# Sustainable Use of Coal and Pollution Control Policy in China

**CCICED Policy Research Report 2009**

**CCICED 2009 Annual General Meeting**

**November 11-13, 2009**

## Task Force Members

***Co-Chair:***

| | |
|---|---|
| Pu Hongjiu | Deputy Director of the National Energy Expert Advisory Committee, the first Vice Chairman of China National Coal Association, President of China Coal Society, Professor |
| Knud Pedersen | Vice President, DONG Energy, Denmark |
| Mark Jaccard | Professor, School of Resource and Environmental Management, Simon Fraser University, Canada |

***Members:***

| | |
|---|---|
| Zhang Yuzhuo | Professor, President of China Shenhua Group Corporation Ltd. |
| Peng Suping | Academician of China Engineering Academy, China University of Mining and Technology (Beijing) |
| Cen Kefa | Academician of China Engineering Academy, ZheJiang University |
| Wang Jinnan | Professor, Vice President of Chinese Academy for Environmental Planning |
| Li Zheng | Professor, Tsinghua University |
| Claude Mandil | Former Executive Director of the International Energy Agency, France |
| Roger Beale | Senior Associate, the Allen Consulting Group, Australia |
| Y.P Chugh | Professor, Southern Illinois University at Carbondale, USA |
| Hans Bolscher | Director for CCS, the ministry VROM as the Ministry of Economic Affairs, Dutch government |

***Support Experts:***

| | |
|---|---|
| Du Minghua | Professor, Vice President of Research Institute of China Shenhua Coal to Liquid and Chemical Co. |
| Hu Zhenqi | Professor, China University of Mining and Technology (Beijing) |
| Chen Hanli | Professor, China Environmental Planning Institute |
| Ning Chenghao | Senior Engineer, Research Institute of China Shenhua Coal to Liquid and Chemical Co. |
| Hu Xingsan | Vice President and Secretary-general of China Coal Society, Professor |
| Jiang Zhimin | Vice Chairman and Secretary-general of China National Coal |

Association, Senior Economist

Zhang Hong — Professor and Senior Engineer, Division Head of China National Coal Association

Kang Rong — Division Head of China National Coal Association

Brian Ricketts — Energy Analyst – Coal, International Energy Agency, France

Rudolph Blum — General Manager, RandD, DONG Energy Power, Denmark

Kevin JianJun Tu — Senior Consultant, MKJA; Research Associate, Canadian Industrial Energy End-Use Data and Analysis Centre, Canada

Li Jing — Lecturer, China University of Mining and Technology (Beijing)

Ma Linwei — Lecturer, Tsinghua University

Chen Xiaojun — Assistant Researcher, Chinese Academy for Environmental Planning

Liu Lancui — PhD, Chinese Academy for Environmental Planning

***Coordinators:***

Hu Zhenqi — Professor, China University of Mining and Technology (Beijing)

Kevin JianJun Tu — Senior Consultant, MKJA; Research Associate, Canadian Industrial Energy End-Use Data and Analysis Centre, Canada

# Contents

# 1 Status and Prospects of the Development and Utilization of Coal Resources in China

## 1.1 Characteristics of Coal Resources and Distribution

### 1.1.1 Characteristics of Coal Resources

Coal resources account for 94% of all fossil fuel endowments in China. The latest "Report on Energy Resource Survey" prepared by the World Energy Council (WEC) estimated that China's gross coal resources and proven coal reserves rank No. 1 and 2 in the world, respectively. According to China Coal Resource Prediction and Evaluation 1999, China's prospective coal reserves have reached 5,555.3 billion-ton (Gt), with cumulative proven reserves at 1,042.135 Gt. The prospective reserves and geologic gross reserves rank No. 1 in the world.

### 1.1.2 Characteristics of Coal Resources Distribution

China's coal resources cover an area of 600-thousand $km^2$. There are five major districts endowed with coal reserves: Northeast China, North China, South China, Northwest China, and Tibet and Yunnan, which are separated by Tianshan-Yinshan orogenic belt, Kunlunshan-Qinling-Dabieshan latitudinal orogenic belt, and Helanshan-Longmenshan longitudinal orogenic belt. The Daxinganling - Taihangshan - Xuefengshan fault belt carved up the three coal reserve districts of East China into six secondary coal reserve areas, i.e., Erlian - Hai'la'er, the Three Provincial Area of Northeast China, Huanghuaihai, Shanxi-Shaanxi-Inner-Mongolia -Ningxia, South China, and Southwest China. See Figure 1.1.

A geographical characteristic of China's coal resources distribution is its extensive coverage and relative concentration in the west and the north. Coal reserves amounting to 4.50 trillion-ton have been found in twelve provinces (municipalities and autonomous regions) including Shanxi, Shaanxi, Inner-Mongolia, Ningxia, Gansu, Qinghai, Xinjiang, Sichuan, Chongqing, Guizhou, Yunnan, and Tibet to the west line of Daxinganling-Taihangshan-Xuefengshan, accounting for 89% of gross coal resources. Twenty provinces (municipalities and autonomous regions) east of this line have coal reserves of 0.56-trillion-ton (without Taiwan), accounting for 11%. Eighteen provinces (municipalities and autonomous regions) including Beijing, Tianjin, Hebei, Liaoning, Jilin, Heilongjiang, Shandong, Jiangsu, Anhui, Shanghai, Henan, Shanxi, Shaanxi, Inner-Mongolia, Ningxia, Gansu, Qinghai, and Xinjiang north of the line of Kunlunshan-Qinling-Dabieshan have coal reserves of 4.74-trillion-ton, accounting for 93.6% of the gross coal reserve. Fourteen provinces (municipalities and autonomous regions) south of this line have coal reserves of 0.32-trillion-ton (without Taiwan), accounting for 6.4% of gross coal reserve. The unbalanced distribution dominated by geologic conditions determines the pattern of coal production and transportation from north to south, and from west to east.

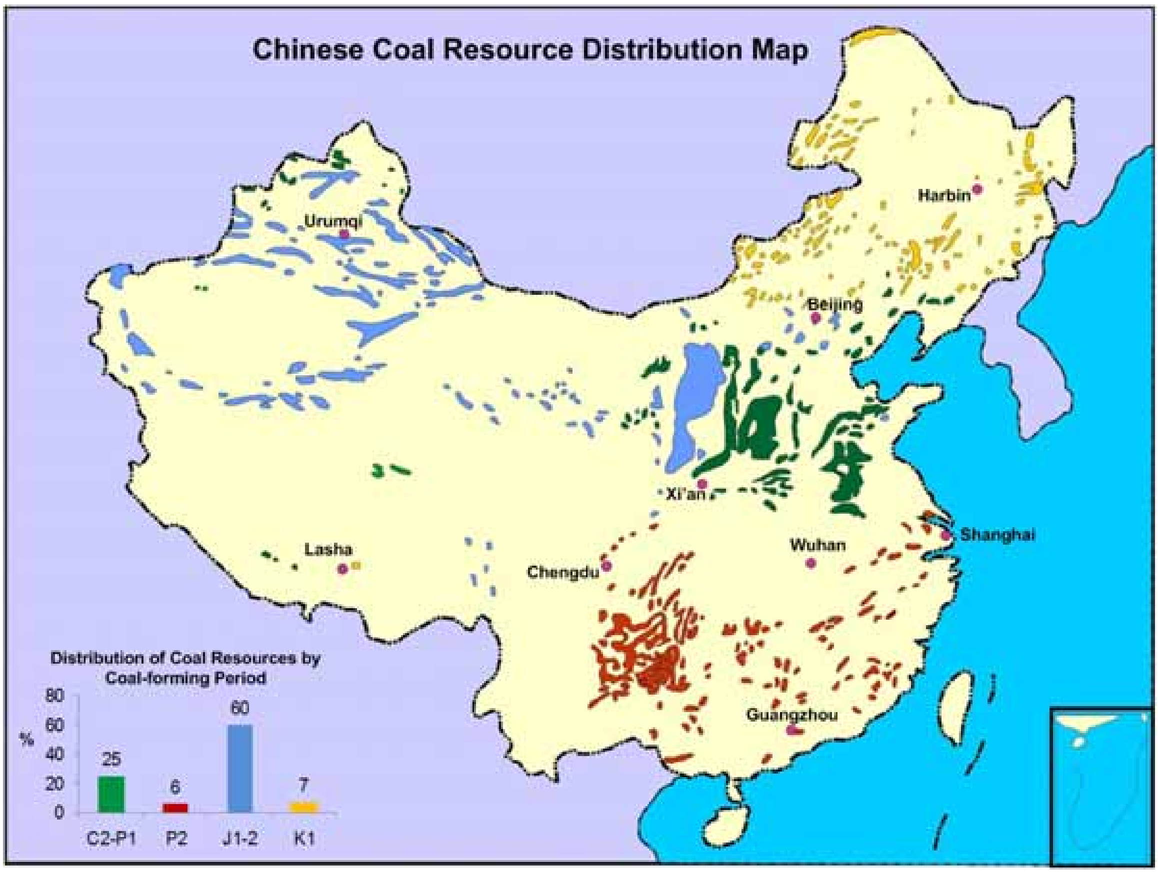


Figure 1.1 Chinese Coal Resource Distribution Map

Coal consumption is closely related to economic development due to the dominant role played by coal in China's energy sector. In China the reserve and supply-demand of coal resources are diversified in different places. The high coal demand in East China resource is met by coal resources transported from Shanxi, Shaanxi, Inner-Mongolia, and Ningxia (Jin-Shaan-Mongolia-Ning), where the coal reserves are the richest in China with output supplying the major parts of China. The four provinces and municipalities of Southwest China have relatively abundant coal reserves, and have the potential to be developed as one of the major coal suppliers in South China. In the broad area of Northwest China such as Xinjiang, where coal consumption is less demanded, and which is remote from the major coal consumers in the east, coal production and consumption is self-sufficient.

## 1.2 Position and Role of Coal in the Development of the Chinese Economy

Energy, especially coal which is dominant in China's energy structure, constitutes the basis for the development of national economy. Even though the coal-dominating energy consumption structure has produced many environmental and social problems, it is still in wide use because China's petroleum and natural gas reserve per capita is only 7.7% and 7.1% respectively of the world's average. For many years coal occupied a ratio of 70% of the energy production and consumption structure in China. In 2007 its ratio in gross energy production reached 76.6% and that in gross consumption 69.5%. Energy consumption has been on rise with the development of the national economy, the process of urbanization, and the increase in the consumption of urban and rural residents. At the same time, China has actively developed hydropower, nuclear power, wind power and other new energy sources. In 1978, hydropower, nuclear power, wind power production accounted for 3.1% of the total energy production, and had increased to 8.2% in 2007. The proportion increased unceasingly in the energy production constitution. However, on the other hand, it is predictable that coal will remain the major energy resource in energy consumption structure in China for a long period in the future.

## 1.3 Status and Prospects of Coal Development in China

China’s coal industry, after 60 years' development, especially in the most recent 30 years of reform and opening up, has filled the gap in coal supply and demand that had existed for more than 30 years after the founding of PRC. This has contributed a huge part to the development of the energy industry and the security of national economic development. With a coal output of 1,397Mt, China became the No.1 coal producer in the world in 1996, and has been since then. This represents 43 times the coal output of 32.43Mt in 1949. In 2003, the raw coal output in China increased to 1,670 Mt, and to 2,793 Mt in 2008. The coal output has an increase of 1,416 Mt from 2000 to 2008.

Up to 2008, coal enterprises have gained a total annual sales profit of over 100-billion-Yuan, an 86.496-billion-Yuan increase, or 11 times more than the year of 2002. By 2007, there were 34 coal enterprises that have an annual output over 11-million-ton accounting for 45% of national output, and 6 coal enterprises that have an annual output over 50-million-ton accounting for 23% of national output. In 2006 major national coal mines have a mining mechanization proportion of 85.50%, with a mechanized mining proportion of 77.47%, an increase of 7.72% and 14.49% respectively from 2002. They also had a mechanized excavation degree of 28.44%, an increase of 12.56% from 2002. As for the death rate per one-million-ton, there has been a dramatic decline, see Figure 1.2 and 1.3. In 2007, the death rate per one-million-ton for the leading state-owned coal mines was 0.383, a decrease from 0.575 or 60.0% less than 2005, or a decrease from 0.887, a decrease of 69.8% from 2002. In 2006, 219 safe and efficient coal mines produced 702-million-ton of raw coal with an average output of 3.207-million-ton per well, a death rate of 0.064 per one-million-ton, an average raw coal work efficiency of 18.8-ton/unit of labor and an average profit of 165-million-Yuan per well. Thirty-five wells had a profit of over 100-million-Yuan, with other economic and technical indexes approaching or attaining the level of the world's major coal producers.

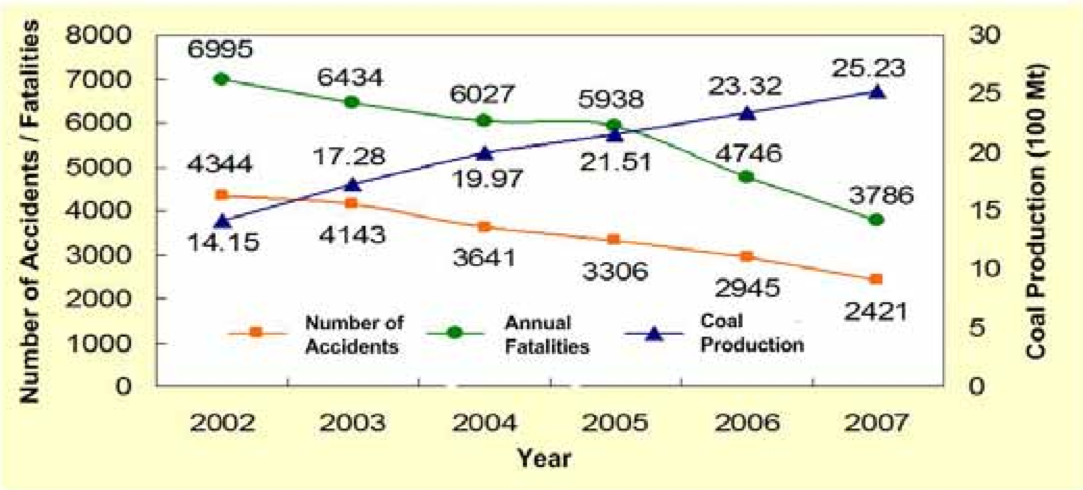


Figure 1.2 Coal Mining Accidents and Fatalities vs. Coal Outputs in China (2002-2007)

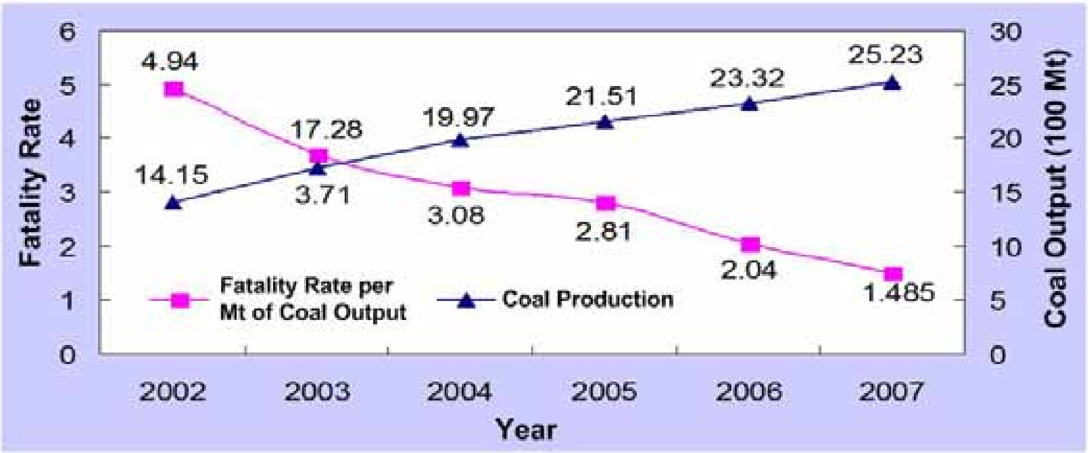


Figure 1.3 Fatality Rate per Mt of Coal Production vs. Coal Output in China (2002-2007)

## 1.4 Status and Prospects of Coal Utilization

In 2007 China's gross coal output is 2,513.77-million-ton, with an import of 51.02-million-ton, an export of 53.19-million-ton, and a consumption of 2,586.41-million-ton. Of this, the end-use is 24.03%, the intermediate consumption is 73.72%, and the washing loss is 2.25%. Sixty-seven percent of the intermediate consumption is for power generation, 21% for coking and 12% is for heat provision and coal gas production. Seventy-nine percent of the end-use is for industrial sectors, primarily consumed by industrial boilers and kilns, and the rest is for civil use or other sectors.

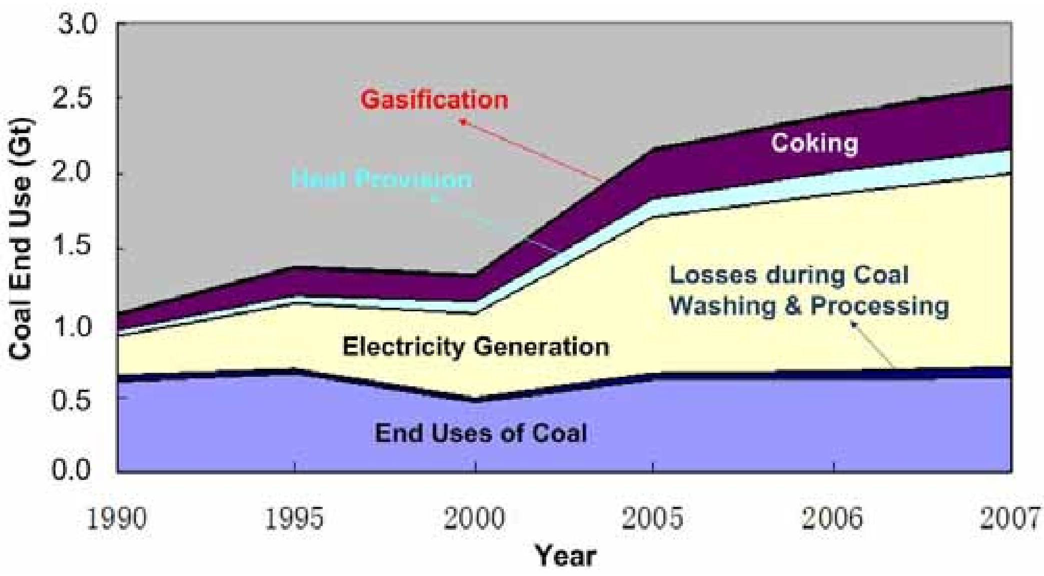


Figure 1.4 Coal Consumption by Sector in China (1990 – 2007)

Coal consumption in China has increased significantly and rapidly year by year from 1990 to 2007. See Figure 1.4. Generally, power generation is always the major consumer of coal production, the consuming ratio of which amounts to 25.78% in 1990 to 50.47% in 2007.

Energy consumption has been on a steady rise because of the economic development and the urbanization process in China. By taking into the consideration the economic structure adjustment, technical progress, and energy saving measures, the predicted domestic coal demand in year 2020, 2030, and 2050 will be 3.5 Gt, 4.0 Gt, and 4.2 Gt, with the ratios of coal in the primary energy consumption of 58%, 53%, and 43% respectively. In years to come, coal consumption demand for electric power will continue to rise, while demand for the building materials industry and steel industries will remain stable, and a new rise for the coal chemical industry is foreseen.

# 2 Strategic Targets and Constraints of Sustainable Use of Coal

## 2.1 Strategic Targets of Sustainable Use of Coal

Being a developing country, China has a huge demand for energy. For a long time coal will remain dominant in the primary energy structure in China because of the natural constraints of resources endowment. Safe, effective, environment-friendly mining and scientific, effective, and clean use of coal will be the theme in the sustainable development of the coal industry.

To realize this goal, coal enterprises have to undergo an intensive mechanization by developing supporting science and technology in the following 20 years (to 2030). These can address China's coal resource reality, which places a high demand for coal in the development of the national economy, while complicated geologic conditions in China's coal reserves makes mining difficult. As for safety, the annual number of deaths in mining accidents shall decrease from more than 3,000 to 300 with a death rate per one-million-ton decline from 1-person/MT to 0.1-person/MT. For effective mining, small mines with 60 to 150-thousand-ton of annual coal production shall be eliminated and closed. The number of coal mines shall decrease from more than 10-thousand to 2,000 or below. The mechanized mining proportion shall increase from 40% to 80%. A small ratio of mines (5%) shall have the mining process automated. The output of scientific mining shall reach 2.6 to 3.7 Gt. For clean mining, all the high gas coal seams will use gas drainage and utilization technology, and 80% of well water will be processed for re-use. Coal gangue piles are to be eliminated, and 80% of the subsided land to be reclaimed.

As for environment protection, pollutants from coal burning shall be strictly controlled, since over 80% of coal products are burned directly in the boilers of power stations, industrial boilers, industrial kilns and domestic cookers. By 2030, more than 80% of the residues of used coal and over 90% of waste water shall be processed. The emission of $SO_2$ and NOx shall be controlled at 14.00-million-t/a and 15.00-million t/a respectively. On the basis of the estimated emission ratio of 85% and 65% of coal burning, the emission of $SO_2$ and NOx from coal burning shall be controlled at 12.00-million t/a and 10.00-million t/a respectively. Meanwhile, with the application of energy saving and CCS techniques, $CO_2$ shall be controlled within 6.5-billion t/a by 2030.

## 2.2 Resource Constraints on Sustainable Development of Coal

Where there is much water, there are less coal resources and vice versa. Coal reserves in East China with a more developed economy only accounts for 7% of national coal reserves, while the water resources in East China accounts for 71.9% of the national total. Central China has coal reserves of 73.6% of the national total, while their water resource is 22.7% of national total. Specifically in Shanxi, Shaanxi, Inner-Mongolia and Ningxia, the proved coal reserve accounts for 64.4% of national gross, while the water resource only accounts for 2.6%. In the self-supply region of West China, coal reserves account for 11.6% of national gross, while the water resource only accounts for 4.6% of national gross. Shortage of water constrains severely the development of the coal resource.

What makes the case worse is that most coal-rich areas are suffering severe loss of water and soil. In these low vegetation coverage areas debris flow and landslides occur frequently, endangering the already fragile eco-environment. Severe environmental problems occur in the process of coal mining, such as land damage and occupation, water pollution and changes in hydro-geologic conditions, gas emission and spontaneous combustion of gangue, etc.

## 2.3 Constraints on Sustainable Use of Coal

### 2.3.1 Energy Efficiency and Pollution Control in Coal-fired Power Generation

Since the reforming and opening up in 1978, China has made a significant progress in energy efficiency and pollution control of the coal power industry. By the end of 2008, the total installed power capacity is 792 GW, of which 600 GW is coal power. The large-scale units (larger than 300MW) now occupy more than 50% of the total installed coal power capacity and the supercritical and ultra-supercritical technologies have become the main choices in newly built power capacity. At the same time, China implemented the policy of promoting the large-scale units and holding or closing down the small-scale ones. With all these efforts, the energy efficiency of coal power generation has been greatly improved. In 2008, the average coal consumption per unit electricity supply has been reduced to 349gce/kWh. In pollution control, more than 50% of coal power units have installed flue gas desulphurization (FGD) facilities, and the total emission of sulfur dioxide and dust by coal power generation has started to decrease.

As for NOx control, more than 50 GW power units have either installed or planned to be equipped with de-NOx facilities. It can be expected that, the new wave of installing de-NOx facilities is coming and the uprising trend of NOx emissions will be consequently reduced.

In general, the constraints on China's coal power industry lie in three aspects:

- supply security, including insufficient production capacity meeting high efficiency and safety criteria and shortage in transportation capacity.
- pollution limitation, including conventional pollutants as SOx, NOx and dust in near term and mercury and respirable particulate matter emissions in long term.
- $CO_2$ emissions limitation.

Therefore, the strategic goals for the coal power industry can be summarized as: under the precondition of meeting electricity demand from social and economic development, the final electric coal demand should be reduced through all kinds of approaches; conventional air pollution should be reduced greatly in accordance with advanced international emission standards and the emission of mercury and respirable particulate matter should be regulated as soon as possible; and there should be early policy, regulation and technology preparations for carbon dioxide reduction. Besides, there is always the need for appropriate business environment and institutional mechanisms to ensure stable business development. The specific targets include the mechanisms for rational profit distribution between power and coal industries, reforming of the regulated electricity pricing mechanism and changing and normalizing of the business expansion model of the power industry.

Nevertheless, the energy efficiency and pollution control of the coal power industry in China is still behind the most advanced level in the world. For example, the fraction of power capacity with unit scale smaller than 100MW is 24.8% in 2007 while it is only 7% in USA in 2007; the average coal consumption per unit coal powered electricity supply in China in 2008 is 11% higher than that of Japan in 2005 (313.3gce/kWh); and the emission of sulfur dioxide and nitrogen dioxide per unit electricity supply of coal power in China in 2007 is 30% and 150% higher than that in USA respectively in 2007.

But with the rapid technology progress in China's coal power industry, these gaps are becoming smaller and smaller. The more urgent problems and challenges to the coal power industry in China includes the continued rapid increase in electricity demand that will bring about more coal consumption and potential emissions, which will be in more serious conflict with the requirements of saving resources and reducing emissions, including conventional pollutants and GHG emissions.

### 2.3.2 Major Problems of Distributed Coal Combustion

Low energy efficiency and huge waste of resources are still the two major problems in China, especially for industries that use coal as the fuel for boilers. Normally the thermal efficiency designed for boilers is between 72%～80%, which is close to the design level of developed countries. But in reality, most of the actual thermal efficiencies are between 60%～65%, 10%～15% lower than the identified thermal efficiency of boilers. Some boilers only have thermal efficiency of 30%～40% in actual application, 30%～50% lower than that of developed countries.

For coal burning boilers, the longer they have been in use, the lower their actual thermal efficiency would be, which is the main cause for the gap compared to that of industrial boilers in application in developed countries.

### 2.3.3 Major Problems of Coal Conversion

1) Outdated techniques and low output, to certain degree, are still in existence. Resource waste and environment pollution are two major problems. Currently, China has hundreds of small mechanized coking installations to be closed or transformed. Their capacity is about 50-million-ton, accounting for 15% or so of the gross capacity of mechanized coking installations in China. Moreover, in some places traditional coking and modified coking are still in production, in spite of the prohibition from the government, with more severe problems of resource waste and environment protection. Statistics show that in China, 55% of synthetic ammonia is produced by enterprises with outdated techniques, low energy efficiency, and environment pollution. The output of large-scale (≥300-thousand-ton/year) and high-tech enterprises only accounts for 25%. As for methanol production, enterprises with a capacity below 200-thousand-ton/year account for 90% of the methanol producers in China, 58% of methanol capacity, and 56% of methanol output. These small-sized coke, fertilizer and methanol producers use outdated techniques and equipment for coal coking, gasification and synthesizing, such as discontinuous fixed-bed gasification techniques resulting in low energy efficiency and heavy pollution. In China today, nearly 50% of mechanized coking enterprises are in operation without dust collecting and processing equipment, or with equipment that fails to run effectively; half of small mechanized coking factories, and some medium coking factories, have incomplete coal gas purifiers (mainly desulphurization installations); a number of processes of mechanized coking have waste water drained directly without denitrification, all of which are far behind the advanced technology in developed countries.

2) The solution to energy inefficiency in new coal-chemical technology is the recovery and utilization of low-quality heat energy. The data analysis on energy balance of new coal chemistry projects indicates that the efficiency of the conversion from coal to oil, chemical products or gas is between 30%~60%, relating closely to the key techniques, product quality, and production processes. The energy loss is concentrated in the reaction process, wherein a lot of heat energy is lost. For example, the reactor has a temperature of 250~260℃ during the process of methanol synthesis. Only medium pressure steam can be generated even if a water jacketed condenser is used. With such inefficient power generation, the output cannot be guaranteed. These old techniques reduce the effective use of the heat energy, and cause the low efficiency of comprehensive coal conversion.

3) The new coal-chemical technology has to solve the problem of converting coal into other energy type in a more effective and cleaner way. In this regard, there still exist such problems in planning, technical development and demonstration, industrial policies, standard systems, and encouragement policies. For example, there is no long-term planning for the development of new coal-chemical industry, nor clear industrial policies to encourage the sealing up of $CO_2$.

## 2.4 Environmental and Climate Constraints in Coal Utilization

### 2.4.1 Serious Air Pollution Caused by Coal Utilization

The coal-based energy structure has caused severe environment pollution in China. In 2007, the total emissions of $SO_2$ has amounted to 24.681-million-tons, NOx to over 20-million-tons, $CO_2$ to being the top 2 on the world list, for which coal use contributed to 80%, 70%, and 80% respectively.

1) Since 2006, the emission of $SO_2$ is decreasing, while NOx is increasing. In 2007 the emission of $SO_2$ was 24.681-million-ton in China, a decrease of between 3.2%-4.7% lower than the previous two years (2005 and 2006). The environmental statistics of China includes the emission of NOx from 2006. In 2007 the emission of NOx was 16.434-million-ton, an increase of 7.8％ more than 2006 (15.238-million-ton). The emission of soot and industrial powder and dust is decreasing from 2006.

2) Electric power industry is a major producer of $SO_2$, NOx and industrial soot and dust. In 2007, this industry took up a dominant position as an emitter of $SO_2$ and NOx, emitting 58.2% and 64.3% respectively of total emissions of industrial $SO_2$ and NOx,.

3) In some cities, ambient air quality has not been in compliance. In 2007, some cities have seen an improvement in the overall quality of urban air. The number of cities with air quality lower than grade Ⅲ has decreased, the number of cities with grade Ⅲ air quality remains unchanged, and the number with air quality better than grade Ⅱ has increased. However, particulate matter is still the major pollutant in most cities. The proportion of tiny particles is increasing year by year. There are still 20.9% of cities with average $SO_2$ concentration failing to meet national standard of grade Ⅱ (0.06-mg/$m^3$). Cities violating Grade Ⅲ (0.1-mg/ $m^3$) are 1.2% of all the cities involved according to the same statistics.

4) The pollution of acid rain is mainly formed by soot. The electric power industry has caused much of the pollution of acid rain. In China the ratio of $SO_4^{2-}/NO^{3-}$ is between 5-3, indicating that $SO_4^{2-}$ from soot is the dominant factor, and that China's acid rain is of the soot type. The main cause of acid rain is the emission of $SO_2$ from coal combustion. The electric power industry consumes 52.6% of the total consumed coal, and emits $SO_2$ and NOx with a ratio of 58.2% and 64.3% respectively of total emissions of each. The electric power industry emits much of $SO_2$ and NOx resulting in acid rain, and which has a great impact due to being transported long distances.

5) In regions with a relatively developed economy in China, the regional structure of composite air pollution has been formed, especially in the city clusters of Beijing-Tianjin-Tanggu, Changjiang River Delta, and Pearl River Delta with emerging composite pollution structures and particular pollution features.

### 2.4.2 Regional Environmental Constraints in Coal Use

The coal consumption, pollutant emission, and pollution treatment level is unbalanced and diversified for regions with different economic development levels in China. Coal consumption per unit area and pollutant emission per unit area in East China are higher than Central China, and much higher than West China. The environmental constraints and development space are also diversified. China has four districts with different economic development levels. They are East China, Central China, Southwest China, and Northwest China. (the regional division is consistent with national Eleventh Five-Year allocation program of the total $SO_2$ emission reduction) Table 2.1 and Table 2.2 show the coal consumption and pollutant emission per unit area and rate of meeting pollutant control standards.

Table 2.1 Coal Consumption and Emissions of $SO_2$ and NOx per Acreage (2007)

| Regions | Area (10,000 $km^2$) | Coal Consumption (10,000 -ton) | SO2 Emission (10,000-ton) | NOx Emission (10,000 -ton) | Coal Consumption Per Unit Area ($t/km^2$) | $SO_2$ Intensity ($t/km^2$) | NOx Intensity ($t/km^2$) |
|---|---|---|---|---|---|---|---|
| East China | 106.78 | 114,695.0 | 913.30 | 807.50 | 1074.12 | 8.55 | 7.56 |
| Central China | 166.87 | 85,489.0 | 667.00 | 428.0 | 512.31 | 4.00 | 2.56 |
| Southwest China | 260.22 | 28980.0 | 489.0 | 202.0 | 111.37 | 1.88 | 0.78 |
| Northwest China | 429.20 | 37,292.00 | 399.00 | 205.70 | 86.89 | 0.93 | 0.48 |
| National Total | 963.07 | 266,457 | 2468.1 | 1643.4 | 276.67 | 2.56 | 1.71 |

Table 2.2 Pollutant Control Standard Compliance Rate (2007)

| Region | $SO_2$ Emission Standard Compliance Rate (%) | Soot and Dust Standard Compliance Rate (%) | Industrial Power Standard Compliance Rate (%) | Industrial NOx Emission Standard Compliance Rate (%) |
|---|---|---|---|---|
| East China | 91.63 | 95.51 | 95.57 | 89.68 |
| Central China | 87.01 | 90.68 | 86.68 | 80.26 |
| Southwest China | 79.10 | 70.33 | 67.83 | 72.82 |
| Northwest China | 68.23 | 68.93 | 66.02 | 70.53 |
| National Total | 86.3 | 88.2 | 88.1 | 77.5 |

From the tables above, the features of East China, Central China, Southwest China, and Northwest China are analyzed as follows:

1) East China has the coal consumption per unit area and pollutant emissions of more than ten times that of West China, and it has less potential for improvement. Moreover, Pearl River Delta, Changjiang River Delta, and Beijing-Tianjin-Tanggu have city clusters featuring interacting pollutants between cities, which makes pollution even more serious. Regional photochemical pollution with photochemical smog and particulates, results in evident reduced visibility. Series of problems often occur during periods of continuous heavy pollution. Most of those regions have heavy acid rain pollution.

Emissions from East China are beyond the capacity of the environment. To increase the coal consumption, it needs to substantially reduce the existing emissions in order to create capacity, and use best practical technology to minimize pollutant emissions. Due to the limited environmental capacity, it is a challenging task to reduce pollutant emission while the coal industry is still to be developed in this region.

2) Coal consumption and pollutant emission per unit area is lower in Central China than in East China, but higher than the national average. The emission standard-meeting rate is at the same level. As far as different regions are concerned, there is still some environmental capacity in the central region, but the distribution is not even. Cities in the provinces of Shanxi, Henan, Hunan, Hebei and Anhui are severely stricken by $SO_2$ pollution. The condition for developing coal industry lies in the reduction of pollutant emission and technical progress, and in being away from cities with severe $SO_2$ pollution.

3) Coal consumption and pollutant emission per unit area is far lower in southwest China and Northwest China than that of East and Central China, and the emission standard-meeting rate has the potential to increase. However, the coal reserves in Guizhou, Sichuan, Chongqing, and Guangxi of Southwest China contain high sulfur for creating acid rain. Northwest China has fragile eco-environment. Guizhou Province, Inner-Mongolia Autonomous Region, Yunnan Province, Chongqing City, Xinjiang Autonomous Region, Guangxi Autonomous Region, Gansu Province, and Shaanxi Province all have cities severely stricken by $SO_2$ pollution. All these environmental factors should be taken into consideration if coal industry is to be developed while other factors such as investment in technical progress and standard emission rate are also met.

### 2.4.3 Needs of Carbon Emission Reductions for Coal Utilization

Demands for more energy are on a rise for economic growth. Therefore, the pressure to reduce carbon emission in coal use is urgent. As predicted in the three scenarios of *World Energy Outlook 2007*, i.e., Reference Scenario, Alternative Policy Scenario, and High Growth Scenario, in 2015 and 2030 China's energy demand and $CO_2$ emission is shown in Figure 2.1 and Figure 2.2.

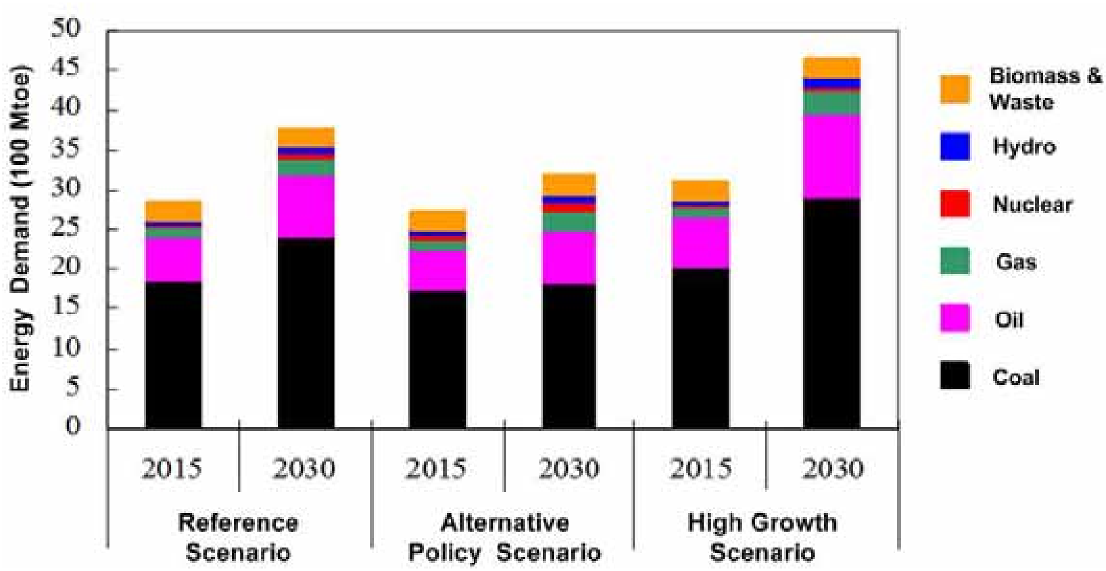


Figure 2.1 China’s Energy Demand in Different Scenarios

(World Energy Outlook 2007)

As shown in Figure 2.1, in 2030 the dominant fuel to meet demand for energy is still coal. The increase of energy consumption and the coal-based energy structure means that $CO_2$ emission will increase accordingly.

In the Reference Scenario, the $CO_2$ emissions are 8.632 Gt in 2015 and 11.448 Gt in 2030. In the Alternative Policy Scenario, the $CO_2$ emissions are 8.092 Gt in 2015, and 8.877 Gt at the end of 2030. In the High Growth Scenario, the $CO_2$ emissions are 9.5 Gt in 2015 and 14.1 Gt in 2030. In each scenario, coal use is the largest producer of $CO_2$, more than 75% of the gross $CO_2$ emission in energy use. This is directly related to the energy consumption structure. $CO_2$ emissions come mainly from coal used in power generation, which accounts for over 60% of total $CO_2$ emissions from all coal uses.

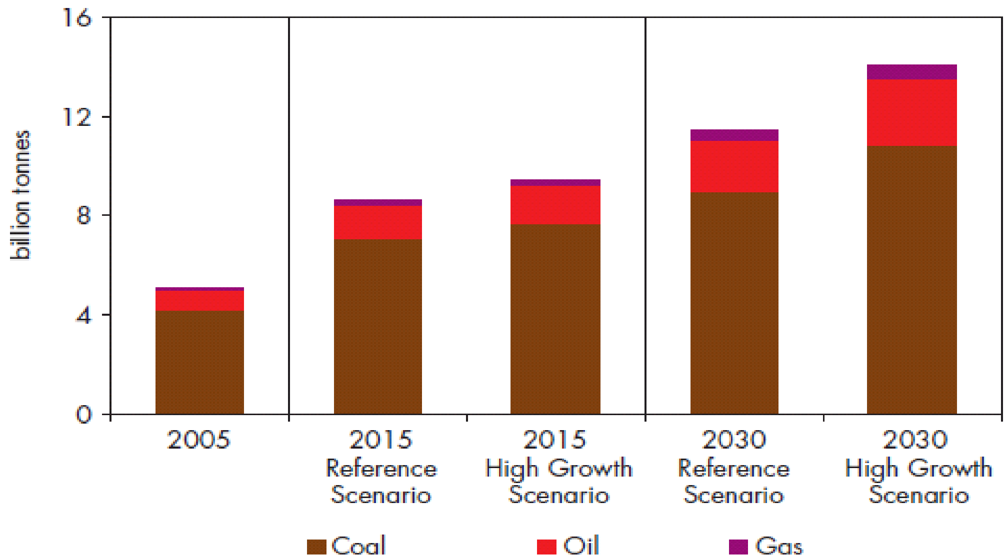


Figure 2.2 China's $CO_2$ Emissions in Different Scenarios (World Energy Outlook 2007)

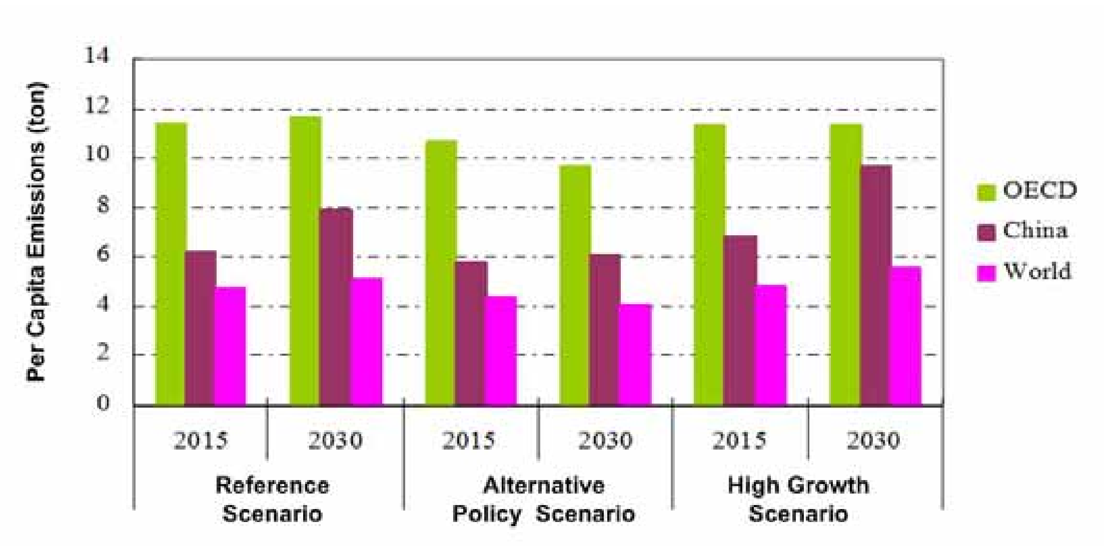


Figure 2.3 China's per Capita $CO_2$ Emissions in Different Scenarios

In the Reference Scenario, $CO_2$ emissions from coal-burning power generation are expected to be 4.328 Gt in 2015, and 5.997 Gt in 2030. In the Alternative Policy Scenario, $CO_2$ emissions from coal-based power generation are expected to be 3.943 Gt in 2015, and 4.465 Gt in 2030. The increase of $CO_2$ emissions, as shown in the Reference Scenario, Alternative Policy Scenario, and High Growth Scenario, makes up 42%, 52% and 49% of the world's gross increase of $CO_2$ emissions respectively, from 2005 to 2030. This shows that $CO_2$ emissions in China are a major contributor to the increase of world $CO_2$ emissions. In the three scenarios, the $CO_2$ emission per capita is evidently higher than the world's average level in 2015, but lower than the level of OECD , as shown in Figure 2.3.

The rapid increase of $CO_2$ emission, especially the increase of $CO_2$ emissions per capita, greatly challenges China's coal-based energy consumption structure and extensive economic growth style. A huge international pressure for emission reduction is already felt in China’s energy industry.

## 2.5 Ineffective Environmental Policies and Sustainable Coal Development

Currently in China, the laws related to coal industry for environmental protection include: Environmental Protection Law, Law on the Prevention and Control of Atmosphere Pollution, Environmental Impact Assessment Law, Energy Conservation Law, Circular Economy Promotion Law, Cleaner Production Promotion Law, Coal Law, Mineral Resources Law, Law on Water and Soil Conservation, and Land Administration Law; related regulations are: Decision of the State Council on Implementing Scientific Viewpoint of Development and Strengthening Environmental Protection, Some Opinions of the State Council on Promoting the Sound Development of the Coal Industry, Provisions for Land Reclamation. Related measures and standards are: Interim Measures for Environmental Protection in Coal Industry, Emission Standard for Pollutants from Coal Industry, Standard of Cleaner Production in Coal Industry, Emission Standard of Coalbed Methane/Coal Mine Gas (Trial), Technical Guidelines for Environmental Impact Assessment - Coal Mining Projects etc. Other environmental protection policies are: National Eleventh Five-Year Plan on Prevention and Control of Acid Rain and SO2 Pollution, "Eleventh Five-year" Plan for the Development of Coal Industry, Coal Industry Policies, Notice on Issuing the Opinions of Energy Conservation and Emissions Reduction Work in Coal Industry, Notice on Issuing Suggestions on Coal Mine Gas Treatment and Utilization, Technical Policies for Prevention and Control of $SO_2$ Emission and Pollution from Coal Combustion, Opinions on Experimental Sustainable Development of Coal Industry in Shanxi Province, National Ninth Five-year Plan of Clean Coal Technology and 2010 Development Program in China, National Preferential Policies for Power Generation with Clean Coal Techniques, etc.

As can be seen from the laws, regulations, standards, and policies above, the environmental protection policies of coal industry in China have a wide coverage throughout the process of coal mining, processing and utilization, including the three fields of eco-environment protection, prevention and control of atmospheric and environmental pollution, and reduction of green house gas emissions, featuring "the involvement of many industrial phases and environmental issues". The key point is that although the environmental protection laws or policies in relation to the coal industry have an extensive coverage, they are difficult to apply either for lack of operationality or the absence of affiliated economic and technical stimulants. Specifically, the problems are: 1) The existing laws, regulations, and policies are insufficient, mostly stating principles without practical value; 2) The existing laws, regulations, and policies have too much focus on pollution control rather than on eco-environment, so it is hard for the eco-environment protection work to be carried out. 3) The existing laws, regulations, and policies tend to focus on administrative approaches rather than on effective measures for internalizing environmental protection cost; 4) The existing regulations and policies are issued by different government offices, resulting in ineffective supervision on environmental protection work; 5) The existing regulations and policies have no means of encouraging the widespread use of key techniques for sustainable development of the coal industry.

# 3 Resources and Environmental Protection Strategies for Sustainable Coal Development in China

## 3.1 Resources Guarantee Strategies for Sustainable Coal Development

### 3.1.1 Analysis on Resources Guarantee Conditions for Sustainable Coal Development

China is rich in coal reserves, however, a big part of it is in deep seams. Initial statistics show that of the available coal reserves, 36.1% are located in depths of less than 300m, 44.6% between 300～600m, and 19.3% between 600～1000m. The average mining depth is 400m. Additionally the geologic structures of coalfields are relatively complicated. Only 9% of coal seams have approximately horizontal slope of less than 5°, 60% of coal seams have slopes between 5°～15°, 28% between 15°～45°, and about 2% coal seams have steep slopes of more than 45°. Only a small number of the existing coal mines have simple seam structure. Moreover, most coal-rich areas in China have fragile eco-environment prohibiting the large-scale increase of coal output. The depth of coal mines in East China is increasing 8～12m every year. The problem of deep mining will become more severe in the future ten years.

### 3.1.2 Gross Output Control of Coal Production

The scale of coal production will be controlled within the allowable limits of environmental capacity, market demand, economic benefits, social benefits, and ecological benefits, and harm done to people's life and posterities, on the basis of well scheduled development by considering the diversified environmental tolerances of different areas. Energy security and safety shall not endanger food safety, ecological safety, social safety, and sustainable development of social economy. Coal mining shall be scheduled in a planned way in terms of resources saving, economical use of resources, the benefit of coal production and land reclamation.

### 3.1.3 Relief of Eastern Coal Resources with Significant Water Hazards

To solve the problem of the coal resources made unavailable due to water presence is an important measure to stabilize the coal output in the east. The coal-bearing carboniferous-permian in North China is one of the major coal-bearing formations in China. Many coal mines in the east are coal seams of carboniferous-permian. However, the middle-and-bottom layers of such coal seams are often made unavailable by Karst water at the bottom. Coal reserves of which amount to more than 20 Gt are affected. To make use of the coal resources disadvantaged by water present, measures will have to be adopted such as to enlarge the well drainage capability, shorten the length of coal pillar, and drain the water of the mining area after the survey of the hydro-geologic conditions.

### 3.1.4 Planned Development and Utilization of Coal Resources in Western China

The shift of coal resources development in China to Shanxi, Shaanxi, Inner-Mongolia, Xinjiang, Yunnan, and Guizhou is determined by China's coal resource conditions and required by the development of regional and social economy. However, the coal resources in the west have to be developed in a well planned way: 1) Water use is to be planned in an integral way to meet the needs of coal resources development and local social and economic development. In so doing, it is critical to survey the hydro-geologic conditions and water resource of coalfields. 2) The quality of mine water is to be maintained to improve the comprehensive utilization ratio of the mine water. 3) Coal mining techniques for environment-friendly mining and development of western coal resources should be developed without delay.

## 3.2 Green Mining Strategies for Sustainable Coal Development

### 3.2.1 Establishment of Clear Environmental Treatment Targets in Coal Mining

By 2020, the subsided and damaged land from coal mining will be recovered up to 75%, and the gangue utilization and disposal proportion up to 95%, of which the utilization ratio will be up to over 85%. The utilization ratio of mining well water will be raised up to 70%, and the gas utilization ratio up to 60%. In 2030, the subsided and damaged land from coal mining will be recovered up to 80%, and gangue use and disposal ratio up to 100%, of which the utilization ratio will be up to over 90%. Hills of gangue shall be basically eliminated. The utilization ratio of mining well water will be raised up to 80%, and the gas utilization ratio up to 70%, basically realizing the full treatment of subsided land, full utilization and harmless disposal of "three wastes", and environment-friendly mining at coal mines.

Source control, prevention of process wastes, and after treatment are the three factors taken into account to realize the goal of environment-friendly mining.

### 3.2.2 Wide Deployment of Green Coal Mining Techniques

Green coal mining techniques are listed as follows: Water resources protection - "water conservation mining" technique; land and buildings protection - "filling mining" technique; gas extraction and emission - "co-mining of coal and gas" technique, etc. The application of these include: 1) To minimize environmental pollution in mining at the source, to promote gangue filling technique, and to build lanes and fill the mined-out area with gangue. 2) To use the pillar and strip mining method for shallow-layer coal seams production, and to use the interval mining and matched mining method for other coal seams to prevent ground subsidence. 3) Further research the technique for gas quality improvement, the technique for coal gas wells under mining and mine gas use.

### 3.2.3 Reclamation of Subsided Land in Coal Mining Areas

Today several modes for reclaiming subsided land are available. However, the land reclamation ratio is still low. Only 12% of subsided land in coal mines is reclaimed, far lower than the average 65% of foreign countries. Subsided land is still on a rise every year with both economic development and further coal mining. Therefore, land reclamation must be strengthened by both promoting and facilitating in order to solve the following problems and techniques: 1) To promote the public-participation mechanism and management for subsided land reclamation in accordance with the different types of subsidence. 2) To improve the precision in predicting the subsidence during coal mining, focusing on the prediction of subsided land when mining coal in complicated environmental conditions such as mountain area, alluvium, deep seam, and intensive mining. 3) To update the existing subsided land reclamation techniques with a focus on mining-farming combined areas, mountain areas, and areas with fragile eco-environment, together with the development of filling-type reclamation techniques and using equipment free of pollution. 4) To develop subsided land dynamic pre-reclamation techniques for land resources protection as well as land reclamation.

### 3.2.4 Promotion of the Disposal and Synthesized Utilization of Coal Gangue

An increasingly enlarged coal mining scale will bring about more solid wastes. Take the coal mining-and-washing industry for example. It produced 187.516-million tons of solid wastes in 2007, accounting for 11.4% of the solid wastes from all the industries. In recent years, the utilization ratio of solid wastes such as coal gangue is on the rise. In 1999 the utilization ratio of solid wastes from coal mining-and-washing was 24.70%, which was increased to 57.42% in 2003. In 2007, the synthesized utilization ratio of solid wastes was 63.64%, and the waste disposal ratio was 28.00%; the waste storage and emission ratios were 6.51% and 1.86% respectively.

China is far behind the developed countries in coal gangue utilization. On the one hand, western countries such as America and Britain have the total coal gangue utilization ratio of more than 90%; on the other hand, except for the coal gangue used as the matting material for road construction and filling material for subsided area, coal gangue is only used for making building materials such as bricks. Coal gangue and sludge for power generation gained little support in terms of policies at price, scale, and emission. In addition, distributed coal gangue sites and high cost of production and transport have greatly limited the large-scale development of power generation with coal gangue.

To deal with the above mentioned problems, countermeasures are given as follows: 1) Measures should be taken to promote synthesized utilization and industrialized production on the basis of different elements contained in the coal gangue. No permanent coal gangue sites shall be constructed. Coal gangue is to be used mainly for power generation, new building materials, reclamation, road construction, and well filling. For those small coal mines which do not have the separate use conditions, should implement the regional concentration of use and centralized management. 2) Actions should be taken by the government to remove the existing hills of gangue, eliminating or lessening hazards from the gangue hills. The 3.55 Gt (Data from 2005) of existing coal gangue should be screened or washed for differentiated use, such as making coal gangue air brick, power generation, filling the mined-out area and subsided land of well mines, reclaiming farms and constructing roads. Coal gangue hills in undeveloped regions, or those unsuitable for other use should be managed to make them harmless and recoverable for eco-environment. 3) Coal gangue hills with spontaneous combustion hazard should be instantly treated to protect people's health, lives, and property loss from $SO_2$ pollution, gangue hill blasts, and slides.

### 3.2.5 Utilization of Coal Mine Water Resources

The major coal fields in China are severely short of water. 70% of coal fields, in terms of coal output, are stricken by severe water shortage for life. However, there is a tremendous use of well water drainage for coal mining. In 2007 6- billion-$m^3$ of mine water was drained, only 26% of which was reused. This means, to some extent, waste water from coal mining has been under control, but the gap in circular use of water is still large. Coal mine water use is unbalanced in different places. In 2005, East China has the highest utilization ratio (65.99%) of coal mine water, and Northwest China has the lowest utilization ratio of 26.93%.

To have coal mine water fully utilized, the following countermeasures are to be taken: 1) The utilization of all methods, utilization capability, and key problems must all be ensured. For coal fields with severe water shortages in North China and Northwest China, where most of the mine water is salt and bitter, water desalinization should be made to provide mine workers and neighboring residents with water. For coal fields with regional water shortages in Southwest China, mine water should be purified for production or domestic use. For coal fields in places with plenty of rainwater, the capability for mine water purifying and processing should be increased to upgrade the mine water utilization ratio in the sequence of industrial use first and domestic use second. 2) As for supporting policies, it is advised that in mining areas with plentiful water drainage (more than 3.5$m^3$/ton) but little ground water, mine water should be purified to the standard of drinking-water use and should be allowed to connect to the municipal water supply utility with a protected price from the government to secure its supply. The government should support the enterprises using purified mine water financially with subsidized loan. The purified mine water that has been certified for drinking use and is supplied to urban residents should be free of water resource fee.

### 3.2.6 Improvement in Coal Mine Gas Extraction and Utilization

Related data show that China has a proved coal-mine-gas reserve of 3.5-trillion-$m^3$, and the anticipated gross reserve is 36.8-trillion-$m^3$. In 2008, about 5.8-billion-$m^3$ of gas has been extracted from coal mines, the utilization of which amounts to 1.7-billion-$m^3$, a utilization ratio of 29%. The gas is applied to 1,104 power generation installations with 920MW of capacity, and to 900-thousand homes. About 25-billion-$m^3$ of low-concentration gas is exhausted by ventilation.

At present, the coal bed gas is mainly applied to the following four directions: Chemical industry, civil use, power generation, and gas liquefying. The application in chemical industry is limited for its volatile source of gas. As for power generation, enterprises show little enthusiasm in the development and utilization of coal bed gas because of small power generation unit and low price of electricity. Gas liquefaction, cooling and separation results in liquefied natural gas (LNG). 1,000-$m^3$ of methane can be converted as one ton of LNG. Therefore, heat supply and power generation will be the major directions of coal bed gas utilization. In so doing, favorable policies would be: 1) To remove industrial protection and apply the same price policy for electricity from the same net so as to build a favorable environment for gas extraction and utilization. 2) To support coal bed gas production with favorable policies in terms of taxation, technological investment, and industrial coordination. As a matter of fact, coal bed gas and natural gas are basically the same in ingredients, application and the downstream market. As they may compensate each other in distribution, both should be planned to use the same net facilities.

### 3.2.7 Reinforcement of the Guarantee System in Coal Mine Environmental Treatment

A special governmental organization is needed to integrate sectors of coal, land, environment, water conservation, electric power, and agriculture, and to supervise coal mining enterprises and local governments to carry out the work of land reclamation. Responsibility target should also be established to promote land reclamation and other environment treatment work.

Up to now, an efficient working mechanism for mine planning, opening and approval of mine closings has not yet been established; resulting in un-recovered mine waste sites and polluted eco-environment that impose long impact on local community. An increasing number of mines running out of coal will be closed in China. To accomplish this task, the following issues have to be taken into consideration: 1) To follow the idea of "Mining for Closure" to schedule the environment protection and recovery tasks throughout the life cycle of coal mines from survey, design, construction, mining, to closure so as not to leave harmful effect behind. 2) To include mine closure part of opening a mine throughout the life cycle of the coalmining project so as to form a complete mine opening-and-closing with publicized standards or criteria. 3) To improve the process of mine-closure planning to allow mine enterprises to bear in mind the duties of mine closing by following stipulated laws, regulations, policies, institutions, economic reward or punishment, and consensus. It should be made known that enterprises will be punished by confiscation of land reclamation security or by depriving their right of applying for new mining license, etc.

Other measures include, for example, amending the *Land Reclamation Law* to apply more strict land reclamation constraints. The reclaimed land ownership should be clearly stipulated and detailed rules and criteria easy for land reclamation operation are made.

What follows is the establishment of the land reclamation security fund system. 1) To clarify the contents and purpose of the land reclamation security fund, consolidating the name of it into "Land Reclamation Security Fund". 2) To improve the chaotic situations such as: more than one governmental office to charge the fee for environment protection and treatment, non-standardized management, poor efficiency of reclamation, loose supervision on reclamation, security pay-in form, payment and return style, and management mode etc. 3) To include “land reclamation security fund system” in national law so as to reinforce its application, which helps to form the security management and use system with clearly defined responsibilities, rights and duties of the government, the enterprise, banks, and the related people.

## 3.3 Environmental Protection Strategies for Coal Development in Western Regions

Water environment protection and water resources regeneration are the two key issues in protecting the eco-environment of the mining area in the west from the damages from coal mining. The coal mine development strategy in the west must be carried out with protecting water resources, which is critical to strengthen the land reclamation and eco-environment recovery of the mining area with fragile eco-environment.

### 3.3.1 Water resources Conservancy Measures for Coal Development in Western Regions

The application of water conservancy mining technique by using the "three unders" mining[1] is to be promoted to minimize the damage to the roof of the coal seams and to prevent the water from flowing from fractured zone. In thin-layer coal seam mining, it is inevitable that the water-bearing stratum is affected. So, in order to realize the water conservancy mining, the water-bearing stratum should be altered to form manual water insulating layer to ensure that the underground water will not flood the well. The water conservancy coal mining techniques, even if extensively applied in "three unders" mining in East China, will still have some technical and economic problems to be solved compared with the same techniques used in western mining areas.

The second measure is to promote water resources recovery and integrated scheduling. Mining areas in the west have shallow coal seams with overlaid rock and soil layer of sandy type, featuring thin water insulating stratum and poor insulating performance that always results in difficult protection of the water-bearing stratum over the coal seam during mining process. In addition, they have a great number of gullies, watercourses, and lakes, which by themselves are good for the storage or transfer of underground water. Underground dams may be built to contain the water drained during mining process to form underground reservoirs, and certain grout curtains can be constructed to intersect water flow. Meanwhile manual transfer and storage of water can be carried out between underground water and ground water. For example, ground water from a wet period can be stored for future use underground, to maximize water conservancy in western mining area.

Thirdly, to improve the circular utilization level of mine water resources. Appropriate processing techniques and equipment are to be used to treat the waste water from mining process, such as depositing and filtering or using integrated techniques depending on the drainage direction and water quality, to remove contaminants or pollutants in mine water and turn it into usable water. The key point is the research and development is needed for new processing and re-generation techniques for highly mineralized mine water, since most mine water in mining areas in West China is highly mineralized.

### 3.3.2 Land Reclamation and Eco-system Reconstruction

The first measure taken is the integrated construction of coal mining and eco-system re-building. Coal mining shall be carried out in the integration of environment protection and eco-system re-building. This integration can turn the coal production process into environment treatment process. For example at the early stage of coal mining, water and soil conservancy preparations such as tree belt protection should be done. In the process of mining, the damaged land should be recovered by planting trees and grasses. After the mining is over, the work should be shifted to a comprehensive treatment of eco-system recovery to make it into grass land to eliminate the secondary impacts from land excavation.

The second measure is the promotion and application of the reclamation techniques for areas with fragile eco-environment. To develop chemical amendment techniques (developing specific

[1] A terminology widely used in the Chinese coal mining industry, which refers to coal mining under buildings, railways and water bodies.

chemical amendments, etc.), green fertilizer improvement techniques, and microbe amendment techniques (soil-free reclamation, etc.) to nourish the soil, improve the physical and chemical properties of soil, preventing slope slides and losses of water and soil. Economic crops and trees suitable for growing in eco-environment fragile areas in Northwest China should be developed and planted.

# 4 Strategies for Efficient and Cleaner Coal Utilization in China

The utilization of coal in China can be approximately divided into three major areas, i.e. power generation, direct combustion in industrial boilers and kilns, and chemical conversion. In 2007, coal consumption split in these three areas was: power generation 50.5%, industrial boilers (kiln) combustion 30%, and coal chemistry 18% in other purposes less than 2%.

## 4.1 Implementing of Highly Efficient and Cleaner Coal-fired Power Generation

### 4.1.1 Scenario Forecast on Thermal Coal Demand and Associated Carbon Emissions

The results of electric coal demand and $CO_2$ emission scenario analysis shows that, depending on the higher and lower social electricity demands due to different energy intensity and extra-high and high levels of lower carbon power installation that could be achieved by 2030, the electric coal demand in 2030 could vary between 1.177-2.143 billion tons, and the $CO_2$ emission could reach 2.892- 5.215 billion tons. If the electric power industry is expected to reduce $CO_2$ emissions further by that time, carbon capture and storage (CCS) should be pursued..

The scenario study also revealed that if the current NOx emissions standards for power plants can be effectively implemented, the NOx emissions from coal power could be controlled to 6.27-8.47 million tons by 2030; if more strict emission standards similar to the current USA NOx emission standard could be fully implemented, the total $NO_X$ emission could be reduced to 2.09-2.82 million tons. As for $SO_2$, if China's emission standard, which will come into effect in 2010, could be effectively implemented, the $SO_2$ emissions could be controlled to 4.67-8.43 million tons by 2030. If even stricter environment policy can be conducted, which means mandatory installation of flue gas desulphurization facilities with de-SOx efficiency of 95% and 98% or higher for all coal power units, the $SO_2$ emission by 2030 could be reduced to 3.3 million tons and 1.32 million tons respectively. So in a technical sense, the NOx and $SO_2$ emissions of China's coal power could be well controlled by making stricter emission standards in cooperation with effective implementation. However, this will no doubt mean great economic cost and have serious impacts on the power industry. The difficulties in implementation should not be under - estimated.

### 4.1.2 Policies for Highly Efficient and Cleaner Coal-fired Power Generation

By scrutinizing the internal and external factors that influence the total electric coal demand, pollutant emissions, GHG emissions and the sustainable development of the power industry, the most important policy interrelations are concluded as follows:

1) Less electricity demand and more low carbon power installation will help reducing electric coal demand, and then reducing coal electricity pollution emissions and $CO_2$ emissions.

2) Coal power efficiency improvement will help reduce the electric coal demand, emissions of conventional pollutants and $CO_2$. Water resources availability will significantly influence the power generation efficiency, and CCS installation will greatly reduce power efficiency.

3) The installation and operation of SOx and NOx reduction facilities and the quality of coal for electricity will directly determine the overall scale of emissions.

4) CCS installation will increase overall electric coal demand because of efficiency reduction, and will influence the future technology options.

5) Rising coal prices in recent years were the primary reason why the Chinese power industry has run into deficit in the past. However, it must be recognized that the current unreasonable expansion strategy of power generation companies without due considerations of market principles and their gaming behaviors, have further weakened the electricity industry's ability for sustainable development.

Therefore, the following policies are suggested:

1) In order to ensure a continuous efficiency improvement of whole power fleet from now up to 2030, it is necessary to optimize the unit size structure of installed capacity, mix continually and maximize the operating efficiency of existing units through all kinds of technical and administrative ways. It is also necessary to keep on developing more advanced next generation technologies such as 700C unit, efficient air-cooling technology and low energy penalty $CO_2$ capture technologies.

2) For the environment protection, it is necessary to strengthen the implementation of desulphurization standards, to, promote the application of de-NOx technology and to further refine and improve the emission standards.

3) For $CO_2$ mitigation, national strategy and policy for CCS development should be clarified as soon as possible. R&D and demonstration of CCS, IGCC and polygeneration should be promoted, and policy support should be given to promote coal/biomass co-firing power generation.

4) For power industry development strategy, the coupling between coal and electricity prices should be built and promoted. National agencies should actively plan and invest coal production capacity expansion based on future electricity demand prediction.

## 4.2 Accelerated Implementation of Energy Conservation and Emission Reduction Measures for Industrial Boilers (Kilns)

### 4.2.1 Promotion of Effective and Cleaner Distributed Coal Combustion Techniques

The objective is to improve the thermal efficiency of coal boilers and kilns and control the emission of pollutants by constructing power coal blending factories, to stabilize and improve the quality of coal for combustion use, to strengthen studies on the performance of coal combustion, and develop advanced combustion techniques of high efficiency and low pollution, automatic control techniques, and advanced pollutant purifying techniques.

### 4.2.2 Guarantee Policies for Effective and Cleaner Distributed Coal Combustion

Accelerate the implementation of the upgraded technology for coal combustion industrial boilers; Select and optimize distribution of combined heat and power supply, central heating, fuel optimization, technical improvement of coal-burning industrial boilers (kilns); Make the "Twelfth Five Year Plan", work out complementary policies, organization and implement them as soon as possible.

For boilers with an actual thermal efficiency of less than 70%, they should be put into the schedule to be upgraded; For those with the thermal efficiency of less than 60%, a deadline should be set for mandatory upgrade; For those with the thermal efficiency transformation of less than 50% and which are already over their design life, they should be eliminated. The focus shall be put on upgrading chain boilers to increase their thermal efficiency up to 75% or more. The thermal efficiency of above 85% should be set for newly installed boilers. The application of highly efficient hop-pocket filter technology and the advanced desulphurization technology should be promoted to meet $SO_2$ emission standards. Certification should be made to promote the main boiler, auxiliary equipment, complete sets of technology and serial production, energy conservation, water conservation and environmental labeling. The monitoring system should be established to accelerate the construction of operational efficiency, and pollutant emissions.

Implementing the task of the technical upgrading of coal combustion industrial boilers (kilns) in needed. Increasing awareness is required of the urgent need for energy-saving and emission-reduction of the coal combustion industrial boilers (kilns). It is also needed to clarify regional implementation of technical indicators and time requirements and to sign responsibility objectives with enterprises. It is up to enterprises to lay out the coal combustion industrial boiler innovation plan, and organize their own implementation. The government's task is, accordingly, to inspect the progress and result made by enterprises through energy and cleaner production audit.

Upgrading the technology and equipment of coal combustion industrial boilers is required. Cement production enterprises should work out a plan to eliminate high energy consuming shaft kilns, wet process kilns, dry kilns, and any other kilns with coal consumption of more than 150 kilograms/ton by developing the decomposition technique of clinker dry process kilns with a daily chamotte production of over 4,000 tons, and by innovating the existing cement kilns so as to lower the energy consumption to 130 kilograms of standard coal / ton clinker or below.

The wall material production enterprises need to work out a plan to displace low-tech kilns with the application of such advanced techniques as high-efficiency coal combustion, waste heat recycling, efficient insulation and automatic detection. After the transformation, the energy consumption should reach 100 grams of standard coal / block standard bricks or below. New techniques such as advanced coal combustion and waste heat utilization should be used in lime kiln furnaces so that the energy consumption can be reduced to 130 grams of standard coal / kg lime or below. Systematic and synthesized transformation has to be made in fire-proof material kilns with the thermal efficiency of 35% or more. The application of advanced technology and supporting equipment, such as high efficiency dust removal, flue gas desulphurization and sulfur emissions and other real-time monitoring, must be made in newly established, revised and expanded coal combustion industrial boilers.

It is important to promote social benefits with the application of energy-saving techniques, green technology services, and market-oriented services. The responsibility for governments at various levels is to made preferential policies to support environmental protection enterprises and to strengthen the supervision.

Related standards and specifications should be made and revised. They include commodity coal quality standards, technical specifications for energy efficiency, and pollutant emission standards.

## 4.3 Strategies for the Promotion of Highly Efficient and Cleaner Coal Conversion

### 4.3.1 Development of Highly Efficient and Cleaner Coal Conversion Techniques

Objectives are: 1) To extend the application of large, advanced energy-saving and environment protection techniques and equipment in the coal coking industry. The focus is to extend the application of clean production techniques such as dry coke quenching and coal moisture control, and to use large coke ovens. 2) To greatly develop effective, low-carbon, clean coal conversion techniques such as coal hydrogenation liquefaction, coal gasification, coal-based Fischer-Tropsch synthesis, coal gas, and integrated gasification combined cycle (IGCC) poly-generation etc., (the modern coal conversion techniques). To develop and import techniques and equipment such as advanced gasification and large synthetic reactor to realize zero emission and clean conversion. 3) To probe into the integration of the effective, low-carbon, and clean coal conversion technique and the carbon sealing-up technique. Clean coal conversion will produce more than 50% of highly purified $CO_2$ of gross carbon emission that allows direct sealing-up of carbon. Promote the application of the integrated coal conversion technique, carbon capture and storage (CSS) techniques and technical experiments.

### 4.3.2 Policies and Measures for Highly Efficient and Cleaner Coal Conversion

1) Improve resources allocation, optimize resource utilization, and allocate the application of low-quality coal and coal with high sulfur in a rational and effective way by using the low-carbon, clean coal conversion technique. Encourage the development of new water-saving techniques of coal chemistry. 2) Actively use advanced and applicable techniques and improve the coal chemical industry with the emphasis on the cultivation of resource-saving and environment-friendly enterprises and industrial clusters. Eliminate enterprises with low capacity, and increase the admittance threshold of coal chemical industry. Encourage the use of advanced, clean coal chemical techniques. Reinforce the supervision and management on energy conversion efficiency and pollutant emission, and carry out examination on clean production. Intensify the independent development of the new coal chemical techniques including coal oil, coal-based methanol/ether, coal-based alkenes, coal-chemistry-power poly-generation and the large set of equipment needed to promote the experimenting and industrialized development. 3) Encourage enterprises to carry out $CO_2$ sealing up and utilization. Strengthen international communication and cooperation. Actively carry out geologic survey into oil fields and gas fields with potential of large $CO_2$ reserve to demonstrate the technical feasibility and economic rationale. Issue particular stimuli to encourage qualified coal chemical enterprises to carry out $CO_2$ sealing up and utilization. 4) Make and amend related standards of energy efficiency and pollutant emission for certain products. The standard making should follow the most advanced domestic or global techniques as the baseline to

promote enterprises for continuous progress in energy-saving and environment protection.

# 5 Environmental Protection Strategies for Sustainable Coal Utilization in China

## 5.1 Implementation of National Coal Consumption Control Targets on the Basis of National Caps on Air Pollutant Emissions

Coal processing and utilization processes are the main emission source of atmosphere pollutants in China. The essential way to control atmosphere pollution is to reduce the coal consumption, which is also the most effective way to carry out multi-pollutants control strategy with least cost. The control on the emission of green house gases will be the main constraint on coal consumption, in the long and middle term, when the problems of acid rain and urban atmospheric pollution are basically solved and when $SO_2$ and NOx treatment techniques have reached a certain level. But in the near future the main constraints on gross coal consumption are still the emissions caps for $SO_2$ and NOx respectively.

### 5.1.1 Medium- to Long- Term National Control Targets for Air Pollutant Emissions

The target of emission cap for atmosphere pollutants is made on the basis of the following three factors: load of sulfur and nitrogen deposition, ambient atmosphere quality, and gradual reduction of total emissions.

1) Target for $SO_2$ control. In China, the total $SO_2$ emissions in 2007 were 24.68 million ton. The *Eleventh Five-year Plan for National Economy and Social Development* demands the reduction of total $SO_2$ emissions by 10% during that period. So the total $SO_2$ emissions in 2010 shall not exceed 22.95-million-ton in China. The total $SO_2$ emissions in 2015, 2020, and 2030 shall not exceed 19-million-ton, 17-million-ton, and 14-millon-ton respectively. Further reduction measures will be carried out after 2030, if the actual $SO_2$ emission does not meet the emissions cap, based on quality requirements of the urban environment.

2) Target for NOx Control. It is anticipated that in 2010 the NOx emission will be 23-million-ton. The total NOx emission in 2015, 2020, and 2030 shall not exceed 21-million-ton, 19-million-ton, and 15-million-ton respectively.

### 5.1.2 National Coal Consumption Cap on the Basis of Air Pollutant Emission Control

Energy consumption structure, coal utilization style, coal quality, and pollution control level are the important factors that affect the emission of pollutants. Two scenarios ([0] and [1]) of coal consumption structure and two pollution control programs ([B] and [S]) are designed to analyze the coal use style and pollution treatment level in the future: [0] and [1] respectively represent the scenario of current coal consumption structure, and the scenario of and adjusted coal consumption structure. The benchmark program of pollution control [B] is to assume more strict control on the emissions from the electric power and transport sectors based on the current development tendency of pollution control policies; the denitrating of electric power plants are slow. [S] is the comprehensive, strengthened control program to take more strict control measures on coal-burning power plants, and industrial and transport sectors, especially to greatly promote the denitrating of power plants and the pollutant controls of coal-burning boilers and kilns.

1) The Scenario and Program of Coal Consumption in 2030

Coal consumption can be classified into three types: coal for power generation, coal for distributed energy supply, and coal for the coal chemical industry, of which the coal for power generation mainly refers to the coal for power generation by industrial boilers at 65 steam-ton/h or above. Coal for distributed energy supply mainly refers to the coal for industrial boilers and various industrial kilns below 65 steam-ton/h. Coal for coal chemical industry refers the traditional use in the coal chemical industry such as coking, synthetic ammonia, and calcium carbide, and the coal for new-type use such as coal oil, coal methanol, dimethyl ether, alkenes, and natural gas. At present these three types of coal consumption respectively account for 51%, 31%, and 18% of the gross consumed coal in China. In the future, the heat and power combined production style will gradually replace the distributed boilers for heat supply. The elimination and alteration of old industrial boilers and kilns will reduce the coal consumption of this type. With the increasing ratio of coal consumed by power generation and coal chemistry, the ratio of coal consumed by distributed heat supply and kilns, the intensity per ton of the pollutants emitted by coal will be decreased. Therefore, the scenario of coal consumption structure is set in 2030 as: The coal consumed by power generation accounts for 70% of the gross consumed coal, and the coal consumed by distributed energy supply and coal chemistry each account for 15%. See Table 5.1.

Table 5.1 Scenarios of Coal Consumption by Sector in China

| Scenario | Ratios of Coal Consumption | | |
|---|---|---|---|
| | Power Plant | Distributed Heat Supply | Coal Chemistry |
| Coal Consumption Structure in 2007 [0] | 51% | 31% | 18% |
| Adjusted Coal Consumption Structure in 2030 [1] | 70% | 15% | 15% |

2) Maximum Coal Consumption Constrained by Upper Limit of Pollutants

In the benchmark control scenario, the coal consumption structure stays the same as that of 2007. The electric power industry has intensified $SO_2$ treatment (See Table 5.2 and Table 5.3). In 2015, 2020, and 2030 the average removal ratios of $SO_2$ are respectively 64%, 81%, and 86% (42% in 2007). For coal-burning boilers and industrial kilns using washed clean coal or simple desulphurization facilities, the unit intensities of $SO_2$ emission will be reduced respectively to 5%, 15% and 30% of that in 2007. In 2015, 2020, and 2030 the gross emission of $SO_2$ will be controlled within the limit of 19-million-ton, 17-million-ton and 14-million-ton. Then the maximum consumable coal will amount to 2.58 Gt, 2.97 Gt, and 3.06 Gt respectively. In 2007 the gross coal consumption in China has been 2.586 Gt. In such a scenario, it is difficult to control the gross coal consumption within the limits. For NOx emission control, if SCR denitrating installation is to equip the newly constructed units in developed eastern region after 2010 and LNB is used for new constructed units in other places, then in 2015, 2020, and 2030, the average removal ratios of NOx in the thermal power industry are expected to reach 36%, 52% and 71%, respectively. In 2020 and 2030, boilers for distributed heat supply and industrial kilns have unit intensities of NOx emission 5% and 15% respectively lower than that of 2007. (In 2015 the emission intensity is the same as 2007). For NOx emissions from oil consumption, it is anticipated that in 2015, 2020, and 2030, the national oil consumption will be 30%, 60% and 100% respectively higher than that of 2007. Meanwhile the respective intensities of NOx emissions from oil consumption will be 10%, 20%, and 30% lower than that of 2007, by applying more rigorous emission criterion, improvement of fuel quality, and installation of emission gas purifiers. Combining the above factors, in 2015, 2020, and 2030 the emission of NOx from oil consumption will respectively be 17%, 28% and 40% higher than that of 2007. In 2015, 2020, and 2030 the emissions of NOx will be kept under 21-million-ton, 19-million-ton, and 15-million-ton respectively. The maximum consumable coal shall be 3.20 Gt, 3.15 Gt, and 2.65 Gt, respectively.

In the scenario of strengthened control, the coal consumption structure is adjusted gradually, and the coal used for power generation has its ratio increased to 70%. Coal-burning power plants, and industrial and transport sectors are under more rigorous control of pollutant emissions. In particular, the power plants greatly intensify the denitrating work, and coal-burning boilers and kilns greatly strengthen pollutant treatment (See Table 5.2 and 5.3). In 2015, 2020, and 2030 the average $SO_2$ removal ratio from the thermal power industry will be increased to 72%, 86%, and 95%, respectively. The $SO_2$ treatment techniques for boilers of distributed heat supply and industrial kilns are progressing quickly, and in 2015, 2020, and 2030 the intensity of $SO_2$ emission will be respectively reduced to 10%, 30%, and 50% lower than 2007. Constrained by $SO_2$ treatment and emission cap control, in 2015, 2020, and 2030 the maximum consumable coal will be 3.04 Gt, 4.01 Gt, and 7.86 Gt. For NOx emission cap control, in 2015, 2020, and 2030 the average NOx removal ratio from the thermal power industry will be increased to 44%, 60%, and 78%, respectively. The unit intensity of NOx emission of boilers for distributed heat supply and industrial kilns will be respectively reduced to 0%, 10%, and 30% lower than that of 2007. The intensity of NOx emission from oil consumption will be respectively reduced to 15%, 30%, and 50% lower than that of 2007. In 2015, 2020, and 2030 the gross NOx emissions from oil consumption will be respectively reduced to 11%, 12%, and 0% higher than that of 2007 (In 2030 the emission level will be the same as that of 2007). Constrained by NOx pollution treatment and emission cap, in 2015, 2020, and 2030 the maximum consumable coal will be 3.51 Gt, 3.89 Gt, and 5.24 Gt.

In the benchmark control scenario, in 2015, 2020, and 2030 the maximum consumable coal will be 2.58 Gt, 2.97 Gt, and 2.65 Gt respectively in China. It is indicated that, by following the more rigorous NOx control, the maximum consumable coal will be on a decline after 2015 if the $SO_2$ and NOx treatment level fails to be improved greatly.

Table 5.2 Scenarios of $SO_2$ Control in China

| Scenario | Year | Average $SO_2$ Removal Ratio of Power Plants | Decreased emission intensity of distributed heat supply, compared to 2007 |
|---|---|---|---|
| Benchmark Control Program[B] | 2015 | 64% | 5% |
| | 2020 | 81% | 15% |
| | 2030 | 86% | 30% |
| Strengthened Control Program[S] | 2015 | 72% | 10% |
| | 2020 | 86% | 30% |
| | 2030 | 95% | 50% |

Table 5.3 Scenarios of NOx Control in China

| Scenario | Year | NOx Reduction % of Power Plants | Decreased emission intensity of distributed heat supply, compared to 2007 | NOx emission increase rate in oil consumption, compared to 2007 |
|---|---|---|---|---|
| Benchmark Control Program [B] | 2015 | 36% | 0 | 17% |
| | 2020 | 52% | 5% | 28% |
| | 2030 | 71% | 15% | 40% |
| Strengthened Control Program [S] | 2015 | 44% | 0 | 11% |
| | 2020 | 60% | 10% | 12% |
| | 2030 | 78% | 30% | 0 |

These two scenarios are compared at Figure 5.1 below.

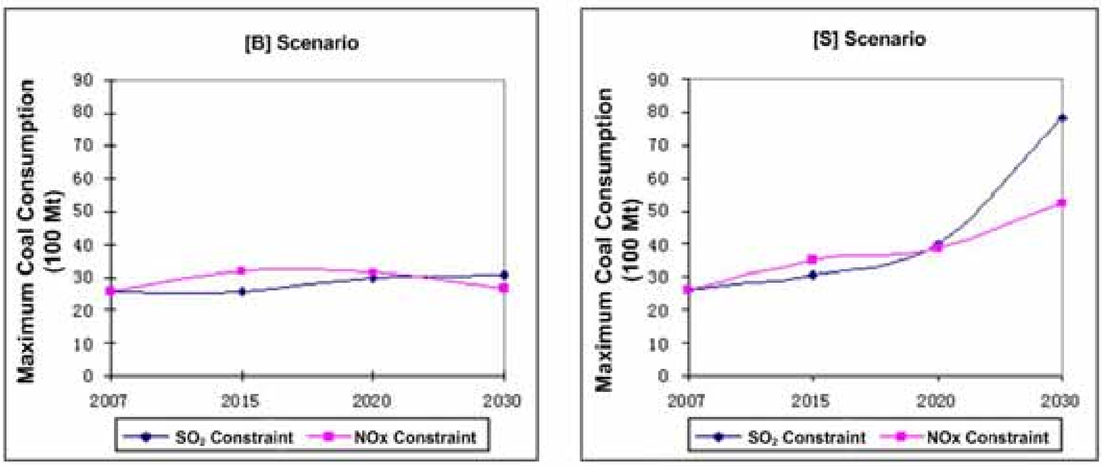


Figure 5.1 Maximum Coal Consumption Constrained by $SO_2$ and NOx Emission Caps

In the strengthened control scenario, the maximum consumable coal may increase due to the adjustment of coal consumption structure and intensified pollution control. In 2015, 2020, and 2030 the maximum consumable coal in China will amount to 3.04 Gt, 3.89 Gt, and 5.24 Gt respectively. Because of the much upgraded pollution control level, the maximum consumable coal may see a large increase after 2020, but will still be controlled under 3.89 Gt before 2020.

It can be seen from the above analysis that the maximum consumable coal has close relations with the pollutant emission caps, coal utilization style, and pollution treatment intensity. If the pollutant emission caps are more rigorous than anticipated or the pollution treatment level fails to increase rapidly, the maximum consumable coal should be capped to meet the pollutant emission caps.

Meanwhile, due to the pressure for greenhouse gases emission reductions, a limit on greenhouse gases emission growth will have to be set in between 2020 and 2030. In that case, greenhouse gases emission control will become major constraint on coal consumption. The maximum coal consumption based on greenhouse gases emission cap might be much lower than the above calculated results.

### 5.1.3 Strategies for Maximum Coal Consumption Control

1) Maximum coal consumption controls will have to be initiated in regions such as Changjiang River Delta, Pearl River Delta, and Beijing-Tianjin-Hebei, which are stricken by severe atmospheric pollution. Effective approaches should be used to eliminate the emission of pollutants and reduce the cost of environment protection. In principle, no new coal-burning power plants are to be built in Pearl River Delta and Changjiang River Delta where the atmosphere and environment capacity has been saturated.

2) Accelerate the adjustment of industrial structure, confine the growth of high energy consuming industries, develop service and high-tech industries, and increase the proportion and level of the tertiary industry in national economy. Meanwhile strengthen the elimination of enterprises with low production capacity and high energy consumptions, and reduce the gross energy demand to decrease the demand for coal consumption.

3) Promote the advancement of an economical society, give priority to energy saving enterprises, promote the development of energy-saving techniques and industrialization, strengthen the management on energy-saving, and increase the energy efficiency at all the phases of the industrial chain.

4) Promote green energy techniques and pollutant emission control techniques, update the traditional technologies, optimize the co-existence of energy, environment, and economic benefits, and apply the cascade and circular utilization of energy and substances to improve energy efficiency.

5) Implement multi-pollutant co-control. Since control techniques and conditions are already well established, people’s health and environmental protection should be maintained by establishing and attaining systematic and scientific atmosphere quality standards and emission standards. Put the issues of atmospheric environment and pollutant control on the same platform or within one framework. Take the co-effects of multi-pollutant control into full consideration in

planning benefit maximization and sustainable development so as to work out comprehensive control strategies and management methods. Techniques for cooperative emission reduction such as dust collection, desulfurization, denitrating, mercury control, and $CO_2$ collection and storage should be developed. Cooperative emission reductions should be encouraged by policies that state the emission control plans for $SO_2$, NOx, $PM_{10}$, Hg, and CO. Planning by administrative agencies should incorporate energy industry development and environment protection in a united way, focusing on energy savings, optimization of energy structure, and furthering of system reform.

6) The central government should organize the making of a national clean air plan that deals with the major issues concerning urban ambient atmosphere quality, compound atmospheric pollution, regional pollution and climate change, which are to be solved within 20 to 50 years in the future. Systematic technical research and development and engineering demonstration projects should be carried out for air pollution control, with a focus on pollution prevention and the treatment of a particular city cluster in China. This would form the research and development basis for further independent innovative systems. Establish mechanisms and systems for quality management of the regional ambient air in China, promote technical progress and innovations in air pollution control industry, applying energy savings and green techniques in sectors of the national economy.

## 5.2 The Application of Economic Instruments for the Promotion of Sustainable Mining

### 5.2.1 Active Promotion of Pricing Mechanism on Acquisition of Mining Rights

The practice of pricing mechanism on acquisition of mining rights should be borrowed from foreign countries. On the one hand, price should be set and money be paid for coal resources before the acquisition of mining rights is made. Coal enterprises can only get the mining rights after paying the lump sum price. The free use of coal mining rights should be abandoned and paid use be practiced in China. On the other hand, coal resources tax should be increased in China to embody the loss of coal resources, rationalizing coal price-forming mechanism, guiding the development of coal industry in a rational and orderly way.

# 5.2.2 Reform on Coal Resources Taxation Policy

Speed up the coal resource tax reform process and the coal resource tax plan so as to make it a “weapon” to truly protect China’s coal resources, rationalize the coal pricing mechanism, and guide the sustainable and orderly development of coal industry. The reform of coal resources tax is to be made in the following two aspects: 1) Change the quantity-based taxation into quantity-price-based taxation or price-based taxation, by linking the coal resource tax with the coal price for the purpose of making it play a role in regulating the behavior of market players and protecting coal resources. When coal price is high, the price-based or partially price-based resource tax should also be raised high in order to reduce the profits of the coal industry, adjust the behaviors of the market players, and effectively constrain blind mining in the coal industry. When the coal price is low, then the price-based or partially price-based resource tax should be lowered correspondingly in order to protect the whole coal industry. 2) Increase the tax rate. At present the quantity-based coal tax rate is 3 – 4 Yuan, 1% lower than that of the coal price, contributing to one major cause why coal price is distorted in China. The tax rate should be greatly increased to include the loss of coal into the coal pricing system.

### 5.2.3 Establishment of Eco-Environmental Compensation System in Coal Mining

Based on the implementation of the eco-environment compensation policies in the coal mining industry in some provinces, more systematic study should be given to this program so as to make it more practical and operational. Related experiments should be carried out in some typical coalfields in Shanxi, Inner-Mongolia, and Xinjiang for the trial implementation of eco-environment compensation rules. Lessons learned from the experiments should be extended in the application of eco-environment compensation systems in the coal mining industry throughout China, providing a standardized and market-oriented institution for the management of the eco-environment in the coal mining areas, and offering a finance channel for the control and recovery of the eco-environment damaged by coal mining.

### 5.2.4 Implementation of Earnest Fund System for Environment Treatment

Earnest fund system for environment treatment should be established in coal industry in China to deal with the existing environmental problems from coal mining. The earnest fund is to be used to supervise and urge coal enterprises to actualize the requirements stated in the *PRC Emission Standard for Pollutants from Coal Industry*, and to effectively urge coal enterprises to adopt pollution treatment approaches, so as to change the status of pollution treatment in the whole coal industry. Expectedly, this earnest fund will strengthen the supervision on the operation of the pollution treatment installations, controlling pollutant emission during the processes of raw coal mining, washing, and the sites for coal storage, loading and unloading, and eliminating the negative impact on the eco-environment.

## 5.3 Establishment of Economic Policy System for Environmental Pollution Control

### 5.3.1 Reform of Pollutant Emission Charge System

A pollutant emission charge system has been implemented ever since the beginning of adopting reform and opening policies in China. For more than 20 years, this system has been gradually improved, playing an active role in urging enterprises to treat pollution and reduce pollutant emissions. However, this system cannot cover the pollution treatment cost and the economic loss brought about by pollution, which leads to the situation that the cost for legal pollution behaviors is high while the cost for illegal pollution behaviors is low. So this system proves ineffective to promote enterprises to treat pollution actively. Therefore, it should be further improved. The increased charge on pollution emission will impel enterprises to treat pollution actively, internalizing all the environmental external cost.

### 5.3.2 Implementation of Environmental Taxation System

Theoretically, environmental tax and pollution emission charges are both effective economic approaches to control environment pollution and internalize the external environmental cost. However, the environment tax has stronger legal force than pollution emission charge, and is easier to collect, providing a stable financial source for environmental pollution treatment. Therefore, by referring to the practice in developed countries, the atmosphere pollution tax ($SO_2$

tax, NOx tax etc.) should be firstly charged to replace the related pollution emission charge for the goal of putting the pollutant emission under control and reducing the environmental impact of energy (for example, coal) utilization phases. Thus, a workable environmental tax system will be finally established in internalizing the external environmental cost.

### 5.3.3 Reform on Electricity Price Subsidy Policy to Promote Environmental Conservation

The theoretical basis of the electric power price subsidy policy is to give certain reward to coal-burning power plants to make up, partly, the cost they spend in pollution treatment. Electric power subsidy policy, environmental tax, and pollution emission charge are the effective approaches to internalize the environmental external cost. However, compared to environmental tax and pollution emission charge, the electric power price subsidy policy is to stimulate coal-burning power plants to take active, necessary approaches to control pollutant emission by "replacing punishment with reward". When the pollutant emission charge is increased to the average marginal cost of pollution abatement, then enterprises will be stimulated to take actions of pollution abatement. However, the present low charge of $SO_2$ emission is insufficient to stimulate enterprises to take actions of pollution abatement. Therefore, it is a necessary complementary approach to the pollution emission charge to include the desulfurization cost into the auditing and determining of electric power price. They will stimulate enterprises to take actions of pollution treatment in a cooperative way. Compared to pollutant emission charge, the electric power subsidy policy is more practical and has stronger stimulation. However, it should not replace the pollution emission charge, as long as we take into consideration the continuity of policies.

### 5.3.4 Overall implementation of Paid-Index System for Pollutant Emissions

At present in some places in China, the paid-use system for pollutant emission allowance has been carried out on a trial basis under the pollutant emission cap. A number of modes appeared, such as Xiuzhou mode in Zhejiang. These modes improved the efficiency of the initial allocation of the emission allowance, attaining outstanding effects of environment and economy. Based on the learned experience of paid-use system from foreign countries, the lessons from local experiments, and China’s reality, the central government should select some advantaged regions or industries to carry out trials of paid-use system for pollutant emission cap. In consideration of the government's "Eleventh Five-year" policies for pollutant emission cap control, the paid-use emission allowance is mainly for $SO_2$ and COD. The trial should include the paid allowance for $SO_2$ emission in the electric power industry and the paid allowance for COD emission in certain areas.

### 5.3.5 Experiment on Pollutant Emission Trade in Electric Power Industry

The thermal power industry is a major producer of air pollutants such as $SO_2$ and NOx in China. In 2007 the thermal power industry has emitted $SO_2$ and NOx accounting for 50.5% and 49.3% of national gross emissions respectively. The pollutant emissions from the thermal power industry affects a wide coverage of areas, for the source of its pollutant emission is normally elevated and its $SO_2$ and NOx emissions are evenly spread. As indicated by the trial on $SO_2$ emission trade in some places in China and the practice of $SO_2$ and NOx emissions trading in America, the electric power industry in China has a sound foundation to initiate the practice of $SO_2$ cap and emissions trading. The successful application of $SO_2$ cap and emissions trading program in the electric power industry will enable the thermal power industry to apply a NOx cap and emissions trading program.

# 6 Main Research Findings

## 6.1 Resource Constraints and Strategies for Sustainable Coal Utilization

### 6.1.1 Abundant Coal Resources and Undesirable Endowment Conditions

In China, coal resource's occurrence conditions are relatively poor. In terms of geological conditions, most coal resources are deeply buried and of less open-pit mining opportunity, resulting in high proportion of well mining. The pattern of resources is "rich in East and North, and poor in West and South", displaying a reverse pattern of the water resources in China, and the opposite direction between the distribution of coal resources and the level of economic development. The contradictions between the scale of resource development and ecological and environmental protection are becoming increasingly evident. The long distance and mass transportation pattern of coal lead to serious bottlenecks. Since clean coal production and fine processing have just started, the demand for coal is extensive and a large quantity of it is directly combusted with much inefficiency and lagged-behind emission control technology, all of which makes coal resource development, regional economic and social sustainable developments, problems and severe challenges.

### 6.1.2 Time Schedule for Gross Coal Production Control

The scale of coal development shall be controlled within the allowable limit of environmental capacity by comprehensively considering market demand, economic benefits, social and ecological benefits, to control total coal development without harming posterity, while considering the contemporary demand. This is calling for changing "making water flow as fast as possible" to "making water flow lastingly though slowly". Coal development shall be scheduled when the diversified environmental tolerances are considered. They include; to relieve the coal resources in the east from water shortage, to develop the coal resources in the west with good planning, to work on new mining techniques, to coordinate the coal resource development and environment protection in western mining areas.

## 6.2 Resource Constraints and Strategies for Sustainable Coal Development

### 6.2.1 Serious Environmental Degradation Caused by Coal Mining

Coal mining will influence the environment, including destruction and occupation of land, water pollution and changes in hydrogeological conditions, air pollution, economical production and social life and so on. Moreover, the fragile environment conditions in the western coal-rich areas have become a serious challenge to the sustainable development of coal.

Until now, coal mining subsidence land area has reached 800,000 hectares and its growth is still at the rate of around 40,000 hectares per year. However, only 12% of subsided land in coal mines has been reclaimed, far lower than the average 65% of developed countries. Since 2005, emissions of coal gangue reach about 180 million tons per year. Although the comprehensive utilization rate is in rapid growth, it was only 66% at the end of 2007, lower than 99% of developed countries, with about 3.8 billion tons of accumulated stock. Main coal-producing areas in China are in severe shortage of water, but the coal mines every year should discharge large quantities of pit water. In 2007, emissions of the pit water all over the country reach about 6 billion cubic meters with only 26% utilization, and the distribution area of coal mine water use is uneven. In 2008, coal gas drainage is about 5.8 billion cubic meters and 1.7 billion cubic meters are used with utilization rate at only 29%. In addition, the spontaneous combustion of coal gangue, coal transportation, gas emission and etc have increased air pollution.

### 6.2.2 Environmental Treatment Targets for Coal Mining Areas

By 2020, the subsided and damaged land from coal mining shall be recovered up to 75% of the area for that year, and the gangue utilization and disposal proportion shall be 95% of the gangue produced that year, of which the utilization ratio shall be over 85%. The mine water shall have a utilization ratio up to 70%, and the gas utilization ratio 60%. By 2030, the subsided and damaged land for coal mining shall be recovered up to 80% of the subsided area of that year, and gangue use and disposal ratio shall be 100% of the gangue produced that year, of which the utilization ratio shall be over 90%. Hills of gangue shall be basically eliminated. The mine water shall have a utilization ratio of up to 80%, and the gas utilization ratio up to 70%, basically realizing the full treatment of subsided land, full utilization and harmless disposal of "three wastes", and environment-friendly mining at coal mines.

### 6.2.3 Comprehensive Guarantee System for Environmental Benign Coal Mining

We should consider source control, pollution prevention during mining and post-mining control, and promote “water conservation exploitation” technology, “filling” technology, “mining coal and gas in total” technology and so on. Innovate the reclamation technology for existing subsidence land, in line with local conditions, and promote dynamic pre-reclamation technology of subsidence land. We should increase the comprehensive utilization of the new generated coal gangue and other solid waste and safe disposal, meanwhile speeding up the elimination of spontaneous combustion in coal gangue hills. Make full use of coal mine water and improve the level of comprehensive utilization of coal gas. Perfect the environmental management of coal mine security systems, including the establishment of mine closure at the approval stage, management and implementation systems, perfect legal regulation system and scientific and complete a land reclamation deposit system, which will provide effective guarantee for the environmental management objectives and the sustainable development of coal mines.

## 6.3 Environmental Constraints and Strategies for Sustainable Coal Utilization

### 6.3.1 Coal-fired Electricity Generation

(1) From 1985 to 2007, the proportion of China’s power generation from coal rose from 20% to 50% and then to 933 million tons of standard coal. At present, power generation from coal is still on a rise and will remain the main power for a long time. The sustained coal power supply is a key factor for sustained coal utilization in China.

(2) China's coal-burning power produces the total emission 45% of $SO_2$, 41% of NOx and 30% of dust. It has been estimated that the emission of $CO_2$ from coal-burning power is about

40% of fossil energy combustion. In spite of the efforts made in recent years, there is still much room for improvement in terms of coal-burning efficiency and contamination control. In addition to the continued improvement of the existing coal steam-electric technologies, we should actively promote the low carbon objectives for the power structure diversification.

(3) The coal-burning steam-power technology is the main technology in service, and the technological development would be directed to improve steam initial and thermal circuit, such as super-critical, extra supercritical and AD700 centigrade. In addition to conventional coal dust boilers, circulating fluid bed techniques are also widely applied in China. The combustion of mixed coal and biomass for power generation can reduce the discharge of $CO_2$, which should be developed in the CCS application.

(4) Normally, coal demand for generating electric power will reach 2.123 billion tons. With the rapid development of nuclear power and renewable energy, the total demand for coal would be 1.768 billion tons, which would greatly facilitate the sustainable development of the coal power industry in China. If all the generators are installed with desulphurization and SCR facilities for the purpose of reaching the targeted emission, much effort has to be made to promote coal-burning technology, contamination control technology, environment protection policy making, and denitration in particular.

### 6.3.2 Distributed Coal Combustion

(1) To promote the utilization efficiency of energy resources, decrease the amount of pollutants discharged, realize the sustainable utilization of distributed coal-burning technology by learning from the international technology and management experience of distributed coal-burning, popularize the application of the technology and the promote its use.

Distributed coal-burning technology is one of the most important coal utilization techniques which China focuses on. Its coal consumption accounts for 30% of the total amount, including about 5 million units of coal-fired industrial boilers in total, 0.4~0.5 billion tons of coal consumption per year, mainly used for industry and heating, and about 1 million units of coal-fired industrial kilns in total, 0.5 billion tons of coal consumption per year, mainly used for steel and building material production.

In recent years, much progress has been made in distributed coal-burning technology by adjusting industry structure, upgrading and promoting new technologies. But in contrast with advanced international techniques, coal-burning industrial boilers and kilns in China still have low utilization efficiency and large amount of pollutant discharge, causing much waste of coal resources and severe air pollution.

As far as the application of distributed coal-burning technology is concerned, the aim to increase the efficient utilization of coal-burning industrial boilers and kilns and to decrease the amount of pollutant discharge can be realized. So the first tasks at present are to speed up the technique promotion and modification of coal-burning industrial boilers and kilns in use, popularize the advanced techniques, accelerate the promotion of set equipment, learn from international management, introduce market mechanisms, make related preferential policies in financial, taxation, pricing, guarantee system, and thereby ensure the sustainable development of distributed coal utilization.

(2)The adjustment of traditional coal structure has promoted the application of advanced energy saving and environmental protection techniques, and it is the main method of pollutant emission reduction. In the future, with the newly-developed coal conversion, the sustainable development of coal conversion should be realized with technological innovation, industry access mechanism, application of energy saving and environment protection standards, high energy conversion efficiency, regular pollutant emission reduction, and CCS realization.

Coal conversion technology is one of the most important coal utilization techniques. Its coal consumption accounts for 18% of the total amount. At present, the main products of coal conversion in China are coking, ammonia synthesis, CTL, MTO and other traditional products. In the future, with the increasing demand of oil and gas, the coal-converted products for substitution will foresee a great development in China.

In recent years, China has accelerated the structural adjustment of the traditional coal conversion industry such as coking, ammonia synthesis, but lagging efficiency still takes a certain proportion, causing high energy consumption and serious pollution problems. The impact of some pollutant discharges is still gravely felt on the improvement of air and water quality. During the process of newly developed coal conversion, the application of advanced energy saving and environmental protection techniques should be highlighted. Meanwhile, the energy efficiency improvement, air pollutant and $CO_2$ emission reduction should also be focused on.

To promote the sustainable development of coal conversion, first, the opportunity for industrial restructuring should be taken, the replacement of traditional coal conversion technology be accelerated, energy utilization efficiency be promoted, and the amount of pollutant emissions be reduced; second, to learn from advanced management experience within China and abroad to improve the market access threshold, set up the energy consumption and pollutant emission standards to ensure techniques of new coal conversion and environment protection are as advanced as any level in the world, and encourage the coal conversion companies to apply CCS.

## 6.4 Air Pollutants Control in the Coal Industry

### 6.4.1 Mid- and Long- Term Targets for Air Pollutants Control

The control objective of the air pollutants' total emission is based on the whole country’s S-N deposition critical loads, atmospheric environmental quality, technology of pollution control and so on, according to three factors.

2015, 2020 and 2030: Sulfur dioxide emissions to be controlled at 19 million tons, 17 million tons and 14 million tons; nitrogen oxides emissions to be controlled at 21 million tons, 19 million tons and 15 million tons.

### 6.4.2 Maximum Coal Consumption Constrained by the Targets on Air Pollutants Control

(1) Reference control scenarios

Coal consumption structure will remain basically unchanged, control rate of sulfur dioxide has increased in various industries, thermal power industry average NOx removal rate gradually increase, but NOx emissions from the national oil consumption gradually increase. In meeting the goal of total NOx emissions in 2015, 2020 and 2030 the maximum consumption of coal is 2.58

billion tons, 2.97 billion tons and 2.65 billion tons.

(2) Enhanced control scenario

Coal consumption structure has adjusted gradually, the desulfurization and denitrification progress of industry has been further accelerated, NOx emissions from oil consumption are under control. The targeted amount control of pollutants has been set and the maximum coal consumption at has been targeted at 3.04 billion tons, 3.89 billion tons and 52.4 billion tons in 2015, 2020 and 2030 respectively.

(3) Greenhouse gas emission constraint

As a result of the pressure for greenhouse gas emissions reduction, China is likely to set the limit for greenhouse gas emissions growth between 2020 and 2030. By then, the greenhouse gas emissions controls will become a major constraint on coal consumption, the maximum coal consumption based on the control of total amount of greenhouse gas emissions may be much lower than the measured results of the above .

### 6.4.3 Regional Environmental Constraints on Coal Consumption

In the eastern region, the pollutant emissions have gone beyond the environmental capacity. With a coal consumption increase, the need has to be met for a substantial reduction in the original pollution emissions so as to leave a space for additional emissions by applying practical technologies to minimize the existing pollutant load. As the existing environmental technology is already advanced, the space for reduction is limited, which makes the environmental constraints more difficult and stringent.

In the central region, there is still some environmental capacity, even if not evenly distributed. Shanxi, Henan, Hunan, Hebei, Anhui and other provinces have more sulfur dioxide pollution in cities. The need to develop the coal industry should be assessed on the basis of the existing emissions reductions and best available implementation techniques, which requires much caution if more coal combustion is planned in already seriously polluted cities.

In southwest and the northwest areas, the amount of coal consumption and pollutant emissions per unit area are much lower than the eastern and central areas, and there is a large potential of emission pass rate with a big environmental capacity, but again with an uneven distribution, especially in Guizhou, Sichuan, Chongqing, Guangxi in southwest area. Because of the high-sulfur coal, the problem of acid rain is serious, the eco-environment is very fragile in Northwest China. There are serious $SO_2$ polluted cities in Guizhou Province, Inner Mongolia Autonomous Region, Yunnan Province, Chongqing City, Xinjiang Autonomous Region, the Guangxi Autonomous Region, Gansu Province, Shaanxi Province, which needed to be identified and treated carefully. The development of the coal industry needs the comprehensive consideration of these environmental factors, development of technology and improvement of emission compliance rate.

## 6.5 Establishment of Effective Environmental and Economic Policy System and Internalization of External Environmental Costs

The focus should be put on economic policy systems such as environment establishment and the consummation: (1) To implement the system of paid-right for coal mining and to accelerate the coal resource tax reform policy; (2) To establish earnest fund system for coal mining, ecological compensation and the implementation of environmental management; (3) To further reform and improve the system of emission charges and the implementation of environmental tax system; (4) To further deepen the environmental price subsidies through preferential policies;(5) to promote the practice of paid emissions and the trial of emissions trading for power industries.

# 7. Policy Recommendations

## 7.1 Improve Governance of the Chinese coal value chain

(1) The Chinese government should create a governance structure through either a separate agency, or through further strengthening an existing government agency or department, with the mandate to improve sustainability of the Chinese coal industry by: (1) coordinating the actions and policies of the various government agencies dealing with China's coal value chain; and (2) integrating the planning, investment and operation of the production, transportation and utilization phases of the coal industry within the overarching framework of a national energy policy that incorporates energy supply security, economic, environmental and social objectives.

- A critical aspect of this governance function is the emphasis on an integrated energy system policy that facilitates and provides incentives for the optimal development of mine sites, power plants, transmission lines, railways, coal ports, and, increasingly, the siting of geological storage of $CO_2$ and the routing of $CO_2$ pipelines.
- This agency or department should be responsible for industry policy, strategy and planning at a macro level rather than at the project level.
- Once a policy is issued, the new department should focus on the monitoring and compliance with its policies by agencies with local level responsibilities.
- To enable effective coordination, this agency or department needs to be at an appropriately high level within the government hierarchy.
- The operations of this agency or department should be performed in a manner that does not diminish or undermine the responsibilities of other governmental agencies, such as the Ministry of Environmental Protection or SAWS, to protect the environment or worker and community health and safety.

(2) The Chinese government should strengthen the enforcement powers of the relevant agencies responsible for mining safety supplemented with the following measurements.

- Establish clear responsibilities at each level of the enterprise and associated penalties for their breach through legislation, with corollary compensation for workers and their dependents for industrial accidents and disease.
- Strengthen the mine inspectorate and the independent investigation of all significant accidents and incidents to provide an opportunity to learn and identify systemic risks and failures.

- Encourage a safety ‘culture’ in both management and the workforce including by training and empowering coal miners to take greater responsibility for their own safety.
- Grant safety inspectors the authority, in the event of non-compliance with safety regulations, to stop mining operations irrespective of mine type without referral to higher authorities.
- Encourage the deployment of state-of-the-art ventilation and dust suppression technology to counter the risks of pulmonary diseases in the coal mining industry.
- Offer safety training programs at appropriate educational institutes within major coal producing regions to encourage greater capacity building for regulators, inspectors, operators and workers – progressively make completion of these courses a requirement for holding key safety positions in either regulatory agencies or enterprises.

(3) The Chinese government must strengthen the capacity and enforcement powers of the relevant agencies responsible for environmental protection standards with the following measures:

- The “one ballot veto” rule should be strictly applied in cases where proposed projects would not comply with environmental laws and regulations – meaning that projects are not able to circumvent the permitting process.
- Independent environmental inspection currently practiced in major key state-owned enterprises should be expanded to the rest of the industry.
- To make informed decisions in support of sustainable development at the earliest appropriate stage of planning and more specifically to address cumulative environmental impacts associated with unprecedented development of the coal industry, the implementation of strategic environmental assessment needs to be strengthened in all coal mining areas but especially in ecologically vulnerable coal producing regions such as Shanxi, Shaanxi, Inner Mongolia and Ningxia.
- Funding for environmental protection agencies should be guaranteed separately and not be linked to revenues from emissions fees or fees for environmental damages.
- The participation of local communities and local interest groups, especially in assessing environmental and social impacts of the different phases of project development in the coal industry should be formalized with specific requirements of input at various stages.

## 7.2 Improve the regulatory system for coal exploitation and use

（1）The Chinese government must improve the capacity and training of public servants working in all areas of the coal value chain and must reform public sector management practices so that salary and career advancement are tied to performance in ensuring full compliance with all laws and regulations

（2）Environmentally sound management of coal mining and processing wastes, during operation and eventual site reclamation, needs to be an integral part of the planning and permitting process. In this regard, mine operators must be held accountable for commitments and obligations established during the permitting process. At this stage, improved standards must be established for: 1) ongoing backfilling for subsidence control; 2) soil and ecological protection and reclamation; 3) acid drainage control; 4) solid mine waste management and dust control; 5) monitoring and control of trace elements in water, air and soils to prevent contamination; and 6) obligations to recover fly ash and other byproducts for use in production of cement, concrete and other products.

(3) In order to lower the burden on China's coal transport infrastructure and improve combustion performance (to be cleaner and more efficient), standards for coal quality need to be strengthened and more widely adopted in commercial contracts with emphasis on ash and sulphur content reductions. In addition, a single coordinating government body responsible for the energy sector could ensure compatible regulations across coal value chain. For example, coal washing standards in the coal mining industry should reflect thermal coal specifications demanded by the electricity industry which again may reflect specifications for reuse of mineral residuals from coal combustion in building materials.

(4) Compulsory emissions standards for $SO_2$, NOx and particulates along the coal value chain need to be tightened for both existing and new plants, with a gradual extension to include VOCs, CO and heavy metals, especially mercury emissions, in the electricity industry. Policy instruments should include minimum performance standards, supplemented with means such as emissions taxes, pollution load based licenses or local, regional and national emission cap and trade systems to meet local air quality objectives and to encourage 'beyond regulation' performance.

(5) Water shortage and ecological vulnerability in the western regions requires that the overall capacity of coal development in these regions must be subject to local environmental carrying capacity assessments, which need to be fully reflected in the mine permitting system. Guidelines for such assessments should be defined.

(6) In densely populated regions with insufficient carrying capacity (e.g. land, water, and air pollutants), coal consumption levels need to be constrained by regional caps on air pollutant emissions such as $SO_2$ or NOx and local water conditions. In the near future, emissions from coal consumption in China should also be constrained by national targets on greenhouse gas (GHG) emission intensity (per unit of GDP), as recently called for by the Chinese president.

## 7.3 Increase the application of market-based instruments

(1) The pilot pricing mechanism on acquisition of coal mining rights, that has been an experiment in eight provinces/regions including Shanxi, Inner Mongolia, Heilongjiang, Anhui, Shandong, Henan, Guizhou and Shaanxi, should be extended to all of China.

(2) The Sustainable Coal Development Fund, a fee levied by the Shanxi provincial government since 2007, should be evaluated by the central government with the goal of improving on this experiment and transferring the lessons learned to other coal producing regions of China.

(3) The current levels of environmental levies in China should be evaluated to ensure that they are gradually adjusted toward reflecting the full environmental and social costs associated with production, transport and utilization of coal. For greenhouse gas emissions, the Chinese government should immediately apply to coal used for combustion a universal carbon tax of 60

yuan/ $tCO_2$, and it should be increased over time. At the same time, the government should fund research and development in China on carbon capture and storage (CCS) technology.

(4) Both the pricing of thermal coal and retail electricity must reflect changing domestic and international market conditions in order to ensure an efficient use of coal and other energy resources. To facilitate closer price linkage between energy input costs and retail electricity prices, the existing Coal-Electricity Price Linkage Mechanism needs to be actually implemented by the NDRC.

## 7.4 Foster a rapid technological change in a sustainable direction with emphasis on Green Mining

(1) A national program on "green mining" should be created with the focus on six main research areas: 1) concurrent mining and reclamation; 2) mined-land subsidence minimization and its management; 3) minimization of coal-related wastes and its environmental sound management; 4) water resource conservation in coal mining and processing; 5) ecosystem protection and risk management in mining areas; 6) safe mine closure and full land reclamation and rehabilitation. Specific green mining technologies with high research, development and deployment priorities include: 1) aquifer protection mining technology to encourage the conservation of water resources in mining areas; 2) subsidence control and backfill mining technologies to protect landscape and surface buildings; and 3) coal mine methane (CMM) / coal bed methane (CBM) techniques to improve coal mine safety and utilization of waste energy with emphasis on the development of methane drainage methods and utilization of low concentration methane.

(2) Rapid development and deployment of more efficient and cleaner coal combustion technologies should be promoted, with emphasis on : 1) ultra-supercritical power generation and integrated gasification combined cycle (IGCC); 2) high efficiency cleaner distributed combustion techniques, including stratified combustion with integrated multi-stage optimization of air distribution systems, high efficiency pulverized coal combustion technology, and multi-coupling combustion; 3) automation technology suitable for the combustion control of various types of coal; 4) key technologies for poly-generation, such as gasification technology, large-scale gas turbines, liquid phase reactors, and new catalyst systems; 5) commercialization of both direct and indirect coal-to-liquid technologies to enable them to fulfill a role as "back-up technology" for China's energy security and perhaps eventually as a means to produce large quantities of hydrogen in combination with CCS; 6) management of combustion and gasification solid byproducts.

(3) Aggressive national pursuit of advanced clean coal technologies with the intention of using the application of these to the domestic market as a means of developing Chinese know-how and a Chinese manufacturing capacity that can become a significant export opportunity as the world shifts toward "the green economy" of the future. Policies focused on specific technologies pathways include: 1) regulations that lead to the development and widespread domestic deployment of deNOx, desulphurization and particulate reduction technologies in China, 2) regulations that lead to the development of coal-biomass co-firing technologies, including advances in boiler design, boiler process control, combustion technologies, fuel-blend control and fuel handling systems, 3) establishment of a national CCS research centre; 4) financial assistance for up-front capital costs and preferential power tariffs for China's first pilot CCS plants; 5) a mandate that requires by 2015 that a small but growing share of all new coal burning facilities are

equipped with emerging CCS capabilities, and 6) a mandate that all new facilities that do not include CCS already, must, at a minimum be designed and constructed as “carbon capture ready”; and 7) an aggressive Chinese effort to fully benefit from international mechanisms that might support the development of CCS, much in the way that China has engaged in the Clean Development Mechanism of the Kyoto Protocol.

(4) Resource characterization and monitoring through the coal value chain that includes: 1) a high resolution geological and geophysical survey of China detailing coal resources by type and characteristics and the potential sites suitable for carbon storage, and 2) the development of a national GIS-based capability that would assist in planning the location and capacities for coal mining, electricity generation, electricity transmission, coal transport, $CO_2$ transport and $CO_2$ storage.

## Acknowledgements

We would like to thank CCICED to provide this platform to study on sustainable use of coal in China.

During the study, China National Coal Association, Shenghua Group, Dong Energy, Ministry of Economic Affairs of Dutch government, Kailuan Group and others provided a lot of help for this Task force. We greatly appreciate their help.

We would like to especially express our sincere appreciation to Ms. Li Jing at China University of Mining and Technology (Beijing) and Maggie Xiao Yan Jiang Lund at DONG Energy for their assistance.

This Volume consists of the agreed Recommendations of the Task Force and a summary analysis prepared by Chinese Team members and other documentation reflecting the research from which these Recommendations were drawn.

**——The Report was provided by Task Force**