China National Energy Strategy and Policy 2020

Subtitle 3: Adjustment and Optimization of Energy Supply Structure in China

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Adjustment and Optimization of Energy Supply Structure in China

(Executive Summary)

I. Challenges and Opportunities for Energy Supply Structure Adjustments and Optimization

After 20 years development since the Reform and Opening Up, China's energy industry has achieved great progress. The production of primary energy increased from 1039.2 Mtce in 1990 to 1390 Mtce in 2002, which made China the third largest energy production country after USA and Russia. With rapid economic growth and further opening up, China's energy mix began to change prominently, and the trend towards diversification has appeared. The proportion of coal in conventional energy consumption is reducing gradually. In 2002, the proportion has decreased to 66.3%. The proportion of oil and gas in energy consumption has increase evidently, and has reached 26.1%. The proportion of hydropower and nuclear power increased rapidly, and has reached 7.6%. Although the energy consumption mix has been somewhat optimized after more than 10 years effort, China is still one of the few countries that based on coal. The energy mix dominated by coal leads not only to low energy utilization efficiency, low economic benefits (especially in energy intensive industries), and weak product competitiveness, but also provides serious impact for Chinese environment. Firstly, coal mining has seriously destroyed land resource, which is already in very short supply in China. Statistics have showed that sinking areas that caused by coal exploitation has reached 15~20 thousand hectare, among which 30% is tillable field. Secondly, coal mining has destroyed groundwater resource. In 2000, the waste water emitted by coal mines has reached 2.75 billion tons. Thirdly, the waste gas emission in coal mining procedure has polluted atmosphere seriously. Fourthly, the pollution cased by coal use has brought heavy pressure for environmental protection in China. In year 2002, sulfur dioxide emission has reached 19.266 million tons, in which 90% is caused by coal combustion. Fifthly, the economic loss cased by environment pollution is great and the cost for reduce pollution is high. the economic loss brought by acid rain is about 2% of GNP.

Therefore, we can recognize that the energy mix dominated by coal is not suitable for the balanced development of economy, energy and environment, and the energy mix in China is facing serious challenge for its adjustment and optimization.

The 16th Communist Party Congress put forth the goal of "building a well-off society in an all-round way" by the year 2020, making efforts to achieve the goal of quadrupling the GDP of the year 2000 based on optimized structure and better economic returns. In order to achieve above objective, China will take a new road to

industrialization. Industries and product structure needs to be updated and optimized, and energy consumption in industrial field should take an optimized development road. Urbanization will be speeded up. It is estimated that in 2020, the proportion of people in city and town will reach 53~58%, which approaches current level in middle-income countries. This will lead to a shift in energy consumption manner. The quality of people's life will increase greatly, and the optimization of civil energy consumption will become a basic requirement and inevitable trend. All these factors above will drive the optimization of our final energy consumption mix, and finally lead to the gradual optimization of the primary energy mix in China.

With the acceleration of global economy and resource integration, and China's jointure in WTO, opportunities are provided for China to utilize global energy resource and optimize domestic energy mix. Technology advancement will provide safeguard for China's energy optimization, too. Therefore, adjustment energy mix and taking an optimized energy development road has become an inevitable choice of realizing "well-off society."

II. Energy Supply Capacity of China in 2010 and 2020

1．Coal resources and supply outlook

Using the international recognized method, the Ministry of Land and Resource has made a techno-economic assessment of detected coal resources recently, which concluded that the recoverable reserve of coal resources in China is 204 billion tons. If the reliable estimated coal resources within 1000 meters depth are considered, too, the total amount of remaining recoverable coal resources will reach 400 billion tons. If the recovery ratio is calculated as the State Owned Mine's 50%, and the annual production of raw coal is assumed to be 2.5 billion tons, the coal supply can sustain 80 years. Therefore, viewed from coal resources only, the supply of coal in China for medium-and-long term in the future can be guaranteed.

Based on the principle of sustainable development, the limitation of coal mining is the environment and water resources. However, up to now, there is no fixed conclusion of the maximum coal mining capacity for China. Based on the former research result, the scale of coal mining *cannot* exceed 3 billion tons per year within the water resources limitation. If additional environmental factors are considered, the coal mining maximum capacity should be far less than this level.

By considering coal exploitation and environment constraint together, we primarily believe that the maximum coal mining scale is *2.8 billion tons per year*. Within this exploitation scale, the principle for identifying domestic coal production capacity will be determined by demand, and with a little excess. The key of coal supply in the future will be the building of the new coal production capacity and infrastructure.

In year 2020, the production capacity of existing and building at present will be

710 tons. According to the Business As Usual Scenario, the energy demand at that time will be 230 billion tons. If the small coalmines are considered, total of 11 billion tons of coal production capacity should be newly built in state-owned mines in the next 20 years, which means 60 million tons new capacity should be built per year. This will be a heavy task.

2．Oil and gas resources and supply outlook

Generally, it is commonly agreed that the total recoverable reserve for oil is about 13~15 billion tons, also, some experts estimated that is merely 11.5 billion tons. Up to the end of year 2001, the accumulated detected reserve of oil resources in China is 21.8 billion tons, the accumulated provide recoverable reserve is 6.2 billion tons, and the remained recoverable reserve is 2.4 billion tons.

By synthesizing the research result of the different domestic institutions, it is estimated that the peak of oil production in China will be appeared near in 2015, with maximum crude oil production of 200 million tons or so. In 2020, the annual crude oil production will be 180~200 million tons.

The total amount of the recoverable reserve of natural gas in China is about 10~13 trillion cubic meters. The rate of exploration progress of natural gas resources is relatively fast in recent 10 years. By the end of 2001, the accumulated detected reserve of natural gas resources in China is about 3 trillion cubic meters, and the accumulated proved recoverable reserve is 2 trillion cubic meters. Remained proved recoverable reserve is 1.7 trillion cubic meters. It is estimated that the detected reserve and the proved recoverable reserve of the nature gas resources will be added respectively 2.2~2.6 and 1.5~2.0 trillion cubic meters in 2001to 2010.

The natural gas industry will be rapidly developed in the next 20 years. It is estimated that natural gas production in 2020 will reach to 130~150 billion cubic meters.

3．Hydropower resource and development outlook

The exploitable resources of national hydropower are 521 million kW, and the annual power generation will be 2.24 trillion kWh. By the end of year 2000, the hydropower capacity in China has reached 79.35 GW, which occupied 24.8% of total power generation capacity. The exploitation rate of hydropower resources is rather low at present, and that in different areas are different.. The exploitation rate of hydropower in year 2000 was about 15%.

According to the plans made by power generation industry, concerning about the building projects at present and the existing pre-works, under the fast hydropower development, the hydro power generation capacity in year 2010 will reach 125~155GW, and the exploitation rate of the hydropower resources will get to 24 percent~30 percent.

It is estimated that the hydropower generation capacity in year 2020 can reach 200~230 GW, with hydropower exploitation rate of 38 percent~44 percent.

4. Nuclear development outlook

For nuclear development in China, it is generally regarded that, the uranium resources in China will "be affluence in short-term, be guaranteed in medium-term, and be good potential for the long-term." Therefore, the barriers to nuclear power generation development in the future in China will be investment, technology and environment.

In 2000, the capacity of nuclear power generation is 2.1GW. In the "ninth five-year" period, 4 nuclear power generation projects (8 units, totally 6.7GW) came into construction. These 4 nuclear power generation projects are going to be commercially operated in year 2005. By then, the capacity of the nuclear power generation in China will reach 8.8 GW.

China has mastered nuclear power generation technology of the grade of 300 MW and mastered basically the design of 600MW Pressurized Water Reactor, 60 percent equipments can be manufactured domestically. But the independent design and localized manufacture of large scale of the nuclear power plants, such as the grade of 1000MW, still needs to be developed.

Presently, whether design capability, manufacture capability or fuel supply capability, China has no the conditions for the nuclear power plants development in a large scale. 4~8 units for 5 years is feasible. If the construction of the nuclear power will have been started at once, **6~8 units can come into operation in 2010, with 14~16 GW's nuclear power generation capacity. It is possible to achieve 32~50 GW's in 2020.**

5. Outlook for renewable energy development

The development and study of wind power generation began in the 1980's. By the end of 2002, the accumulate wind power generation onto grid has reached 460 MW.

Currently, the manufacture technology of 200~600kW wind power units has been mastered. The wind power generation units of 200kW, 250kW, 300kW and 600kW have been developed and has obtained successfully operating experience over 2 years, and the comprehensive performance indexes has reached the level in early 90's of foreign countries.

With the support of the incentive policies in China, the wind power generation will be developed rapidly by decreasing initial investment, increasing unit capacity, trying to make it in domestic.

Before 2010, the working focus should be in the coastal area. A series of wind power fields of 100 MW grade will be built. The bases of the 3 GW grade wind power will be built in Fujian, Guangdong and Inner Mongolia Province. Therefore, by 2010, the wind power generation capacity will reach 3~5 GW.

Around year 2010, the wind power field development will be focused in the Inner Mongolia, Hebei province, Northeast area, Ningxia and Gansu province. About 10 GW grade of wind power fields will be built. In addition, sea wind power fields will be developed, too, which hope be developed up to 5 GW. That is to say, in year

2020, the wind power generation capacity can reach 10~30GW.

III. Analysis of Energy Supply Scenarios in China

1. Scenario design

The objective of scenario design is to describe possible energy supply development tendency and the supply structure optimization level in the future 20 years in China through quantitative analysis. The analysis and assessment is done through different scenarios from different aspects such as resource availability, environmental impact, investment demand and social cost etc.

In the subproject report "Energy Demand Scenario Analysis to 2020", the final energy demand in the coming 20 years in China is analyzed and estimated through three scenarios. According to the result of that research, the final energy demand will increase from 985 Mtce in 2000 to 1424~1580~1620 Mtce in 2010, to 1905~2252~2484 Mtce in 2020. Based on the demand-supply estimates, the final energy demand of Scenario 2 is used as the Reference Scenario for energy supply analysis. Another Optimized Scenario is designed in addition to that one.

1） Reference Scenario

In this scenario, the final energy demand is a result of somewhat energy mix optimization. The primary energy supply amount, structure and investment need in the coming 20 years in China for the Reference Scenario is analyzed with the precondition of meeting the need of final energy demand.

2）Optimal Scenario －a scenario for intensified high-quality energy utilization

Based on Reference Scenario, the development and use of high-quality energy (natural gas, hydropower, nuclear power and renewable energy) is strengthened. The possibility of energy supply structure optimization under the pre-condition of meeting the need of final energy demand is analyzed.

In this scenario, the development of hydropower and nuclear power is strongly promoted. In 2010, compared with Reference Scenario, there is 30 GW additional hydropower capacity, 2 GW additional nuclear power capacity, 2 GW additional wind power capacity, 7.6GW natural gas based on meeting the demand of final power demand, the coal-fired power generation capacity decreased 30.80GW. In 2020, compared with Reference Scenario, there is 30 GW additional hydropower capacity, 1.8 GW additional nuclear power capacity, 2 GW additional wind power capacity, 3.0 GW natural gas based on meeting the demand of final power demand, the coal-fired power generation capacity decreased 77.60GW.

Moreover, natural gas is further used in towns, industrial boilers, and petrochemical industry to substitute coal.

As it is not encourage by Chinese government that fuel oil is used for power generation, however, Chinese government encourage oil conservation and substitute other energies for oil. Considering the above factors and oil supply security, petroleum demand in optimized scenario is the same as that in reference scenario.

2. Assumptions

Resource guarantee. The guarantee level of all energy resources for their supply. In the Reference Scenario, the production capacity of all domestic resources (except oil) used the values of the lower scenario of their supply potential analysis. In the Optimized Scenario, the production capacity of all domestic resources (except oil) used the values of the higher scenario. The production capacity of oil production equals the medium value of oil supply potential analysis.

Capital cost. Location variety, newly built and extended energy production capacity for the exploitation of all energy resources is considered. For the capital investment for all power generation technologies, not only present technological level is considered, but also the impact brought by future technology advancement is taken into account.

Import cost. The import cost of oil and natural gas is calculated by IEA's world oil and natural gas price estimation for the future 20 years, which was accomplished in 2002.

Environmental cost. SO_2 is one of the main pollutants in China. Compared with other pollutants, the SO_2 polluted area is quite large and with serious consequence. So, SO_2 pollution is listed as one of the key objectives for pollution control. The exploitation and utilization of coal is the main source of SO_2 emission, therefore, only ount of SO_2 emission set by State Environment Protection Bureau, that is SO_2 emissionthe direct economic loss from environmental and ecological devastation by coal mining and utilization is considered in the environmental cost.

Environment impact. SO_2 emission limitation is used as a key constrain for energy supply structure optimization. In the two scenarios, SO_2 emission in 2010 is to adopt the control am limitation in 2010 is 16 million tons. The SO_2 emission limitation in 2020 is to introduce the result of the subtitle of the project, that is SO_2 emission in 2020 will be controlled around 13.5 million tons.

Energy dependence level on foreign countries. For the oil supply security, the oil import reliance in 2010 in both scenarios will both be controlled below 45 percent, and below 55 percent in 2020. Considering the natural gas pipeline network construction and LNG import, in the Reference Scenario, the natural gas import reliance in 2010 is controlled below 15 percent, in the Optimized Scenario is controlled below 20 percent. In 2020, the import reliance in the Reference Scenario is controlled below 30 percent, with below 40 percent in Optimized Scenario.

Technology advancement. For renewable energy power generation technologies, only currently commercialized technologies or that can be commercialized by the year 2010 are considered. Technology advancement will promote the increase of power generation efficiency. It is estimated that the coal consumption for unit electricity generation in 2020 has 3 percentage lower than the value of 2000.

3. Estimation result

Based on above analysis, the estimation results of the two scenarios are listed in Table 1.

4. Conclusions

Based on the scenario analysis, the following conclusions are obtained:

1) To ensure GDP increasing by 4 times and sufficient energy supply for establishing a "well-off society" during the future two decades, Chinese energy output

Table 1 Primary Energy Supply

	Reference Scenario			Optimized Scenario		
	Standard quantity	Physical quantity	Structure (%)	Standard value	Physical quantity	Structure (%)
Year 2000						
Coal Mtce(Mt)	861.3	1206.3	66.1			
Oil Mtce(Mt)	320.5	224.3	24.6			
Domestic production	233.2	163.2				
Import	87.3	61.1				
Natural gas Mtce(Bm^3)	32.6	24.50	2.5			
Domestic production	32.6	24.50				
Hydropower Mtce(GW)(Inc. Small Hydropower)	82.3	79.35	6.3			
Nuclear power Mtce(GW)	6.1	2.10	0.5			
Renewable Energy Mtce(GW)	0.2	0.33	0.0			
Total （Mtce）	**1303.0**		**100**			
Year 2010						
Coal Mtce(Mt)	1301.2	1822.4	63.1	1166.9	1634.4	58.0
Oil Mtce(Mt)	457.3	320.0	22.2	457.3	320.0	22.7
Domestic production	257.2	180.0		257.2	180.0	
Import	200.1	140.0		200.1	140.0	
Nature gas Mtce(Bm^3)	119.7	90.0	5.8	159.6	120.0	7.9
Domestic production	105.1	79.0		133.0	100.0	
Import	14.6	11.0		26.6	20.0	
Hydropower Mtce(GW)(Inc. Small hydropower)	148.8	125.0	7.2	184.5	155.0	9.2
Nuclear power Mtce(GW)	33.3	14.0	1.6	38.1	16.0	1.9
Renewable energy Mtce(GW)	2.3	3.0	0.1	3.9	5.0	0.2
Total （Mtce）	**2062.6**		**100**	**2010.3**		**100**
Year 2020						
Coal Mtce(Mt)	1648.7	2309.1	59.0	1339.1	1875.5	50.2
Oil Mtce(Mt)	600.2	420.0	21.5	600.2	420.0	22.5
Domestic production	271.5	190.0		271.5	190.0	0.0
Import	328.7	230.0		328.7	230.0	0.0
Nature gas Mtce(Bm^3)	239.4	180.0	8.6	332.5	250.0	12.5
Domestic production	172.9	130.0		199.5	150.0	0.0
Import	66.5	50.0		133.0	100.0	0.0
Hydropower Mtce(GW)(Inc.	231.0	200.0	8.3	265.7	230.0	10.0

Small hydropower)						
Nuclear power Mtce(GW)	68.6	32.0	2.5	107.3	50.0	4.0
Renewable energy Mtce(GW)	7.6	10.0	0.3	22.8	30.0	0.9
Total （Mtce）	**2795.5**		**100**	**2667.5**		**100**
2001~2020 total investment, trillion Yuan *	63099			64484		
2001~2020 Env. Cost	23814			21193		
Emissions in 2000						
SO_2, Mt	19.93					
NO_X, Mt	7.43					
CO_2, Mt	2939.07					
Emissions in 2010						
SO_2, Mt	16.16			16.01		
NO_X, Mt	11.21			10.08		
CO_2, Mt	4523.91			4253.97		
Emissions in 2020						
SO_2, Mt	13.56			13.37		
NO_X, Mt	14.22			11.62		
CO_2, Mt	5945.24			5325.11		

Notes: Constant price in 2000. Environmental cost means the direct economic losses of ecologic and environmental damages derived from exploring and utilizing coal resource.

should be doubled accordingly.

It is expected that the output of primary energy will be increased from 1303 Mtce in 2000 to 2063~2010 Mtce in 2010 and 2795~2667 Mtce in 2020. Up to 2010, coal output will be increased to 1822~1634 Mt, crude oil to 320 Mt (with the imported of 140 Mt), natural gas to 90~120 Bm^3 (with the imported of 11~20 Bm^3), hydropower to 125~155 GW, nuclear power to 14~16 GW, power generated by new and renewable energy to 3~50 GW. Up to 2020, outputs of said energy are expected to be increased further, such as coal to 2310~1870 Mt, crude oil to 420 Mt (with the imported of 230 Mt), natural gas to 180~250 Bm^3 (with the imported of 50~100 Bm^3), hydropower to 200~230 GW, nuclear power to 32~50 GW, power generated by new and renewable energy to 10~30 GW.

Considering that the economy might overheat and energy demand might exceed the prediction in the future, energy supply capacity of China should leave enough flexibility and potential for further expansion.

2) Fully exploring domestic high-quality energy resources and utilizing overseas high-quality energy resources will markedly reduce the consumption of coal resource and total amount of energy consumption.

Research shows that Chinese primary energy structure is expected to change greatly in 2020, provided energy policies are readjusted and relevant measures are

taken. Although coal will be still in the first place in 2020, the proportion of coal in the energy structure will decrease from 66.1 percent of 2000 (excluding biomass energy) to 50.2 percent (the optimized scenario) and 59 percent (the Reference scenario).

If the investment and the exploitation & utilization of natural gas, hydropower, nuclear power and renewable energy are both enhanced, according to the optimized scenario, demand of primary energy in 2020 will drop by 4.6 percent compared with that of the Reference scenario, using less energy of 128 Mtce.

3) Limited by domestic production capacity for oil and natural gas, the imported amount will increase fast, and the import dependence of oil and natural gas will also increase.

It is predicted that imported amount of oil and natural gas will increase from 61 Mtoe of 2000 to 150.2~158.6 Mtoe in 2010, by 9.4~10 percent annually, and to 276.5~323.Mtoe in 2020, by 6.3~7.4 percent annually. The import dependence of energy will increase from 7 percent of 2000 to 10.4~11.3 percent in 2010 and 14.1~17.3 percent in 2020. The import dependence of oil and natural gas will increase from 27.2 percent to 37.2~36.7 percent in 2010, and 47.1~49.5 percent in 2020.

4) In order to control pollutions to the environment, apart from enhancement of using high-quality energy resources, restrict measures should be taken in coal process plants for emission reduction.

Research shows that desulphurization equipment will be required for new installed capacity in coal burning power station for the both scenarios in 2010 and 2020, so that to meet the goal of controlling SO_2 emission. In 2010, desulphurization device need to be installed for 70 percent of old machine set of coal burning plant in the Reference scenario, and for 48 percent in the optimized scenario. In 2020, desulphurization device is needed for all old machine set in the Reference scenario, and still for 48 percent in the optimized scenario.

5) Enhancing the use of high-quality energy resources and reducing coal consumption can bring both sound social and economic benefits.

It can reduce direct economic losses of ecologic and environmental damages derived from exploring and utilizing coal resource by enhancing the use of high-quality energy resources and reducing the use of coal resource. Through research, it is learned that in the optimized scenario the external cost for ecologic and environmental damages that are derived from exploring and utilizing coal resource will be RMB262.1 billion yuan less than that of the Reference scenario (the economic losses in the optimized scenario is dropped by 11 percent compared with that of the Reference scenario), which is far more than the additional investment (RMB139.3 billion yuan) that is required for replacing the Reference scenario with the optimized scenario.

6) It is impossible to rely on sole energy resource to restructure and optimize Chinese energy structure, however, the optimization of energy structure calls for fully use of two kinds of resources and two markets, and multiple high-quality energy resources.

7) Apart from restructuring and optimization of primary energy, the end-use energy consumption structure should be optimized as well. The analysis of the

optimized scenario shows that the proportion of power generation by coal burning will be improved from 50 percent of 2000 to 52 percent in 2010 and 77 percent in 2020. However, it should promote the replacement of coal with natural gas and power amongst end users, such as to substitute natural gas for chemicals and fuel used for middle- and small-size boilers, furnaces, kilns and civil cooking etc., so that to improve the terminal utilization of natural gas and reduce the proportion of coal in energy structure.

IV. Energy Strategy

The energy supply strategy in China will be:

To guarantee energy supply: providing sufficient energy for quadrupled future GDP growth and building a well-off society, and make great efforts to enhance the supply security degree;

To optimize energy mix: reducing the coal consumption as soon as possible and increasing the proportion of high-quality energy utilization;

To be clean and high efficiency: being clean and high efficiency in exploiting and utilization energy resources: development the energy resources that are friendly to environment, extending the utilization techniques of clean energy resources, protecting and improving entironment, and increasing energy efficiency and benefit;

To be economic and rational: allocating and utilization energy resources economically and rationally, providing knight service with the minimum cost.

V. Policy Recommendations

1. To establish risk fund, increase investment to basic exploration, improve system of commercial investigation, strengthen the safeguard degree of the backup energy resource, especially high-quality energy resource, by enhancing the exploration of energy resource,

According to the Business As Usual Scenario, the demand for primary energy in China will reach to 2.796 billion tce in 2020, of which including 2.3 billion tons of coal. However, the total production capacity of the existing and under-constructing state coal mine in China will be about 0.71 billion tons by then. Taking into account the production capacity of small-scale coal mine, about 1.25 billion tons of production capacity of state coalmine should be added. According to the construction regulations of the coal mine, 175 billion tons of proved reserves for large and medium scale coal mine are needed. Currently, the un-utilized proved reserves are only 61.7 billion tons, some of them cannot be utilized due to the constraints of geographic and mining condition, some others is only suitable for local small-scale mining, the proved reserves suitable for large-scale mining are only 30-40 billion tons. Therefore, the coal proved reserves in support for large and medium scale mining are very

insufficient.

Since 1990s, the investment system of coalfield exploration has been changed greatly with the transformation of economic system. The nation will be only responsible for the payment on the initial exploration, the project owners should take the duty of the exploration of the proved reserves. However, the majority of coal corporations is still in a hot water, there is no sufficient capital for resource exploration, therefore, the investment on coal exploration is very limited, and the geological work of coal mining is almost in logjam. The exploration of coalfield should be strengthened, and the investment on commonwealth exploration should be increased, the investment system of commercial exploration should be improved, the proved rate of coal resources should be greatly elevated, and the backup industrial reserves in support should be enlarged to meet the demand of the new built mines.

The detected rates of oil and gas resources in China are very low, only 23 percent and 10.7 percent respectively, and have large potential to be increased. However, since the regroup and reformation of oil industry, the work of perspective investigation and development strategic orientation of oil resource has been declined. The oil company will not undertake the work of basic oil investigation. The governmental departments are in the transitional period of reformation and restructuring, and haven't efficiently organize the national work on oil and gas resource investigation and assessment, leading to the severe deficiency of the backup resource and area for oil and gas. Currently, the detected recoverable reserves of oil resources in China are 2.4 billion tons, the proportion of marginal resource is large, so the backup resources is seriously insufficient.

A new investigation on oil and gas resources in whole China should be carried out, based on new oil and gas geographic theories and assessment methods, to make clear the strategic backup area of oil and gas resources. The domestic oil and gas exploration should be strengthened. Venture fund for exploration should be set. The risk exploration by oil companies should be encouraged. Policies should be established to encourage and promote oil companies to set annual specific proportion of capital for the risk exploration.

Investigation and research on renewable energy (hydropower, wind, biomass, geothermal energy, and etc.) should be carried out, to scientifically confirm the total quantity, the technical developable quantity and the status of renewable energy resource, to provide basis for planning rational utilization of renewable energy.

2. Implement the capitalized management of energy resources, set preferable price to the high-quality energy sources, strengthen the monitor of resources exploited, and improve the mining rate of resource.

Driven by economic profit, there is a waste of resources, such as " only mining the thick coal-bed and discard the thin coal-bed" in some of the coal production enterprises, especially in the areas with abundant coal resource or fine mining conditions. The resources recovery rates in some small mines are less than 20 percent, so the damage and waste of resources are very serious. Currently, the taxation was

based mainly on the coal outputs in China, and the resources value discrepancy of the different coal quality and the different recovery condition has not been embodied. The market system of coal resources should be established; the capitalized management on coal resource should be implemented; rational resources price should be set on the basis of coal quality, recovery condition, natural status and etc, the preferable price should be set for high-quality resources. Practical monitoring methods should be taken; the basic work of resources management during mining process should be enhanced; the resources waste should be deterred relying on the law; and the resources recovery rate should be improved.

There is a problem of "different quality with same price" in oil and gas industry . The proportion of heavy oil, dense oil and low-penetration oil production will be increased. The proportions of "three low" types of natural gas resources will also be high. To effectively develop and utilize the unconventional oil and natural gas resources, the resources tax and mineral resources compensatory fee on the heavy oil, the high solidification oil the third oil recovery and "three low" types of natural gas should be reduced; the policies toward gangue recovery should be set to promote the development and utilization of old oil field and the low-penetration oil field.

3. The effective approaches of energy mix optimization in China are to give priority to the development of hydropower, to accelerate the development of nuclear power, and to actively develop the new and renewable energy.

China should resume the prophase work on hydropower, enhance the exploration of water resources and hydropower planning, and add the hydropower backup projects. The medium and long-term plan of hydropower should be reinforced. From the standpoint of national economic development, energy mix adjustment and sustainable development, the west hydropower base should be organically combined with the electric power plan in the east electricity receiving areas. The local electricity market should be opened gradually, to optimize the resource in the maximum areas. Equity should be given to hydropower in taxation and other policies.

China should make medium and long-term plan of nuclear power from the standpoint of energy supply security, energy mix optimization, environmental protection and keeping the national nuclear technique advance ability. During the construction of nuclear power projects, the government should give support in the aspects of the favorable financing policies, payback term and etc. The 1 GW Pressurized Water Reactor development route should be kept on; international technical improvement and renovation experiences should be applied, the batch of 1 GW grade nuclear power station should be constructed; the nuclear equipment supply, construction and management should be localized as soon as possible. The monopolization of nuclear power construction and production should be broken, other power companies should be allowed to participate in the construction and production of nuclear power to completely solve the problem of high cost on nuclear power plant and grid price in China. Specific organizations should be set to coordinate and uniform the important issues, such as the technical approaches, equipment localization

and inviting foreign public bidding.

The prophase work on the wind energy resources assessment and the wind field construction should be accelerated, and the wind power equipment manufacture technology should be improved, to create a good condition for the development of the wind power in China. The Stimulant policies of the renewable energy development should be set, the development goal for renewable energy should be definite, to give rational priority to the development of the indispensable renewable energy in the future. Specific renewable energy funds should be set, the renewable energy investment channel should be established, and the favorable policies of the derating tax should be carried on to the renewable energy in China.

4. Make great efforts to bring the action of "two resources and two markets" in to play, to accelerate energy mix optimization in China.

According to the Regular scenario, in year 2020, the international reliance of oil and gas in China will reach 54.8 percent and approximately 30 percent respectively. Therefore, the strategy of internationalization should be kept carrying on, and the development acceleration and rate increasing for oil companies to share oversea oil and gas resources should be encouraged. The approval procedure for oil companies to invest in the overseas oil resources should be simplified; the coordination of overseas business of three big oil companies should be reinforced, to avoid bad competition among of the national enterprises in oversea market; the government should give necessary diplomatic and military support and guarantee for the oversea business of oil companies. China should actively enter the international oil market, take the international market as the main approach for acquiring oversea oil and gas resources, and participate in the spot transactions and time-bargain in the international oil market.

In recent years, China has made some favorable policies to encourage coal export for the coal enterprises to develop. However, from the long-term standpoint, China should not take the coal exportation as the development strategy of coal industry. On the contrary, some coal import from neighboring countries should be encouraged in the southeast coastal areas to meet the demand of local economic development, not only to mitigate the environment pressure brought by the coal resources exploiting, but also to reduce the growing gradually pressure in coal transportation.

5. Taking comprehensive measures to improve energy supply security of China

In the coming 20 years, the basic domestic demand can be supported by the domestic oil and natural gas production. The growth of economy will make China be able to import energy to make up the insufficiency of domestic supply. Future the problem of the energy supply security will be caused mainly by the instability of oil supply countries, and oversea oil transportation channel.

The strategy of increasing oil imports should be actively carried on. Firstly,

attach importance to diverse import sources and import locations, take active measures to increase the oil imports from Russia and Central Asia area, to raise the proportion of crude oil import from Africa and Latin America areas. Imports from Middle East should be scattered in the different countries too. The dispersion oil import sources and locations will not only benefit the oil supply security for China, but also help to solve the discriminating price importing cured oil from the Middle East area. Secondly, mobilize local entities, enterprises and nongovernmental organizations, and use various ways to establish a sound oil stockpile system to avoid accidental interruption. Thirdly, carrying on the area energy co-operation, and establish reciprocal area oil security system through participating in the international and area energy co-operation organizations. Shanghai Cooperation Organization should be used to strengthen our energy cooperation with Central Asia and Russia. Energy mutual cooperation among of the countries in the Northeast Asia should be enhanced, while oil and natural gas import pipeline project should be regarded as an important composition of our foreign trade, to promote the construction of oil and natural gas transportation pipeline among of the countries in Northeast Asia. Dialogue and cooperation with Southeast Asia area should be put up to solve the problem of oil and gas resources exploitation in South China Sea and the security of transportation channel at sea. For the oil and gas resources in South China Sea, besides laying the disputes aside, we should exploit actively. For the fourth, we should not miss the chance of participating in Energy Charter Treaty to increase the security of the cross-bordered oil and natural gas pipeline between China, Russia and Central Asia countries.

Because the supply security of natural gas and electricity will influence directly the living of all people, it should be high lighted. For the supply side, there should be multiple supply sources of the natural gasand the main pipelines and branch pipelines should form a grid. The oil or gas in different pipelines can be adjusted. Proper scale underground gas storage should be established to solve the peak load problem. For the demand side, the user structure of natural gas should be rational. Some gas air-conditioners and tri-generators should be developed to cut peak period and fill valley, which helps to reduce the peak-valley difference and to improve the security of natural gas supply.

The construction of electricity grid should be developed in ahead. The planning and controlling of electricity grid should be unified. The construction of the power sources should be developed in a measurable advance to guarantee the necessary backup capacity. The structure of electricity grid should be improved to increase the capability of coping with the accidents. In order to improve the electric grid reliability and realize the resources optimization, the hydropower and thermal power among different grids should complementary and exchanged**.(ignore)** The security of electricity system should be attached much importance. New investment and financing mechanism should be established for the development of electricity grid, which should solve utterly the financial problem. . A rational electricity price generation mechanism should be established. The prices in the different processes of generation and transmit electricity should be rational, the current situation of the

low price in the power transportation and distribution should be changed, and the proportion of the grid sector should be increased.

6. Carrying on the clean coal utilization strategy, and promoting industrialization of the related clean coal technologies, with special choice and emphasis, are the strategic measure to guarantee the sustainable development in China

Research result had showed that no matter which scenario is selected, coal would play an important role in future energy supply system in China. Developing and promoting clean coal technology is the strategic choice to guarantee the sustainable development in China.

According to the demand estimation result, in 2020, coal demand will reach about 2.3 billion tons, of which 70~75 percent will be used for power generation and heat supply, 10 percent for industrial boilers, 7 percent for coke making, 4 percent for chemical raw material and 3~4 percent for civil use.

Therefore, clean coal power generation technology should be attached importance in China in the future. Super critical and ultra-super critical units should be promoted as main units for future power generation. Circulating Fluidized Bed Combustion (CFBC) will be developed as complementary units. Integrated Gasification Combined Cycle (IGCC) and Pressurized Fluidized Bed Combustion (PFBC) demonstrations should be planned and arranged. The desulfurization technology of the flue gas and the low NOx combustion technology should be promoted in a large scale. . The retrofit for industrial boilers should be strengthened, and advanced industrial boilers should be developed actively.

Coal washing and selection is the source of clean coal utilization. The proportion of selected coal should be increased. So, a series of coal selection plants should be retrofitted and constructed, the large coal mines should be equipped with coal selection plants, and the small coal mines should use the coal selection plants of the nearby big mines, or many small mines construct one coal selection plant together.

New clean coal utilization approaches should be actively researched, including coal slurry technology, poly-generation technology for coal chemistry, coal liquefaction, and gasification, and underground coal gasification technology..

7. Based on the economic principle, utilization rationally high-quality energy properly

The external costs such as ecological loss, environment destruction, and heath damage etc, which is caused by coal mining, transportation and utilization, should be calculated into coal price in the future gradually. In order to promote the optimization of China's energy mix, the coal price should be raised to a rational level to increase the competition capability of high-quality energy. Secondly, a reasonable natural gas pricing mechanism should be formed as soon as possible to propel the usage of natural gas. The goal of natural gas pricing reform in China should be changed from

determined by cost into determined by value. For different users, different alternative energy should be identified, which helps to decide natural gas price of different users. Thirdly, considered from long-term development, the affordability of commercial and civil use of natural gas will be higher in the future, so the natural gas market for commercial and civil use should be developed with higher priority. In the initial stage of natural gas development, in order to promote the development of natural gas industry and accelerate the start-up of natural gas market in China, the big and stable users, such as power plants and chemical plants, should be offered with favorable gas price or favorable policy in taxation. The fourth is to reduce the inconsistency of power generation and coal industry to make these two industries economical, rational and equal. Coal enterprises and power generation enterprises can be combined to form strategic alliance. Through holding, sharing or controlling each other's stock, various capitals could be combined, merged or re-structured to form mixed operation. In this way, coal price can be stabilized. In one hand, it can solve the problem that coal enterprises only offers primary products, can extend the industry chain of coal enterprises, and let coal enterprise use resource advantage to infiltrate into power generation. On the other hand, the stability of coal price and coal supply for power generation enterprises could be guaranteed, and the risk of supply is reduced. In order to achieve the goal of participating competition from the source side, power generation enterprises should pervade into coal industry by investing in new mine, and merge or purchase existing coal mine. A reasonable price system should be studied and developed. Levers such as price should be used to lead consumers to choose economic and proper end-use energy consumption devices such as, high energy-efficient air-conditioners.

Adjustment and Optimization of Energy Supply Structure in China(Report)

I. Challenges and Opportunities for Energy Supply Structure Adjust and Optimization

After 20 years development since reform and opening up, China's energy industry has achieved great progress. The production of primary energy increased from 1039.2 Mtce in 1990 to 1390 Mtce in 2002(Fig.1-1), which made China the third

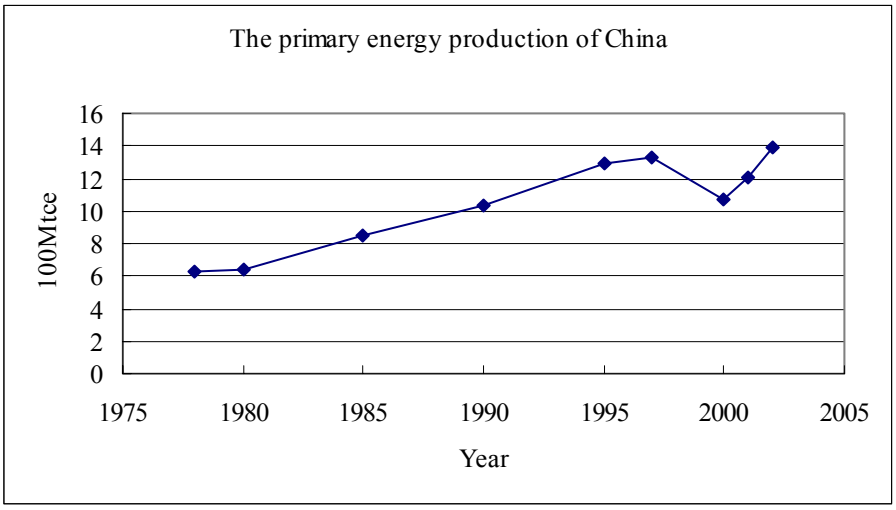

Fig.1-1 The Development Trend of Primary Energy Production in China

largest energy producing country after the United Statesand Russia. With rapid economic growth and further opening up, China's energy mix began to change prominently, and the trend towards diversification has appeared. The proportion of coal in conventional energy consumption is reducing gradually. In 2002, the proportion has decreased to 66.3 percent. The proportion of oil and gas in energy consumption has increase evidently, and has reached 26.1 percent. The proportion of hydropower and nuclear power increased rapidly, and has reached 7.8 percent(Fig.1-2). Although the energy consumption mix has been somewhat optimized after more than 10 years effort, China is still one of the few countries that based on coal(Table 1-1). The energy mix dominated by coal leads not

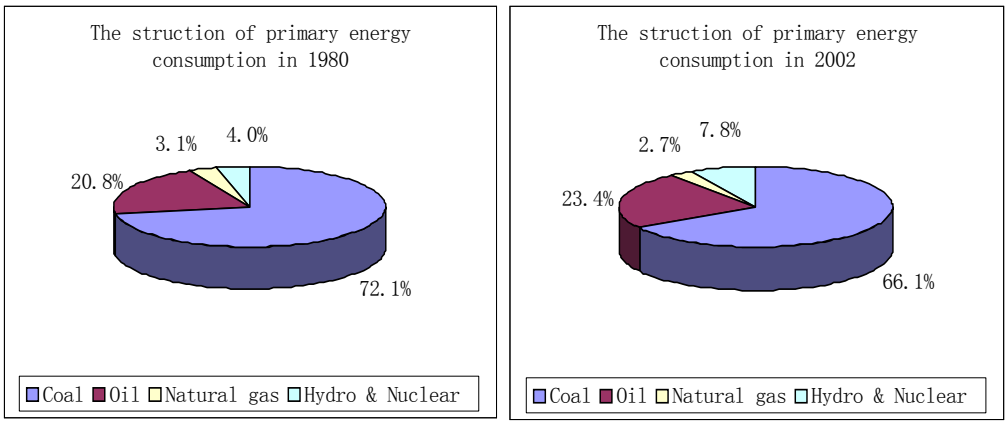

Fig.1-2 The Structure of Primary Energy Consumption in China

Table 1-1 Primary Energy Consumption Mix in the World in 2002

	Oil (%)	Natural Gas(%)	Coal (%)	Nuclear (%)	Hydro (%)	Total (Mtoe)
USA	39.0	26.2	24.2	8.1	2.5	2,293.0
North America	**39.2**	**26.2**	**21.8**	**7.5**	**5.2**	**2,715.4**
Argentina	31.4	50.8	1.1	2.4	14.2	53.5
Brazil	48.1	6.9	6.8	1.9	36.3	177.5
S. & Cent. America	**47.9**	**19.7**	**4.0**	**1.0**	**27.4**	**448.2**
Europe & Eurasia	**32.7**	**33.2**	**17.9**	**9.9**	**6.3**	**2,829.5**
Middle East	**51.5**	**45.9**	**2.1**		**0.5**	**403.1**
Africa	**40.8**	**20.9**	**31.1**	**1.0**	**6.4**	**291.0**
Australia	33.7	19.1	43.8		3.4	112.9
China	24.6	2.7	66.5	0.6	5.6	997.8
Hong Kong SAR	63.6	10.2	26.2			20.6
India	30.1	7.8	55.6	1.4	5.2	325.1
Japan	47.6	13.7	20.7	14.0	4.0	509.4
Malaysia	43.4	46.9	6.4		3.3	51.8
South Korea	51.0	11.5	23.9	13.1	0.6	205.8
Asia Pacific	**36.5**	**10.9**	**43.5**	**4.3**	**4.7**	**2,717.8**
TOTAL WORLD	**37.5**	**24.3**	**25.5**	**6.5**	**6.3**	**9,405.0**
European Union 15	43.2	23.6	14.8	13.7	4.7	1,468.9
OECD	40.8	23.1	20.9	9.8	5.4	5,346.1
Former Soviet Union	17.8	54.1	17.0	5.6	5.5	946.1

Source: BP statistical review of world energy 2003, www.bp.com

only low energy utilization efficiency, low economic benefit (especially in energy intensive industries), and weak product competitiveness, but also provides serious impact for Chinese environment. Firstly, coal mining has seriously destroyed land resource, which is already in very short supply in China. Statistics have showed that sinking areas that caused by coal exploitation has reached 15~20 thousand hectare, among which 30 percent is tillable field. Secondly, coal mining has destroyed

groundwater resource. In 2000, the waste water emitted by coal mines has reached 2.75 billion tons. Thirdly, the waste gas emission in coal mining procedure has polluted atmosphere seriously. Fourthly, the pollution cased by coal use has brought heavy pressure for environmental protection in China. In year 2002, sulfur dioxide emission has reached 19.266 million tons, in which 90 percent is caused by coal combustion. Fifthly, the economic loss cased by environment pollution is great and the cost for reduce pollution is high. the economic loss brought by acid rain is about 2 percent of GNP.

Therefore, we can recognize that the energy mix dominated by coal is not suitable for the coordinate development of economy, energy and environment, and the energy mix in China is facing serious challenge for its adjustment and optimization.

The 16th Communist Party Congress had raised the goal of building a well-off society in an all-round way by the year 2020, making efforts to achieve the goal of quadrupling the GDP of the year 2000 based on optimized structure and better economic returns. In order to achieve above objective, China will take a new road to industrialization. Industries and product structure needs to be updated and optimized, and energy consumption in industrial field should take an optimized development road. Urbanization will be speeded up. It is estimated that in 2020, the proportion of people in city and town will reach 53~58 percent, which approaches current level in middle-income countries. This will lead to a shift in energy consumption manner. The quality of people's life will increase greatly, and the optimization of civil energy consumption will become a basic requirement and inevitable trend. All these factors above will drive the optimization of our final energy consumption mix, and finally lead to the gradual optimization of the primary energy mix in China.

With the acceleration of global economy and resource integration, and China's jointure in WTO, opportunities are provided for China to utilize global energy resource and optimize domestic energy mix. Technology advancement will provide safeguard for China's energy optimization, too. Therefore, adjustment energy mix and taking an optimized energy development road has become an inevitable choice of realizing well-off society all-roundly.

II. Energy Supply Capacity of China in 2010 and 2020

1．Coal resources and supply outlook

Using the international recognized method, Ministry of Land and Resource has made a techno-economic assessment of detected coal resources recently, which concluded that the recoverable reserve of coal resources in China is 204 billion tons. If the reliable estimated coal resources within 1000 meters depth are considered, too, the total amount of remaining recoverable coal resources will reach 400 billion tons.

If the recovery ratio is calculated as the State Owned Mine's 50 percent, and the annual production of raw coal is assumed to be 2.5 billion tons, the coal supply can be sustained 80 years. Therefore, viewed from coal resources only, the supply of coal in China for medium-and-long term in the future can be guaranteed.

Based on the principle of sustainable development, the limitation of coal mining is the affordability of environment and water resources. However, up to now, there is no fixed conclusion of the maximum coal mining capacity for China. Based on the former research result, **the scale of coal mining cannot exceed 3 billion tons per year within the water resources limitation**. If additional environmental factors are considered, the coal mining maximum capacity should be far less than this level.

By considering coal exploitation and environment constraint together, we primarily believe that **the maximum coal mining scale is 2.8 billion tons per year. Within this exploitation scale, the principle for identifying domestic coal production capacity will be of "determined by demand, and with a little excess". The key of coal supply in the future will be the building of the new coal production capacity and infrastructure.**

In year 2020, the production capacity of existing and building at present will be 710 tons. According to the Regular Scenario, the energy demand at that time will be 230 billion tons. If the small coal mines are considered, total of **11 billion tons of coal production capacity should be newly built in State Owned Mines in the next 20 years, which means 60 million tons new capacity should be built per year.** This will be a heavy task.

2．Oil and gas resources and supply outlook

Generally, it is commonly agreed that the total recoverable reserve for oil is about 13~15 billion tons, also, some experts estimated that is merely 11.5 billion tons. Up to the end of year 2001, the accumulated detected reserve of oil resources in China is 21.8 billion tons, the accumulated provide recoverable reserve is 6.2 billion tons, and the remained recoverable reserve is 2.4 billion tons.

By synthesizing the research result of the different domestic institutions, **it is** estimated **that the peak of oil production in China will be appeared near in 2015, with maximum crude oil production of 200 million tons or so. In 2020, the annual crude oil production will be 180~200 million tons.**

The total amount of the recoverable reserve of natural gas in China is about 10~13 trillion cubic meters. The rate of exploration progress of natural gas resources is relatively fast in recent 10 years. By the end of 2001, the accumulated detected reserve of natural gas resources in China is about 3 trillion cubic meters, and the accumulated proved recoverable reserve is 2 trillion cubic meters. Remained proved recoverable reserve is 1.7 trillion cubic meters. It is estimated that the detected reserve and the proved recoverable reserve of the nature gas resources will be added respectively 2.2~2.6 and 1.5~2.0 trillion cubic meters in 2001to 2010.

The natural gas industry will be rapidly developed in the next 20 years. It is estimated that natural gas production in 2020 will reach to 130~150 billion cubic

meters.

3．Hydropower resource and development outlook

The exploitable resources of national hydropower are 521 million kW, and the annual power generation will be 2.24 trillion kWh. By the end of 2000, the hydropower capacity in China has reached 79.35 GW, which occupied 24.8 percent of total power generation capacity. The exploitation rate of hydropower resources is rather low at present, and that in different areas are different. The exploitation rate of hydropower in 2000 was about 15 percent.

According to the plans made by the power generation industry, taking in consideration current construction and existing projects, under fast hydropower development path, the hydropower generation capacity in year 2010 will reach 125~155GW, and the exploitation rate of the hydropower resources will reach 24-30 percent.

It is estimated that the hydropower generation capacity in year 2020 can reach 200-230 GW, with hydropower exploitation rate of 38-44 percent.

4. Nuclear development outlook

F**or nuclear development in China,** it is generally regarded that**, the uranium resources in China will "be affluence in short-term, be guaranteed in medium-term, and be good potential for the long-term"**. Therefore, the barriers to nuclear power generation development in the future in China will be investment, technology, and environment.

In 2000, the capacity of nuclear power generation is 2.1GW. In the "ninth five-year" period, 4 nuclear power generation projects (8 units, totally 6.7GW) came into construction. These 4 nuclear power generation projects are going to be commercially operated in year 2005. By then, the capacity of the nuclear power generation in China will reach 8.8GW.

China has mastered nuclear power generation technology of the grade of 300 MW and mastered basically the design of 600MW Pressurized Water Reactor, 60% equipments can be manufactured domestically. But the independent design and localized manufacture of large scale of the nuclear power plants, such as the grade of 1000MW, still needs to be developed.

Presently, whether design capability, manufacture capability or fuel supply capability, China has no the conditions for the nuclear power plants development in a large scale. 4~8 units for 5 years is feasible. If the construction of the nuclear power will have been started at once, **6~8 units can come into operation in 2010, with 14~16 GW's nuclear power generation capacity. It is possible to achieve 32~50 GW's in 2020.**

5. Outlook for renewable energy development

The development and study of wind power generation began in the 1980's. By

the end of 2002, the accumulate wind power generation onto grid has reached 460 MW.

Currently, the manufacture technology of 200~600kW wind power units has been mastered. The wind power generation units of 200kW, 250kW, 300kW and 600kW have been developed and has obtained successfully operating experience over 2 years, and the comprehensive performance indexes has reached the level in early 90's of foreign countries.

With the support of the incentive policies in China, the wind power generation will be developed rapidly by decreasing initial investment, increasing unit capacity, trying to make it in domestic.

Before 2010, the working focus should be in the coastal area. A series of wind power fields of 100 MW grade will be built. The bases of the 3 GW grade wind power will be built in Fujian, Guangdong and Inner Mongolia Province. Therefore, by 2010, the wind power generation capacity will reach 3~5 GW.

Around year 2010, the wind power field development will be focused in the Inner Mongolia, Hebei province, Northeast area, Ningxia and Gansu province. About 10 GW grade of wind power fields will be built. In addition, sea wind power fields will be developed, too, which hope be developed up to 5 GW. That is to say, in year 2020, the wind power generation capacity can reach 10~30GW.

III. Design of Energy Supply Scenarios in China

1. Scenario design

The objective of scenario design is to describe possible energy supply development tendency and the supply structure optimization level in the future 20 years in China through quantitative analysis. The analysis and assessment is done through different scenarios from different aspects such as resource availability, environmental impact, investment demand and social cost etc.

In the subproject report "Energy Demand Scenario Analysis up to 2020", the final energy demand in the coming 20 years in China is analyzed and estimated through 3 scenarios. According to the result of that research, the final energy demand will increase from 985 Mtce in 2000 to 1424~1580~1620 Mtce in 2010, to 1905~2252~2484 Mtce in 2020. Based on the demand-supply estimation, the final energy demand of scenario 2 is used as the Reference Scenario for energy supply analysis. Another Optimized Scenario is designed beside that one.

1) Reference Scenario

In this scenario, the final energy demand is a result of somewhat energy mix optimization. The primary energy supply amount, structure and investment need in the coming 20 years in China for the Reference Scenario is analyzed with the precondition of meeting the need of final energy demand.

2) Optimized Scenario－a scenario for intensified high-quality energy utilization

Based on Reference Scenario, the development and use of high-quality energy

(natural gas, hydropower, nuclear power and renewable energy) is strengthened. The possibility of energy supply structure optimization under the pre-condition of meeting the need of final energy demand is analyzed.

In this scenario, the development of hydropower and nuclear power is strongly promoted. In 2010, compared with Reference Scenario, there is 30 GW additional hydropower capacity, 2 GW additional nuclear power capacity, 2 GW additional wind power capacity, 7.6GW natural gas based on meeting the demand of final power demand, the coal-fired power generation capacity decreased 30.80GW. In 2020, compared with Reference Scenario, there is 30 GW additional hydropower capacity, 1.8 GW additional nuclear power capacity, 2 GW additional wind power capacity, 3.0 GW natural gas based on meeting the demand of final power demand, the coal-fired power generation capacity decreased 77.60GW.

Moreover, natural gas is further used in town gas, industrial boilers and petrochemical industry to substitute coal.

As it is not encourage by Chinese government that fuel oil is used for power generation, however, Chinese government encourage oil conservation and substitute other energies for oil. Considering the above factors and oil supply security, petroleum demand in optimized scenario is the same as that in reference scenario.

2. Assumptions

Resource guarantee. The guaranteed level of all energy resources for their supply. In the Reference Scenario, the production capacity of all domestic resources (except oil) used the values of the lower scenario of their supply potential analysis. In the Optimal Scenario, the production capacity of all domestic resources (except oil) used the values of the higher scenario. The production capacity of oil production equals the medium value of oil supply potential analysis.

Capital cost. Location variety, newly built and extended energy production capacity for the exploitation of all energy resources is considered. For the capital investment for all power generation technologies, not only present technological level is considered, but also the impact brought by future technology advancement is taken into account.

Import cost. The import cost of oil and natural gas is calculated by IEA's world oil and natural gas price estimation for the future 20 years, which was accomplished in 2002.

Environmental cost. SO_2 is one of the main pollutants in China. Compared with other pollutants, the SO_2 polluted area is quite large and with serious consequence. So, SO_2 pollution is listed as one of the key objectives for pollution control. The exploitation and utilization of coal is the main source of SO_2 emission, therefore, only the direct economic loss from environmental and ecological devastation by coal mining and utilization is considered in the environmental cost.

Environment impact. SO_2 emission limitation is used as a key constrain for energy supply structure optimization. In the two scenarios, SO_2 emission in 2010 is to adopt the control amount of SO_2 emission set by State Environment Protection Bureau, that is SO_2 emission limitation in 2010 is 16 million tons. The SO_2 emission limitation in 2020 is to introduce the result of the subtitle of the project, that is SO_2 emission in

2020 will be controlled around 13.5 million tons.

Energy dependence level on foreign countries. For the oil supply security, the oil import reliance in 2010 in both scenarios will both be controlled below 45%, and below 55% in 2020. Considering the natural gas pipeline network construction and LNG import, in the Reference Scenario, the natural gas import reliance in 2010 is controlled below 15%, in the Optimized Scenario is controlled below 20%. In 2020, the import reliance in the Reference Scenario is controlled below 30%, with below 40% in Optimized Scenario.

Technology advancement. For renewable energy power generation technologies, only currently commercialized technologies or that can be commercialized by the year 2010 are considered. Technology advancement will promote the increase of power generation efficiency. It is estimated that the coal consumption for unit electricity generation in 2020 has 3 percentage lower than the value of 2000.

IV. Analysis on Energy Supply Scenario in Year 2010 and 2020

1. Reference Scenario Analysis

According to the design of reference scenario made in chapter 3.1, supply and the structure of primary energy of China in future two decades are shown in Table 4-1-1 and Table 4-1-2.

Table 4-1-1 Primary Energy Supply and Structure of China in Future Two Decades (Reference Scenario)

	2000	2010	2020
Total energy amount (Mtce)	1303.0	2062.62	2795.51
Coal (Mt)	1206.3	1822	2309
Oil (Mt)	224.3	320	420
Domestic production	163.2	180	190
Imported	61.1	140	230
Natural gas (Bm^3)	24.50	90.0	180.0
Domestic production	24.50	79.0	130.0
Imported	0.00	11.0	50.0
Hydro power (GW)	79.35	125	200
Nuclear power (GW)	2.10	14.00	32.00
New and renewable energy (Mtce)	0.24	2.35	7.59

Note: new and renewable energy are only the new energy used for power generation, i.e. wind energy; small size hydro power station is included in hydro power station.

1.1. Primary Energy Supply and Structure

To ensure GDP increase by 4 times and sufficient energy supply for establishing well-off society during future two decades, Chinese energy output should be doubled

accordingly. Based on the analysis in scenario 2(the subproject report "Energy Demand Scenario Analysis up to 2020"), it is expected that the output of

Table 4-1-2 Primary Energy Supply Structure of China in Future Two Decades(Reference Scenario)

Unit: %

	2000	2010	2020
Total energy amount	100	100	100
Coal	66.10	63.09	58.98
Oil	24.60	22.17	21.47
Natural gas	2.50	5.80	8.56
Hydraulic power	6.31	7.21	8.26
Nuclear power	0.47	1.62	2.46
New and renewable energy	0.02	0.11	0.27

(1) primary energy will be increased from 1303 Mtce in 2000 to 2063 Mtce in 2010 and 2795 Mtce in 2020. Up to 2010, coal output will be increased to 1822 Mt, crude oil to 320 Mt (with the imported of 140 Mt), natural gas to 90 Bm^3 (with the imported of 11 Bm^3), hydro power to 437.5 TWh, nuclear power to 98 TWh, power generation with new and renewable energy to 36.9 TWh. Up to 2020, outputs of energy are expected to be increased further, such as coal to 2309 Mt, crude oil to 420 Mt (with the imported of 230 Mt), natural gas to 180 Bm^3 (with the imported of 50 Bm^3), hydro power to 700 TWh, nuclear power to 208 TWh, power generation with new and renewable energy to 23 TWh.

(2) In the future two decades, coal will still be in the first place as a major energy consumed in China, however, its proportion in the supply structure of primary energy will be decreased to 63.1% in 2010 and 59.0% in 2020 from 66.1% in 2000.

(3) Oil will still be the second major energy in the future 20 years, however, its proportion in the supply structure of primary energy will be decreased to 22.2% in 2010 and 21.5% in 2020. Restricted by domestic oil resource, the oil production cannot meet the need. Beginning from 2015, the major oil suppliers will be shifted from China domestic supply to foreign countries. In 2010, imported oil will be increased to 140 Mt, and in 2020 the amount will be 230 Mt. Chinese oil dependence level on foreign oil resources will be 43.8% in 2010 and 54.8% in 2020.

(4) As the enhancement in resource exploitation and initial establishment of national gas pipe network, the natural gas industry will be developing fast during the future 20 years, and in 2020 natural gas will be the third major energy resource surpassing hydraulic power. Proportion of natural gas in the supply structure of primary energy will be increased from 2.6% in 2000 to 5.8% in 2010, and even to 8.6% in 2020. The output of natural gas is expected to increase fast, but imported natural gas is still inevitable, as the demand will increase greater. In 2010, imported natural gas is predicted to be 11Bm^3, and 50 Bm^3 in 2020.

（5） New installed capacity of hydro power station will have increased by 45.6 GW by 2010, and actual installed capacity will reach 125 GW at that time, accounting for 7.2% in primary energy structure. From 2010 to 2020, newly increased installed capacity will be 75 GW, and actual installed capacity will reach 200 GW, with proportion by 8.3%.

（6） Proportion of nuclear energy in primary energy structure will also be increased. From 2000 to 2010, it will increase new installed capacity of 12 GW, and actual installed capacity will be 14 GW, accounting for 1.6% in primary energy structure. Up to 2020, newly increased installed capacity will be 18 GW, and actual installed capacity will reach 32 GW, accounting for 2.5% in primary energy structure.

（7） With political supports, new and renewable energy are expected to maintain the development in high speed. Power generation capacity by new and renewable energy will increase by 2.67 GW till 2010, and actual capacity will reach 3 GW, accounting for 0.11% in primary energy structure. From 2010 to 2020, newly increased capacity will be 7 GW, and actual capacity will be 10 GW, accounting for 0.27% in primary energy structure.

1.2. Analysis on Environmental Effects

Development of energy will undoubtedly result in many environment problems, esp. various pollutants. However, this study only makes prediction for emission of SO_2, NO_X and CO_2 that are generated by energy consumption.

（1）Emission coefficient of SO_2. Based on Chinese actual situations, it is defined that sulfur contained in coal (considering coal washing factors), oil and natural gas is 0.85%, 0.15% and 0.13gram/m^3 respectively. The conversion factor for sulfur dioxide from combustion of sulfur is 2. It is learned through studies that sulfur dioxide emission derived from combustion of coal, oil and natural gas is 0.01445 t/t, 0.002 t/t, and 0.242 g/m^3 respectively.

（2）Emission coefficient of nitrogen oxides. Pursuant to experts' analysis and calculations, emission coefficient of nitrogen oxides for coal is defined as 0.006 t/t, 0.00086 t/t for oil and 0.0025 g/m^3 for natural gas.

（3）Emission coefficient of carbon dioxide. In accordance with experts' analysis and calculation, emission coefficient of carbon dioxide for coal is defined as 1.85 t/t, 2.87 t/t for oil and 2.6 g/m^3 for natural gas.

Table 4-1-3 Prediction for Pollutants Caused by Energy Consumption in China(Reference Scenario)

		2000	2010	2020
Gross energy supply	MTCE	1303.0	2062.62	2795.51
Coal, Mt		1206.3	1822	2309
Oil, Mt		224.3	320	420
Natural gas, Bm^3		24.5	90.0	180.0
Emission of SO_2	Coal, Mt	19.48	15.52	12.66
	Oil, Mt	0.45	0.64	0.84
	Total	19.93	16.16	13.50
Emission of NOx	Coal, Mt	7.24	10.93	13.85
	Oil, Mt	0.19	0.28	0.36
	Natural gas, Mt	0.00061	0.00225	0.00450
	Total	7.43	11.21	14.22
Emission of CO_2	Coal, Mt	2231.61	3371.51	4271.84
	Oil, Mt	643.77	918.40	1205.40
	Natural gas, Mt	63.69	234.00	468.00

	Total	2939.07	4523.91	5945.24

With said assumptions and emission limitation, it is expected that SO_2 emission derived from energy consumption will be 16.16 Mt in 2010, 3.77 Mt less than that of 2000, of which the SO_2 emission caused by consuming coal accounts for 96%; NOx emission will reach 11.21Mt, increasing by 3.78 Mt compared with that of 2000; and CO_2 emission is estimated to be 4524 Mt, in which the CO_2 emission caused by consuming coal accounts for 74.5%, increasing by 4.4% annually compared with 2000. In 2020, SO_2 emission will reach 13.5 Mt, 2.7 Mt less than that of 2010; NOx emission will reach 14.22 Mt, increasing by 3.01 Mt compared with that of 2000; and CO_2 emission is estimated to be 5945 Mt, in which the CO_2 emission caused by consuming coal accounts for 71.8%. During 2010~2020, CO_2 emission will be increased by 2.8% annually. Table 4-1-3 prescribes an estimation of pollutants caused by consuming energy in the future 20 years.

1.3. Investment Analysis

Basic assumptions for investment analysis:

（1） Production capacity of coalmine.

Studies show that established and building coalmines of state-owned of 2000 are expected to create coal production capacity of 794 Mt in 2010 and 709 Mt in 2020. Provided the output of coalmines in villages and towns to be 450 Mt in 2010 and 500 Mt in 2020, the coal supply gap in 2010 and 2020 will still be 580 Mt and 1090 M t.

In recent 20 years, the investment cost for coalmine construction has been increasing. During 1986~1990, the average rate per ton of new building coalwell was RMB157.8 Yuan/t and unit investment for coalmine was RMB227.6 Yuan/t. During 1991~1996, the rate and the unit investment were increased to RMB233.9 Yuan/t and RMB702.6/t. If regular small coalmines in villages and towns were standard established, currently the average unit investment cost would be RMB80 Yuan1.

On the other hand, the unit investment costs differ greatly in different places although the production size are quite similar, as geologic conditions for reserving coal resource are quite different. In eastern areas of China, such as Jiangsu, Anhui, Shandong and Henan provinces, the unit investment cost is very high. For example, the production capacity of Cheji Coalmine of Yongfeng Group in Henan province is designed as 1.8 Mt while total investment is estimated as RMB147.72 million yuan, so the unit investment cost is RMB817 yuan. However, the unit investment cost in western areas of China is relatively lower, for example, it is less than RMB300 yuan in Heidaigou Minecoal of Shenhua Group.

In addition, the unit investment cost differs in different sizes of coalmine. Generally speaking, the unit investment cost for large and middle size of coalmines is high and for small size ones is relatively lower. And the unit investment cost for newly-established coalmines is higher than that of expanding coalmines.

This study compares the investment cost for newly-built and expanding industrial strip coalmines in different locations in 2000. See Table 4-1-4 for details.

[1] Commented by Zhou Fengqi and Wang Qingyi etc., Chinese Coal Sector.

Table 4-1-4 Investment Cost for New and Expanding Coalmines

Unit: RMB/ton

	New	Expanding
Beijing, Tianjin & Hebei province (Jing, Jin, Ji)	450	300
shansi, Shanxi, Inner Mongolia & Xizang provinces (Jin, Shan, Meng, Xi)	350	150
Northeast of China	350	250
East of China	700	450
Mid and south of China	700	400
Southwest of China	300	200
Xinjiang, Gansu, Ningxia & Qinghai provinces (Xin, Gan, Ning, Qing)	300	200

From the production capacity analysis on Chinese coalmines, considering the strategic layout of future development for Chinese coalmines, it is learned that:

① In the future, newly-established coalmines will be distributed in Shansi, Shanxi, Inner Mongolia (and Xizang) provinces, majoring in building large and middle size new coalmines and complemented with expanding ones. In these places, few of coalmines are discarded as useless.

② There will be no big change of the coalmine production capacity in Beijing, Tianjn and Hebei provinces. The production capacity of new coalmines will basically equal to that of the discarded coalmines. The newly-built coalmines will be mainly located in Wei County of Hebei province. The sum of expanding production capacity of other existing coalmines will equal to the discarded production capacity.

③ The coalmine production capacity in east of China are expected to increase markedly, esp. newly-built coalmines will be established in north and middle part of Anhui province and Juye of Shandong province. However, the production capacity of old coalmines there will decrease in different levels.

④ There will be not obvious production capacity increase in the coalmines in mid and south of China, new coalmines will be mostly built in Yongcheng and Dengfeng of Henan province, and the production capacity of other coalmines in these places will decrease as a whole.

⑤ As the development of Panjiang, Shuicheng and Laochang in Guizhou Province, the production capacity of coalmines in southwest of China are expected to increase, however, it will decrease in Sichuan province.

⑥ East of Inner Mongolia is a major area where the coalmine production capacity will increase, and Heilongjiang province will be in the second place, however, the coalmine output in Liaoning and Jilin provinces will decrease.

Based on said analysis, Table 4-1-5 provides an initial assumption for the production capacity of coalmines in different places, considering future demand of

coal resource and the resource conditions.

Table 4-1-5 Assumption of Distribution of Coalmine Output (Reference Scenario)

unit: 104 tons

	Capacity of 2000	Output of 2002	2000~2010					2010~2020				
			New	Expanding	Discarded	Villages & towns	2010	New	Expanding	Discarded	Villages & towns	2020
Jing, Jin, Ji	4876	6666	900	300	300	600	7000	150		1000	600	6150
Jin, Shan, Meng, Xi	28148	57406	35000	800	500	18000	75000	35000	500	320	18000	110180
Northeast	9836	13279	6000	300	1700	1400	29200	3000	200	1100	1400	31300
East	14683	24585	9000	200	1200	2000	23000	2000	100	1300	2000	23800
Mid & south	8436	14861	4600	200	220	3000	16000	1000	200	1040	3000	16160
Southwest	6595	15400	8000	50	230	8000	21000	8000	300	210	8000	29090
Xin, Gan, Ning, Qing	4361	7138	2500	150	150	2000	11000	6000	200	230	2000	16970
Total	76935	139335	66000	2000	4300	35000	182200	55150	1500	5200	35000	230700

Based on the data in Table 4-1-4 and Table 4-1-5, it is estimated that the investment made by the nation for new and expanding coalmines will be RMB279.2 bln during 2000~2010 and RMB200.2 bln during 2010~2020, so that to meet regular coal supply.

（2） New coal separation capacity and investment.

In 2000, as the separation rate of raw coal was only about 35%, lots of raw coal was burned without processing, which resulted in serious air pollutions. Separation of raw coal is the groundwork for clean use of coal, which greatly improves the quality and value added for coal products and reduce the air pollutions, therefore, we should develop the coal separation to the most extent. Coal separation capacity in 2000 was about 550 Mt, and it is assumed that current coal separation plants can still operate normally in 2010 and 2020; if the separation rate is improved to 50% by 2010 and

Table 4-1-6 Estimation for New Coal Separation Capacity and Investment Required

	2000~2010		2010~2020	
	New separation capacity (Mt)	Investment ($RMB10^8$)	New separation capacity (Mt)	Investment ($RMB10^8$)
Reference scenario	361	216.60	474	284.64
Optimized scenario	430	258.24	145	87.12

60% by 2020, and the unit investment cost of newly-built coal separation plant is RMB60 yuan, it will call for new separation capacity of 360 Mt and investment of RMB21.6 billion yuan by 2010, and 474 Mt and RMB28.4 billion yuan by 2020. The estimation is shown in Table 4-1-6.

（3）Infrastructure construction of coalmine

As the geographic distributions of coal production and consumption are imbalance in China, it has formed a situation that the coal produced in the north is delivered to the south and produced in the west is delivered to the east. Coal transportation mainly relies on the railway, and it accounts for 70% of total transportation amount. The coal amount transported from Shansi, Shanxi, Inner Mongolia (and Xizang) provinces accounted for 43% of total railway transportation amount (in 2002). As the further development of coalmines in the west areas of China, the proportion for transporting coal from the west will be higher. According to the analysis made in the previous section about coalmine output in different places, it can roughly estimate the amount of coal in 2010 and 2020 that will be transported outward from Shansi, Shanxi, Inner Mongolia (and Xizang) provinces. And then the investment for railway transportation can be estimated (see Table 4-1-7) by referring to the cost of transportation between Shenmu – Huanghua cities. The estimation shows that transportation of coal by railway needs the investment of near RMB70 billion yuan by 2010 and more than RMB83 billion yuan from 2010 to 2020.

Table 4-1-7 Estimation for the Investment Required for New Transportation Capacity

Unit: billion yuan

	Reference scenario	Optimized scenario
2002~2010	69.6	52.2
2010~2020	83.52	43.5
Total	153.12	95.7

（4）Production of oil and natural gas

The investment for exploring and developing oil and gas fields differ from each other, as geologic conditions of reserving the resources, development levels and geographic conditions of the fields are diversified. For lack of financial materials, it can’t make accurate calculations, but a rough estimation from macro stand point of view. Since 1990, the exploration investment to oil industry has been increased in large scale, according to relevant statistics. China National Petroleum Corporation, for an instance, spent RMB1.79 billion yuan for seeking oil filed having oil reserve of 100 million tons. In 1998, the investment was increased to RMB2.286 billion yuan, by 27%. And the investment for oil field with production capacity of million tons increased from RMB16.89 million yuan in 1990 to RMB25.66 million yuan in 1998, by 51.9% during 8 years. Apart from increasing prices, diversification of explored fields and development difficulties are major reasons causing the rapid increase of the exploration cost.

This study mainly concerns the investment for newly-built oil fields. It firstly analyzes oil output of the oil fields located in east and west China and on the offshore in 2010 and 2020; and then makes estimation on the investment for developing oil

fields in these three areas in the future 20 years. It is estimated that during 2001~2010, the investment for developing national oil fields will reach RMB1325.9 ~ 2375.6 billion yuan, and the investment for developing natural gas fields will be RMB197.4 billion during 2001 ~ 2010, and RMB662.9 ~ 1072.4 billion during 2011 ~ 2020.

（5）Oil refining

Chinese oil products are mainly refined and produced by petrochemical enterprises, so the expansion of oil refining capacity in the future will mostly rely on the supply and demand gap of raw oil. The investment for an oil refining plant rests with the plant size and refining degree. For easier calculation, it assumes that future oil plants will be developing into large-oriented size so that to improve comprehensive efficiency and benefits of the oil plants. If an oil refining plant is built with the output of 10 Mt, it will calls for RMB10 billion of comprehensive investment (including the primary and secondary processing capacity) for the plant for future 20 years, according to experts' estimation.

Table 4-1-8 Estimation of Investment for New Oil Processing Capacity

	2001~2010		2011~2020	
	New capacity (Mt)	Investment ($RMB10^8$)	New capacity (Mt)	Investment ($RMB10^8$)
Reference scenario	58	583	108	1075
Optimized scenario	58	583	108	1075

（6）Investment for the infrastructure of natural gas

It is not easy to estimate pipeline construction in the future two decades, so it can only make a rough estimation on the investment for currently constructing and designed pipelines. As future import of natural gas mainly depends on import of LNG, the investment for LNG receiving terminal and transportation artery will be estimated based on current LNG projects being carried on in Guangdong and Fujian provinces.

（7）Hydropower

The construction and investment for hydropower station refers to current small size of hydropower projects, pursuant to the unit investment of RMB7000 yuan/kW.

（8）Nuclear power

Before 2010, the investment for nuclear power station is estimated as RMB15000 yuan/kW. During 2010~2020, the investment will decrease to RMB12000/kW as domestically produced level of construction is expected to be improved.

（9）Thermal power

The investment for thermal power by consuming natural gas is estimated as RMB4000 yuan/kW, and by consuming coal as RMB5000 yuan/kW. Cost for desulphurization is estimated about RMB400yuan/kW, based on the case using stack gas desulphurization equipment and desulphurization rate by 95%

（10）New and renewable energy

The investment for renewable energy is calculated based on that for wind power station, i.e. RMB7000 yuan/kW before 2010; and RMB6000 yuan/kW during 2010~2020, as domestically produced level of construction and technical level will be both improved.

Said assumptions states that output construction of energy resources must be enhanced in large scale, so that to ensure the energy demand of well-off society can be meet in 2020. It is predicted that the investment to Chinese energy system will be RMB6309.1 billion yuan in the future two decades from 2000 (according to the fixed price of 2000), and annual investment will be RMB45315.5 billion yuan. During 2001~2010, the investment required will be RMB2579.6 billion yuan, while RMB3729.5 billion yuan will be required for 2011~2020. (See Table 4-1-9 for details).

Table 4-1-9 Forecast for Investment of Energy System (Reference Scenario)

Unit: RMB10^8

	2001～2010	2011～2020
Subtotal for coal	3704.6	2811.64
Production	2792	2002
Separation	216.6	284.64
Infrastructure construction	696	525
Subtotal for oil	4585	7773
Production	4002	6698
Refining	583	1075
Subtotal for natural gas	1440	3977
Production	1338	3466
Infrastructure construction	102.2	511
Subtotal for power generation	16066	22733
Hydropower	3196	5250
Nuclear power	1785	2160
New and renewable energy	187	420
Coal power	10243	13567
Natural gas power	656	1344
Total	**25796**	**37303**

Due to fast increase in quantity of power installed capacity, the investment to electrical power industry will go up rapidly in the future two decades, sharing the largest part of total investment to energy industry by 62%. With the output increasing, the investment to oil industry will be in the second place following electrical power industry, accounting for 20%, as the cost for oil exploitation is relatively high. As the fast development of natural gas industry, the investment is also rising fast. The investment to natural gas industry will only account for 5.6% before 2010; however, the proportion will mount up to 10.7%. However, the investment to coal industry will be in a downtrend, as amplitude of coal supply will drop down. Fig. 4-1-1 has details for the investment distribution to energy industry.

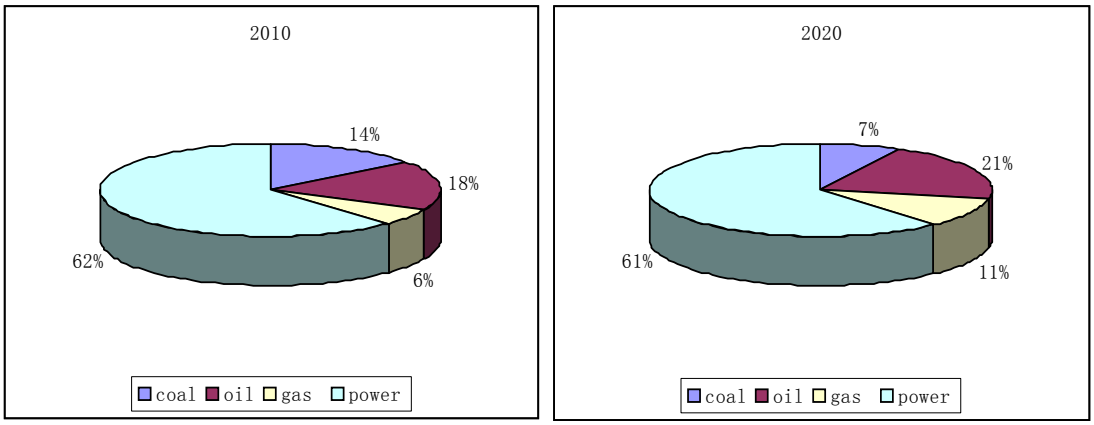

Fig. 4-1-1 Forecast of Investment Distribution for Energy Industry

1.4 Estimation of Direct Economic Loss of Environmental and Ecological Damage Derived from Coal Exploitation and Utilization

The exploitation and utilization of coal resource causes serious and complex damages, esp. the external environmental losses that can be known only after several or even dozens of years. Actually, it is difficult to price the economic loss caused by exploring and utilizing coal resource, because it cannot simply price the environmental losses, and the influence to biological chains is even more difficult to be counted. Therefore, any existing prices to such losses have certain limitations.

In recent ten years, some research institutions or individuals at home and abroad have made calculations on the economic losses caused by exploring and utilizing coal resource. Major calculation results are shown as follows:

① Shang Yong and Su Jing made an initial investigation and concluded that the economic loss (including damages on forest and crops, corruption of materials and respiratory tract disease to human beings etc.) caused by burning one ton of coal is about RMB50~70 yuan; in early 1990's, the economic loss of RMB28.8 billion yuan (price of 1993)2 was caused by acid rain corruption to crops, forests and construction materials, which accounted for 0.83% of current GDP. As the expansion of the area of acid rain, the proportion that acid rain area account for country area has been increased from 30% in early 90's to near 40% in 1998, and the economic losses caused by acid rain was more than RMB150 billion yuan, accounting for 2% of GNP.

② The economic losses caused by air pollution was US$95 billion yuan each year in China, accounting for 7% of GNP, according to the statistics made by World Observation and Research Institute of the United States3.

Said two studies only concerned the economic losses caused by utilization of coal, but didn't involve the losses derived from damages on environment during the process of exploring coal resource.

In 2000, Shansi Provincial Planning Commission had experts conducting assessment and analysis on the economic damages derived from environmental and

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[2] Shang Yong and Su Jing, Chinese Sustainable Development Approach in 21st Century, China Economy Press

[3] World Observation and Research Institute of the United States: "Vital Sings" (1996)

ecological damages in five aspects, such as atmospheric environment, water environment, emission of solid wastes, geologic condition for coal exploitation and ecological environment etc. The study result showed that direct economic losses derived from environmental and ecological damages in Shansi province was RMB15.234 bln in 1999, accounting for 9.82% of GDP (shown in Table 4-1-10).

Table 4-1-10 Direct Economic Losses Derived from Environmental and Ecological Damages in Shansi Province

Unit: RMB10^8

Item	Air pollution	Water pollution	Pollution of solid wastes	Damage of coal exploitation	Environmental damage	Total
1999	44.16	21.2	21.35	10	55.69	152.34
Proportion of damage in exploring and using coal	85%	75%× 75%	80%	100%	60%	54%
Damage derived from exploring and using coal	37.54	11.93	17.1	10	33.41	109.97

The calculation of loss caused by air pollution considered the losses derived from damages to agricultural economics, human heath, additional rinse and corruption to construction materials etc. The loss of water pollution includes damages that sewage brings to crops, soil, water source, landscape, environment, human health and civic water supply etc. The economic losses of solid wastes include damages to earth, atmosphere, rivers and underground water and ecologic environment. The environmental and ecological damages derived from exploring and utilizing coal resource considered damages to ground and underground water, land resources, ground buildings, water resource facilities, road traffic, and power facilities etc. Ecological damages included the damages derived from soil erosion, land desertification, land salinization, forest destroy, grassland degradation, destroy on mine land, agricultural ecological conditions and social entironment etc. The study comprehensively accounted for the economic losses derived from environmental pollutions and ecological damages, so the study result can be regarded scientifically reasonable.

This study is planned to adopt the study result concluded by Shansi Provincial Planning Commission, to independently calculate direct economic losses derived from environmental and ecological damages in the process of exploring and utilizing coal resource, by separating other losses, and then get the direct loss per ton of coal. Therefore, the calculation result can be used to reckon direct economic loss derived from environmental and ecological damages in the process of exploring and utilizing coal resource in nationwide scale.

Undoubtedly, there must be some inaccuracy to use the case of Shansi province to reckon the situation for the whole country, however, it is impossible of conducting a monographic study specific for this subject in the study. In this article, we reckon the external costs for exploring and utilizing coal resource, which will be an original data prepared for converting the external costs into internal costs in exploring and

utilizing coal resource.

According to the study result concluded by Shansi Provincial Planning Commission, Table 4-1-10 presents the economic losses derived from environmental and ecological damages in the process of exploring and utilizing coal resource is shown in. It is known that damage of air pollution is mainly caused by utilization of coal and 70% of entironmental damage is also caused by utilization of coal, which results in direct economic loss of RMB6093 million yuan by utilizing coal resource. And exploitation of coal resource causes the other direct loss of RMB4904 million yuan. The coal consumption and production was 137.56 Mt and 248.94 Mt respectively in Shansi province in 1999, so the direct economic loss for utilizing and exploring per ton of coal resource was RMB44.3 yuan/t and RMB19.7 yuan/t. A forecast of economic losses derived from environmental and ecological damages in the process of exploring and utilizing coal resource by 2010 and 2020 is shown in Table 4-1-11. During 2001~2010, accumulated direct economic loss might be RMB1050 billion yuan, and during 2010~2020, the figure might further increase to RMB1331.4 billion yuan. Therefore, it is obvious that the exploitation and utilization of coal resource brings seriously adverse influences to direct economic losses.

Table 4-1-11 Forecast of Economic Losses Derived from Environmental and Ecological Damages in the Process of Exploring and Utilizing Coal Resource

		2000~2010	2011~2020
Reference scenario	Economic losses by utilizing coal ($RMB10^8$)	7268	9215
	Economic losses by exploring coal ($RMB10^8$)	3232	4098
	Total	**10500**	**13314**
Optimized scenario	Economic losses by utilizing coal ($RMB10^8$)	6856	7813
	Economic losses by exploring coal ($RMB10^8$)	3048	3475
	Total	**9905**	**11288**

2. Optimized Scenario Analysis

Even under the same energy demand conditions, the optimized scenario diversifies in many aspects compared with the Reference scenario, such as energy supply amount, energy structure, environmental effects and investment demand etc. (see Table 4-2-1 and 4-2-2). Followings are detailed analysis for the optimized scenario.

2.1. Primary Energy Supply and Structure

(1) In 2010, as installed capacity of gas-fired power station will increase, demand of natural gas will increase by 30 Bm^3 compared with the reference scenario, and total demand of natural gas will be 120 Bm^3, in which 100 Bm^3 will depend on domestic production while the other 20 Bm^3 will be imported; as further development of hydropower station, power output generated by hydropower station will increase to 542.5 TWh, 105 TWh more that that of the Reference scenario; and power output

generated by nuclear energy will also increase to 112 TWh, 14 TWh more than that of the Reference scenario. In 2020, demand of natural gas will increase to 250 Bm^3, 70 Bm^3 more than that of the Reference scenario, in which 150 Bm^3 will be domestically produced; hydropower output will increase to 805 TWh, 105 TWh more than that of the Reference scenario; and nuclear power output will increase to 325 TWh, 117 TWh more than that of the Reference scenario. Since the enhancement of using natural gas, hydropower and nuclear power, the coal supply will be dropped in certain level. It is predicted that the coal supply in 2010 will be 1634 Mt, 188 Mt less than that of the Reference scenario; and the coal supply in 2020 will be 1875 Mt, 43 Mt less than that of the Reference scenario.

(2) In the future two decades, coal will be still the primary energy in China, however, the proportion that coal accounts for in the supply structure of primary energy will further drop, compared with that of the Reference scenario. In 2010, the proportion will drop by 5.1% compared with that of the Reference scenario, to 58% in 2010, and by 9% compared to that of the Reference scenario, to 50.2% in 2020.

(3) Although hydropower is encouraged in this optimized scenario, it still functions little to the supply structure of primary energy due to the limitations in hydroelectricity resource and exploitation conditions. The proportion that hydropower accounts for in the supply structure of primary energy will improve by 2% more than that of the Reference scenario to 9.2% in 2010, and improve by 1.7% to 10% in 2020.

Table 4-2-1 Supply and Structure of Primary Energy of China in Future Two Decades(Optimized Scenario)

	2000	**2010**	**2020**
Total energy amount (Mtce)	1303.0	2010.3	2667.5
Coal (Mt)	1206.3	1634.4	1875.5
Oil (Mt)	224	320	420
Domestic production	163	180	190
Imported	61	140	230
Natural gas (Bm^3)	24.5	120.0	250.0
Domestic production	24.5	100.0	150.0
Imported	0	20.0	100.0
Hydraulic power (GW)	79.35	155.0	230.0
Nuclear power (GW)	2.1	16	50.0
New and renewable energy (GW)	33	500	3000

(4) In the optimized scenario, the proportion that nuclear power accounts for in supply structure of primary energy will increase by 0.3% compared to that of the Reference scenario, to 1.9% in 2010, and increase by 1.5%, to 4% in 2020.

With the analysis above, it is known that the adjustment and optimization of Chinese energy structure in the future two decades must rely on kinds of high-quality energies instead of sole energy.

Table 4-2-2 Supply Structure of Primary Energy of China in Future Two Decades (Optimized Scenario)

Unit: %

	2000	**2010**	**2020**
Total energy amount	100	100	100
Coal	66.1	58.0	50.2
Oil	24.6	22.7	22.5
Natural gas	2.5	7.9	12.5
Hydraulic power	6.3	9.2	10.0
Nuclear power	0.5	1.9	4.0
New and renewable energy	0.0	0.2	0.9

2.2. Analysis on Environmental Effects

In the optimized scenario, as the enhancement of high-quality energies – natural gas, hydropower and nuclear power and the diminution of use of coal, the pollutants emitted will be controlled within certain level. SO_2 emission derived from energy consumption will be controlled within 16 Mt in 2010 and 13.4 Mt in 2020. NOx emission will reach 10.08 Mt in 2010. And CO_2 emission is estimated to be 4524 Mt in 2010, in which the CO_2 emission caused by consuming coal accounts for 74.5%, increasing by 4.4% annually compared with 2000. NOx emission will reach 11.62 Mt in 2020. CO_2 emission is estimated to be 5325 Mt in 2020, in which the CO_2 emission caused by consuming coal accounts for 71.8%. Compared with 2010, CO_2 emission will be increased by 2.8% annually till 2020. Table 4-2-3 prescribes an estimation of pollutants caused by consuming energy in the future two decades.

Table 4-2-3 Prediction for Pollutants Caused by Energy Consumption in China (Optimized Scenario)

		2000	2010	2020
Gross energy supply, Mtce		1303.0	2010.3	2667.5
Coal, Mt		1206.3	1634.4	1875.5
Oil, Mt		224	320	420
Natural gas, Bm^3		24.5	120.0	250.0
Emission of SO_2	Coal, Mt	19.48	15.37	12.53
	Oil, Mt	0.45	0.64	0.84
	Total	**19.93**	**16.01**	**13.37**
Emission of NOx	Coal, Mt	7.24	10.93	13.85
	Oil, Mt	0.19	0.28	0.36
	Natural gas, Mt	0.00061	0.00225	0.0045
	Total	**7.43**	**11.21**	**14.22**
Emission of CO_2	Coal, Mt	2231.61	3371.51	4271.84
	Oil, Mt	643.77	918.40	1205.40
	Natural gas, Mt	63.69	234.00	468.00
	Total	**2939.07**	**4523.91**	**5945.24**

2.3. Investment Analysis

It is predicted that the investment needed for exploring primary energies during 2000~2020 will be RMB6448.4 billion yuan(fixed price of 2000), and average annual investment will be 322.4 billion yuan, RMB7000 million yuan more than that of the Reference scenario, in which, the investment of RMB2673.8 billion yuan for 2000~2010 and RMB3774.6 billion yuan for 2011~2020 (see Table 4-2-4 for details).

Table 4-2-4 Investment Forecast for Energy Industry (Optimized Scenario)

Unit: RMB10^8

	2001—2010	2011—2020
Subtotal for coal	3190.44	1099.12
Production	2097	577
Separation	258.24	87.12
Infrastructure construction	835.2	435
Subtotal for oil	4585	7773
Production	4002	6698
Refining	583	1075
Subtotal for natural gas	1908.24	5025.2
Production	1698	3974
Infrastructure construction	210.24	1051.2
Subtotal for power generation	17055	23848
Hydropower	5296	5250
Nuclear power	2085	4080
New and renewable energy	327	1500
Coal power	8387	10778
Natural gas power	960	2240
Total	**26738**	**37746**

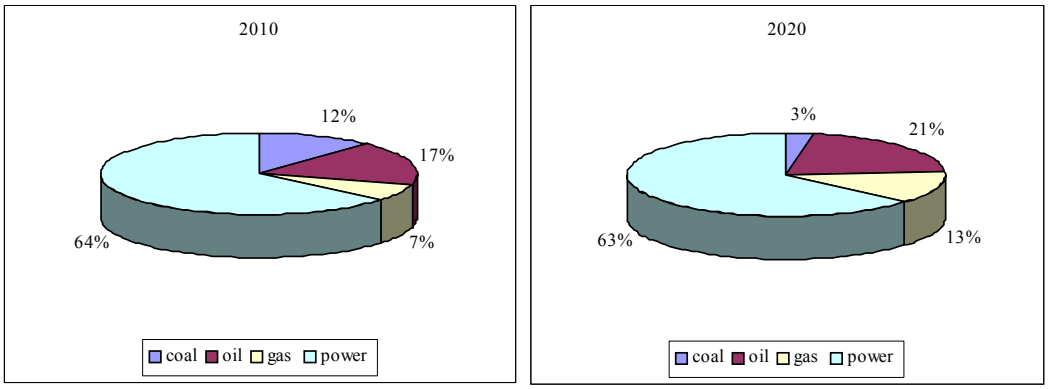

Fig. 4-2-1 Forecast of Investment Distribution for Energy System (Optimized Scenario)

Since the energy structure is adjusted in the optimized scenario, the investment for energy industry will be changed accordingly. As the energy structure in the optimized scenario is improved, utilization of coal is reduced, the investment for coal industry in 2010 and 2020 is expected to account for 12% and 3% of that for energy

industry respectively.

If the external cost of ecological and environmental damages that are derived from exploring and utilizing coal resource is taken into account, the optimized scenario will obtain better economic benefits than the Reference scenario does. From Table 4-1-11, it is learned that in the optimized scenario such external cost will be RMB262.1 billion yuan less than that of the Reference scenario, which is far more than the additional investment (RMB139.3 billion yuan) that is required for replacing the Reference scenario with the optimized scenario. Therefore, restructured and optimized energy structure can bring both sound social effects and economic benefits.

3. Conclusion

Based on the analysis above, comparison of predictions for the two scenarios are shown in Table 4-3-1 and Fig. 4-3-1 ~ 4-3-6.

Table 4-3-1 Supply of Primary Energy

	Reference Scenario			Optimized Scenario		
	Standard quantity	Physical quantity	Structure (%)	Standard value	Physical quantity	Structure (%)
Year 2000						
Coal Mtce(Mt)	861.3	1206.3	66.1			
Oil Mtce(Mt)	320.5	224.3	24.6			
Domestic production	233.2	163.2				
Import	87.3	61.1				
Natural gas Mtce(Bm^3)	32.6	24.50	2.5			
Domestic production	32.6	24.50				
Hydropower Mtce(GW)(Inc. Small Hydropower)	82.3	79.35	6.3			
Nuclear power Mtce(GW)	6.1	2.10	0.5			
Renewable Energy Mtce(GW)	0.2	0.33	0.0			
Total （Mtce）	**1303.0**		**100**			
Year 2010						
Coal Mtce(Mt)	1301.2	1822.4	63.1	1166.9	1634.4	58.0
Oil Mtce(Mt)	457.3	320.0	22.2	457.3	320.0	22.7
Domestic production	257.2	180.0		257.2	180.0	
Import	200.1	140.0		200.1	140.0	
Nature gas Mtce(Bm^3)	119.7	90.0	5.8	159.6	120.0	7.9
Domestic production	105.1	79.0		133.0	100.0	
Import	14.6	11.0		26.6	20.0	
Hydropower Mtce(GW)(Inc. Small hydropower)	148.8	125.0	7.2	184.5	155.0	9.2
Nuclear power Mtce(GW)	33.3	14.0	1.6	38.1	16.0	1.9
Renewable energy Mtce(GW)	2.3	3.0	0.1	3.9	5.0	0.2
Total （Mtce）	**2062.6**		**100**	**2010.3**		**100**

Year 2020						
Coal Mtce(Mt)	1648.7	2309.1	59.0	1339.1	1875.5	50.2
Oil Mtce(Mt)	600.2	420.0	21.5	600.2	420.0	22.5
Domestic production	271.5	190.0		271.5	190.0	0.0
Import	328.7	230.0		328.7	230.0	0.0
Nature gas Mtce(Bm^3)	239.4	180.0	8.6	332.5	250.0	12.5
Domestic production	172.9	130.0		199.5	150.0	0.0
Import	66.5	50.0		133.0	100.0	0.0
Hydropower Mtce(GW)(Inc. Small hydropower)	231.0	200.0	8.3	265.7	2×30.0	10.0
Nuclear power Mtce(GW)	68.6	32.0	2.5	107.3	50.0	4.0
Renewable energy Mtce(GW)	7.6	10.0	0.3	22.8	30.0	0.9
Total （Mtce）	**2795.5**		**100**	**2667.5**		**100**
2001~2020 total investment, trillion Yuan *	63099			64484		
2001~2020 Env. Cost	23814			21193		
Emissions in 2000						
SO_2, Mt	19.93					
NO_X, Mt	7.43					
CO_2, Mt	2939.07					
Emissions in 2010						
SO_2, Mt	16.16			16.01		
NO_X, Mt	11.21			10.08		
CO_2, Mt	4523.91			4253.97		
Emissions in 2020						
SO_2, Mt	13.56			13.37		
NO_X, Mt	14.22			11.62		
CO_2, Mt	5945.24			5325.11		

Notes: Constant price in 2000. Environmental cost means the direct economic losses of ecologic and environmental damages derived from exploring and utilizing coal resource.

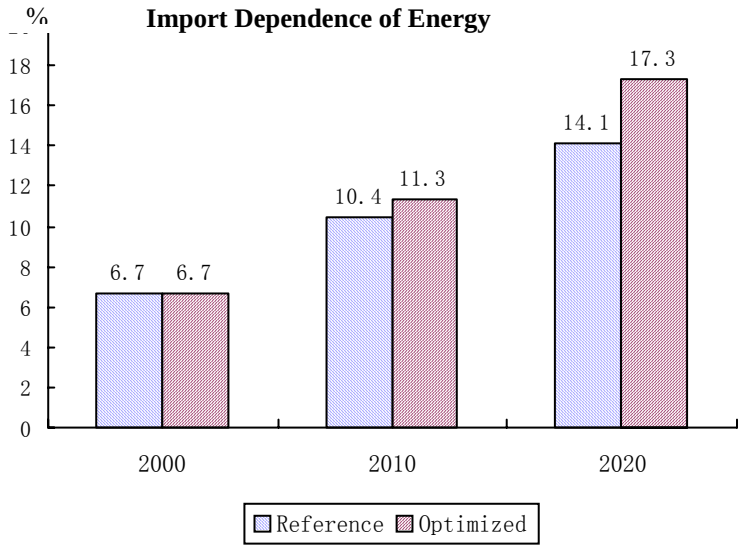

Fig. 4-3-1 Comparison of the Two Scenarios in Import Dependence of Energy

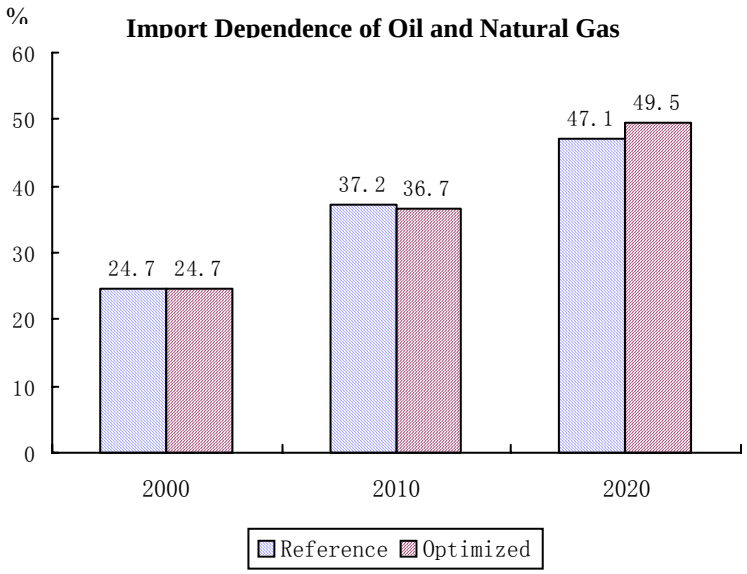

Fig. 4-3-2 Comparison of the Two Scenarios in Import Dependence of Oil and Natural Gas

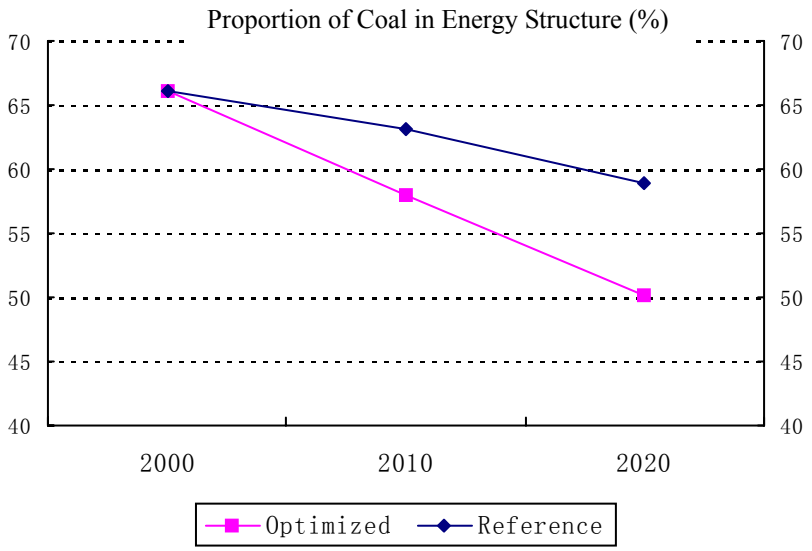

Fig. 4-3-3 Comparison of the Two Scenarios in Proportion of Coal in Energy Structure

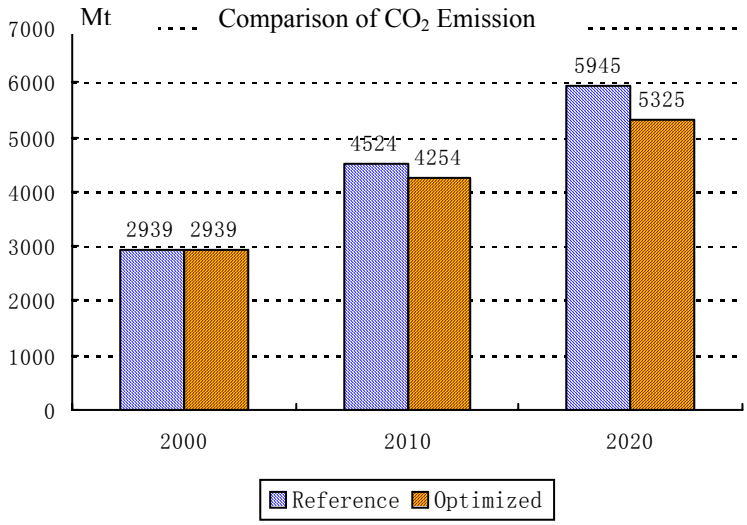

Fig. 4-3-4 Comparison of the Two Scenarios in CO_2 Emission

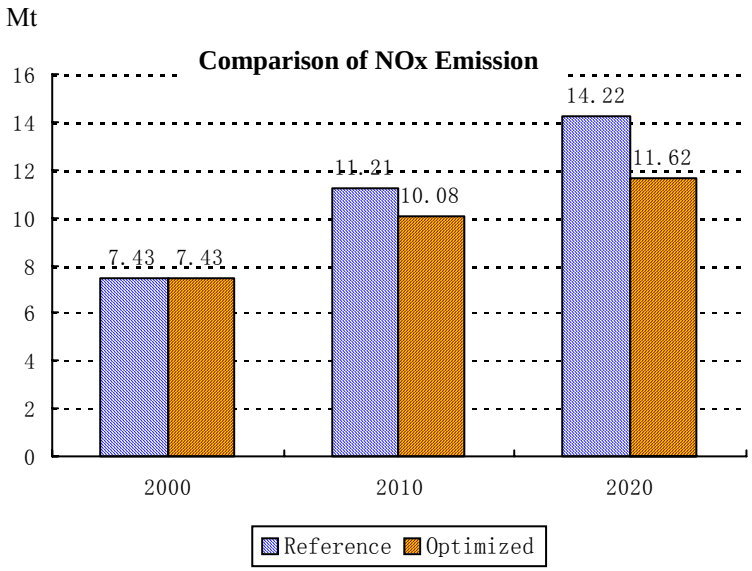

Fig. 4-3-5 Comparison of the Two Scenarios in NOx Emission

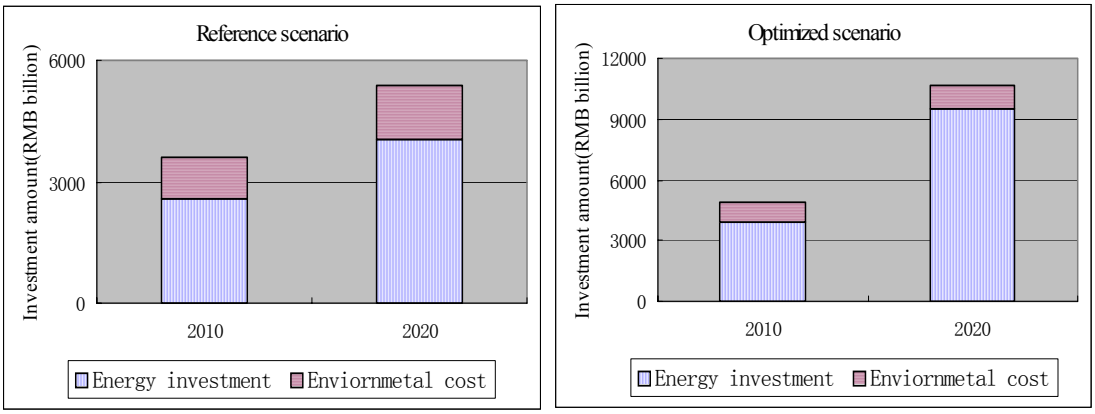

Fig. 4-3-6 Comparison of the Two Scenarios in Energy Investment and Environmental Cost

Following conclusions are drawn out through the analysis on the above two scenarios:

1) To ensure GDP increasing by 4 times and sufficient energy supply for establishing well-off society during the future two decades, Chinese energy output should be doubled accordingly.

It is expected that the output of primary energy will be increased from 1303 Mtce in 2000 to 2063~2010 Mtce in 2010 and 2795~2667 Mtce in 2020. Up to 2010, coal output will be increased to 1822~1634 Mt, crude oil to 320 Mt (with the imported of 140 Mt), natural gas to 90~120 Bm^3 (with the imported of 11~20 Bm^3), hydropower to 125~155 GW, nuclear power to 14~16 GW, power generated by new and renewable energy to 3~50 GW. Up to 2020, outputs of said energy are expected to be increased further, such as coal to 2310~1870 Mt, crude oil to 420 Mt (with the imported of 230 Mt), natural gas to 180~250 Bm^3 (with the imported of 50~100 Bm^3), hydropower to 200~230 GW, nuclear power to 32~50 GW, power generated by new and renewable energy to 10~30 GW.

Considering that economics might increase in an excessive speed and energy demand might exceed the prediction in the future, energy supply capacity of China should leave enough flexibility and potential for further expansion.

2) Fully exploring domestic high-quality energy resources and utilizing overseas high-quality energy resources will markedly reduce the consumption of coal resource and total amount of energy consumption.

Research shows that Chinese primary energy structure is expected to change greatly in 2020, provided energy policies are readjusted and relevant measures are taken. Although coal will be still in the first place in 2020, the proportion of coal in the energy structure will decrease from 66.1% of 2000 (excluding biomass energy) to 50.2% (the optimized scenario) and 59% (the Reference scenario).

If the investment and the exploitation & utilization of natural gas, hydropower, nuclear power and renewable energy are both enhanced, according to the optimized scenario, demand of primary energy in 2020 will drop by 4.6% compared with that of the Reference scenario, using less energy of 128 Mtce.

3) Limited by domestic production capacity for oil and natural gas, the imported amount will increase fast, and the import dependence of oil and natural gas will also increase.

It is predicted that imported amount of oil and natural gas will increase from 61 Mtoe of 2000 to 150.2~158.6 Mtoe in 2010, by 9.4~10% annually, and to 276.5~323.Mtoe in 2020, by 6.3~7.4% annually. The import dependence of energy will increase from 7% of 2000 to 10.4~11.3% in 2010 and 14.1~17.3% in 2020. The import dependence of oil and natural gas will increase from 27.2% to 37.2~36.7% in 2010, and 47.1~49.5% in 2020.

4) In order to control pollutions to the environment, apart from enhancement of using high-quality energy resources, restrict measures should be taken in coal process plants for emission reduction.

Research shows that desulphurization device will be required for new installed capacity in coal burning power station for the both scenarios in 2010 and 2020, so that to meet the goal of controlling SO_2 emission. In 2010, desulphurization device need to be installed for 70% of old machine set of coal burning plant in the Reference scenario, and for 48% in the optimized scenario. In 2020, desulphurization device is needed for all old machine set in the Reference scenario, and still for 48% in the optimized scenario.

5) Enhancing the use of high-quality energy resources and reducing coal consumption can bring both sound social and economic benefits.

It can reduce direct economic losses of ecologic and environmental damages derived from exploring and utilizing coal resource by enhancing the use of high-quality energy resources and reducing the use of coal resource. Through research, it is learned that in the optimized scenario the external cost for ecologic and environmental damages that are derived from exploring and utilizing coal resource will be RMB262.1 billion yuan less than that of the Reference scenario (the economic losses in the optimized scenario is dropped by 11% compared with that of the Reference scenario), which is far more than the additional investment (RMB139.3 billion yuan) that is required for replacing the Reference scenario with the optimized

scenario.

6) It is impossible to rely on sole energy resource to restructure and optimize Chinese energy structure, however, the optimization of energy structure calls for fully use of two kinds of resources and two markets, and multiple high-quality energy resources.

7) Apart from restructuring and optimization of primary energy, the end-use energy consumption structure should be optimized as well. The analysis of the optimized scenario shows that the proportion of power generation by coal burning will be improved from 50% of 2000 to 52% in 2010 and 77% in 2020. However, it should promote the replacement of coal with natural gas and power amongst end users, such as to substitute natural gas for chemicals and fuel used for middle- and small-size boilers, furnaces, kilns and civil cooking etc., so that to improve the terminal utilization of natural gas and reduce the proportion of coal in energy structure.

V. Energy Strategy

The energy supply strategy in China will be:

To guarantee energy supply: providing sufficient energy for quadrupled future GDP growth and building a well-off society, and make great efforts to enhance the supply security degree;

To optimize energy mix: reducing the coal consumption as soon as possible and increasing the proportion of high-quality energy utilization;

To be clean and high efficiency: being clean and high efficiency in exploiting and utilization energy resources: development the energy resources that are friendly to environment, extending the utilization techniques of clean energy resources, protecting and improving environment, and increasing energy efficiency and benefit;

To be economic and rational: allocating and utilization energy resources economically and rationally, providing knight service with the minimum cost.

VI. Policy Recommendations

1. To establish risk fund, increase investment to basic exploration, improve system of commercial investigation, strengthen the safeguard degree of the backup energy resource, especially high-quality energy resource, by enhancing the exploration of energy resource,

According to the Regular Scenario, the demand for primary energy in China will reach to 2.796 billion tce in 2020, of which including 2.3 billion tons of coal. However, the total production capacity of the existing and under-constructing state coal mine in China will be about 0.71 billion tons by then. Taking into account the production capacity of small-scale coal mine, about 1.25 billion tons of production

capacity of state coalmine should be added. According to the construction regulations of the coal mine, 175 billion tons of proved reserves for large and medium scale coal mine are needed. Currently, the un-utilized proved reserves are only 61.7 billion tons, some of them cannot be utilized due to the constraints of geographic and mining condition, some others is only suitable for local small-scale mining, the proved reserves suitable for large-scale mining are only 30-40 billion tons. Therefore, the coal proved reserves in support for large and medium scale mining are very insufficient.

Since 1990s, the investment system of coalfield exploration has been changed greatly with the transformation of economic system. The nation will be only responsible for the payment on the initial exploration, the project owners should take the duty of the exploration of the proved reserves. However, the majority of coal corporations is still in a hot water, there is no sufficient capital for resource exploration, therefore, the investment on coal exploration is very limited, and the geological work of coal mining is almost in logjam. The exploration of coalfield should be strengthened, and the investment on commonweal exploration should be increased, the investment system of commercial exploration should be improved, the proved rate of coal resources should be greatly elevated, and the backup industrial reserves in support should be enlarged to meet the demand of the new built mines.

The detected rates of oil and gas resources in China are very low, only 23% and 10.7% respectively, and have large potential to be increased. However, since the regroup and reformation of oil industry, the work of perspective investigation and development strategic orientation of oil resource has been declined. The oil company will not undertake the work of basic oil investigation. The governmental departments are in the transitional period of reformation and restructuring, and haven't efficiently organize the national work on oil and gas resource investigation and assessment, leading to the severe deficiency of the backup resource and area for oil and gas. Currently, the detected recoverable reserves of oil resources in China are 2.4 billion tons, the proportion of marginal resource is large, so the backup resources is seriously insufficient.

A new investigation on oil and gas resources in whole China should be carried out, based on new oil and gas geographic theories and assessment methods, to make clear the strategic backup area of oil and gas resources. The domestic oil and gas exploration should be strengthened. Venture fund for exploration should be set. The risk exploration by oil companies should be encouraged. Policies should be established to encourage and promote oil companies to set annual specific proportion of capital for the risk exploration.

Investigation and research on renewable energy (hydropower, wind, biomass, geothermal energy, and etc.) should be carried out, to scientifically confirm the total quantity, the technical developable quantity and the status of renewable energy resource, to provide basis for planning rational utilization of renewable energy.

2. Implement the capitalized management of energy resources, set preferable price to the high-quality energy sources, strengthen the monitor of resources

exploited, and improve the mining rate of resource.

Driven by economic profit, there is a waste of resources, such as " only mining the thick coal-bed and discard the thin coal-bed" in some of the coal production enterprises, especially in the areas with abundant coal resource or fine mining conditions. The resources recovery rates in some small mines are less than 20%, so the damage and waste of resources are very serious. Currently, the taxation was based mainly on the coal outputs in China, and the resources value discrepancy of the different coal quality and the different recovery condition has not been embodied. The market system of coal resources should be established; the capitalized management on coal resource should be implemented; rational resources price should be set on the basis of coal quality, recovery condition, natural status and etc, the preferable price should be set for high-quality resources. Practical monitoring methods should be taken; the basic work of resources management during mining process should be enhanced; the resources waste should be deterred relying on the law; and the resources recovery rate should be improved.

There is a problem of "different quality with same price" in oil and gas industry too. The proportion of heavy oil, dense oil and low-penetration oil production will be increased. The proportions of "three low" types of natural gas resources will also be high. To effectively develop and utilize the unconventional oil and natural gas resources, the resources tax and mineral resources compensatory fee on the heavy oil, the high solidification oil the third oil recovery and "three low" types of natural gas should be reduced; the policies toward gangue recovery should be set to promote the development and utilization of old oil field and the low-penetration oil field.

3. The effective approaches of energy mix optimization in China are to give priority to the development of hydropower, to accelerate the development of nuclear power, and to actively develop the new and renewable energy.

China should resume the prophase work on hydropower, enhance the exploration of water resources and hydropower planning, and add the hydropower backup projects. The medium and long-term plan of hydropower should be reinforced. From the standpoint of national economic development, energy mix adjustment and sustainable development, the west hydropower base should be organically combined with the electric power plan in the east electricity receiving areas. The local electricity market should be opened gradually, to optimize the resource in the maximum areas. i Equity should be given to hydropower in taxation and other policies.

China should make medium and long-term plan of nuclear power from the standpoint of energy supply security, energy mix optimization, environmental protection and keeping the national nuclear technique advance ability. During the construction of nuclear power projects, the government should give support in the aspects of the favorable financing policies, payback term and etc. The 1 GW grade Pressurized Water Reactor development route should be kept on; international technical improvement and renovation experiences should be applied, the batch of 1

GW grade nuclear power station should be constructed; the nuclear equipment supply, construction and management should be localized as soon as possible. The monopolization of nuclear power construction and production should be broken, other power companies should be allowed to participate in the construction and production of nuclear power to completely solve the problem of high cost on nuclear power plant and grid price in China. Specific organizations should be set to coordinate and uniform the important issues, such as the technical approaches, equipment localization and inviting foreign public bidding.

The prophase work on the wind energy resources assessment and the wind field construction should be accelerated, and the wind power equipment manufacture technology should be improved, to create a good condition for the development of the wind power in China. The Stimulant policies of the renewable energy development should be set, the development goal for renewable energy should be definite, to give rational priority to the development of the indispensable renewable energy in the future. Specific renewable energy funds should be set, the renewable energy investment channel should be established, and the favorable policies of the derating tax should be carried on to the renewable energy in China.

4. Make grate efforts to bring the action of "two resources and two markets" in to play, to accelerate energy mix optimization in China.

According to the Regular scenario, in year 2020, the international reliance of oil and gas in China will reach 54.8% and approximately 30% respectively. Therefore, the strategy of "going abroad" should be kept carrying on, and the development acceleration and rate increasing for oil companies to share oversea oil and gas resources should be encouraged. The approval procedure for oil companies to invest in the oversea oil resources should be simplified; the coordination of overseas business of three big oil companies should be reinforced, to avoid bad competition among of the national enterprises in oversea market; the government should give necessary diplomatic and military support and guarantee for the oversea business of oil companies. China should actively enter the international oil market, take the international market as the main approach for acquiring oversea oil and gas resources, and participate in the spot transactions and time-bargain in the international oil market.

In recent years, China has made some favorable policies to encourage coal export for the coal enterprises to get out of puzzledom. However, from the long-term standpoint, China should not take the coal exportation as the development strategy of coal industry. On the contrary, some coal import from neighboring countries should be encouraged in the southeast coastal areas to meet the demand of local economic development, not only to mitigate the environment pressure brought by the coal resources exploiting, but also to reduce the growing gradually pressure in coal transportation.

5. Taking comprehensive measures to improve energy supply security of China

In the coming 20 years, the basic domestic demand can be supported by the domestic oil and natural gas production. The growth of economy will make China be able to import energy to make up the insufficiency of domestic supply. Future the problem of the energy supply security will be caused mainly by the instability of oil supply countries, and oversea oil transportation channel.

The strategy of the oil multitude import should be actively carried on. Firstly, attach importance to multitude import sources and import locations, take active measures to increase the oil import amount from Russia and Central Asia area, to raise the proportion of crude oil import from Africa and Latin America areas. The import from Middle East should be scattered in the different countries too. The dispersion oil import sources and locations will not only benefit the oil supply security for China, but also help to solve the discriminating price importing cured oil from the Middle East area. Secondly, exert the enthusiasm of local entities, enterprises and nongovernmental organizations, and use various ways to establish a sound oil stockpile system to avoid accidental interruption. Thirdly, carrying on the area energy co-operation, and establish reciprocal area oil security system through participating in the international and area energy co-operation organizations. Shanghai Cooperation Organization should be used to strengthen our energy cooperation with Central Asia and Russia. Energy mutual cooperation among of the countries in the Northeast Asia should be enhanced, while oil and natural gas import pipeline project should be regarded as an important composition of our foreign trade, to promote the construction of oil and natural gas transportation pipeline among of the countries in Northeast Asia. Dialog and cooperation with Southeast Asia area should be put up to solve the problem of oil and gas resources exploitation in South China Sea and the security of transportation channel at sea. For the oil and gas resources in South China Sea, besides laying the disputes aside, we should exploit actively. For the fourth, we should not miss the chance of participating in Energy Charter Treaty to increase the security of the cross-bordered oil and natural gas pipeline between China, Russia and Central Asia countries.

Because the supply security of Natural gas and Electricity will influence directly the living of all people, it should be high lighted. For the supply side, supply source of the natural gas should be multitude and the main pipelines and branch pipelines should be formed a grid. So the oil or gas in different pipelines can be flexibly adjusted. Proper scale underground gas storage should be established to solve the peak load problem. For the demand side, the user structure of natural gas should be rational. Some gas air-conditions and heat-power-cool tri-generation should be developed to chop the peak and to fill the valley, which helps to reduce the peak-valley difference and to improve the security of natural gas supply.

The construction of electricity grid should be developed in ahead. The planning and controlling of electricity grid should be unified. The construction of the power sources should be developed in a measurable advance to guarantee the necessary backup capacity. The structure of electricity grid should be improved to increase the capability of coping with the accidents. . In order to improve the electric grid reliability and realize the resources optimization, the hydropower and thermal power

among different grid should be commutated and exchanged. The security of electricity system should be attached much importance. New investment and financing mechanism should be established for the development of electricity grid, which should solve utterly the financial problem. . A rational electricity price generation mechanism should be established. The prices in the different processes of generation and transmit electricity should be rational, the situation of the low price in the power transportation and distribution should be changed, and the proportion of the grid sector should be increased.

6. Carrying on the clean coal utilization strategy, and promoting industrialization of the related clean coal technologies, with special choice and emphasis, are the strategic measure to guarantee the sustainable development in China

Research result had showed that no matter which scenario is selected, coal would play an important role in future energy supply system in China. Developing and promoting clean coal technology is the strategic choice to guarantee the sustainable development in China.

According to the demand estimation result, in 2020, coal demand will reach about 2.3 billion tons, of which 70~75% will be used for power generation and heat supply, 10% for industrial boilers, 7% for coke making, 4% for chemical raw material and 3~4% for civil use.

Therefore, clean coal power generation technology should be attached importance in China in the future. Super critical and ultra-super critical unit should be promoted as main units for future power generation. CFBC will be developed as complementary units. IGCC and PFBC demonstrations should be planned and arranged. The desulfurization technology of the flue gas and the low NOx combustion technology should be promoted in a large scale. . The retrofit for industrial boilers should be strengthened, and advanced industrial boilers should be developed actively.

Coal washing and selection is the source of clean coal utilization. The proportion of selected coal should be increased. So, a series of coal selection plants should be retrofitted and constructed, the large coal mines should be equipped with coal selection plants, and the small coal mines should use the coal selection plants of the nearby big mines, or many small mines construct one coal selection plant together.

New clean coal utilization approaches should be actively researched, including coal slurry technology, poly-generation technology for coal chemistry, coal liquefaction and gasification, underground coal gasification technology etc.

7. Based on the economic principle, utilization rationally high-quality energy properly

The external cost such as ecological loss, environment destruction, and heath damage etc, which is caused by coal mining, transportation and utilization, should be calculated into coal price in the future gradually. In order to promote the optimization

of China's energy mix, the coal price should be raised to a rational level to increase the competition capability of high-quality energy. Secondly, a reasonable natural gas pricing mechanism should be formed as soon as possible to propel the usage of natural gas. The goal of natural gas pricing reform in China should be changed from determined by cost into determined by value. For different users, different alternative energy should be identified, which helps to decide natural gas price of different users. Thirdly, considered from long-term development, the affordability of commercial and civil use of natural gas will be higher in the future, so the natural gas market for commercial and civil use should be developed with higher priority. In the initial stage of natural gas development, in order to promote the development of natural gas industry and accelerate the start-up of natural gas market in China, the big and stable users, such as power plants and chemical plants, should be offered with favorable gas price or favorable policy in taxation. The fourth is to reduce the inconsistency of power generation and coal industry to make these two industries economic, rational and equal. Coal enterprises and power generation enterprises can be combined to form strategic alliance. Through holding, sharing or controlling each other's stock, various capitals could be combined, merged or re-structured to form mixed operation. In this way, coal price can be stabilized. In one hand, it can solve the problem that coal enterprises only offers primary products, can extend the industry chain of coal enterprises, and let coal enterprise use resource advantage to infiltrate into power generation. On the other hand, the stability of coal price and coal supply for power generation enterprises could be guaranteed, and the risk of supply is reduced. In order to achieve the goal of participating competition from the source side, power generation enterprises should pervade into coal industry by investing in new mine, and merge or purchase existing coal mine. A reasonable price system should be studied and developed. Levers such as price should be used to lead consumers to choose economic and proper end-use energy consumption devices.

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