China National Energy Strategy and Policy 2020

Subtitle 6: Energy，Environment and Its Public Health Impact

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Executive Summary

The Chinese Central Government has put forth the goal of "building a well-off society in all-round way" by 2020. The environment plays a critical role in achieving this goal. As the pace is speeding up to achieve this goal, stricter requirements for energy production and energy consumption have been put forward. China has become a big country of energy production and consumption in the world.

Energy development and environmental production is of momentous significance to China. On the one hand, in "building a well-off society", China's energy need is in the continuous growth stage; on the other hand, the energy structure and great energy consumption strength pose a heavy pressure to China's air pollution prevention. In the future 20 years, China's energy development is faced with four environmental challenges: environmental constraints, environmental capacity, environmental management constraints, and global climate change. The Chinese Government and energy production and consumption sectors must face these challenges and pressures, formulate appropriate policies under the guidance of scientific development outlook and take some measures to minimize the impact of energy development and environmental health.

1. Energy activities have caused tremendous hazards to environmental quality and public health

China's traditional coal-based energy structure has resulted in large quantities of pollutants emissions in the energy consumption and a deteriorating urban environment. This has not only increased operation costs, but also seriously threatening people's health. The impact of energy activities on the environment and health will be one of the major problems for future development of Chinese society and economy.

1) Primary cause: Coal based energy structure

China's energy source condition has determined that our country's coal based energy consumption structure will be difficult to change in the short term, and in the future coal will still play an irreplaceable role in the whole energy process.

Due to lack of incentives for the production and consumption of washed coal, 80 percent of coal consumption is through direct burning of raw coal. In China, 60 percent of coal is for power generation. Due to nvarious reasons, coal combustion pollution of thermal power industry is still not regulated. At present, urban residents in some regions burn coal to cook meals or warm themselves and central heating in residential areas and business zones is mostly supplied by small coal burning boilers. With the development of the third industrial sector, such as the food and beverage industry, the number of eating facilities and restaurants that use coal based cooking ranges continues to increase. Therefore, industrial and residential coal-fired boilers are the main cause of extensive indoor and outdoor air pollution.

Numerous low-efficiency coal burning equipment, traditional coal consumption methods, and low coal quality and insufficient pollution controls that burning coal pollution will still be the main part of air pollution in quite a long period in China and also determines that burning coal pollution as a result of energy structure will be difficult to be effectively and comprehensively controlled in the near term.

2) Manifestation: discharge of pollutants is difficult to be reduced

(1) Discharge of air pollutants

In China, air environmental pollution is directly related to energy consumption and the pollution produced from coal consumption is China's biggest air environmental pollution problem. 70 percent smoke dust emission, 90 percent sulfur dioxide emission, 67 percent nitrogen oxide and 70 percent carbon dioxide in China are from coal combustion. In 2000, China's total energy consumed reached 1.3 billion tce, emission of sulfur dioxide was 19.95 million tons and emission of smoke dust is up to 11.65 million tons. It is observed that the emission of major air pollutants in China ranks first in the World.

During exploitation, refining and supply, energy may also produce a great deal of harmful gases, seriously affecting air environmental quality. In 2000, smoke dust emitted from the industries related to energy production accounted for 29.8 percent of the total emission of smoke dust in China, which caused severe pollution to the air environment.

(2) Discharge of water pollutants

Statistics show that coalmines in China produce various wastewaters every year, accounting for 25 percent of the total quantity of wastewater. In 2000, wastewater discharged from coal mines in the country reached 2.75 million tons including 2.3 billion tons of mine water, 350 million tons of industrial wastewater, 50 million tons of coal washing wastewater and 45 million tons of other wastewater [(1)].

(3) Emission of carbon dioxide

Emission of carbon dioxide is closely related to energy structure, consumption and energy efficiency. China is the second largest of carbon dioxide emission country only next to the United States. From 1990 to 2000, China's carbon dioxide emission was increased from 666 million tons of carbon to 881 million tons of carbon and from 11.6 percent of global emission to 13.7 percent (according to Japanese Research Institute of Energy Economy). Due to a great population, China's carbon dioxide emission per capita is lower than world average level; in recent years, thanks to improvement of energy utilization efficiency and continuous technical progress, carbon dioxide emission for 10,000 Yuan GDP is gradually decreasing.

3) Impact: high economic and public health cost

(1) Causing air pollution and acid rain pollution

Pollutants emitted from utilization process of large amount of energies (especially coal) have caused severe deterioration of urban air quality in China. World Bank development report in 2001 listed the most seriously polluted cities in the world, of which 16 are in China. Particulates closely related to coal are still the main pollutants affecting China's air quality. Among the 341 cities in 2002 statistics, 64.1 percent cities have annual average concentration of particulates exceeding national Grade 2 air quality standard and 101 cities have annual average concentration of particulates exceeding Grade 3 standard, accounting for 29.2 percent cities in the statistics.

Research shows that acid rain in 1990s in China was sulfuric acid type. The sulfur dioxide emitted from such human activities as coal burning is the main cause of acid rain. In mid-1990s, the area affected by acid rain increased 1 million km^2 compared with 1980s, and the area with pH of annual average precipitation lower than 5.6 was only around 30 percent of total area in China.

(2) Economic cost of energy pollution

China started to research the economic loss caused by environmental pollution since 1980s. Synthesizing the research findings of different research institutes, China's air pollution loss is already 2-3 percent GDP. World Bank predicts according to present development trend, that China will have to pay an economic price of 390 billion Yuan for diseases resulting from burning coal pollution in 2020, accounting for 13 percent gross domestic product, which shall draw high attention from Chinese Government.

At present, the main pollutant causing air pollution loss in China is sulfur dioxide. In calculation of sulfur dioxide pollution loss, what is most referred to is the findings of *National Acid Rain Control Scheme* completed by Chinese Research Academy of Environmental Sciences: acid rain and sulfur dioxide emission in 1995 resulted in a loss of 110 billion Yuan.

(3) Impact of air pollution on health

In the regions with serious air pollution, total death rate and incidence rate of respiratory diseases are both higher than those regions with light pollution. Symptom of chronic bronchitis is worsened with increase of air pollution. In the eleven biggest cities in China, smoke dust and fine particulates in air result in an early death of 50,000 people and cause 400,000 people to be infected with chronic bronchitis.

In recent years, not a few scholars in China have conducted research of the impact of pollutants produced from different fuels through combustion on human health. Wang Lihua et al. investigated some cooking women aged 40-65 in Beijing City and have found that, of the women of coal burning households, 50.4 percent have developed respiratory system diseases while 40.0 percent for gas cooking households ($P<0.05$), relative risk factor is 1.94[(2)]. Southwest region in China is the important production area of high sulfur bituminous coal. Investigation conducted for a village in Guizhou Province in Southwest China shows that with open kitchen range of coal combustion, concentration of sulfur oxide, arsenic and fluorine in indoor air exceeds standard for 3.2-64 times and arsenic and fluorine content in corn and pepper stored indoors exceeds 1.1-1126 times [(3)]. In most villages and medium- and small-scaled towns in China, cooking and heating with open kitchen ranges is very common and indoor air pollution caused wherefrom is very serious.

2. Environmental challenge of energy development strategy

China's future economic and social development needs appropriate energy development to provide support and guarantee while energy development will be sure to increase the risk of environmental quality deterioration. With the raising of the objective of all around construction of moderately well off society, improvement of environmental quality has become an important part of people's pursuit of happy life. Therefore future energy development in China must satisfy the environmental requirement and confront the environmental challenge.

1) Substantive energy consumption makes it difficult to achieve the goal of environmental well-off

Environmental well-off is one of important contents for China's all round realization of moderately well off society in 2020. However, energy development and increase of coal utilization will consequentially cause increase of air pollutant discharge. Increase of urban motor vehicles also results in increasing aggravation of motor vehicle pollution. Control objective of urban air environmental quality and regional acid rain pollution required by environmental well-off is facing a great threat. The requirement of environmental well-off has put forward a severe challenge to China's energy development.

According to prediction, by 2010, China's coal consumption will reach 1.69 billion -1.99 billion tons while in 2020 raw coal consumption will reach 20.5 million-290 millon tons. It is obvious that energy need has a greatest potential pressure to environmental quality. If we do not take effective measures, pollutants produced from energy activities will continuously increase and the objective of environmental well-off will be difficult to achieve. If estimated based on high value of coal consumption, production of sulfur dioxide, nitrogen oxide and carbon dioxide in 2020 will increase 49 percent, 116 percent and 66 percent respectively compared with 2000.

Pollution of pollutant emission and motor vehicle tail gas emission brought about by energy development is mainly concentrated in urban areas and urban population is the major victim of urban air pollution. If urban air environment is not effectively treated and air environmental quality continues to deteriorate while energy is being developed, the population affected by air pollution will be 340 million in 2010 and 490 million in 2020, accounting for 24.7 percent and 33.3 percent of the total national population in the same period respectively. If environmental quality continues to deteriorate in the upcoming 20 years, the number of urban peoples of early death due to air pollution will be increased. The urban population of early death due to air pollution in 2010 and 2020 in China will reach 380,000 and 550,000 respectively and corresponding economic loss will be 28 billion and 41 billion Yuan respectively.

2) Insufficient pollution control will lead to continuous deterioration of environmental quality

With continuous growth of total energy quantity consumed, generation of sulfur dioxide and nitrogen oxide will also keep increasing, but resource of air environmental capacity is limited.

According to research made by Chinese Research Academy of Environmental Sciences, only if national energy structure, industrial structure, urban layout and meteorological condition are not significantly changed and Xinjiang and Tibetan region are not considered and national SO_2 discharge is controlled at 12 billion tons, can SO2 concentration in most Chinese cities reach Grade 2 national standard. The research of "National acid rain control scheme" made by Chinese Research Academy of Environmental Sciences shows that in order to meet the requirement of critical load of sulfur deposition, China's annual total SO_2 emission shall be controlled at 16.2 million tons. However, according to the prediction of pollutant emission resulting from energy development, even if calculated based on low development scheme, production of sulfur dioxide will still reach 26.8 million tons and 27.8 million tons in 2010 and 2020 respectively. If calculated based on high development scheme, it will also reach 31.74 million tons and 39.45 million tons respectively, both far exceeding the environmental capacity required by environmental objective.

According to analysis, when sulfur content of coal is 1 percent, only when desulphurization percent reaches 75 percent, can upper limit of coal consumption reach 2.82 billion tons, which approaches the predicted high coal utilization scheme in 2020. Therefore considering environmental capacity of sulfur dioxide, China only has two ways to go in order to increase coal consumption: one is to increase desulphurization efficiency and the other is to decrease sulfur content of coal. In view of the less-than-10 percent desulphurization percent of power industry in 2003 and China's coal quality condition, it is very difficult to bring about the above objective.

At present the state has not implemented total quantity control for nitrogen oxides. It is predicted (low scheme) that only the nitrogen oxides produced from coal combustion may increase from 18.8 million tons in 2000 to 24.67 million tons and 28.7 million tons in 2010 and 2020 respectively. If the nitrogen oxide emitted from automobile tail gas is added, the generation of nitrogen oxides will further increase in the next 20 years. Hence, the task of reducing the emission of nitrogen oxide in the next 20 years will be severer than that of reducing the emission of sulfur dioxide.

3) Increasingly strict environmental requirement results in inability of energy dependent enterprises to exist

During the 10^{th} Five-Year Plan period, China's control objective of total quantity of major pollutants has changed from "balance" in the 9^{th} Five-Year Plan period to "10 percent decrement" in the 10^{th} Five-Year Plan period. Whether "balance" or "10 percent decrement", it is required that pollution control speed exceed economic growth rate. According to this requirement, sulfur dioxide will decrease from 19.95 million tons in 2000 to 18.2 million tons in 2005 in China's 10^{th} Five-Year Plan period.

As far as power industry is concerned, it is the key to realizing decrement control objective for new and old units to take control measures simultaneously for the purpose of reducing 10-20 percent SO_2 emission in 2005 compared with 2000. In order to attain the total quantity control objective, desulphurization units shall be at least 23 percent of total thermal power generating units. It is expected that it would be impossible to achieve this goal in the upcoming two years. To realize the SO_2 reduction objective of power industry in the next 20 years, the thermal power generating units with desulphurization equipment (FGD) will have to be 70 percent of total thermal power generating units (calculated based on installed capacity), thus desulphurization task of thermal power plants is very onerous.

The new "Emission Standard of Air Pollutants for Thermal Power Plants" issued and put into practice in 2004 greatly increases the emission limit of sulfur dioxide with reference to international advanced standard. Regardless of sulfur content of coal, new thermal power plants will not be up to standard unless they adopt FGD equipment. Old thermal power plants will implement the standard of the same period after forenotice period, and must carry out desulphurization as required except in buffering construction period. At the same time, the standard also proposes requirements for reduction of nitrogen oxides of thermal power plants.

Therefore, energy production and consumption enterprises, especially thermal power generating industry, must take active and effective measures to reduce emission of pollutants and improve environmental behavior, which not only satisfies the need of environmental management but also is the need of enterprise's long-term development and competitiveness strengthening. In the future market competition, green enterprises and green products will undoubtedly have significant advantage.

4) Fulfillment of international conventions will make energy sectors pay high economic cost

According to analysis and predication of "Analysis of China's energy need in 2020" by the Energy Research Institute of the State Development and Reform Commission, emission of carbon dioxide in 2020 in China will be 1.3 billion tons to 2 billion tons and carbon emission per capita will be 0.9 to 1.3 tons. With increase of reduction level of greenhouse gases, marginal reduction cost of carbon dioxide will tend to increase. By 2020, even for the goal of 10 percent reduction, annual reduction cost needed will reach more than 50 billion Yuan.

In terms of carbon emission control and reduction, energy departments have inescapable responsibility and obligation. Economic investment and external diseconomy required for emission reduction of greenhouse gases will force China's energy sectors to reposition in development process and will generate a certain impact on China's overall economic development.

3 Energy and environmental sustainable development policy project

For the next 20 years, China's objective of energy environmental policy is to minimize environmental cost caused by energy production and consumption, protect public health and good natural environment, slow down emission of global greenhouse gases, actively promote establishment of hydrogen energy and hydrogen economic and social system and realize sustainable development of energy and environment under the precondition of ensuring all around construction of moderately well off society and guaranteeing state energy security.

To achieve the above objective, China's energy environmental strategy in the next 20 years is:

- **Raise energy conservation to the height of basic state policy, establish energy efficiency standard and identification system for terminal energy consuming equipment and establish new energy conservation mechanism under market economic condition;**
- **Push environmentally friendly energy strategy by governmental drive, public participation, total quantity control and pollution emission trading;**
- **Raise pollutant emission charging standard, implement emission trading and electric power environmental protection discount, cancel production subsidy for high energy consuming products and realize internalization of energy environmental cost;**
- **Rely on scientific and technical progress to carry forward energy structural readjustment and energy greening, strictly control urban traffic environmental pollution and actively respond to the challenge of global climate warming.**

1) Energy and environmental sustainable development policy matrix

Viewing from China's energy development trend and environmental protection requirement, to realize harmonious development of energy and environment, it is necessary to implement long-term energy conservation preference strategy, push on the greening progress of energy structure, all out develop environmentally friendly energy and hydrogen energy and carry out sustainable development of rural energy.

Carry out energy conservation preference strategy. Long-term implementation of energy conservation preference strategy is the preferred policy of harmonious development of energy and environment. It is suggested to accelerate harmonization of energy conservation management system and government institutions shall take the lead in demonstration of energy conservation to facilitate the integration of energy conservation and clean production and take the advantage of pollutant emission charging policy to facilitate the implementation of energy conservation policy.

Facilitate greening of energy structure. Establishment of environmentally friendly energy structural readjustment is the long-term task of China's energy sustainable development and the necessary requirement of China's social and economic development and environmental protection. It is suggested to gradually reduce the utilization rate of urban energy coal and vigorously develop low carbon and carbon-free energy, hydrogen and renewable energy.

Rely on technical progress to further reduce pollution. On the one hand, utilize environmental standard to drive energy technical progress, reduce energy consumption of unit economic activities and realize linkup between power generation emission performance and power generation coal consumption standard, between environmental label and energy efficiency standard and between automobile emission standard and fuel economical efficiency standard; on the other hand, vigorously develop low-pollution emission power generation technology, zero-emission technology and high-efficiency desulphurization and decarburization technology, accelerate increase of automobile tail gas emission standard and develop low-emission and even zero-emission automobiles.

Exercise economic means to promote environmentally friendly energy. During establishment and perfection of market economy in the next 20 years, it is necessary to exercise comprehensive market economic means to control pollution and promote energy sustainable development. Market means can be started with the following aspects: first, utilize such tax and price policies as sulfur tax, nitrogen tax, ecology environment compensation and power environmental protection discount to realize environmental cost internalization of energy activities, and second, utilize such market means as pollutant emission trading, green electric power market and renewable energy source quota to reduce social cost of pollution.

2) Several suggestions on important power policy scheme

(1) **Accelerate power desulphurization progress**

Reduction of sulfur dioxide and nitrogen oxides for thermal power industry in the upcoming 20 years will be directly related to the achievement of the state air pollutant total quantity control objective and the favorable turn of acid rain. It is suggested that emission control objective of sulfur dioxide and nitrogen oxides for China's electric power industry in 2020 should be controlled at 5.9 million tons and 7.65 million tons respectively.

At present, emission reduction of sulfur dioxide for thermal power plants mainly adopt the following ways: coal washing, clean coal combustion technology, burning of low sulfur coal and flue gas desulphurization. Selection of various technologies and combination of emission reduction methods are a comprehensive judgment and decision making process.

China's coal fired power plants started to control the emission of nitrogen oxides not long ago and national emission standards proposed limit requirement of NOx emission for new built large coal fired power plants only in January 1997. While a large quantity of advanced high capacity coal fired power generating units were being introduced in mid- and late 1980s, the manufacturing technology of boiler low NOx burners were also introduced, based on which low NOx combustion system was developed in combination with Chinese coal quality and pulverization system. Presently, some capable regions are spreading low nitrogen combustion technology and researching low cost post-combustion denitration technological equipment.

In aspect of environmental economic policy and management measures, the presently implemented economic policy is sulfur dioxide pollutant charging system. Environmental protection discount standard study has been conducted in combination with electric power restructuring, and some provinces and cities have carried out pilot study in pollutant emission trading. It is suggested to regard pollutant emission charging system and emission trading as basic policy combination orientation, capital support as auxiliary means and discount standard as complementation or perfection of pollutant emission charging system. The specific suggested measures are: conduct experimental spot of emission right; implement power environmental protection discount standard; carry out strict power industry emission standard; introduce power generation emission performance management mechanism; push power plant environmental information announcement system; and strengthen supervision of management ability construction etc.

(2) Construct West-to-East power transmission green project

During the 10^{th} Five-Year Plan period, the state lays stress to accelerating the construction of the south line power supply and transmission line of the West-to-East power transmission project. According to the strategic planning suggestion on the south channel of the west-to-East power transmission project, more than 10 thermal power plants will be built in the corridor at the junction of Yunnan and Guizhou provinces with 6 million kW power supply capacity added in the 10^{th} Five-Year Plan period. If no measure is taken, thermal power generation projects in Guizhou will have an additional emission of 201,700 tons of sulfur dioxide and thermal power generation projects in Yunnan will have an additional emission of 136,800 tons of sulfur dioxide.

To achieve the total quantity control objective of sulfur dioxide emission in the 10^{th} Five-Year Plan period, Yunnan and Guizhou provinces will need a total capital of 4.03 million Yuan for desulphurization. Therefore while constructing West-to-East" power transmission project, we should increase investment in the control and treatment of sulfur dioxide and take effective control measure to ensure that emission of sulfur dioxide meets the national and local requirement of total quantity control in the 10^{th} Five-Year Plan period and air quality is improved to some extent so as to attain the goal of constructing West-to-East power transmission green project.

The State shall organize to conduct desulphurization feasibility study for the West-to-East power transmission thermal power project in Yunnan and Guizhou provinces and formulate practicable sulfur dioxide reduction plan and scheme as soon as possible so as to realize the sulfur dioxide reduction objective at the minimum cost.

The State shall gradually increase sulfur dioxide emission charging standard to make it close to or higher than treatment cost so as to impel pollutant emission enterprises to actively increase investment and control and treat pollution on their own initiative. While implementing total quantity control and up-to-standard emission, gradually establish sulfur dioxide emission right trading system to continuously reduce prevention and control cost of sulfur dioxide and acid rain pollution for the whole society. Establish a supervision mechanism to ensure the achievement of sulfur dioxide emission reduction objective and the achievement of the State's prevention and control objective for sulfur dioxide pollution and acid rain.

(3) Integrated reduction of traffic environmental pollution

To resolve motor vehicle pollution problems, it is necessary to start with the perfection of the whole traffic system and the improvement of fuel structure to reduce motor vehicle pollutant emission fundamentally.

Urban environmental pollution caused by motor vehicles is mainly tail gas. The suggested policies mainly include: exert the "troika' function of vehicles, fuels and legislations to reduce motor vehicle tail gas pollution; rationally and effectively control the development of motor vehicle traffic volume, vigorously develop public means of transport and pollution-free vehicles, implement motor vehicle whole process control and life cycle management; exercise economic means such as tax to encourage the development of clean and energy saving mode of transport and adopt departmental coordination to strengthen decision making package.

(4) All out develop rural renewable energy sources

The fundamental approach to resolve China's rural energy environmental pollution is to vigorously develop modern renewable energy sources suitable for rural area and to reduce firewood and straw energy utilization which pollutes the environment, endangers health and destructs ecology.

It is suggested that, based on currently implemented rural energy construction plans such as Chengfeng Program, Lighting Engineering Project, rural integrated energy construction, Straw Gasification Pilot Project, National 100-County Small Hydropower Station Program and Ecological Homeland Enriching Program, formulate and implement the "national rural green energy program" to promote the development of renewable energy sources in rural area. This program focuses on increasing rural energy utilization energy efficiency, advocating water saving irrigation technology, encouraging the use of high-efficiency, low-toxicity and less-persistent pesticide and organizing farmers to carry out rational application technical training. Actively develop ecological agriculture with ecological farmer enriching program as the basis and breakthrough. The State shall formulate appropriate encourage policy to support rural area to quicken the development of renewable energy sources and enable farmers to truly afford to build and use such expensive, clean and modern renewable energy sources.

1. Energy and Environment

Energy production and consumption is closely related to environmental pollution, public health, and global environmental change. China is a big country of energy production and consumption and a big environmental country. China's total energy production in 2002 is 1.09 billion tons standard coal, ranking the third in the world, and total energy consumption is 1.28 billion tons of standard coal, ranking the second in the world. Corresponding emission of sulfur dioxide and carbon dioxide ranks the first and the second in the world. The major purpose of this chapter is through comparative analysis between energy and environment to find the relation between energy and environment in order to realize the important harmony of energy and development.

1.1 Impact of Energy Activity on Environment and Public Health

Energy production and consumption activities have important impact on environment and public health. The following text will mainly analyze the possible impact of production and consumption processes of such conventional energy sources as coal, petroleum, natural gas and hydropower on the environment and public health according to the different types of energies.

1.1.1 Coal

China is a country with coal as the main energy source. Pollution caused in the coal utilization process is the biggest air environmental pollution problem in China. 70 percent smoke dust emission, 90 percent sulfur dioxide emission, 67 percent nitrogen oxide and 70 percent carbon dioxide in the country come from coal combustion. It causes serious air pollution and even acid rain occurs in some regions and cities in a developing trend. At present, the cities in the country with air pollution exceeding Grade 2 standard account for 34 percent of the monitored cities and the area affected by acid rain is already 30 percent of the country's territory area [4].

China's coal mining safety production problem is very serious and only in 2002, as many as 359 mine accidents with death toll exceeding three occurred with total death of 2,432 persons. Coal based energy production and consumption structure is not completely rational and coal proportion is too great, resulting in huge environmental pressure.

Table 1-1 Impact of Coal Production and Consumption on Environment and

Health

Impact factor	Exploitation	Coal washing	Consumption
Atmosphere	Greenhouse gas CH_4 is emitted during coal exploitation and outdoor coal stacking and storage cause increase of TSP in air, belonging to regional pollution		A large quantity of SO_2, CO_2, NOx, CO, smoke dust and mercury pollutants are generated from coal utilization, which is the main cause of air pollution and acid rain and the main emission source of greenhouse gases, tending to cause global environmental problem.
Water	Acidic mine wastewater and gangue piles easily cause surface water and ground water pollution.	Coal washing wastewater contains much sulfur and causes water body pollution and water body pH change.	Acid rain and acid deposition cause water body pollution and lake acidification.
Soil	Ground collapse of mine gob area; stacking of stripmining surface soil occupies vast land and the generated solid waste causes soil environmental pollution.	Mainly caused by coal washing wastewater and coal slurry.	Stacking of coal slag etc causes land occupation and soil pollution and release low radiation pollution.
Ecology	Causes mine ecological environmental damage and forms mud and rock flow etc.	Affect aquatic ecosystem.	Acid rain causes damage of various ecological systems.
Human health	Mainly caused by SO_2 and TSP in air. Additionally, unexpected accidents often occur in mining work. Coal mining is a serious trouble hidden industry that affects workers' life safety in China.	Pollution of drinking water is harmful to human health.	Poisonous and harmful gases tend to cause respiratory diseases and result in grievous damage to the health of town dwellers. Heating througy coal burning may possibly directly causes death by CO poisoning.

1.1.2 Petroleum and natural gas

In 2000, petroleum consumption by China's traffic sector reached 89.9 million tons, being 45 percent of terminal total petroleum consumption. Exploration of petroleum and natural gas produces a large amount of pollutants hazardous to the environment, which not only causes damage to the atmosphere, ocean and ecology etc, but also directly or indirectly affects human health.

According to research of U.S. California Air Resources Board Commission (ARB), tail gas of diesel engine is found to contain many carcinogenic pollutants and workers exposing to high-concentration diesel engine tail gas have a very high incidence rate of lung cancer. In 1999, the CaliforniaState Government had determined the tailpipe emissions of diesel vehicles to be carcinogenic chemical substances [6].

Table 1-2 Impact of Petroleum and Natural Gas Production and Consumption on Environment and Health

Impact factor	Exploitation	Oil refining	Consumption
Atmosphere	Oil and gas wells blow off exhaust gas to cause air pollution.	Oil refining process generates a large quantity of exhaust gas to cause air pollution.	Fuel combustion and automobile tail gas etc cause air pollution and emit such pollutants as SO_2, NOx, CO_2, CO and VOC.
Water	Offshore oil extraction and oil tanker accidents cause ocean pollution and petroleum leakage cause ocean and water body pollution.	Oily wastewater pollutes water environment and causes thermal pollution of water body etc.	Pollutants enter into water body via sedimentation to affect water quality.
Soil	Excessive exploitation causes ground subsidence etc.	Oily wastewater causes soil pollution.	Heavy metals such as mercury enter into soil via water body to cause pollution.
Ecology	Causes damage to mine ecological environment, threatens living beings' habitation environment. Offshore oil extraction affects ocean ecological system and petroleum leakage causes damage to ocean and water	Environmental pollution causes damage to ecological system.	Environmental pollution causes damage to ecological system.

	body ecological environment and death of animals.		
Human health	Pollution of atmosphere and water body causes damage to human health and mine accidents cause potential safety hazard to people.	Atmospheric pollutants are harmful to respiratory system and have adverse effect on human health.	Atmospheric pollutants are harmful to respiratory system and have adverse effect on human health.

1.1.3 Hydropower

Theoretical water power reserve in China is 676 GW, technically exploitable resource is 379 GW, economically exploitable resource is 290 GW and annual average power output is 1,260 TWh.

By September 2003, our country's installed generating capacity reached 373.76GW including 89.34 GW hydropower, accounting for 23.9 percent. Large sized hydropower stations in the country are in a large proportion and hydropower station resources with single station greater than 2 GW is 50 percent. More than 300 counties in the country mainly rely on small hydropower stations for power supply and have realized rural primary electrification. In the approximate 800 mountainous counties (cities) that mainly rely on small hydropower stations in the country, over 318 rural hydropower primary electrification counties (cities) and 1 rural hydropower primary electrification region have been built and more than 40 regional power grids have been formed (7).

Table 1-3 Impact of Hydropower Production and Consumption on Environment and Health

Impact factor	Construction and production	Consumption and utilization
Atmosphere	Construction equipment used for dam construction emits a large quantity of pollutants.	Replace thermal power generation to mitigate air pollution caused by thermal power generation.
water	River closure weakens diffusibility of pollutants and affects water body self-purification capacity. Submerges land, ground facilities and historic sites and affects landscape especially natural landscape. Sediment accumulation shrinks rivercourse section in the upper reaches and raises river bed, and makes the river bank eroded in the lower reaches and causes rivercourse	Has not adverse effect.

Ecology	change. Changes groundwater flow and direction, makes groundwater level rise, causes soil salinization and even to form marsh, and results in deterioration of environmental sanitation conditions to lead to outbreak of diseases. Quarrying and filling during construction damage natural environment; installation of floodway deflector damages hydrobiont such as fish and closure blocks fish migration. May change river depth, water temperature, flow rate and reservoir area microclimate and result in adverse effect on hydrobiont and genobenthos in the reservoir area; possibly causes earthquake.	Has not adverse effect.
Human health	May cause migration of some reservoir areas and triggers earthquake to cause death and injury.	Has not adverse effect.

1.1.4 Household fuel

Burning of household fuels is the main cause of indoor pollution. In China, indoor air pollution is mainly caused by combustion of coal and biomass energy. As shown by the result of investigation for coal burning hazard in the village in Guizhou Province in Southwest China, with open kitchen range of coal combustion, concentration of sulfur oxide, arsenic and fluorine in indoor air exceeds standard for 3.2-64 times and arsenic and fluorine content in corn, rice and pepper stored indoors exceeds 1.1-1126 times. The coal with complex components in combustion process not only emits sulfur dioxide, arsenic and fluorine, but also emits over 10 types of other harmful substances into indoor air to harm human health (3).

The monitoring and research for air pollution index before and after the change of household fuels in Taiyuan City, China show that after change of fuel burning to gas combustion, NOx increases 1.4-5.0 times, SO_2 decreases 0.6 time, TSP decreases 0.3-0.7 time and CO does not change significantly. Compared with coal burning, although overall index of coal gas combustion decreases to some extent, index of nitrogen oxides is higher (3).

Table 1-4 Relation between Biomass Utilization and Target Population

Index	Biomass percent in energy consumption (%)				
	0~20	20~40	40~60	60~80	>80
Number of countries	70	12	14	10	16
Death rate (%)	8.6	7.6	10.9	12.8	18.1
Life expectancy (years)	71.5	66.5	59.5	54.5	47.0
Male	68.5	64.0	57.8	53.0	45.8

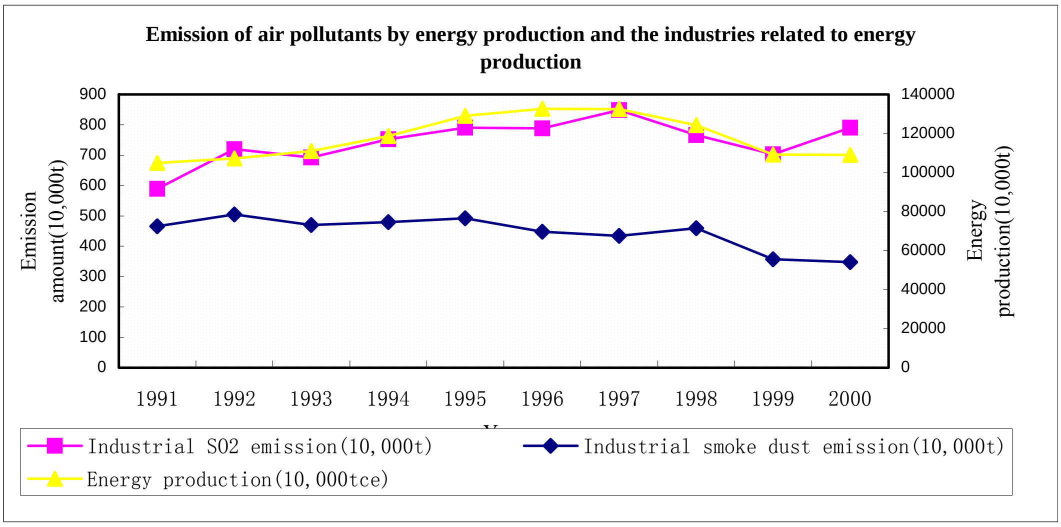
Female	74.7	68.8	62.0	55.1	48.3
Infant mortality (%)	22.5	46.6	64.7	82.16	116.8
Infant mortality (%)	27.5	59.3	93.0	135.3	173.0

Source: UNDP, 1999.

1.2 Relation between Energy Production and Pollution Discharge

1.2.1 Emission of air pollutants

In 2000, the smoke dust emitted by the industries related to energy production is 29.8 percent of total emitted smoke dust quantity in China and caused severe pollution to environment.



Note: smoke dust emitted by the industries related to energy production is an estimated value.

Figure 1-1 Emission of Air Pollutants by Industries Related to Energy Production

It can be seen from the above figure that overall change of SO2 emission is in the trend of first rising and then dropping with energy production and it slightly rose in 2000. Smoke dust emission of the industries related to energy production is not significant compared with SO2, but the figure also shows the change of smoke dust emission by these industries with the change of energy production.

1.2.2 Discharge of water pollutants

Statistics show that China's coal mines produce various wastewaters which account for 25 percent of total wastewater quantity in the country. In 2000, discharge of wastewater from coal mines in the country reached 2,750,000,000t including 2.3 billion tons of mine water, 350 million tons of industrial wastewater, 50 million tons of coal washing wastewater and 45 million tons of other wastewaters. According to investigation, due to coal washing, the country generates 45 million tons of washed gangue, 40,000 tons of coal washing wastewater and 2 million m^3 coal slurry every year(1).

During oil extraction, refining, storage, transportation and use, crude oil and various petroleum products enter into environment and cause pollution. According to related statistic data, the quantity of petroleum and petroleum products leaked into ocean via various ways is 0.5 percent of total petroleum output in the world, and pollution caused by oil tanker wreckage is most serious(8). Oil refineries also discharge a large quantity of oil sludge to pollute surface water.

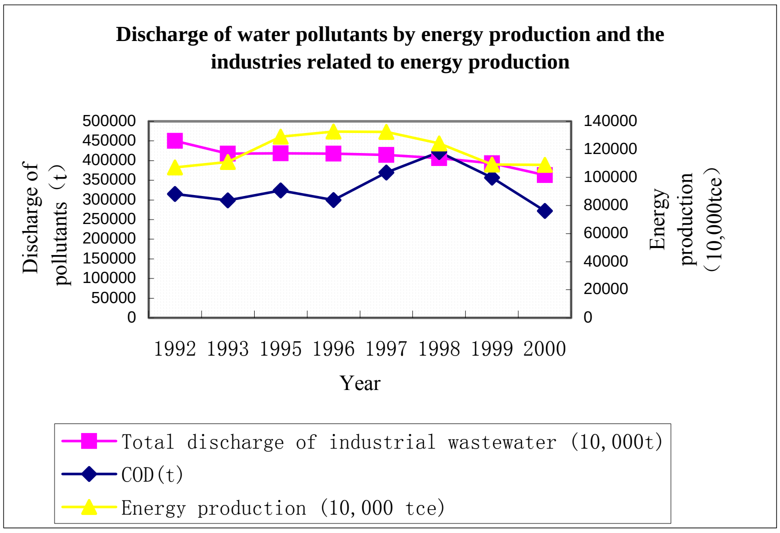


Figure 1-2 Discharge of Water Pollutants by Industries Related to Energy Production

It can be seen from the above figure that change of pollutants discharge tends to be consistent with the change of energy production quantity, which indicates that energy production is closely related to pollution of water environment.

1.2.3 Discharge of solid waste

Energy production and consumption inevitably generates a large quantity of solid wastes, cause serious environmental pollution. Energy production quantity has important relation with the discharge of solid wastes from the industries related to energy production (mainly include mining industry, petroleum processing, coking, electric power coal gas and water production supply industries).

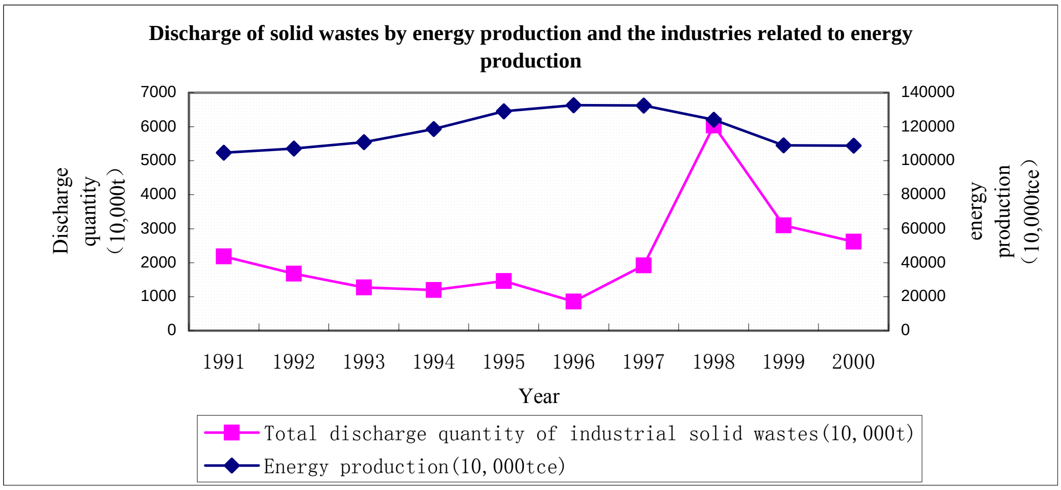


Figure 1-3 Discharge of Solid Wastes by Industries Related to Energy Production

1.3 Relation between Energy Consumption and Environmental Pollution

In view of present environmental problem in China, air environmental pollution resulted from energy consumption and the impact of global climate change are one of the most important problems.

1.3.1 Energy consumption and emission of air pollutants

Air environmental pollution in China mainly is smoke black pollution and the major pollutants are sulfur dioxide, smoke dust and nitrogen oxides. This is closely related to China's coal based energy consumption structure. Table 1-5 shows the primary energy consumption composition over the last ten years in China. Obviously, coal is around 70 percent of total energy consumption in China.

Table 1-5 Primary Energy Consumption and Composition

Year	Total energy consumption (10,000 tce)	Coal	Petroleum	Natural gas	Hydropower*
		Percentage (%)	Percentage (%)	Percentage (%)	Percentage (%)
1990	98703	76.19	16.62	2.05	5.14
1991	103783	76.10	17.10	2.00	4.80

1992	109170	75.70	17.50	1.90	4.90
1993	115993	74.70	18.20	1.90	5.20
1994	122737	75.00	17.40	1.90	5.70
1995	131176	74.60	17.50	1.80	6.10
1996	138948	74.70	18.00	1.80	5.50
1997	137798	71.50	20.40	1.70	6.20
1998	132214	69.60	21.50	2.20	6.70
1999	130119	68.00	23.20	2.20	6.60
2000	130297	66.10	24.60	2.50	6.80
2001	134914	69.30	24.30	2.70	7.70
2002	148000	66.1	23.4	2.70	7.80

Data source: National Bureau of Statistics, China Statistical Yearbook, 2003.
Note: hydropower has included nuclear power since 1991.

1.3.1.1 Coal energy is the main cause of air pollution in China

Refer to table 1-6 for energy consumption situation and emission of major air pollutants in recent years in China. China's energy consumption reached the maximum in 1996 and then dropped slightly in 1997-2000 and energy utilization efficiency gradually increases. Emission of SO_2 and smoke dust for unit GDP decreases year after year, which indicates China has increased pollution control strength on the one hand, and this is related to energy structural readjustment on the other hand. Since 2002 however, energy consumption has been rising continuously and coal consumption reached 1.58 billion tons in 2003.

According to statistics in the last decade, China's SO2 and smoke dust emission increases with increase of total energy consumption and emission quantity has a highly positive correlation with energy consumption as shown in figure 1-4. Due to continuous growth of total coal consumption, total emission quantity of air pollutants still stays in the very high level.

Table 1-6 Relation between Energy Consumption and Air Pollutants in China

Year	GDP 2000 constant price (100 million Yuan)	Energy consumption (10,000 tce)	SO_2 emission (10,000t)	Smoke dust emission (10,000 tons)	Unit GDP energy consumption (tce/10,000Yuan)	Unit GDP SO_2 Emission (t/10,000Yuan)	Unit GDP smoke dust emission (t/10,000Yuan)
1989	32906.1	96934	1564	1398	2.95	0.048	0.042
1990	34156.5	98703	1495	1324	2.89	0.044	0.039
1991	37298.9	103783	1622	1314	2.78	0.043	0.035
1992	42595.4	109170	1685	1414	2.56	0.040	0.033
1993	48345.7	115993	1795	1416	2.40	0.037	0.029
1994	54437.3	122737	1825	1414	2.25	0.034	0.026
1995	60153.2	131176	1891	1478	2.18	0.031	0.025

1996	65927.9	138948	2242.5	1697	2.11	0.034	0.026
1997	71729.6	137798	2346	1873	1.92	0.033	0.026
1998	77331.4	132214	2090	1452	1.71	0.027	0.019
1999	82853.6	130119	1857.5	1159	1.57	0.022	0.014
2000	89442.2	130297	1995.1	1165.4	1.46	0.022	0.013
2001	95971.5	134914	1948	1059	1.41	0.020	0.011
2002	102389	148000	1927	1012	1.45	0.019	0.0099

Source: compiled according to China Statistic Yearbook and Environmental Statistic Yearbook.

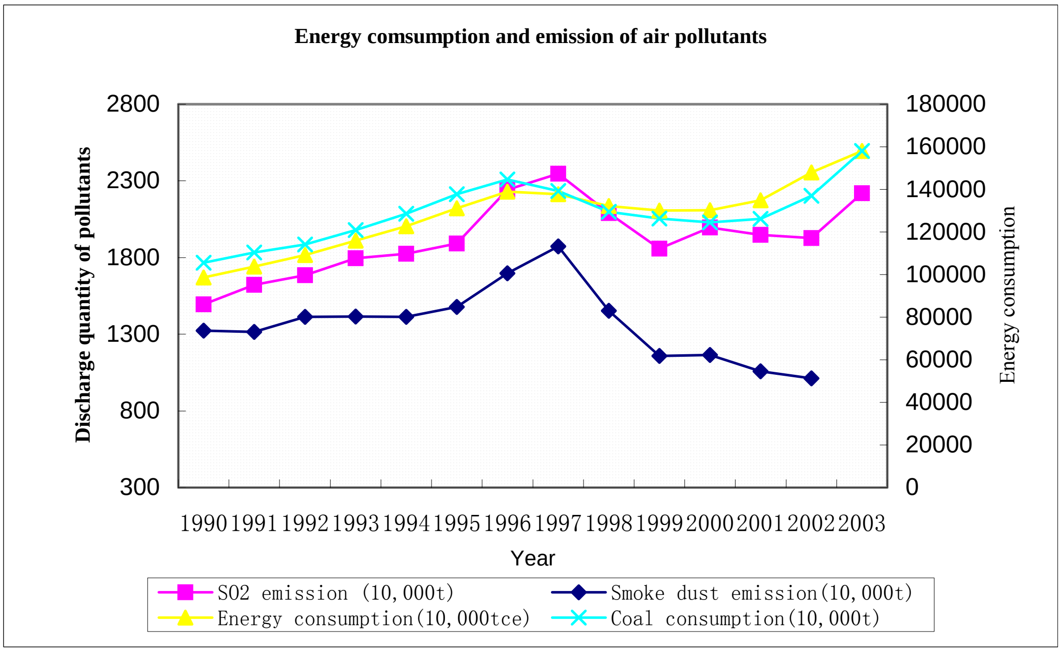


Figure 1-4 Energy Consumption and Emission of Major Air Pollutants in Recent Years in China

1.3.1.2 Emission elastic coefficient of air pollutants decrease steadily

Refer to table 1-7 for energy consumption and pollutant emission elastic coefficient over the last decade in China. From figure 1-5, we can see that China's energy consumption elastic coefficient is less than 1 (since 1990), which indicates that energy consumption growth rate is less than the growth rate of national economy. The elastic coefficient has been less than zero in recent years, which means energy consumption starts to see a negative growth and embodies the Government's effort and achievement in energy conservation and energy efficiency improvement.

In emission of pollutants, elastic coefficient is less than 1 and has been a negative value for years. This indicates emission rate of pollutants is also less than the development rate of national economy and decreases year after year at times. Change of emission elastic coefficient for SO2 is almost the same as that for smoke dust, also indicating the two are affected by energy consumption.

Table 1-7 Energy Consumption Elastic Coefficient and Pollution Emission Elastic Coefficient

Year	Growth of energy consumption over the previous year (%)	Growth of SO_2 emission over the previous year (%)	Growth of smoke dust emission over the previous year (%)	Growth of GDP over the previous year (%)	Energy consumption elastic coefficient	SO_2 emission elastic coefficient	Smoke dust emission elastic coefficient
1989	4.2	\	\	4.1	1.03	\	\
1990	1.8	-4.4	-5.3	3.8	0.48	-1.16	-1.39
1991	5.1	8.5	-0.8	9.2	0.56	0.91	-0.09
1992	5.2	3.9	7.6	14.2	0.37	0.27	0.54
1993	6.2	6.5	0.1	13.5	0.46	0.48	0.01
1994	5.8	1.7	-0.1	12.6	0.46	0.13	-0.01
1995	6.9	3.6	4.5	10.5	0.65	0.34	0.43
1996	5.9	18.6	0.148	9.6	0.62	1.94	0.0154
1997	-0.6	4.6	0.104	8.8	-0.06	0.52	0.012
1998	-4.3	-10.9	-22.5	7.8	-0.55	-1.40	-2.88
1999	-1.6	-11.1	-20.2	7.1	-0.22	-1.56	-2.85
2000	0.1	7.4	0.6	8.0	0.02	0.93	0.08
2001	3.5	-2.4	-9.1	7.3	0.49	-0.33	-1.33
2002	9.7	-1.02	-5.5	8.0	1.21	-0.13	-0.69

Note: Growth rate of gross domestic product is calculated as per comparable price.
Data source: compiled according to China Statistic Yearbook (2001).

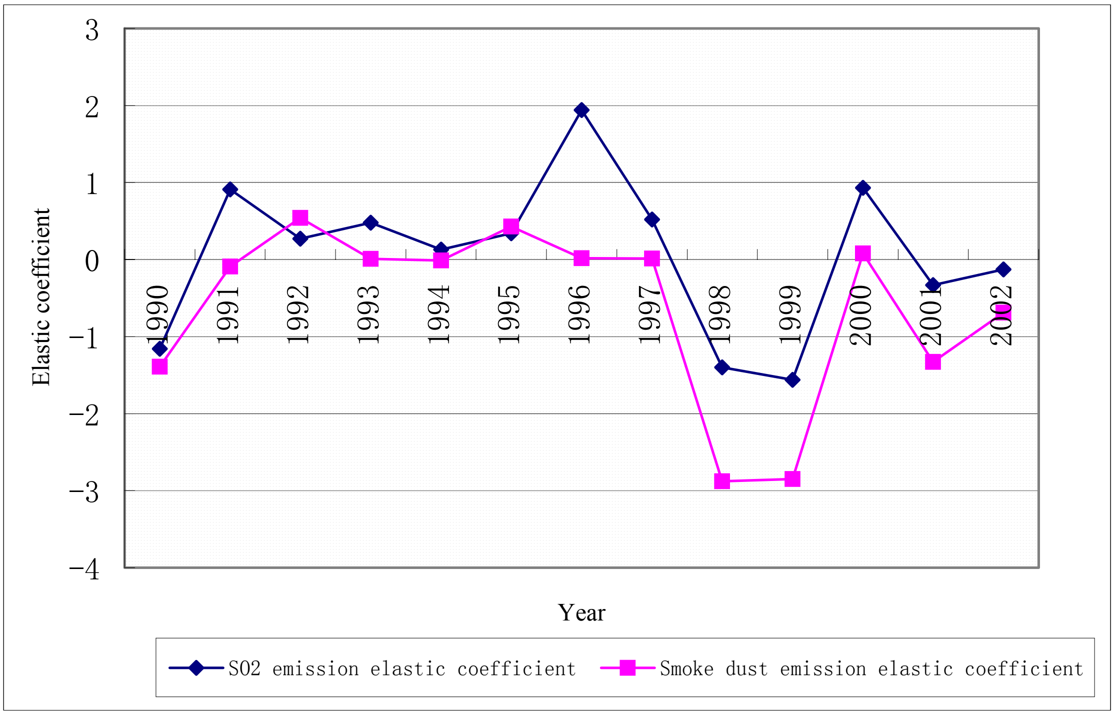


Figure 1-5 GDP Pollution Emission Elastic Coefficient of Major Air Pollutants

1.3.2 Electric power industry and sulfur dioxide emission

With rapid development of national economy, thermal power industry is facing an increasing pressure of reducing sulfur dioxide, nitrogen oxides and carbon dioxide.

1.3.2.1 Electric power industry is the major industry of sulfur dioxide emission

Coal fired power plants are the major coal users with coal consumption for electric power being 60 percent of total coal yield, and are major sulfur dioxide emission organizations as well. Statistics show that coal fired power plants emitted 810,000 tons of sulfur dioxide in 2000, accounting for 41 percent of total emission quantity in the country. Thus it can be seen that whether total emission quantity or total emission percentage, emission of sulfur dioxide by electric power industry is in the upward trend (see figure 1-6).

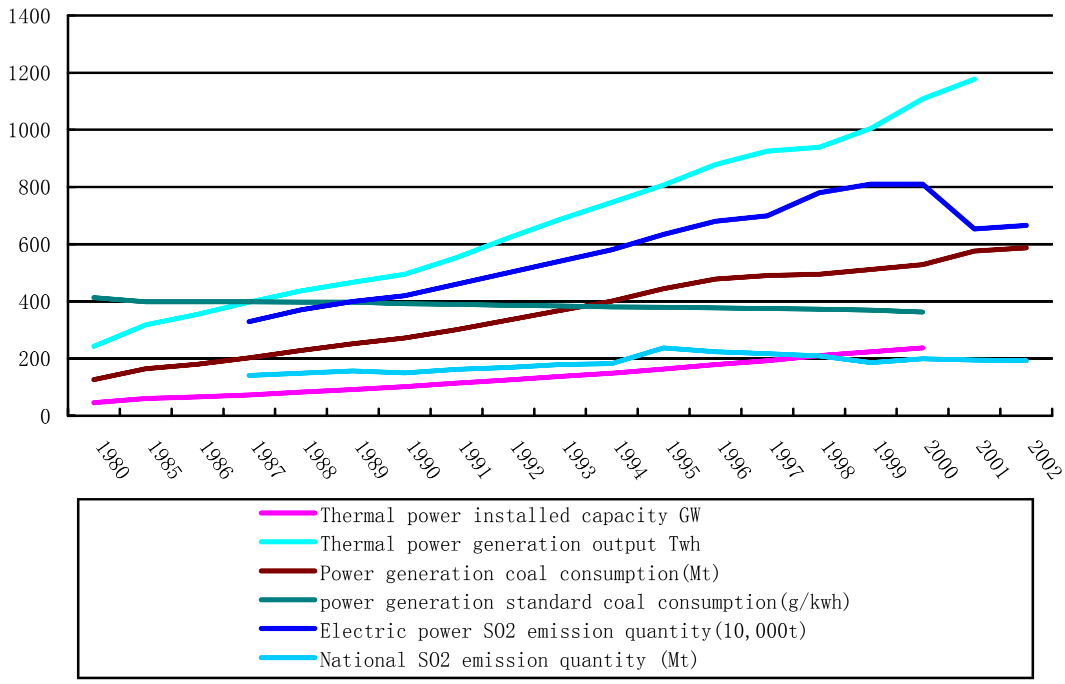


Figure 1-6 Electric Power Industry Development and SO2 Emission in Past Years

Source: calculated and compiled according to "China Environment Yearbook 1991-2002" and "China Electric Power Yearbook 2002".

1.3.2.2 Sulfur dioxide emission is closely related to power industry layout

It can be seen from figure 1-7 that Shandong, Hebei, Guangdong and Jiangsu emit more sulfur dioxide than other provinces in the country. Compared with the percentage of their power generation quantity, they are the provinces whose thermal power installed capacity ranks the first in the country.

In view of the whole country, emission from the "two-control area" is 67 percent of total emission quantity in the country while emission from the "two-control area" of power industry is 78.5 percent of the emission from the whole industry and 48.3 percent of total emission quantity from the "two-control area", indicating that emission of sulfur dioxide from electric power industry has stronger characteristic of regional concentration and is the major sulfur dioxide emission source of the "two-control area".

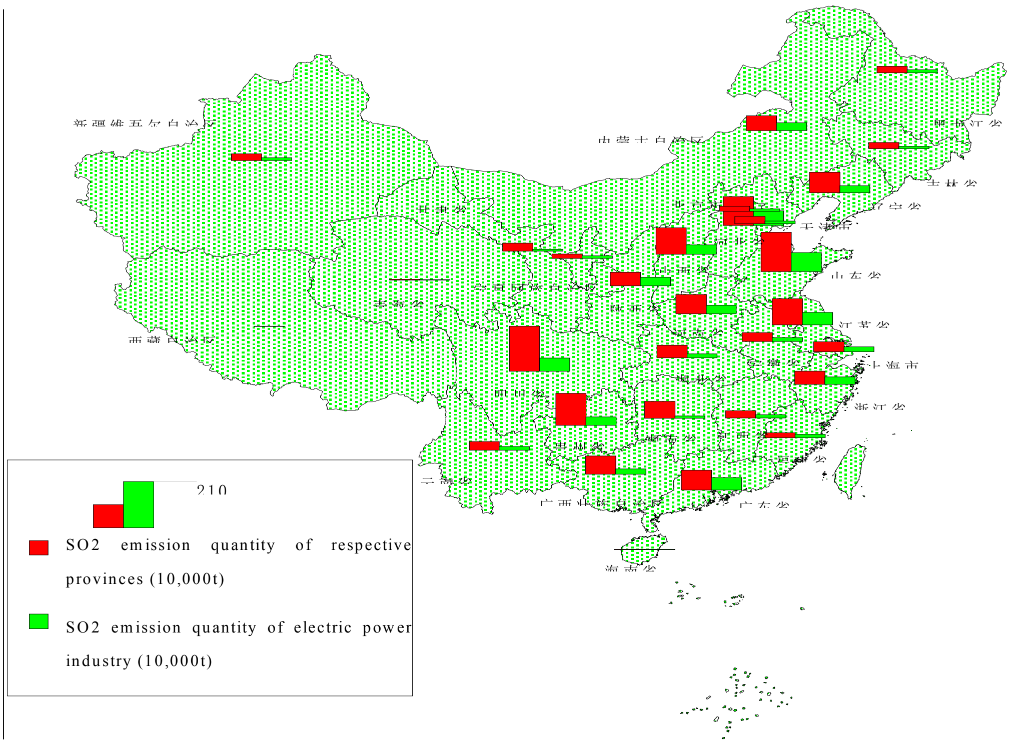


Figure 1-7 Sulfur Dioxide Emission of Respective Provinces and Emission of Electric Power Industry in 2000

1.4 Environmental Cost Analysis for Energy Activity

Fossil fuel combustion, other industrial sources and automobile tail gas etc are the major sources of air pollutants. Environmental cost of energy production and consumption is represented in physical damage and currency damage.

1.4.1 Cause air pollution and acid rain pollution

Utilization of energy (especially coal energy) emits a great deal of pollutants and causes serious deterioration of urban air quality in China. Of the 20 most seriously polluted cities in the world listed in World Bank Development Report 2001, 16 are in China. Particulates closely related to coal utilization are still the major pollutant of air quality in China. Among the 341 cities in 2001 statistics, 64.1 percent cities have annual average concentration of particulates exceeding national Grade 2 air quality standard and 101 cities have annual average concentration of particulates exceeding Grade 3 standard, accounting for 29.2 percent cities in the statistics. The quantity of the cities with annual concentration of sulfur dioxide not reaching national Grade 2 standard is 19.4 percent of the cities in the statistics. Of the 47 key environmental protection cities, only 19 have their environmental air quality reaching Grade 2 air quality standard (4). See figure 1-8 for the change of national SO2 emission and urban SO2 average concentration. Obviously, although SO2 emission has been balanced in the last ten years, urban SO2 concentration has slightly decreased. This indicates that urban domestic energy readjustment in recent years has generated good environmental effect.

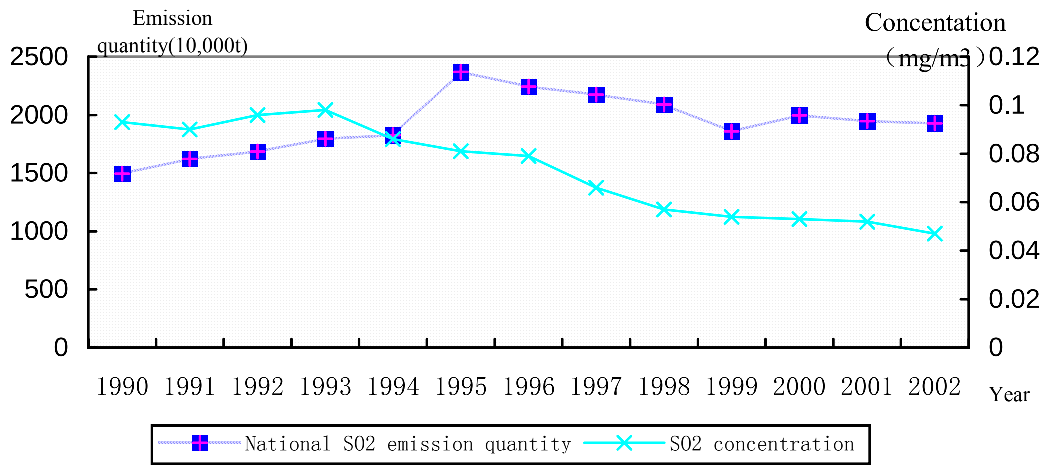
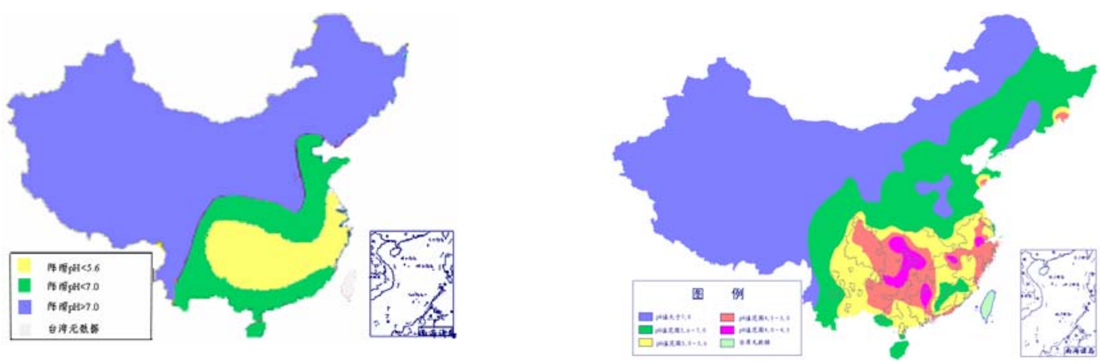


Figure 1-8 Change Trend of Sulfur Dioxide Emission and Environmental Quality

Research shows that acid rain in 1990s in China was sulfuric acid type. Sulfur dioxide emitted by such human activities as coal burning is the main cause of acid rain. Area affected by acid rain in mid-1990s increased 1 million km^2 than 1980 and area with pH of mean annual precipitation lower than 5.6 was already 30 percent of total area in the country. For specific change situation, refer to figure 1-9.



Precipitation ph<5.6	pH>7.0	pH 4.5-5.0
Precipitation ph<7.0	pH 5.7-7.0	pH 4.0-4.5
Precipitation ph>7.0	pH 5.0-5.6	No data for Taiwan

No data for Taiwan

Figure 1-9 Acid Rain Distribution Change in 1980 and 1990 in China

During the Ninth Five Year Plan period, SO2 emission in the country was in a downward trend, area affected by acid rain did not change significantly, percentage of cities with pH of acid rain less than 4 in acid rain control region dropped slightly and the percentage of cities with acid rain frequency greater than 80 percent in the national control acid rain network also dropped slightly. Table 1-8 shows the percentage of acid rain cities in the cities of national control acid rain network at various pH stage values from 1996 to 2000. It can be seen from table 1-8 that acid rain improvement is not significant.

Table 1-8 Ph City Percentage of Acid Rain Control Regions (%)

pH	≤4.0	4.0~4.5	4.5~5.0	5.0~5.6	5.6~7.0	>7.0
1996	1.2	3.7	24.4	22.0	37.8	11.0
1997	1.1	4.4	25.0	16.3	41.3	12.0
1998	0	5.4	25.7	19.1	39.0	10.8
1999	0	1.9	17.9	20.8	46.2	13.2
2000	0	3.92	31.37	35.29	29.41	0
2001	0	4	37	28	25	4
2002	0	7	30	27	31	2

Source: China National Environmental Monitoring Center, 2002.

1.4.2 Impair public health

1.4.2.1 Impact of air pollution on health

In the regions with air seriously polluted, total death rate and incidence rate of respiratory diseases are both higher than the regions with air relatively less polluted. In the eleven biggest cities in China, smoke dust and fine particulates in air causes an early death of 50,000 people and 400,000 people to catch chronic bronchitis every year [10].

Air pollution already poses a great threat to China’s economic construction. Total suspended particulates (TSP) and sulfur dioxide (SO2) particularly impair the health of Chinese people. In 1995, the country incurred an estimated health loss of 17.1 billion Yuan due to TSP (and SO2) air pollution [11].

1.4.2.2 Impact of indoor air pollution on health

Investigation data of Harbin Medical University shows that urban residents in North China spent 89 percent their time in indoor environment. Therefore, hazard of indoor air pollution to human health is not ignorable. Different types of fuels produce different types and quantities of pollutants. As reported by related data, pollution ranking sequence from slight to severe is power, natural gas, coal gas, liquefied petroleum gas and coal etc [(12)].

Substances released from coal combustion mainly have seven types of components: carbon oxides, oxygen containing hydrocarbon, polycyclic aromatic hydrocarbon, sulfur oxides, fluoride, metallic and non-metallic oxides as well as suspended particulates. The above seven harmful substances are the major pollutants in indoor air pollution in present China. See table 1-12 for indoor air pollution by particulates released from coal combustion.

Table 1-9 Indoor Air Pollution by Particulates Released from Coal Combustion

Location	Urban/rural	Particulates (mg/m3)
Shanghai	Urban	500-1000
Beijing	Urban	17-1000
Shenyang	Urban	125-270
Taiyuan	Urban	300-1000
Harbin	Urban	390-610
Guangzhou	Urban	460
Chengde	Urban	270-700
Yunnan	Rural	270-5100
Beijing	Rural	400-1300
Jilin	Rural	1900-2500
Hebei	Rural	1900-2500
Inner Mongolia	Rural	400-1600

Data source: World Health Organization (WHO), 1998, *Health and Environment in Sustainable development: Five years after Earth Summit*, p86.

In recent years, not a few scholars in China have conducted research for the impact of pollutants produced from different fuels through combustion on human health and they have found that incidence rate of respiratory diseases in coal burning families is higher than gas burning families.

Qin Yuhui et al. investigated and found that in the case of severe indoor coal burning pollution, incidence rate of children's respiratory system, physical sign and diseases rise to some extent [(13)]. Popular lung cancer in Xuanwei is also caused by indoor coal burning (without chimney).

1.4.2.3 Pollution of liquefied petroleum gas

According to investigation and research by Ma Yinghua et al, combustion of liquefied petroleum gas leads to rise of indoor SO2, NOx and CO concentration: kitchen NOx and CO concentrations are 1-3 and 3-9 times more than the national hygienic standard (daily average maximum permissible concentration of harmful substances in air in residential area) respectively, bedroom CO concentration exceeds standard for 1-4 times and indoor SO2 concentration does not exceed hygienic standard. The result shows that combustion of liquefied petroleum gas is the main cause of indoor NOx and CO pollution.

1.4.2.4 Pollution of biomass fuel

According to research of indoor air pollutants in Xuanwei County, Yunnan Province, 94 percent particulates emitted from firewood burning is 1-30μm and 6 percent is less than 1μm, which can be inhaled and settle in lung. Health hazard for severe contact with the combustion products of biomass fuel can be divided into five types: (1) chronic obstructive pulmonary diseases; (2) heart disease, especially pulmonary heart disease caused by lung lesion; (3) cancer; (4) acute respiratory tract infection; (5) low birthweight infant.

1.4.3 Economic cost of energy pollution

China started to research the economic loss caused by environmental pollution in 1980s. In 1984, Guo Xiaomin and Zhang Huiqin et al conducted “China Environmental Forecasting and Countermeasure Research in 2000”, which, for the first time, estimated the loss caused by environmental pollution in the country, i.e. annual average loss from 1981 to 1985 was 38 billion Yuan, being 6.75 percent of GNP in 1983. According to research made by Xia Guang of the Policy Research Center of the State Environmental Protection Administration, China’s loss caused by environmental pollution in 1992 was about 109.6 billion Yuan, 4.5 percent of GDP of the same year. Chinese Academy of Social Sciences conducted research of “Estimation of Economic Loss Caused by Environmental and Ecological Problems in 1990s” and stated that the loss caused by environmental pollution in 1993 was 108,500,000,000 Yuan, 3 percent of GDP of the same year. It is estimated by “Green Water and Blue Sky: China’s Environment in 21st Century” by World Bank, that China’s loss caused by air pollution and water pollution in 1997 was 7.7 percent of the year’s GDP.

1.4.3.1 Economic loss caused by air pollution

Refer to table 1-13 for economic loss caused by air pollution in China by different research institutes in different periods. According to these different estimates, we can find that China’s air pollution loss is already 2-3% of GDP.

Table 1-10 China’s Economic Loss Caused by Air Pollution

Estimator	Year	Pollution loss (100 million Yuan)	Percentage of Pollution loss in GDP (%)	Air pollution loss (100 million Yuan)	Percentage of air pollution loss in total loss (%)	Remarks
Guo Xiaomin, Zhang Huiqing (Chinese Research Academy of Environmental Sciences)	1983	380	6.75	124	32.5	Loss of air pollution mainly is building materials and health loss.
Xu Songling (Chinese Academy of Social Sciences)	1993	1085	3.16	483	44.56	Loss of air pollution mainly is health loss.
Xia Guang (Policy Research Center of State Environmental Protection Administration)	1992	1096	4.5	605	55.2	Loss of air pollution includes building materials, health and agricultural loss.
World Bank	1997	4330	7.7	4110	92.8	Loss of air pollution mainly is health loss.
Cao Hongfa (Chinese Research Academy of Environmental Sciences)	1995	No estimation	2 (only acid rain pollution)	1100		Loss of air pollution mainly is the loss of ecological system and health caused by acid rain.

According to present development trend, World Bank predicts that China will have to pay an economic price of $390 billion USD for the diseases caused by coal combustion in 2020, accounting for 13 percent of gross domestic product, which shall draw high attention from Chinese Government.

In calculation of sulfur dioxide pollution loss, what is most referred to is the findings of “National acid rain control scheme” completed by Chinese Research Academy of

Environmental Sciences: acid rain and sulfur dioxide emission in 1995 resulted in a loss of 110 billion Yuan. In addition, According to research findings of Zhou Fengqi and Zhou Dadi et al from Energy Research Institute, Academy of Macroeconomic Research, the State Planning Commission, economic loss caused by SO2 is different in all regions and is in the range of 1,300-8,000 Yuan/t.

Table 1-11 Estimated Value of Economic Loss Caused by SO2 Emission

Region	North China	Northeast	Northwest	Southwest	South China	East China	Central China
High estimated value (Yuan/t SO_2)	3000	3000	1500	6000	8000	8000	6000
Low estimated value (Yuan/t SO_2)	2500	2800	1300	1500	3900	3300	1700

Source: Zhou Fengqi, Zhou Dade et al. "China: Medium- and Long-Term Energy Strategy", China Planning Press, January, 1999.

1.4.3.2 Environmental cost of coal fired power generation

To synthesize the above estimation of air pollution loss and sulfur dioxide loss made by related department, economic loss caused by SO2 pollution of electric power industry in 2000 was about 44.5 billion Yuan if pollution loss caused by emission of sulfur dioxide is calculated based on 5,000Yuan/t. Thermal power output in 2000 was 1107.936 billion kwh, corresponding to 4.02 fen/kwh. According to the estimate of World Bank and GEF "China's renewable energy source development project", power generation pollution loss in 2010 will be 1-8 fen/kwh.

1.5 Current Energy Environmental Policy Analysis

China's present energy policy is related to several departments such as State Development and Reform Commission, electric power and environmental protection departments. Proceeding from the need of their own management, they put forward different requirements for the environmental problems in energy development. However, present energy environmental policy also has some problems and needs further improvement.

1. 5.1 Energy management system

China's power management system is related to several departments which are responsible for different aspects of energy management depending on their responsibilities. The following is the main related departments and their specific responsibilities:

1.5.1.1 State Development and Reform Commission

Energy Bureau (State Petroleum Reserve Office) mainly has the following responsibilities: researches domestic and foreign energy development and utilization situation, proposes energy development strategy and major policy; draws out energy development program, brings forward suggestion on structural reform; carries out management for such energies as petroleum, natural gas, coal and power etc; manages national petroleum reserves; puts forward policy measures for energy conservation and new energy development.

Department of Environment and Resource Comprehensive Utilization has the following main responsibilities: researches and resolves major problems for harmonious development of economy and society with environment and resources; puts forward energy conservation and comprehensive utilization policies; compiles resource conservation and comprehensive utilization plan and participates in compilation of environmental protection program; organizes and coordinates related work of environmental protection industries and organizes and coordinates promotion work of clean production; organizes and coordinates related major pilot projects and popularization and application of new product, new technology and new equipment.

1.5.1.2 Ministry of Science and technology

Hi-Tech Development and Industrialization Department mainly has the following functions: researches high-tech technical development and industrialization policies in industrial field; organizes and puts forward hi-tech development program and planning in industrial field; organizes to implement hi-tech research and development plan in information, automation, energy and new materials etc; organizes to implement national key technologies R&D programme and technological innovation project; undertakes related work for national-level hi-tech industrial development zone; pushes reform of scientific and technological system and construction of technical service system such as productivity promotion center.

1.5.1.3 Ministry of Agriculture

Technology and Education Department mainly has the following responsibilities in renewable energy resources: organizes the selection and conducts management for major agricultural technology introduction project; organizes foreign exchange and international cooperation work in agricultural science and technology education; organizes and instructs comprehensive development and utilization of rural renewable energy resources and scientific research and experimental spot demonstration for major technologies; instructs construction of rural renewable energy system and industrial development.

1.5.1.4 State Environmental Protection Administration

Pollution Control Department, Science and Technology Standard Department and Clean Production Center etc of the State Environmental Protection Administration also have formulated appropriate regulations for comprehensive energy utilization and pollution emission in energy activities. Science and Technology Standard Department etc also have formulated a series of pollutant emission standards, including: Emission standard of air pollutants for light cars (GWPB1-1999), Emission standard of air pollutants for coal--burning oil-burning gas-fired boilers

(GB16297-1996), Emission standard of air pollutants for industrial kilns (GB9078-1996), Emission standard of air pollutants for thermal power plants (GB13223-1996), and Emission standard of air pollutants for coke ovens (GB16171-1999) to limit energy production and utilization activities to some extent.

In general, China implements comprehensive management for energy activities, which is a distributed multi-department management model. It is adverse to the healthy development of energy industry and is difficult to undertake the important task of long-term safeguarding national energy safety (15). Now China urgently needs to establish centralized management organization to supervise the development of energy sector. Therefore, it is very important to rational and efficient energy utilization to coordinate energy management of all sectors and formulate unified laws and regulations.

1.5.2 Environmental policy

To effectively control impact of energy activities on environment, environmental management departments at various levels in China have formulated a series of laws, regulations, policies and standards. Current environmental policy system in energy is mainly embodied in the following levels:

- Related national and local laws and regulations, e.g. “Environmental Protection law of the People’s Republic of China”, “Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution”, “Cleaner Production Promotion Law of the People’s Republic of China” etc. Some local governments also have formulated some corresponding laws and regulations related to energy activities.
- Related national and local policies, e.g. the State Environmental Protection Administration has formulated regulations on sulfur dioxide control for the “two-control area” and the “fifteen smalls” policy for close and stop high energy consumption and high pollution etc. Since the Ninth Five Year Plan period, the State Environmental Protection Administration has implemented total quantity control system for pollutant emission and further strengthened and deepened it in the Tenth Five Year Plan period.
- National and local environmental standards, including compulsory standards and non-compulsory standards. The State Environmental Protection Administration has issued a series of emission standards to strictly restrict energy enterprises from emitting pollutants. Some standards are in revision and perfection and other new standards are compilation. Some local environmental protection departments also have formulated some local environmental standards. Besides compulsory emission standards, environmental departments have issued some non-compulsory standards, e.g. national cleaner production standards etc.

Table 1-16 lists some national environmental laws and regulations and policies related to energy activities. Pollution discharge from energy industries are still in a high level and the main causes are:

- Present energy environmental policies are produced from various departments and lack effective comprehensive decision mechanism and unified management organizational framework, resulting in ineffectiveness of control measures for all aspects of impacts produced by energy activities on environment and failure to propose comprehensive pollution prevention and control countermeasure for energy activities as a whole.

- China's coal based energy structure and the need of rapid economic development for energy determines that reduction of pollution emission caused by energy activities is a long-term onerous task.
- Operability of laws and regulations is not strong. Clauses of some laws and regulations are formulated too vaguely without implementing the rules complete with laws and regulations; therefore they are very difficult to be effectively implemented.
- Although relatively laws and regulations and policy systems for energy environmental management have been formed at present, some fields still have vacancies in the management of policy and laws and regulations.
- As energy activities involve numerous sectors and industries and present China's environmental law enforcement capability is limited, problems of slack law enforcement and oversight exist.
- Energy production and consumption enterprises are in various levels. Some enterprises have indifferent environmental awareness and lack capital support for environmental pollution treatment, and on the other hand, desulphurization potential of big pollution discharge organizations needs further development. Therefore insufficient pollution treatment and control of energy enterprises especially small enterprises and power industry is also one of the main causes that pollution discharge of energy industries stays in the high level.

Table 1-12 Requirements of Environmental Laws and Regulations and Policies for Energy Sources

Environmental policies, laws and regulation	**Energy related regulations and contents**
Environmental Protection Law	Article 25 For the technological transformation of newly-built industrial enterprises and existing industrial enterprises, facilities and processes that effect a high rate of the utilization of resources and a low rate of the discharge of pollutants shall be used, along with economical and rational technology for the comprehensive utilization of waste materials and the treatment of pollutants.
Air Pollution Prevention and Control Law	Chapter 3 Prevention and control of air pollutants produced from coal combustion Article 24 The State implements coal washing, dressing and processing to reduce coal sulphur content and ash content and limits exploitation of high sulphur and high ash coal. The newly built coal mines that exploit high sulphur and high ash coal must build supporting coal washing and dressing facilities to make coal sulphur content and ash content reach specified

	standards. The already built coal mines that exploit high sulphur and high ash coal shall build supporting coal washing and dressing facilities within the time limit according to the planning approved by the State Council. Exploitation of coals containing standard-exceeding poisonous and harmful substance such as radioactive substance and arsenic is prohibited. Article 25 Related departments of the State Council and local people's governments at various levels shall take measures to improve urban energy structure and popularize clean energy production and utilization. The people's governments of the key cities for air pollution prevention and control can delimit in the district under their jurisdiction the area where sales and use of highly pollutant fuels specified by the administrative department in charge of environmental protection under the State Council are prohibited. All organizations and individuals within this area shall stop using highly pollutant fuels and strart to use natural gas, liquefied petroleum gas or other clean energies within the time limit specified by local people's government. Article 26 The State adopts economic and technical policies and measures conducive to clean coal utilization to encourage and support the use of low sulfur and low ash high quality coals and to encourage and support the development and popularization of clean coal technology. Article 27 Related administrative departments of the State Council shall specify appropriate requirements in the quality standards of boiler products according to the Emission Standard of Air Pollutants for Coal-Burning, Oil-Burning Gas-Fired Boiler specified by the State; the boilers that do not meet the specified requirements are not allowed to be manufactured, sold or imported. Article 28 Urban construction shall be overall planned, and heat sources shall be resolved in a utified way and central heating shall be developed in the regions with heat supply by coal combustion. Coal combustion heat supply boilers shall no longer be built in the regions covered by central heating supply pipe network. Article 29 People's governments in big and medium-sized cities shall formulate plans to require catering service enterprises to use natural gas, liquefied petroleum gas, electricity or other clean energy within the time limit. The other civil cooking ranges in the urban areas of big and medium-sized cities that are not defined as the area where use of highly pollutant fuels is prohibited shall be changed to use sulfur retention coal or other clean

	energies. Article 30 The new built and expanded thermal power plants and other big and medium-sized enterprises that emit sulfur dioxide, if exceeding specified emission standard of pollutants or total quantity control index, must build supporting desulphuration and dust collecting units or take other measures to control emission and sulfur dioxide and to remove dust. In the acid rain control area and SO2 pollution control area, the already built enterprises shall be treated within specified time limit according to article 48 of this law if they exceed emission standards of pollutants. The State encourages enterprises to adopt advanced desulphuration and dust collecting technology. Enterprises shall take control measures for nitrogen oxides produced in fuel combustion process. Article 31 When storing coal, gangue, coal slag, coal ash, sandstone and gray soil in densely populated area, it is necessary to take fireproof and dustproof measures to prevent air pollution. Chapter 4 Prevention and control of pollutants emitted by motor vehicles and power driven vessels Article 34 The State encourages the production and consumption of motor vehicles and power driven vessels that use clean energy. The State encourages and supports production and use of high-quality fuel oil, and takes measures to reduce pollution of air environment by harmful substances in fuel oil. Organizations and individuals shall stop production, importation and sale of leaded gasoline within the time limit specified by the Stage Council. Chapter 5 Prevention and control of waste gas, dust and odor nuisance Article 38 The enterprises that emit sulphide containing gases during petroleum refining, synthetic ammonia and coal gas production, coal carbonization, and non ferrous smelting shall install desulphurization unit or take other desulphurization measures.
Cleaner Production Promotion Law	Article 13 Related administrative departments of the State Council can approve the establishement of product identification for environmental protection and resource conservation such as energy conservation, water conservation and wastes reutilization as needed and formulate appropriate standards according to national regulations. Article 16 People's governments at various levels shall give priority to purchasing the products conducive to environmental protection and resource

	conservation such as energy conservation, water conservation and wastes reutilization. Article 18 New built, rebuilt and expanded projects shall conduct environmental impact evaluation, analyze and demonstrate raw material utilization, resources consumption, comprehensive resource utilization and pollutants production and treatment, and give priority to the clean production technique, technology and equipment with high resource utilization and low pollutants production.
compulsory elimination of “fifteen smalls”	The enterprises that adopt indigenous method are required to be closed or to stop production before September 30, 1996, including the enterprises that make arsenic, mercury, lead and zinc and refine oil and dress coal by using indigenous method, and the enterprises that produce pesticide, blanch and dye with colour for fabric, conduct electroplating, produce asbestos products and radioactive products by using indigenous method.
Environmental standards for coal fired industries	Emission Standard of Air Pollutants for Coal-Burning, Oil-Burning Gas-Fired Boiler (GWPB3-1999)
	Emission standard of air pollutants for industrial kilns (GB9078-1996)
	Emission standard of air pollutants for thermal power plants (GB13223-1996)
	Emission standard of air pollutants for coke ovens (GB16171-1996)
Environmental standards related to motor vehicles	Emission standard for exhaust emissions from motorcycle (operating condition method) GB 14621-2002
	Hazardous Materials Control Standard For Motor Vehicle Gasoline GWKB1-1999
	Emission standard for pollutants from light-duty vehicle GWPB1-1999
	China automobile industry policy

2. Environmental Impact of Energy Development Strategy Scheme

This Chapter will predict the influence of national energy development on the environment and public health in the light of energy need for comprehensive realization of moderately well off society in 2020.

2.1 Analysis of Energy Development Scenario Scheme in Next 20 Years

Different research institutes and experts put forward different analysis and prediction result for China's power development. For convenience of research, we will select three scenario schemes from them as the basis for analyzing the influence of energy development on environment and health.

2.1.1 Review and analysis of energy development scenario scheme

To more accurately compare the prediction of different research institutes and experts and scholars for China's future energy development, we hereby list the prediction results of the Energy Research Institute of the State Development and Reform Commission, the State Environmental Protection Administration, Asian Development Bank and China Academy for Environmental Planning, and analyze these predicted conditions and results respectively.

2.1.1.1 Project of "China Sustainable Energy and Carbon Emission Scenario analysis"- the Energy Research Institute of the State Development and Reform Commission

For the "Analysis of China's energy need in 2020" undertaken by the Energy Research Institute of the State Development and Reform Commission, the energy development prediction put forward in early 2003 is shown in table 2-1. In view of predicted result, the energy consumption elastic coefficient and type constitution ratio of energy consumer goods of the three schemes are rational and acceptable. According to this predicted high scheme, China's coal consumption will be 1.55 billion tons of standard coal by 2010 and 2. 09 billion tons of standard coal by 2002; and for the low scheme, coal consumption will be 1.05 billion tons of standard coal by 2010 and 1.33 billion tons of standard coal by 2020.

Table 2-1 China's Energy Development Prediction-Energy Research

Institute of the State Development and Reform Commission

Scheme	Year	GDP growth rate (%)	Energy Consumption elastic coefficient	Total energy consumption quantity (Mtce)	Type constitution of primary energy consumer products (%)				Total coal consumption quantity(Mtce)
					Coal	Oil	Gas	Power	
Scheme 1	1998			1360.3	77.0	18.9	1.4	2.7	1047.4
	2010	7.3	0.536	2159.5	71.8	19.5	3.7	5.0	1550.5
	2020	6.7	0.549	3099.3	67.5	21.5	5.0	6.0	2092.0
Scheme 2	1998			1360.3	77.0	18.9	1.4	2.7	1047.4
	2010	7.3	0.459	2023.5	69.4	19.9	5.3	5.4	1404.3
	2020	6.7	0.471	2761.2	62.3	22.4	8.1	7.2	1720.2
Scheme 3	1998			1360.3	77.0	18.9	1.4	2.7	1047.4
	2010	7.3	0.355	1850.0	66.4	20.3	7.0	6.4	1228.4
	2020	6.7	0.339	2316.5	57.3	21.7	10.7	10.2	1327.4

However, this prediction scheme also has defect. GDP growth degree of the three schemes is the same, i.e. 7.3 percent from 1998 to 2010 and 6.7 percent from 2010 to 2020. According to this economic development rate, China's economy will be difficult to realize the requirement of one-time growth on the basis of 2000 in 2010 proposed in "16th CPC National Congress", and China's economic development rate has been 7.8-8 percent from 1998 to 2003. Therefore this prediction differs slightly from current economic development rate and has the possibility of lower prediction result.

This project also has predicted China's future population, automobile, and car retention quantity (table 2-2).

Table 2-2 Prediction of China's Future Automobile and Car Retention Quantity

Prediction index	2000	2005	2010	2020
Automobile (10,000)	1610	2550	4010	7700
Private car (10,000)	370	810	1580	4150
Population (100 million)	12.66	13.21	13.78	14.7
Car retention quantity/100persons	0.3	0.6	1.1	2.8

2.1.1.2 "National Environmental Safety Strategy Report"-State Environmental Protection Administration

The State Environmental Protection Administration presented "National Environmental Safety Strategy Report" in December 2002 and pointed out that the situation of China's air environmental safety is pressing and coal based energy structure will affect air environment for a long time. The report has predicted China's medium- and long-term energy consumption need and the result is shown in table 2-3.

Table 2-3 China's Medium- and Long-Term Energy Consumption Need-State Environmental Protection Bureau

Predicted year	2000	2005	2010	2015	2020
GDP(100,000,000Yuan)	90652		178827		367007
Total energy consumption (10,000t standard coal)	128000	146239	167728	185379	205678
Percentage of raw coal in total energy consumption (%)	67.1	63.2	61.0	58.0	54.0
Total coal consumption (10,000t standard coal)	85888	92423	102314	107520	111066
Unit GDP energy consumption (t standard coal/10,000 Yuan, changeable price of 1990)	2.635	2.141	1.727	1.446	1.199

The energy consumption prediction in this report assumes that GDP growth rate is 7 percent from 2000 to 2010 and 7.5 percent from 2010 to 2020, differing to some extent from the development objective for China's future 20 years determined in the 16th CPC National Congress and the development rate in the several years of the 10^{th} Five-Year Plan period. On the other hand, this prediction set the percentage of coal consumption in total energy consumption at 61 percent in 2010 and 54 percent in 2020, having some difference from the assumed setting by the State Development and Reform Commission.

In addition, the report has predicted fuel utilization situation of urban households in China in the future 20 years by regarding the year 1996 as base year. See table 2-4 for result.

Table 2-4 Prediction of Fuel Utilization Situation of Urban Households in China

Predicted year	1996	2000	2010	2020
Urban population (100 million)	3.62	3.9	6.2-6.4	7.9-8.2
Gas utilization population (100 million)	1.38	1.8	4.1-4.3	5.8-6.1
Coal utilization population (100 million)	2.24	2.1	2.1-2.2	2.1
Percent of coal utilization in total urban population (%)	61.8	53.8	34	26

2.1.1.3 "Overview of China's renewable energy sources, energy efficiency and greenhouse gas emission reduction technology"-Asian Development Bank

In 2000, Asian Development Bank organized to carry out the regional research project entitled "Driving renewable energy sources, energy efficiency and greenhouse gas emission reduction". In October of the same year, Chinese expert panel completed the research report of "Overview of China's renewable energy sources, energy efficiency and greenhouse gas emission reduction technology" which predicted China's medium- and long-term energy consumption. See table 2-5 for the result.

Table 2-5 Prediction of China's Future Energy Consumption-Asian Development Bank (Chinese Expert Panel)

Predicted year	2000	2010	2020
GDP (100 million Yuan)	89404	179000	345600
Energy consumption elastic coefficient (%)		0.28	0.27
National commercial energy consumption (100 million tons standard coal)	13.03	16.2	19.6
Percentage of coal in the primary energy constitution (%)	65.8	54.7	43
Total coal consumption (100,000,000t raw coal)	12.0	12.4	11.8

Note: GDP adopts the fixed price of 2000.

GDP growth rate in this prediction is 7.2 percent from 2000 to 2010 and 6.8 percent from 2010 to 2020. In view of predicted result, both GDP development rate and energy consumption elastic coefficient are lower than afore mentioned several predictions and total coal consumption is significantly lower than the previous prediction.

2.1.2 Selection of energy development scenario scheme

Energy Efficiency Center of the Energy Research Institute of the State Development and Reform Commission synthesized the prediction for China's future energy development by the subject of "Analysis of China's sustainable energy and carbon emission situation" and proposed three scenario schemes A, B and C for the energy development in 2020 in August 2003.

To show the similarities and differences of the three scenarios, the subject group made a description by regarding the two main factors - the implementation strength of "sustainable development policy" and the strength of "market opening degree and degree of adaptation to accession to WTO and globalization progress (marketization progress for short) – as the main drive variables of the difference of the three scenarios: for scenario B, execution effect of sustainable development policy is relatively successful and market economic construction and opening gains result; compared with scenario B, scenario C is more ideal whether in terms of execution strength of sustainable development policy or in terms of market construction and opening degree of adaptation to globalization; while scenario A is poorer than scenario B whether in terms of sustainable development strength or market construction and development degree.

The subject of "Analysis of China's energy need in 2020" predicts the retention quantity of automobiles and cars in future China as follows:

Table 2-6 Prediction of Retention Quantity of Automobiles and Cars in future China

Index	2000	2005	2010	2020
Automobile (10,000)	1608	3800	6800	11000
Private car (10,000)	370	1200	3200	7200
Population (100 million)	12.66	13.21	13.78	14.7
Retention rate of automobiles per capita (%)	0.3	0.9	2.3	4.9

Compared with the prediction of table 2-2, the predicted result of "Analysis of power need in 2020" is obviously higher than the prediction of "Analysis of China's sustainable energy and carbon emission situation". As the prediction time of the latter is relatively early, possibility of lower result exists.

In the subject of "Analysis of power need in 2020", the prediction of the total primary energy need and constitution for the three different situations is shown in table 2-7.

Table 2-7 Comparison of Total Primary Energy Need and its Constitution

Scenario scheme	Type	Total energy need (Mtce)			Annual growth rate	Constitution (%)		
		2000	2010	2020	2000~2020	2000	2010	2020
High scheme	Coal	907	1425	2074	4.22%	69.9%	66.7%	63.2%
	Petroleum	324	538	877	5.10%	25.0%	25.2%	26.7%
	Natural gas	36	112	220	9.44%	2.8%	5.2%	6.7%
	Primary power	29	63	109	6.77%	2.3%	2.9%	3.3%
	Total	1297	2137	3280	4.75%	100.0%	100.0%	100.0%
Medium scheme	Coal	907	1365	1788	3.45%	69.9%	66.0%	61.7%
	Petroleum	324	524	795	4.58%	25.0%	25.3%	27.5%
	Natural gas	36	108	193	8.74%	2.8%	5.2%	6.7%

	Primary power	29	70	120	7.28%	2.3%	3.4%	4.1%
	Total	1297	2068	2896	4.10%	100%	100%	100%
Low scheme	Coal	907	1205	1466	2.43%	69.9%	64.8%	59.4%
	Petroleum	324	460	638	3.44%	25.0%	24.7%	25.9%
	Natural gas	36	115	219	9.41%	2.8%	6.2%	8.9%
	Primary power	29	79	144	8.26%	2.3%	4.3%	5.8%
	Total	1297	1859	2466	3.26%	100%	100%	100%

Note: electric power is converted as per electrothermal equivalent.

In view of predicted result, China's coal consumption will reach 1.69 billion - 1.99 billion tons by 2010 and raw coal consumption will reach 2,050,000,000t - 2.9 billion tons by 2020.

Besides prediction of energy and coal consumption, the above research subject has predicted the power generation capacity and its constitution of the three scenario schemes in the next 20 years. See table 2-8 for result.

Table 2-8 Power Generation Capacity and its Constitution of the Three Schemes in Next 20 Years

Scheme		Power generation (TWh)			Constitution		
		2000	2010	2020	2000	2010	2020
Low scheme	Gross generation	1364	2392	3755	100.0%	100.0%	100.0%
	Coal fired power generation	1072	1622	2416	78.6%	67.8%	64.3%
	Oil fired power generation	46	14	5	3.4%	0.6%	0.1%
	Gas fired power generation	6	110	188	0.4%	4.6%	5.0%
	Hydropower	224	525	835	16.4%	21.9%	22.2%
	Nuclear power generation	17	102	261	1.2%	4.3%	7.0%
	New energy source	0	19	49	0.0%	0.8%	1.3%
Medium scheme	Gross generation	1364	2455	3822	100.0%	100.0%	100.0%

	Coal fired power generation	1072	1634	2551	78.6%	71.1%	69.8%
	Oil fired power generation	46	18	11	3.4%	0.8%	0.3%
	Gas fired power generation	6	107	161	0.4%	4.7%	4.4%
	Hydropower	224	572	888	16.4%	20.3%	18.8%
	Nuclear power generation	17	57	126	1.2%	2.8%	5.7%
	New energy source	0	5	19	0.0%	0.4%	1.0%
High scheme	Gross generation	1364	2510	4218	100.0%	100.0%	100.0%
	Coal fired power generation	1072	1722	2645	78.6%	73.9%	73.7%
	Oil fired power generation	46	19	23	3.4%	0.8%	0.6%
	Gas fired power generation	6	113	167	0.4%	4.8%	4.7%
	Hydropower	224	485	789	16.4%	17.9%	15.4%
	Nuclear power generation	17	48	112	1.2%	2.3%	4.8%
	New energy source	0	5	19	0.0%	0.3%	0.8%

In the mean time, the above research subject also has predicted the consumption of power coal for the three scenario schemes and the result is shown in table 2-9.

Table 2-9 Comparison of Power Generation Coal for the Three Scenario Schemes in Next 20 Years

Scheme	2000	2005	2010	2020	2000~2020

	Total quantity (100,000,000 t)	Percentage of coal consumption (%)	Total quantity (100,000,000 t)	Percentage of coal consumption (%)	Total quantity (100,000,000 t)	Percentage of coal consumption (%)	Total quantity (100,000,000 t)	Percentage of coal consumption (%)	
Low scheme	5.5	61	6.9	65	7.9	66	10.7	73	3.4%
Medium scheme	5.5	61	7.2	63	8.8	64	12.4	69	4.1%
High scheme	5.5	61	7.3	63	9.3	64	14.8	71	5.1%

Considering the time effect of the subject "Analysis of energy need in 2020" and the unification of prediction statement of the whole research project, the subsequent environmental impact analysis is based on the prediction by the Energy Efficiency Center of the Energy Research Institute of the State Development and Reform Commission when undertaking the project of "Analysis of energy need in 2020".

2.2 Prediction of Environmental Impact of Energy Development

Environmental impact caused by energy development mainly has the two aspects: first, large quantities of coal combustion cause emission of air pollutants, and second, increase of retention quantity of urban motor vehicles results in increasing pollution of motor vehicles.

In a future period, thermal power plant will be the major coal user in China. Power generation coal is 65 percent of total coal consumption, and is expected to be 64 percent in 2010 and 72 percent in 2020. Carbon dioxide emitted due to energy utilization in China is 80 percent of emission quantity of various greenhouse gases and is expected to exceed the United States in 2020, ranking the first in the world.

According to prediction by the Chinese Research Academy of Environmental Sciences, based on present control level, with sharp increase of motor vehicle retention, emission of pollutants by motor vehicles will be two times in 2010 as much as in 2000.

2.2.1 Total emission of air pollutants

80 percent coal consumption in China is through direction combustion of raw coal. Besides pollution of coal combustion by thermal power industry, the medium- and small-sized boilers with coal as fuel and civil coal utilization are the major resource of sulfur dioxide and smoke dust in air (5).

2.2.1.1 Emission of coal burning pollutants

With reference to the coefficient used by related research institutes in calculating the emission of different pollutants in their research and combining the prediction of coal utilization in the previous section, we can obtain the generation quantity of major air pollutants caused by coal combustion in China in the next 20 years [6].

Table 2-10 Generation Quantity of Major Air Pollutants in China in Next 20 Years

Prediction index	2000	2010			2020		
		Low scheme	Medium scheme	High scheme	Low scheme	Medium scheme	High scheme
Total energy consumption (10,000t standard coal)	129700	185900	206800	213700	246600	289600	328000
Total energy consumption (10,000t standard coal)	126977	168697	191096	199496	205236	250315	290354
Percentage of coal consumption in energy (%)	69.9	64.8	66.0	66.7	59.4	61.7	63.2
Generation quantity of sulfur dioxide (10,000t)	2647	2680	3040	3174	2789	3401	3945
Generation quantity of nitrogen oxides (10,000t)	1880	2467	2727	2846	2870	3501	4061
Generation quantity of smoke dust (10,000t)	12567	18495	20950	21871	23351	28479	33035
Total emission of carbon (10,000t carbon)	83161	107303	121550	126893	125895	153547	178108

For emission of sulfur dioxide, China has proposed definite control objective, i.e. controlled at 18 million on the basis of 19.95 million tons in 2000. In the "Research of medium- and long-term sulfur dioxide emission reduction planning and implementation scheme for national electric power industry", Chinese Academy for Environmental Planning has proposed the country's control objective of sulfur dioxide emission, i.e. 16 million tons in 2010 and 13.5 million tons in 2020 respectively. For emission of smoke dust, the State also proposed the control objective of 10 percent reduction in 2005 on the basis of 2000 in the 10th Five-Year Plan period.

For other pollutants such as nitrogen oxides, the State has not proposed definite long-term control objective. Up to now, statistic calculation of emission of sulfur dioxides has not been formally established.

2.2.1.2 Emission of motor vehicle pollutants

At present, China's automobile retention quantity has exceeded 10,000,000. Statistics show that CO, HC and NOX emitted by motor vehicles in urban area in Shanghai are 86 percent, 90 percent and 56 percent of total pollutant emission load;

and during non-heating period in Beijing, CO, HC and NOX emitted by motor vehicles in urban area are 86 percent, 90 percent and 56 percent of total pollutant emission load; emission pollution caused by urban motor vehicles is becoming more and more serious.

The prediction of emission quantity of pollutants from motor vehicles involves many factors and is of great uncertainty. Here the “Emission standard for pollutants from light-duty vehicles”, issued by the State Environmental Protection Administration in 1999 and put into practice on January 1, 2000, is used as the unified emission coefficient of different motor vehicles. The standard includes three pollutants which are carbon monoxide, hydrocarbon, nitrogen oxides and particulates. Table 2-11 shows the relative strict emission limit at model certification test in the second phase.

Table 2-11 Emission Standard for Pollutants from Light-Duty Vehicles-Issued in 1999 (6)

Model	Pollutants	Emission standard value (g/km)	
		Phase 1 (January 1, 2001 – June 30, 2005)	Phase 2 (after July 1, 2005)
First class	CO	2.72	2.2
	HC＋NOx	0.97	0.5
	PM	0.14	0.08
Second class	CO	5.17	4
	HC＋NOx	1.4	0.6
	PM	0.19	0.12

According to the prediction of motor vehicle retention quantity in future China by the Energy Efficiency Center of the Energy Research Institute of the State Development and Reform Commission in previous section, Table 2-12 shows the pollutant emission of light-duty automobiles and private cars in China in different target years. The calculation of the prediction is based on the following assumptions: retention quantity of light duty automobiles is 80 percent of total quantity of automobiles; light duty automobile adopts the emission coefficient of the second class of vehicles; percentage of compression ignition engine in light duty automobiles is 10 percent in 2000, 15 percent in 2010 and 20 percent in 2020; and its percentage in private cars is 1 percent in 2000, 5 percent in 2010 and 10 percent in 2020. Light duty vehicles run 100km per day on average; private cars run 50km per day on average; reference quality of the second class of automobibles adopts median; and emission coefficient in 2000 adopts the emission standard of the first phase.

Table 2-12 Prediction of Emission Quantity of Pollutants from Motor Vehicles in China in Next 20 Years

Type of motor vehicles	pollutants	2000	2005	2010	2020
Light duty vehicles (t/d)	CO	6651	12160	21760	35200

	HC+NOx	1801	1824	3264	5280
	PM	24	44	98	211
Private cars (t/d)	CO	503	1320	3520	7920
	HC+NOx	179	300	800	1800
	PM	0.3	1.0	6.4	28.8

Obviously, assuming all motor vehicles can reach the present strictest emission standard, even based on the lowest emission factor, the emission quantity of pollutants from light-duty automobiles and private cars is rather considerable. Emission quantity of HC+NOx in 2020 will reach over 2,500,000t.

2.2.2 Analysis of emission characteristic of air pollutants

In view of the development trend of China's energy consumption in the future, the characteristic of concentration of energy consumption industries and concentration of regions is increasingly apparent, therefore emission of air pollutants shows the following characteristics:

2.2.2.1 Characteristic of industrial concentration

In 2000, power industry consumed 48.3 percent coal in China. According to the prediction of Chinese Academy for Environmental Planning, percentage of coal consumption by electric power industry in the state will reach 53.1 percent in 2005, 62.6 percent in 2010, 68.4 percent in 2015 and 69.8 percent in 2020, while the prediction of "Analysis of energy need in 2020" is higher than this level. From emission of sulfur dioxide, electric power industry was 44.6 percent of total emission in the state in 2000, and is expected to reach 45.6 percent in 2010 and 46.7 percent in 2020. Apparently, the characteristic of emission concentration of pollutants from electric power industry will continue to exist for a long period of time due to concentration of coal consumption.

Besides electric power industry, development of high energy consuming industries such as mining, metallurgy, building materials, non-ferrous metal and petrochemical industries certainly will bring relative concentration of energy consumption in these industries and will surely assume the characteristic of centralized emission of air pollutants in these industries.

2.2.2.2 Characteristic of city concentration

It is predicted that in 2000-2020, energy consumption by transportation sector will increase at the rate of 9.6 percent annually while retention quantity of automobiles and retention quantity of private cars will increase at the annual rate of 8.2 percent and 12.8 percent respectively.

Thus, with increase of motor vehicle retention quantity and relative concentration of energy consumption in urban area, air pollution in some cities in the future may possibly transform from smoke black type to the mixed type of smoke black and nitrogen oxides. A few cities may possibly change to the pollution type of nitrogen oxides [4].

2.2.2.3 Characteristic of regionality

The regionality characteristic of air pollutant emission due to energy consumption is mainly embodied in two aspects: first, concentration of energy consuming regions and industries brings about concentration of regional emission; second, the emission of elevated sources of power industry brings about long distance trans-regional transmission of air pollutants.

Transfer and concentration of severe polluting industries and high-energy-consuming industries to economically underdeveloped regions is bound to bring about the relative concentration of air pollutant emission in these regions and increase the difficulty of air environmental treatment and control in these regions.

Electric power industry is the big energy consumer and emission of elevated sources of thermal power plants decides that emission of air pollutants from big energy consumers is not only limited to the local area of energy consumption but has the characteristic of trans-regional transmission.

2.3 Prediction of Loss Caused by Energy-Induced Air Pollution

Economic losses caused by air pollution mainly include loss of human health, loss of agricultural production due to acid rain and loss of increased cleaning cost due to damage of articles.

2.3.1 Identification of health risk of air pollution

Energy utilization, especially pollutants emitted from coal combustion, seriously affects human health. These pollutants include sulfur dioxide, total suspended particulates, carbon dioxide, nitrogen oxide and acid rain resulting from emission of sulfur dioxide and nitrogen oxides.

2.3.1.1 Health risk caused by emission of sulfur dioxide

Sulfur dioxide rarely exists in the atmosphere by itself and often enters into the human body together with particulates. If it adheres to particulates, it can enter into alveolus of bronchiole with particulates. Metallic ions on particulates may catalyze sulfur dioxide to oxidize into sulfuric acid, whose stimulant action is 4-20 times greater than sulfur dioxide.

WTO summarized air pollution incidents happened in last 30 years and proposed the expectable action of air pollution to human health.

Table 2-13 Expectable Action of Air Pollution to Human Health

Contact type	Expectable action	Average concentration of pollutants (μg/m3)	
		SO2	Smoke dust
Short time contact	Over death of people above middle age or having chronic diseases	500 (daily average)	500 (daily average)
	Exacerbation of respiratory disease patients	250 (daily average)	250 (daily average)
Long time contact	Exacerbation of residents' respiratory diseases and increase of incidence rate of respiratory diseases	100 (annual average)	100 (annual average)

2.3.1.2 Health risk caused by emission of particulates

Total suspended particulates emitted into the atmosphere after combustion of coal and petroleum include soot particles, trace metals, hydrocarbon and smoke dust etc. particulates suspended in air directly act on human respiratory organs. As time passes, it will cause cynanche, bronchitis, pneumonia and lung cancer etc. It is noteworthy that the trace metals, such as antimony, tin, barium, cadmium, aluminum, iron and calcium, contained in coal itself will combine with water soluble low-concentration harmful gas SO2, NO2 and chlorine, which are all absorbed by the upper respiratory tract and lung to form bronchitis and pneumoconiosis etc.

2.3.1.3 Health risk caused by emission of carbon monoxide

Carbon monoxide is a colorless, odorless and virulent gas. Its affinity to hemoglobin is 300 times as much as oxygen and can impair the capability of hemoglobin to deliver oxygen to all organs, especially causing cerebral hypoxia and damage of nerve center. If breathing for one hour in the air containing 0.1 percent (volumetric) carbon monoxide, people may have a headache or feel like vomiting; if breathing 20-30 minutes in the air containing 0.5 percent (volumetric) carbon monoxide, feeling, reaction, perception and memory may be impaired or even life risk is caused.

2.3.1.4 Health risk caused by emission of nitrogen oxide

Nitrogen oxide can push deeply into upper respiratory tract and be inhaled to bronchi and alveolus, causing obliterative bronchiolitis and/or pulmonary edema. Nitrogen monoxide in nitrogen oxides has a much stronger affinity to blood hemoglobin than carbon monoxide. If excessively inhaled, the consequence is horrific.

2.3.1.5 Health problem caused by acid rain

Acid rain can enter lung tissue with respiration and can cause lung phlogosis and pulmonary edema in severe cases. Acid rain can decrease children’s immunologic function, increase incidence rate of chronic pharyngitis and bronchial asthma and increase morbidity rate of old people’s ophthalmic diseases and respiratory diseases.

2.3.1.6 Health risk caused by lead pollution

Lead contained in air enters into human body via respiratory tract with respiration and can be easily absorbed by alveolus. Most lead entering into blood combines with red blood cells and also combines with plasma proteins. A small part forms lead phosphate and glycerophosphoric acid.

Lead is biotoxin heavy metal. It mainly acts on the hemopoietic system, nervous system and digestive system to cause acute and chronic poisoning. Lead is particularly dangerous to children. Some researches show that lead contact can seriously reduce the intelligence quotient of low school-age children.

2.3.1.7 Health risk caused by motor vehicle pollution

As tail gas of motor vehicles is emitted at low altitude just in the range of human respiration, its impact on human health is very significant.

For example, the emitted carbon monoxide and nitrogen oxides can greatly block human oxygen delivery function; lead can suppress children’s intelligence development and cause dyshepatia; and particulates have carcinogenesis. In addition, the carbon monoxide, nitrogen oxides and hydrocarbon emitted by automobiles can react in the atmosphere under sun illumination to form photochemical smog and its pollution range is even wider and its hazard to human health and ecological environment is even greater.

2.3.1.8 Positive analysis of health impact by air pollution

Due to severe air pollution in China, incidence rate of respiratory diseases in China is very high. Chronic obstructive respiratory diseases including emphysema and chronic tracheitis are the major cause of death and its disease burden is twice as much as that of average level in developing countries.

Although air pollution in China take a favorable turn locally, the general situation is far to be optimistic. Incidence rate of urban respiratory diseases and lung cancer has risen to some extent. Death rate of respiratory diseases in 1994 was 94.4 persons/100,000persons; the highest male death rate is malignant tumor, being 156.01persons/100,000persons. In urban areas, the highest death rate is lung cancer, being 35.36persons/100,000persons. Analysis indicates that due to air pollution, outpatient service rate of respiratory diseases in hospitals increases for 36,600 cases; severe air pollution leads to 6,800,000 person-time first aid cases every year; and loss of work caused by air pollution pathogenesis is as high as 4,500,000 person-times every year.

In 1989, researchers studied the correlation between air pollution and daily death rate in two residential areas in Beijing. Very high concentration of total suspended particulates and sulfur dioxide was monitored in both areas. The estimated results indicates that if sulfur dioxide concentration in air increases one time, total death rate will increase 11 percent, incidence rate of chronic obstructive pulmonary diseases increase 29 percent, heart and lung diseases increase 19 percent, cardiovascular diseases increase 11 percent, other chronic diseases increase 8 percent and cancers increase 2 percent; if concentration of total suspended particulates increases one time, total death rate will increase 4 percent. Analysis of death cause shows that concentration of total suspended particulates increases one time, death rate of chronic obstructive respiratory diseases will increase 38 percent and death rate of pulmonary heart diseases increases 8 percent. In 1992, researchers studied the correlation between air pollution and daily death rate in Shenyang and concluded that the concentration of sulfur dioxide and total suspended particulates increases 100microgram/m3, total death rates increase 2.4 percent and 1.7 percent respectively.

Research conducted by Chinese and American scientists shows that the severer the pollution degree, the higher the abnormality rate of children's pulmonary function. Serious air pollution may significantly affect children's pulmonary function; the probability of children catching cold cough, cold expectoration, cold asthma and bronchitis is significantly positively correlated to the concentration of PM10 and PM2.5 and Children's asthma is significantly positively correlated to SO2 pollution concentration (r=0.707).

Research conducted by Chinese Medical Association indicates that in Beijing, Shenzhen, Taiyuan and Guangzhou, 20 percent, 65 percent, 64 percent and 83 percent children respectively have body lead content exceed the safety standard recognized by WTO and it is estimated that 50 percent urban children in the country have body lead content exceed standard.

Research of indoor pollution made in some regions in China shows that the level of indoor particulates (come from biomass energy and coal combustion) is usually higher than outdoors (exceeding 500micrograms/m^3), and concentration of particulates in kitchens is the highest (exceeding 1,000micrograms/m^3). According to conservative estimation, annual early death caused by indoor air pollution in China is as many as 110,000 persons.

2.3.2 Estimation of economic loss caused by air pollution

2.3.2.1 Economic loss caused by air pollution

With reference to the huge economic loss caused by air pollution, present researches are mostly estimates for loss of air pollution in mid-1990s in China. Due to different calculation method and point of view, there exists a difference in the calculation of air pollution losses. Here we select three representative results (table 2-14): the "Estimation of Economic Loss Caused by Economic Pollution in Mid-1990s in China' conducted by the Environment and Development Research Center of the

Chinese Academy of Social Sciences, the "Economic Measurement and Research of Environmental Pollution Losses in China" conducted by Xia Guang, the Policy Research Center of the State Environmental Protection Administration and the "Green Water and Blue Sky: China's Environment in 21st Century" conducted by World Bank.

Table 2-14 Calculation of Air Pollution Losses in Mid-1990s

Research report	Estimation of loss (100,000,000)				
	Human health	Crops and forest	Cleaning cost	Building materials	Total
Research 1: Estimation of Economic Loss Caused by Economic Pollution in Mid-1990s in China	171	95	60－160	35	361－461
Research 2: Economic Measurement and Research of Environmental Pollution Losses in China	202	72	155	10	439
Research 3: Green Water and Blue Sky: China's Environment in 21st Century	869	277		16	1162

Note: Estimation of World Bank selects human capital approach and exchange rate of RMB and USD adopts 5.8 according to the level in early 1990s.

Viewing from the air pollution constitution of the above researches, the loss of human health caused by air pollution is over 50 percent of total losses and calculation of World Bank is as high as 74 percent. Therefore, health hazard caused by air pollution is very severe.

Take sulfur dioxide as an example, the State Environmental Protection Bureau summarized the evaluation by related research institutes and experts in "National Environmental Safety Strategy Report"(16) to estimate economic losses caused by air pollution such as acid rain, and concluded that pollution of 1t sulfur dioxide causes a loss of more than 5,000Yuan (mainly based on the estimate of World Bank, possibly exorbitant).

2.3.2.2 Control cost of sulfur dioxide pollution

Future prevention and control cost of sulfur dioxide pollution is based on present desulphurization cost of thermal power plants. At present, thermal power plants invest average 500Yuan in desulphurization for 1kw installed capacity. According to this standard and assuming sulfur content of power generation coal in 2010 and 2020 is 0.9 percent and 0.85 percent respectively, coal consumption of unit power supply is 368g/kwh and 340g/kwh. Assuming desulphurization of other methods (changed to burn low-sulfur coal, desulphurization by circulating fluid bed) is 40 percent in

2010 and 30 percent in 2020, according to the cost parameter provided in the "Research of medium- and long-term sulfur dioxide emission reduction planning and implementation scheme for national electric power industry" by Chinese Academy for Environmental Planning, average cost for sulfur dioxide reduction is 900Yuan/t if changed to burn low-sulfur coal and desulphurization cost of circulating fluid bed is 250Yuan/kw installed capacity, then the finally calculated cost necessary for control of sulfur dioxide in the country in 2010 and 2020 is shown in table 2-15.

Table 2-15 Reduction Quantity of Sulfur Dioxide and Investment Demand in Next 20 Years in China

Prediction index	2000	2010			2020		
		Low scheme	Medium scheme	High scheme	Low scheme	Medium scheme	High scheme
Total energy consumption (10,000t standard coal)	129700	185900	2068	2137	2466	2896	3280
Total coal consumption (10,000t raw coal)	126977	168697	191096	199496	205236	250315	290354
Generation quantity of sulfur dioxide (10,000t)	2647	2680	3040	3174	2789	3401	3945
Control objective of sulfur dioxide (10,000t)	1995	1600	1600	1600	1350	1350	1350
Reduction quantity needed (10,000t)	0	1843	2300	2472	2706	3597	4388
Investment for reduction (100,000,000Yuan)	0	1633	2101	2300	2913	3912	4797

2.3.3 New trend of air environmental pollution hazard

Air pollution type of Chinese cities is changing from smoke black type to mixed type or motor vehicle pollution type and this pollution situation is particularly evident in Beijing, Guangzhou and Shanghai cities.

Viewing from the genesis of air pollution, urban air pollution is in a pluralistic development trend, rapid increase of motor vehicles makes emission amount of NOx and volatile organic compounds contributes more and more to urban pollution, and at the same time, sources of the major pollutant in urban air-total suspended particulates-is becoming increasingly complicated.

2.3.4 Prediction of impact of energy development on public health

The relation between energy development and health is a relatively complicated problem and it is very difficult to establish direct relation between them. For this reason, this section proposes the scenario scheme of different urban environmental quality change which is used as the basis of analysis.

2.3.4.1 Urban environmental quality scenario scheme

Change of urban environmental quality caused by energy development is the most direct factor of affecting health level. To better describe the environmental impact caused by energy development, three scenario schemes of future China's urban air environment are hereby proposed. The purpose is to describe the impact on urban environmental quality caused by energy development through comparison and describe health impact caused by energy development according to urban population change.

Setting of scenario scheme is to use the percentage of different environmental quality cities in total number of cities as variable, to select particulates and sulfur dioxide as characteristic pollutants and to use the air environmental quality of Chinese cities in 2001 as the basis.

Figure 2-1 gives the change situation that urban particulates and sulfur dioxide in China exceeded national Grade 2 quality standards in 1992 and 2002. It can be seen from the figure that early and mid-1990s was the most serious sulfur dioxide pollution period in Chinese cities; from the end of 1990s to 2000, the cities with sulfur dioxide exceeding standard saw a stable downtrend; and in recent years it basically maintains at 20 percent.

It can also be seen from this figure that the peak urban particulate pollution in China was in mid- and late 1990s; from the end of 1990s to 2002, the percentage of urban particulates exceeding standard slightly ascended. Improvement of particulate environmental quality in late 1990s is due to the associated effect of sulfur dioxide reduction. But till recent time, stagnation of sulfur dioxide reduction and rapid increase of urban motor vehicles are the major cause of urban particulates exceeding standard.

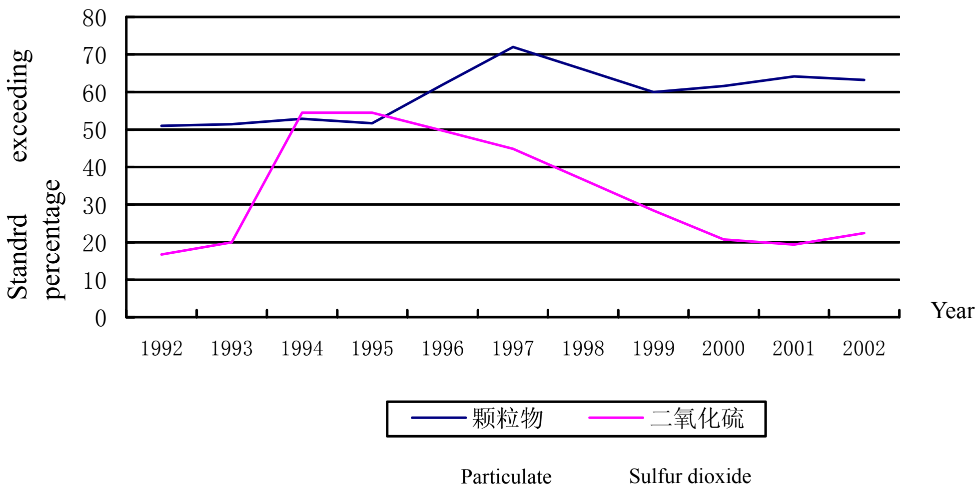


Figure 2-1 Environmental Standard Exceeding Situation of Urban Particulates and Sulfur Dioxide in China in Recent Years

Data source: "Environmental Condition Bulletin" of past years

Setting of scenario scheme is shown in table 2-16. Basic scheme is the statistic data of Environmental Condition Bulletin in 2001. Supposing generation quantity of pollutants increases due to energy development and increase of coal and motor vehicle fuel oil in 2010 and 2020, as necessary control measure is taken however, urban environmental quality level has not further deteriorated and maintains at the level of 2002.

In the scheme of slightly improvement, assuming the percentage of cities with particulate environmental quality poorer than grade 3 drops to 18 percent in 2010 and to 8 percent in 2020 and the percentage of cities poorer than grade 2 drops to 55 percent in 2010 and to 45 percent in 2020; and assuming urban sulfur dioxide environmental quality all reaches grade 3 quality standard and the percentage of cities poorer than grade 2 drops to 10 percent and to 2 percent in 2020, and 98 percent cities have their sulfur doxide environmental quality reaches or excels grade 2 standard.

In the scheme of continuous deterioration, assuming the percentage of cities with particulate environmental quality not up to standard increases slightly, the percentage of cities poorer than grade 3 reaches 32 percent in 2010 and maintains at 32 percent in 2020, and the percentage of cities poorer than grade 2 reaches 68 percent in 2010 and maintains at this level in 2020. The percentage of cities with sulfur dioxide environmental quality poorer than grade 3 reaches 15 percent in 2010 and increases to 20 percent in 2020, and the percentage of cities poorer than grade 2 reaches 25 percent in 2010 and increases to 30 percent in 2020.

Table 2-16 China's Future Air Environmental Change Scenario scheme - Percentage of Cities with Different Environmental Quality

Year	Scenario scheme	Particulate			Sulfur dioxide		
		Up to grade 2 (%)	Poorer than grade 2 (%)	Poorer than grade 3 (%)	Up to grade 2 (%)	Poorer than grade 2 (%)	Poorer than grade 3 (%)
2001	Basic scheme	6.3	64.1	29.6	70.9	19.4	9.7
2010	Maintains present situation	6.3	64.1	29.6	70.9	19.4	9.7
	Slightly improved	27	55	18	90%	10	0
	Continuous deterioration		68	32	60	25	15
2020	Maintains present situation	6.3	64.1	29.6	29.1	19.4	9.7
	Slightly improved	47	45	8	98%	2	0
	Continuous deterioration		68	32	50	30	20

2.3.4.2 Health hazard caused by urban air pollution

Quantity of urban population is directly related to the hazardous degree of air pollution to human health. The project of "Analysis of China's sustainable energy and carbon emission situation" assumed by the State Development and Reform Commission predicts China's population urbanization level in next 20 years by three scenario schemes and its prediction is basically the same as the prediction (table 2-3) made by the State Environmental Protection Administration in "National environmental safety strategy report". Synthesizing these two researches, prediction of China's population in next 20 years is shown in table 2-17.

Table 2-17 Prediction of China's Population and Urbanization Level in Next 20 years

Content	2000	2010	2020
Population (100,000,000)	12.66	13.78	14.7
Urbanization rate (%)	36.1	44.01	55.78
Urban population (100,000,000)	4.6	6.1	8.2
Percentage of downtown population in urban population (%)	60	70	75
Downtown population (100,000,000)	2.7	4.2	6.1

According to calculation of World Bank, the population exposing to polluted air in cities is approximately 80 percent of total urban population. Based on this calculation and in combination with the “future China’s air pollution scenario scheme” given in table 2-16 and the “China’s future urban population and downtown population” given in table 2-17, we can calculate the number of population exposing to air pollution in different target years. Here from the conservative point of view, only the number of population exposing to particulate population environment is calculated. The urban environment up to grade 2 national air environmental standard is regarded as up-to-standard air environment, the urban air environment poorer than grade 2 but better than grade 3 is regarded as light pollution, and the urban air environment poorer than grade 3 is regarded as severe pollution. The calculation result is shown in table 2-18.

Table 2-18 Population Exposing to Pollution in Different Air Environmental Quality Scenario schemes (unit: 1,000,000persons)

Year	Maintains present situation			Slightly improved			Continuous deterioration		
	Up-to-standard environment	Light pollution	Severe pollution	Up-to-standard environment	Light pollution	Severe pollution	Up-to-standard environment	Light pollution	Severe pollution
2001	68	138	64						
2010	105	215	99	175	185	60	84	228	108
2020	153	313	144	351	220	39	122	332	156

It can be seen from the above table that if urban air environmental quality maintains unchanged, the urban population affected by air pollution (exceeding grade 2 national quality standard) will reach 310,000,000 in 2010 and 450,000,000 in 2020, being 22.5 percent and 30.6 percent of total national population of the same period respectively.

Viewing from literature collection and analysis, almost all researches of health impact caused by air pollution in China are based on two research cases of epidemiology, i.e. Shenyang Case and Beijing Case, especially on the deduction of their achievements. Here only particulate is used as calculation basis and mainly Shenyang research conclusion is referred to, which is adjusted and enlarged to calculate the situation in the country.

According to above analysis of population exposing to air pollution, urban population can be divided into three categories, i.e. population in the regions not exceeding standard, population slightly exceeding standard and population severely exceeding standard. Early death of exposed population in the region severely exceeding standard is regarded as close to Shenyang level (TSP>400microgram/m^3). If Shenyang has a population of 2,000,000, the number of early dead people is 3,200.

For slightly populated region, its average concentration is estimated to be 300microgram/m^3, and the calculation is made by the following equation:

$$P_p = P_E \bullet M \bullet M_P = P_E \bullet M \bullet D_r \bullet (A_1 - A_0)$$

where:

P_E: Exposed population;
M: Regional crude death rate;
M_P: Change percentage of total death rate;
D_r: Gage reactivity coefficient;
A_1: Calculated pollution concentration;
A_0: Reference pollution concentration

It is based on 200micrograms/m3 (TSP grade 2 national quality standard) to calculate the total death toll increased when pollution level changes to 300micrograms/m3 (TSP grade 3 national quality standard). Dr is 10 percent, PE is calculated based on exposure population in table 2-15 and M is 0.009. By adopting the estimated economic loss obtained by World Bank using the human capital approach (only including the wage income loss caused due to early death) in "Green Water and Blue Sky: China's Environment in 21st Century", i.e. 9,000USD/person, the economic loss caused due to early death in urban area under different schemes is calculated and the calculation results are shown in table 2-19.

Table 2-19 Health Loss under Different Air Environmental Quality Scenario schemes

Change trend of air quality	Maintains present situation		Slightly improved		Continuous deterioration	
	People of early death (10,000 persons)	Economic loss (100,000,000 Yuan)	People of early death (10,000 persons)	Economic loss (100,000,000 Yuan)	People of early death (10,000 persons)	Economic loss (100,000,000 Yuan)
2001	22.7	169.6				
2010	35.3	263.7	26.3	196.5	37.8	282.4
2020	51.3	383.2	26	194.2	54.9	410.1

Note: 1 USD=8.3 Yuan RMB

Due to restriction of various conditions, the results in table 2-19 can not be regarded as accurate prediction results, but the table at least gives the quantitative damage situation of human health caused by urban air pollution due to energy utilization from

2.4 Summary: Future Energy Environmental Cost

Environmental impact of energy development is mainly embodied in the two aspects: first, emission of air pollutants caused by coal combustion results in impact on regional environmental quality and human health; second, tail gas of motor vehicles results in urban environmental problem. See table 2-20 for the prediction of China's future energy development and its resultant environmental impact.

Table 2-20 China's Future Energy Development and its Environmental Impact

Prediction index	2000	2010			2020		
		Low scheme	Medium scheme	High scheme	Low scheme	Medium scheme	High scheme
Prediction of energy and coal consumption							
Total energy consumption (10,000 tec)	129700	185900	206800	213700	246600	289600	328000
Coal percentage in total consumption (%)	69.9	64.8	66.0	66.7	59.4	61.7	63.2
Total coal consumption (10,000 tc)	126977	168697	191096	199496	205236	250315	290354
Prediction of pollutants emission quantity							
Generation quantity of sulfur dioxide (10,000t)	2647	2680	3040	3174	2789	3401	3945
Generation quantity of nitrogen oxides (10,000t)	1880	2467	2727	2846	2870	3501	4061
Generation quantity of smoke dust (10,000t)	12567	18495	20950	21871	23351	28479	33035
Total emission of carbon (10,000t)	83161	107303	121550	126893	125895	153547	178108
Estimation of sulfur dioxide pollution control cost and economic loss							
Sulfur dioxide control objective (10,000t)	1995	1600	1600	1600	1350	1350	1350
Needed reduction quantity of sulfur dioxide (10,000t)	0	1843	2300	2472	2706	3597	4388

Accumulated investment in SO2 reduction (100,000,000 Yuan)		0	1633	2101	2300	2913	3912	4797
Annual pollution loss (100,00,000 Yuan)		500	320			203		
Prediction of motor vehicle retention quantity and pollutant emission								
Automobile (10,000)		1608	6800			11000		
Private car (10,000)		370	3200			7200		
Light-duty vehicle (10,000t)	CO	242	794			1284		
	HC＋NOx	66	119			192		
	PM	0.9	3.6			7.7		
Private car (10,000t)	CO	18	128			289		
	HC＋NOx	6.5	29.2			65.7		
	PM	0.01	0.23			1.05		

According to calculation by related experts, in mid-1990s, economic loss caused by air pollution was 50 billion Yuan, of which loss of human health is 50 percent of total air pollution loss, being 25 billion Yuan.

Impact of energy development on human health has some uncertainty. To better describe the health impact by future energy development, this section provides three scenario schemes of future urban environmental quality change and estimates the loss of human health caused by air pollution under different schemes.

Table 2-21 gives the health loss prospect of air pollution under these three scenario schemes. In future 20 years, China must take effective measure to control emission of air pollution and improve urban air environment to reduce economic loss caused by air pollution. Optimization of energy structure, reduction of coal consumption rate, improvement of coal utilization efficiency and strengthening of motor vehicle tail gas management are important measures to improve urban air environmental quality.

Table 2-21 Analysis of Impact of Future Air Pollution on Human Health

Scenario scheme	Loss index	2001	2010	2020
Maintains present situation	Rising exposure population (1 million people)	202	314	457
	Rising number of early-death people (10,000 people)	22.7	35.3	51.3
	Increased economic loss (100 million Yuan)	169.6	263.7	383.2
Slightly improved	Rising exposure population (1,000,000 people)	0	245	336
	Rising number of early-death people (10,000 persons)	0	26.3	26
	Increased economic loss (100 million Yuan)	0	196.5	194.2

Continuous deterioration	Rising exposure population (1 million people)	0	259	488
	Rising number of early-death people (10,000 people)	0	37.8	54.9
	Increased economic loss (100 million Yuan)	0	282.4	410.1

3. Four Major Environmental Challenges before Energy Development

Energy development and environmental protection are of great significance to China. China's energy development in the next 20 years is confronted with four major environmental challenges including environmental need, environmental capacity, environmental management and global climate change.

3.1 Environmental Need is Increasing Rapidly

China has formulated the phased objective of all around constructing moderately well off society and realizing production development, living in affluence and good ecology, and environmental obojective is an important part of it.

3.1.1 Environmental need for moderately well off society

In 1991, the research personnel of the former State Planning Commission jointly with those of statistic, financial, health and education departments (totally 12 departments) organized the subject group to research and formulate the "Basic standard for national people's moderately well off living standard" and determined 16 basic monitoring indices and the moderately well off standard reference value to be used as a measure of realization degree for national people's moderately well off living standard. It included one environmental protection index-forest cover rate. Former State Planning Commission used the comprehensive scoring method through zone distance realization degree to measure and calculate the 16 indices. National moderately well-off realization standard was 48 percent in 1990 and 96 percent in 2000.

With the proposal of all round construction of moderately well off society in 2002, research and formulation of relate national system of indices are still underway, but it includes ten basic standards in substance. Some departments and experts built five sub-systems and 28 indices to form the system of indices and weighting with reference to the ten modernization indices proposed by Inkeles and according to specific Chinese situation and suggestion of experts, including two environmental protection indices: treatment rate of three industrial wastes, and the percentage of rural population drinking tap water in total rural population.

The above indices are not enough to thoroughly and deeply reflect the enivironmental need for moderately well off society, and particularly they can not reflect the energy development and environmental need for realizing the moderately well off society.

3.1.2 Energy based environmental need

All round construction of moderately well off society must realize the harmonious development of energy and environmental need. In the world, per capita energy consumption and per capita power consumption are import indicators of national economic development level and modernization degree. Energy statistical data of countries in 2000 indicated that when per capita GDP reaches 3,000 USD, per capita energy need (TPES) is 2.06toe/person and 2,584kWh/person; China's per capita TPES in 2000 was 0.90 toe/person and 993 kWh/person. Calculated either based on population or on GDP, our country energy need in 2020 is 3 billion toe, corresponding to 4.3 billion tce, and is 3.36 times more than 2000. From the viewpoint of China's energy resource and supply and demand, obviously, domestic market is impossible to satisfy this huge energy need and particularly our country's coal based energy structure is difficult to meet the requirement of sustainable development strategy for all round construction of moderately well off society.

The motive of energy need comes from people's will and wishes and governments (at various levels)'s responsible legal rules for local environmental quality. National people sent 55,800 letters to report environmental pollution in 1991 and the number sharply increased to 248,000 letters in 2000. The letters reported five types of environmental pollution and the letters reporting air environmental pollution ranked the first or the second. On the other hand, in order to improve urban environmental quality, the Environmental Protection Committee of the State Council issued the "Decision on quantitative evaluation of urban environmental comprehensive treatment" on July 13, 1988. Presently, the State evaluates 47 key cities, the total number of cities to be evaluated in provinces and autonomous regions has exceeded 600 and quantitative evaluation is carried out to the full.

Whether people's will and wishes or governments' responsibilities, environmental need is usually embodied in environmental protection objective and eventually included in environmental quality standard. According to China's Air Quality Standard (GB3095-1996), daily average concentration of sulfur dioxide is 0.15mg/m^3, daily average concentration of TSP is 0.30mg/m^3, PM_{10}0.15mg/m^3, NO_X0.10 mg/m^3, $NO_2$0.08 mg/m^3 (grade 2 standard). The fact is: the population of cities with air quality being up to standard is only 26.3 percent of total number of statistical urban population and the urban population exposing to substandard air quality is approximately 3/4 of the statistical urban population.

According to indices for performance check such as national environmental protection model city, ecological province, ecological city and ecological demonstration district (county) and referring to the experience of national energy and environmental development, we propose the energy need indices for China's energy development in the next 20 years. See table 3-1 for details.

Table 3-1 System of Indices for China's Energy Development and Environmental Need in Next 20 Years

Index	Unit	2000	2010	2020

Social economy and energy sources	GDP (Fixed price in 2000)	100,000,000 Yuan	89404	182383	358776
	Total population	100,000,000 persons	12.66	13.6	14.31
	Per capita GDP	USD/person	851	1616	3021
	Total energy consumed	100,000,000 tce	13.58	17.73	20.68
	Total power generation	100,000,000 kwh	13685	27434	44263
Energy consumption structure	Percentage of coal in total energy consumed	%	67.9	60.6	64.2
	Percentage of hydropower (nuclear power) in total power generation	%	18.99	21.96	23.03
	Percentage of renewable energy sources in total energy consumed	%	2	6	8
Energy consumption level	Energy consumption strength	tce/10,000 Yuan GDP	1.52	0.97	0.58
	Energy conservation rate	%	4.68	4.36	5.09
	Per capita energy consumption	tce/person	1.07	1.30	1.45
	Per capita power consumption	kwh/person	1081	2017	3093
Coal utilization	Total coal consumption	100,000,000 tce	12.91	15.05	18.58
	Percentage of terminal coal consumption	%	39	26	14
	Percentage of coal consumption for processing conversion	%	60	73	85
	Raw coal washing rate	%	35	50	70
Total quantity control of air pollutants	Total quantity control objective of sulfur dioxide emission	10,00t	1995	1616	1309
	Total quantity control objective of smoke dust emission	10,000t	2257	1600	1000
	Total quantity control objective of NO_x emission (calculated as per NO_2)	10,000t	1890	1800	1600
Air pollution treatment and control	Industrial smoke prevention and dust control rate	%	91.41	100	100
	Smoke dust reduction rate	%	91.8	95	97
	Sulfur dioxide reduction rate (combustion)	%	10.3	50	70
	Industrial dust reduction rate	%	82.1	90	95
	Percentage of desulphurization units in the capacity of thermal power generating units	%	2.1	29	40

Environmental protection investment	Percentage of Environmental protection investment in GDP	%	1.1	1.5	2
Air environmental quality	Days with air quality index better than grade 2	Day	N/A	200	300
	Daily average concentration of SO_2	ug/m^3	150	150	150
	Daily average concentration of inhalable particulate matters	ug/m^3	150	150	150
Urban living environment	Popularization rate of urban gasification	%	84.2	60.0	75.0

3.2 Environmental Capacity Is Extremely Limited

At present, total emission capacity of sulfur dioxide in the country is 12 million t – 16.2 million tons. Environmental capacity of nitrogen oxides is also basically saturated.

3.2.1 Analysis of environmental capacity for sulfur dioxide

Environmental capacity for sulfur dioxide mainly depends on urban air quality and national acid rain control.

3.2.1.1 Air-quality-based sulfur dioxide capacity

Research shows that only under the condition that national energy structure, industrial structure, urban layout and meteorological condition are not significantly changed, Xinjiang and Tibetan regions are not considered and national SO2 emission is controlled to 12 million tons, can SO2 concentration of most cities in the country reach national Grade 2 standard. According to the result of 16 air environmental resource areas concluded by Chinese Research Academy of Environmental Sciences, table 3-2 lists the regions that must reduce emission of air pollutants and that may increase some emission in the next 10 years. Thus it can be seen that most urban areas, coastal rapid economically developing regions and the regions suffering serious pollution of acid rain and sulfur dioxide basically have not air environmental capacity resources.

Table 3-2 Analysis of Air Pollution (SO2) Emission Reduction Potentiality in Respective Regions

Province (regions)	Regions that may increase emission	Regions that must reduce emission
Inner Mongolia	East and west	Huade, Hohehot, Dongsheng regions in central part
Heilongjiang	North	Qiqihar region in Southwest, Harbin in South, North of

		Xingkai Lake in Southeast
Laoning	Northwest	Shenyang, Anshan in Central part, South of Peninsula
Guangxi	Northeast	Liuzhou in North, Nanning in South
Xinjiang	Other vast regions	Urumchi region
Gansu	Northwest	Lanzhou and Tianshui regions in Southeast
Ningxia	South	Yinchuan region in Central part
Shanxi	Hequ region in Northwest	Taiyuan region in Mid-East, Northeast, South
Shannxi	North of Yanan in North	Guanzhong Plain in South, north of Qinling Mountains, Hanzhong Plain
Shandong	East end of Peninsula	Jinan in Central part, Qingdao in Southeast
Fujian	Southwest	Coastal Fuzhou, Fuding regions
Jilin		Mid-South
Hebei (Beijing, Tianjin)		East part, Shijiazhuang, Xingtai, North of Taihang Mountain Piedmont, Yanshan Mountain Piedmont, Beiing-Tianjin-Tangshan region
Hubei	Exi region in Southwest	Hankou region in East
Hunan	Songzhi, Jishou in Northwest	Most part of East region, Shangsha
Hainan	Most part	North, Haikou
Gongdong	East, North	Mid-South, Guangzhou, Shenzhen
Anhui	Most part is low-emission region	Northeast, Bangbu region
Jiangxi	Xunwu in South	Nanchang region in North
Yunnan	Most part	East border, Xingren region
Sichuan		South, Chongqing, Yibin, Chengdu
Guizhou	East border	Southwest, Guiyang
Zhejiang	Southwest part has low emission	Northeast, Hangzhou and coastal region
Henan	Southeast part is low-emission region	North, Anyang, Central part, Zhengzhou and other most regions
Shanghai, Jiangsu		Shanghai, South of Jiangsu, Nanjing

Source: Ren Zhenhai, 1999 (18).

3.2.1.2 Acid-rain-control-based sulfur dioxide capacity

With other conditions determined, rational layout of pollution sources and adjustment of emission height can also improve ground environmental quality. However resource of air environmental capacity is limited and it is also limited by the degradation capability bearable by ecological system, or in other words, the critical load bearable by ecological system [8].

According to research of "National acid rain control scheme" by Chinese Research Academy of Environmental Sciences, to meet the requirement of sulfur sedimentation critical load, China's annual total emission of sulfur dioxide shall be eventually controlled at 16.2 million tons.

At present, sulfur sedimentation of many regions in China has exceeded the critical load bearable by ecological system. Figure 3-1 is the sketch of our country's sulfur sedimentation supercritical load regions in the "Research of acid rain control scheme and SO2 total quantity control scheme", the key technologies R&D programme of the 9th Five-Year Plan by the Environmental Engineering department of Tsinghua University. It can be seen from figure 3-1 that if not controlled, China's SO2 pollution range and degree will increase rapidly. Supercritical load regions of sulfur settling volume increase from 23 percent of national territory area in 1995 to 32 percent in 2020 and supercritical load degree is becoming more and more serious.

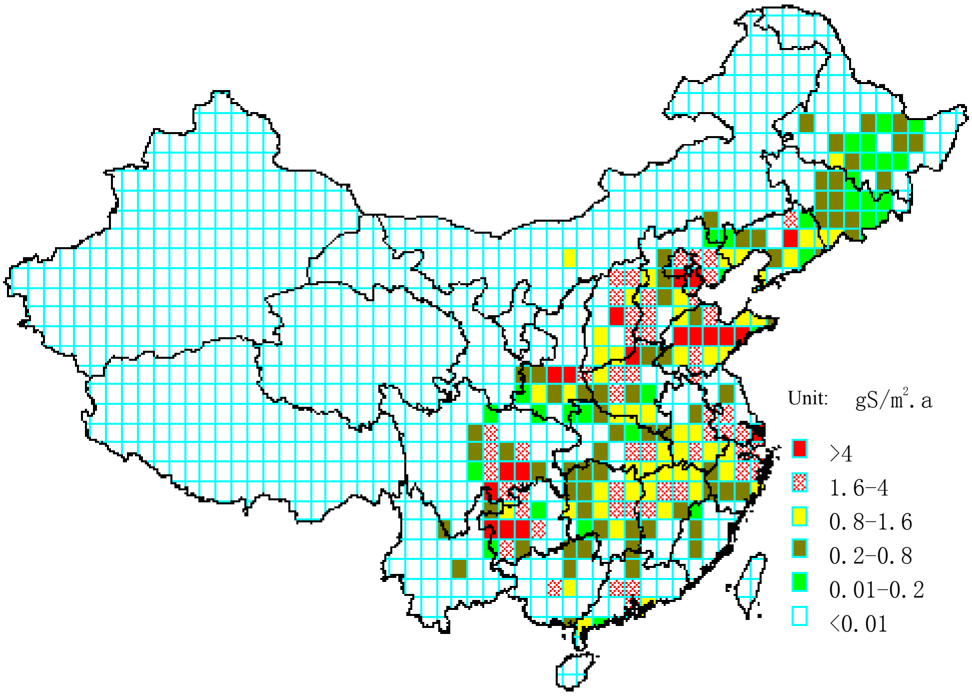


Figure 3-1a Sketch of Our Country's Sulfur Sedimentation Supercritical Load Regions in 1995

Another characteristic of sulfur dioxide pollution is the continuous enlargement of pollution zone centered on key cities. According to research made by Chinese Research Academy of Environmental Sciences, potential total emission of sulfur dioxide in 2002 was 19.27 million tons. Therefore if measured by total quantity of quality capacity, it is necessary to reduce 7.27 million tons of sulfur dioxide compared with 2002; if measured by total quantity of sulfur sedimentation critical load capacity, it is necessary to reduce 3 million tons.

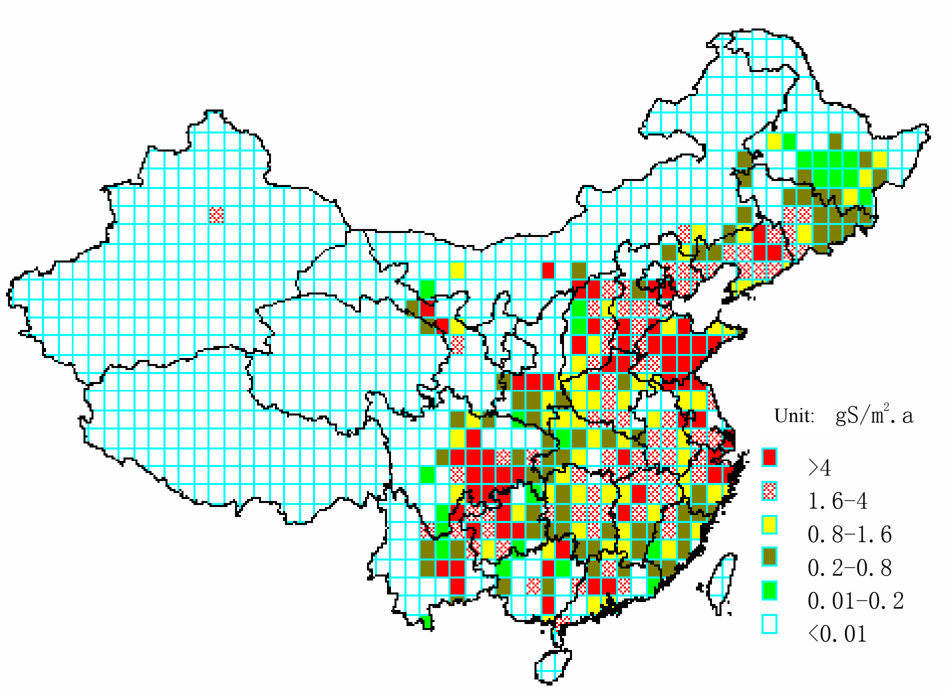


Figure 3-1b Sketch of Sulfur Sedimentation Supercritical load Regions without Control in 2020

3.2 .2 Analysis of nitrogen oxide environmental capacity

According to research result of "National acid rain control scheme" by Chinese Research Academy of Environmental Sciences, emission of nitrogen oxides from administrative units at various levels in the country is shown in figure 3-2.

For total quantity control of nitrogen oxides especially sulfur dioxide, research basis is relatively weak and the State has not started total quantity control. In view of nitrogen oxide environmental quality over the last ten years, environmental capacity of nitrogen oxides is basically in a saturated state.

Therefore, according to research prediction of Chinese Research Academy of Environmental Sciences, if emission of sulfur dioxide increases from 10.65 million tons in 1995 to 25 million tons in 2010, the task of reducing the emission of nitrogen oxides is more austere than reducing sulfur dioxide. As no systematic research of environmental capacity for nitrogen oxides has been made in our country, it is impossible for this research to draw a conclusion for the environmental capacity of nitrogen oxides. However, in the light of aggravation situation of urban nitrogen oxide pollution and national acid rain pollution at present, we think that environmental capacity of nitrogen oxides in the country is at least not higher than the emission of nitrogen oxides in the country in 2000, or in other words, environmental capacity for nitrogen oxides in the country is not higher than 18,800,000t.

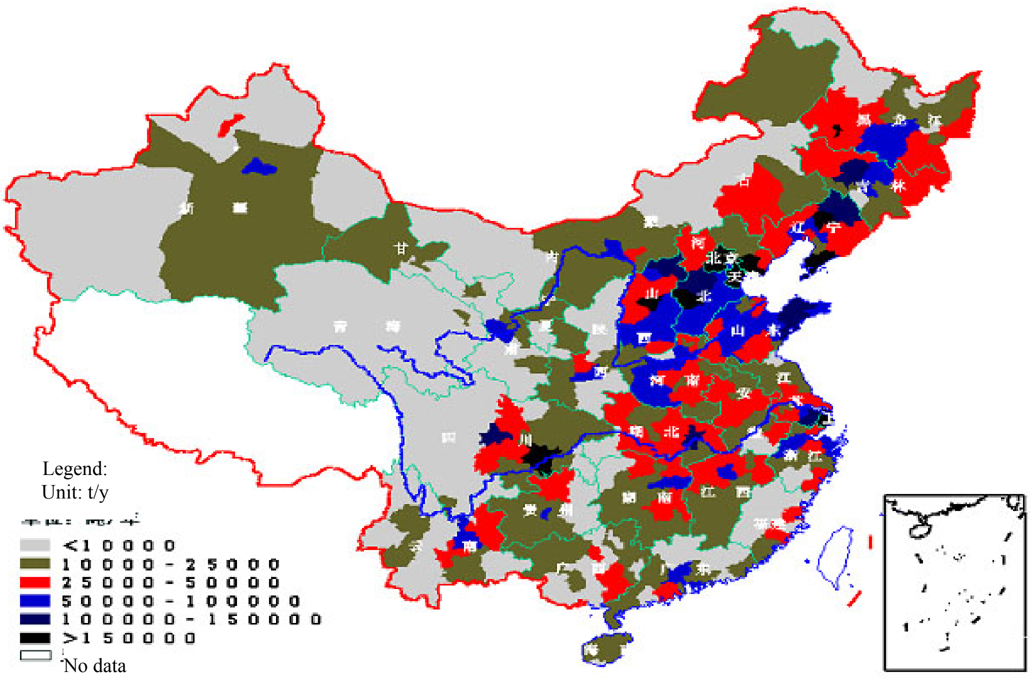


Figure 3-2 Distribution of Emission Quantity of Nitrogen Oxides in China (1995)

3.2.3 Upper limit of environmental-capacity-based coal combustion

According to 12 million tons of sulfur dioxide, the upper limit of environmental quality capacity, figure 3-3 gives the upper limit of coal consumption with different desulphurization efficiency under the condition of different sulfur content.

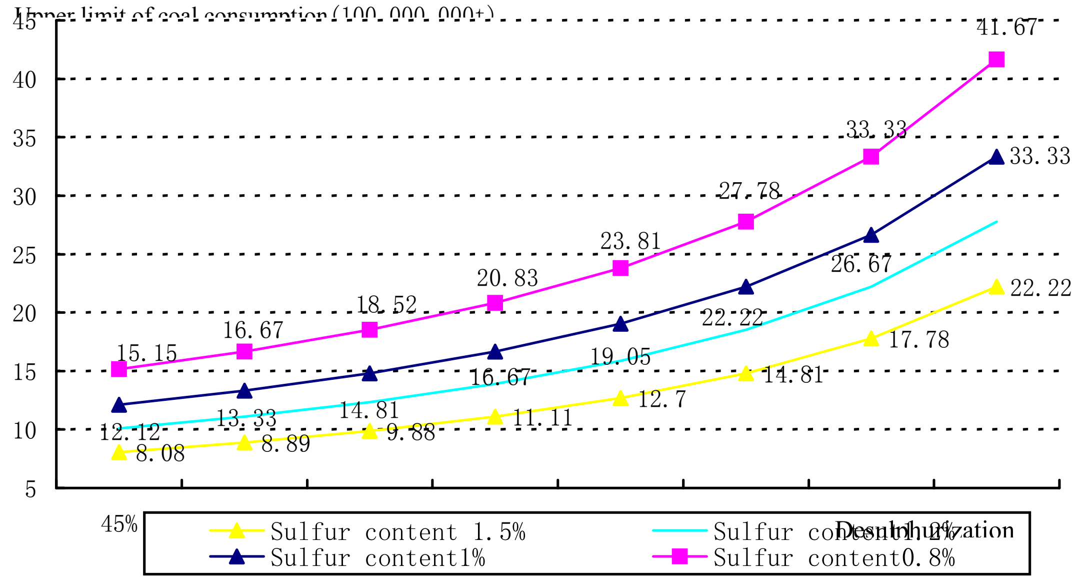


Figure 3-3 Upper limit of coal consumption of Different Desulphurization Efficiency under 12,000,000t Sulfur Dioxide Environmental Capacity

Considering sulfur dioxide environmental capacity, if China wants to increase coal consumption, it only has two ways to go: first, increase desulphurization efficiency, and second, reduce coal sulfur content. However, desulphurization efficiency of the coal combustion desulphurization user, the power industry, is not up to 10 percent at present while China's coal quality determines that low sulfur coal resource is very limited. As a result, China's coal consumption is faced with rigorous challenge from environmental capacity.

3.3 Environmental Standard Is Increasingly Strict

In view of China's environmental management trend, environmental standard is increasingly strict. Particularly total quantity control objective and pollution emission standard will be a huge challenge to the energy development in the next twenty years.

3.3.1 Total emission quantity control of pollutants

"Prevention and control law of atmospheric pollution" provides legal basis for the implementation of total quantity system and the "National management regulations on total emission quantity control of major pollutants" has been reported to the State Council for examination and approval, which is expected to be issued and put into practice very soon. This "Regulations" will provide more comprehensive and more operable laws and regulations for the implementation of total pollutant emission quantity control system.

Table 3-3 shows the sulfur dioxide control objective in the Tenth Five Year Plan period. By 2005, China's total power generation will exceed 2 trillion kwh, increasing 48.4 percent than 2000 and exceeding 16.0 percent than the predetermined objective in 2005, of which thermal power generation increases 45.6 percent than 2000 and power supply coal consumption rate only decreases 3.1 percent than 2000. If emission of sulfur dioxide in 2005 is reduced for 10-20 percent compared with 2000, the upper limit shall be 7.5 million tons even based on power statistical data. This requires all new built thermal power generating units to be equipped with desulphurization facilities, old thermal power generating units to be equipped with desulphurization facilities corresponding to control objective and both new and old units to take control measures, which is the key to realizing reduction control objective. To achieve total quantity control objective, desulphurization units shall at least be 23 percent of thermal power generation unit capacity in 2005.

Table 3-3 Total Quantity Control Scheme of Sulfur Dioxide in the Country's Tenth Five Year Plan Period (unit: 10,000t)

Region	Control objective in 2000	Emission quantity in 2000	Control objective in 2005	Two-control area index in 2005	Reduction quantity compared with Ninth Five Year Plan objective	Reduction compared with 2000
Beijing	38.0	22.4	18.8	15	50.5%	16.1%
Tianjin	33.0	32.9	29.0	25	12.1%	11.9%
Hebei	170.0	132.13	120.0	50	29.4%	9.2%
Shanxi	181.0	120.16	110.0	36	39.2%	8.3%
Inner Mongolia	80.0	66.38	68.2	38	14.8%	-3.1%
Laoning	107.7	93.24	98.9	67	8.2%	-6.1%
Jilin	28.0	28.57	28.0	6	0.0%	1.9%
Heilongjiang	31.0	29.66	30.0	0	3.2%	1.1%
Shanghai	50.0	46.50	45.0	45	10.0%	3.2%
Jiangsu	139.0	120.18	100.0	82	28.1%	20.3%
Zhejiang	61.0	59.27	61.0	55	0.0%	16.7%
Anhui	50.0	39.53	36.0	12	28.0%	8.9%
Fujian	30.0	22.50	25.0	17	16.7%	11.1%
Jiangxi	63.0	32.31	30.5	16	51.6%	5.6%
Shandong	243.0	179.59	150.0	69	38.3%	16.5%
Henan	154.0	87.69	100.1	15	35.0%	-14.2%
Hubei	65.0	56.04	54.3	33	16.5%	3.1%
Hunan	88.0	77.25	65.0	51	26.1%	15.9%
Guangdong	100.0	90.47	69.3	45	30.7%	23.4%
Guangxi	102.0	83.03	68.1	43	33.2%	17.9%
Hainan	8.0	2.04	2.2	0	72.5%	-7.8%
Chongqing	100.0	83.94	70.0	37	30.0%	16.6%
Sichuan	110.0	122.30	100.0	85	9.1%	18.2%

Guizhou	140.0	145.01	140.0	70	0.0%	3.5%
Yunnan	44.0	38.59	36.0	23	18.2%	6.7%
Tibeta	0.2	0.08	0.2	0	0.0%	-150.0%
Shannxi	114.9	62.33	75.0	26	34.7%	-20.3%
Gansu	50.0	36.85	35.0	20	30.0%	5.0%
Qinghai	5.0	3.20	5.0	0	0.0%	-56.3%
Ningxia	23.0	20.58	15.7	13	31.7%	23.7%
Xinjiang	41.0	31.05	33.6	6	18.0%	-8.2%
Whole country	2449.8	1995	1819.8	1000	25.7%	8.8%

By analyzing present situation, if we want to realize the objective that the whole country emits 12 million tons sulfur dioxide in 2020, we have to reduce emission of 2 million tons of sulfur dioxide every five years on the basis of 2000. In this case, control requirement of sulfur dioxide for electric power industry in the next 20 years is shown in table 3-4.

Table 3-4 Electric Power Desulphurization Task When the Country Reduces Emission of 2,000,000t Sulfur Dioxide Every 5 Years

Index	Unit	2000	2005	2010	2015	2020
Total generation of sulfur dioxide	10,000t	2647	2768	3040	3186	3401
Where: generation of sulfur dioxide from coal fired power generation	10,000t	926	1400	1710	2030	2390
Total emission quantity control objective of sulfur dioxide		2069	1800	1600	1400	1200
Emission quantity control objective of Sulfur dioxide from electric power industry	10,000t	849	764	688	619	590
Sulfur dioxide reduction task of the country	10,000t	578	968	1440	1786	2201
Where: sulfur dioxide reduction task of electric power industry	10,000t	77	636	1022	1411	1800
Needed desulphurization units	10,000 Kwh	500	7971	13360	19281	26019
Coal fired power generating units	10,000 Kwh	24000	35000	43000	54000	*66000*
Percentage in coal fired installed Capacity %	%	2%	23%	31%	36%	39%

Note: 10% gradual reduction for electric power industry from 2000 to 2015 and balanced from 2015 to 2020. This table is calculated with net coal export volume deducted.

To reduce desulphurization pressure for other fuel coals, the power industry needs to increase desulphurization strength in the 10th and 11th Five-Year Plans and at least gradually reduces 15 percent of its emission of sulfur dioxide from 2000 to 2010, otherwise it is difficult to achieve the national set objective.

According to the above prediction, provided that use of low-sulfur coal is continued, sulfur content of coal used by thermal power plants continues to decrease (to 0.9 percent in 2020) and supercritical technology and circulating fluid bed technology are used for units of some thermal power plants; in order to realize the reduction objective of sulfur dioxide for power in dusty in the next 20 years, the thermal power generating units equipped with desulphurization devices (calculated as per installed capacity) shall be 23 percent, 31 percent, and 39 percent of total thermal power generating units in 2005, 2010 and 2020 respectively. If low sulfur coal and circulating fluid bed technology are not considered and only desulphurization devices (FGD) are installed, it is expected that the quantity of thermal power generating units equipped with desulphurization devices (FGD) will be 70 percent of total thermal power generating units.

3.3.2 Emission standard of power industry

Since 1973, after 30 years of practice, China's environmental standards have been gradually perfected and have formed the environmental standard system composing of quality, emission, method, standard sample and others. By the end of 2001, China had formulated and issued 468 various environmental standards including 371 national environmental standards and 97 industrial environmental protection standards.

In general, the revision process of pollutant emission standard for electric power industry embodies a process from general control to gradually strict control. The "Emission standard for the three industrial wastes (GBJ4-73)" put into practice on January 1, 1974 specified the emission rate of sulfur dioxide based on the height of exhaust stack, which provided the basis for prevention and control of sulfur dioxide pollution from thermal power plants. The "Emission standard of air pollutants for coal fired power plants" (GB13223-91) put into practice in August 1992 used P value method that is conducive to strengthening environmental impact evaluation and environmental management. The "Emission standard of air pollutants for thermal power plants" (GB13223-1996) put into practice on January 1, 1997 improved P value method and specified the concentration limit in the third phase, which drove the low-sulfur coal strategy and desulphurization pilot project for electric power industry.

The "Emission standard of air pollutants for thermal power plants" (see table 5-3 and 3-6) put into practice on January 1, 2004 will greatly increase sulfur dioxide emission limit with reference to advanced international standards. Regardless of sulfur content of coal, new thermal power plants will not be up to standard unless they adopt FGD equipment. Old thermal power plants will implement the standard of the same period after forenotice period, and must carry out desulphurization as required except buffering construction period. At the same time, the standard also proposes very strict requirements for reduction of nitrogen oxides of thermal power plants.

Table 3-5 Maximum Permissible Emission Concentration of Sulfur Dioxide

for Coal Fired Boiler (unit: mg/m^3)

Phase	Phase 1		Phase 1		Phase 3
Time of implementation	January 1, 2005	January 1, 2010	January 1, 2005	January 1, 2010	January 1, 2004
Coal fired boiler and oil fired boiler	2100[1]	1200[1]	2100 1200[2]	400 1200[2]	400 800[3] 1200[4]

Notes:

(1 This limit value is the aveage value of thermal power generating boilers in the first phase.

(2 Before the implementation of this standard, the desulphurization units approved by environmental impact report and the boilers of pithead power plants burning low-sulfur coal (as received basis sulfur content of coal entering furnace is less than 0.5%) in the Western non-two-control areas execute this limit value.

(3 Comprehensive resource utilization thermal power generating boilers with gangue etc as main fuel (as received basis low heat value of fuel entering furnace is less than or equal to 12,550kJ/kg) execute this limit value.

(4 The boilers of pithead power plants burning very low sulfur coal (as received basis sulfur content of coal entering furnace is less than 0.5%) in the Western non-two-control areas execute this limit value.

Table 3-6 Maximum Permissible Emission Concentration of Nitrogen Oxides from Coal Fired Boilers and Gas Turbine Units (unit: mg/m^3)

Phase		Phase 1	Phase 2	Phase 3
Time of implementation		January 1, 2005	January 1, 2005	January 1, 2004
Coal fired boiler	V_{daf}<10%	1500	1300	1100
	10%≤V_{daf} ≤20%	1100	650	650
	V_{daf}>20%			450

Oil fired boiler		650	400	200
Gas turbine unit	Fuel oil			150
	Fuel gas			80

3.4 Global Environmental Pressure Is Steadily on the Increase

In the all round construction progress of moderately well off society in the next 20 years, the pressure applied to China's energy development by global climate change and greenhouse gas reduction is not negligible. It can be said that this is the biggest external environmental challenge before China's future energy development.

3.4.1 China's carbon emission will increase rapidly

According to the research of "Analysis of China's Power Need Scenario in 2020" conducted by the Energy Research Institute of the State Development and Reform Commission, the sulfur dioxide emission prediction under different economic development scenario schemes in the next 20 years is shown in figure 3-4. Obviously, emission of carbon dioxide in China in 2020 will be between 130 million tons and 200 million tons, being 1.5-2.2 times the emission of carbon dioxide in the country in 1998.

Composition of CO2 emission sectors is shown in table 3-7. Calculated according to this table, per capita carbon emission level of China in 2020 will be 0.9-1.3t. See table 3-8 for details.

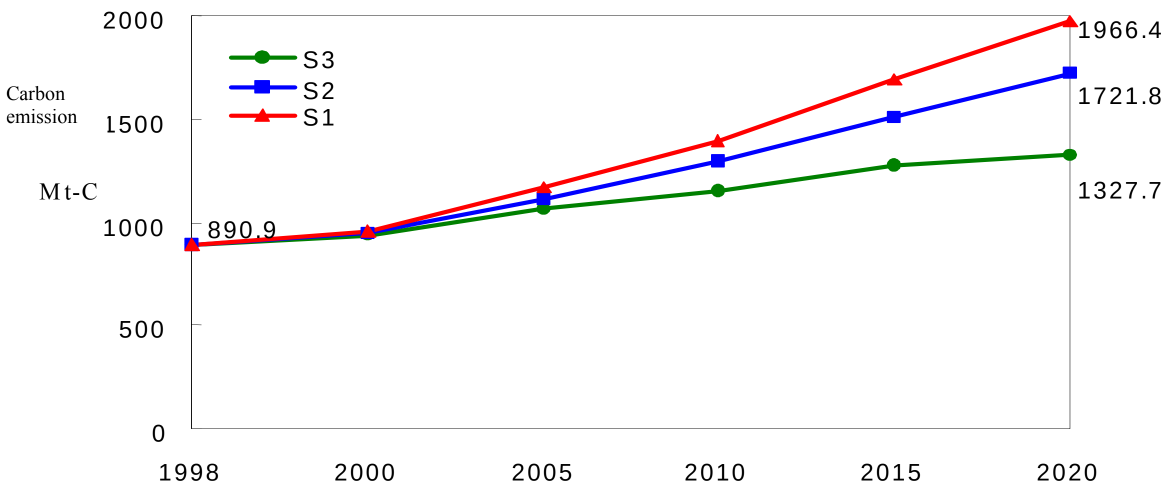


Figure 3-4 Prediction of China's Carbon Emission in Next 20 Years

Table 3-7 Prediction of Composition of China's Carbon Emission Sectors in Next 20 Years

Scenario	Sector	Carbon emission (Mt-C)			Annual average growth rate	Composition of sector		
		1998	2010	2020	1998~2020	1998	2010	2020
Scheme 1	Terminal sector	582.1	847.1	1108.4	2.97%	65.3%	60.7%	56.4%
	Processing and conversion sectors	308.8	547.8	858	4.75%	34.7%	39.3%	43.6%
	Total	**890.9**	**1394.9**	**1966.4**	**3.66%**	**890.9**	**1394.9**	**1966.4**
Scheme 2	Terminal sector	582.1	777.1	968	2.34%	65.3%	60.2%	56.2%
	Processing and conversion sector	308.8	514.7	753.8	4.14%	34.7%	39.8%	43.8%
	Total	**890.9**	**1291.8**	**1721.8**	**3.04%**	**890.9**	**1291.8**	**1721.8**
Scheme 3	Terminal sector	582.1	699.4	764.7	1.25%	65.3%	60.8%	57.6%
	Processing and conversion sector	308.8	451.3	563	2.77%	34.7%	39.2%	42.4%
	Total	**890.9**	**1150.7**	**1327.7**	**1.83%**	**890.9**	**1150.7**	**1327.7**

Table 3-8 Prediction of China's Per Capita Carbon Emission Level in Next 20 Years (t-C/person)

Year	1998	2000	2005	2010	2015	2020	1998~2020
Scheme 1	0.7	0.8	0.9	1.0	1.2	1.3	2.85%
Scheme 2	0.7	0.8	0.8	0.9	1.1	1.2	2.28%
Scheme 3	0.7	0.7	0.8	0.8	0.9	0.9	1.15%

3.4.2 Huge economic cost for carbon reduction

Although China has great potential in improving energy efficiency of national economy, any commitment to reduce emission of greenhouse gases in short term will have to pay some economic cost as China's economic development is still in industrialization stage. Table 3-9 shows the marginal reduction cost of carbon dioxide and corresponding reduction cost under different assumed objectives in 2020.

Table 3-9 China's Reduction Cost of Carbon Dioxide under Different Reduction Objectives in 2020

Reduction objective (%)	5%	10%	15%	20%	25%
Reduction cost (Yuan/t	25	60	110	155	205

carbon)					
Reduction quantity (100 million tons carbon)	8.745	9.19	9.635	10.08	10.525
Emission quantity (100 million tons of carbon)	8.455	8.01	7.565	7.12	6.675
Reduction cost (100 million Yuan)	218.6	551.4	1059.8	1562.4	2157.6

4. Analysis of Energy and Environment Sustainable Development Policy

In the upcoming 20 years, the development objective of China's energy environmental policy is: under the condition that all round realization of moderately well off society is ensured and national energy security is guaranteed, minimize the environmental cost caused by energy production and consumption, protect public health and good natural environment, mitigate emission of global greenhouse gases, actively promote the establishment of hydrogen energy and hydrogen economic and social system and realize sustainable development of energy and environment.

To achieve the above objective and respond to environmental challenge of future energy development, China's energy environmental strategy in the next twenty years shall be: **raise the conservation of energy resources to the height of basic state policy, establish energy efficiency standard and identification system of terminal energy utilization equipment and establish new energy conservation mechanism under market economic condition; push environmentally friendly energy strategy through governmental drive, public participation, total quantity control and pollution emission trading; Raise pollutant emission charging standard, implement emission trading and power environmental protection discount, cancel production subsidy for high energy consuming products and realize internalization of energy environmental cost; Rely on scientific and technical progress to carry forward energy structural readjustment and energy greening, strictly control urban traffic environmental pollution and actively respond to the challenge of global climate warming.**

For this purpose, this chapter will center on this policy objective to propose the policy matrix of energy and environmental sustainable development, which mainly includes harmonious development strategy of energy and environment, relying on science and technology progress to reduce energy environmental pollution, and exercising economic means to promote energy sustainable development etc.

4.1 Harmonious Development Strategy of Energy and Environment

To realize harmonious development of energy and environment, it is necessary to implement the strategy of energy conservation priority, drive the "greening" progress of energy structure, exert great efforts to develop environmentally friendly energy and push sustainable development of rural energy sources.

4.1.1 Long-term implementation of energy conservation priority strategy

Since 1980, Chinese Government has issued the "Energy Conservation Law" and formulated a series of energy saving policies for the purpose of improving energy efficiency, energy saving work gaining enormous achievements. Since 1997, through initiating the projects of energy efficiency improvement and adjusting economic structure, Chinese Government has reduced emission of carbon dioxide for 17% while national economy is rapidly developing. Table 4-1 shows the prediction of environmental benefit gained by improving energy efficiency of national economy in the next 20 years. If China continues to carry out energy saving priority strategy, environmental benefit will be very significant. From environmental protection point of view, long-term implementation of energy saving strategy is the preferred policy for harmonious development of energy and environment. The most pressing task at the moment is to accelerate the establishment of energy conservation model conforming to the requirement of market economy.

Table 4-1 Prediction of Environmental Benefit by Improving Energy Efficiency of National Economy in Next 20 Years

Year	2000	2005	2010	2015	2020
GDP predition (100,000,000 Yuan)	90652	129238	182963	261370	349500
Total energy consumption (Mtce)	1452.7	1729.9	2023.4	2404.6	2761.1
Eenergy consumption for 10,000 Yuan GDP (tce)	1.43	1.34	1.11	0.92	0.79
Total energy consumption under unchanged energy efficiency (Mtce)	1452.7	1848.10	2616.4	3737.6	4997.9
generalized energy conservation quantity (Mtce)	0	118.2	593.0	1333.0	2236.8
Reduction of SO2 emission (10,000t)	0	161.9	812.4	1826.2	3064.4
Reduction of NOx emission (10,000t)	0	152.6	765.6	1720.7	2887.8
Reduction of CO2 emission (10,000t)	0	7332.9	36735.9	82578.9	138572.2

4.1.1.1 Rearrange energy conservation management system

Although policies determine energy conservation to be the "preferred" national energy development strategy, actually it has not been truly put in the "preferred" position. On the contrary, energy development has always been in the true preferred position. Suggestions:

(1) Evaluate the implementation effect of "Energy Conservation Law", find important problems and obstructions in the implementation process of this

law, and, in combination with current electric power restructuring and next-step energy management system reform, accelerate revision of "Electric Power Law" and revise "Energy Conservation Law" at appropriate time.

(2) In the reform of the organizational structure of new government, the State shall not loosen macroscopic management of energy conservation and consumption reduction. The State shall strengthen governmental energy management and rearrange energy management system, especially energy conservation management system. Governmental energy conservation management function shall mainly include formulation of energy conservation policies and laws and regulations, formulation of energy efficiency standards and specifications, compulsive elimination of high-energy consuming and low-efficiency products, and all-out popularization of high-efficiency and energy-saving products.

(3) Clearly define the energy management function of government sectors and intermediary organs. Sufficiently utilize the force of trade societies, associations and scientific research institutions to strengthen the macroscopic management and instruction of national energy conservation and all out support the development of energy efficiency service agencies.

4.1.1.2 Government agencies take the lead in demonstrating energy conservation

According to preliminary statistics, energy consumption by national government agencies reached 57.22 million tce in 2000 including 18.62 million tons of petroleum and 63.4 billion kWh. Energy consumption of government agencies corresponded to that of agriculture, forestry, fishery and water conservancy industry (57.87 million tce), power consumption approached the household electricity consumption (67.5 billion kWh) of 800 million rural residents in the country and its energy expenditure reached 100 billion Yuan (19). Therefore, government agencies and their public sectors are China's bid energy consumers and should take the lead in becoming China's big energy savers. Suggestions:

(1) According to "Government Procurement Act", formulate management method for government agencies to procure low consumption, low energy consumption and low pollution products. Accelerate the implementation of national building energy conservation standard. All government agencies and public sectors shall give priority to procurement of the energy utilization equipment and products whose energy efficiency conforms to national standards and the products that have obtained national water conservation certification and environmental labeling certification.

(2) Architectural design and construction of government agencies shall include audit of building energy conservation and equipment energy conservation. Government agencies and public sectors shall vigorously popularize energy conservation demonstration buildings and establish building energy conservation design standards for public sectors. After 2005, 80% buildings of government agencies and public sectors shall reach national building energy conservation standard.

(3) Ecological building demonstration projects of government agencies and public sectors shall comprehensively adopt new energy conservation

technique and materials as well as renewable energy resource utilization equipment such as green lighting, combined heat and power supply, combined heat and power and cold supply, central heating regulating and control system, solar energy and earth heat.

(4) In taking the leading in energy conservation, government agencies shall give full scope to the energy conservation intermediary organs, actively develop energy service companies and encourage energy service companies to participate in the energy conservation projects of government agencies.

(5) Formulate preferential taxation policy to encourage energy conservation. For example, exempt from value added tax for energy saving products in 3 years; 50% discount interest on loans for energy saving projects, energy saving loans can be repaid before payment of income tax.

4.1.1.3 Integration of energy conservation and clean production

Energy conservation is an important part of clean production. “Cleaner Production Promotion Law” was put into practice in January 2003 and its implementation stilly has many problems. Very possibly similar to “Energy-Saving Law”, the implementation effect of this law has great uncertainty. Suggestions:

(1) Formulate the implementing rules of “Cleaner Production Promotion Law” and add contents related to energy conservation and water conservation. Research to incorporate present “Energy-Saving Law” and “Cleaner Production Promotion Law” into “Cleaner Production and Energy Conservation Promotion Law” or “Cleaner Production Law” to realize the unification of clean production and energy conservation management and have the State Development and Reform Commission to carry out unified management.

(2) The guide list of clean production technique, technology, equipment and products issued by the State shall include energy saving products, water saving products and environmental labeling products. The list of production technique, technology, equipment and products to be eliminated within limited time issued by the State shall also include high energy consuming products, high water consuming products and seriously polluting products.

(3) The State shall approve of establishing the product identifications such as energy conservation, water conservation, waste reutilization and environmental labeling as needed and formulate appropriate standards. The environmental labeling products closely related to energy consumption and water consumption shall first obtain energy conservation certification and water conservation identification certification.

(4) In the development funds of medium and small-sized enterprises established according to related national regulations, it is necessary to arrange an appropriate amount as needed to support medium and small-sized enterprises to carry out clean production and energy conservation projects. Enterprises’ clean production audit shall include energy conservation audit and water conservation audit. Enterprises’ cost used for clean production audit, energy conservation audit, water conservation audit and related training cost may be listed in enterprise operating cost.

4.1.2 Promote the "greening" of energy structure

The task of adjusting energy structure in the next 20 years is very onerous. According to the prediction (table 4-2) made by the Energy Research Institute of the State Development and Reform Commission and Tsinghua University, energy consumption structure in the next 20 years will be further adjusted and gradually develop towards the "greening" direction beneficial to environmental protection. But the two prediction results differ greatly and corresponding environmental prospects are also completely different [(14)]. The situation of energy consumption structure in the next 20 years is not very clear.

However, the adjustment of energy consumption structure in the last ten years has generated enormous environmental benefit. According to preliminary estimate, thanks to reduction of coal consumption percentage in the last decade, China has seen an accumulated consumption reduction of 645 million tons of coal over last ten years, corresponding to emission reduction of 13.82 million tons SO2, 10 million tons of NOx and 422,927,000t CO2 respectively (table 4-2). See table 4-2 for the predictions made by the Energy Research Institute of the State Development and Reform Commission and Tsinghua University.

Table 4-2 Prediction of Environmental Benefit due to Adjustment of Primary Energy Consumption Structure in China

Year	Total consumption (10,000 tce)	Coal consumption (10,000t)	Coal consumption percentage (%)	Reduced coal consumption (10,000t)	Reduced SO2 emission (10,000t)	Reduced NOx emission (10,000t)	Reduced CO2 emission (10,000t)
1990	98703	105523	76.19	0	0	0	0
1991	103783	110432	76.10	266	5.7	4.2	174.2
1992	109170	114085	75.70	2362	50.6	37.0	1546.9
1993	115993	120920	74.70	2802	60.0	43.9	1835.1
1994	122737	128532	75.00	2384	51.1	37.3	1561.4
1995	131176	137677	74.60	2240	48.0	35.1	1467.0
1996	138948	144734	74.70	3473	74.4	54.4	2274.6
1997	138173	139248	71.50	8132	174.1	127.3	5325.9
1998	132214	129492	69.60	11532	246.9	180.6	7552.6
1999	130119	123871	68.00	14918	319.5	233.6	9770.2
2000	128000	120062	67.00	16467	352.6	257.8	10784.7
Sub-total	1349016	1374576		64576	1382.9	1011.2	42292.7
Prediction of the situation in next 20 years							
2000	130300 (Tsinghua University)	120029	65.8	0	0	0	0

	145270 (Energy Research Institute)	154767	76.1	0	0	0	0
2010	159150 (Tsinghua University)	121874	54.7	24732	504.8	423.6	15731.2
	202350 (Energy Research Institute)	196599	69.4	18980	387.4	325.0	12072.6
2020	190950 (Tsinghua University)	114949	43.0	60950	1204.6	1045.8	37387.7
	276120 (Energy Research Institute)	240827	62.3	53345	1054.3	915.3	32722.7

In pushing the "greening" of China's energy structure in the next 20 years, it is recommended to gradually lower the coal percentage in the primary energy structure and increase coal cleanness level.

4.1.2.1 Gradually lower coal consumption percentage

According to previous predictions, if coal consumption percentage is not lowered, China's coal consumption in 2020 will reach 2.46 billion –3.28 billion tons. This will undoubtedly increase huge pressure to China's air pollution. Therefore we suggest:

(1) Resolve the structural contradiction of petroleum deficiency and increase petroleum percentage in the primary energy consumption. Petroleum energy percentage in the primary energy consumption structure in 2010 and 2020 should be increased to 27 percent and 32 percent respectively.
(2) Resolve petroleum supply shortage problem, sufficiently utilize international and domestic markets and the two types of resources, increase supply of petroleum resources and accelerate establishment of national petroleum strategic reserves.
(3) Increase hydropower percentage in the primary energy consumption. Combining national West development strategy, develop hydropower in Southwest regions to increase hydropower percentage in the primary energy consumption for 3-5 percentage points in the next 20 years.
(4) China is a country with richest water energy in the world and water energy is 16.3 percent of total quantity in the world, development potential being great. However, hydropower development must give consideration to ecological environmental protection to ensure dam construction has minimum impact on ecological environmental system.

(5) All out develop clean energy, high-quality energy and renewable energy sources such as natural gas and increase their weight in energy consumption. Endeavor to increase China's natural gas to 10 percent and renewable energy sources to 4 percent in 2020.

(6) With nuclear safety and minimum environmental risk ensured, properly develop nuclear power to make total nuclear power installed capacity reach 12,000,000kw in 2010 and China's nuclear power reach 40,000,000kw in 2020.

4.1.2.2 Improve coal cleanness and its market competitive power

An important means to push the "greening" of energy structure is to improve coal cleanness level and enhance coal competitive power in energy market.

(1) All out adjust coal product structure, accelerate development and popularized application of clean coal technologies such as coal washing and dressing, briquette, powered coal blending, coal gasification and liquefaction, increase development strength of coal gas reservoir, actively develop deep coal processing and improve overall quality of coal industry.

(2) Accelerate industrialized engineering construction of coal gasification and make coal gasification as petroleum substitution product, which is regarded as an energy development strategy. The key to implement this strategy is, on the basis of current domestic technology, to reduce the cost of coal gasification and petroleum substitution product and improve market competitive power of coal gasification products. At the same time, actively explore and develop coal liquefaction technology and popularize and apply it in the conditionally mature regions and industries.

(3) Continue to close, stop, merge and transform small coal mines that do not conform to national energy industrial policies, illegally exploit, are not rationally arranged, seriously pollute environment and lack safe production condition, and to close coal mine enterprises with resource depletion and with no hope of making up deficits. Investigate the responsibility of local governments if the closed or stopped small coal mine enterprises start production again. Restrict and eliminate exploitation of bone coal and sulfur coal.

(4) Power generation by coal clean combustion. It is expected that national installed capacity will reach 900 million kw in 2020 (State Grid Corporation of China 2003), of which coal fired power generation will exceed 60 percent, and new added coal will mainly be used for power generation. Therefore, how to realize clean coal power generation will be a major problem before us in the next 20 years. IGCC and PFBC technologies appear good in energy efficiency and pollution emission, but investment cost is high and has not cost competitive advantage compared with high steam parameter coal fired power plant. It is necessary to give priority to low sulfur coal and washed coal. Clean coal combustion power generation can be realized by adopting conventional coal fired power plant technology of conventional supercritical high steam parameter plus dedusting, desulphurization and denitrification facilities. As an industrial policy, it is recommended that State Development and Reform Commission and the State Environmental Protection Administration should regard the ultra-supercritical parameter coal fired

power plant of dedusting, desulphurization and denitrification as clean coal technology to vigorously popularize in the country, which is used as basic production design requirement for new built coal fired power plants. It is expected the extensive popularization of IGCC and PFBC power generation technology will be possible only after 2015 or 1020.

4.1.3 Exert great efforts to develop environmentally friendly energy

From environmental protection point of view, exert great efforts to develop environmentally friendly energy and increase the weight of environmentally friendly energy in energy consumption structure, which is the basic approach to realize harmonious development of energy and environment.

4.1.3.1 Exert great efforts to develop low-carbon or carbon-free energy

Renewable energy source is most environmentally friendly energy source and is low-carbon or carbon-free energy source. In the past 20 years, China's renewable energy sources gained great development, especially small hydropower stations and solar energy water heaters.

(1) Development objective of renewable energy sources. The State shall base on the *10th Five-Year Plan of New Energy and Renewable Energy Industrial Development* to formulate a long-term new energy and renewable energy development strategy and determine the new energy and renewable energy development objective in 2010 and 2020. It is suggested that new energy and renewable energy should be 1.5 percent and 4 percent of the primary energy consumption in 2010 and 2020.

(2) Organize to implement the integration demonstration project of solar energy and buildings. Actively instruct solar energy water heater production enterprises to participate in the construction of demonstration project; continue to implement wind power generating equipment nationalization demonstration project and select the regions with good resource condition and high economic strength to construct 100,000kw wind power plant. Support wind power generating equipment manufacturers to develop and produce large scaled wind power generating equipment and parts and components having independent intellectual property rights. By nationalization to reduce equipment cost, make initial investment of wind farms greatly reduced; organize to implement bagasse cogeneration technology commercialized demonstration project and biomass grid interconnection power generation commercialized demonstration project.

(3) Research and formulate renewable energy preferential taxation policy and power generation grid interconnection encouraging policy, and drive effective market demand through effective policy promotion. In the implementation of West development strategy, give full play to the advantage of new energy and renewable energy sources in West region and adopt such measures as policy inclination to drive the development and industrialization construction of new energy and renewable energy sources in West region.

(4) Establish "National environmentally friendly energy development fund" to

support the development of renewable energy sources. Fund resources are recommended to come from sulfur dioxide emission charging, possible environmental protection discount capital of coal fired power plants and national finance special fund etc. Fund scale is controlled to 5 billion -10 billion Yuan and wind energy power generation and biomass energy power generation are mainly supported.

(5) Carry out Renewable Portfolio Standard (RPS) and establish renewable portfolio standard credit (electric power green certificate) trading market. The State shall determine the renewable energy power generation quota for major power generating group companies and specify the renewable energy power generation quota in the purchased electric quantity of power grid companies. Utilize RPS to drive the development of renewable energy sources in West region and give full scope to mutual complementary advantage of energy and economic cooperation of Mid-West region.

4.1.3.2 Actively develop clean energy and hydrogen energy

In the future 50 years, we should exert great efforts to develop clean energy and new energy and create an environmentally friendly epoch.

(1) Wind electric power generation. China is rich in wind energy resources. The key to promotion of wind electric power generation is to solve the problems including present weak wind power generation infrastructure, low nationalization technological capability, high wind power generation cost, lack of wind power generation price difference sharing encouraging policy and lack of standard power purchasing agreement etc. If SO2 emission fee is levied on coal fired power generation and CDM project is used to sell CO2 reduction credit etc on the basis of wind power tax reduction, the cost difference between wind power and coal power will be greatly reduced and in the regions where coal price is relatively high such as Fujian and Guangdong, wind power has greater cost competitive power than coal power (see table 4-3). Considering future reduction of wind power generation cost and safety cost of coal mining, wind power cost may very likely be lower than coal power cost after 2010.

Table 4-3 Cost Comparison between Wind Power Generation and Coal Fired Power Generation (tax included)

Region	Coal fired power generation (Yuan/kwh))	Wind power generation (Yuan/kwh)	Cost price difference (Yuan/kwh)	Cost policy space (Yuan/kwh)	Remarks
Xinjaing	0.32	0.689	0.369	0.147	Assuming tax reduction policy reduces 25 percent wind power cost, coal power increases 3 fen/kwh
Inner Mongolia	0.35	0.713	0.363	0.135	
Liaoning	0.45	0.95	0.50	0.21	
Shandong	0.45	0.80	0.35	0.10	
Zhejiang	0.50	0.79	0.29	0.04	

Fujian	0.55	0.79	0.24	-0.01	due to increase of SO2 emission fee and CDM project reduces 2 fen/kwh power generation cost.
Guangdong	0.60	0.77	0.17	-0.08	

(2) Solar energy utilization. In utilization of solar energy, China mainly involves in general solar heat utilization. It has obtained great achievement in recent years and entered into practical use and commercialization stage. China shall quicken the development progress of solar power generation technology and shorten the difference with foreign countries. In the next 10 years, our government shall give maximum possible support to this field. It is recommended that the Government continue to increase support strength in tax policy and deduct and exempt all taxes in solar energy utilization industry.

(3) Motor ethanol gasoline. China started to use motor ethanol gasoline in Jilin Province and Henan Province etc since 2001. According to related laws and regulations of Chinese Government, since June 1, 2001, it started to implement a series of preferential economic policies such as preferential tax policy, preferential price policy, preferential credit policy and subsidy policy to farmers and manufacturers of motor alcohol and motor ethanol gasoline to make final sales price of of ethanol gasoline not higher than the price of motor lead-free gasoline of the same grade. At present, motor ethanol gasoline is under popularization and some ethanol gasoline production enterprises have been built by utilizing national debt in Jinlin and Henan provinces.

(4) Nuclear power generation. Nuclear power is an environmentally friendly energy source. From environmental protection point of view, China should develop nuclear power in measure in a future period of time. It is recommended that the State should levy nuclear waste treatment fee on nuclear power plants according to their power output and implement the State unified safety treatment of nuclear wastes and safety treatment projects for out-of-service thermal power plants.

(5) Hydrogen energy: hydrogen energy is the optimal substitute for the carbon (hydrocarbon) energy to be exhausted very soon. Hydrogen energy is widely distributed and is inexhaustible in supply. It is transmitted through “network”, and is pollution-free, safe and democratic. Hydrogen energy is new revolution of global energy in the 21st century. Development of hydrogen energy shall be in close combination with development of renewable energy sources. It is recommended to select Henan Province to carry out experimental spot of energy and hydrogen economy. First, actively enlarge hydrogen sources, develop hydrogen making technology and establish hydrogen energy transmission system, and reduce hydrogen energy cost price.

(6) From environmental protection point of view, it is suggested to adopt the following policies to support renewable energy, clean energy and hydrogen energy: a. formulate encouraging economic incentive mechanism; b.

establish “national environmentally friendly energy development fund” to support renewable energy power generation and new energy. If environmental protection discount of coal fired power plants is put into practice recently, discount capital can be used to support wind energy power generation; c. establish the user sharing and social sharing policy of renewable energy power generation price difference and establish user-based green power market purchase system; d. increase emission charging standard of sulfur dioxide from coal fired power plants; e. utilize clean development mechanism (CDM) projects to support renewable energy power generation, particularly to reduce wind power generation cost.

4.2 Rely on Technical Progress to Comprehensively Reduce Energy Pollution

While implementing harmonious development strategy of energy and environment in the upcoming 20 years, China shall accelerate scientific and technological progress of energy environmental protection, utilize high and new technology and operative technology to comprehensively reduce environmental pollution caused by energy activities and mitigate the impact of energy development on global climate change.

4.2.1 Utilize environmental standards to push energy technological progress

In the rapidly growing stage of energy demand, China shall sufficiently utilize environmental standards to push the technological progress of energy production and consumption and reduce energy-related environmental pollution from headstream. In addition, Environmental standards shall not be only limited to traditional pollutant emission standards, but shall include any standards and labelings capable of protecting environment, saving energy and promoting renewable energy sources.

4.2.1.1 Power generation performance standard and coal consumption standard

Power generation performance standard shall be incorporated into revision plan of electric industry emission standards as a complementary method of total quantity and emission trading. Related departments of the State Development and Reform Commission and former State Economy and Trade Commission deeply understand power industry emission performance standard and hope that emission performance standard is issued and put into practice at the time of power industry restructuring.

Under the support of American Energy Foundation China Sustainable Energy Project, Chinese Academy of Environmental Planning researched the use of GPS to control the pollution of sulfur dioxide from power industry and proposed appropriate sulfur dioxide emission performance standard (shown in table 4-4). Considering present problems in implementation of power plant sulfur dioxide emission performance standards and their coordination with current emission standards and environmental management policies, it is suggested:

(1) If the new revised “Emission Standard of Air Pollutants for Power Plant” can not fully embody emission performance standard, the emission performance standard should be incorporated in the “Emission Standard of Air Pollutants for Power Plant” as a recommended standard and incorporated in as compulsory emission standard in the next revision of emission standard.

(2) Power plant emission performance standard shall not include sulfur dioxide but shall include nitrogen oxides, carbon monoxide, mercury, water pollutants and waste residues. Emission performance standard shall link with corresponding total pollutant emission charging policy and electric power environmental protection discount policy. It is necessary to formulate emission charging and electric power environmental protection discount policies based on emission performance or total emission quantity as soon as possible and consider the harmony between emission charging and electric power environmental protection discount policies.

(3) In the near future, we can utilize the technical line of emission performance standard to determine the allocation of total emission quantity indices of pollutants such as sulfur dioxide and nitrogen oxides for the power industry based on emission performance. This allocation method is also beneficial to establishment of a fair and just environmental resource allocation mechanism. As the first step, it is recommended to allocate sulfur dioxide emission indices for power plants in the country in the next 10 years according to emission performance method.

(4) The State Environmental Protection Administration is formulating clean production technical guideline for several industries, in which pollutant emission intensity indices are proposed for related industries. For electric power industry, emission intensity index is pollutant emission quantity per unit power generation, i.e. power generation emission performance. Emission performance standard of power plants should be incorporated into this technical guideline. And besides sulfur dioxide emission performance index, nitrogen oxides, carbon monoxide, smoke dust, mercury, water pollutants and solid wastes shall also be incorporated.

(5) Power generation emission performance is closely related to fuel selection of power plants, power generation technology and scale as well as desulphurization facilities etc. Particularly when power output of thermal power plants is given, it is closely related to power generation coal consumption. Therefore coal consumption standard for thermal power plants shall also be formulated while emission performance standard is executed. As the first step, coal consumption standard belongs to recommended standard and will be changed to compulsory standard after execution for a period of time. This is also a compulsory auxiliary policy to close and stop small thermal power plants.

Table 4-4 Recommended SO2 Emission Performance Standard for Coal Fired Power Plant (g/kwh)

Index	Before 2005	2005~2009	2010～2014	After 2015

Outside two-control area	7.0	6.2	4.3	3.2
Inside two-control area	6.7	5.1	3.7	3.2

Source: Yang Jintian, Cao Dong et al, 2003 [20] .

4.2.1.2 Environmental labeling and energy efficiency standard identification

Up to now, China has issued technical requirements of environmental labeling product for more than 50 types of product and conducted environmental labeling certification for over 30 types of products; products of more than 500 enterprises in the country have passed environmental labeling product certification.

In 1989, China started to introduce energy efficiency standard identification system. It issued the first energy efficiency standard for 9 items of household appliances in December 1990, which was revised and issued as compulsory standard in 1995. It started to implement energy saving certification logo system in 1998. By now, China has conducted energy saving product certification for household appliances, industrial energy consuming products and office equipment etc.

Energy conservation and water conservation are the specific representation of environmental protection and are one of the basic conditions for obtaining environmental labeling product certification.

(1) It is suggested to strengthen compulsory elimination of high energy consuming products while implementing energy saving product certification or compulsory energy efficiency identification certification. The products listed as compulsory certificated products are not allowed to produce or sell without certification.

(2) Technical requirement of environmental labeling products shall sufficiently embody the requirements of energy conservation, consumption reduction, water conservation and pollution reduction. Obtainment of energy saving product certification and water saving product certification, or attainment of energy saving product standard, energy efficiency standard and water saving product standard are the basic conditions for obtaining the labels of environmental labeling products.

(3) Environmental labeling product certification shall strictly follow energy saving and water saving product certification standards, adjust technical requirements of environmental labeling products at appropriate time, maintain the leading advantage of environmental labeling products in energy conservation and water conservation and truly embody economic precedence of environmental labeling products. When conditions are ripe, implement

environmental labeling hierarchy system, incorporate energy saving product (and water saving product) certification into environmental labeling certification and reduce enterprise certification and management costs.

4.2.1.3 Motor vehicle emission standard and oil consumption standard

In the next 20 years, China shall formulate strict motor vehicle oil consumption standard and tail gas emission standard and avoid going on the old track of motor vehicle pollution prevention and control: "improving engine→oxygen catalyst→three-way catalyst→electric control effect catalyst→hybrid-electric car→electric motor car"

Presently, China has not established systematic motor vehicle oil consumption standard and pollutant emission intensity of home made motor vehicles are significantly higher than imported vehicles. Table 4-5 shows the actual determination of oil consumption per 100km for major homemade vehicles presently in China.

Table 4-5 Comparison of Oil Consumption per 100km for New Homemade Vehicles (1998)

Type of motor vehicles	Type of fuel oil	Nominal oil consumption (L/100Km)	Type average oil consumption (L/100Km)	Number of companies used for calculation
Heavy duty truck	Diesel oil	20.5~26.0	22.6	3
Medium duty truck	Diesel oil	17.3~19.0	17.5	2
	Gasoline	25.0~26.5	25.1	2
Light duty truck	Diesel oil	11.0~12.0	11.5	3
	Gasoline	10.5~14.0	12.7	3
Mini truck	Gasoline	6.0~6.7	6.5	3
Large bus	Diesel oil	22.5~30.0	24.8	3
Medium bus	Diesel oil	18.0~28.5	19.2	2
	Gasoline	28.0	28.0	1
Light bus	Diesel oil	8.0~13.0	8.5	2
	Gasoline	8.0~10.5	8.5	2
Mini bus	Gasoline	6.0~6.9	6.3	3
Medium grade car	Gasoline	9.3~12.6	8.0	3
General car	Gasoline	5~6.9	6.2	3
Minicar	Gasoline	5	5.0	3
Agricultural quadricycle	Diesel oil		6.5	
Agricultural tricycle	Diesel oil		2.8	
Motorcycle	Gasoline		2.04	

Source: compiled according to "China Fuel Economic Efficiency Background Report".

China's automobile industrial sector and environmental protection sector shall cooperate to utilize environmental standards to accelerate technical progress of automobile industry and drive sustainable development of the whole national automobile industry.

(1) Give comprehensive consideration to motor vehicle oil consumption and tail gas emission and oil product quality. The strategy to control pollution of motor vehicle tail gases is to comprehensively consider oil consumption, oil products and tail gas emission while formulating and implementing oil consumption standards and tail gas emission standards. As the first step, it should strictly implement oil product standard and practically incorporate environmental performance requirement into oil product standard to control emission of pollution from the headstream of fuel oils.

(2) Draw on the experience of developed countries (America, Japan and EU) to establish Company Average Fuel Economy standard. Formulate standard of oil consumption per 100km for different types of new vehicles as the first step, which is the national compulsory standard. In view of rapid automobile technological progress, we can directly make reference to the standards of America, Japan and EU while formulating China's CAFF standard. Considering the link with motor vehicle tail gas emission standard, give priority to EU or Japanese automobile oil consumption standard. CAFF standard shall have dynamic function and forward looking feature to instruct automobile manufacturers to quicken automobile technical innovation.

(3) Raise and unify motor vehicle tail gas emission standard. The present practice of first carrying out strict new motor vehicle tail gas emission standard in some cities or regions in China is adverse to the technological progress of the whole national automobile industry. It is suggested to issue and implement nationally unified motor vehicle tail gas emission standard according to national automobile industry development strategy and emission standard shall divide time periods so that automobile manufacturers can have sufficient time to respond to the challenge of emission technology.

(4) New vehicle emission standard is disengaged with fuel oils. It is suggested that the State should formulate policies to require the imported automobiles to reach parent home country emission standards and CO2 emission reduction requirement.

(5) When conditions are ripe, popularize the practice of oil consumption standard and emission standard integration to other traffic fields.

4.2.2 Fully implement comprehensive pollutant reduction policy

In the next 20 years, China shall fully implement comprehensive pollutant reduction policy, especially comprehensive reduction of the pollution caused due to coal mining and utilization.

4.2.2.1 Use minimum cost to reduce coal pollution

Prevention and control of coal burning pollution shall adopt the idea of overall process control and do best to control and reduce pollution emission from the headstream so as to minimize pollution reduction cost. The following will describe the selection of pollution prevention and control technology for coal production and utilization with the example of emission reduction of sulfur dioxide from coal combustion.

(1) The key point of coal mining process is to protect ecological environment. It it suggested to build different types of mine field ecological construction demonstration bases through national support, ban high-sulfur coal mining and increase the strength of closing and stopping small coal mines to increase coal mining and utilization rate through economic and legal means and strict production safety requirements. Endeavor to make mine water repeating utilization factor of large- and medium-sized coal mines reach 80 percent and 90 percent in 2010 and 2020 respectively and to reduce water environmental pollution during exploitation.

(2) From SO2 control point of view, technical line of coal pollution prevention and control shall be: ban the exploitation and use of high-sulfur faulty raw coal with sulfur content higher than 3 percent→restrict the use of some raw coal with sulfur content between 2-3 percent→coal washing and dressing→use briquette→adopt circulating fluid bed boiler→power plant boiler FGD [21].

(3) Stop exploitation and utilization of high sulfur coal is the most economical technological selection to reduce coal combustion SO2. Estimate shows that if combustion of high sulfur faulty raw coal with sulfur content higher than 3 percent is completely stopped and utilization of some raw coal with sulfur content between 2 percent-3 percent is restricted, the country can reduce emission of 4.5 million-6 million tons of SO2 every year. However, it is necessary to spend 2.2 billion Yuan capital every year arranging the reemployment of the workers of the stopped and closed coal mines and disposal of fixed assets of the coal mines in the upcoming ten years. As matters stand at the moment, this is an unlikely technological selection. We can only stop exploitation and utilization of some high-sulfur coals and, ideally, it is expected to reach one third. The cost for reducing SO2 by this measure is about 0.9Yuan/kg.

(4) Coal washing and dressing is also a technical measure of SO2 reduction with relatively low investment and operation cost. If the country invests 16 billion Yuan in increasing 140 million tons of raw coal washing capability, emission of 1.5 million tons of SO2 can be reduced each year. The cost for reducing SO2 by this measure is about 1.2Yuan/kg.

(5) Popularization of briquette is the third technological selection to reduce emission of SO2. If 2 billionYuan is invested, the production capability can be increased on current basis: 20 million tons of industrial coal, 13 million tons of gasified coal and 35 million tons of domestic coal, making annual total production capability of sulfur retention coal reach 113 million tons. If calculated as per 30 percent sulfur retention rate, emission of 100,000t sulfur dioxide can be reduced every year. The cost for reducing SO2 by this measure is about 1.2Yuan/kg.

(6) Adoption of circulating fluid bed technology by a large quantity of civil cooking ranges and industrial boilers is the fourth technological selection to reduce sulfur dioxide. Estimate shows that if 8 billion Yuan is invested in replacing current small boilers with circulating fluid bed boilers, emission of 300,000 tons of SO2 can be reduced every year in the next 10 years. The cost for reducing sulfur dioxide by this measure is 1.9Yuan/kg.

(7) The final technical selection to reduce the emission of sulfur dioxide from coal combustion is flue gas desulphurization of power plants. As pointed out in 4.1.2, adoption of traditional high parameter power generating technology

can also realize clean coal power generation. Conventional flue gas desulphurization can reduce over 95 percent SO2. Desulphurization investment is about 10-15 percent of total investment, desulphurization investment for each kw is 500-1,200 Yuan and cost for reducing SO2 is 1.2-4.3 Yuan/kg [(23)]. If 4 billion-7 billion Yuan is invested each year in the next 10 years, emission of 3.1 million tons of SO2 can be reduced [(21)].

(8) Reduction of sulfur dioxide can reduce corresponding pollution economic loss. This actually is the benefit of reducing sulfur dioxide. See table 4-6 for the comparison of economic cost and benefit through reduction of coal combustion sulfur dioxide by the above technical measures. If all these technical measures are taken in the next 10 years, a reduction capability of 6,700,000t sulfur dioxide can be formed in 2010. Calculated on this basis, the total cost for reducing sulfur dioxide in the next 10 years will be 203 billion Yuan, corresponding economic loss of 275 billion Yuan will be reduced and average benefit-cost ratio will be 1.7. Obviously, this technological selection is economically reasonable, but it is necessary to resolve many policy problems to truly implement it.

Table 4-6 Economic Comparison for Selection of Coal Combustion Desulphurization Technological Schemes in Next 10 Years

Comparison index	Unit	Stopping use of high sulfur coal	Coal washing and dressing	Use sulfur retention coal	Circulating fluid bed boiler	Stack desulphurization of power plants (conventional wet method)	total/average
Desulphurization efficiency	%	20	50	20～50	～75(Ca/S=2)	～75(Ca/S=1.1)	
Reduction of emission quantity in 2010	10,000t	70	130	10	30	310	670
Investment coefficient	Yuan/t-y	10476	12300	20000	27000	22600	18475.2
Gross investment in 10 years	100,000,000Yuan	74	160	20	80	700	1034
Cost for reduction (including discount)	Yuan/kg	0.90	1.20	0.80	1.9	2.3	1.42
Cost for reduction in 10 years	100,000,000Yuan	63	156	8	57	713	997

Gross cost for reduction	100,000,000Yuan	137	316	28	137	1413	2031
Economic benefit	100,000,000Yuan	350	650	50	150	1550	2750
Benefit-cost ratio		2.555	2.057	1.785	1.095	1.09	1.716

4.2.2.2 Comprehensively reduce pollution from thermal power industry

Pollution control for thermal power plants is the key point of China's energy environmental protection in the next 20 years. To carry out sustainable development of thermal power industry and reduce long-term cost for reducing pollution, thermal power plant must carry out comprehensive reduction strategy.

(1) Implement comprehensive control policy for multiple pollutants. China's thermal power industry currently controls smoke dust and wastewater and its control for sulfur dioxide has just been started. China's related departments shall conduct the research for comprehensive reduction of pollution from thermal power industry and propose a control scheme and the emission standard representing long-term control objective.

(2) Implement comprehensive pollutant emission standard. In emission standard of pollutants from thermal power industry, it is necessary to give unified consideration to wastewater pollutants, smoke dust, sulfur dioxide, nitrogen oxides, mercury, carbon monoxide (and even carbon dioxide) and solid wastes. For those not controlled or not required to reduce in near term, it is also necessary to propose the emission standard requirements in the future 10 years and even 20 years. This method can make enterprises conduct technical arrangement as early as possible and realize minimum cost for pollution reduction.

(3) Reduction of sulfur dioxide adopts three-step strategy. The first phase is initial phase from now to 2005. In view of current conditions, it is necessary to formulate long-term reduction plan and conduct corresponding project preparation for the desulphurization measures adopted in power industry in recent time under the condition that change to use of low sulfur coal meets the annual reduction requirement of environmental protection department and according to long-term control objective and requirement for power industry. The second phase is the mixed phase of low sulfur coal and flue gas desulphurization in the Eleventh Five Year Plan period. The interim phase of sulfur dioxide emission reduction for power industry mainly refers to 2006 to 2010. Emission reduction for this phase is 7.3 million tons. To realize the planned total SO2 quantity control objective, Installed capacity of units with desulphurization equipment shall reach 93 million kw. In this phase, besides some power plants have to burn low sulfur coal, a large number of power plants need to install desulphurization facilities before the planned objective is achieved. The third phase is the all round flue gas desulphurization phase following the 11th Five-Year Plan period. In this phase, control objective of sulfur dioxide for power industry is 6.3 million tons. The main reduction measure is engineering measure, i.e. flue gas desulphurization, and desulphurization units will reach 170 million kw. Control measure of sulfur

dioxide adopted by power plants in Western developed countries already shows such regularity [20].

(4) The second run of electric power dedusting “revolution”. In the last 20 years, China’s power industry has gained great achievement in smoke reduction and dust removal. TSP concentration in many cities is significantly decreased. Although fire particulate comes from a wide range of sources, smoke particulate emitted from power plants is one of the major sources. Therefore it is necessary to strictly control emission of smoke dust from power plants in the next phase and carry out the second run of dedusting “revolution” for power industry. New requirement for the second run of dedusting shall be incorporated in the new power industry emission standard as soon as possible.

(5) Wastewater zero-discharge strategy for thermal power plants. Discharge of China’s industrial water and wastewater is concentrated on thermal power generation, textile, paper making, iron and steel and petrochemical industries. Therefore control of wastewater discharge from power industry is also an important task for power industry to reduce pollution. Some power plants in the country have reached the requirement of “zero discharge”. Thus it is suggested to carry out thermal power plant wastewater “zero discharge” strategy nationwide. As the first step, the power plants with over 600,000kw installed capacity shall reach wastewater “zero discharge” requirement.

4.2.2.3 Strengthen the pollution reduction from non-power coal utilization

Pollution reduction of non-power coal utilization shall still draw extensive attention in a very long period in the future.

(1) Increase treatment strength of civil boiler and industrial boiler. Civil boiler and industrial boiler, especially small capacity civil and industrial boilers, are the key point of non-power coal pollution control. According to statistics, besides coal fired power plants, our country has approximately 410,000 industrial boilers and 180,000 industrial kilns that burn coal. These three big coal users consume 30 percent, 30 percent and 20 percent coal respectively in China.

(2) Continue to implement powerful environmental policies. At present, many cities with serious air pollution issue bans via government rules and regulations to restrict the use of boiler below a certain capacity in urban area. Beijing City adopts stricter measures to close and stop coal fired boilers in urban area and periphery area, or force coal fired boilers changed to burn natural gas. The State also implements the “fifteen smalls” policy to close and stop high energy consumption and high pollution. These mandatory environmental policies implemented via environmental departments play an active role in restricting pollution emission of non-power coal combustion, improving utilization efficiency of non-power coal utilization and strengthening pollution control of non-power coal utilization.

(3) Limit export of high energy consuming products. Another effective measure to strengthen pollution reduction of non-power coal utilization is to limit export of high energy consuming products. Import and export management departments and customs offices carry out effective management for the export of high energy consuming products to control the production of

domestic high energy consuming products, lower unit energy consumption of related products, improve energy comprehensive utilization efficiency, and reduce coal consumption especially the pollution of non-power coal consumption.

4.3 Wield Market Means to Promote Energy Sustainable Development

In the construction and completion process of market economy in next 20 years, it is necessary to wield market economic means to control pollution and promote energy sustainable development. Market means can start with two aspects: first, utilize tax price policy to realize environmental cost internalization of energy activities; and second, utilize market transaction means to reduce social cost for pollution reduction.

4.3.1 Promote environmental cost internalization of energy activities

The economic policies to promote environmental cost internalization of energy activities mainly include environmental expenses of taxation and derivative ecological environmental compensatory tax, coal fired power plant environmental protection discount and public benefit fund etc. China's relatively successful environmental economic policies at present mainly include emission charge and other policies are under research and discussion.

4.3.1.1 Emission charge and ecological compensatory charge

Emission charge is an economic means of environmental management and what is most influential to energy industries is sulfur dioxide charge. Since June 2003, sulfur dioxide charging standard will be gradually raised to 0.60Yuan/kg in three years and the levied objects will be extended to all pollution sources of sulfur dioxide. If calculated as per 0.6Yuan/kg, annual charge of electric power industry will be more than 4,000,000,000Yuan. At the same time, it is necessary to collectively use sulfur dioxide charge, which can be granted to or subsidize power plants to carry out desulphurization and to resolve trans-regional acid rain problem.

(1) New sulfur dioxide charging standard is relatively low compared with reduction cost of sulfur dioxide and is only 50 percent of average treatment cost of sulfur dioxide. Therefore in order to increase the stimulation of emission charging to power plants to reduce sulfur dioxide, it is necessary to further raise sulfur dioxide charging standard.
(2) To increase levying strength and stimulating strength of sulfur dioxide charge, if environmental tax is established, sulfur dioxide charge can be included in the environmental tax as a sulfur tax item [22]. And coal sulfur content can be directly used as tax base to incorporate fuel oil in sulfur tax to be collectively levied.
(3) New sulfur dioxide charging policy shall be in harmony with coal fired power plant environmental protection discount policy possibly to be put into

practice in the future [23]. It is suggested to abandon the view "sulfur dioxide charging and power plant environmental protection discount can not be implemented in parallel" and to sufficiently utilize sulfur dioxide total quantity charging system to strengthen power generation environmental protection discount policy.

(4) China started to discuss ecological environmental compensatory charge since 1990s and has made experiment in some places. It is suggested to implement ecological environmental compensatory charging for large scaled hydropower, coal mining and petroleum extraction projects.

4.3.1.2 Electric power environmental protection discount

At present, under the support of American Energy Foundation China Sustainable Energy Project, Chinese Academy for Environmental Planning has proposed the policy schemes for emission performance discount of coal fired power generation [23].

(1) The implementation objects of power generation environmental protection discount standard mainly are coal fired power plants, garbage power generation plants, oil fired power plants, cogeneration power plants, industrial power plants and the power plants presently not conforming to industrial policies. Heat supply of cogeneration power plant is converted into power for calculation. All power output in power grid are converted into money including the part of own demand.

(2) It is suggested that discount scheme selects linear discount. The start point of discount is at 3g/kwh. For the power plants with emission performance lower than 3g/kwh, discount is not given; and for the power plants with emission performance over 3g/kwh, discount is given in electric cost according to their emission degree. Discount standard is 0.1 fen/kwh discounted from the electricity price for emission of 1g/kwh.

(3) Collection of discount capital must link with present electricity cost settlement system while discount capital must be used for the projects related to environmental protection. It is suggested that emission performance discount capital be transferred to national financial account and national power plant desulphurization and renewable energy development special fund or environmentally friendly energy fund be established, and no organizations and individuals should not retain, seize or embezzle the fund. Funds are mainly used to control pollution from power plant and to support renewable energy development in the form of allotment subsidy or loan discount interest, and mainly are used for subsidy of the following projects: power plant flue gas desulphurization facilities (FGD); power plant flue gas pollutant emission automatic monitoring equipment (CEM); power plant pollution emission tracking system network construction (ETS); renewable energy projects (RE); and clean coal power generation technology development.

(4) Power emission discount is a very good economic policy of truly promoting power industry to reduce emission of sulfur dioxide. Emission charging and emission discount shall not substitute for each other, but shall be mutually complementary and be implemented.

(5) Power emission discount shall be linked up with emission performance or

performance standard and shall not be separate from power plant sulfur dioxide emission performance. It is suggested that environmental protection departments and power grid companies jointly check and ratify the pollution emission performance of power plants: Use the power plant sulfur dioxide emission quantity checked and ratified by environmental protection departments at the time of total sulfur dioxide quantity charging as the sulfur dioxide emission quantity to check and ratify emission performance. Use the traded and settled power output confirmed by power generation companies and power grid companies as the basis of electric quantity. Power output of industrial power plants is directly obtained from operating condition data of power plants.

(6) It is suggested to strengthen the accuracy of power emission quantity and measurement of power output as well as development and research of data transmission system. It is suggested that the State Environmental Protection Administration and the State Electricity Regulatory Commission should jointly establish the pollution source monitoring system integrated with sulfur dioxide total quantity charging, power plant environmental discount, sulfur dioxide emission trading and thermal power plant emission permit. Environmental protection departments should accelerate the formulation of installation schedule of national power plant pollution emission continuous monitoring device (CEM).

4.3.1.3 Environmentally friendly energy fund

In the fields related to energy and environment, China has established China Environmental Protection Foundation, Beijing Energy Conservation Fund, Electric Power Construction Fund and the Three Gorges Construction Fund. It is suggested to establish a functionally extensive and environmentally friendly energy fund by drawing the experience of these funds.

(1) The main purpose of establishing Environmentally Friendly Energy Fund (EFEF) is, under new electric power system, to reduce production cost of environmentally friendly energy, improve market competitive power of environmentally friendly energy, save public expenditure in energy consumption, bring economic benefit and environmental improvement benefit for the public and realize harmonious development of energy and environment. Environmentally Friendly Energy Fund is a macroscopic readjustment and control means that the government uses to carry out energy industrial adjustment.

(2) The main function of environmentally friendly energy fund is to support demonstration projects and development projects such as renewable energy, clean energy, power plant desulfurication and improvement of energy efficiency, support new energy technical industrialization development, trans-regional procurement of renewable energy and clean energy resources, support economic development of environmentally friendly energy production regions, subsidize poor families for energy expenditure, and support terminal user demand side management and energy comprehensive planning etc.

(3) Capital sources of environmentally friendly energy fund mainly include: electricity price additional charge, sulfur dioxide charge, electric power

environmental protection discount, hydropower environmental compensation charge, governmental financial allocations, social contribution and benefits generated from use of fund etc.

4.3.2 Utilize market mechanism to decrease pollution reduction cost

While market means is providing flexibility for controller and controlled emission sources, its maximum advantage is to facilitate the whole society to minimize pollution reduction cost. Such market means mainly includes pollution emission trading, green power market mechanism and renewable energy quota credit sale etc. we think that emission trading and green electric power are the market means that China should first introduce in energy environmental field.

4.3.2.1 Sulfur dioxide emission trading market

China started to try emission trading system in some cities in 1990s. In the last three years, The State Environmental Protection Administration carried out sulfur dioxide emission trading experimental spot projects in four provinces and 6 cities in the country and obtained some preliminary experience. Chinese Research Academy of Environmental Sciences and American EPA completed the feasibility study of utilizing trading mechanism to reduce sulfur dioxide in China and concluded that it is necessary and feasible to establish national-level sulfur dioxide emission trade. In order to lower the sulfur dioxide reduction cost, it is recommended that the State Environmental Protection Administration should continue to try out sulfur dioxide emission trading.

(1) National sulfur dioxide emission objective determination, emission quota allocation, market unitarity, emission monitoring and fiscal levy problems can not be resolved at the level of a city or a provincial government and can be only resolved at the national level. Therefore it is suggested that next step of experimental spot work be changed to national electric power industry or the electric power industry in acid rain control area.

(2) Before conducting sulfur dioxide emission trading system in electric power industry, it is necessary to carry out some basic technical support work, including electric power industry sulfur dioxide emission quota allocation method based on emission performance, determination of national sulfur dioxide emission total quantity control objective, determination of medium- and long term sulfur dioxide emission control objective for electric power industry, and sulfur dioxide emission index allocation for major thermal power plants in the country in next 10 years.

(3) Propose the modification and design scheme of current laws and regulations and policy system in order to carry out sulfur dioxide emission trading. Specific contents include: definition of emission trading commodities, assessment, monitoring, issuance, report, violation punishment and supervision etc. Formulate "Management method of sulfur dioxide emission trading for electric power industries in two-control areas".

(4) Establish appropriate support agency to support SO2 emission right trading and transfer related function to some existing agencies. These agencies may include SO2 monitoring agency, trading agency and information agency etc.

Develop sulfur dioxide emission tracking system (ETS) and allocation tracking system (ATS) for electric power industries in the country.

(5) Propose the plan of sulfur dioxide emission trading for electric power industries in the country and train related personnel. Establish frontpage concerning China's sulfur dioxide emission trading, release trading information and provide publicity and exchange platform.

4.3.2.2 User-based green power market

According to the survey conducted by China Consumers' Association, 94.2 percent users in the country are willing to spend a little more in each kwh to purchase green power. Research made by Beijing Tianheng Research Institute shows that green power has unforeseen market demand. For this reason, it is suggested:

(1) Beijing takes the advantage of the good opportunity of 2008 "Green Olympics" to establish green power market demonstration project. Establishment of Beijing green power market not only promote Beijing's "Green Olympics" image and raises the public's green energy awareness, but also supports the development of economically underdeveloped regions. Certainly, the big cities with high public environmental awareness such as Shanghai, Guangzhou, Wuhan and Shenzhen can also conduct experimental spots.

(2) Users of green power market shall be first locked to enterprise users with great power consumption. For enterprise users of green power, provide support for them in enterprise green image publicity etc.

(3) Green power market mechanism can be implemented simultaneously with renewable energy quota (RPS) policy. As a basic national policy, it shall determine renewable energy power quota for major power companies or power grid companies in different stages. Of course, different power generating companies or unit companies may also trade renewable energy quota.

4.4 Summary: Policy Matrix

The above text has analyzed energy and environment sustainable development policies from three aspects including harmonious development of energy and environment, relying on technical progress to comprehensively reduce pollution and wielding market means to promote energy sustainable development. These policies are not mutually independent but mutually complementary and supporting. And in different phases, selection of these policies is different. Selection of these policy means in different energy sectors is shown in table 4-7. Chapter 5 will make a specific analysis for some major policies in this policy matrix and propose the policy schemes that should be implemented in near term or in the Eleventh Five Year Plan period.

Table 4-7 Energy Environment and Sustainable Development Policy Matrix

Policy means	**Coal**	**Petroleum**	**Hydropower**	**Renewable energy**
Energy conservation priority strategy				
System rearrangement	++	++	++	++
Government energy conservation	++	++	++	++
Clean production	++	++	+	
Optimizing energy structure				
Lowering coal percentage	++			
Coal cleanness	++			
Promotion of environmental standards				
Power generation performance standard and coal consumption	++	+		
Environmental label and energy efficiency identification	+	+	+	++
Automobile emission standard and oil consumption		++		
Energy environmental technological progress				
Reducing coal pollution at low cost	++			
Reducing pollution from thermal power industry	++	+		
Environmental cost internalization				
Emission charging	++	++		
Ecological environment compensatory charging	++	++	++	
Electric power environmental protection discount	++	+		++
Environmentally friendly energy fund	+			++
Wielding market economic means				
Emission trading	++	+		
Green power market			+	++
Renewable energy quota credit			+	++

Note: + means that this policy applies; ++ means that this policy highly applies.

Implementation priority

System rearrangement	Government energy conservation	Clean production	**Energy conservation priority strategy**
Coal cleanness	Lowering coal percentage		**Optimizing energy structure**
Power generation performance standard	Environmental label and energy efficiency identification		**Promotion of environmental standards**
Reducing pollution from thermal power industry	Reducing coal pollution at low cost		**Energy Environment technological progress**
Electric power environmental discount	Ecological environment compensatory charge	Environmentally friendly energy fund	**Environmental cost internalization**
Emission trade	Renewable energy quota	Green power market	**Wielding market economic means**

Figure 4-1 Arrangement for Implementation of Energy Environmental Policy

As different policies have different action time and scope, implementation priority of policies and time sequence are also different to some extent. To better describe the implementation sequence of the above policies and provide more vigorous support for decisions, figure 4-1 gives the implementation arrangement and priority of energy environmental policies in 2020.

5. Several Important Energy Environmental Policy Schemes

This chapter will analyze several important energy environmental policies and propose appropriate suggested policy schemes in the light of major environmental challenges before China's energy development in the next ten years. These policies mainly include accelerating power industry desulphurization and decarburization progress, reducing environmental pollution caused by West-to-East power transmission, preventing and controlling automobile tail gas pollution as well as rural energy environmental protection etc. We think that these policies are the policy measures that we should first take at present and in the next ten years.

5.1 Accelerate Electric Power Desulphurization Progress

Electric power industry (especially thermal power) will be China's most rapidly developing industry in energy industry in the next 20 years. According to analysis in Chapter 2, reduction of sulfur dioxide and nitrogen oxides by thermal power industry in the next 20 years will have a direct effect on the achievement of the State's sulfur dioxide total quantity control objective.

5.1. 1 Power industry total quantity control objective

China's coal-consumption-based energy characteristic determines that electric power structure will still be based on coal and coal consumption will be still increase. If not more strictly controlled, emission of SO2 and NOx will also increase. Therefore electric power pollution control will be the key point of China's acid rain and sulfur dioxide pollution control. In accordance with analysis of Chapter 2 and 3 of this research, table 5-1 gives pollution control objective of power industry in the next twenty years.

Table 5-1 Power Industry Development Prediction and Pollution Control Objective in the Next Twenty Years

Index	Unit	Background value in 2000	2005	2010	2015	2020
Total installed	100,000,000kw	3.2	4.8	6.5	7.8	9.5

capacity						
Installed capacity for thermal power	100,000,000kw	2.4	3.3	4.3	5.4	6.6
Total power output	100,000,000kwh	13685	22200	29000	34200	39400
Thermal power output	100,000,000kwh	11079	16400	21600	25000	28900
SO2 generation quantity	10,000t	926	1400	1710	2030	2390
SO2 control objective	10,000t	849	764	688	619	590
NOx control objective	10,000t	765	765	765	765	765

5.1.2 Power group total quantity objective allocation

At the end of 2002, five major power generation group corporations were reorganized, i.e. Huaneng Group., Datang Power Generation Co., Huadian Corporation, GuoDian (Group) Corporation and China Power Investment Corporation. After reorganization, Huaneng Group may have controllable capacity of 37,970,000kw and thermal power installed capacity of 31,160,000kw; Datang Power Generation Co. has controllable capacity of 32,250,000kw and thermal power installed capacity of 25,360,000kw; Huadian Corporation has controllable capacity of 31,090,000kw and thermal power installed capacity of 26,710,000kw; GuoDian (Group) Corporation has controllable capacity of 30,430,000kw and thermal power installed capacity of 25,120,000kw; China Power Investment Corporation has controllable capacity of 29,890,000kw and and thermal power installed capacity of 20,630,000kw. No accurate statistical data are available for the emission quantity of sulfur dioxide and nitrogen oxides from respective groups. According to reorganized power generation capacity and power generation structure, the present situation of pollutant emission from respective groups is preliminarily estimated. Based on the total emission of former Guodian Corporation, the required emission performance level is unified and preliminary allocation is carried out. In virtue of total control objective of electric power industry and electric power planning requirement of the Tenth Five Year Plan, the control requirement of respective groups are hereby proposed. See table 5-2.

Table 5-2 Emission-Performance-Based Sulfur Dioxide Emission Quota of Five Major Power Generation Groups in Next 20 Years

Year	2000	2005	2010	2015	2020
Huaneng Group (10,000t)	85	76	69	64	60
Datang Corporation (10,000t)	73	66	60	55	52
Huadian Corporation (10,000t)	76	68	62	57	54
GuoDian Corporation (10,000t)	73	66	60	55	52
China Power Investment Corporation (10,000t)	60	54	49	45	43
Total (10,000t)	367	330	300	275	260

5.1.3 Selection of pollution reduction technical line schemes

At present, sulfur dioxide emission reduction methods for thermal power plants mainly are: coal washing and dressing, clean coal combustion technology, combustion and utilization of low sulfur coal and FGD. The State has successively formulated such policy measures as reduction of high-sulfur coal mining, promotion of clean washing and dressing and FGD development and application.

Selection of various technologies and combination of emission reduction methods are a comprehensive judgment and decision making process. According to present situation of sulfur dioxide control and management fundamentals as well as sulfur dioxide emission control objectives for electric power industry, technical lines of emission reduction in respective phases are:

5.1.3.1 Present–2005: initial phase of low sulfur coal combustion and desulphurization engineering measure

For the desulphurization measures adopted in power industry in recent time, it is necessary to formulate long-term reduction plan and make corresponding project preparation under the condition that change to use of low sulfur coal meets the annual reduction requirement of environmental protection department and according to long-term control objective and requirement for power industry. It will be very difficult to achieve the sulfur dioxide reduction objective for electric power industry by only relying on the use of low sulfur coal in the Tenth Five Year Plan period and it is still needed to take some engineering measures. In the Tenth Five Year Plan period, the State increased requirement for desulphurization of coal fired power plant and by the end of 2003, the installed capacity of coal fired desulphurization units already constructed and under construction had reached 24,000,000kw.

5.1.3.2 2006-2010: mixed phase of low sulfur coal and FGD

The mid-phase of sulfur dioxide emission reduction for electric power industry mainly refers to 2006 to 2010. Emission reduction objective in this phase will be 7,300,000t. If average sulfur content of the coal burnt by power plants is 0.90 percent and desulphurization measure is not taken, the generation quantity of sulfur dioxide by electric power industry by only burning low sulfur coal will reach 14,190,000t, leaving a gap of 6,890,000t from the planned control objective. To achieve the total quantity control objective of sulfur dioxide, the installed capacity that need to install desulphurization equipment will reach 204,000,000kw. In this phase, except some power plants burn low sulfur coal, a considerable quantity of power plants needs to install desulphurization facilities to ensure the achievement of the planned objective.

5.1.3.3 2011-2020: all round FGD phase

This is the late phase of total quantity control objective implementation (2011-2020) and sulfur dioxide control objective for electric power industry is 6,300,000t. Before this phase, some simple methods such as combustion of low sulfur dioxide can no longer meet the requirement of total quantity control objective. With enlargement of power industry scale, the main measure for emission reduction shall be engineering measure, i.e. FGD, and desulphurization units will reach 330,000,000kw.

5.1.3.4 Push the development and utilization of nitrogen oxide emission reduction technology

Currently adopted low NOx emission technical measures are divided into two types: combustion control and flue gas control. China's coal fired power plants started to control nitrogen oxides relatively late and it was until January 1997 that national emission standards proposed limit requirement for NOx emission from new built large scaled coal fired power plants. In mid- and late 1980s, while some advanced large capacity coal fired power generation units were introduced, manufacturing technology of low NOx boiler burners was also introduced. On this basis, low NOx combustion system was developed in combination with characteristic of China's coal quality and pulverizing system. At present, low nitrogen combustion technology is being popularized and low cost post-combustion denitration technical equipment is researched.

5.1.4 Environmental economic policy and management measure

At present, the economic policy implemented for pollution control of sulfur dioxide is emission charging system; research of environmental protection discount standard is performed in combination with electric power structural reform; at the same time, some provinces and cities have conducted experimental spot research for emission trading. It is suggested to make emission charging system and emission trading as basic policy combination direction, capital support as auxiliary means and discount standard as supplementation or perfection for emission charging system.

5.1.4.1 Carry out emission right trading experimental spot

China started to carry out emission trading experimental spot work in 1990s. Although it is still not complete, the fundamental condition used to support emission trading project has been formed. In 2000, China revised "Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution", thereby providing legal basis for emission total quantity control policy, which has determined emission index of sulfur dioxide (e.g. upper limit of emission). Presently, the State Environmental Protection Administration is carrying out experimental spots in some provinces and cities to lay a foundation for China to implement sulfur dioxide pollution emission trade.

To reduce SO2 emission at minimum cost, it is suggested to introduce emission trading mechanism in the power industry in the "two-control area". Trading range is mainly in large power plants of power industry, i.e. first in the 120 largest power plants in the two-control area, and at the same time, preparation shall be made for the implementation of NOx emission trade.

5.1.4.2 Implement electric power environmental protection discount standard

It is suggested to adopt method of actual discount and down discount, i.e. give discount for electricity price when settling electric charge according to the size of SO2 emission performance of power plants (emission of sulfur dioxide for 1kwh) and discount standard. As the theoretical basis for discount standard and emission charging is the internalization of environmental cost, determination of standards shall consider the combined action of the two polices to attain the goal of stimulating pollution prevention and treatment. It means to give discount to the power plants whose emission performance exceeds 3g/kwh, deducting 0.1 fen/kwh for each increase of 1g/kwh. 70 percent sulfur dioxide emitted from power industry is concentrated in the two-control area, thus it is necessary to implement the policy in the two-control area. When conditions are ripe, introduce the factor of nitrogen oxides.

5.1.4.3 Implement strict power industry emission standard

The “Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution” newly issued in 2000 requires the implementation of SO2 emission total quantity control and atmospheric pollution emission license system in the “two control area”. The “Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution” also specifies the implementation of pollutant emission total quantity charging system and new emission charging regulations have been issued. Close and stop of small thermal power plants are still the important measure to control emission of sulfur dioxide for China in the Tenth Five Year Plan period. In view of structural readjustment of thermal power industry, the power generating units of less than 100,000kw are the major units to be eliminated and closed and stopped while the power generating units of more than 600,000kw will be promoted and developed. Pollution emission standard for thermal power plants shall give definite policy guide orientation to structural readjustment of thermal power plants and implement strict emission standard for high-pollution, high-energy-consumption and low-efficiency power generating units. It is necessary to introduce emission standard based on output and power generation performance.

To strengthen control of air pollutant emission from thermal power plants, the State revised the emission standard of air pollutants for thermal power plants for another time in 2003. New standard was put into practice on January 1, 2004. It has proposed very stringent concentration requirement for smoke dust, sulfur dioxide and nitrogen oxides from coal fired power plants in three phases according to different construction time of thermal power plants, and proposed the requirement for maximum permissible emission rate of sulfur dioxide for the whole plant and maximum permissible emission control ratio for respective regions. Under the requirement of the new standard, new power plants must conduct desulphurization to reach the standard and old power plants also must install desulphurization device after the buffering period as specified by the standard.

In addition, new emission standard has formulated NOx emission concentration criteria in three phases. The emission standard of 650mg/m3 for thermal power plants in the new standard is close to the average emission limit of 400-500mg/m3 in foreign countries, thus it has proposed stricter requirement for emission of nitrogen oxides from thermal power plants.

5.1.4.4 Introduce power generation emission performance management mechanism

Power generation performance standard (GPS) is the quantity of a certain kind of pollutant emitted for 1khw generated by power generating unit/power plant or power generating company in unit time and it is used to show the emission intensity of this pollutant for unit electric quantity. It is output-based pollution control mechanism and can be used as power plant emission standard and total quantity allocation method. This mechanism shall ensure that it will not create competitive advantage for seriously polluting enterprises and can prevent power industry from causing decrease of air quality in the course of reform and reorganization and rapid power growth.

Formulation of GPS standard will perfect the present “Emission Standard of Air Pollutants for thermal power plants”, accelerate structural readjustment of power industry, promote technical progress of thermal power plant and facilitate the achievement of pollutant emission total quantity control objective. Additionally, adoption of GPS can provide a fair and effective competitive mechanism for electric power structural reform and reduce output of “dirty power”; at the same time, it can increase energy utilization efficiency, promote utilization of clean energy and reduce emission of pollutants and reduce economic loss caused by environmental pollution. Implementation of GPS standard will lead to organic combination of pollutant total quantity policy and measure with national industrial policy and technology policy.

Another important application of GPS is to use GPS as the total quantity allocation method. Different from the top-to-bottom control plan based on environmental protection objective currently adopted by China, it is a top-to-bottom quota determination method, and total quantity allocation of air pollutants for power industry is the ideal field that China can use GPS to allocate. For big sulfur dioxide emission organizations of the power industry, allocation of total quantity and centralized management by the State in a unified way is not only conducive to the achievement of national total quantity control objective, but also conducive to the resolution of trans-regional environmental pollution problems. This mechanism provides a new method for total quantity allocation and makes total quantity allocation more scientific and rational. GPS-based total quantity allocation method closely combine total quantity control of pollutants with the development of power industry and is easy to operate and can facilitate the increase of energy efficiency and structural readjustment of power industry.

5.1.4.5 Carry out power plant environmental information announcement system

Publish environmental information of electric power enterprises. On the one hand, strengthen the intensity and channel of public participation and facilitate energy conservation work through public participation; on the other hand, enterprises will be inspired to reduce pollution in order to set good public image. It can be started with listed enterprises and gradually expand to all enterprises. Publicize environmental performance and economic index simultaneously. The public can look into environmental data related to enterprises in internet or newspapers and periodicals and know the pollution resulted from their daily power consumption so as to be inspired to participate in environmental protection.

5.1.4.6 Strengthen construction of supervision and management ability

Supervision and management ability is a means to guarantee the successful implementation of various policies and laws and regulations. China started to introduce flue gas CEMS in 1986. According to preliminary estimation by related departments, presently more than 70 thermal power plants have purchased approximately 90 sets of flue gas CEMS and provided vigorous support for environmental management. However some on-line continuous monitoring equipment are not operating satisfactorily and have not accurate monitoring data, bringing pressure to the implementation of total quantity control. Therefore it is necessary to strengthen construction of monitoring and management ability. For economically practicable emission sources, it is necessary to popularize application of automatic monitor; for emission sources without automatic monitor, it is necessary to formulate more accurate emission measuring method. Sulfur dioxide emission charge fund can be used to establish emission tracking system and subsidize enterprises to install on-line monitoring system.

5.2 Construct West-to-East Power Transmission Green Project

5.2.1 Major environmental pressure before us

According to planning of related departments, West-to-East power transmission project will form three major channels. First, develop the hydroelectric power resources of Wujiang River in Guizhou, Lantsang River in Yunnan, Napan River, Beipan River and Hongshui River at the junction of Guangxi, Yunnan and Guizhou provinces as well as the electric energy of pithead thermal power plants in Guizhou and Yunnan provinces to transmit to Guangdong to form the south channel of West-to-East power transmission; second, transmit hydroelectric power of the Three Gorges and Jinsha River trunk streams and tributary streams to East China to form the middle channel of West-to-East power transmission; third, transmit hydroelectric power of upper reaches of Yellow River and pithead thermal power of Shanxi and Inner Mongolia to Beijing-Tianjin-Tangshan region to form the north channel of West-to-East power transmission.

In the Tenth Five Year Plan period, the State will mainly accelerate the construction of power and transmission line for the south channel of West-to-East power transmission. According to strategic planning suggestion for the south channel of West-to-East power transmission, over ten thermal power plants will be built in the corridor at the junction of Yunnan and Guizhou provinces to increase 6,000,000kw power supply capacity. For so concentrated construction of large scaled thermal power plants in acid rain control area and surrounding area in East Yunnan and South Guizhou, if strict measures are not taken to protect environment, it will generate some impact on the air quality in local and peripheral area and on the achievement of total quantity control objective of sulfur dioxide in China's Tenth Five Year Plan period.

The regions possibly affected by West-to-East power transmission construction project are in the south of our country, especially the acid rain control area: Yunnan, Guizhou, Sichuan, Chongqing, Hunan and Guangxi provinces, municipalities and autonomous regions. Guizhou and Yunnan are in our country's Southwestern acid rain area. In 2000, annual average concentration of sulfur dioxide in the ambient air of major cities in Yunnan Province did not exceed national air quality Grade 2 standard, but ambient air quality in Guizhou Province is not optimistic and the percentage of the cities exceeding Grade 3 standard is as high as 54.5 percent.

According to conclusion drawn by the State Environmental Protection Administration after review of "Environmental impact statement of planned project area for thermal power plants in the south channel of West-to-East power transmission", if no control measure is taken for new built thermal power plants, sulfur dioxide pollution in Yunnan and Guizhou provinces in the Tenth Five Year Plan period will double that at present; if some new built projects are installed with desulphurization equipment and Yunnan and Guizhou provinces increase treatment strength for existing thermal power plants, total sulfur sedimentation will drop significantly, but still sulfur dioxide index of some cities exceeds air quality Grade 2 standard; if all new built projects have desulphurization equipment and existing thermal power plants in Yunnan and Guizhou provinces are treated, then local air environmental quality will be improved significantly and concentration of sulfur dioxide can even reach air quality Grade 1 standard.

Therefore, it is necessary to take effective control measure while constructing West-to-East power transmission project to ensure emission of sulfur dioxide can meet the total quantity control requirement of national and local Tenth Five Year Plan period, improve air quality to some extent and realize the construction objective of green West-to-East power transmission project.

5.2.2 Emission of sulfur dioxide increased due to West-to-East power transmission

5.2.2.1 Existing power plants and sulfur dioxide emission

Up to 2000, total installed capacity of existing thermal power generating units in Guizhou Province was 3,476.50MW including 676.5MW for small thermal power plants; total sulfur dioxide emitted from thermal power plants was 557,500t, accounting for 38.45 percent of total emission quantity of sulfur dioxide in the whole province. Yunnan Province presently has 2,933MW total installed capacity of thermal power generating units including 533MW small thermal power plants; total sulfur dioxide emitted from thermal power plants is 142,400t, accounting for 36.9 percent of total emission quantity of sulfur dioxide in the whole province.

5.2.2.2 Control objective of sulfur dioxide in the Tenth Five Year Plan

In 2000, emission of sulfur dioxide in Guizhou Province was 1,450,100t, ranking the second in the country, of which emission of sulfur dioxide in the two-control area was 849,200t, being 58.56 percent of that in the whole province. Emission of sulfur dioxide in Yunnan Province was 385,900t, ranking the nineteenth in the country, of which emission of sulfur dioxide in the two-control area was 272,400t, being 70.57 percent of that in the whole province. In the Tenth Five Year Plan period, total emission quantity of sulfur dioxide in the country will decrease 10 percent on the basis of that in 2000 and total emission quantity of sulfur dioxide in acid rain control area and sulfur dioxide control area (hereinafter referred to as "two-control area") will decrease 20 percent compared with 2000. According to requirement of the "Tenth five-year-plan of ational environmental protection", by 2005, emission of sulfur dioxide in Guizhou Province shall be controlled at 1,276,000t, decreasing 12 percent than 2000, of which emission of sulfur dioxide in the two-control area shall be controlled at 630,000t, decreasing 25.8 percent than 2000. Emission of sulfur dioxide in Yunnan Province shall be controlled at 380,000t, decreasing 1.5 percent than 2000, of which emission of sulfur dioxide in the two-control area shall be controlled at 218,00t, decreasing 20 percent than 2000.

Thus it can be seen that reduction pressure of sulfur dioxide for Yunnan and Guizhou provinces is great (especially two-control area), and in order to achieve the task of West-to-East power transmission, the two provinces will construct some thermal power construction projects in the Tenth Five Year Plan period, which are most in the two-control area and will increase new burden for the already very arduous reduction task of sulfur dioxide. Therefore it proposes severe challenge to economic development and environmental protection of Yunnan and Guizhou provinces. Multiform methods must be taken to control sulfur dioxide, particularly emission of sulfur dioxide in the two-control area.

5.2.2.3 Emission increase of sulfur dioxide from thermal power construction projects

In the Tenth Five Year Plan period, Guizhou Province will complete three thermal power plants with total installed capacity of 3,000MW and increase 7,000,000t coal consumption. Meanwhile, under possible condition, some units of Nayong No.2 plant, Yaxi Power Plant and Qianxi Power Plant will also be put into production in the Tenth Five Year Plan period. Yunnan will build four new thermal power plants with total installed capacity of 3,000MW and increase 9,660,000t coal consumption; at the same time, Xuanwu Phase 5 will be put into production in the Tenth Five Year Plan period. If no measure is taken in the ten-five-year-plan period, thermal power projects will increase 201,700t emission of sulfur dioxide in Guizhou and 136,800t in Yunnan.

5.2.3 Total quantity control of sulfur dioxide in Yuannan and Guizhou provinces

Yunan and Guizhou provinces shall use economic, policy and management means to try to make power plants take desulphurization measure. Only by doing so, can the control objective of sulfur dioxide in the Tenth Five Year Plan period be achieved.

5.2.3.1 Desulphurization scheme and capital demand of new thermal power plants

In the thermal power project of West-to-East power transmission in Guizhou Province, sulfur content of design coal type for Anshun Power Plant Phase 2 Project, Qianbei Power Plant and Nayong Power Plant exceeds 0.9 percent and desulphurization shall be considered. In the thermal power project of West-to-East power transmission in Yunnan Province, sulfur content of design coal type only for Kaiyuan Power Plant exceeds 1 percent and desulphurization shall also be considered; sulfur content of design coal type for Diandong Power plant and its Phase 2 Project is 0.8 percent, and it may not consider desulphurization for the time being, but must reserve desulphurization site. If all power plants adopt wet desulphurization, based on 90 percent desulphurization, the three power plants in Guizhou may reduce 130,000t sulfur dioxide every year and need 1,800,000,000Yuan capital; and a power plant in Yunnan may reduce 61,400t sulfur dioxide every year and needs 360,000,000Yuan capital.

5.2.3.2 Desulphurization scheme and capital demand for existing thermal power plants

In Guizhou Province, Anshun, Kaili, Guiyang and Zunyi power plants of over 100,000kw have desulphurization potential. Considering suggestions of the State Environmental Protection Administration, the State Power Corporation of China and Guizhou, the existing 6 desulphurization projects of thermal power plants with total installed capacity of 2,400MW can reduce 301,400t sulfur dioxide every year and need an investment of 1,460,000,000Yuan (600-659 Yuan investment for unit kw).

Of the existing thermal power plants in Yunnan Province, only Xiaolongtan Power Plant (coal sulfur content is 1.6 percent) and Yangzonghai Power Plant (coal sulfur content is 1.0 percent) have desulphurization potential. According to the requirement of the State Environmental Protection Administration and former State Power Corporation of China for desulphurization of thermal power plants in the Tenth Five Year Plan period, it is planned to arrange these two power plants to install desulphurization equipment with total installed capacity of 600MW, which can reduce 56,200t sulfur dioxide every year and needs an investment of 410,000,000Yuan.

5.2.3.3 Reduce emission of sulfur dioxide from other pollution sources

Guizhou Provincial People's Government has filed to the State Environmental Protection Administration the "Commitment Letter of Guizhou Provincial People's Government for environmental protection for the implementation of West-to-East power transmission thermal power project" (QFH[2001]No.387), and made commitment for reduction of sulfur dioxide in the aspect of desulphurization of thermal power project, out-of-service of small thermal power generating units, surface source and other industrial sources. Besides desulphurization of thermal power plants, Guizhou Province plans to close and stop seven small power plants of total 197MW in the Tenth Five Year Plan period and expects to reduce 42,000t sulfur dioxide each year. Through close, stop and elimination of backward production technology and gradual change of energy structure and increase of simple desulphurization for boilers and kilns, it plans to reduce 80,100t emission of industrial sulfur dioxide each year; through popularization of electric heat gasification, generalization of marsh gas and reduction of coal sulfur content, it plans to reduce 72,400t urban and rural domestic emission of sulfur dioxide and reduce totally 194,500t emission of sulfur dioxide each year.

According to the key sulfur dioxide pollution treatment plan reported to by Yunnan Province to the State Environmental Protection Administration, Yunnan will close ten small power generating units with total installed capacity of 300MW, which may reduce 23,000t sulfur dioxide each year. It will control and treat several major industrial pollution sources in Kunming, Qujing, Yuxi, Chuxiong and Kaiyuan cities and popularize town electricity utilization and liquefied petroleum gas project to reduce 26,000t sulfur dioxide each year. It plans to reduce 49,000t emission of sulfur dioxide each year.

5.2.4 Policy suggestions on West-to-East power transmission green project

West-to-East power transmission project is the key project of national West development strategy. In order to build the West-to-East power transmission project into national green project and control acid rain pollution and sulfur dioxide pollution in Yunnan and Guizhou provinces, it is suggested:

- The State should gradually raise sulfur dioxide emission charging standard and enlarge charging range to make it close to or higher than control and treatment cost, truly make pollution control cost become an integral part of total product cost and form the mechanism of who pollutes suffers economic loss so as to facilitate pollution emission enterprises to actively increase investment and reduce sulfur dioxide emission.
- The State should issue power plant environmental protection discount policy to carry out environmental protection discount for the power plants whose generation performance exceeds 3g/kwh, and give discount to all power connected to grid that exceeds 3g/kwh at 0.02Yuan/kwh so as to realize fair market competition for desulfurized power and not desulfurized power.
- Trial-implement emission right trading system in Yunnan and Guizhou

provinces and exert action of market mechanism in sulfur dioxide control. With total quantity and up-to-standard emission implemented, gradually establish sulfur dioxide emission right trading system to continuously reduce the prevention and control cost of sulfur dioxide and acid rain pollution for the whole society and to provide flexible choice for power plants to reduce sulfur dioxide.

- If new built thermal power plants in Yunnan and Guizhou provinces can install desulphurization equipment and can realize up-to-standard emission of sulfur dioxide and nitrogen oxides, it is suggested that South China Power Grid Co. should give priority to grid connection when incorporation of power generation in power grid and give support in terms of power generation hours.
- The State shall organize to carry out desulphurization feasibility study of West-to-East power transmission thermal power project in Yunnan and Guizhou provinces as soon as possible, formulate practicable sulfur dioxide reduction plan and scheme to realize reduction objective of sulfur dioxide at the minimum cost. At the same time, the State shall establish a certain supervision mechanism and ensure the achievement of sulfur dioxide emission reduction objective and the achievement of prevention and control objective for sulfur dioxide pollution and acid rain.
- Implement the policy of “the old help the new to catch up”. Even complete desulphurization is realized for West-to-East power transmission project, total quantity of sulfur dioxide will increase compared with 2000. Therefore it is necessary to close and stop existing thermal power plants of less than 50,000kw according to national industrial development policy while constructing new power plants.

5.3 Integrated Reduction of Traffic Environmental Pollution

5.3.1 Environmental problem of motor vehicle development

As automobiles are concentrated in cities, the contribution rate of urban pollution sources such as CO, NOx, ozone and hydrocarbon etc emitted from automobiles have undergone structural change, i.e. change from original smoke-black-based pollution to tail-gas-based pollution emitted from motor vehicles. Its share percentage is already close to that of developed countries, which indicates that China’s automobile tail gas is rising to be the main urban pollution source (table 5-3).

Table 5-3 Percentage of Automobile Tail Gas Emission in Total Quantity of Urban Pollutants

Pollutant	Beijing (1992)		Guangzhou (1994)	Average of 7 American cities
	Heating period	Non-heating area		
CO	47.3	80.3	88.8	84.0
NOx	15.7	54.8	79.3	42.0
HC	61.3	79.1		70.0

Data source: "Sustainable Development and Traffic and transportation", China Railway Publishing House, 2000 [24].
http://www.newenergy.org.cn/meeting/paper/paper39.html

Although China's motor vehicle tail gas emission has become the major urban pollution source, China is still in the very low level in view of the percentage of the whole traffic and transportation system energy consumption in the total energy consumption (table 5-4).

Table 5-4 Comparison of Traffic and transportation Energy Consumption in 2000 (Unit: Mtoe, %)

Country	America	Japan	Canada	UK	France	Germany	Italy	Russia	China	OECD	World
Traffic energy utilization	610	94	54	53	53	67	42	79	74	1203	1751
Percentage in total terminal energy consumption	40.7	27.1	28.1	32.7	31.4	31.2	32.1	18.9	13.2	34.1	29.0

Data source: Japanese Research Institute of Energy Economy, 2003

With acceleration of China's modernization progress, energy consumption including automobile will still continuously increase and the environmental impact caused by it will also draw more and more attention. Presently, China's some big cities such as Beijing, Shanghai and Guangzhou etc already started to take measure to control emission of motor vehicle pollutants and have gained some achievements.

At present, China's automobile retention quantity increases very fast and annual average growth rate is about 15 percent. At the end of 1998, national automobile retention quantity was 13,200,000 and in 2002 the quantity increased to 20,530,000.

Related research departments and experts have made prediction for China's future traffic demand and motor vehicle retention quantity under different development condition and also made different research for the prediction of future emission quantity of motor vehicles.

According to prediction, Emission of NOx and HC in 2020 will be 2,580,000t, which is apparently lower compared with possible emission quantity. According to prediction of national motor vehicles in table 2-2, national retention quantity of civil automobiles will reach 40,100,000 in 2010 and 77,000,000 in 2020. Calculation shows that 1,000 automobiles emit 50-150kg NOx and 200-400kg HC per day on average [(24)]. On the base of this emission coefficient, it is possible to calculate emission of major pollutants emitted from motor vehicles in the country in 2010 and 2020.

Table 5-5 Potential Emission Pressure of Automobile Pollutants in China in Next 20 years

Year	2001	2010	2020
NOx emission quantity (10,000t)	65.8	146.35	281.2
HC emission quantity (10,000t)	197.3	439.04	843.4

Thus in a future period, China must strengthen management and control for emission of motor vehicle tail gas to reduce motor vehicle pollution to the minimum level.

5.3.2 Comprehensive reduction strategy of motor vehicle pollution

To resolve motor vehicle pollution problem, it is necessary to start with perfection of the whole traffic system and improvement of fuel structure and fundamentally reduce emission of motor vehicle pollutants.

5.3.2.1 Perfect comprehensive transport system and develop low-energy-consumption and less polluted mode of transport

To perfect comprehensive transport system, the first thing to do is optimize transport structure and transform it to resource saving and environmental protection transport structure. The most fundamental means to reduce motor vehicle pollution emission is to reduce use of motor vehicles, thus it is necessary to vigorously develop rail transport to reduce land occupation and exhaust gas pollution, all out develop clean energy vehicles, save resources and reduce pollutant emission quantity.

Second, we shall sufficiently exert the advantage of various transport modes to make the best use of all transport modes and reduce such resource waste phenomena as construction of redundant projects and blind construction, and shall fully exert the advantage of various transport modes including motor vehicles to improve transport efficiency, save land resources and reduce noise and air pollution.

Third, we shall encourage the development policy of environmentally friendly transport means, including reduction policy of traffic congestion, public transit policy and reduction policy of fuel consumption, and shall strictly execute technical measure and management for automobile tail gas pollution, including formulation of tail gas emission standard, installation of catalytic purification device, reduction of automobile life length and development substitute fuel etc.

5.3.2.2 Formulate harmonious development policy of different transport modes with environment

Establish sustainable-development-oriented and environmentally friendly comprehensive traffic system, comprehensively improve various transport modes and vehicles and formulate appropriate environmental policies and measures to realize the greening of traffic and transportation.

Road transport sector shall strictly execute scrapping standard of motor truck and passenger automobile, stop production and sale of motor leaded gasoline, reinforce supervision and management for emission pollution of new produed motor vehicles, strictly carry out pollution emission monitoring and management for automobile, motorcycle and automobile engine products.

Railway sector shall gradually reduce and eventually eliminate steam locomotives and improve steam locomotive design, operation and maintenance; the enterprises that construct and produce in densely populated area to generate noise and pollution shall take noise reduction measures or improve production technology; prohibit arbitrary discharge of wastewater and treat and control the discharge of wastewater to realize up-to-standard discharge; research and adopt passenger car feces collection device to treat passenger’s feces.

Water transportation sector shall use method to reduce ship noise pollution and treat and control port dust pollution and port water surface oil pollution.

Civil aviation sector shall sufficiently consider impact of airport construction and air transport on surrounding residents, reduce noise and exhaust gas pollution, strengthen the treatment of the three wastes from civil aviation factories and realize up-to-standard emission.

5.3.2.3 Utilize new technology to improve traffic energy consumption structure

Resource shortage and environmental pollution lead to the improvement of petroleum based energy consumption structure for traffic and transportation and the improvement direction is mainly oil conservation and clean energy. Motor transport shall actively research and develop liquefied natural gas and electric automobile on the basis of lead-fee gasoline popularization.

Looking for substitute energy source is the necessary supplementation for price regulation means. Price based policy itself will impellingly stimulate people to invest in various energy conservation and pollution reduction technologies. The government shall also strengthen powerful cooperation of the industries such as automobile industry and petrochemical industry through encouragement and guidance of industrial policies.

5.3.2.4 Strengthen cooperation and coordination of various transport modes

Facing with double pressure of resource and environment, it is impossible to only rely on ability construction to resolve problems and it is necessary to conduct continuous reform of management system and production operation mode, adopt the idea of “time for space and efficiency making up ability” to make limited resource to generate maximum efficiency. Therefore vigorously strengthening the coordination and cooperation between various transport modes is the indispensable and tried and true solution for meeting increasingly growing transport demand at the present time and in a future period of time.

5.3.3 Policy measure to reduce automobile pollution

Urban environmental pollution brought about by motor vehicles is mainly tail gas. The purpose of treating and controlling automobile tail gas is to make vehicle emission level reach a certain standard and make air quality not affect human health. To achieve such an objective, it is necessary to formulate conditionally permissible comprehensive strategic measures that conform to economic and social bearing capability.

5.3.3.1 Exert “troika” action to reduce pollution of vehicle tail gas

In improvement of living environmental quality and reduction of air pollutants, foreign developed countries usually adopt the strategy of “troika” to start with vehicle, fuel and laws and regulations.

Fuel measures include: prohibition of use of leaded gasoline, fuel improvement, substitute fuel, fuel quality improvement etc. The productive capacity of lead-free gasoline for China’s petrochemical industrial system is already half of output. But the existing problem is that retention quantity of low grade gasoline is great, transformation fee of original gas stations and storage and transport equipment is high and transformation is difficult. As a result, use of lead-free gasoline is impossible to completely cover the whole country.

Improvement of motor vehicle emission performance includes: engine improvement, tail gas purification, particulate collector and vehicle maintenance and service etc. Carrying out strict periodic inspection/maintenance (I/M) system is particularly important to reduction of total emission quantity. Experience of developed country shows that implementation of good I/M schedule can reduce 30 –40 percent total emission of pollutants.

Laws and regulations are embodied in formulation of traffic demand management policy and formulation of fuel and vehicle emission control laws and regulations.

5.3.3.2 Rationally and effectively control the development of motor vehicle traffic volume

In a future period of time, development of automobile industry will drive urban motor vehicles to develop at high speed, and implementation of vehicle total quantity control policy is neither practical nor conducive to development of automobile development. In the light of mitigating urban air environmental quality, the key point shall be the restriction of urban vehicle traffic volume growth and improvement of motor vehicle quality.

5.3.3.3 Vigorously develop public means of transport and pollution-free vehicles

Urban public transit system may greatly reduce vehicle operation quantity and emission quantity and is the preferred selection for exertion of urban traffic efficiency. In the relatively busy urban center area, increase of bus lines and bus quantity not only make traffic developed but also is advantageous to environment. Particularly we shall advocate using the pollution-free public transit system and urban bicycles such as subway traffic system and trolley bus and tram car.

5.3.3.4 Implement whole process control and life cycle management for motor vehicles

In various links of motor vehicle production, sale and consumption, actively initiate clean production, ISO14000 certification, environmental label and product life cycle management and strengthen publicity and guidance of green consumption and promote green production from consumption field.

5.3.3.5 Wield economic means such as taxation to encourage development of clean and energy saving mode of transport

Utilize market force to change the adjusted price that reflects social cost to powerful means so as to make producers and consumers to endeavor to protect environment. As controlled price gives place to market-determined price, the government can gradually increase fuel tax, and with reduction of the gap between China’s and international price level, further encourages people to save oil so as to adjust oil consumption.

Implement related policies conducive to clean automobile and clean fuel as soon as possible, especially economic policy, and promote the cleaning of motor vehicle and fuel. Issue and implement preferential tax policy for motor vehicles of different emission standards and tax difference policy for different fuel qualities as soon as possible.

5.3.3.6 Adopt departmental coordination and strengthen comprehensive decision

The biggest obstruction for effectively resolving urban traffic and its pollution is possibly that responsibility of urban traffic system belongs to different agencies. This separating condition will still exist, but as long as we define scope of authority and strengthen effective coordination between departments, the goal of improving urban traffic and reducing pollution is realizable.

Improvement of urban traffic and air quality involves various traffic problems and each city needs a comprehensive decision suitable for itself to resolve these problems. China shall draw lessons from developed countries and start to take positive measures before motor vehicle pollution generates great impact.

5.4 Exert Great Efforts to Develop Rural Renewable Energy

In 2000, 60.91 percent rural population created 15.4 percent of national GDP while total consumption of rural energy (including non-commercial energy) is 53 percent of national energy consumption, of which commercial energy consumption is 30 percent national energy consumption. Rural energy development has a direct impact on rural production, farmer’s life, farmer’s health and rural environment. Therefore the rural energy environmental protection objective in China in the next 10 or 20 years is: first, increase farmer’s living standard, which is conducive to promoting farmers to realize moderately well off society; second, promote improvement of rural ecological environment; third, promote reduction of rural indoor air pollution and increase farmers’ health level.

5.4.1 Analysis of rural energy environmental characteristic

Environmental characteristic of China’s rural energy sources is mainly embodied in the following three aspects:

5.4.1.1 Low high-quality energy rate and serious ecological damage

In 2002, national rural energy consumption was 782,790,000t standard coal (including 495,610,000t standard coal for commercial energy), accounting for 53 percent of total national energy consumption (including non-commercial energy). National rural energy consumption per capita increases from 0.67t standard coal in 1995 to 1t standard coal in 2002 and annual average growth is 3.35 percent (table 5-5). However, percentage of high quality energy is very low in rural energy. Even in rural production energy, percentage of firewood in 2000 was still 5 percent (table 5-6 and table 5-7). Burning and use of firewood in large quantities will surely cause rural forest vegetation damage and eventually lead to soil erosion in rural area. Rural domestic energy utilization depends greatly on burning straws, which results in impossibility of large quantity of straws to return to fields and causes reduction of soil fertility and decrease of soil organic matter content.

Table 5-6 China's Rural Energy Consumption and its Structural Change

Year	Rural energy consumption (10,000 tce)	Rural energy consumption per capita (tce)	Percentage of domestic energy consumption (%)	Percentage of production energy consumption (%)
1995	64742.96	0.67	58.95	41.05
1996	63962.31	0.70	53.26	46.74
1998	67213.28	0.76	54.24	45.76
2000	67047.09	0.79	55.18	44.82
2002	78279.00	1.00	58.06	41.94

Source: "China Rural Energy Yearbook 1997" and "China Rural Energy Yearbook 1998-2000", China Agricultural Press.

Table 5-7 Structural Change of Rural Domestic Energy Utilization in China

Year	Rural domestic energy consumption (10,000 tce)	Straw percentage (%)	Firewood percentage (%)	Raw coal percentage (%)	Electricity percentage (%)	Kerosene percentage (%)
1995	38165.49	39.54	26.24	22.56	10.98	0.67
1996	34069.49	35.21	24.36	29.64	8.55	1.38
1998	36456.61	33.68	23.04	32.01	8.18	1.77
2000	36999.19	33.41	21.76	31.90	9.31	2.05

Source: "China Rural Energy Yearbook 1997" and "China Rural Energy Yearbook 1998-2000", China Agricultural Press.

5.4.1.2 Low energy efficiency and serious environmental pollution

Compared with national and urban energy efficiency, China's rural energy utilization efficiency is low. Energy consumption strength of rural township enterprises is 50 percent higher than state-owned large- and medium sized enterprises on aveage. Large quantities of lowly efficient energy consumption have caused national rural environmental pollution. National township enterprises started to emit more and more pollutants in 1990s and emission quantity of sulfur dioxide and smoke dust from rural township enterprises in 2000 reached 4,400,000t and 4,360,000t respectively, being 27 percent and 46 percent of national industrial emission quantity (see table 5-8). In addition, mining of large numbers of rural small coal mines seriously pollutes environment and waste coal resources.

Table 5-8 Air Pollutants Emitted from China's Township Enterprises (unit: 10,000t)

Year	Emission quantity of sulfur dioxide		Emission quantity of smoke dust		Emission quantity of dust	
	Industrial industry	Township enterprise	Industrial industry	Township enterprise	Industrial industry	Township enterprise
1997	1772	409	1265	588	1505	957
1998	1594.4	384.4	1178.5	495.8	1321.2	815.2
1999	1460.1	382.3	953.4	396.9	1175.3	717.4
2000	1612.5	440.9	953.3	436.2	1092.0	687.8

Source: State Environmental Protection Administration, China Environmental Statistical Annual Report, 2000.

5.4.1.3 Serious indoor air pollution directly harm farmers' health

As calculated from table 5-6 and 5-7, approximately 470,000,000 rural population uses firewood and straws as domestic energy in China. Rural indoor pollution is much more serious than urban indoor pollution and concentration of particulates is twice as much as the latter (see table 1-12). Therefore, resolution of rural energy need and rural indoor air pollution is a challenge that energy development and environmental protection must be confronted with in the next twenty years.

5.4.2 Implement "National rural green energy program"

At present, related departments of Chinese Government have implemented a series of plans or action projects in rural energy development field, which plays a good role in promoting rural renewable energy development. These programs include:

It is suggested that, based on currently implemented rural energy construction plans such as Chengfeng Program, Lighting Engineering Project, Straw Gasification Pilot Project, National 100-County Small Hydropower Station Program and Ecological Homeland Enriching Program.

It is suggested to formulate and implement "National rural green energy program" based on these rural energy programs.

(1) In the light of the present rural major problems existing in energy utilization, the key point in the "National rural green energy program" is to increase rural energy utilization efficiency, advocate water saving irrigation technology, encourage the use of high-efficiency, low-poison and less-persistent pesticide and organize farmers to carry out training in rational application technology. Make Ecological Homeland Enriching Program as foundation and breakthrough and actively develop ecological agriculture such as comprehensive utilization of marsh gas etc.

(2) If it is difficult to implement "National rural green energy program" in one step, we can first make integration appropriately and gradual carry out centralized management towards to agricultural sector, reduce governmental

sectors for operation and increase utilization efficiency of national capital. For some wind power generation and small hydropower stations, they can be constructed by the five major power group corporations by regulating their green power production quota or renewable energy quota requirement. Encourage power group corporations to support rural renewable energy construction.

(3) Continue to increase comprehensive construction strength of rural energies at county level. The State shall continue to select 100 counties to carry out three types of demonstrations of rural energy comprehensive construction in the Eleventh Five Year Plan period and the Twelfth Five Year Plan period: poverty reduction and elimination and food and clothing, moderately well-off and well-off demonstration. The state revenue shall mainly support rural energy construction demonstration project of poverty reduction and elimination and food and clothing type and moderately well-off type. In combination with rural energy comprehensive construction, actively popularize courtyard economy mode, North rural energy ecological mode, South rural energy ecological mode and large and medium sized livestock and poultry cultivation farm energy ecological environmental projects linked by marsh gas comprehensive utilization technology and encourage different types of regions to explore various energy ecological environmental engineering modes in the light of local conditions.

(4) Straw energy cleanness, gasification and industrialization. Straw is the richest biomass energy source in China’s rural area. In the rural regions, especially in the West region and remote poor areas, we shall continue to carry out crop straw gasification demonstration project and popularize straw gasification operative technology in rural area. To reduce construction cost of straw gasification, the State shall continue to give capital support.

(5) Continue to attach great importance to rural energy saving work. In recent 10 years, the key point is to popularize firewood saving and coal saving cooking ranges and domestic coal in West region and remote rural areas. Energy saving work for rural township enterprises shall focus on high-energy-consuming enterprises such as tile and brick, cement, coking and paper making. It is necessary to close, stop, merge and change those small enterprises that consume great amount of resources, seriously pollute environment, produce low-quality products and have many potential production safety hazards.

(6) Help farmers reduce indoor air pollution. The measures to reduce indoor air pollution caused by use of traditional renewable energy include: first, the State organizes related organizations to research and popularize clean firewood and straw burning technology and develop low-pollution and high-efficiency domestic firewood stoves to reduce resultant indoor pollution; second, with improvement of farmer’s living standard, reduce direct burning and use of traditional renewable energy and raw coal and select clean energy; third, educate farmers to know the hazard of indoor air pollution to human health and let farmers know the cause of indoor air pollution.

5.4.3 Reduce the use cost of renewable energy

The fundamental approach to resolving China’s rural energy environmental pollution is to exert great efforts to develop modern renewable energy suitable for rural area and reduce the use of firewood and straw energy that pollute environment, harm heath and damage ecology. At present, it is urgent to resolve the policy problem to support rural renewable energy development, particularly how to reduce the cost of low-income farmers to "enjoy" renewable energy as soon as possible.

The State shall formulate appropriate encouraging policies to support rural area to accelerate the development of renewable energy and make farmers truly affort to build and use these expensive, clean and modern renewable energies.

(1) Continue to perfect the "construction subsidy capital for rural energy project of rural small sized public welfare facilities' established by the state revenue, enlarge the scale of subsidy capital (e.g. increase to 1,000,000,000 Yuan annually) and increase capital support for rural renewable energy project. Subsidy capital is mainly used to develop rural marsh gas, straw gasification, wind energy and solar energy projects.
(2) In West development, the State shall accelerate the formulation of policies and, through such preferential policies as tax reduction and exemption, credit period extension, loan discount interest and increase of central capital investment, support rural renewable energy development and attract foreign investment. One of presently feasible measures is to allocate a certain percentage of capital in the West development national debt capital arranged by the Central Government to use in the rural renewable energy development and mainly support the development of rural marsh gas and new energy such as solar energy and wind energy.
(3) While implementing the clean development mechanism (CDM) project for reducing the emission of greenhouse gases, the State shall mainly support the renewable energy development project for rural areas and utilize carbon dioxide emission reduction credit of CDM project to lower the cost of renewable energy. At the same time, the State shall reduce project development cost for rural CDM projects through appropriate technical service and support.
(4) In the principle of "reducing farmers' burden", accelerate rural and urban electricity price reform progress and implement rural and urban electricity utilization at the same quality and the same price. Meanwhile, execute preferential policy for power connection of a certain scale of rural wind energy and utilize the "National Environmentally Friendly Energy Fund" to give price difference subsidy to wind power grid connection or directly give subsidy to farmer and herdsman users of wind power.

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