REPORT OF THE WORKING GROUP ON SCIENTIFIC RESEARCH, THCHNOLOGICAL DEVELOPMENT AND TRAINING

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CLEANER PRODUCTION AND USE OF COAL

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Executive Summary

1. Background

Energy production in China is developing rapidly due to their economic development. The total production of energy in 1992 was 1, 072. 56 Mtce and the composition of the primary energy production was 74% coal, 19% crude oil, 2% natural gas, and 5% from hydro power generation. The total primary energy production reached 1, 186 Mt in 1994 and will increase 1, 400 Mt in 2000. However, pollution prevention technologies are seldom incorporated into coal priorities. Regulatory controls are lax, and violations are rarely punished. Today it is believed that 90% of SO2, 70% of NOx, and 73% of soot and dust are caused by coal. Unless environ mental preservation measures are implemented, waste gas and wastewater are afraid to increase with coal consumption. This will lead to more serious environmental problems such as air pollution and water contamination.

2. Current State and Problems

2.1 Coal Mining, Preparation and Transportation

In China, 97% of the coal mining sites is for underground mining. Machine mining is adopted by 41% of the medium- and large-sized mines. In mining coal, large quantities of coal refuse, wastewater, and gases are discharged, polluting the surrounding land and air. The output of coal refuse is equivalent to 10 to 12% of the total coal production, or about 150 Mt of coal refuse are disposed every years, The accumulated coal refuse has totalled about 2, 000 Mt which formed over 1,000 waste rock dump. The 145 waste dump are in selfiginition which continues to pollute the air. While, from coal mines, 6,000 Mm3 of coal bed methane gas is exhausted annually. Of this, only 300 Mm3 of methane gas is recovered. The remaining gas is exhausted into the air.

The ratio of coal preparation to raw coal production is just about 20%. The coal for powering is hardly prepared. Utilizing raw coal without preparation will ca use heavy traffic of transportation to consumption sites, and bring about negative impacts, including waste of transportation, loss of coal utilization, and environmental pollution through coal combustion. By coal preparation, the reduction of ash and sulfur, the raising of heating value, and the reduction of the pollutant gas emission in combustion is possible.

It is estimated that about 60% of coal output is transported via railroads. With coal transportation of railroad, truck and ship, discharge of coal dust into the air during transportation has totaled 3 Mt every year. Moreover, it is reported that if coal dust scattering from coal mining sites and open coal yards at consumption sites are added, coal dust scattered will reach 30 Mt. This posse a g rave problem to the environment and economic loss as well.

2.2 Coal Utilization Technologies

Efficient coal utilization and environmental preservation are major issues. The problems should be met by improved thermal efficiency for large-scale thermal power plants and environment preservation measures by putting together polluting sources. More specifically, inefficient small-capacity boilers to be used for residential purposes should be replaced with a large-scale thermal power plant to distribute electric power to broader areas, and with a heat supply plant in the local area to supply heat for homes. Such replacements will allow centralized control of exhaust gas, contributing to an economical and efficient operation. The environment will be improved when efforts for promoting city gas and centralized heat supply are made not only for the central part of metropolitan area, but also for their suburbs, medium-sized cities, and rural areas. Demand for artificial coal, oval briquette, and other briquettes is expected to increase in China for the time being, and it is important to improve the desulfurization caking ratio of coal briquette and to develop a low-pollution combustion oven. As an effective environment preservation technology, a low-priced, semi-dry process simplified flue gas desulfurizer is currently available. For small- and medium-capacity boilers, circulating fluidized bed combustion technology is also available because of utilizing coal sludge and refuse and reducing SOx and NOx emissions by in -situ desulfurization and denitration in the furnace.

In the present report, utilization of coal consumption must be broken down into the industrial use sector, thermal power generation sector, and residential sector. As clean coal technologies, burning, gasification, pyrolysis, and coke production technologies are available for industrial use, and the briquette production technology is available for residential use. Furthermore, flue gas treatment technology is available for both uses. In any application, high efficient utilization of energy and reduction of the load on the environment are essential.

The industrial boiler in China is defined as a boiler with steam output below 65 t/h and steam pressure below 2. 5 MPa. It is reported that in 1990 over 500 boiler manufactures 38 series, 85 types, and 282 specifications of boilers. Totally 17, 200 units of boilers were produced with the total steam output of 56,000 t/ h. Boilers installed throughout China number 430,000 units. Brokendown, steam boilers number about 280,000 units and total about 700,000 t/h steam output, while hot water boilers number 150,000 units. For industrial use sector, coking coal consumption for coke ovens in the steel industry, accounted for 69%, and genera l coal consumption for steam generation and electric power generation boilers ac counted for 25%. Steam generation by some 4,300 industrial boilers owned by leading Chinese steel companies was 32,000 t/h, or average 8 t/h per boiler. The average thermal efficiency of the boilers is 60%, which is 10 to 20% lower than that of similar type boilers in advanced nations. Coal consumption for chemical applications accounts for 50% of 65 Mt of coal consumption in the chemical industry. The remaining portion of coal is used for coal boilers, industrial furnaces, and private power generation. By business types, the synthetic ammonia industry is the largest consumer of coal, accounting for about 50% of the total consumption in the chemical industry. Production of fuel gas, synthesis gas and city gas f or industrial use should increase with the development of coal gasification technologies with high efficiency and environment preservation measures.

Coal consumption by the electric power companies account for 30% of total coal consumption. The power generation industry of power generation in 1992 was 183 GW and that of the coal thermal power generation was about 126 GW, or 70% of the total capacity. In the coal thermal power generation, facilities having a large-or medium-capacity generator of 100 MW or more per unit facility accounted for about 70% of the total facilities but the number is small. The greater part of facilities is occupied by the decrepit and low efficiency boilers having 6 MW capacity or more. With an increasing number of large capacity units and continued improvements of coal combustion technologies, thermal efficiency is improving, However, the average coal consumption rate of total coal thermal power generation in 1993 was higher as 415 gce/kWh than for 300 MW boilers used in advanced nation. This mean that China's coal consumption rate mentioned above was 25 to 30% higher than the coal consumption rate in advanced nation. The consumption rate per power generation should be decreased by increasing efficiency of electric power generation. In addition, most boilers are equipped with a dust-collector for treating exhaust gas generated from coal firing. The soot and dust content is hundreds mg/Mm3, which is 2 to 5 times more than the content in advanced nations. Flue gas desulfurizer and denitration facilities are not installed in China. As a result, air pollution by soot and dust, SO2, and NOx pose a grave concern.

For residential sector, coal is the major source of energy. Coal accounts for more than 80% of fuel consumption in this sector. It is estimated that small-type stoves, coal cookers, and other firing apparatuses number 140 million units. How ever, because most of them are old in fashion, they allow direct burning of raw coal, hence their thermal efficiency remains at just 15 to 20%. An increasing number of stoves, cookers, and other firing apparatuses are adopting briquettes. The equipment improves thermal efficiency by 10 to 20%. Moreover, the apparatus reduces the emission content of soot and dust, SO2, and other air pollutants substantially. Natural gas, coal gas, and other city gases are beginning to increase in popularity in many metropolitan cities. District heating system will allow a large-capacity boiler to operate, which will lead to a substantial improvement in thermal efficiency.

2.3 Management System

As China is transforming into an industrial society, energy consumption is also increasing rapidly. Hence, environmental preservation measures cannot catch up with the changes. Self-help alone cannot make progress. International cooperation is also important. To promote steady pollution prevention measures, it is important to assign an emission controller and an energy manager at power generation plants and other plants. These personnel are expected to play a leading role in t he operation and formulation of a boiler modification plan as environmental regulations are enacted. for the personnel to become experts in the field, a relevant public qualification system as well as an education system through various institutions in China should be arranged to grow and train on-site engineers of coal utilization and the personnel relating to measurement and improvement of environment preservation technologies. Such education and training systems should be supported with education and training programs through international cooperation s agencies.

1. Summary

1.1 Sustainable Development and Clean Utilization of Coal

Energy production in China is developing rapidly due to their economic development. The total production of energy in 1992 was 1, 073 Mtce, with coal accounting for about 74% of the total. Coal consumption and the composition ratio reveal a similar percentage of the total consumption and composition, respectively. Thus, coal is the most important energy source in China. Chinese industries and their economic development depend on coal. coal utilization in China is shifting increasingly from direct consumption (direct burning) to indirect consumption such as secondary energy conversion (electric power). Electric power companies account for about 30% of total coal consumption, and are the largest industrial coal utilizers in China, However, pollution prevention technologies are seldom incorporated into coal production and facilities which utilize coal, due to economic priorities. Regulatory controls are lax, and violations are rarely punished. Today it is believed that 90% of SO2, 70% of NOx, and 73% of soot and dust are caused by coal. In other words, coal utilization is the greatest source of the air pollution. Unless environmental preservation measures are implemented, waste gas and wastewater are afraid to increase with coal consumption. This will lead to more serious environmental problems such as air pollution and water contamination.

1.2 Environmental Issues in Coal Utilization

Sulfur, nitrogen, and ash contents in coal will discharge SOx, NOx, dust and particulates into the air when coal is burned. pollution has a direct effect on the environment, ecology, and human body, while also having an indirect effect on the environment such as acid rain, greenhouse effect, and others covering wide areas. A large volume of coal refuse, wastewater, and gas are discharged during co al mining. The scattering of coal dust also usually occurs during transport. The coal preparation ratio is just about 20%. Transporting of coal containing a high ratio of ash and sulfur equates to transporting of unnecessary ash, and produces more pollution than conventional coal. Coal conversion technologies, combustion, gasification, pyrolysis, liquefaction, and coke production are currently available. Coal preparation is indispensable for using coal proper for such coal conversion technologies.

When coal is utilized a source of energy of thermal power plants and industrial boilers, there is a problem of low utilization efficieney of coal. In addition, insufficient flue gas desulfurization and denitration facilities are major reasons for the large emissions of SOx, NOx, and other pollutant gases. Thus, to improve coal utilization efficiency and to perform environment preservation measures, reducing coal consumption by employing innovative technologies, and reducing ash as a by-product in burning by improving coal quality are important. Also, a more positive application for coal by-products must be discussed.

1.3 Current State and Problems of clean Coal Technology

The Chinese Government is developing energy resources in its basic policy of the 8th Five-Year Plan" centering on electric power, based on coal". Coal consumption by the electric power companies account for 30% of total coal consumption. The power generation industry is the largest consumer of coal in China. To make a detailed analysis, utilization of coal consumption must be broken down into the industrial use sector, thermal power generation sector, and residential sector. In any application of combustion, gasification, pyrolysis, and coke production technologies available for industrial use, while the briquette production technology available for both uses, high efficient utilization of energy and reduction of the load on the environment are essential.

In coal combustion technology, efforts for more efficient coal utilization and better thermal efficiency for electric power generation boilers and industrial boilers will continue. compared with advanced nations, however, the efficiency of coal utilization in China is low, and consumption is increasing, while discharging a large amount of pollution into the air. In other areas, efforts for high efficient coal utilization and reduced pollution are being made with technological innovations and from transferring overseas technology into China. Considering the situation in China, technology transfer must be economical, complete, and easy to operate and maintain. The technology from abroad is vital to future Chinese advancement in technology.

1.4 Strategies and Counter-measures for clean Coal

Efficient coal utilization and environmental preservation are major issues. The problems should be met by improved thermal efficiency for large-scale thermal power plants and environment preservation measures by putting together polluting sources. More specifically, inefficient small-capacity boilers to be used for residential purposes should be replaced with a large-scale thermal power plant to distribute electric power to broader areas, and with a heat supply plant in the local area to supply heat for homes. Such replacements will allow centralized control of exhaust gas, contributing to an economical and efficient operation. The environment will be improved when efforts for promoting city gas and district heat supply are made not only for the central part of metropolitan area, but also f or their suburbs, medium-sized cities, and rural areas. Demand for artificial co al, oval briquette, and other briquettes is expected to increase in china for the time being, and it is important to improve the desulfurization caking ratio of coal briquette and to develop a low-pollution combustion oven. As an effective environment preservation technology, a low-priced, semi-dry process simplified flue gas desulfurizer is currently available. For small- and medium-capacity boilers, circulating fluidized bed combustion technology is also available because of utilizing coal sludge and refuse and reducing SOx and NOx emissions by in-situ desulfurization and denitration in the furnace.

As China is transforming into an industrial society, energy consumption is also increasing rapidly. Hence, environmental preservation measures cannot catch up with the changes. Self-help alone cannot make progress. International cooperation is also important. Appropriate environment preservation technologies and coal utilization technologies which have proved effective in advanced nations must be transferred into China in efficient and effective ways. To promote steady pollution prevention measures, it is important to assign an emission controller and an energy manager at power generation plants and other plants. These personnel are expected to play a leading role in the operation and formulation of a boiler modification plan as environmental regulations are enacted. For the personnel to become experts in the field, a relevant public qualification system as well as an education system through various institutions in China should be arranged to grow and train on-site engineers of coal utilization and the personnel relating to measurement and improvement of environment preservation technologies. Such education and training systems should be supported with education and training programs through international cooperation agencies.

2. Introduction

2.1 Environmental Problems Caused by Coal

China has about 9.6 million km2 of land (3rd place in the world), 1. 11 billions of people (1st place in the world), and about 966,700 Mt of coal reserves (2nd place in the world). The nation is the 3rd largest consumer of energy in the world. The role of the Asia and Pacific region is becoming increasingly important in the world economy and market. The regions are making remarkable economic progress. In particular, the economic development of china is noteworthy. The primary energy demand in the Asia and Pacific regions in 1990 accounted for 20% of the world energy demand. It will account for 32% in 2010, and China's energy demand is estimated over one-third of the energy demand in the regions. Energy production in China is increasing rapidly in parallel with the economic development. The total primary energy production of China in 1949 reached 23.74 Mtce. It reached 1,073 Mtce in 1992, or an average annual increase of 4.9% for the past 10 years. The composition of the primary energy production in 1992 was 74% coal, 19% crude oil, 2% natural gas, and 5% hydro power generation. Coal production in 1993 was 1, 140 Mt and accounted for 24% of the world coal production. It increased to 1,186 Mt in 1994, and set a goal of production of 1,400 Mt by the year 2000 and 2,100 Mt by 2010. Primary energy consumption in China in 1992 was 1,089 Mtce, and the breakdown of the production composition ratio was similar to that of the output composition ratio. It should be noted that the rates of coal production and coal consumption in the primary energy source are as large as 73% and 76%, respectively and will be increasing. For coal consumption by sectors, the heavy industry accounted for 750 Mtce, or 68% of the total coal consumption. coal utilization is shifting from direct consumption to indirect consumption such as electricity and other secondary energy resources.

The Chinese Government has been developing energy resources based on its basic policy of the 8th Five-Year Plan "centering on electric power, based on coal " since 1991. The government regards development of coal resources and production increase as the greatest goal for energy production in China. When compared by co al consumption types, intermediate consumption (electric power generation, heating, coke production, and gas production) in China is increasing. China's direct consumption by burning, accounts for about 60% of the total coal consumption. Th e huge consumption is putting a growing concern of causing a serious environment al problem in the years to come.

Coal utilization in China is the largest source of environmental pollution. Its breakdown is as follows:

(a) Discharging large quantities of coal refuse, wastewater, and gas in coal mining

(b) Discharging coal refuse, marl, wastewater in coal preparation

(c) Scattering dust and particulate in transportation

(d) Discharging of soot and dust, SO_2, NO_x, and CO_2 in coal burning

(e) Discharging of ash after coal burning

2.2 Concept of Clean Production Related to Coal

Coal is the most important energy resource for China. The industrial and economic developments of the nation largely depend on coal. Of the total energy consumption in China, coal accounts for 76%, and the percentage is expected to remain over 70% even in year 20000. Industrial development, modernization, coal production and utilization in China will continue to increase in the future. The coal consumption by the electric power companies for electric power generation is expected to rise from the current 28% to 50% of the total coal producation by the year 2030. However, to deter additional costs, pollution prevention technologies are seldomly incorporated in the coal mining and utilization facilities in china. In addition, regulations are lax and strict enforcement and penalties are very rare-Consequently, it is estimated that 90% of SO_2, 70% of NO_x, and 73% of dust in China come from coal utilization. In other words, coal thermal power generation is the major source of environmental pollution. Unless appropriate environment preservation measures are implemented, coal consumption increases will be accompanied by waste gas and wastewater increases, causing more serious environmental pollution by air pollution and contaminated water. The promoting of clean coal production is significant. This report describes coal preparation relating to clean coal production, current situation of coal transportation and coal utilization technologies, and the current situation of environmental problems caused by co al consumption.

2.3 Structure of Report

Chapter 1 describes the summary. Chapter 2 discusses the major problems caused by coal consumption and the significance of clean coal production. Chapter 3 refers to the air pollution and other environmental problems relating to coal utilization technologies, current coal utilization technologies, current environmental regulations and energy control systems, and the necessity and motivation for clean coal. Chapter 4 describes the development of individual clean coal technologies and their problems. Chapter 5 explains strategies of coal production and processing technologies, coal conversion technologies as well as personnel education and training strategies.

3. Energy and Environmental Issues in Coal Utilization

3.1 Air Pollution

Coal consumption ratio for coke production is estimated at 10% of total coal consumption, for chemical products at 6-7% and for direct burning at 80%. Large quantities of particulate, SO_x, NO_X, CO_2 etc. are emitted following coal burning and then the pollutants bring about indirect effects covering broad areas, such as acid rain and greenhouse effect as well as direct effects on the natural environment, ecology, and inhabitants. Exhaust gas in China in 1993 totaled 11.0° ¡10 12 Nm3. The discharge content of soot and dust in exhaust gas was 14. 16 Mt. Discharge of SO_2 was 17.95 Mt. Industrial dust was 6. 17 Mt, and all of them are on the increase. As previously described, these contents from coal correspond to 70% of total amount of discharged SO_2, 70% of NO_x and 73% of dust.

3.1.1 Dust

Total suspended particulates (TSP), constituting particulates, traces metals, hydrocarbons, and soot, and is the major components of air pollution. The total amount of suspended particulates was 14. 16 Mt and the concentration range was 108 to† 815 ¶Ãg/m3 in average per day in 1993. Although average values of air pollutant are low, the averages are less important than heavy values at a specific location. In other words, a strong density of air pollutants at a specific location poses a very serious threat on nearby inhabitants. For example, when the density of the particulates is high, it may cause chronic asthma and/ or other respiratory illnesses. Since the emission content of particulates depends on ash content of the coal, combustion temperature, boiler, or stove design conditions, there is much room to improve.

3.1.2 SOx

The total amount of SO_2 in 1993 was 17. 95 Mt and the average was within the range from 8 to 451 ¶Ãg/m3 per day. About 90% to 95% of the sulfur contained in coal transforms to SO_2 during the burning process. If the facility is not equipped with flue gas treatment, the gas will be discharged from the stack. The relation between the coal consumption from 1983 to 1991 and the SO_2 emission in the same years was close, and the correlation coefficient was 0. 94. In other words, SO_2 is derived from the sulfur contained in coal during coal combustion.

3.1.3 NOx

The average NOx per day was within the range from 10 to 147 ¶Ãg/m3. Nitrogen oxides are derived from nitrogen in coal and the nitrogen and oxygen in the air during the burning process. More NOx will be discharged when the combustion temperature is higher. In Japan and other countries, NOx is discharged mostly from automobiles and other means of transportation while in China NOx is discharged mostly from coal burning. NOx control measures are not incorporated with coal combust ion facilities in Chins. As industries continue to develop and automobiles become more popular in China, NOx pollution will become more serious, thus requiring counter-measures as soon as possible.

3.1.4 Emission standards

The upper limit (¶Ãg/m3) of the density of environmental standards in China is shown below.

	1st-class standard	2nd-class standard	3rd-class standard
TSP	300	1000	1500
SO_2	150	500	700
NO_2	100	150	300
CO	10,000	10,000	20,000

In total, the upper limit of discharge or density of 13 kinds of industrial toxic substances, including the above four matters, are regulated.

3.1.5 Acid rain

If the density of both SO2 and NO2 is high, these pollutants will promote not only combined pollution but in some cases also generate oxidants through suspended particulate matters and/or acid. Rain. Acid rain will cause metals to elute in the waterway and soil, affecting the entire ecosystem. The annual average of acid rain pH during rainfall fell within the range of 3. 94 to 7.63. The cities having pH values of 5. 6 or more accounted for 49.3%. Areas of rainfall with pH 5. 6 or less (standard of acid rain) expanded from 1. 75 x 106 to 2.8 x 106 km2 over the last 8 years. In the past, the rainfall areas of the acid rain were limited. However, it is reported that the area has recently moved form the west to the north, from the Yangtze River to the Yellow River.

3.2 Energy Efficiency

In the 1980s, energy consumption in China in creased with economic growth, The annual average growth of GDP from 1987 to 1992 was recorded at 9. 0%, while the annual average growth of the primary energy consumption in the corresponding year s was recorded at 4.7%. Annual energy consumption rates per GDP unit have been on the decrease. The energy elasticity for demand per GDP (=index of the relation between the major economic indexes, such as GDP, and energy demand. As energy utilization efficiency improves, the energy elasticity coefficient for demand tends to decrease) has been within the range from 0. 5 to 0. 6 since 1980. Meanwhile, the energy consumption for residential in 1980 was 97. 1 kgce per capita. It increased to 138.1 kgce in 1991, or a 42.2% increase over the last 12 years. Th e electric power consumption per person in 1980 was 10.7 kW ° §h. It increased rapidly to 46.9 KW° §h in 1991. Improving power generation efficiency become essential for saving energy in future.

According to the energy consumption rates of the electric power generation industry, steel industry, and cement industry, all of which are typical energy consumption industries, the standard coal consumption per power generation from 1985 through 1992 decreased from 398 to 386 g/kW ° §h, or 3% fall (equivalent to an annual energy saving rate of 0.4%). Standard coal consumption per ton of steel decreased from 1,746 to 1,574 kg/t, or 9. 9% fall (equivalent to an annual energy saving rate of 1. 5%). Standard coal consumption per ton of cement also decreased from 201 to 178 kg/t, or 11. 4% fall (equivalent to an annual energy saving rat e of 1. 7%). Although, as mentioned above, energy efficiencies in many Chinese industries are improving, the energy consumption rates of electric power in advanced nations are 300 g/kW ° §h or more. Thus, china still has room for improvement.

3.3 Current Situation of Coal Utilization

3.3.1 Problems in coal mining

In China, 97% of the coal mining sites is for underground mining. Machine mining is adopted by 41% of the medium- and large-sized mines. In mining coal, large quantities of coal refuse, wastewater, and gases are discharged, polluting the surrounding land and air. The output of coal refuse is equivalent to 10 to 12% of the total coal production, or about 150 Mt of coal refuse are disposed every yea r. The accumulated coal refuse has totalled about 2, 000 Mt. which formed over 1. 500 waste rock dump, or 13.000 ha of land is occupied. The 145 waste dump are in self-ignition which continues to pollute the air. Rainwater from the dump also pollute the surrounding surface water and underground water. Every year, 1,800 Mt of mine wastewater is discharged. The water is frequently re-used as irrigation water, industrial water, and living water. The remaining water is discharged without proper treatment. Mixed constituents, heavy metals, high acid material, etc. continue to pollute neighboring sources of water.

From coal mines, 6,000 Mm3 of coal bed methane gas is exhausted annually. Of this, only 300 Mm3 of methane gas is recovered. The remaining gas is exhausted into the air. The emission also pollutes land, and has left 3. 2 million ha of cultivated land devastated and/or subsided, etc. so far. About 22,000 ha of land is devastated every year.

3.3.2 Problems in coal preparation

The coal preparation rate has been about 18% in average for a long time and was 6% in rural mining. About 80% of the coal without preparation was directly burned. The coal production for powering is about 500 Mt. The average contents of coal ash and sulfur are respectively 27% and 1. 1% was 452 Mt. Coal preparation at most preparation coal plants is 0. 6 to 3. 6 Mt/year. The maximum coal preparation is 15 Mt/year. In coal preparation, 15-20% of raw coal is disposed as coal ref use. Because about 200 Mt of raw coal is prepared every year, 30 to 40 Mt of coal refuse is disposed. About 30 Mt of waste-water and about 0. 3 Mt of sludge are also discharged from small-scale coal washing plants. Due to sedimentation treatment and recycling of coal washing water being increasingly popular in recent years, less wastewater and sludge is discharged, Yet, the problems relating to coal washing and water discharge must be solved completely. Utilizing raw coal with out preparation will cause heavy traffic of transportation to consumption sites, and bring about negative impacts, including waste of transportation, loss of coal utilization, and environmental pollution through coal combustion.

3.3.3 Problems on transportation

It is estimated that about 60% of coal output are transported via railroads. Be sides railroad transportation, as truck transportation and ship transportation a re included, discharge of coal dust into the air during transportation has total led 3 Mt every year. Moreover, it is reported that if coal dust scattering from coal mining sites and open coal yards at consumption sites are added, coal dust scattered will reach 30 Mt. This poses a grave problem to the environment and economic loss as well.

3.3.4 Problems in utilization

In China, 76% of fuel for power generation, 75% of fuel for industrial use, 80% of fuel for residential use and 60% of materials for chemical products are caused by coal. 10% for coke, 6-7% for chemical products and 80% for direct burning consumes coal. Industrial consumption accounted for 15% of the total coal consumption in 1991, respectively. Of the industrial consumption, heavy industrial consumption accounted for 68.0% By coal consumption types, secondary energy conversion (electric power generation: 27.3%, heating: 3.1%, coke: 9.8%, steam: 03 .3%) or indirect coal consumption accounted for 40.6% Compared with past coal consumption is decreasing. The fact indicates that demand for coal thermal power generation and demand of oil for industrial and transportation fuel are increasing. The electric power companies consumed 300 Mt of coal, which accounted for a bout 30% of total coal consumption. The electric power generation industry is the largest consumer of coal. In order to understand the end users of coal, it should be broken down into the industrial sector, thermal power generation sector, and residential sector.

(1) Industrial sector. The industrial boiler in China is defined as a boiler with steam output below 65-t/h and steam pressure below 2.5 MPa. It is reported that in 1990 over 500 boiler manufactures 38 series, 85 types, and 282 specifications of boilers. Totally 17,200 units of boilers were produced with the total steam output of 56, 000t/h. Boilers installed throughout China number 430, 000 Units. Broken-down, steam boilers number about 280,000 units and total about 700, 000t/h steam output, while hot water boilers number 150,000 units. In the Chinese steel industry, coking coal consumption for coke ovens accounted for 69%, and general coal consumption for steam generation and electric power generation boilers accounted for 27%. Steam generation by some 4,300 industrial boilers owned by leading Chinese steel companies was 32,000 t/h, or average 8t/h per boiler. About 30,000 units of new boilers are manufactured every year. Almost all of them are small boilers under 4t/h capacity with stoker firing. The average thermal efficiency of the boilers is 60%, which is 10 to 20% lower than that of similar type boilers in advanced nations. When the thermal efficiency of the Chinese boilers is converted into

coal consumption, Chinese boilers consume 15-20% more coal. Naturally, this will lead to additional emission of environmental pollution material. Coal consumption for chemical product accounts for 50% of 65 Mt of coal consumption in the Chinese chemical industry. The remaining portion of coal is used for coal boilers, industrial furnaces, and private power generation. By business types, the synthetic ammonia industry is the largest consumer of coal, accounting for about 50% of the total consumption in the chemical industry.

(2) Electric power generation sector. The power generation capacity at 1992 was 183 GW. The coal thermal power generation capacity was 126 GW and accounted for 70% of the total facility. The boilers from 500 MW to 600 MW capacity numbered 7 units in 1992 and accounted for 3.3% only of the total capacity. The boilers having 125 to 360 MW capacity numbered 420 units and accounted for 58.2% of the total capacity. The boilers having 100 MW capacity or less accounts for 38.5% of the total capacity. The decrepit and low efficiency boilers have 6 MW capacity or more number more than 2,300 units. With an increasing number of large capacity units and continued improvements of coal combustion technologies, thermal efficiency is improving. The average coal consumption rate of total coal thermal power generation in 1993 was 415 gce/kW ° §h in standard coal conversion. However, China's coal consumption rate mentioned above was 25-30% higher than the coal consumption rate of 320 to 330 gce/kW ° §h for 300 MW boilers used in advanced nations.

Most boilers in China are equipped with a dust-collector for treating exhaust gas generated from coal firing. The soot and dust content is hundreds mg/Nm3, which is 2 to 5 times more than the content in advanced nations. Flue gas desulfurizer and denitration facilities are not installed in China, except for a couple of facilities. As a result, air pollution by soot and dust, SO2, and NOx pose a grave concern.

(3) Residential sector. Coal is the major source of energy for residential in China. Coal accounts for more than 80% of fuel consumption in this sector. It is estimated that small-type stoves, coal cookers, and other firing apparatuses for residential use number 140 million units. However, because most of them

are old in fashion, they allow direct burning of raw coal, hence their thermal efficiency remains at just 15-20%. An increasing number of stoves, cookers, and other firing apparatuses for residential use are adopting briquettes. The equipment improves thermal efficiency by 10-20%. Moreover, the apparatus reduces the emission content of soot and dust, SO2, and other air pollutants substantially. Natural gas, coal gas, and other city gases are beginning to increase in popularity in man y metropolitan cities. Also, an increasing number of heat sources for heating systems is being centralized for the central heat supply. Centralization of heat sources will allow a large-capacity boiler to operate, which will lead to a substantial improvement in thermal efficiency.

3.4 Emission Control and Energy Control System

3.4.1 Emission control

The air pollution control in China has been strengthened since the 1980s. In 198 4, the Chinese Government formulated a policy of smoking-type coal pollution prevention technologies. In 1992, the government established air pollution standards for boilers and air pollution standards for coal firing power generation pants. The Chinese Government is beginning to promote air pollution applications and a license control system aiming to control the total emission of air pollutants. The government has begun to collect a SO2 emission fee as an experiment. However, regulations are lax and violators are seldom punished. Thus, no substantial reduction is expected on pollution discharge. The Chinese Government formulated an environmental policy called the Agenda 21 in 1993 in cooperation with the national Planning commission, National Science and Technology Committee, and other relevant agencies. This policy, financed by UNDP, set goals for year 2000 and 2010, Specifically, the policy discusses measures relating to energy and environmental problems, including comprehensive energy planning and control, improvement of energy utilization technologies, coal mining technologies with a small burden on the environment, development of clean coal technologies, and development of new and recyclable energy sources.

3.4.2 Energy control system

The Chinese Government is in the process of incorporating energy saving technologies with environmental technologies to control air pollution. It will improve coal firing technologies, modify firing appliances, and combine desulfurization and dust-reduction technologies to limit soot and dust discharge content. It will also strengthen the installation of dust processing equipment. To promote the policy, implementation of energy controls (saving) system relating to firing improvement and growing relevant personnel is important. China's energy saving policies are being promoted by the State Council Energy Conference, the Improving Energy Efficiency and Energy Conservation Agency of the State Economic and Trade Commission, the Improving Energy Efficiency and Energy Conservation Agency of the State Economic and Trade Commission and other government agencies. In 1991, an Energy Saving Information Center was formed by the Resource Saving and General Utilization Agency. The center supports provincial governments, city municipal, universities, and research institutes to hold seminars, with certificates issued to all attendees. However, Chinese regulation does not require the assigning of an energy controller to a coal firing plant or to a plant with a large power consumption. To promote streamlining of energy utilization and energy saving, energy control plants must be designated to implement energy control.

3.5 Incentive for Clean Coal

Energy production in China is increasing due to its economic development. Industrial and economic development in China would be unthinkable without coal. With the continued industrial development and modernization, coal production and utilization are on the increase in China while environmental pollution is expected to expand. Environmental pollutants, especially, large quantities of soot, dust and SOx discharged during coal firing can be attributed mainly to low energy efficiency. Low efficiency lies in the insufficient control of energy in China. Although China has begun to take environmental preservation measures, the firing control and recycling measures taken are insufficient. Other major facts of environmental pollution include consumption of the coal containing a high ratio of sulfur, no coal preparation or coal

washing, and little installation of flue gas desuflfurizers.
Since environmental preservation measures in China cannot catch up with the economic development followed by vast energy consumption, clean production of coal, and high efficient utilization of coal, environmental preservation measures are extremely important. To promote clean production of coal, self-help by the Chine se people and international cooperation are urgent in considering that the environmental pollution and energy consumption in China will affect the entire world. In particular, a quantitative measurement of the relation between the domestic production, energy consumption, and environmental pollution in China must be carried out. Also, possibilities of transferring energy saving and environmental technologies from advanced nations must be discussed to improve energy efficiency and to reduce air polluting factors in China.

4. Current State and Problems in Developing Clean Coal Technologies

4.1 Technologies recently introduced, under Development and to be developed

4.1.1 Combustion technologies

There are three means of coal combustion: (a) firing lump coal like stoker firing, (b) firing coarse grain coal (about 3 mm diameter) as the fluidized bed boiler, and (c) firing fine pulverized coal as the large-scale thermal power generation plant. In recent years, all boilers with a large capacity used for thermal power generation plants have adopted pulverized coal combustion system. In 1992 China had a plan of building 7 large-scaled thermal power generation plants with a capacity of over 500 MW.Due to economic expansion, the number of large-scale thermal power generation plants will increase. Meanwhile, to replace small-scale boilers with low efficiency for residential uses, large-scaled power generation plants will be built to distribute electric power and to supply steam or water to the residential area. In other words, large-scale power generation plants aiming to supply large electric power and heat will play important role to expel the small-scale boilers for domestic use. Some of such cogeneration systems in power plants are put to practical use.

The capacity of stoker boilers accounts for 60% of the total capacity of industrial boilers. The capacity of chain-grate stoker accounts for 20-25% of the total capacity. The stoker boiler is easy to operate but the thermal efficiency is as low as 55%, which is 10-15% lower compared with that of other stoker boilers manufactured in advanced nations. The fluidized bed boiler can fire low-grade coal and/or coal refuse as feedstock. The number of fluidized bed boilers with a steam capacity of 2 to 130t/h and an average of 10t/h bubbling totals about 3,000 units in China. The largest atmospheric fluidized bed combustion (AFBC) boiler was equipped at Jixi Coal Mine. The steam capacity is 130t/h combined with 25MW power plant. In-situ desulfurization in the furnace is available by using limestone or dolomite as a sorbent. Also, denitration effect is available at low temperatures (750 to 900° Ê) and by char and CO in reducing condition. Thus, in-situ desulfurization and denitration are becoming popular as feasible means of low-pollution firing. The main problem in operation is the erosion of boiler tubes and other accessories. The recovery of fly ash should also be improved. According to a re port published, the efficiency was recorded at 80-85% when lignite was used as fuel, 75-80% when bituminous coal or sub-bituminous coal was used, and 70-75% when coal refuse was used as fuel.

The circulating fluidized bed combustion (CFBC) boiler, having a high efficiency of desulfurization and denitration, is operated at a gas flow velocity faster than the above bubbling fluidized bed. Research and development of the CFBC in China has been underway since 1984. A 2. 8 MWt CFBC was constructed at the Institute of Engineering Thermophysics, Chinese Academy of Sciences to supply heat for residential area. Up to 1993, over 100 units of such boilers were sold for industrial use, and 40 units of them are operating, According to a published report, the boiler has a advantage of firing low-quality coal and performing furnace desulfurization and denigration, in addition the annual revenue is one-third to one -half of the boiler cost. Teinghau University has developed two types of internal circulating fluidized bed boilers with a capacity of 6t/h and 10 t/h, respectively. Due to the technology transfer from advanced nations, the Harbin Institute of Technology has also constructed boilers with a capacity of 35t/h, 75t/h, in cooperation with Beijing Babcock and Wilcox. In addition, the Beijing Boiler Factory has manufactured a 65t/h circofluid type boiler in cooperation with Riley Stoker. Moreover, an agreement of constructing two units of pryroflow boilers with a capacity of 220 t/h was concluded in 1994 between Dalian Chemical Industrial Company and Ahlstrom Pyropower. The introduction of an increasing number of upgraded medium- and large-capacity CFBC boilers is on the way.

The current utilization ratio of 28%, or the ratio of coal firing at power generation plants to the total coal production in China, is expected to rise to about -50% in year 2030. At present, it is estimated that coal firing produces 90% of SO2, 70% of NOx, and 73% of soot and dust in China and that coal thermal power generation is the largest source of the air pollution. Without adopting clean coal technology, air pollution will be promoted by increasing coal firing. A method of reducing the environmental pollution is to improve the thermal efficiency at coal thermal power generation plants. The integrated coal gasification combined cycle (IGCC) system and the pressurized fluidized bed combustion (PEBC) system are noteworthy. The PFBC can fire the coal containing a higher ratio of ash and sulfur. Its construction cost is lower than that of the IGCC. However, the desulfurization efficiency is 90-95%, a little lower than that of the ICGG with 40-42% efficient. The efficiency of the 2nd generation PFBC at pilot plants is expected to improve to 45-47%.

Southeast University has been engaging in the development of a PFBC system since 1981. The university has succeeded in operating a 1 MWt pilot test facility for over 700 hours. In addition, the Chinese Government decided to construct a technologically advanced PFBC pilot plant with a capacity of 15 MWe (steam turbine: 12MWe, gas turbine: 3 MWe). Construction of the pilot plant and the operation was scheduled to be complete in 1995. Although development of a 150 NWe class PFBC is expected, there are still many problems that must be cleared beforehand. The problems include erosion, corrosion, fouling at the gas turbine, gas purification at high temperatures, grain handling, and other problems that may arise during a long-term operation. In addition, research and development changes of load and control must be carried out.

4.1.2 Gasification technologies

Coal gasification methods are classified into fixed or moving bed (500–1000° Ê, Lurgi, Slagging Lurgi), which is easy to operate and have records of industrial applications; the fluidized bed (900° Ê, Winkler, HYGAS) which has a long char residence period and a large capacity of processing content; and the entrain bed (1 ,50° Ê, Texco,Shell) which can control the generation of tar and oil constituents and has a large capacity of processing content which is also classified as the slagging bed having a high gasification efficiency and discharging fused ash. Those gasification technologies, except for the Lurgi, has been developed to operate at the atmospheric pressure. However, almost all gasification technologies".† China produces fuel gas, synthesis gas, and city gas, by using coal gasification technologies. All of which are for industrial use. Production of synthesis gas with coal gasification has increased with the development of the synthesis ammonia industry. China, being a leading producer of coal-based synthesis gas, has an annual production of over 20,000 Mm3 of synthesis gas (CO + H2 basis, mainly from coke ovens) based on coal. The nation has been producing feed gas for chemical industries by using the fixed bed water gas generator, which produces coal-base d low calorie fuel gas and synthesis gas.

China has 35 medium-scale fertilizer plants. Of these coal-based plants, 12 plants are discussing their modification, including technology transfer from advanced nations. Since the natural gas reserves in China are limited and also the prospect of gas production using coke ovens is limited, the coal gasification process has a promising future. The existing gas generators in China constitute UGI gasifire (gasification technology at the atmospheric pressure imported in the 1930s from the United States) and fixed bed gas generators including the Lurgi oven. As a recent move, Texaco entrained gasifier (USA), which are embodiments of second generation gasification technology, are being imported into or under construction in Beijing (processing capacity: 1,000 t/day, fuel gas for steel plants), in Lunan (processing capacity \: 1, 500 t/day, ammonia synthesis gas). These are gasifiers with oxygen blown. Lurgi moving beg gasifier be imported at Lucheng ammonia plant. Institute of Coal Chemistry is developing an ash agglomerating gasifier for produce fuel gas or synthetic gas as a state-sponsored key project. Beijing Institute of Coal Chemistry of

Ministry of Coal Industry is developing a 1.6m diameter two-staged water gas generator.

The entrained bed gasifier which accepts high-quality coal and the coal containing many purverulences is used for producing ammonia, metal, and sulfur. Methanol production is about 600, 000t per year. The fixed bed gas generator which accepts low-quality coal is used for producing city gas because the gasifier can produce methane and the gas containing much hydrogen by applying a small quantity of oxygen.

The development of an integrated coal gasification combined cycle (IGCC) is underway in advanced nations due to the shortage of natural gas and due to the environmental controls becoming increasingly stricter, and to improve power generation efficiency. China is discussing the possibility of importing the IGCC.

4.1.3 Pyrolysis technologies

Coal pyrilysis as at produ7cing gas, oil, and char. Dalian University of Science and Technology constructed a 55,00 t/year demonstration plan for lignite pyrolysis at Pingzhuang Mine located in Inner Mongolia and completed a series of demonstration tests by 1993. Also, the Beijing Institute of Coal Chemistry of Coal Industry is developing a different type of pyrolysis process with a capacity of 20, 0-00 5/year at Haila'er in Inner Mongolia.

4.1.4 Coke production technologies

The current 469 units of coke ovens in China consist of large-, medium-, and small-scale ovens. Although their technical levels are different, the average thermal efficiency is about 70%. As of the end of 1992, the production capacity of large-scale coke ovens in a more then 5-meter high carbonization chamber was about 11 Mt. which accounted for 17% of the total coke production capacity. The product ion capacity of medium-scale coke ovens in a 3.0-meter high carbonization chamber is nearly 39 Mt, which accounts for 60% of the total production capacity. Besides those coke ovens, there are substantial numbers of small-scaled coke ovens to meet the local economy. The number of coke ovens account for 70% of the nationwide coke ovens, but account for just over 20% of the nationwide production cap acit76y. In addition, there are old-type production facilities with an annual production capacity of over 20 Mt of open-fired coke. However, these facilities have low efficiencies and waste a lot of resources, polluting the environment. They should be subject to regulatory control. The major pollutants in producing coke in China are dust in coke ovens, wastewater, fly chemicals, and mine waste. Although dust prevention apparatuses and wastewater treatment facilities are installed, their efficiency is low. Desulfurizers and decyanidation facilities are installed in less than 10% of the total coke ovens. Gas combustion at coke ovens of these facilities discharge about 0.2 Mt of SO2 every year.

4.1.5 Briquette technologies

Briquettes for residential and industry use are produced. Briquette includes artificial coal for residential and oval briquette for industrial use. The production of briquette in 1990 was 33 Mt/year for residential use, which accounted for 30% of coal for home use. The production for industrial use was 22 Mt/year. Briquette for residential is mainly hollow artificial coal. In particular, it is used for cooking, heating at home, hot water boiling, and "ondoru" (floor heating system at home in Korea). The production method of briquette is almost the same everywhere in China; anthracite culm containing much ash of 30-40%, 3-30% of clay, and lime for stabilizing the sulfur in coal are mixed before they are put into the compacting machine. Drying treatment is not always applied after molding and then much of the briquette is cracked during transportation and before putting into the coal cooker. The combustibility is also low. Thus, the quality of artificial coal factories must be improved.

Oval briquette is produced at low-pressurized molding machines, and the production volume is small, because it constitutes coal containing a high ratio of ash ad clay more than artificial coal, the quality and the hardness are low. Development of oval briquette for industrial use has been underway since the 1950s. The production volume ranges from 1,000 t/year to 25,000 t/year. In the central area of metropolitan cities, gas supplying systems and central heating systems are expected to become popular. In the suburbs of metropolitan cities, medium-and small-sized cities, and rural areas, demand for briquette is expected to increase. Thus, desulfurization and caking rate of briquette must be improved. Also, beside s the development of a caking agent, a combustion oven for producing briquette, which discharges less air pollutants, must be developed. Recent briquette technologies include the production of smokeless artificial coal and briquette. These products are made from smoking coal which is carbonized at 400° Ê or so. Most of the existing briquette machines are capable of compressing briquette at 0.2 to 0. 3 t/cm2. This type of briquette machine is used to compress the mixture of coal and biomas (vegetable fiber material) to which a desulfurization agent is added. The mixture is molded into a biocoal. As clean solid fuel, biocoal has excellent combustibility, and contributes to a substantial reduction of soot and dust and SOx discharges.

4.1.6 CWM production technology

Because the CWM technology can deal with fluid coal, it faces no disadvantage of handling solid materials in transportation and deposit. In other words, only pumps, pipeline, and tanks are needed for coal hoisting, coal transportation, and coal stocking, and no other extra facilities are required. Containerized fluid coal can prevent coarse particulates from scattering, preserving a clean environment. In addition, fluid coal can be used directly as fuel for boilers without draining. China has begun to develop a high-density slurry since 1981. In particular, the Beijing Research Department of China College of Mine was engaged in developing a production process and an additive evaluation, while the Institute of Energy of Zhejiang University was engaged in the evaluation of combustibility and boiler designing. The Tangshan Branch of the Chinese Institute of Coal chemistry was engaged in the evaluation of luid flow in pipelines. China has 6 CWM production plants including those under construction and 1 Mt CWM under construction. Besides the two plants, which are operated with technical assistance by Japan and Sweden, China has designed, constructed, and operated the remaining CWM production plants by itself. CWM combustion is carried at 10 t/h, 35t/h, and 60t/h capacity industrial boilers for steam generation. CWM is also used for 150 MW class power generation boilers, for heating at steel plants, and for melting. To pro mote the CWM utilization, a number of large-scaled pipeline projects, boiler design projects, and modification projects is underway.

4.1.7 Desulfurization technologies

China, the largest consumer of coal in the world, discharges 16.8 Mt of SO2. SO2 causes acid rain at some parts of China. Since 1992 the total emission control has been strengthened. Although SO2 discharge from fuel has been charged with penalty since 1994, the number of desulfurizers installed are still short, and SO2 discharge continues. To improve the situation quickly, the transferring flue-gas-desulfurization (FGD) technologies into China are necessary. The fluidized bed-firing boiler is an effective means of desulfurization. For large-scale business, a bubbling fluidized bed-firing boiler with a capacity of 350 MW, the largest capacity in the world, will be operating in 1995 in Japan. This type will still take some time to spread. Installing FGD is a realistic means of reducing SOx. Currently, the wet desulfurizer process is most popular. The dry process and semi-dry desulfurizer process can be used for 300 MW. Desulfurization in furnace by spray sorbents can be used for from 300 MW to 600 MW. The wet desulfurizer process is typical because it can recover useful by-products. However, the wet process technology's installation and operation is costly. Also, the technology requires a water supply system and a drainage system for operation. Thus, the wet process technology has certain limits to be installed. The only wet desulfurizer process for practical use was installed in a power generation plant in Chongqing. This desulfurizer adopts the wet process lie-gypsum desulfurization technology transferred from Japan. The technology that meets the current situation in China must satisfy the conditions as follows: such as the desulfurizer must be economical; the technology must be complete or close to completion; the desulfurizer must be easy to operate and maintain. Specifically, the following methods are promising; the rolling spray dryer method (semi-dry process), calcium spray into furnace, simplified lime-gypsum method (wet process), and the ammonium phosphate fertilizer method (activated carbon method + compound fertilizer method).

4.1.8 Dust collection technologies

Electrostatic precipitator, water-screen dust collector and bag filter are installed into the boilers of a power generation plant in China. However, the particulate collection efficiency is not sufficient. Thus, it is needed to spread more efficient electrostatic precipitators and to improve the dedusting efficiency of water-screen dust collectors and their operation. The electrostatic precipitators adopted in advanced nations have a high dusting performance and their operational costs are lower compared with other types of dust collectors. However, they are vulnerable to physical and chemical influences of exhaust gas because of electric processing, and require sufficient experiences before operation. On the hand, bag filter are applicable to soot and dust under conditions except for extreme deliquescence, high dew-point gases, and high temperatures.

4.1.9 Denitration technologies

Any denitration apparatus is not installed in China. NOx in the gas discharged from boilers contains NO and No2. NO accounts for 95% of NOx. Usually nitrogen in coal constitutes 0. 5 - 1.5%. NO is generated when nitrogen in coal and the air is oxidized. If no denitration treatment is made, Nox to be generated will range from 300 to 1,500 ppm, depending on the firing condition. When the flame temperature is lowered or when the density of the oxygen in firing, residence time, or the nitrogen content is reduced. NOx production is grealty reduced. Thus, when a low NOx burner, exhaust gas circulation, two-stage combustion, combustibility improvement, or catalyst stack-gas denitration equipment is introduced, NOx can be reduced. Combustion improvement measures are recommended to reduce NOx because the de NOx equipment costs too much to install. China is also discussing possibilities of importing an electronic beam radiation-ammonia (EB) process technology from Japan, the United States, France, or Germ any. This technology will remove 85% of NOx and 95% of sulfur and generate fertilizer as a by-product.

4.2 Current State and Problems in Capability of Technology Development

4.2.1 Environment preservation measures

In 1992, the exhaust gas smoke and dust collection rate of fuel combustion in China recorded 85.7% The exhaust gas clarification treatment rate of fuel combustion was 68.9%. The soot and dust emission standard achievement rate from industrial boilers recorded 75%. The soot and dust emission achievement rate of kilns in the ceramic industry was 51.3%. The industrial wastewater standard achievement rate of kilns in the ceramic industry was 51.3%. The industrial wastewater standard achievement rate was recorded at 52.9%. These figures indicate the implementing of environmental control in China has been gaining. However, it cannot catch up with the rapid economic development and increasing demand for energy. Unless environmental preservation measure are implemented, the demand for coal, waste g as and wastewater are afraid to increase, leading to more serious air and water pollution problems than today.

4.2.2 Organization and human resources

Since 1992, the Chinese Government has introduced a simplified and more efficient organizational structure and transferred powers to it in order to reform the government organizations into a more functional and effective system. For example, the Energy Department was dismissed and its powers were transferred into units of the National Planning Commission. However, it is recognized that the newly created energy related government organizations would be provisional. Regarding coal utilization, the Fuel Coal Industry Department is responsible mainly for the development and utilization of coal resources, promotion of the coal market, improvement of management skills based on scientific and technical developments, and improvement of management efficiency; the Electric Industry Department is responsible for the management of thermal power generation, hydro-power generation, hydro-power generation, and the power generation business in regions. The Nuclear Industry General-Directorate is responsible for the construction of nuclear power generation plants. When there is a plan to construct a power generation plant, the master plan to be submitted by the metropolitan municipal government will be examined by the responsible department (for example, Electric Power Industry Department) before it is submitted to the National Planning Commission for approval.

4.2.3 International cooperations

International cooperation relating to coal utilization involves many companies in the coal utilization sector, hence describing the entire activity is difficult. As some example, according to joint international researches on coal utilization technologies being promoted by the Chinese Institute of Coal Chemistry, a direct coal liquefaction technology project and a coal gasification technology project are being transferred from Japan, Germany, and the United States. In addition, Canada is cooperating with China to transfer a coal and waste oil simultaneous smelting technology, while Denmark is engaged in a joint development to change coal gas into methane. Many projects to be carried out in the future are being discussed. These projects include a CWM production technology from slurry and combustion technology project, manufacturing technology of industrial-use briquette from brown coal and slurry, coal cleaning technology for high sulfur coal (desulfurization technology), general utilization technologies of coal refuse, and utilization technologies of heavy tar discharged from coke plants.

The stage that the Chinese Government should discuss inevitable international cooperations in the environmental area has already passed. Both government and private sectors are boosting international cooperation in areas of high efficient power generation projects and environment preservation technology projects. In transferring technologies from overseas in order to achieve an effective and efficient transfer of technologies, the transferring party and the transferred party must have sufficient knowledge of their social structure and lifestyle, including production management and organization management skills. More specifically, a technology transfer system must be formed in China so that coal utilization technologies and environment preservation technologies will be rooted in China and that China will be able to promote relating technologies by itself in the future. Also, through international cooperation agencies for less developed nations including China, advanced nations are recommended to offer opportunities for education and training.

Educational training for on-site engineers and for managers with joint research activities, the fossil fuel life cycle study relating to the global environment and other relevant education and joint study programs must be provided for government officials in charge of making the policies. In other words, through international cooperation, roles and contributions by China must be defined more clearly.

4.2.4 Execution of development

A new industry is expected to emerge in China to solve the environmental pollution problem. More specifically, industrial development areas are expected to unite with scientific research. For example, Yixing was approved in 1992 by the State Council as an industrial area for environmental science technology development out of the 52 advanced technology development areas. The Chinese Government is hoping to increase international cooperation in the environmental area. The environment related industrial facilities are expected to promote machine processing, industrialization, and internationalization of scientific researches and environment related technologies. I addition, it is important to educate and train on-site engineers of coal utilization technologies and facilities as well as to educate engineers and managers involved in measurement and improvement technologies relating to the environment. Nationwide education through relevant agencies is strongly desired.

5. Development Strategies and Counter-measures for Clean Coal Utilization

5.1 Policies of Energy and the Position of Coal

China has achieved an average 9.5% GNP growth in real term over last 10 years. The similar economic growth is expected to continue until year 2000, and then average 7% GNP growth per year. However, the energy production has indicated average 4.9% growth per year over last 10 years. The energy elasticity per GNP was 0.5 5% in average. In other words, China is achieving high economic growth while deploying corresponding energy saving measures. The nation will continue to modify technologies and import new technologies to save energy.

The Chinese Government is also promoting aggressive energy resource developments. The energy policy is mainly based on coal and sets a goal of 1.4 Gt coal output in year 2000. China changed in position to an oil importer in 1993. Considering the subatantial increase of automobiles in China in the future, the saving of oil and improving the utilization efficiency are urgent for the time being. The growth rate of electric power consumption has increased rapidly compared with the growth rate of the primary energy consumption. The fact indicates that with economic growth, energy consumption has been shifting from direct consumption of coal to indirect consumption of coal by the electric power generation industry. Brokendown, the coal thermal power generation ratio is unchanged and accounts for 75% of the total coal consumption in the power generation industry. The role of coal as being a vital factor in China's continued economic growth is believed to continue. Thus, the environmental pollution brought about following coal production, transportation, and consumption is urgently needed to be resolved. The Agenda 21 that the Chinese Government formulated in October 1993 discusses the following four plans relating to energy issues.

(a) Comprehensive energy plan and control
It is necessary to formulate a comprehensive plan on energy, environment, and economic development, which fit China's situation and the socialist market economy, and to increase the ratio of clean energy and high efficient energy by improving the energy supply structure.

(b) Improving energy utilization efficiency and saving energy
It is necessary to achieve an annual energy saving rate of 4% or higher by controlling energy resources. Likewise, it is necessary to save energy by efficiently producing and transporting coal, and by adopting large-scaled high-efficient thermal power generation, central heat supply, and cogeneration.

(c) Developing clean coal and a mining technologies which relieves the burden

on the environment
It is necessary to develop and spread a coal washing technology and a high efficient combustion technology, to generate electric power at coal mining sites, to reduce transportation volumes and environmental load through coal gasification, to develop dedusting and desulfurization technologies and to promote their demonstration projects, and to spread briquette and city gas.

(d) Developing new energy resources and recyclable energy
It is necessary to promote the development of hydro-power generation. Likewise, the development of wind power generation and biogas power generation in rural areas must be performed.

5.2 Suggestions for Solving the Problem of Coal Production and Transportation

5.2.1 Mining
- Regarding over 100 coal refuse and other waste stacks having natural firing, strengthen fire extinguishing activities to end as early as possible.
- To prevent repeated firing, plant trees fit for the location and climate on the coal refuse stack. Through the afforestation, the air pollution caused by SO_2, H_2S, and soot and dust will be reduced substantially.
- Annual discharge of coalbed methane gas totals 6,000 Mm^3 or more, thus it is important to collect the gas as much as possible to prevent local warming. The gas recovery technology has been transferred from the United States. The inclusion of technical development will help to improve the gas collection rate substantially.

5.2.2 Coal preparation
- The coal preparation rate in China is about 20%. China seeks to raise it to 45%, the level of advanced nations, then ultimately to 100%.
- By washing coal, the reduction of ash and sulfur, the raising of heating value, and the reduction of the pollutant gas emission in combustion is possible. By reducing the content of ash in coal, a reduction in the transportation load is also made possible.
- To improve the coal preparation rate, set reasonable price differences

according to coal quality.

5.2.3 Transportation

- Increase coal processing near the coal mining site to reduce the transportation of raw coal.
- Construct large-capacity power generation plants near coal mining sites and transmission lines to supply electric power to consumer areas. Also, construct thermal power generation plants that consume low-quality coal generated from coal washing.
- Produce CWM (coal water mixture) near the mining site before transporting to consumer areas, such as coastal areas, through pipelines.
- At the mining sites where fine coal is produced, process the fine coal into briquettes (oval coal) before transportation. Such briquettes must be molded in the form and hardness that can withstand transportation.
- Change coal into gas at the mining site before transporting to consumer areas through gas pipelines.
- To select an optimal method from the above methods, conduct a sufficient feasibility study.

5.3 Suggestions for Solving the Problem of Coal Utilization

5.3.1 Improving utilization efficiency

Direct firing of coal accounts for 84% of the coal consumption in china. The average coal utilization efficiency is 22%, a very low percentage compared with that of advanced nations, Thus, to solve environmental pollution problems, the main theme is to make a substantial improvements of coal utilization efficiency. Its concrete methods are shown below by coal consumption sectors.

(1) Industrial sector

- Increase the ratio of electric power as a power source. Put together the boilers that supply the necessary steam and hot water by the region and gain the scale merit. Abolish old and low efficiency small-type boilers step-by-step. In constructing large-scaled boilers, promote the cogeneration of heat and electric power.
- Check for boilers, coke ovens, and kilns being operated. Based on the result,

modify some of the facilities according to the annual plan formulated, and check for progress of the coal consumption rate improvement every year.
- Strengthen and rearrange regulatory measures relating to the current energy saving and energy controls to insure efficiency improvement. Apply the two improvement measures mentioned above to the power generation sector.

(2) Power generation sector
- Corresponding to the arrangement of electric power transmission systems, upgrade the unit power capacity of new facilities to 600 MW to 1,000 MW. At the same time, if possible, install a large-capacity cogeneration system of heat and electric power for industrial use and residential.
- Set a goal of higher efficiency by construction of a new energy-saving electric power generation facility with super-critical steam conditions, although this requires a large amount of initial investment.
- In expanding large-capacity and high efficiency power generation facilities, for the time being, foreign capital investment and technical transfer (BOT or BOO) would be inevitable. Promote localization through technical cooperation with f oreign companies through regulatory assistance.
- To reduce increasing coal consumption in China, accelerate the development of large-capacity hydro-power generation and nuclear power generation.

(3) Residential sector
- Urge spreading of city gas in city areas to reduce the environment pollution caused by direct firing of coal.
- In regards to city gas, select coke oven gas, carbonized oven gas, or Pressurized Lurgi oven gas, etc. according to the coal type.
- In case of using coal, select a briquette (artificial coal, oval coal) Containing sulfur stabilization agent and the relevant firing apparatus.
- Put together hot water supply boilers for heating by the region to shift to a large-capacity system, if possible.
As mentioned above, by improving the coal utilization efficiency, reduce coal consumption by the unit output, thus contributing to the reduction of environmental pollutants. Moreover, when the capacity of coal combustion facilities are upgraded, pollution sources will be localized. This will become advantageous to take environmental measures from economical viewpoint.

5.3.2 Adoption of flue gas treatment technologies

(1)Combustion system

- For a new large-capacity boiler like a thermal power generation plant, install an electric dust collector designed for the coal type to be used.
- For a relatively new small- or medium-capacity boiler like industrial boilers, install electrostatic precipitator or bag filter according to the type and capacity of the boiler and the coal type.
- For the time being, the soot and dust concentration in flue gas is subject to the emission control standard (250 to 300 mg/Nm3) or less enacted in 1992. Research, development, and operation data must be collected to set the future goal to 100mg/Nm3 or less.
- Publicize step-by-step regulatory measures to strengthen the emission control for the existing boilers. For example, the boilers with a capacity of 10t/day coal consumption or more should be subject to the emission standard after year 2000,and after 2010,all the boilers for industrial use should be subject to the emission standard. Such step-by-step measures will promote putting together small-type boilers.

(2)SOx removal system

- Place the business operator of a large-capacity boiler that is newly installed for power generation under an obligation to install a desulfurizer as early as possible. However, to deter the additional cost following the installation of the desulfurizer, operating cost, and the subsequent increase of electricity chargs, for the time being, allow to install a simplified desulfurizer with an efficiency of 60 to 70% and an SO2 discharge density of 300 to 400 ppm.
- For new installations of boilers for industrial use, adopt circulating fluidized bed boilers for industrial use to perform in-situ desulfurization because thistype has gone under commercial production in China. In implementing a SO2 emission control, introduce a subsidization measure (preferential taxation, interest subsidization, etc.) to promote, and to spread simplified desulfurizers, of fluidized bed boilers.
- For the plants and power generation plants where a boiler with a cetaincapacity or above is being operated, plan to implement an SO2 discharge control after a certain calendar year (for example, year 2005).

(3) NOx removal system

- NOx is one of major pollutant relating to acid rain. The NOx concentration in the air is afraid to rise with a rapid increase of automobiles. Thus the NOx emission from both the movable source of pollution like automobiles and the stationary source of pollution like power generation plant and boilers must be regulate d. However, immediately installing deNOx equipment with a boiler is not realistic because it requires a large capital investment.
- As a realistic NOx counter-measure, it is possible to reduce the NOx discharge density to 300 to 600 ppm, or about a half of the current discharge density, by adopting a low NOx burner, a multi-stage combustion system, or a low ratio of air combustion, and other new combustion improvement technologies for a newly installed boiler at power generation plants, etc. This requires a relatively small amount of initial investment.
- Low combustion (800 to 900° Ê)in the fluidized bed boiler enables to deter NOx generation at low level.

(4) Management system

- To promote steady environmental pollution prevention measures, assign an environmental pollution prevention controller to the power generation plants.
- In parallel with enacting environmental regulations, an environmental pollution prevention controller shall cooperate with an energy manager to play a leading role in formulating an operation, management, and modification plan of boilers, etc.
- It is essential to educate a large number of people with specialty knowledge by rearranging school education and the certified qualification system as early as possible.

5.3.3 Improving energy pricing

Huge capital investment is expected in to boost energy production and introduce environment preservation measures. To continue and justify an enlarged reproduction or additional investments, coal price, electricity charge, and other energy prices must come closer to the international market price or be raised gradually to a reasonable price based on production cost. In other words, the pricing policy must be formulated by reflecting the economic conditions of China.