaction process, which is of Chinese intellectual property right developed by the Coal Science Academy Beijing Coal Chemistry Branch. Key features of the catalyst include high activity, sufficient raw material availability, lower production costs and easy preparation relative to existing catalysts.

4.2 Indirect Coal to Liquids (ICL)

The earliest example of Indirect Coal to Liquids (ICL) technology was developed by the Coal Chemistry China Academy of Science (ICCCAS). Since then, three organizations that have successfully developed their own FT synthesizing technology for ICL: the Institute of Coal Chemistry of CAS, the Shenhua Group and the Yankuang Group. As a whole, the ICL technologies are still in development. But in recent years, there are lots of ICL projects

[4] The Zeus Library, 2009, http://www.zeuslibrary.com/vel/Gasification/China/180CG/01PO.asp, The Free Library, 2008, http://www.thefreelibrary.com/Shenhua+inaugurates+production+of+DCL+project.-a0192639229

announced or planned in China. While seldom do projects actually go ahead, some of them have made progress recently. These projects are as follows.

Mobil Two-Stage Fischer-Tropsch (MFT) technology by ICCCAS[5]

1. The Shanxi Lu'an Mining Group started to construct a 160,000t/a size industrial demonstration Fischer-Tropsch (FT) synthesizing device with iron base catalyst in Changye, which is also the first oil-power polygeneration device. Lu'an Mining Group reported they have successfully tested the plant and produced qualified oil product in December 2008 and July 2009.[6]

Two section Fischer-Tropsch (FT) synthesizing technology by Shenhua Group

While not yet in operation various initiatives have recently been undertaken to push it towards commercialization.

- The Shenhua Group plans to apply the FT synthesizing technology (developed by Sasol, South Africa) to construct coal indirect conversion device in Shanxi and Ningixa. The expected total output of this device is 80,000 barrels oil products per year. This is progressing with a major FEED study underway.
- In 2006 the Institute of Coal Chemistry (in cooperation with Inner Mongolia Yitai Group) founded Zhongke Synthetic Oil Co. with the aim to develop projects. At the end of 2008, a 160,000 t/d ICL demo plant was built in Ordos, and a test was run in March 2009 and qualified oil product was successfully produced [7].

4.3 Coal to Methanol (CM)[8]

Methanol can be used as alternative liquid fuel to oil and as a feedstock for DME plants and methanol-to-ethylene or methanol-to-propylene (MTO/MTP) plants. In 2007, the total consumption of methanol in China was about 10 million tonnes with about 65% of it produced by coal. Table 8 shows the main methanol manufacturers in China and their production capacities (up to September 2006, the ones with an output over 70,000t/a).

Currently, of the raw materials required for methanol production in China, petroleum accounts for 55.2%, coal 30.0% and natural gas 14.8%. Since China has a lack of oil and gas but rich in coal, the country will be focusing on coal to produce methanol for a long period of time in the future.

Table 8: List of the main methanol manufacturers in China and their outputs

No.	Area	Company name	Output (10 kt/y)	Feeding

[5] Asia Times, 2006, http://www.atimes.com/atimes/China_Business/HL21Cb01.html
[6] http://www.cnluan.com/mjhcy/ShowArticle.asp?ArticleID=7558l; China Energy, Jan 2009, v31(1): p45
[7] http://www.synfuelschina.com/news/a23.html
[8] Market Avenue, 2008, http://www.marketavenue.cn/upload/ChinaMarketReports/REPORTS_1010.htm

1	Central China	Henan Lantian Group	85	Natural gas, coal
2	Southwest	Sichuan Lutianhua (Group) Corporation	45	Natural gas
3	Northwest	Yulin Natural Gas Chemical Industry Corporation	43	Natural gas
4	South west	Sichuan Vinylon Factory of SINOPEC	35	Natural gas
5	East China	Shanghai Jiaohua Corporation	35	Coal
6	Central China	Henan Junma Group	30	Coal
7	Central China	Shandong Hualu Hengsheng Group Corporation	27	Coal
8	Central China	Shandong Guotai Chemical Industry Corporation of Yankuang Group	24	Coal
9	Central China	Shandong Jiutai Chemical Industry S&T Corporation	22	Coal
10	Northwest	Shanxi Shenmu Chemical Industry Corporation	20	Coal
11	Central China	Shandong Deqilong Chemical Industry Corporation	20	Coal
12	North China	Inner Mongolia Tianye Group	20	Natural gas
13	North China	Hebei Qian'an Fertilizer Factory	20	Coal
14	Northeast	Methanol Factory of Daqing Oil Field	20	Natural gas
15	North China	Sulige Natural Gas Chemical Industry Corporation of Inner Mongolia Group	18	Natural gas
16	Northeast	Harbin Gasification Factory	16	Coal
17	Southwest	Sichuan Jiangyou Methanol Factory of CNPC	15	Natural gas
18	East China	Lunan Ferlizer Factory of Shandong Yankuang Group	15	Coal
19	East China	Shandong Shouguang Union Chemical Industry Group Corporation	15	Coal
20	North China	Hebei Zhengyuan Group	15	Coal
21	Central China	Yima Gasification Factory of Henan Coal Gasification (Group) Corporation	14	Coal
22	North China	Shanxi Fengxi Group	12	Coal
23	Central China	Henan Zhongyuan Chemical Industry Stock Corporation (Puyang Methanol Factory)	12	Natural gas
24	Central China	Hunna Zhicheng Chemical Industry Corporation	11	Coal
25	East China	Ammonia Factory of Zhejiang Juhua Stock Corporation	10	Coal
26	Southwest	Yunnan Zhanyi Fertilizer Factory	10	Coal
27	North China	Shanxi Yuanping Zhongtong Chemical Industry Corporation	10	Coal
28	North China	Shanxi Danfeng Chemical Industry Corporation	10	Coal
29	Northwest	Germu Oil Refinery Factory of CNPC	12	Natural gas
30	East China	The Second Fertilizer Factory of Qilu Petroleum Chemistry Corporation	10	Coal
31	Central China	Hubei Yihua Group	10	Coal
32	North China	Hebei Jiantao Xingtai Jiaohua Corporation	10	Coal
33	Northwest	Methanol Factory of Changqing Oil field	10	Natural gas
34	Northwest	Xinjiang Luntai Bazhou Dongchen Methanol Factory	9	Natural gas
35	Northwest	Tuha Methanol Factory of CNPC	8	Natural gas

36	North China	Xinle Xinhua Stock Corporation	8	Coal
37	Central China	Hubei Baike Medicine Stock Corporation	8	Coal
38	Central China	Henan Weishi Chemical Industry Factory	8	Coal
39	East China	Anhui Linquan Chemical Industry Stock Corporation	8	Coal
40	East China	Anhui Sanxing Chemical Industry Group Corporation	8	Coal
41	East China	Anhui Haoyuan Chemical Industry Corporation	8	Coal
42	Northwest	Liujiaxia Fertilizer Factory	7	Coal
43	Central China	Henan Xinxiang Aluminum Factory	7	Coal
44	Central China	Henan Qixian Chemical Industry Factory	7	Coal

4.4 Dimethyl Ether (DME) Synthesizing

Today, DME is primarily produced by the gasification of coal or natural gas via syngas, followed by methanol dehydration. Usually a two-step process (indirect synthesis) the process starts with methanol synthesis and ends with DME synthesis. Alternatively, DME can be produced through direct synthesis, a procedure that, by eliminating the intermediate methanol synthesis stage, offers efficiency advantages and cost benefits.

For the past few years, the total output of DME in China has been increasing rapidly while a number of large size industrialization projects are planned. It is estimated that DME produced by methanol was about 0.6 million tonnes in 2006. Table 9 shows the large size DME producing corporations that are in operation or in construction and their projected outputs.

Table 9: New large-scale DME producing corporations in operation in China after 2008

Corporation	Location	Output/t/a	Construction start-up time (Operation start-up time)
Yuannan Coal Chemistry Corporation	Yunnan	150,000	Late 2007 (Operated in Jan 2009)
Shanxi Lanhua Clean Energy Corporation	Shanxin	100,000	Late 2007(Operated in Aug. 2008)
Jiutai Energy (Inner Mongolia) Corporation	Erdos, Inner Mongolia	100,000 (1,000,000 methanol)	Late 2007 (Still in construction)
Tianmao Group	Jingmen Hubei	200,000	(Operated in June 2008,total plant capacity is 300,000)
Yongmei Group	Henan	200,000	(Operated in Dec 2008)

Besides the projects listed above, which are led by the National Development and Reform Commission (NDRC), a consortium of companies (including the China Zhongmei Energy Group, CINOPEC, Shenneng Group, China Yintai Investment Corporation and Inner Mongolia Manshi Coal Industry Corporation) will set up the Zhongtian Hechuang Energy Corporation together, which will build large size projects including coal mining, chemical industry, power generation and transportation infrastructure. The estimated production output of this operation is 20million t/a of coal feedstock, 4.2million t/a methanol and 3million t/a DME.

5 Summary

China has entered a phase of rapid expansion of power capacity while coal combustion has been the dominant technology deployed. The main way to increase power efficiency has been to develop larger scale and more efficient plants while shutting down smaller scale and less efficient ones. To further increase power efficiency the Chinese power sector has started to deploy Ultra-Super-critical (USC) and Super-Critical (SC) coal combustion technologies, and is the world leader in the use of cleaner coal power generation technologies.

Alongside coal combustion technologies, coal gasification and liquefaction technologies have also gained significance for large-scale non-power applications.

Different Coal Gasification Technologies ("gasifiers") being tested or put into operation in China include:

- Entrained flow gasifiers
- Fluidized bed gasifiers
- Moving bed gasifiers

The entrained flow coal gasification technologies have become the most promising technology while other kinds of technologies develop only slowly. Fixed bed coal gasification technologies are still the major existing technology in the coal chemical industry but they are becoming a comparably backward technology. Coal gasification technologies can also be applied to Integrated Coal Gasification Combined Cycle (IGCC) plants to generate power as well as to poly-generation plants based on coal gasification. In China there were more than 10 IGCC and poly-generation projects were planned in 2007. But as of July, 2009 only one plant (GreenGen) has officially been given the go ahead.

The main sub-divisions of coal liquefaction include.

- Direct coal to liquids (DCL). Being the most efficient way of coal liquefaction so far this technology has just started to be deployed in one plant on a demonstration scale.
- Indirect coal to liquids (ICL). This technology is still in its development stage.
- Coal to Methanol (CM). In 2007, the total consumption of methanol in China is about 10 million tonnes while about 65% of it was produced by coal.
- Dimethyl Ether (DME). During the past few years, the total output of DME in China has been increasing rapidly while a number of large size industrialization projects are in plan. It is estimated that DME produced by methanol was about 0.6 million tonnes in 2006.

All of these plants would have substantial CO_2 emissions if built which will continue to present a challenge in terms of GHG mitigation. For a rough estimation, coal to liquids (DCL, ICL, CM and CDME) will, on average consume 3-5 tonnes coal and generate about 3-10 tonnes CO_2 emission to produce 1 tonne oil.

References

Bulletin of energy saving and emission reduction situation of power companies in 2007.

Bulletin of shutting down small thermal power units in 2007. China State Electricity Regulatory Commission

China Energy Statistical Yearbook 2006. China Statistics Press, 2007

China Energy Statistical Yearbook 2007. China Statistics Press, 2008

China Energy Statistical Yearbook 2008. China Statistics Press, 2009

China State Electricity Regulatory Commission, China National Development and Reform Commission, China Energy Bureau

China Statistical Yearbook 2008. China Statistics Press, 2008

Coal Gasification for Power Generation---A New Way for Coal to Meet America's Energy and Environmental Challenges. ChevronTexaco IGCC White Paper2003

Donald L. Bonk (Senior Technical Advisor, National Energy Technology Laboratory). Coal Gasification as Alternative Fuel for Industry Gasification Primer. Showcase Crowne Plaza Cleveland City Centre, Cleveland, September 29, 2005

Electricity Reliability Index 2007 released. China State Electricity Regulatory Commission, Electricity Council

Electricity Reliability Index 2008 released. China State Electricity Regulatory Commission, Electricity Council

Jeff Seabright,Arthur Lee,Richard Weissman. Environmental Enterprise: Carbon Sequestration using Texaco Gasification Process. National Conference on Carbon Sequestration .May 14-17, 2001 Washington D.C.

Tang Hongqing. Overview of new technoogies for one carbon chemical. Tang Hongqng. Nitrogenous fertilizer and methanol Editorial, 2006.12

Zao, L.. et al. (2008, p. 2709), Technical, environmental, and economic assessment of deploying advanced coal power technologies in the Chinese context, Energy Policy, 2009, www.elsevier.com/locate/enpol

Internet Sources:

Asia Times, 2006, http://www.atimes.com/atimes/China_Business/HL21Cb01.html

The Free Library, 2008, http://www.thefreelibrary.com/Shenhua+inaugurates+production+of+DCL+project.-a0192639229

Market Avenue, 2008, http://www.marketavenue.cn/upload/ChinaMarketReports/REPORTS_1010.htm

http://www.cgerc.com/untitled/d.asp

http://www.tpri.com.cn/9xjszx/xjszxcg/xjszxcg02.htm

http://www.nwrici.com/

http://hgxy.ecust.edu.cn/

http://www.cas.ac.cn/

http://www.973.gov.cn/ReadItem.aspx?itemid=347

China Coal Research Institute, http://www.ccri.com.cn/

Zeus Library, 2009, http://www.zeuslibrary.com/vel/Gasification/China/180CG/01PO.asp