INCORPORATION OF ENVIRONMENTAL CONSIDERATIONS IN ENERGY PLANNING IN THE PEOPLE'S REPUBLIC OF CHINA

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Foreword

Incorporation of Environmental Considerations in Energy Planning in the People's Republic of China

by

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As developing economies grow, they will begin to catch up with the levels of energy consumption and industrial production of the high-income countries. In today's industrialised countries the main period of industrialisation saw rapidly increasing pollution. How far can the developing countries avoid repeating that experience and benefit from the ways in which the richer countries have learned to reduce pollution from energy use and industrial production even as output expands. This has been one of the key objectives of the two major UNEP sponsored energy-environment studies, in India and China, completed during 1995. These studies represent two of the key activities in UNEP's energy programme in recent years. Both projects aimed specifically to strengthen national and regional institutional capacity in the area of energy environmental analysis and to promote policies that would reduce energy-related environmental emissions. The detailed studies of the two countries addressed all aspects of energy and environment policy and planning, with substantial participation of local teams.

To put the scope and importance of both the projects in correct perspective it is necessary to visit the global energy future and assess India and China's share in it. With 40% of the world's people, China and India together loom large in any analysis of energy futures and related environmental impacts. The World Energy Council (WEC) allocates "centrally planned Asia" (a category dominated by China) and "South Asia" (dominated by India) a quarter of world energy consumption by 2020 in their recent projections. In the International Energy Agency's scenario, China and India will produce a bigger increase in emissions from 1990 to 2010 than the entire OECD. Between them they will emit as much as a quarter of the world's total by 2010. China plans to burn 1.4 billion tonnes of coal a year by 2000, which is equivalent to one third of the world coal output in 1992.

The shift in global energy consumption towards the developing world demands new policies in these countries; especially in China and India. Focus must be on how to ensure economic development based on clean and efficient energy production and utilization in order to avoid the otherwise potentially very severe environmental problems at both local, regional and global levels.

The China project was started in June 1993 with the signing of an agreement between UNEP and the National Environmental Protection Agency (NEPA) of the People's Republic of China. The project aimed to provide a broad overview of the national energy development situation, to develop an alternative national energy scenario, and to identify economic and technological factors that might constrain the implementation of energy systems which minimise environmental impacts. The project also included detailed regional studies for Beijing and Guanxi provinces.

The project aimed specifically to explore the economic and environmental impacts of a range of integrated energy policy measures, and to examine a range of different environmental indicators, such as emissions of SO_x, NO_x, CO, CO_2 and particulates. Rather than attempting to predict what would happen as a result of specific policies, the study report describes what could happen under assumptions of particular packages of policies and technologies.

The analytical tool used in the study, the LEAP/EDB model accounting framework, which has been developed with UNEP support, was well suited to this task, and staff from the Stockholm Environment Institute's Boston Centre were involved in implementation and training in the use of the tool. The use of the accounting framework contrasts with the optimisation approach used in the India study. In this case a simple approach based on physical simulation of energy flows was used, providing the analyst with a set of tools for checking the consequences (energy, economic and environmental) of different scenarios.

The UNEP Collaborating Centre on Energy and Environment, Denmark was involved closely in the substantive work of the project, through formal and informal training, and close collaboration on the use of energy-environment modelling tools. In this connection, a number of members of the Chinese team had extended stays at the Centre during 1994.

On the basis of the detailed analysis, the UNEP/NEPA project study team arrived at a number of key policy recommendations for changing the present pattern of energy production and consumption, and establishing an energy system which is more compatible with a path of sustainable development. These policy recommendations include the following:

- Changes in the energy production mix - especially increasing the provision of high quality energy
- Promotion of clean-coal production and consumption technologies
- Improvements in energy efficiency
- Introduction of integrated energy-environment planning
- Introduction of environmental regulations and economic instruments which facilitate the implementation of an environmentally friendly energy strategy
- Strengthening of international co-operation and transfer of technology.

A major achievement of the China study is that the analysis identifies relevant decision levels and actors, and specifies conflicting objectives and strategies. All these factors are likely to play a decisive role in the formulation of a long-term energy strategy for China and I expect that the project will form part of the basis for future policy decisions in the energy area.

Finally, I wish to thank those who have been involved in the various stages of research and advisory activities and in the workshops that have lead to this publication. I sincerely acknowledge the co-operation of the various arms of the Government of the Peoples Republic of China especially the implementing agency - the National Environment Protection Agency. I commend the technical role of the Chinese research institutions particularly, the Modern Policy Research Centre for Environment and Economy, the Energy Research Institute and the Department of Environmental Engineering at Tshinghua University. The technical support given by the UNEP Collaborating Centre on Energy and Environment is also appreciated.

I am confident that also other developing country governments, policy makers, academicians, researchers, and other users of this report will find a great deal of inspiration and useful material for their activities in the area of energy, environment and sustainable development.

Contents

Executive Summary

INTRODUCTION

The degradation of the environment at the local, regional and global levels caused by present patterns of energy production and use is an important issue of worldwide concern. One of the alarming consequences of unbridled energy consumption is the large-scale release of pollutant emissions from the production and consumption of fossil fuels, especially coal. Currently, China accounts for 10 percent of global energy use. However, with continued rapid rate of eonomic growth well into the 21th century, there will be an unsatiable demand for additional energy. As a result, various kinds of pollutants emitting from energy consumption will increase considerably. Coal is the main energy source in China. It is envisaged that in the coming 30 years, China's energy mix in which coal dominates is not likely to alter. Since the comprehensive utilization ratio of coal over the whole process from coal production to consumption, is only 10 percent, the pollutants stemming from direct combustion of large quantities of coal have become the main factor for regional and global environmental issues such as air pollution, acid precipitation and global climate change, in which acid precipitation in China is more prominent. Thus, areas covering southwest and south China have become one of the three acid rain zones in the world, and farmland encroached by acid rain has totalled 40 million *mu*, hence diminishing 5-10 percent of crop output which is equivalent to economic loss of several billion Yuan annually. SO_2 induced acid rain and the emission of green house gases in China has been causing global alarm. Additionally, on the global level, China ranks third in the world in terms of emissions of carbon dioxide with annual emissions of approximately 650 MtC. With the stipulated growth in coal consumption, this will reinforce Chinese position as one of countries with the highest level of emissions of carbon dioxide. Chinese planners are aware that in order to protect the fragile eco-system, there is an urgent need to incorporate environmental considerations (especially air pollutant emissions like SO_2, CO_2, particulates, NO_x, etc.) in the formulation of an integrated energy plan.

This summary report is the accomplshment of a two-year research by a joint study team of representatives from the Modern Policy Research Center for Environment & Economy (MPRCEE) under the National Environmental Protection Agency (NEPA) and the Energy Research Institute (ERI) under the State Planning Commision (SPC) of China, the Tsinghua University of China, the United Nations Environment Programme (UNEP) Collaborating Centre on Energy and Environment (UCCEE), and other domestic institutes, with support from the UNEP.

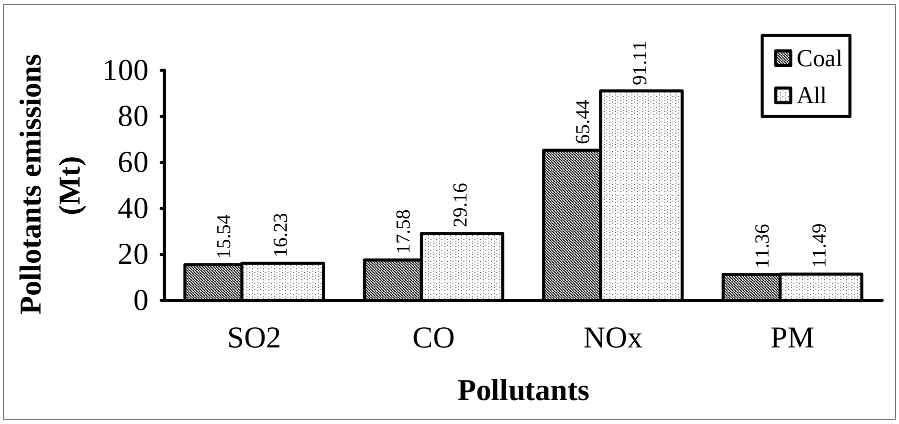
In accordance with the catalytic role of UNEP, one of the major activities of the energy sub-programme is to initiate and support the incorporation of environmental considerations in national energy planning and strategies. The object of this study is to forecast what would happen over the entire energy system, based on the current official economic, energy and environmental policies, and juxtapose against this an environmentally friendly scenario that offers policies and mitigation options for a coordinated development of economy, energy and the environment.

ESTIMATIONS OF ENERGY-RELATED POLLUTANT EMISSIONS

Energy consumption in China is by far the largest contributor to air pollutant emissions, and coal-smoke type air pollution in urban areas formed by smoke dust and sulfur dioxide from coal consumption has become a major environmental issue in China. In 1990, China consumed 1.05 billion tons of raw coal which accounted for 76 percent of primary energy consumption. Of this, coal consumption for electricity generation was 260 million tons and industrial boilers consumed 350 million tons.

In 1990, SO_2 emissions from the entire energy system in China were estimated at 16.23 million tons, 95.71 percent of which were related to coal combustion; 11.44 million tons of smoke dust emissions, 98.83 percent of which were related to coal combustion; emissions of CO_2 amounted to 650 million tons of carbon equivalent, 87.20 percent of which are related to coal combustion; emissions of NOx stood at 91.11 million tons, 71.84 percent of which are related to coal combustion; emission of CO was 29.16 million tons, 60.29 percent of which are related to coal combustion (See Fig 1).

Figure 1. China's Major Pollutant Emissions Related to Energy in 1990



METHODOLOGY

The study entailed collection of extensive reliable data at the national and local levels. In addition, findings of two local case studies of Beijing city and Guangxi Zhuang Autonomous Region were used as inputs to the policy study.

The "bottom-up" or "end-use" approach, which is applied in this study for energy planning, makes demand and supply projections at a more disaggregated level, relying more upon surveys, engineering studies, and expert judgments about important (and often price-independent) effects such as technological innovations, energy transitions, market saturation and other structural shifts. The LEAP software, developed by the Stockholm Environment Research Institute-Boston Center, which incorporates an accounting framework and cross-sectoral comprehensive analysis and a long-term energy planning system, has been employed. The year 1990 was selected as the base year and 2000, 2010 and 2020 as the forecast periods. All the fuels and all links (end-use demands, transformation, transmission and distribution, resources, economy and environment) in the energy system, energy demands of different economic sectors, and the energy systems for household in urban and rural areas have been analysed. The possible energy demands and supply over the time horizon and emissions of various pollutants (CO_2, SO_2, NOx, PM and CO) have been predicted. The Business-As-Usual (BAU) scenario and two scenarios with regard to possible energy future (enhanced scenario I and enhanced scenario II), based on the same economic growth and economic structure, have been constructed.

Business-As-Usual Scenario: As far as possible, the BAU scenario reflects currently official Government policies and forecasts of macroeconomic, demographic and energy sector indicators. Instead of attempting to make precise predictions or to derive optimal solutions, BAU dictates what would happen to possible energy future and potential environmental loadings. Of course, BAU scenario includes a lot of pro-environmental measures, such as structural changes among industrial subsectors, improvement of energy efficiency, development of renewable and clean energy (e.g. hydropower, nuclear power, etc.), import of clean energy (e.g. crude oil and natural gas), and adoption of end-of-pipe technologies (e.g. flue gas desulfurization). It should be noted that the BAU scenario is not a static scenario.

Enhanced Environmental Scenario I presumes that barriers for implementation of packages of recommended energy policies still exist to a certain extent and thus the behavior of consumers/producers is affected by market imperfection. As a result, some of above mitigation options were included at an appropriate and realistic penetration rates for the market with considerations of market imperfection.

Enhanced Environmental Scenario II assumes that suggested policies are pursued under well-established market mechanisms, and correspondingly, consumers/producers not only choose the mitigation options with full knowledge of the future profile of costs and benefits, but also implement them instantaneously. Therefore, all of above mitigation options were included at maximum penetration rates.

Seen from the viewpoint of environment, BAU and scenario II respectively represent environmental implications for the energy system over the time horizon with pessimistic and optimistic extremes, while scenario I does the most “likely” situation. Furthermore, BAU and enhanced II are marginal scenarios with the minimum and maximum environmental loadings. A range of scenarios can be potentially realized between these two scenarios.

MACRO-PARAMETERS

Even if the energy intensity (energy consumption per GNP) decreases greatly by 2020, China's continued economic growth will also trigger off a marked growth of pollutant emissions. Under the BAU scenario and two enhanced environmental scenarios developed by the study team, China's economic growth rate during the nineties would be 9.0 percent, 7.5 percent dring 2000-10 and 6.0 percent from 2010 onwards till the terminal year of the study. Correspondingly, the annual energy conservation rate would be 4.34 percent, 4.0 percent and 3.48 percent respectively. Hence, energy consumption elasticity is estimated at 0.47, 0.43 and 0.40 respectively. Moreover, in the industrial structure, the share of the secondary industry is slightly decreased, while the share of the tertiary or service sector is expected to increase sharply, largely offseting a fall in agriculture contribution to GNP. Additionally, China will continue to adopt policies for family planning and the total population would be controlled at 1.45 billion by 2020. (See Table 1).

Table 1 Table of Macro-Parameter

Year	1990	2000	2010	2020
Economic growth rate, %	9.0	7.5	6.0	
First industrial share, %	28.4	18.4	12.2	8.7
Secondary industrial share, %	44.3	45.2	43.3	41.0
Tertiary industrial share, %	27.3	36.4	44.4	50.3
Population, billion	1.143	1.294	1.390	1.450
Population growth rate, %	1.25	0.72	0.42	
Coefficient of elasticity of energy demand	0.47	0.43	0.40	
Energy saving rate, %	4.34	4.00	3.48	

Prior to the implementation of this study, the Asian Development Bank (ADB) and the Global Environment Facility (GEF) provided financial support for two similar research projects conducted in China, that is "***National Response Strategy for Global Climate Change: People's Republic of China***" (or the ADB project for short) and "***China: Issues and Options in Greenhouse Gas Emissions Control***", (or the GEF project for short). The macro-parameters for this study differ slightly from the two projects in terms of the economic growth rate and the energy consumption elasticity. The economic growth rate for this study is identificated in accordance with economic growth target of the Eighth Five-Year Plan from the Economic and Social Development, while the energy consumption elasticity is addressed in the light of expert judgement based on the actual statistical data from late eighties to the present.

On 25-28, September 1995, an important document titled Suggestions for the Ninth Five-Year Plan for Economic and Social Development and the long-term plan for 2010: China was passed in the Fifth Session of Fourteenth National Congress of the Communist Party. This document predicted that by the year 2000, GNP per capita should quadruple from that of 1980, subject to an increase in population of 300 million, and economic growth rate during Ninth Five-Year plan should be controlled by approximately 8%. Also, by 2010, GNP should double that of 2000, and thus the economic growth rate should fall into the range of 7-8%. Shifting from conventional planned economic system to a market based economic system with emphasis on socialism and shifting to an intensive economic growth mode, which are of overall significance, are critical to ensure the realization of the targets stipulated in this document. Of course, shifting of economic growth mode would rely on reforming the economic system to formulate enterprise orientation system which is favored to save resources, decrease consumption and increase benefits.

SCENARIO COMPARISONS

What would happen under the BAU scenario with regard to pollutant emissions? By 2020 the emission of various pollutants arising from the use of fossil fuel will grow enormously in China. The emission of SO_2 will grow from 16.23 million tons in 1990 to 35.52 million tons by 2020, registering an average annual growth rate of more than 60 thousand tons; the emission of smoke dust will be up from 11.44 million tons to 29.63

million tons, showing an average annual rise of more than 60 thousand tons; the emission of CO_2 will jump from 650 million tons to 1.64 billion tons of carbon equivalent, an average annual rise of 33.12 million tons of carbon equivalent. Emissions of NOx and CO will also be doubled and redoubled.

What could happen under two enhanced environmental scenarios, compared with the BAU scenario?

- *Changing mix of primary energy supply:* In scenario I, by 2020, the proportion of coal would decrease from 64% in BAU to 59.83%, correspondingly, the share of hydropower would increase from 6.95% in BAU to 8.36% and nuclear power from 2.61% in BAU to 4.30%. In scenario II, by 2020, the proportion of coal would decrease from 64% in BAU to 55.1%, correspondingly, the share of hydropower would increase from 6.95% in BAU to 9.49% and nuclear power from 2.61% in BAU to 7.28%.
- *Reducing the supplies of primary energy:* Enhanced environmental scenario I and II would reduce the supplies of primary energy, in which coal supplies greatly decrease while hydropower, nuclear power and biomass energy increase.
- *Mitigating emissions of various pollutants*: By 2000, SO_2 emissions will be 20.84 Mt in scenario I which is less by about 2.96 Mt than that of BAU scenario. This figure has reached the objective with regard to SO_2 emissions set by the Chinese government. Starting from 2010, although the energy consumption grows, SO_2 emission will basically be stabilized within the range of 25-26Mt. SO_2 emissions in scenario II will be 20.45 Mt in 2000 which is less by about 3.35 Mt than that in BAU scenario, and also meeting the objective of SO_2 emissions set by Chinese government. Over the coming 20 years, in spite of the increase in energy consumption, SO_2 emissions starts decreasing from 2010. (See Fig. 2). The reduction on smoke dust, NO_x and CO_2 are also obvious in enhanced scenarios.

Since any scenario between the BAU and scenario I is possible, SO_2 emissions from the entire energy system over time horizon would fall into a range of 20.45-23.80 Mt in 2000, 23.52-31.09 Mt in 2010 and 22.74-35.52 Mt in 2020. Of course, other pollutant emissions would also have a range which is seen in Table 5-3.

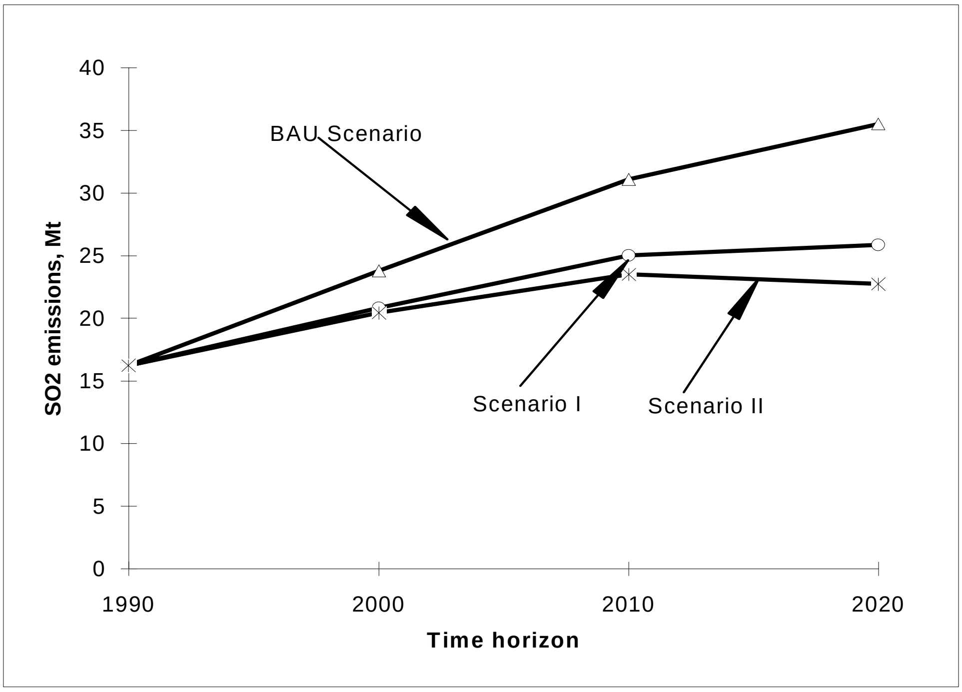


Figure 2 SO_2 emissions (million tons) under various scenarios

SPECIFIC MITIGATION OPTIONS FOR POLLUTANT EMISSIONS

The research findings indicate that on the one hand, the pollutant emissions arising from production and consumption of fossil fuel in China is the highest in the world; on the other hand, there is still a great potential for reducing pollutant emissions. Counter measures for mitigating pollutant emission should be addressed from a long-term point of view, efforts should be made to improve China's primary energy production mix and reduce the share of coal by developing hydropower and nuclear power in a big way and expanding the imports of oil and natural gas. This is the only way to fundamentally solve environmental issues arising from energy production and consumption in China. The most realistic way is to adopt advanced technologies, improve energy utilization efficiency, reduce energy consumption per unit of production, and popularize traditionally clean coal technology and techniques.

Cost/effectiveness analysis: To screen and identify candidate mitigation options for pollutant emissions, using a common metric, i.e. the cost per ton pollutant emissions reduced or avoided. Owing to the fact that mitigation options are focused on emissions of sulfur dioxide and carbon dioxide, the study steam calculated the incremental cost of candidate mitigation options, and the cost per ton of sulfur dioxide emissions reduced or avoided, as opposed to apportioning the incremental cost by various pollutant emissions, though an option can simultaneously mitigate various pollutant emissions.

Improvement of energy efficiency: In addition to the indirect energy savings brought about by adjusting the industrial structure, there exists substantial potential for direct energy saving. By reviewing some mitigation options to be included in Business-

As-Usual scenario, in the enhanced scenario, following measures have been employed to promote direct energy saving and enhance energy efficiency:

(1). Shifting of high quality coal from utility to industrial boilers in urban areas. The cost per ton SO_2 emissions reduced is 117 Yuan.
(2). Switching from raw coal to washed coal for industrial boilers and by enlarging steam coal washing capacity. The cost per ton SO_2 emissions reduced is 400 Yuan.
(3). Switching from raw coal to sulfur fixed briquettes for industrial boilers with small capacity. The cost per ton SO_2 emissions reduced is 1600 Yuan.
(4). Expediting commercial application of advanced clean coal technology for electricity generation, including Flue Gas Desulfurization (FGD), Integrated Gasification Combined Cycle (IGCC) Combustion, Pressurized Fluided Bed Combustion (PFBC). The cost per ton SO_2 emissions reduced of FGD, IGCC and PFBC is 1196, 2126 and 3326Yuan respectively.
(5). Improving energy-efficiency of honeycomb briquette stoves. The cost per ton SO_2 emissions reduced is 572 Yuan.
(6). Energy-efficiency improvement in existing buildings of the residential sector. The cost per ton SO_2 emissions reduced is 2134Yuan.
(7). Improving energy efficiency of biomass-saving stoves.

Alternative energy: Over the study period, it is impossible to realize the substitution of coal with low carbon fuels by merely relying on the market forces in China. A long-term programme with a clear target through governmental and international co-operation for technical development must be utilized. Following major measures will be used to replace coal and reduce the emission of SO_2 and other pollutants:
(1) To accelerate exploitation of hydropower and realizing the substitution of coal-fired power. The cost per ton SO_2 emissions avoided is 6875 Yuan.
(2) Develop indigenously key components for nuclear power, and promote nuclear power in a big way. The cost per ton SO_2 emissions avoided is 11806 Yuan.
(3) Substituting raw coal with biomass

BENEFITS AND COSTS

The net added cost to realize enhanced environmental scenarios I and II respectively amount to 64 and 110 billion Yuan RMB, and the benefit/cost ratio for scenarios I and II are respectively 0.750 and 0.732. The ratio implies that the benefits incurred in enhanced scenarios are insufficient to justify the added cost. However, two important benefits are excluded in two enhanced environmental scenarios. The first is external environmental cost that are difficult to quantify in monetary terms. For example, reductions of pollutant emissions would bring about environmental benefits, subject to the realization of enhanced scenarios. Unfortunately, the environmental benefits can only be presented in physical units, as opposed to monetary units, based on current domestic research accomplishments. The second is energy saved in transportation cost due to LEAP software specific imperfection. For instance, under the realization of enhanced scenarios, approximately**??** millions of coal are avoided and coal through washing will decrease ash in coal, thus reducing transportation costs. However, such benefits are not embodied in the cost benefit analysis.

Additionally, the levelized cost per ton SO_2 emissions reduced or avoided is respectively 1440 Yuan/t and 1520 Yuan/t, subject to the realization of enhanced environmental scenarios I and II. The figures are somewhat higher than 1200 Yuan/t which is the cost per ton SO_2 reduced with FGD. However, it should be noted that SO_2 emissions reduction is by no means a unique objective to the project. Moreover, the net added cost for two enhanced scenarios should be shared by emissions reductions of SO_2, CO_2, NO_x, PM, etc. as opposed to the emissions reductions of SO_2 alone.

POLICY RECOMMENDATIONS

Based on its extensive analysis, the project study team has concluded that the following policy recommendations are very important in changing the present patterns of energy production and consumption, and establishing an energy system which is environment friendly and in tune with the strategy for sustainable development:

(1)Improving primary energy production mix by increasing the share of clean energy
(2)Promoting clean coal technology in energy production and consumption
(3)Further improving energy efficiency
(4)Establishing an integrated energy-environment planning system
(5)Strengthening international cooperation and transfer of technology
(6)Environmental instruments to ensure the implementation of packages of energy policies recommended

Improving Primary Energy Supply Mix by Increasing the Share of Clean Energy

To incorporate environmental considerations in energy planning, improving primary energy supply mix (decreasing coal share and increasing clean energy share) is very important. Notwithstanding the fact that the share of coal in the primary energy supply is expected to gradually decrease under current official policies, the negative impacts from entire energy system on environment in term of pollutant emissions gradually increase. Therefore, further not only there exists potential for lowering the share of coal in the primary energy supply but is also necessary. By reviewing current official energy policies on the improvement of primary mix, the following policies are recommended: accelerating development of hydropower, further expanding both exploitation and import of oil and natural gas, moderately speeding up the development of nuclear power, utilizing biomass energy efficiently and increasing the reliance on new energy sources in line with local conditions.

1. Accelerating the development of hydropower.

(1) Technical and economic assessment for hydropower engineering projects should be made in a composite and scientific way. While assessing investments for hydropower and thermal power projects, we should take into account the entire costs for the construction of supporting facilities such as coal mine, railway and harbour construction. According to the findings by a domestic study team, if investments consider the construction capital of supporting facilities, then the amount of investments made for hydropower and thermal power projects differs only slightly. Additionally, the investment for end-of-pipe facilities, such as electrostatic precipitators, desulfurization devices and Nox control, should be included in the construction investment for thermal power, while hydropower possesses not only environmental benefits (no pollutant

emission) but also social benefits, such as irrigation and anti-flood. Therefore, incorporation of above considerations in the comparison and trade-off between coal-fired power and hydropower, the rationale for developing hydropower is more obvious.

(2) The state should favour investments in hydropower projects. The reform orientation shows that investments for hydropower will be mainly made by enterprises. However, at present, policy-related investments listed by the state should be used for the development of hydropower projects by the state. Hydropower projects are mainly constructed with investments made by local governments. Because hydropower projects are mainly constructed in economically underdeveloped regions, while thermal power projects are mainly constructed in economically developed regions, the state should gradually increase its investments for hydropower projects. Simultaneously, the state should reduce the interest rate for hydropower projects so that hydropower projects can enjoy 30 percent reduction of the fixed loan interest rate for the development of primary energy. The terms of loan redemption shall be appropriately extended so as to support the enthusiasm of local governments for constructing small and medium-sized hydropower stations.

(3) Establishment of a revolving fund for hydropower construction. A part of profits from nationwide sale of electricity from hydropower should be retained as the revolving fund which could be used as the main investment for the exploitation of hydropower in the western parts of the country.

(4) Adjusting hydropower electricity price and sharing of investment cost. With the decontrol of coal and oil prices, prices of hydropower should also be readjusted in line with the principle of equal value for hydropower and thermal power in the economy. Electricity price for hydropower stations that have been constructed should be raised and the practice of calculating peak-valley and full-low electricity prices should be implemented. Investments and costs for hydropower projects with comprehensive efficiency will be shared so as to promote hydropower development and comprehensive utilization of river and lake resources.

2. Further expanding both exploitation and importation of oil and natural gas

(1) Vigorously strengthen geological exploration of oil and gas resources and put an end to the unfavourable situation of irrational ratio between exploitation and storage. While making investments in oil industry in the future, the investment proportion for the exploration of oilfields should be raised annually. Investments for exploratory wells should be higher than that for development wells so as to ensure reserves required for the exploration of oilfields. Special attention should be paid to the exploration and development of natural gas resources. Increase in the reserves of natural gas and its development and utilization have made rapid progress among various energy resources abroad. Because great risks are involved in exploration and control of natural gas, the state should adopt preferential policies and support a faster exploration and development of natural gas.

Funds for the exploration of oil resources should be enhanced. China has since 1988 started implementing the practice of using reserves with compensation. All the funds are used for the exploration of resources. In 1988, a levy of five yuan on using the reserve with compensation for each ton of crude oil was made. The figure jumped to 25 yuan in the following year and will be gradually raised in the future. The charge for the use of oil and gas reserves with compensation is, in principle, equal or higher than the actual exploratory cost of oil and gas so as to increase self-accumulation and the ability for development.

(2) Increase import of oil and natural gas. The coastal economically developed regions should expand their import of oil and natural gas from their neighbouring countries by making use of their favourable marine transportation conditions. In view of the fact that old oilfields in the eastern parts of the country are at the degenerating stage, exploitation cost will become increasingly high. With regard to the exploitation of oilfields in the western parts of the country, the cost of marketing cannot be reduced because of long transportation distances. Under the circumstances in which domestic oil prices are close to world oil prices, the advantages of two resources and two markets should be fully utilized. Co-operation and exchanges with other countries will be expanded and import of oil and natural gas should be raised. The state should adjust the energy import and export policy in a macro-economic way, decontrol restrictions on the import of oil and natural gas, reduce customs duties and tax rates, import value-added products so as to encourage coastal regions to actively import oil and natural gas and substitute the energy structure centered on coal. In order to maintain stable oil import resources, it is necessary to link long-term trading contracts with foreign oil exporters. China will directly invest in foreign oil exporting regions and encourage foreign oil exporters to invest in China for the processing of crude oil.

(3) Update the existing oil and gas management system and establish a number of integrated group corporations with competitive mechanisms. The oil industry is currently a sector with the highest planned management element among the energy sector and its management system is still bound by administrative controls. Its price, output, distribution and mandatory plan are closely linked. The oil enterprises have no rights to sales and foreign trade. And, what is more, at both higher and lower levels, domestic and foreign trade are mechanically separated. Oil exploration and processing are, fundamentally speaking, conducted as a business without competition. A number of integrated group corporations with abundant manpower, financial and material resources and integration of higher and lower levels and domestic and foreign trade should be established in accordance with the requirement of the market economic system so that various oil corporations compete with each other for the exploration and development of oil and gas. The government should only make macro regulation and control and offer policy guidance for oil enterprises.

3. Moderately speeding up the development of nuclear power.

(1) Preferential policies of the state. The state should give financial and policy support to the research work for Chinese-made 300 MW and 600 MW nuclear power equipment and enable it to attain commercialization and batch manufacturing as quickly as possible. Simultaneously, advanced nuclear fuel concentration technique, GW grade pressurized water reactor and 600 MW pressurized water reactor techniques should be developed and manufactured expeditiously.

(2) Actively introduce foreign capital and equipment and construct large nuclear power stations. In the coastal areas, where energy is in short supply and the economy has made rapid progress, utilization of foreign capital will be increased and nuclear power

stations of larger unit sizes will be constructed so as to reduce per unit investment cost and operational expenses.

4. Efficiently utilizing biomass energy and increasing the reliance on new energy resources.

(1) Top priority should be given to the development of biomass energy and new sources of energy in the state's energy development strategy. Proper financial and preferential tax measures and economic means should be taken to increase investments for the development of biomass energy and new sources of energy and also encourage local governments and users to implement projects at the local level.

(2) It is necessary to increase research and development of utilization techniques for biomass energy and new sources of energy, reduce as far as possible investment and operational expenses and raise the thermal utilization efficiency so as to popularize and use them at an early date and on a large scale.

Promoting clean coal technology in the process of energy production and consumption

1. Boosting the use of clean coal by actively promoting conventional coal cleaning techniques such as coal washing, screening, sorting and briquetting

Notwithstanding that China has abundant coal resources, the coal reserves are unevenly distributed. Moreover, the average quality of coal is comparatively both low and limited. Coal will continue to be the main energy source in China well into the future. Promotion of the conventional technique of coal washing, screening, sorting and coal briquetting is the most economical and realistic way for China to solve environmental pollution caused by coal.

(1) Prices for coal will be brought into better balance and policy to reflect prices for quality will be implemented. The reform target for coal prices is determined by relations between supply and demand in the market. At present, the state controls coal prices so as to gradually form the supply price mechanism centered on requirement. The coal price policy of the state is to fix prices in line with the usage of fuel. Coal-fired equipment is roughly divided into four categories: power station boilers, industrial boilers, industrial kilns and stoves for civilian use. Different coal qualities are required for different types of equipment. The state will define the standard and base scope of the coal quality for different usages, allow the coal market to trade coal within the scope of the base price in accordance with relations between supply and demand on the market and ensure the policy of favourable prices for good quality.

(2) Construction of coal mines shall be planned in an integrated manner and commissioned simultaneously with the construction of washing and processing projects. When examining and approving the feasibility reports for coal mines, the state should include the construction of coal washing and processing projects as an indispensable single project for the construction of coal mines. The project should be implemented simultaneously with the construction of coal mines. The environmental protection department should regard the washing and processing of coal as the environmental engineering devices and strengthen its supervision. Production mines where the washing and processing devices have not been installed should install the same in a planned manner, within a definite time frame.

(3) Administrative means will be adopted and transportation and sale of low and inferior quality coal will be strictly forbidden for which the state should make administrative stipulations. Low and inferior coal should be washed and processed at the mines. Low and inferior quality coal which has not been washed should not be allowed to be transported. Inferior quality coal should also not be allowed for use in key cities for environmental reasons. The Chongqing municipal government in China has adopted administrative and economic measures to restrict the sale and use of coal with a high sulphur content. A fine of ten yuan per ton is charged for units that sell coal with more than 25% sulphur, while five yuan is the fine on users for purchasing one ton of coal with a high sulphur content.

(4) The State Development Bank will finance coal mines to construct washing and processing equipment and grant loans on preferential terms.

(5) Scientific research for tackling the problem of coal for industrial purposes will be strengthened, and costs reduced. The state will grant tax reduction and exemption so as to encourage popularization and utilization of industrial coal.

2. Accelerating the development of modern clean coal technologies.

Coal dominates in the fuel share of thermal power and is the major source of air pollution and high pollutant loadings. Also, the current official policies encourage faster development of coal fired power stations. Therefore, the development of modern clean coal technologies needs to be accelerated to reduce the pressure on environment from coal-fired power stations. Some recommended policies which are critical to ensure the acceleration of the development of modern clean coal technologies are discussed below.

(1) Introduce foreign advanced demonstration devices through expanded international cooperation.

Although China has mastered some key techniques of PFBC-CC power generation, some problems and difficulties remain unsolved. IGCC power generation technology is still at the research stage. In order to speed up the research process, it is necessary to introduce advanced demonstration projects, including the establishment of 150 MW PFBC-CC commercial demonstration power stations and 200 MW large demonstration power stations, through strengthening of international cooperation, and research & development.

(2) Absorption and assimilation of new technologoes with increased indigenisation efforts and commercialization

China has introduced a dozen or so oil and gas combined cycle power generating units whose efficiency is satisfactory. However, investments for these units are high. Thus, in order to introduce demonstration projects, it is necessary to organize technical expertise for absorption and assimilation of these demonstration projects and gradually increase their indigenous content. Only then can be the investments be reduced and these projects popularized throughout the country.

Further improving energy efficiency

Per capita energy consumption in China is relatively low and the gap between energy demand and supply is likely to continue into the long term time frame. Hence, the strategy for economic development in China must be based on resource conservation through improving energy efficency. Also, this strategy will result in reduced air pollution. A review of pro-environmental measurements to be adopted in BAU indicates that the following measures should be given importance in implementation.

1. Energy-efficiency improvement in past buildings of the residential sector

Improving building thermal efficiency is a major step in saving space conditioning energy use. Thus, Energy-Efficiency Design Standards for Residential Building in Heating Zone explicitly states that newly constructed buildings must adopt energy-saving measures. The China Agenda 21 stipulates energy-efficient building standards, i.e. in the first step, to reduce space-heating fuel intensity of new buildings to a level that is 30% less than their 1981 values by 1990; in the second step, to further reduce space-heating energy intensity of new buildings to the level that would be 30% lower by 2000. Unfortunately, buildings constructed in the past, when retrofitted, have failed to adopt this energy-saving standards and are continuing to perform poorly in this regard due to inadequate regulatory enforcement, insufficient technical support, temporary financial constraints, and the pressure of soaring housing demand. The experiences of developed countries shows that realization of energy conservation would be limited if energy efficiency measures were taken on new construction alone because the stock of older buildings are by far much larger than annual new constructions. Thus, efforts are made to promote energy-efficiency measures in existing buildings, while ensuring energy-saving measures on new construction. The followings are recommendations to execute energy-efficiency improvement in existing buildings in the residential sector.

(1) To carry out retrofit of energy-saving measures in existing buildings with heating and air-conditioning in a planned way. A plan for energy saving shall be formulated, funds allocated, and efficient urban central heating expedited to replace scattered small boiler heating, thereby improving energy utilization ratios.

(2) To use economic measures to encourage the adoption of heat-insulated building materials. For example, the production of clay bricks of poor property of thermal insulation should be restricted, or higher taxes levied on them, while taxes should be reduced or exempted or preferential loans granted to building materials with good thermal insulation. This not only can save energy in buildings, but also helps reduce destruction of the land.

(3) To strengthen scientific-technological development of energy saving in buildings. Though design standards have been formulated, they cannot be implemented due to several reasons, and in particular because the technologies available cannot come upto standards specified. Therefore, technical know-how of various departments should be organized to strengthen research on key technologies such as energy savings in buildings and utilization of solar energy. The state should support them in terms of funding for research, and international cooperation should be intensified, foreign technologies for energy saving materials and equipment should be imported, indigenised and absorbed, while the dissemination work of energy saving building materials and technologies should becarried out simultaneously.

2. Propogate commercially manufactured biomass-saving stoves.

The firewood and coal economizing cooking stoves can save fuel and are also convenient for use. Their average thermal efficiency exceeds 25 percent, which saves fuel by more than one-third in comparison to the traditional cooking stoves. These can effectively save energy and improve the environment. Therefore, the Chinese government has taken up continuing to popularize the firewood and coal economizing cooking stoves of high thermal efficiency ' as a basic industrial policy in the energy industry. To speed up the commercial production of firewood and coal economizing cooking stoves, the state should give support in terms of reduced taxes and loan, so that the production cost and hence, the price of commercial cooking stoves can be controlled, thus facilitating the substitution of manually built ones. To improve the service life of the firewood and coal economizing cooking stoves, it is necessary to organize scientific research to tackle key problems, so that the service life of these stoves can reach the design requirement.

3. Improving energy-efficiency of honeycomb briquette stoves

As the manufacture and use of honeycomb is financially attractive, the stoves are common in urban areas and further expanded to rural areas. However, the current efficiency of honeycomb briquette stoves is about 25-30% which is 10% higher as compared to traditional raw coal stoves. Even so, this is only equivalent to the level of efficiency in the 1930s abroad. Relatively simple squeezing technology to manufacture honeycomb briquette, together with backward stoves has resulted in efficiency being at standstill. In view of their large scale applications, some domestic experts are studying the sulfur fixed honeycomb briquette and high efficiency stoves. The pilot results show that over 10% efficiency can be gained if existing stoves are replaced with laboratory ones. As a result, realization of efficiency and environmental gains through such substitution is sufficient to justify the increased price for consumers.

(1) The state should provide funds to support the research on sulfur fixed honeycomb briquette and high efficiency stoves in order that the technology matures as soon as possible.

(2) The state should work out dissemination program for the technology. Also, the state should provide favourable taxes and loans for enterprises which manufacture and sell sulfur fixed honeycomb briquette and high efficient stoves for promoting them into commercial application as soon as possible.

Establishing an integrated energy-environment planning system

An integrated energy plan will consider all environmental factors and identify the least cost option for implementation. This then can be implemented by adopting uniform standards to assess the effects of management policy for energy supply and demand and measures for environmental protection. This would facilitate an overall analysis and study of problems in the field of energy, environment and economy, thereby achieving a unified coordination and balance among energy, environment and economic development. Therefore, in order to realize an energy scenario that emphasizes environment, besides adjustment of the existing energy policies, there is an urgent need to establish an integrated energy plan that would fit into the socialist market economic system.

(1) There is a need to work out and establish a methodology of an integrated energy plan that conforms to the situation in China and the requirements of the market economics and an indicator system for the assessment of energy, environment and

economy, and bring the costs of environmental damage and resource compensation into the cost of production of energy.

(2) There is a need to strengthen the organizational structure in the energy sector. An integrated energy plan for the environment and economy is a trans-sectoral plan and thus the need to strengthen the organizational structure that can formulate the energy plan and also coordinate the development plans between the state and regions. There are two options: the first one is that the Environmental Protection Commission under the State Council will participate in and carry out coordination required. The energy sector will formulate the integrated energy plan that incorporates environmental factors, and which will be examined by the Environmental Protection Commission and approval for implementation given by the State Council; the second option is to set up a special-purpose institution for which the stafff are drawn from the energy and environmental sectors which would prepare the integrated energy plan for implementation.

Strengthening international cooperation and transfer of technology

There are two key problems in implementing the enhanced environmental scenario: The first is finances, and the second relates to technology. The enhanced scenario I requires a net additional cost of 2.1 billion yuan (in 1990 prices) per annum on the base investment made by the energy sector. The enhanced scenario II requires a net additional cost of 3.7 billion yuan annually. Such a huge investment is a problem for China where capital is in short supply. Since its reform and opening up, China has made remarkable progress in utilizing foreign loans and in attracting direct foreign investment in the energy sector. In the implementation of enhanced environmental scenario, in addition to actively utilizing domestic funds, China should attract more extensive participation and support from all international sources and strive for various bilateral and multi-lateral international aid funds, while encouraging inputs in and cooperative exploitation of energy. Continued and expanded support from international agencies is also required to implement the technical options for SO_2 reduction outlined above, such as energy efficiency improvements, alternative energy technologies, and modern clean coal technologies. In addition, the Chinese government should seek to ensure that only energy efficient technologies and processes are brought into the country.

Environmental instruments to ensure implementation of recommended energy policy package

1. Legal Measures

●The state should formulate standards for isentropic sulphur and ash content in coal to improve coal quality.

●The National Environmental Protection Agency should, jointly with departments concerned determine the standards for acid rain control areas and SO_2 pollution control according to the stipulations of "Law on Air Pollution".

●The state and local environmental protection departments should, jointly with the state and local fuel departments, formulate specific measures for use of formed coal according to the stipulations of “Law on Air Pollution” which would ensure that domestic stoves use formed coal instead of direct combustion of raw coal.

2 Economic Measures

●Implementing “pollution levy fee system”

①To rationalize pollution charges. According to the principle of “polluters should pay”, besides the costs for pollution discharge of those whose discharge quantity exceeds standard limits, normal “pollution discharge fee” shall be charged, and the charge shall be marginally higher than the cost of bringing pollution under control. This will be beneficial for promoting the initiative of enterprises to bring pollution under control.

②To direct the utilization of the pollution discharge fee. Granting subsidies to enterprises to control pollution shall be stopped, and the pollution discharge fees received shall be put unto a fund and used for control of pollution.

③To expand the range of pollutants to be charged. Besides the current charge for smoke dust generated by coal combustion, charges for SO_2 emission shall be added.

④The pace of experimental work of charge for SO_2 pollution discharge in two provinces (Guizhou and Guangdong) and nine cities (Chongqing of Sichuan, Hangzhou of Zhejiang, Yichang of Hubei, Qingdao of Shandong, Changsha of Hunan, and Nanchang of Jiangxi) shall be expedited, and experiences studies, thereby creating conditions in the whole country for carrying out the charges for SO_2 pollution discharge.

●To establish the system of levying “environmental resource compensation” and CO_2 taxes.

The levy on “environmental resource compensation” and CO_2 taxes is of significant importance for the expansion of channels for environmental protection investment and to the prevention of environmental pollution. Efforts should be made to establish a whole set of effective system of levying "environmental resource compensation" and CO_2 taxes within a 3-5 year time frame.

3. Administrative measures

●Perfection of “environmetal impact assessment”system

①“Environmental impact assessment” should be extended to include assessment for energy related departments and the state’s economic policies. For instance, prior to the publication of industrial energy policies formulated by the state, local governments and industries, the views of the environmental protection department should be solicited for “environmental assessment” so as to identify measures for controlling environmental problems brought about by improper economic and energy development;

②"Environmental impact assessment" should be conducted for the various projects at the design stage so as to enable the environmental protection department to audit the designed projects from raw material sampling (fuel), technology choice and whether products to be produced conform to the legal stipulations and clean production requirements in accordance with relevant laws and regulations of environmental protection.

③ If, after “environmental assessment”, it is found that issues are still not up to the requirement of environmental protection, an analysis will be carried out to fix responsibility (including personnel engaged in "environmental assessment"). Liability shall be pursued in accordance with law and fines levied. Simultaneously, remedial measures will be taken so as to attain the levels for environmental protection.

●To adopt a time bound plan for limiting environmental emissions

①The task of controlling pollution projects within a definite time by the government shall be assigned to the environmental protection departments so as to simplify the procedures and enhance management efficiency.

②Supporting measures for the control and elimination of pollution within a definite time should be intensified. Enterprises shall be requried to adopt recovery and utilization measures to limit environmental impacts. Again, some coal-fired boilers, kilns and large stoves whose smoke dust exceeds the standard shall be required to use washed coal, honeycomb coal briquettes or other clean fuels. Those who do not adopt measures for controlling and eliminating the pollution sources will pay for excessive discharge of pollutants by 100 percent.

③If the polluters fail to control and eliminate pollution by the deadline as required, or have adopted the above-mentioned measures, but still cannot meet the prescribed local standards for pollution discharge, they shall be ordered to close down, suspend, merge with other enterprises, change their lines of products, or move to other locations.

4. Education and training

●On-the-job education and training for officials of the energy sector

①In order to enable the decision makers and planners to foster increased awareness for environment, energy savings, a comprehensive training and education plan will be undertaken.

②It is necessary to draw up training programmes for those who are engaged in energy planning and management to enable them to meet the requirements under the new energy scenarios.

③There is also an urgent need to make energy and environmental education universal.

●Public Education on Energy and Environment

①We shall strengthen elementary education on energy and environment.
②We shall strengthen professional education on energy and environment.
③We shall popularize scientific knowledge of energy and environment.

The environmental department should also participate in the preparation of the integrated energy plan, that includes environmental factos as well, jointly with the energy sector and related economic departments. This will enable a better understanding and appreciation of the problems of environmental impact caused by energy production and consumption.

Chapter 1 Project Background and Objectives

1.1 Project background

Energy resources are crucial for socio-economic development. However, the process of exploiting and utilizing energy also increases the threat to the environment. The degradation of the environment at the local, regional and global levels caused by present patterns of energy production and use is an important issue of worldwide concern. Especially sulfur dioxide, nitrogen oxides, hydrocarbons and particulate matter released from the production and combustion of coal have been the main causes for urban air pollution. All these air pollutants not only create serious health hazards for people, but also damage the infrastructure and buildings. Sulfur dioxide in particular is the main precursor of 'acid rain', and inflicts substantial damage to soils, forests and lakes in several regions. It is generally accepted that carbon dioxide released from fossil fuel combustion is the main contributor to the greenhouse effect, and measures have to be taken to limit future emissions in the energy sectors worldwide.

China is a developing country with approximately one fifth of the world's population. In 1990, the production of primary energy exceeded 1,080 Mtce with a growth rate of 3-4% annually. The annual coal consumption is about 75% of the total primary energy consumed in the country. Although these figures only lead to a very modest consumption per capita, they cause great concern from an environmental point of view.

The concentrations of particulate matter and sulfur dioxide are already beyond the national ambient air standards in many cities. Acid rain is also recognized as an increasingly pressing problem in the southern part of China. All these facts are of great concern to the Chinese government and efforts are being undertaken to try to limit the emission of pollutants. With rapid economic development in China, however, the demand for energy, especially for coal, will continue to increase significantly.

On the global level, China ranks third in the world in terms of emission of carbon dioxide with an annual emission of approximate 680 million tons. With the stipulated growth in coal consumption, this will reinforce Chinese position as one of countries with the highest level of carbon dioxide emissions.

One line of action which was proposed and was strongly supported by the UNEP Governing Council at its 15th and 16th sessions is 1989 and 1991 is to promote, in developing countries, strategies for action which, while not slowing development, makes optimum use of energy production and consumption systems that are safe, affordable and efficient, and at the same time minimize the negative impacts on the environment.

1.2 Objectives

Long term objectives: Incorporation of environmental criteria into energy policy and planning in China, and to promote the production and utilisation of energy with minimum environmental impact.

Short-term objectives: To promote national and regional policy, reducing energy-related emissions of atmospheric pollutants, especially oxides of sulfur and nitrogen, particulate matter and carbon dioxide. To strengthen the national institutional capacity to formulate and implement energy strategies in selected regions. To enhance the policies for energy conservation efficiency and increase the use of renewable energy sources.

Chapter 2 Characteristics of Energy Use and Production

2.1 Energy Production

Coal production in China reached 1.08 billion tons in 1990, out of which, the amount of coal washed only was 179 million tons, or about 16% of the total coal production. In spite of 980 GW potential capacity of hydropower resources in China (which puts China in the first position in the world), China has only exploited 9.1% of the potential by 1990. It must however be pointed outthat the hydropower resources are concentrated in the region of south-west, north-west and central China.

Total hydropower capacity reached 36.046 GW at the end of 1990 while energy generation was 126.71 Twh. This accounted for 26.1% of the national installed capacity and 20.4% of the electricity generation, respectively.

Based on the assessment of China's oil-gas resources completed in 1987, the total petroleum resources stored in the continent and continental shelf are estimated at 78.75 billion tons and the total natural gas resources are placed at 33.3 trillion cubic meters. At present, the exploration for oil-gas in China reamins at the preliminary stage, with only parts of the reserves being proven and 85% of them concentrated geographically in eastern region lying north to the Yongtze River. China's crude oil production was 138.31 million tons in 1990 and 15.3 billion cubic meters for natural gas.

Biomass resources in China consist of three parts, i.e., crop residues which can be used as fuel, various kinds of trees which are cut down economically for fuelwood usage, and human and animal wastes as well as organic waste water which produce biogas. Production of crop residues in 1990 was estimated as 544 million tons, of which 295 million tons, equivalent to 143 Mtce, were used as fuel (53.3%). To date, the trees cut down economically provide 90 million tons of fuelwood each year. The amount of fuelwood burned directly was estimated at 215 Mt in 1990, equivalent to 123 Mtce.

Thus, it can be concluded that China possesses abundant energy resources and is relatively rich in various energy sources. At the same time, energy production per capita remains low and the distribution of energy is uneven.

With the rapid development of energy production, coal production had increased from 32 million tons in 1949 to 1.08 billion tons in 1990, crude oil from 12 to 138.31 million tons, natural gas from 7 to 15.3 billion cubic meters and power generation from 4.3 to 621.1 TWh. The total commercial energy production in 1990 was 1039.22 Mtce, ranking third in the world.

2.1 Energy Consumption

The share of consumption of energy in China from different energy sources is shown in Table 2-1.

Table 2-1   China's primary energy consumption and shares in 1990

	Total consumption (Mtce)	Coal (Mt)	Petroleum (Mt)	Natural gas (Billion m^3)	Hydropower (TWh)

Consumption	987.03	1055.23	114.86	148.0	1252.0
Share (%)	100	76.19	16.63	2.05	5.13

Source: China Energy Statistical Yearbook, 1991

Figure 2.1 depicts the status of energy consumption in various sectors in China. As shown in Figure 2.1, industrial and household sectors account for 68.48% and 16.01% respectively, while the other sectors account for a small share in total energy consumption.

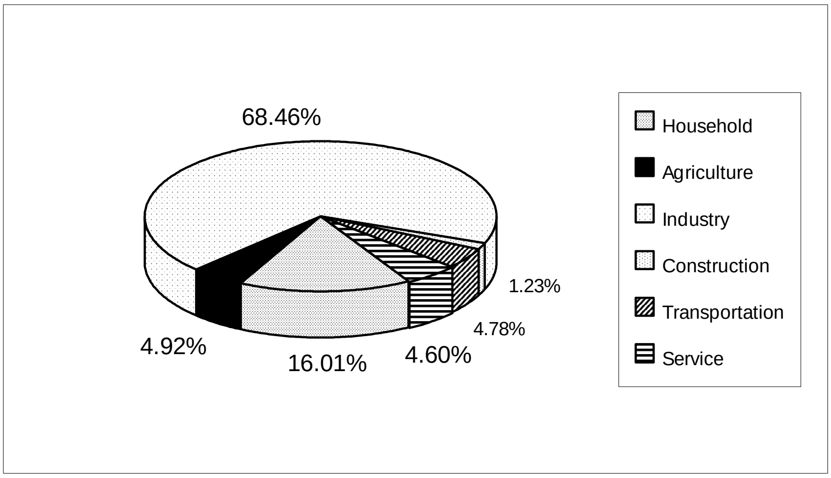


Figure 2.1 Energy consumption and composition by sector in 1990 (%)

Not only is China's energy consumption different from the developed countries', but there also exists a significant difference between China and the other developing countries as well. The notable characteristics of China's energy consumption are as follows,

----China relies on domestically produced energy for economic development. The ratio of self-sufficiency in energy in China reached 98 % in 1990. China imported 13.097 million tons coal equivalent, while 58.75 Mtce of energy was exported. Thus, China was a net exporter of energy equivalent to 45.653 Mtce, accounting for 4.6% of the total domestic consumption.

----China is one of the few countries in world where coal is the major energy source. In 1990, energy from coal accounted for 76% of the total primary energy consumption. China's coal dominated energy mix is facing a severe challenge, as a continuous increase coal production and consumption has put increased pressures on environment and transportation.

----Coal and other conventional energy sources are the major energy forms consumed for end use in China. The sectoral composition of energy consumption is shown in Table 2-2. Nearly 50% of the energy consumed in rural areas is from non-commercial energy and 80% of household energy is from biomass. Due to direct combustion of a large amount of coal and burning biomass inefficiently, not only is energy wasted, but the environment is polluted and ecological balance is disturbed.

Table 2-2 The composition of energy consumption for end use in various sectors (%)

Sector	Total	Coal	Coke	Gasoline	Diesel	Fuel oil	Gas*	Heat	Electric	Others
Total	100	46.23	6.74	2.83	3.79	2.96	1.92	2.55	24.87	8.11
Agriculture	100	33.05	1.20	4.43	26.47	0.08	0	0	34.66	0.11
Industry	100	40.10	9.69	1.28	1.30	3.73	2.17	3.10	28.41	10.22
Construct.	100	27.36	0.42	10.85	15.97	5.57	11.62	0.29	21.11	6.81
Transp.	100	36.06	0.09	20.09	22.76	6.55	0.56	0.04	9.19	4.66
Commerce	100	64.85	0.60	5.43	2.63	0.18	0	0.54	24.07	1.70
Non-subs.	100	42.68	0.05	16.65	9.11	0.66	0	1.41	22.97	6.56
Household	100	80.19	0	0	0	0	4.22	2.28	11.99	1.32

Note: * including natural gas, LPG and coal gas. *Source: China Energy Statistics Yearbook, 1991.*

---- Energy consumption per capita is quite modest, energy intensity for the economy is high. In 1990, per capita commercial energy consumption was only 864 kgce (equivalent to 40% of world average), while energy consumption of per million Yuan GNP was 926 tons coal equivalent, a figure much higher than that of the developed countries.

2.3 Environmental Impacts Related to Energy Use and Production

The negative impacts imposed on the environment through energy production, transportation and consumption are quite varied. Backward technologies and unreasonable patterns of energy development and use inevitably damage the eco-environment with different implications depending on the patterns of consumption and the different forms of energy sources as well.

In view of the coal dominated energy mix in China, pollution caused by coal exploitation and use necessarily constitutes the major energy related environmental issue in China, such as the surface collapse by coal exploitation, noise by coal production, gangue and slurry from coal-preparation plants, particulate and sulfur dioxide and so on from coal combustion, etc.

The surface collapse accompanying coal exploitation brings about the destruction of infrastructure and buildings, barren cultivated farmland and hence worsening the eco-systems. According to available statistics, area covered by the surface collapse has reached approximately 870 thousand hectares. With a general ratio of 20 hectares of farmlands collapsed per million ton coal mined, 4 thousand hectares each year are collapsed, since 200 mt coal is mined in the plain areas annually by China's State-owned Mine Corporation.

In general, mining equipment generates noise pollution, with features of high noise pollution level (NPL). In the operation of equipment, more than 70% noise generated is beyond 90 dB, 45% between 90-100 dB, and 25% between 100-130 dB.

From coal preparation, the annual output of by-product gangue fluctuates around 100 million tons, and the total gangue stacked has reached over 1.2 billion tons. As a result, not only is a great deal of farmland occupied, but severe pollution is also caused mainly due to self-combustion of gangue. According to available statistics, there are over 1200 gangue hills across China, among them, more than 110 hills are burning spontaneously. A large amount of sulfur dioxide, nitrogen oxides, carbon monoxide, and smoke dust emitted from self-combustion inevitably cause serious environmental problems, such as restraining plant expansion, corroding buildings, etc.

During the coal washing process, the waste water discharged, especially from floating washing, contaminates the water body nearby with excessive negative effects. For example, this causes decrease in crop production if used for irrigation, has negative impact on aqua-culture, if the drainage is into the river, and degrades drinking water quality by contaminating ground water. Although the main contributor to the contamination in coal mines is on account of suspended substances, its harmfulness can not be neglected because of the large quantities involved.

Direct combustion of raw coal brings about the serious atmospheric pollution, and as a consequence, air pollution in urban areas is coal-smoke type pollution caused by SO_2 and smoke dust. Coal consumption for electricity generation, steam supply in industry, and cooking and heating in households emits a large amount of sulfur dioxide, particulate matter, carbon dioxide, carbon monoxide and nitroge oxide, etc. polluting the atmosphere severely. In 1990, the emissions of smoke dust and sulfur dioxide were about 12 and 16 million tons, respectively, while up to 70% and 90% of them were from coal combustion. The large volume of sulfur dioxide emissions in particular, has turned into a major local environmental issue, such as acid precipitation which further creates material corrosion, eco-evironmental degradation, and impact on human health. It is estimated that, in 1990, 85% of carbon dioxide released from the burning of fossil fuel was due to coal combustion. In general, the level of air pollution in some cities in China by now has equalled that during 1950s and 1960s in the developed countries.

Hydropower is a renewable energy source. However, hydropower exploitation generally causes farmland flooding and population dispalcement due to the construction of storage dams which not only damages the eco-systems, but imposes threats to animal and plant habitats.

The extraction of oil and natural gas on-shore leads to soil erosion and contamination of ground water, while the extraction offshore also causes damages to the marine environment.

Excessive consumption of biomass energy, deforestation and failures in burning crop wastes in the fields for the next cropping cycle have resulted in soil erosion and decrease of organic substance in farmland. At present, the total area of soil erosion land in China has reached 150 million hectares and the average content of organic substance in China's farmland is less than 1.5%.

On the global level, China ranks third in the world in terms of emission of carbon dioxide with an annual emission of approximate 680 million tons of carbon equivalent. With the expected growth in coal consumption, this will reinforce Chinese position as one of countries with the highest level of emission of carbon dioxide.

In short, pollutant emissions caused by energy production and energy use are a great threat to the fragility of the eco-systems locally, regionally and on a global scale. The Chinese government and energy planners havae been focussing on energy related environmental issues. In recent years, a number of measures including legal, administrative, technological and economic have been taken to limit the emissions of pollutants, and significant achievements have been made in preventing and controlling pollution and improving the eco-environment.

2.4 Current national policies on energy

Traditional energy policies reflect the strategy of national economic development, concentrating purely on economic growth rate regardless of quality of life and related benefits. In such a development pattern, Chinese energy policies also pursue the growth of energy production in order to reduce the gap between energy supply and increasing demand with little attention to the ensuing negative impacts on the resources and environment. Undoubtedly, traditional energy policies has played a key role in developing the energy industry and fostered the growth of national economy in China. It has led to the establishment of a giant energy industry, improvement of primary energy mix from merely coal production to multiple energy production, perfection of laws and regulations on energy industry, and realizing energy conservation gains. However, it is undeniable that the traditional policies inherently possessed a weaknesses, such as overstressing the coal dominated primary energy mix, which creates low conversion efficiency of energy processing and negative impacts on eco-environment, seldom paying attention to environmental considerations in energy planning, distorting energy prices which reflect neither real costs of energy resources nor environmental resources correctly.

Since the middle of 1980s, with rapid growth in the national economy and concomitant expansion of energy production and consumption have imposed increasing pressure on China's resources and transport system. There is therefore a need to reform traditional energy policies and to develop routines that practice both exploitation and energy-saving with the latter being preferred. in a transition from planned economy to market economy, China is currently overhauling energy prices gradually so as to provide opportunities to the energy industry for development on the basis of fair competition in the market. Environmental protection actions, especially increasing international cooperation in the field of environment and development call for coordinated and balanced development of energy industry in terms of reasonable exploitation and consumption of resources and environmental protection. All these require changes in traditional energy policies and the formulation of new energy policies which could best incorporate sustainable development strategies.

China Agenda 21 has been approved by Chinese government and has become a guiding document for long-term planning for national economic and social development.

It provides China with sustainable development strategies and principles on energy production and use. In line with this document, the goal of energy policies should be to achieve sustainable development of the energy industry by coordinating and balancing energy production and use, economic growth, and environmental protection. In this document, new energy policies has been put forward, including: (1) comprehensive energy planning and management by establishing a set of methodologies for integrated energy, environmental and economic planning, strengthening the structure of energy management and the distribution of energy supply, accelerating the development of new energy sources and electrification in rural areas to prevent environmental degradation brought about by the excessive consumption of biological resources. (2) improving energy efficiency and energy conservation policies through implementing National Law on Energy Conservation . (3) Disseminating information on less polluting coal mining and clean coal technologies. (4) Development of new and renewable energy resources.

In response to the document, China put forward energy industry policies in 1994, which guide industrial development as well as measures to carry out sustainable development strategies. Important and specific energy policies are summarized as follows:

1. China's energy development principles. China plans to meet most of the country's future energy demand with indigenous resources and domestic markets, and also attempts to make full use of foreign resources and international markets in line with the principles that measures taken should be suitable to local conditions and multiple energy sources will complement one another. On the other hand, both developing and saving energy should be emphasized with priority for energy conservation. The ultimate target is to make energy resources, national economy and environmental protection develop in harmony.

2. Policies of developing energy resources. The energy industry should center on electric power, on the basis of coal. Adequate efforts should also be given to oil and natural gas development. At the same time, new and renewable energy sources should be developed actively in order to optimize the energy structure. In general, high-quality energy must be enhanced in energy supply.

① ***Coal***. Coal exploitation should be done under the coordination of the Central and local governments. Large, medium, as well as small sized coal mines can co-exist. Coal companies should be encouraged to run a diversified business with coal as a main component.

② ***Oil and natural gas***. Oil and natural gas resources should continue to be developed as before. Their exploration must be enhanced so as to find more reserves and increase their production. Meanwhile, China should also take part in exploration and exploitation of foreign oil and natural gas resources.

③ ***Electric power.*** The basic principles are: separating enterprise management from government administration, making a province an entity, interlinking electricity transmission networks and unifying management, and raising funds for more power stations. High priority should be given to hydropower first and thermal power next. However, nuclear power should also be developed. Hydropower development must cover large, medium as well as small sized stations so that they can distribute in a rolling manner and at all levels. Thermal power development should focus on setting up stations on gallery opening and a number of stations should be near harbors and main highways according to transport conditions. Nuclear power development should based mainly on indigenous development and also in cooperation with other countries.

④ ***New and renewable energy resources***. Measures should be suitable to local conditions; multiple energy resources should complement one another; energy resources should be used comprehensively; and benefits should be emphasized.

⑤ ***Coal bed methane.*** Coal bed methane should be tapped and explored under an unified plan. The short-term objective would be to undertake a pilot study on the gas tapping projects. Qualified gas resources should be given the first priority to be exploited on a vast scale.

3. Energy consumption policies. National economy will shift to energy-saving by optimizing the industrial structure, product structure, and energy consumption structure. Technology advances should be promoted to reduce energy loss and waste throughout the whole chain from production to its end-use and to improve energy efficiency. State should place constraints on industries and products consuming more energy from being located in energy deficient regions and encourage them to shift to the places near energy production centers.

4. Energy technology policies.

①***Coal industry.*** By the year 2000, large mines should reach international levels of 1980s, i.e. mechanizing coal extraction and tunneling, monitoring safety, automating coal transporting and lifting, and modernizing management. Medium and small sized mines are required to adopt comprehensive mining and advanced general mining technologies and to get to the technological levels of China's large sized mines in 1970s. Township mines should reach current technical levels of local State-run mining companies. Under unified planning, the order "extracting (coal bed gas) first and then mining (coal)" should be followed gradually.

②***Oil and natural gas industry.*** By the year 2000, the technology and equipment used by the oil and natural gas industry should be at or close to the advanced levels in the world. In order to get more efficient and successful in exploration, technologies of high-resolution digital seismic prospecting and oil reserve description should be at the advanced levels of the world.

③***Power industry.*** New thermal power plants should adopt units with large capacity, be efficient, and have peak modulation feature. Hydropower sector should study and master techniques of designing and constructing 300-meter high dam and underground plant buildings with high over-burden, long tunnel, and broad span. Large water turbine generators over 500,000 kw per unit should be developed. The equipment of pressurized-water reactor should be manufactured indigenously. By the year 2000, 600,000-kw reactors should be built at home and 1000,000-kw reactors studied.

5. Energy and environmental policies. Environmental protection should be stressed in the entire energy system. Environmental pollution should be prevented and treated simultaneously during exploitation of energy resources. State should encourage and support development and utilization of clean coal technologies to reduce environmental pollution derived from coal consumption.

6. Energy import and export policies. China should rely mainly on indigenous energy resources while taking fully advantages of foreign energy resources and international energy markets to adjust domestic market and balance the supply and demand of energy sources. Both imports and exports of energy is necessary for China's energy industry to progressively enter international energy markets.

①Crude petroleum is the first priority in oil import. Oil products must be constrained strictly. In accordance with domestic needs and possibility, a certain volume of liquefied petroleum gas, liquid and pipe-transmitting natural gas can be imported.

②In order to ensure oil supply, State should install facilities to store oil in a planned way and establish national oil storage system.

③ Coal industry should continue enlarging its share of international coal market and increase coal export. Some coal can be imported into southern coastal region in accordance with the demand.

Chapter 3. Methodology

3.1 Choice of Methodology

The two most common approaches for energy modeling are often referred to as "top-down" and "bottom-up" approaches. The "top-down" approach attempts to capture the aggregate behavior of energy systems by use of equilibrium or partial equilibrium models which simulate prices, demand, supply, and investment interactions assuming a long-term market equilibrium. The "bottom-up" or "end-use" approach makes demand and supply projections at a more disaggregated level, relying more upon surveys, engineering studies, and expert judgment about important (and often price-independent) effects such as technological innovations, energy transitions, market saturation and other structural shifts. In the bottom-up approach, econometric methods are not rejected but instead are made use of on an *ad hoc* basis only where the analyst feels they are appropriate. In fact, most bottom-up analyses are formulated within a broad framework of macro-economic assumptions, which are often formulated using econometric models.

The methodology chosen for any analysis will depend on the objectives. The UNEP/NEPA project aims to study how different energy and environmental policies and technology choices might effect environmental conditions in China over the 30 year period from 1990 (the base year chosen for the study) to 2020. Because of this, the project adopts a bottom-up methodology, which can be used to examine in detail the economic and environmental implications of different energy polices.

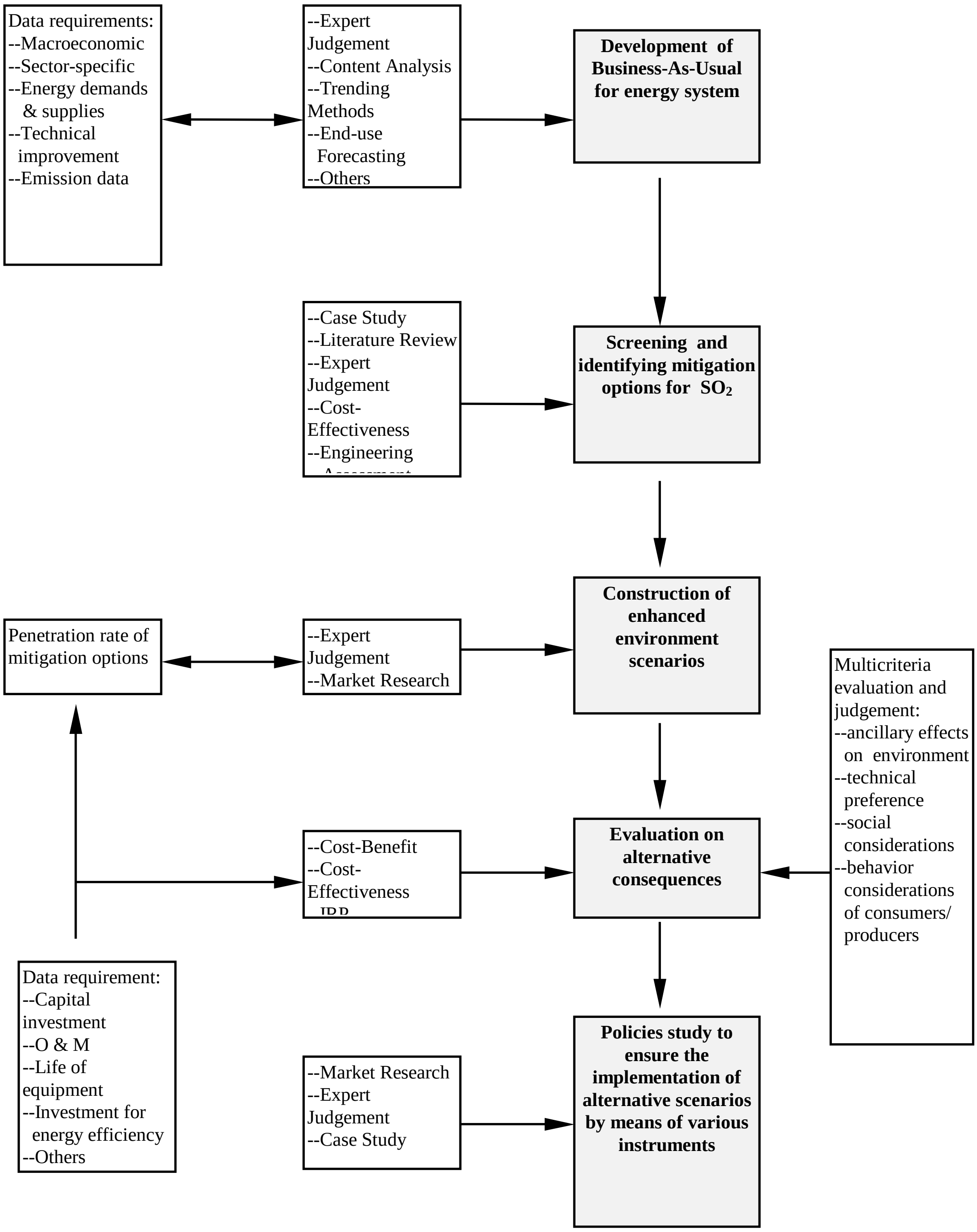
A range of different techniques are available for studying energy-environment systems. The two most widely used types are normative (optimizing) models and a more simple technique: the accounting framework. Optimizing models typically use linear programming to discover a system configuration which maximizes or minimizes some objective function (e.g. minimizing costs or pollutant loadings). They have found favor in such applications as least cost electricity planning studies but have generally not been seen as suitable for modeling disaggregated energy systems where the analyst is not generally attempting to make an optimal investment decision, but instead is attempting to quantify the economic and environmental impacts of a range of different scenarios. The accounting framework adopts a simpler approach based on a physical simulation of energy flows, and provides the analyst with a set of tools for studying the consequences (energy, economic and environmental) of a range of different scenarios.

The project as such attempts to explore the economic and environmental impacts of a range of integrated energy policy measures, and examines a range of different environmental indicators (including loadings of SO_x, NO_x, CO, CO_2, particulates). Instead of attempting to predict what would happen as a result of specific policy, it does describe what could happen within assumed technologies and a packages of policies. For this reason, the analyses in this project have been carried out using accounting framework tools by means of LEAP model.

3.2 **Analysis structure**

This study can be divided into four main areas which are data, methodology, analysis and impacts, and the analysis structure is illustrated in Fig 3.1.

Data The first column comprises all the numerical information which is exogenous, i.e. based on external estimates as opposed to being estimated by model as such. It includes national development indicators on economy, population, etc. sector-specific physical and economic development parameters, energy demands and productions in energy system; technical improvement and emission factors.



Data **Methodology** **Analysis**
Impacts

Fig 3.1 The analysis structure

Methods The second column refers to both forecasting methods which range from the use of expert judgment to sophisticated end-use methods for projection of future value and assessment ones which are quantitative and qualitative for evaluation of options and scenarios. Their methods are embodied in detail in the analytical procedures.

Analysis The third column which is an important component of the project describes the main steps in the analysis conducted in the study. It consists of five major steps, including development of BAU, identification of mitigation options, construction of enhanced environment scenarios, evaluation on alternative scenarios, and study of policy options.

Impact The final column represents multi-criteria analysis of a broad range of issues concerning ancillary environmental effects, technical preference, etc.

3.3 Methods for Development of Business-As-Usual (BAU)

3.3.1 Data requirements

In view of the data-intensive characteristics of LEAP model, there is a need for substantial data collection from published statistics, reports and research sources. In general, data collection begins with the aggregate annual energy use and production figures typically found on national energy balance sheet. Data for the year 2000 is basically derived from national and sector-specific plans and thereafter is modified based on other relevant studies and expert judgment. Typical data for BAU are shown in Table 3.1.

Table 3.1 Data requirement for BAU

Data Categories	Types of Data	Common Data Source
Macroeconomic Variables		
Sectoral driving variables	GNP, Gross output value, physical production , population, household size, transportation requirements, agricultural irrigated area.	National statistics and plans; GEF and ADB project in China; Macroeconomic studies;
Energy Demand		
Sector and subsector total	Fuel use by sector/subsector	National energy statistics; national energy balance, energy sector yearbooks
End-use and technology characteristic by sector/subsector	Energy consumption breakdown by end-use and device: energy intensity, efficiency, vintage, etc.	Domestic relevant studies, surveys, audits; experts judgments
Energy Supply		
Characteristics of energy supply, transport, and conversion facilities	Capital and O&M costs, performance (efficiency, unit intensity, capacity factors, etc.)	National energy statistics, sector-specific plans
Energy prices	Prices for imported/exported fuel	International relevant studies

Energy resources	Estimated, proven recoverable reserves of fossil fuels	Domestic relevant studies
Emission Factors		
Air pollutant emission factor	Pollutant emissions per unit fuel consumed, produced, transported	NEPA publications; GEF project; EDB; on-site measurement; other studies

3.3.2 Methodology

In view of the characteristics of energy planning by means of LEAP model which divides the overall energy system into five stages (covering energy reserves, production, conversion, transmission & distribution, end-use), at end-use comprising five economic sectors (agriculture, industry, transportation, construction and service and the household sectors, at the energy transformation stage, there are twelve processes to be included (including T&D, electricity generation, biogas production, heat supply, gasification, coke making, oil refining, coal briquetting, coal washing, natural gas & crude oil exploitation, coal mining). At each stage, a range of different forecasting methodologies to assemble projected data into model are applied either alone or in mutual combination.

①**Expert judgment.** As China is a developing country being in the transition period from planning to market economy, expert judgments are required at every field and plays an important and prominent role in forecasting future values.

②**Content analysis** is a technique sometimes used to forecast broad social and technology trends. The technique entails a review and analysis of content of the information carried through various media with respect to emerging social trends.

③**Trend analysis** are simple linear or logarithmic projections of historical trends. A related method generally known as correlation analysis can be used in some cases to associate social and environmental trends with variables that, in theory, are more predictable.

④**End-use forecasting** is that energy use can be accurately represented as the product of the number of energy-using devices and the efficiency of those devices. In addition, it should be combined with the growth in device stock over time, the change in device efficiency that could be expected purely as the result of technological progress, versus the change due to price and income changes, and the emergence of new technologies. It is widely applied in this study.

⑤**Multi-approach combination** is often used to predict total sector-specific energy demand with high level of disaggregation by two or more methods combination.

3.4 Methods for Screening and Identification of Mitigation Options

Several methods which are applied in this study to address and rank mitigation options are described as follows:

① **Case studies** are useful to support identification of certain mitigation measurements by means of case studies.

② **Literature review** can provide information to help identification of options with their key parameters such as cost, performance and emissions.

③ **Expert judgment:** Experts in government, academia, industry, consumer group, etc. can provide much information about options as well as their specific cost and performance data.

④ **Engineering assessment:** The most common form of engineering assessment is the project pre-feasibility study which considers the scope of the project, source of project input (e.g. materials and equipment), engineering cost data, and environmental considerations(e.g. emission factor).

⑤**Cost-effectiveness analysis** provides a framework for comparing a common economic metric, i.e. cost per unit sulfur dioxide reduced (CSR), within mitigation options. It is mainly applied in ranking of these mitigation options. CSR is determined by the following equation.

$$CSR=(C_m - C_a)/(E_a - E_m)$$

Where:CSR=cost per unit sulfur dioxide reduced

C_m =levelized cost of mitigation options (usually per unit energy saved or produced)

C_a =levelized avoided cost, ie. what would have occurred in BAU(per unit energy avoided)

E_a =emissions associated with avoided BAU activity (per unit energy avoided)

E_m =emissions associated with mitigation options (per unit energy saved or produced)

3.5 Construction of enhanced environmental scenarios

The key parameter is the penetration rate of selected mitigation options. Its estimation mainly depends on expert judgment and market research by analyzing the barriers to policy implementation, behavior of consumers and producers and types of instruments. In addition, all capital, operating and maintenance, and resource cost differences between scenarios need to be addressed. In this way, the study took an integrated cost perspective in which demand-side conservation measures were evaluated on an equal footing with supply-side measures. No attempt was made to put a monetary value on environmental externalities (e.g., SO_2 damage cost).

3.6 Methods for Evaluation on Alternative Consequence

The implications of the two scenarios relative to each other and relative to the BAU reference scenario are compared. Outputs include cumulative net present values (NPV) and the discounted levelized costs of reducing SO_2 emissions in each scenario. Non-SO_2 emissions were also studied for each of the two enhanced environmental scenarios. Results are presented for CO_2, CO, NO_x, and particulates.The feasibility of the two scenarios are studied with multi-criteria considerations.

Although the analysis of non-monetary social, environmental, technical impacts plays an important role in evaluating a scenario, a central objective of mitigation scenarios is to identify the set of actions that maximize economic benefits or minimize the economic costs of implementing a scenario. The basic principles of evaluating a scenario are similar with those in Integrated Resource Planning (IRP) which ensures that both demand-side and supply-side costs and benefits were fully considered. The main methods for assessing two alternative scenarios of this study are described as follows:

Cost-benefit analysis: Streams of costs and benefits (it refers to avoided cost in this study) over time are identified, discounted to their present value using an appropriate discount rate, and subtracted to determine net benefits. The ratio of benefits and costs (see Chapter 5) is a key indicator.

Cost-effectiveness analysis: It is similar to cost-benefit analysis. The difference between them is that this method incorporates environmental implications into the assessment of scenarios. As environmental implications are difficult to be valued, an indicator such as cost per ton pollutant(s) reduced is introduced. Levelized cost per ton SO_2 reduced is applied as a key indicator. (see Chapter 5).

3.7 Uncertainty analysis

There are three aspects in this study that are not explored adequately.

①**Treatment regarding substitutability**: This study did not take into account costs incurred on some technologies such as fuel switching (e.g. switching raw coal to washed coal), because it was difficult to identify such costs.

②**Treatment regarding indirect cost:** This study only included direct costs for mitigation options and did not include the indirect costs, such as cost of equipment, O&M, etc. However, the administrative and program costs for implementing the enhanced environmental scenarios were accounted for.

③**Inclusion of feedback effects:** Some of the changes in energy use that are reflected in the alternative scenarios may have secondary impact on energy costs and uses. However, this study has not made an attempt to incorporate them. For instance, actions to mitigate SO_2 emissions simultaneously reduce energy demands. As a consequence, this also causes energy prices to fall. As energy prices become cheaper, demand will begin to rise again.

④**Uncertainty in the analysis of cost/benefits:** The term benefit only includes avoided costs in enhanced environmental scenario, compared to BAU. However, two important benefits are not taken into account. The first is external environmental cost that are difficult to quantify in monetary units. For example, reductions of pollutants emissions would bring about environmental benefits, subject to the realization of enhanced scenarios. Unfortunately, the environmental benefits can only be presented in physical units, as opposed to monetary units, based on current domestic research accomplishments. The second is energy transportation cost due to LEAP software-specific imperfection. For instance, under the realization of enhanced scenarios, coal through washing will decrease ash in coal, thus the transpotation turnovers would be saved. However, such benefits are not embodied in the analysis of costs and benefits.

⑤**Uncertainty in the identification of mitigation options:** A common metric, which is termed the cost per ton SO_2 emissions reduced or avoided, to screen and identify the candidate mitigation options is applied in this study. Unfortunately, the metric only is taken as reference index, as opposed to the decisive one, because many coefficients to calculated the metric are static and come from different references.

3.8 Methods for Policy Studies

Expert judgment: Experts in government, academia, industry, consumer group, etc. provided much information about necessary instruments and cross-sectoral and specific responsibilities as well as barriers to implement them.

Market research: Feedback from public and experts on the packages of modified policy were analyzed and the instruments readjusted.

Case studies: Two case studies in Beijing city and Guangxi Zhuang Autonomous Region provided additional support to those instruments which were formulated at national level.

Chapter 4 The Business-As-Usual Scenario (BAU)

4.1 The definition of BAU scenario

The focus of energy planning in BAU is on energy system reliability with little attention being given to environment. As far as possible, the BAU scenario reflects the current official policies of the Government and forecasts of macroeconomic, demographic and energy sector indicators. Instead of attempting to make precise predictions or to derive optimal solution, BAU determines as to what would happen to possible energy future and potential environmental loadings. Of course, BAU scenario includes a lot of pro-environmental measurements, such as adjustment of industrial structure, structural changes among industrial subsectors, improvement of energy efficiency, development of renewable and clean energy (e.g. hydropower, nuclear power, etc.), imports of clean energy (e.g. crude oil and natural gas), and adoption of end-of-pipe technologies (e.g. flue gas desulfurization). It should be noted that the BAU scenario is not a static scenario.

4.2 The assumptions for establishment of BAU scenario

Energy is one of the important resources for national economic development, and it is also a strategic factor for modernization of China. As the economy shifts toward energy intensive stage from labor intensive stage, the energy demand will increase substantially, and this will result in increasing requirement for energy supply. However, many factors, such as the state of energy resources, the ability to invest in technologies for energy production, the feasibility of energy imports and environment bearing capacity, etc., would impose the constraints on the growth of energy supply. Integral considerations for all these factors as well as their mutual relations constitute the basis for setting the Business-As-Usual Scenario. The major assumptions are as follows:

1. In the coming 30 years, China will open up to the outside world. This will consequently accelerate the shift of the current macro industrial structure to subsector structure in industry and the matrix of product to be such that it has the dual features of being beneficial to the development of economy and on energy-saving economic structure.

2. China will continue to implement “Family Planning” to control total population to a level below 1.45 billion by end of the Year 2020.

3. China will continue to implement the energy strategy of: ①laying equal emphasis on both energy development and conservation, ②improving the primary enrgy cosumption and production mix, ③enhancing the energy management and promoting technologies for energy saving, ④developing energy in such a pattern that electricity is regarded as the center of the whole energy system, coal serves as the foundation, vigorous efforts are made for oil and natural gas exploitation, strong support for hydropower and nuclear power, suitable development for new energy (wind, solar, geothermal), ⑤improving the efficiency of energy conversion and end-use through the innovation, ⑥rationalizing energy prices. By adopting commercial energy-saving technologies and improving the existing energy utilization system, the total energy savings will amount to over 30% of the total energy use in 1990 in China.

4. Energy demand will increase with rapid economic development while investments on environmental protection would be difficult to enhance at the same pace. Therefore, the environmental issues related to energy consumption and supply should be

tackled on the basis of the energy efficiency improvement, acceleration of alternative energy development, energy mix optimization and proper energy imports, in combination with the adoption of economic and practical technologies and measures of environmental pollution control.

5. Over the next 30 years, energy production and supply will progressively shift toward a market based system. As the energy supply market expands, the entire energy system will open up to both the domestic and international markets. From the view point of energy utilization, import of crude oil, and the import of natural gas for power generation, household use and industrial purposes, will push development of China's economy. Energy open to market also means that energy prices will be internationalized, which will be beneficial not only to the development of energy industry itself, but also to energy efficiency improvement.

6. In order to raise the standard of living of the people and improve the quality of household energy, energy supply structure is required to change. However, from the viewpoints of resources, capital and technology, coal will continue to be the major energy source for a long time in China. Also, while the share of coal in total energy supply will be gradually decreased, coal for power generation will increase .

4.3 The projection of energy demand

Energy demand is affected by many factors such as the population, industrial structure, investments, energy consumption mix, energy saving potential, technology level, sector-specific development plan, energy production capacity and environmental loading capacity. Using the planned indicators national economy and social development, energy demand projection from 1990 to 2000 under the BAU scenario in China is carried out by using the LEAP model, based on the end-use energy consumption in the base year 1990.

4.3.1 Setting of indicators (driving activities)

1.Macroeconomic and demographic indicators

As a developing country, the primary goal for China is to boost her economic development and to promote the standard of living of the people. In China, the strategic objective of energy development is bound with that of economic development. The Chinese government has already set up targets of economic development, that is *"By the end of Year 2000, GNP will quadruple that of 1980 and the people's living standard will come up to comfortable levels; by the end of Year 2010, GNP will double that of 2000, and by the middle of the next century, GNP per capita will attain that of middle-upper-developed countries and the people will live a relatively rich lifestyle, i.e. modernization will almost be achieved"*. This implies that the economic growth rate would reach 8-9% in 1990s, 7-8% in 2000s and 5-6% in 2010s, respectively.(See Table 4-1).

Being a developing country with a large population, China is faced with the challenge of how to sustain economic prosperity without sacrificing environmental well-being. Since late 1970's, China has taken up family planning as one of the basic national policies. In recent years, the population policy has proven to be so effective in its execution that the population growth has shown a tendency of slowing down. According to the population growth control plan, by the end of this century, the annual average natural population growth rate should be controlled bellow 12.5‰ for the best, and the total birth rate will decrease from 2.3% in 1990 to 2.0%, that is at present the average of developed countries'. It is also expected that the population in China will remain stable within 1.5 to 1.6 billion by the middle of next century. In this perspective, the population growth indicator is set as follows. The annual average population growth rate over time horizon would be 1.25% during 1990s, 0.72% during 2000s and 0.42% during 2010s, thus total populations in 2000, 2010 and 2020 would be 1.294, 1.390 and 1.450 billion. (See Table 4-1). In addition, rapid economic development has fostered faster urbanization and expedited migration of a large number of rural population into urban areas. As a result, the natural population growth rate in cities and towns will be higher than that in the rural areas and the population in cities and towns will share an increasing percentage in total population. In 1990, the population in cities made up 26.4% of total population. It is projected that in 2000, 2010 and 2020, the population in cities will constitute 31.4%, 37.4% and 44.8% of the total population, respectively.

Table 4-1 Macroeconomic and demographic indicators

	1990	2000	2010	2020
GNP growth rate, %		9.0	7.5	6.0
GNP, billion Yuan RMB	1768	4185	8625	15445
Population, billion	1.143	1.294	1.390	1.450
Population growth rate, %		1.25	0.72	0.42
Population in urban	3.02	4.06	5.10	6.50
Population in rural	8.41	8.88	8.80	8.00

2. Characteristic variables for sector-specfic development plan

The energy planning over the time horizon in China covers all stages in the entire energy system, including energy end-use, T&D, transformation (secondary energy production), primary energy production and reserves, pollutant emissions.

The energy end-use stage is divided into five sectors: agriculture, industry, construction, transportation, service and househould sector. Data are assembled in a hierarchical format, based on four levels: *Sectors*, *Subsectors*, *End-uses*, and, *Devices*. After characteristic variables at above four levels such as energy service activities (in appropriate physical or monetary units), end-use saturation levels and device and fuel shares are addressed, total demand for a given fuel is estimated by aggregating over activity levels and energy intensities (the amount of energy consumed per unit of service delivered). Hence, the first step is to identify the sector-specific variables which are listed in Table 4-2.

In the energy transformation stage, the energy conversion processes that turn primary resources, such as coal, hydropower and crude oil, into final fuels, such as electricity, are simulated. This stage compares the primary resources and fuel imports and exports required to provide the final fuel consumption calculated in the energy end-use stage. The stage includes ten processes which comprise China’s energy industry, such as coal mining, crude oil exploitation, natural gas exploitation, coal washing, briquetting, gasification, coking, oil refinery, heat supply, electricity generation. The characteristic variables consist of capacity, capacity factor, energy conversion efficiency and process internal energy use and so on which are tabulated in Table 4-3.

In energy T&D stage, the main process is electricity T&D losses. In pollutants emissions stage, environmental loadings are calculated by multiplying energy consumed with emission factors which are derived from either core EDB in LEAP model or published statistics.

Table 4-2 Characteristic variables for sector-specific plan

Sector	Subsector	Characteristic variable	1990	2000	2010	2020

Agriculture		Cultivated Land (Million ha.)	95.7	92.0	89.0	85.0
	Ferrous	Crude steel output (Mt)	66.3	110	140	150
	Building	Cement output (Mt)	209	500	600	600
	material	Brick&tile output(Trill. piece)	0.458	0.60	0.65	0.50
		Glass output (Million box)	80.7	130	150	150
Industry	Chemical	Fertilizer output (Mt)	18.8	24.3	30	30
		Element chemicals(Bill.Yuan)	151	387	720	1104
	Nonferrous	Output (Mt)	2.4	4.4	6.0	7.0
	Light industry	Gross output (Trillion Yuan)	1.18	3.0	5.5	8.5
	Machinery	Gross output (Trillion Yuan)	0.38	1.2	2.6	4.2
Construction		Gross Output (Tillion Yuan)	0.30	0.78	1.61	2.75
		Freight turnover (Trill. tkm)	2.62	4.20	6.80	10.0
Transportation		Passenger turnover(Trill.pkm)	0.56	0.87	1.35	2.00
		Motorcycle(Million stock)	4.21	20.0	51.9	92.9
		Private car (Million stock)	0.03	0.52	20.0	44.0
	Commercial	Gross output (Trillion Yuan)	0.17	0.55	1.43	2.80
Service	Other	Gross output (Trillion Yuan)	0.44	1.47	3.81	7.49
	Urban	Households (Million)	79.4	112.5	149.6	201.9
Househould	Rural	Households (Million)	193.4	222.6	235.7	228.6

source: 1. ADB report, National Response Strategy on Global Climate Change of PRC, 1994
2. WB main report and subreports, China: Issues and Options of Greenhouse Gas Control, 1995
3. Sector-specific development plan.
4. China Statistics Yearbook, 1991

Table 4-3 Characteristic variables of energy processes

Process		Capacity	1990	2000	2010	2020
Coal mining		Billion t/y_r.	1.094	1.55	2.0	2.3
Crude oil exploitation		Mt/y_r.	141.3	165	200	220
Natural gas exploitation		Billion m^3/y_r.	15.8	30	50	80
Oil refinery		Mt/y_r.	145.2	200	280	350
Coal	for coking coal	Mt/y_r.	150	230	300	300
washing	for steam coal	Mt/y_r.	102	102	102	102
Coal briquetting		Mt/y_r.				
Coke-making		Mt/y_r.	100	115	145	160
Coal gasification		Billion m^3/y_r.	5.83	9.0	13.5	20.0
Heat supplying		Million GJ/y_r.	490	830	1260	200
	Coal-fired	GW	77.84	171.70	294.64	399.85
	Cogeneration	GW	10	22.5	35	45
	Oil-fired	GW	10	18	30	45
Power	Gas-fired	GW	4	8	15	25
	Hydro power	GW	36.04	66.5	100	138
	Nuclear power	GW	0	2.7	10.7	32
	Wind power	GW	0.01	1	4	10
	Geothermal	MW	21	60	100	150
	Solar power	MW	0.3	80	1000	5000
	Subtotal	GW	137.89	290.54	490.44	700

Source:1. WB report : Issues and options of Greenhouse Gas Control in China
2. Energy Statistics Yearbook, 1991
3. Electricity Power Academy: Forecast of Power Industry Development, 1993
4. Yan Changle: China Energy Development Report, 1994.

4.3.2 Estimation for technical level in the future

The increasing need for energy services to sustain continued rapid economic development can be provided only through a balanced combination of increases in energy supply and improvements in the efficiency of energy use. It is important to address the issue of energy intensities in order that the choice of technology and their potential for application are determined. According to sector-specific technical policy, the study team conducted an estimation of technology choices by sectors in the future.

1. Househould

Energy service in urban and rural household mainly comprises of cooking and hot water, space heating, lighting and appliances.

Cooking and hot water. Coal-fired equipments used by urban residents for cooking and hot water refer to various kinds of household coal stoves with a low heating efficiency of 20%. To improve their burning efficiency, vigorous efforts have been made to develop the residential briquette technology. As a result, consumption of residential briquette in 1990 amounted to 38 Mt. At present, the heating efficiency of coal stove with briquette can reach 30%.

At present, the major gas fuels used in China are natural gas, LPG, coking gas and producer gas, and the average heat efficiency of the gas-fired stove for cooking is only 55%, lower than the value of 70% in the developed countries. In order to mitigate the air pollution in urban areas, the Chinese government has put forward a policy of giving priority to clean and quality energy supply for urban household use.

Large-scale biomass consumption is a striking feature of rural residential energy use in China. The growth rate of biomass consumption is gradually diminishing as end use efficiency improves and coal becomes more accessible. Biomass still commands about 80% of rural energy use in 1990. At present, the heating efficiency of ordinary firewood stoves is only 10% and the demand for firewood and crop residues in rural area is often excessive. Seeing the danger of chronic rural fuel shortages and unstainable firewood consumption, the government launched a programme of biomass-saving stoves with rated heat effiency of 25-30% and tree-planting programs in the early 1980s. By 1990, 128.9 million househoulds had been equipped with the biomass-saving stoves.

There are four main measures to be carried out for energy saving in residential cooking and hot water in the future. The first one is to promote the adoption of gas fuel as a substitute for coal in urban areas and to develop various kinds of gas fuels in light of local conditions. Given the limits to production and refinement capacity of oil, demand for coke, and the investment on town gas, the supply of LPG, coking gas and producer gas is not likely to increase. However, keeping in view the development of the natural gas, the growth rate of natural gas supply for household use would be fairly high. In 1990, the consumption of natural gas for civil use was only about 7.6% of the total consumption of natural gas in China, however, this is expected to go beyond 20% in 2000. Beyond 2000, natural gas would become the major fuel for household use while the share of gas fuels in the total energy cosumption would increase rapidly.

The second important measure for energy saving in the household sector is to promote residential briquette technology across China.

The third measure is to improve the heat efficiency of household stoves, including briquette stoves and biomass-saving stoves. By increasing the adoption of efficiency stoves, the average heat efficiency of household stoves will be improved progressively. The Chinese government has incorporated a policy of “continuously promoting biomass-saving stoves in rural area” in the National Idustrial Policy on Energy Industry. Meanwhile, a penetration rate of 90% for biomass-saving stoves, which is taken as an objective in Energy Planning from 1990 to 2000 should be achieved.

Finally, in order to alleviate the pressure imposed on ecosystem due to the excessive use of biomass, the Chinese government promotes another energy-efficient and a much cleaner option for rural cooking, i.e. the utilization of biogas. Furthermore, the program of constructing biogas digesters for rural households has heen undertaken for about two decades. This technology will be continously promoted. In addition, solar, wind and other renewable energy sources will also be promoted.

Space heating. There are two major modes of space heating for urban residents in China, which include coal-fired stoves and central heating. Stove heating is a backward technology, despite the fact that the utilization of energy may be up to 85% when putting stoves in room and the pollution caused by burning will be mitigated in case of the replacement of briquette with raw coal. The heat efficiency of scattered boiler house is quite low (only 58%), while the efficiency of central boiler house and thermal heating is much higher (about 65%). However, the level of central heating in urban areas is only 9.4%. For rural residents, space heating with coal-fired or biomass-fired stoves is the main mode.

The main energy conservation measures used in household heating in urban areas are as follows: ❶to develop central heating. In the near future, central boiler houses will replace small coal-fired stoves and scattered boiler houses gradually, and the long term goal is to develop cogeneration in the districts. ❷to improve heat efficiency of boilers. By means of revisions in energy saving on boiler structure and reinforcement of management on boiler operation, the heat efficiency of boilers can be raised from current 65% in 1990 to more than 72% in 2020.❸ to improve the thermal efficiency of buildings. The energy consumption for space heating is about 30% higher than that in some developed countries, subject to the same effectiveness. The reason for that is the poor thermal efficiency of buildings. Thus, Energy-efficiency Design Standards for Residential Building in Heating Zone" explicitly states that newly constructed buildings must adopt energy-saving measures, and "China Agenda 21" stipulates energy-efficient building standards, i.e. in the first step, to reduce space-heating fuel intensity of new buildings to the level that would be 30% less than their 1981 value by 1990, in the second step, to further reduce space-heating energy intensity of new building to the level that would be 30% less than their value by 2000.

Lighting and appliances: The electricity used for lighting stands for 24.7% of the total household electricity consumption with the average electricity use per capita of 22.3 kWh. More than 95% of bulbs used in household are incandescent light bulbs and tube fluorescent ones whose lighting lumen level are 5% and 60% lower than the advanced level in the world respectively. According to the estimation made by experts, if only half of urban household replaced incandescents with an energy-efficient bulb, and also considered their use in new dwellings in future, by the end of 2000, the electricity conservation would have reached 1500 GWh. Moreover, the lighting quality and level will also be raised. According to 'The Lighting Design Standards for Civil Buildings' set up by the Chinese government, energy-efficient bulbs must be included in the architectural designs. With the above measures, the growth rate of electricity use for lighting will reduce.

The appliances owned by urban household are television, refrigerator, electric fan, washing machine and air conditioner, etc.With the improvement of housing condition and income level, air conditioner begins to enter into household in 90s, and its growth is likely to be very rapid. Electricity conservation measures will be implemented to ensure that these appliances are efficient.

2. Agriculture

The agricultural sector can be divided into five subsectors, which includes cropping, forestry, fishery, side-line production, and animal husbandry. The energy consumption in agriculture is confined to cultivation machines, irrigation pumpsets, tractors, motor fishing boats and farming trucks.

Due to the low extent of mechanization, the energy consumption per unit output in China is still far below that in the industrialized countries. For example, the energy intensity in China stands around 4 litres of diesel and 126 kWh electricity per hectare farmland for producing grain, while it was 51 litres diesel and 236 KWh electricity per hectare in the mid-80's in America, where due to high extent of mechanization, the labour productivity of grain production is 100 times higher than in China. At present, the operating efficiency of irrigation pump remains 20% below the designed value and 30% below that of the foreign counterparts. Additionally, in terms of a single tractor, energy consumption in China is 10% more than that in the other countries.

In the future, the Chinese government will attach more importance to increasing the extent of mechanization in agriculture and developing agriculture steadily over the time horizon. Given the inexorable decline in the cropped area over time as a result of population growth, accelerated urbanization and rapid development of town and village industry, a swift transformation from extensive to intensive cultivation and improving mechanization brook no delay in order to achieve the stable production of agricultural products.

3. Steel and Iron

The main energy sources for Ferrous sector are coking coal, steam coal, electricity, fuel oil and natural gas. The total energy consumption reached 98.7 Mtce in 1990, of which about two third was for a few major processes such as coking, sintering, blast furnace operation, steel conversion and rolling. At presently, much of the equipment is quite old and the technologies are relatively backward. Efficiency is therefore generally lower than that for corresponding activities in developed countries. However efforts to modernize the industry have been pursued vigorously in recent years through introduction of laws and regulations on energy conservation, improvement of working procedures, elimination of many energy inefficient technologies and practices, installation of new energy saving facilities, adoption of energy saving technical measures, such as converter gas recovery, continuous casting, multi-lance oxygen blowing of open hearth furnaces, blast furnace coal injection, and greater utilization of waste heat. As a result, the integrated energy consumption per ton of steel has reduced from 2.04 tce to 1.61 tce. In key enterprises and local major enterprises, the comparable energy consumption per ton steel has reduced from 1.3 tce in 1980 to 1.034 tce in 1990 (about 20% decline) at a decrease rate of 2.32% a year. Nevertheless, compared to the average level of major steel-making countries, this figure is still 30% higher.

To narrow the gap between specific energy consumption for steel-making in China and the developed countries, the following measures should be adopted: ❶To regulate the composition of manufactured products. ❷To recover combustible gas and surplus energy arising from making steel and iron. ❸To develop cogeneration and central heating system. ❹To increase the spread of electricity-saving technology. 5) Energy conservation in working procedures.

In order to achieve the goal for energy saving, relevant policies are strengthened to ensure the implementation of the energy saving measures. As a result, it is estimated that the overall energy consumption per ton steel will fall from 1.61 tce in 1990 to 1.45 tce in 2000, to 1.3 tce in 2010, and 1.2 tce in 2020 respectively. This implies that specific energy consumption in 2020 would close to or reach that of developed countries in 1990.

4. Building materials

The Building materials sector includes manufacture of construction materials, non-metallic mineral products and inorganic materials. The sector covers over one thousand products, and the main products are cement, flat glass, ceramics, bricks, tiles and lime. In the recent decade, the building materials industry has been expanding rapidly in China, but there has been little progress in the overall level of technology being used in this sector. The main reasons is that the excessive demand for construction throughout the country results in increased demands for building materials and products; meanwhile the raw materials are easy to acquire for building materials production, which is also characterized by simple technology and is profitable. This resulted in many small-sized enterprises which are equipped with out-of-date, even obsolete equipment and this includes the rural enterprises as well.

Cement: The thermal efficiency of cement production is about 42%, and the average energy consumption is 188.21 tce per ton of cement, mainly utilizing technologies of decomposition out of kilns and rotary kilns in the large and medium-scale plants. Units which use the wet process have a thermal efficiency of only 27.6%, and the average energy consumption is 247.92 tce per ton of cement. Therefore, while the technology of wet-process should be replaced by the dry rotary kilns and decomposition process out of kilns gradually, over the long term, say by 2010, this process would be entirely eliminated in the large/medium-scale plants. On the other hand, by 2010, the technical process in small-sized plants should also be renovated, and over the long term, say by 2010, the small indigenous vertical kilns with high energy consumption and severe environmental pollution would be phased out, while the small machinery vertical kilns would have to be retrofitted. Moreover, further efforts must be made for improving the dedusting efficiency in the plants. Overal, the specific energy consumption would drop from 1.97 tce/t cement to 1.52 in 2000, 1.38 in 2010 and 1.30 in 2020, respectively. This implies that specific energy consumption in 2020 would be close to or reach the level present in the developed countries in 1990.

Glass: As the float glass technology marks the technical level of flat glass production worldwide in a country, China will devote every effort to developing the same, and the share of float glass products would account for 60% in the total output of glass by 2000. Internationally advanced technique of float glass production in the 1990s would have to be applied in the newly-built glass plants, and by 2000, the overall glass production technique in China would meet the level present in the mid-eighties in the developed countries.

Brick & tiles: Reducing the output of solid clay bricks and developing new wall materials, using waste materials such as slag and fly ash are future technologies that would be utilized in China.

5.Chemicals

The wide range of processes, plant scale and age within the chemical sector is the cause of extreme variations in energy efficiencies.

Fertilizer industry: Ammonia-synthesizing is the biggest energy-consuming subsector among the chemical industry. For large-sized plants, the equipment was mainly imported between the 1970s and 1980s, which mainly used natural gas as raw material. For medium-sized plants, the equipment is almost at the technical levels of the 1950s-1960s, taking oil, gas and coal as raw materials. Small-sized plants are characterized by high energy consumption and backward techniques, mainly using coal as the raw material. Compared with the energy consumption of synthetic ammonia production in the developed countries in the 1980s, the energy consumption of a large scale enterprise that uses natural gas as the raw material is quite close to the levels present in the advanced enterprises, and the energy consumption of the medium/small scale enterprises that use coal and oil as materials is over six times. Out of the total energy consumption of the Chinese fertilizer industry in 1990, 42.3% was consumed as raw materials and the rest as fuel. Coal consumed accounts for over 50% of the total energy consumption of China's fertilizer industry and the energy consumption per ton of chemical fertilizer is therefore estimated at 2.766 tce.

The technology innovation program in the fertilizer industry emphasises mainly on optimum control of the production process with microcomputer technique, and energy savings through introduction of advanced technologies. The program includes: ❶ restructuring the production scales, ❷ enforcing measures for innovating energy saving techniques in large-sized synthetic ammonia plants by preheating the air combusted in a section of furnace to reduce the natural gas consumption, recovering the synthetic release of gas by means of importing Prison equipment, improving the Benphilto heat pump to reuse the steam, substituting physical absorption for chemical absorption to remove carbon dioxide, not using steam, etc., ❸ improving energy saving techniques in the medium scale synthetic ammonia plants through adopting automatic machines to add coke and superheated vapor to produce gas, and recovering the surplus energy of gas and adding Prison hydrogen-recovering equipment, etc, ❹ improving the final design of equipment in small scale synthetic ammonia plants by adopting automatic coke adding machine and new furnace grate, and installing the humidifying tower for nitrogen-air, thus producing synthetic ammonia with self-supporting steam, ❺ raising the efficiency in heating system, improving the boiler by heat and power combination, adopting microcomputer process controls for automatic control of main energy consumption process, and using electric motor and heat exchanger of high efficiency and low energy consumption.

Chemical elements: The main products that consume energy include caustic soda, ethylene, calcium carbide and sodium carbonate, etc. Taken as a whole, the levels of production technologies of these products generally fall behind those existing in 1980s in the industrialized countries, and there is a great difference with respect to energy consumption per unit of products. Energy-consuming equipment covers boilers, kilns, motors, pumps, fans etc. Most furnaces are small, many are chain grate stokers, the average combustion efficiency of which is estimated at 65%.

The main measures for energy conservation includes: ❶developing cogeneration to improve energy efficiency, ❷improving the operating efficiencies of fan, pump and heat exchanger ❸Substituting the electrolyzer with metal positive plate and three-stage evaporating device for the electrolyzer with graphite positive plate and two-stage evaporating device in the sectors that produce alkali chlorides to save energy, ❹ in the sodium carbonate production, improving the method for salt solution purification, and substituting the metal positive plate with graphite positive.

6.Nonferrous

At present, most technologies and facilities adopted in non-ferrous industry are quite backward, only equivalent to 50s' and 60s' levels of the world, and inevitablly, lead to high energy consumption. Since 1980s, however, vigorous efforts have been made to reduce energy consumption by process renovation, equipment modernization and the utilization of new technologies. By the early 90s, the total output of non-ferrous metals increased to 90%, while the corresponding energy consumption only grew by 70%. Some energy conservation measures that will continue to be implemented over 90s, including ❶for copper smelting, the flash furnace will be further developed to replace the blast furnace, ❷in the processing of aluminum oxide, great emphasis is laid on the Bayer process. With respect to electrolytic refining of aluminum, the production capacity of prebaked anode cells will be further increased, ❸in the production of lead, improvements include using modern technologies for lead smelting, increased use of waste heat from smelters, installation of waste heat boilers on calcining and distilling furnaces, use of this steam for electricity generation, ❹with respect to zinc, ISP smelting technology will be given the priority for adoption.

7. Light industry

The light industry includes paper-making, textile, wine and beer, medicines, sugar, tobaco, food-processing, etc. In these subsectors, there is a common characteristic, i.e. coal and electricity are the dominant fuels. Coal is mainly consumed in boilers with efficiency of 55-60%, compared to 75-80% in modern coal-fired boilers internationally, and electricity is mainly used for motor, pump, fans and specific electric devices.

There exists substantial energy saving potential in the light industry. During the 1980s, light industrial output grew rapidly while maintaining an energy consumption elasticity of about 0.4 which is similar to that for the industrial sector as a whole. In 1990, the energy efficiency of China’s pulp industry was very low due to the use of low-grade raw materials and backward technologies. Energy use per ton of paper in 1990 was 1,245 kgce, which was considerably above the levels prevalent in the advanced countries (440 kgce/t in 1990). The textile industry compared less favourably against industrialized countries in energy intensity due to lack of mechanization.

According to the report titled “China: Energy Conservation Study, 1993”, energy efficiency gains mainly lie in quality improvements and changes in product mix, improvement in the efficency of electric motors and associated equipment, improvement in the efficiency of coal-fired industrial boilers, etc.

8. Machinery and Electronics

The Machinery and Electronics sector includes the manufacture of automobiles, boilers, furnaces, telecommunication, electronic equipment and other special equipment. Coal is mainly consumed in furnaces and boilers and electricity is mainly consumed in electric devices. Energy saving in this sector will largely rely on the improvement of technologies, production process and management.

9. Transportation

Energy-consuming equipment includes locomotives in rail, vehicles on road, ships for water transport and air transport.

Rail transportation: The current thermal efficiency is reported as 19% for diesel locomotives, 20.8% for electric locomotives and as low as about 8% for steam locomotives in China. Due to the high energy consumption and pollutant emissions from steam locomotives, China stopped the production of steam locomotives in 1988, and it is anticipated that the currently used steam locomotives will be phased out by 2020. However, in order to improve the efficiency and reduce the related pollution for the existing steam locomotives, great efforts have been made to improve the quality of coal for locomotive uses, which mainly refers to gradual replacement of raw coal by high quality coal block and locomotive briquette. If quality coal is burnt in all the steam locomotives, it is estimated that approximate 10% of the coal consumption could be saved. In addition, given the fact that considerable rail lines suffer from poor railroad quality and the situation is not likely to change in the near future, it is estimated that there will be little or no change in transport efficiencies of diesel and electric locomotives. The exception is likely to be the electric passenger locomotives, whose specific intensity will increase remarkably as the extent of automation raises. In the future the share of diesel and electric locomotives will gradually increase, while steam locomotives will be gradually reduced.

Road transportation: The stock of motor vehicles has been increasing at an average annual rate of 12.44% since 1980s, with 17.6% as the average annual growth rate for passenger vehicles and 11.28% for freight vehicles. There were over 5.5 million freight and passenger vehicles in 1990, with each category accounting for 66.8% and 29.4%, respectively, the others being vehicles for various special uses. Besides, as the people's living standard improved, the stock of motorcycles increased dramatically, e.g., at an average growth rate of 38% per annum during 1980s and up to 34.21 million in 1990. In addition, the stock of household cars rose to 34 thousand in 1990.

Although the road transport develops rapidly in China, the overall standards are quite low, which is seen from the poor fuel economy and low operation efficiency. Therefore, with the continual increase of the demands for motor vehicles as indicated from the future trends of transportation, more importance should be attached to improving the overall standards of highway transportation in order to lighten the pressure on energy demand and alleviate the environmental pollution. The main measures: ❶To improve the engine designs for motor vehicles. The popular models of domestic-made trucks and buses consume nearly twice as much more energy than their modern foreign counterparts, and it is expected that introducing modern designs and technologies represents 10-20% increase in fuel economy over popular domestic engine models. ❷To increase the share of diesel motor vehicles. In China, the gasoline-driven vehicles make up most of the stock of motor vehicles, and hence the diesel motor vehicles only share as low as about 15%, compared to over 50% in developed countries. In general, the diesel vehicles use less fuel than gasoline vehicles, e.g., 33% less fuel per unit freight movement and 18.2% less fuel per unit passenger traffic. By means of developing diesel vehicle production and substituting for gasoline vehicles, there exists great potential for energy savings in transportation. ❸To adjust the inefficient vehicle fleet structure. The current ratio of the number of vehicles between large (payload≥7 ton), mid (payload 5-7 ton), and small (payload≤4 ton) trucks is 1:6:3 in China, while the optimal ratio is considered to be 1:2:7 according to the practice in developed countries. Obviously, the share of mid payload trucks is too high in China. It is reported that under the same work load, the large payload trucks consume 20% less energy per 100 ton-km than mid payload trucks. There is a potential of 10-15% in energy savings from this source. ❹To improve the road quality and management system of transportation. The share of the higher class roads is very low in China. Related tests have shown that motor vehicles consume 10-15% less fuel on bituminous roads and high quality cement roads than on stone or dirt roads. Since 1990s, great efforts have been made to construct higher class highways in China, and the related potential in energy saving is expected to be significant.

Water transportation: The high specific energy consumption of water transportation can be mainly attributed to the general aging of vessels in use, backward ship-building techniques, small scale of fleets, blockage of the inland channels, insufficient capacity of the ports, etc. In 1986, the Ministry of Communication issued the

“Regulations on the Management of Energy Conservation in the Transport Industry” which emphasized the need “to strengthen the energy management in a scientific way, to renew and renovate energy intensive equipment in a planned way, and to utilize energy rationally”. Since then, the old steam vessels have been phased out, and for motor vessels in use, renovation has carried out on the engine, model and navigation conditions. As a result, energy savings were achieved to some extent. Moreover, these measures will continuously be carried out in future with further efforts in replacing the old vessels by new efficienct vessels, expanding the scale of fleets, promoting the use of containers in water transport, increasing the capacity of ports and inland waterway transport.

10. Service sector

The service sector comprises commercial establishments, hotels and restaurents, water supply, marketing & cold storage of material and other service sectors.

Coal is mainly used for space heating in commerical and public buildings which share similar physical characteristic with residential buildings, and partly for cooking and tea boilers, and electricity is mainly consumed for lighting which is considered low efficiency because most fluorescent fixures in commercial buildings are equipped with electro-magnetic ballasts and large wattage incandescent lamps are also widely used. In the next 30 years, the central heating system and HVAC systems would expand rapidly and would gradually replace such heating mode as coal stove in floor space, the scattered small boilers and small-scale heating systems, thus increasing the combustion efficiency of boilers by around 20%. With economic development and modernization, the demand for cooling and heating system with air conditioners would rise gradually, and so would the demand for electricity. With respect to cooking in the commercial sectors, the laws and regulations of environmental protection would be revised, and eventually, the coal-fired stoves for cooking would be eliminated in cafeterias, while clean gas would substitute raw coal in a phased manner. With regard to electricity for lighting, the current stock of lamps would be gradually replaced by high-efficiency fluorescent tubes and electronic ballasts which are 25% more efficient.

11. Coal mining

Energy consumed in this industry is mainly in the form of coal and electricity. Since the level of mechanization is low in China s coal mines, mining energy intensity, especially electricity intensity, is also low. In 1990, the national average energy intensity was 35kgce/t, and that for local state-owned and township and village coal mines was 34 and 19 kgce/t, respectively. However, internal coal consumption for national state-owned coal mines is very high. Therefore, acceleration of mechanization level and energy conservation would receive emphasis in the future. According to the National Industrial Policy on Energy Industry, by the year 2000, large mines should reach international levels of 1980s, i.e. mechanizing, coal extraction and tunneling, monitoring safety, automating coal transporting and lifting, etc. Medium and small sized mines are required to adopt comprehensive mining and advanced general mining technologies and to get to the technological levels of China's large-sized mines in 1970s. Township mines should reach current technical levels of local State-run mining companies. Under the unified planning framework, the order "extracting (coal bed gas) first and then mining (coal)" should be followed gradually.

12. Oil and natural gas

Crude oil and NG exploitation: According to the National Industrial Policy on Energy Industry, by the year 2000, the technology and equipment possessed by the oil and natural gas industry should be at or close to the advanced levels in the world. To be more efficient and successful in exploration, technologies of high-resolution digital seismic prospecting and oil reserve description should be at advanced world levels.

13. Power industry.

Thermal power. In 1990, the net coal rate was 427 gce/kwh which was lower by about 100gce/kwh, compared to the level prevalent in industralized countries, while gross coal rate was 392 gce/kwh with generation efficiency of 31.3%. According to sector-specific programs, there will be a reduction of about 60 gce/kwh in 2000. In view of the National Industrial Policy on Energy Industry, China's future technology options for coal combustion in the power sector can be grouped into four broad categories; traditional coal-fired power plants, innovative and efficient clean coal technologies (CCTs), pollution control devices (pre-combustion, process change and end-of pipe), and retrofitting of old boilers for efficiency improvement.

❶New thermal power plants should adopt units with large capacity, high performances, and qualified peak modulation feature.❷PFBC and IGCC will be be disseminated on a certain scale application, based on domestic technology.❸The installed capacity for coal-fired power with FGD will reach 12GW in 2003.❹ The medium and low steam pressure condensing units with serious pollution in urban areas would be gradually retrofitted or shifted out. ❺The installed capacity of heat and power cogeneration will be increased. ❻ More attention would be paid to renovation of auxiliary machines with lagged technique and high energy consumption in order to reduce plant internal electricity use which is expected to decrease from 8.22% in 1990 to 7.2% in 2000.❼ Emphasis would be placed on strengthening the construction of new transmission and distribution networks, reforming the existing networks, replacing energy intensive equipments with efficient ones, assembling the non-power compensation facilities, etc. It is expected that gross coal rate would reduce to 350 in 2000, 330 in 2010 and 320 gce/kwh in 2020 with the implementation of the above measures.

Hydropower: According to the National Industrial Policy on Energy Industry, hydropower should master techniques of designing and constructing 300-meter high dam and underground plant buildings with high over-burden, long tunnel, and broad span. Large turbine generators of over 500 MW per unit should be developed. Simultaneously, pumped storage hydropower will be utilized wherever feasible. It is estimated that the installed capacity of hydropower would increase to 66.5 in 2000, 100 in 2010 and 138 GW in 2020, respectively.

Nuclear power: According to the National Industrial Policy On Energy Industry, the equipment of pressurized-water reactor for nuclear power should be indigenously manufactured as soon as possible. Before the year 2000, 600 MW reactors should be built at home and 1GW reactors be studied. It is estimated that the installed capacity of nuclear power would increase to 2.7 GW in 2000, 10.7 GW in 2010 and 32 GW in 2020, respectively.

Wind, solar and geothermal power: It expected that the installed capacity for wind power would expand from 10 MW in 1990 to 1 GW in 2000, 4 GW in 2010 and 10 GW in 2020, that for solar power would increase from 0 to 80 MW in 2000, 1 GW in 2010 and 8.2 GW in 2020, while geothermal capacity would go up from 20 MW in 1990 to 60 MW in 2000, 100 MW in 2010 and 150 MW in 2020.

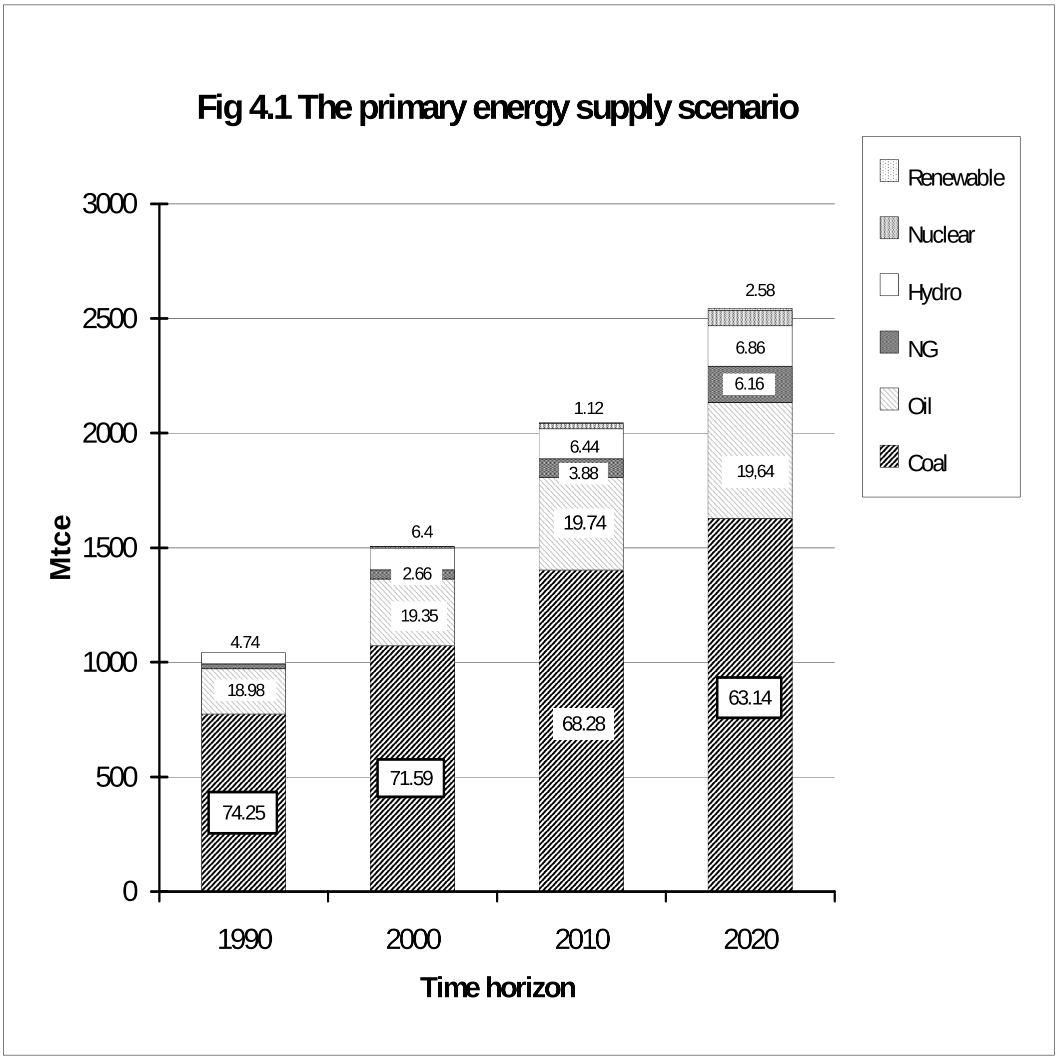
4.4. "What would happen" under BAU

4.4.1.Primary energy supplies and mix

Based on the above assumptions, the primary energy supplies and mix are presented in Table 4-4 and graphically in Figure 4.1.

Table 4-4 The scenario of the primary energy supply (BAU), 1990-2020

	Unit	1990		2000		2010		2020	
		Quan.	%	Quan.	%	Quan.	%	Quan.	%
Commercial energy	Mtce	1042	79.54	1506	84.79	2046	88.62	2545	91.61
Coal	10^8 t	10.83		15.00		19.63		22.77	
	Mtce	773.6	74.25	1072.4	71.23	1401.8	68.53	1626.3	63.91
Crude oil: Output	10^8 t	1.38		1.65		2.00		2.21	
	Mtce	197.69		235.79		285.80		314.38	
Import	10^8 t	0		0.38		0.84		1.34	
	Mtce	0		54.14		119.47		191.59	
Supply	10^8 t	1.38		2.03		2.84		3.55	
	Mtce	197.7	18.97	290	19.26	405.3	19.81	506.0	19.88
Natural gas: Output	10^8 t	157.74		300		500		800	
	Mtce	20.98		39.92		66.40		106.24	
Import	10^8 t	0		0		100		400	
	Mtce	0		0		13.24		52.37	
Supply	10^8 t	157.74		300		600		1200	
	Mtce	20.98	2.01	39.92	2.65	79.64	3.89	158.61	6.23
Hydro-power	10^8 kwh	1266		2665		4008		5526	
	Mtce	49.63	4.76	95.95	6.37	132.3	6.47	176.8	6.95
Nuclear power	10^8 kwh	0		176		696		2080	
	Mtce	0		6.33	0.42	22.98	1.12	66.57	2.61
Renewables	10^8 kwh	1.02		24.17		108.79		330.31	
	Mtce	0.04		0.87	0.06	3.59	0.18	10.57	0.42
Subtotal	Mtce	1042	100	1505	100	2046	100	2545	100
Biomass	Mtce	268.07	20.46	270.09	15.21	262.57	11.38	233.01	8.39
Total	Mtce	1310	100	1776	100	2308	100	2778	100



Note: Figures in the shadows refer to the proportion of energy sources.

According to current government policies on energy, the focus of energy planning was to narrow the gap between energy demand and supply with little or no attention being given to environmental considerations. As a result, with macroeconomic structural adjusments, structural changes in industry, together with the widespread promotion of energy conservation programes, the mix of primary energy production has improved to a certain extent, in which the share of coal would decrease by about 10% within 30 years, i.e. from 74.25% in 1990 to 63.14% in 2020. Moreover, annual energy conservation rate is expected to reach 4.34% during 1990s, 3.97% during 2000s, 3.48% during 2010s, while energy demand elasticity is estimated at 0.47 during 1990s, 0.43 during 2000s and 0,40 during 2010s. The energy consumption per GNP would decrease by 35% in 2000, 57% in 2010 and 70% in 2020, compared to that in 1990. The energy savings (*jie neng liang*) over the 30 year period would appromixately accumulate to 2 billion tce (543 Mtce during 1990s, 715 Mtce during 2000s and 7.34 Mtce during 2010s), which is equivalent to a reduction of more than 30 Mt SO_2 emissions and one Bt of CO_2 emissions. (See Table 4-5, 4-6).

Table 4-5 Summary of energy demand projections over time horizon

	1990	2000	2010	2020
GNP growth rate, %		9.0	7.5	6.0
GNP, Billion Yuan RMB (Real 1990 price)	1767.6	4184.6	8624.6	15445.3
Population, Billion	1.143	1.294	1.390	1.450
Primary commercial energy consumptions, Mtce	987	1498	2053	2576
Per capita energy use (kgce),	863	1158	1478	1776
Energy use per unit GNP	0.56	0.36	0.24	0.17
Energy conservation rate, %		4.34	4.00	3.48
Annual growth rate of energy use, %		4.26	3.20	2.30
Energy/GNP elasticity		0.47	0.43	0.40
Energy consavings over one decade, Mtce		543	715	734

4.4.2. Environmental implications

1.Total pollutant emissions

Pollutant emissions from the entire energy system are given in Table 4-6.

Table 4-6 Pollutants emissions over time horizon

Pollutants	1990	2000	2010	2020
CO_2, Mt-C	647	1027	1369	1636
$SO_{2,}$ Mt	16.23	23.80	31.09	35.52
$NO_{x,}$ Mt	9.11	15.60	21.92	28.39
PM, Mt	11.49	17.99	24.59	29.63
CO, Mt	29.16	50.43	70.40	85.78
$CH_{4,}$ Mt	7.69	11.05	15.09	18.29

2.SO_2 emissions by sector

Sectoral SO_2 emissions are given in Table 4-7. It is obvious that although annual growth rate for total SO_2 emissions gradually decrease, total SO_2 emissions still reveal a difficult future. In addition, SO_2 emissions from power sector dramatically increase and contribute to over half of the total emissions in 2020, while that from households and industry sector steadily goes up.

Under current government policies, improvements in energy use efficiency are probably the most single important means to tackle China's growing problems of air pollution and greenhouse gas emissions. In addition to the direct positive impact of reductions in energy consumption, energy efficiency gains and environmental protection also are interwined. However, it is a fact that the total pollutant emissions would be extremely large, for example, SO_2 and CO_2 emissions are estimated at 35.50Mt (approximately 2 times as that in 1990) and 16.35 MtC (2.5 times as that in 1990), respectively. Thus, this will inevitably further degrade local, regional and global environment. As a result, there is an urgent need for a packages of additional policy interventions and adoption of additional mitigation options for reducing pollutant emissions.

Table 4-7 Sectoral SO_2 emissions and shares under BAU

	1990		2000		2010		2020	
	Emiss. Mt	Share %	Emiss. Mt	Share %	Emiss. Mt	Share %	Emiss. Mt	Share %
Household	2.91	18.00	3.39	14.24	3.66	11.77	3.70	10.41
Agriculture	0.48	3.00	0.53	2.22	0.58	1.86	0.61	1.72
Industry	6.08	37.46	8.08	33.95	9.32	29.98	9.12	25.68
Transport.	0.30	1.85	0.24	1.00	0.15	0.48	0	0
Building	0.11	0.68	0.13	0.56	0.15	0.48	0.15	0.43
Services	0.56	3.46	0.86	3.61	1.24	3.98	1.62	4.56
Power	5.10	31.40	9.50	40.00	14.49	46.61	18.06	50.84
Heat	0.52	3.20	0.82	3.44	1.16	3.73	1.86	5.23
Other	0.17	0.95	0.25	0.98	0.34	1.11	0.40	1.13
Total	16.23	100	23.8	100	31.09	100	35.52	100
Annual growth rate %			3.90		2.71		1.34	

4.5. Comparison among various studies

Recently, China conducted two similar studies, one, named GEF project, was finalized in 1994, which is entiled "China: Issues and Options in GreenHouse Gas Emissions Control", to be funded by Word Bank. Another, named ADB project, was finalized in 1993, which is titled "National Respone Strategy for Global Climate Chang: PRC" to be funded by Asian Developmnet Bank. Each project constructs a Business-as-usual or baseline scenario which estimates China's energy future and their results are listed in Table 4-8.

Table 4-8 China's energy future as estimated by the various studies

		1990	2000	2010	2020
Commercial	UNEP study	987	1498	2053	2576
energy use	GEF study	987	1560	2380	3300
Mtce	ADB study①	987	1490	1962	2434
CO_2	UNEP study	647	987	1369	1635
emissions	GEF study	650	1026	1512	2045
MtC	ADB study①	617	907	1190	1354
SO_2	UNEP study	16.23	23.80	31.09	35.50
emissions	GEF study	16.23	23.40	28.50	33.10
Mt	ADB study①	16.23	27.00	41.00	55.00

Note: ① ADB study divides time horizon into 1990-2000, 2000-2020 and 2020-2050, data in 2010 are calculated by UNEP team.

China's energy future is influenced by many factors which are interlinked, such as economic growth rate, population growth, structural changes in industry, energy efficiency, etc. Obviously, this will result in different results due to differing assumptions. When a comparison is carried out of some fundamental assumptions, it may be possible to know the reasons for the different projections for energy demands.

1. Economic growth rate

Faster economic growth can be expected to result in faster growth in energy use. The relationship between the two, however, is not linear. Energy/GDP elasticities are expected to be significantly lower if China's economy continues to grow more rapidly. Table 4-9 illustrates the assumptions with regard to economic growth rate and elasticities.

Table 4-9 Economic growth rate and elasticity from three studies

Variable		2000	2010	2020
GNP or GDP	UNEP study	9.0	7.5	6.0
growth rate	GEF study	9.5	8.5	6.5
%	ADB study	8.5	7.0	6.0
Energy/GDP	UNEP study	0.47	0.43	0.40
elasticity	GEF study	0.49	0.43	0.51
	ADB study	0.53	0.53	0.47
Energy	UNEP study	4.34	4.00	3.48
Conservation	GEF study	4.30	3.90	3.00
rate, %	ADB study	3.70	3.00	3.10

In the early 80s, the Chinese government stated that "By the end of Year 2000, GNP will quadruple that of 1980 and the people's living standard will come up to comfortable level, and by the middle of the next century, GNP per capita will attain that of middle-upper-developed country and people will live in a relatively rich manner, i.e. modernization will almost be achieved". In the 5th session under the 14th National Congress of Community Party to be held in 1995, the goal that "By 2010, GNP will double that of 2000" was set by the government. These implies that economic growth rate would reach 8-9% in 1990s, 7-8% in 2000s and 5-6% in 2010s, respectively. Therefore, the UNEP project accurately reflects the government's targets.

2. Population growth

The range of future population growth estimates from the three studies is relatively narrow. By 2020, China's population would reach under 1.45 billion which is the same for three studies.

3. Industrial structure

Each of three studies assumes that in the industrial structure, the share of the secondary industry gradually reduces, while the share of the tertiary or services sector is expected to increase sharply, largely offseting a fall in the primary industry contribution to GNP. Although there are a few differences among three studies, the overall effect of this macroeconomic structural change on energy demands is not large, because neither agriculture nor tertiary industry are energy-intensive sectors.

4. Technical energy efficiency

Reductions of energy and environmental loadings from technical energy efficiency improvement can be realized almost immediately. Both ADB and UNEP studies assume that key unit consumption parameters in 2020 would reach levels closely approximating advanced international levels in 1990, while GEF study assumes that equal efforts during 1980s in energy efficiency improvements would continue in furture, thus maintaining the energy-GDP elasticity at 0.5-0.6 between 1990 and 2020. Table 4-10 illustrates the differences among three studies with regard to key unit consumption parameters.

Table 4-10 Key unit consumption parameters from three studies

Product	Unit	Advanced international level in 1990	China 1990	2020 GEF	2020 ADB	2020 UNEP
Steel	kgce/t	629	1,610	1,284①	640	1,200①
Cement	kgce/t	113	208	196	115	130
Ammonia	kgce/t	1,000	2,066	1,665	1,000	1,350
Caustic soda	kgce/t	1,428	1,790	1,325	1,430	1,300
Gross net rate	gce/kwh	330	392	320	330	320
Boiler efficiency	%	75	55-60	70		72

① Overall energy consumption (not directly comparable with international statistics)

In addition to the above, the UNEP study drew upon the experience of other two studies for reference. This is expected to reflect government policies more closely.