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China's National Energy Strategy and Reform

Background Reports

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National Energy Strategies and Policies

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Background

China's progress in energy development during the past 20 years can be summarized in the following three aspects:

1. The amount of energy consumption has only doubled while gross domestic product (GDP) has quadrupled. Consumption of primary energy amounted to 1480 Mtce in 2002, ranking second in the world. While China's GDP increased by 9.7% in the period from 1980 to 2000, its corresponding average annual energy consumption rose only by 4.6%, far below the economic growth rate in the corresponding period. The elasticity coefficient of energy consumption was only up to 0.47 (see Table 1). About 1260 Mtce was saved from 1981 to 2002, meeting the goal of supplying energy required by China's economic growth half by exploitation and half by saving. Such a low elasticity coefficient of energy consumption is rare both in developing countries and developed countries.

Table 1: Relationship between Economic Growth and Energy Consumption during Different Periods in China

Year	1980~1985	1986~1990	1991~1995	1996~2000	2002/2000
GDP growth rate	10.7%	7.9%	12.0%	8.3%	7.7%
Growth rate of energy consumption	4.9%	5.2%	5.9%	-0.1%	6.6%
Elasticity coefficient of energy consumption	0.46	0.66	0.49	-0.02	0.85

2. The efficiency of energy use has been greatly improved. Energy consumption per unit GDP has continuously decreased. Energy consumption by ten thousand RMB GDP, calculated on the basis of constant price of the year 2000, decreased from 4.28 TCE in 1980 to 1.45 TCE in 2000 (see Chart 1 attached for details). Accordingly, the GDP produced per ton of coal equivalent rose from 2335 RMB in 1980 (according to the constant price of the year 2000) to 6880 RMB in 2000. The energy consumption of unit output was reduced by 64% with average annual conservation rate up to 4.6% during the 20 years (1980-2000). The world average energy consumption per unit output fell by 19% in the corresponding period. OECD member countries had an average drop of 20%. In another aspect, energy consumption per unit product has dropped considerably in major high energy-consuming sectors (such as metallurgy, chemical industry, building materials, petrochemical, and power). The unit consumption indicator as general energy

consumptions of per ton steel, copper metallurgy, compound ammonia and oil consumption of internal-combustion engines fell by more than 30%, narrowing the energy consumption gap of major energy-consuming products with international advanced level. For example, the difference of coal consumption by thermal power generation has decreased from 32.5% in 1980 to around 21%[1] today, and the comparable energy consumption of per ton steel has also dropped from 70.4% in 1980 to today's approximately 20%.

3. Great achievements have been made in environment benefits. China achieved continued emission reduction of carbon dioxide up to 770 million tons, and 19 million tons of sulfur dioxide during the period from 1981 to 2002 due to energy saving and reduction in energy use. Since the 1980s, energy projects (gas, small hydros) and energy saving technologies have been established in vast rural areas according to local needs. Energy saving of buildings in urban areas has been in practice. New energies such as solar, wind and geothermal energy have been under development and utilization. The benefits brought by these measures in recent ten years are energy saving and reduction in consuming 30 Mtce conventional commodity energy, equal to carbon dioxide emission reduction of 20 million tons each year. Some progress has been made on the sustainable development path.

Basic experiences that brought about China's energy development progress

First, the evolution of industrial structure has resulted in structural changes. Phenomenal changes have taken place in China's industrial structure in the past twenty years, especially in the industrial sectors consuming mostly primary energy (the proportion of energy consumption by industrial sectors to the total national energy consumption remained at about 70% in the 1990s). The structural changes have produced obvious energy saving results. The proportion of low value-added and energy-intensive industries has dropped, while the proportion of high value-added and energy saving industries has increased. For example, metallurgy industry has decreased in proportion. However, the proportion of electronics and communications equipment manufacturing has risen. Product and technical structures have been upgraded. According to calculations, more than the 70% saved or reduced energy came from the restructuring of industries and products, equal to a decrease in carbon dioxide emissions of 400 million tons of carbon annually.

Second, economic institutional reforms have brought great system changes. New waves of economic system reforms have changed the resources allocation approach adopted during the planned economy. The market mechanism has played a fundamental role in resources allocation. Extensive economic growth has been changing gradually. The efficiency of energy production and utilization has been improved by market economic incentives, accelerating the elimination of high energy-consuming and material-consuming enterprises, products and technologies. Significant examples have been achieved in the reform of the energy pricing system. Energy pricing reform goes from (1) mandatory pricing by government, to (2) combination of government pricing

[1] In 2002, China's coal consumption for power supply by thermal plants is 383 coal equivalent

and market pricing, then (3) gradually deregulating pricing in the market where the volatility of prices are determined by the demand and supply of the market, and price mechanism plays an adjusting role in the supply and demand for the energy products.

China's energy efficiency was 25.9% in 1980 and 29% in 1992, increasing by 3.1% within the 12 years. In 1995 after the reform of finance, taxation, price, investment and financing, China's energy efficiency reached 34.1%[2], increasing by 5.1% just within three years. China has maintained an energy saving rate of 3.6% from 1981 to 1990. With the adjustment of energy prices and improvement in the market mechanism since the 1990s, the annual average energy saving rate reached 5.6% during the 8th Five-Year Plan period. The annual average energy saving rate further rose to 7.1% during the 9th Five-Year Plan period.

Third, the implementation of energy-specific energy policies has brought about significant policy changes. The Chinese government has employed, in a comprehensive way, laws, policies, standards, and economic and administrative tools to promote energy saving and to optimize the energy mix. The guideline for energy development in 1980, "Emphasize both development and savings derived from energy saving as the priority in the short term." Energy savings was incorporated into national economic plans and social development. A more complete energy saving system was established. The *Energy Conservation Law* was promulgated in 1997 and there have been 164 state standards for energy and energy savings implemented. Since the 1990s the government has set a series of new development goals such as improving the environment, achieving sustainable development, and realizing a new type of industrialization. A series of plans and pilot projects have been organized and carried out, e.g. developing green energy, and promoting energy saving products and techniques. These were the result of industrial policies and limiting and eliminating high material-consuming, energy-consuming, technologies or enterprises, and establishing emissions fees system to improve environmental quality as well as by designating" two acid rain control regions" and their control objectives. New mechanisms and methods that fit into the market economy have been under discussion recently. New concepts and methods have been gradually introduced for demonstration and promotion such as integrated resources planning (IRP), demand side management (DSM), and energy services company (ESCO).

As to energy supply, the government adopted the projects "Generating Power by Pooling Capital" and "Managing Mines by Non-government Entities" to boost energy supply and alleviate severe energy shortages. Efforts were made in rural electrification by establishing small hydro to reduce the number of people who had no electricity to consume from 450 million in 1978 to 28 million in 2000. However, there still leaves two billion people without electricity to use at present in the world.

1. **China will face relatively severe energy problems in the next 20 years. The key to whether China could carry forward its achievements lies in whether it adopts rational policies.**

The first 20 years of this century are an important strategic period with both the opportunities and challenges for China's economic and social development. The 16th

[2] China Middle-and Long-Term Energy Strategies, China Planning Press

National Congress of the CPC has made the quadrupling of GDP by 2020 a national goal; it is also referred to as "Building a well-off society in an all-round way." Calculated on the basis of purchasing power parity (PPP), China's per capita GDP will surpass USD $10,000 by then. According to international experience, this 20 years is a key period for realizing industrialization and an important phase in which significant changes could take place in the economic structure, urbanization level, and the population's consumption structure. Most developed countries have also experienced the processes of rapid growth of energy consumption per capita (especially when the per capita GDP was between USD $3000 to USD $10,000) and rapid change (demand for oil rising proportionally) in the energy mix. Add to this to the special conditions of China, and in the context of economic globalization and environmental protection, the problems facing China are much more complicated than those facing developed countries.

How much energy will be needed in building its "well-off" society to support the economic and social development objectives, and what challenges and pressures China may face will depend on both the laws of economics and social development as well as the types of economic, energy and environmental policies the government may adopt. To illustrate the demand for energy and its social effects by adopting different policies, we set up three scenarios.

Scenario A is called the Business as Usual Scenario where no special policy measures are taken for policies to bring great effects on energy demand and social benefits.

Scenario B the related policies will be adjusted accordingly.

Scenario C can be called the Advanced Policy Scenario where a greater policy adjustment will be made to make the policies practical to highlight the influence of the economic, energy and environmental policies under the prerequisite that these policy adjustments are feasible.

What should be mentioned here is that existing policies cannot be used even under Scenario A. Consideration should be given to both the sophistication of relevant policies in force in the sectors of industry, transportation, buildings, and energy transformation, and the implementation of the policies in contemplation (see Table 1 for detailed policies). The difference between Scenario A and the other two Scenarios is only the time taken to implement policies under consideration. Please see the attached Table 2 for the difference in policies adopted by different Scenarios.

Table 2 shows the total demand for primary energy, and the energy mix under the three scenarios. Table 3 gives the demands for coal, oil, and natural gas under the three scenarios.

Table 2 Comparison of Total Demand for Primary Energy and its Constitution

Scenarios	Kind	Total demand for energy ? Mtce?			Annual growth rate	Proportion (%)		
		2000	2010	2020	2000~2020	2000	2010	2020
A	Coal	907	1425	2074	4.22%	69.9%	66.7%	63.2%
	Oil	324	538	877	5.10%	25.0%	25.2%	26.7%
	Gas	36	112	220	9.44%	2.8%	5.2%	6.7%
	Primary power	29	63	109	6.77%	2.3%	2.9%	3.3%
	Total	1297	2137	3280	4.75%	100.0%	100.0%	100.0%
B	Coal	907	1365	1788	3.45%	69.9%	66.0%	61.7%
	Oil	324	524	795	4.58%	25.0%	25.3%	27.5%
	Gas	36	108	193	8.74%	2.8%	5.2%	6.7%
	Primary power	29	70	120	7.28%	2.3%	3.4%	4.1%
	Total	1297	2068	2896	4.10%	100%	100%	100%
C	Coal	907	1205	1466	2.43%	69.9%	64.8%	59.4%
	Oil	324	460	638	3.44%	25.0%	24.7%	25.9%
	Gas	36	115	219	9.41%	2.8%	6.2%	8.9%
	Primary power	29	79	144	8.26%	2.3%	4.3%	5.8%
	Total	1297	1859	2466	3.26%	100%	100%	100%

Note: Power is calculated by electrothermal equivalent, Mtce means million tons of coal equivalent.

Table 3 Demand for Coal, Oil, and Natural Gas under the Three Scenarios

	Scenario	2000	2005	2010	2020
Coal ？100 million tons？	A	12.7	16.2	20.0	29.0
	B	12.7	16.2	19.1	25.0
	C	12.7	15.2	16.9	20.5
Oil ？100 million tons？	A	2.3	2.9	3.8	6.1
	B	2.3	2.9	3.7	5.6
	C	2.3	2.7	3.2	4.5
Natural gas ？100 million cubic meter？	A	272	399	840	1654
	B	272	406	811	1453
	C	272	445	863	1645

We can draw the following conclusions from the above forecasted results.

First, China promises to keep energy demand growing at relatively lower rate in the future 20 years if the right energy strategies and related policies and measures are taken. The demand for primary energy will reach 2500-3300 Mtce by 2020, with the average at 2900 Mtce and 2.2 times that of the year 2000. This means that China may achieve sustainable rapid growth with relatively less use of energy, and may further improve people's living standards by using less energy consumption per capita than that of existing developed countries.

Second, while keeping the same economic growth, there would be differences in energy mix and energy efficiency improvements, due to different policy measures adopted, hence resulting in a big difference possible for the demand of primary energy of 800 Mtce by 2020. That is to say, although all scenarios meet the economic development objectives, different energy development strategies may produce completely different results in energy supply, energy security, and environmental protection.

Third, with the improvement of living standards and the upgrading of the consumption structure, great changes would take place in the energy demand mix, especially in the transportation sector, and the growth rate of energy demand for buildings will be higher than that of industrial sector and the whole society in the

corresponding period. The proportion of the energy consumption of these two sectors to the total new additional energy consumption will increase from less than 35% at present to 57-75% by 2020, gradually becoming the major factors demanding energy growth. Therefore, more attention should be paid to the energy supply and energy efficiency for these energy-consuming sectors with rapid growth as well as the problems of oil security and environmental protection.

On its road to building a "well-off" society China will face a series of challenges in the field of energy.

First, China's excessive dependence on fossil fuels may put great pressure on its sustainable supply of resources. China's recoverable reserves per capita are far below the world average level. The recoverable reserves of oil per capita was only 2.6 tons in 2000, natural gas recoverable reserves per capita 1074 cubic meters, and coal recoverable reserves per capita 90 tons, equal to 11.1%, 4.3% and 55.4% of the world average level respectively. The output of China's oil cannot increase considerably, which is estimated to reach 180-200 million tons by 2020 and then fall gradually.

Although abundant in rich coal resources, the degree of verification is very low in China. The economic reserves for building new coalmines were only 20.3 billion tons[3] in 2000, which could hardly meet the needs of recent coalmine construction. Therefore, exploitation has to be accelerated. Moreover, 86% of the concentrate reserves spread in the middle and western regions where water shortages exist and far away from consumption centers, thus increasing the difficulty in development, transportation, and utilization of the coal.

From a worldwide perspective, global fossil fuels reserves at low mining costs will be completely used up by the mid or late 21st century according to the World Energy Commission and International Institute of Application System Analysis.

Second, while economic and social development depends heavily on energy, it is more difficult than 20 years ago to improve energy efficiency despite great potential. China's economic and social development depends more heavily on energy than developed countries. End use energy consumers in China spent 12,500 RMB on energy consumption in 2001, comprising 13% of total GDP, while only 7% in the U.S. From the perspective of energy utilization efficiency, the energy consumption per unit product in China is relatively high[4]. At present, the energy consumption per unit product in eight high energy-consuming sectors where energy consumption makes up 73% of the total energy consumption of industrial sectors, is 47% higher than that of the world average

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[3] Zhang Rongli etc. Coordinative and Stable Development of Coal Industry and its Development -Construction Levy Out Research , China Coal, 2003，No,4

[4] Comparing energy intensity (energy consumption per unit GDP) between countries, there will be great deviation due to the currency conversion. If calculated with nominal exchange rate, China's energy intensity in 2000 was 9.7 times that of Japan, and 3.4 times the world average level, which shows that China's energy intensity was overestimated. If calculated with purchasing power parity, China's energy intensity was just 20% higher than that of Japan and even 8% lower than the average level of OECD member countries, which shows obvious underestimate. Therefore, we choose energy consumption per unit product as the base for comparison.

advanced level. Compared to the international advanced level from this calculation, China's industrial sectors consume an additional 230 Mtce. From the above analysis we can see that **the possibility exists to reduce consumption of 800 Mtce by 2020.** Yet, it is more difficult than in the past 20 years to achieve this goal. The good results of energy saving achieved by economic system reform and restructuring in the past 20 years mean great potential to tap in the future. However, with the new conditions of heavy chemical industry and the transferring of international manufacturing, workable policies and measures must be taken in the aspects of economy, energy, and environment to achieve remarkable success.

Third, China will face relatively bigger pressures and challenges to keep sustainable development, especially in meeting environmental demands for a well-off society. China cannot avoid the practice of implementing control after pollution. Take the air pollution as an example. China's emission of carbon dioxide and sulfur dioxide rank first and second in the world respectively. Although the carbon dioxide emissions per unit GDP is obviously declining, (a drop of 52% from the year 1990 to 2001), the total CO2 emissions increased from 349 million tons in 1980 to 832 million tons in 2001. Sulfur dioxide emitted by coal burning is the main cause for acid rain. Acid rain in the mid 1990s affected over one million square kilometers more than that in the 1980s. The areas of annual average rainfall with PH value below 5.6 have been up to 30% of the nations total areas. Serious environmental pollution has caused high economic and environmental costs, and brought about great damage to public health. Statistics by domestic and foreign research institutes show that the losses caused by air pollution takes up 3 to 7% of the GDP. The main reason for such serious air pollution lies in the fact that China uses coal as major fuel in its energy mix, and no effective measures have been taken to protect the environment. Seventy percent of CO2 emissions, 90% of SO_2 emissions, and 67% NOx emissions come from coal. In addition, pollution becomes even more serious due to the increasing number of vehicles. According to the analysis of the energy demand scenarios, the estimated sulfur dioxide and NOx emissions by 2020 is shown in Table 4 based on the present level.

Table 4 Estimated Sulfur Dioxide and NOx Emissions

	Scenarios	2000	2010	2020
Sulfur dioxide	A	2719	4072	5738
? 10,000 tons?	B	2719	3900	4947
	C	2719	3443	4056
NOx	A	1988	3417	4982
? 10,000 tons?	B	1988	3273	4295
	C	1988	2889	3521

From the perspective of environmental capacity, the whole country can contain at best 16.2 million tons[5] if the SO2 emissions are kept under the capacity that the ecological system can bear. For NOx, the environmental capacity cannot exceed 18.8 million tons. And these standards are the lowest standard required by the "Environmental Well-off standard." However as shown in Table 4, an environmental "deficit" already exists. SO2**and NOx emissions had exceeded environmental capacity even under Scenario C with least emissions of pollutants. To meet today's control requirements, the two pollutants should be reduced respectively by 24.36 million tons and 16.41 million tons, decreasing by 60.1% and 46.6% respectively.** If under the conditions of Scenario A with much more pollutants, then there would be even more serious air pollution. In addition, carbon dioxide emissions will increase considerably. China is under increased pressure from international circles to limit greenhouse gas emissions. In light of the international experiences and China's potential, it is not impossible to reduce environmental pollution considerably to meet the environmental requirements by a "well-off" society while maintaining economic growth and energy development. However, this will be a great challenge.

Fourth, it is imperative to maintain energy security, especially the oil security. Serious issues may arise if improper measures are taken. With the rise of income per capita, China will inevitably face two issues: (1) the evident increase in oil consumption; and (2) the large quantity imported oil to meet domestic needs due to limited domestic oil resources. These problems have already emerged.

China has become a net import country of oil since 1993, and its dependence on foreign oil had risen from 7.6% in 1995 to 31% in 2000. **Oil consumption will reach at least 450 million tons by 2020 and China's dependence on imported oil might be close to 60%, equal to the level of the U.S. today (U.S. dependence on foreign oil being 58%).** The fact that most of its oil supply comes from international resources will affect the supply and demand in the international oil market, and will make China's oil a prominent security issue. Chinese government and enterprises will need to learn (1) how world events impact oil security, (2) how to fully utilize domestic and foreign resources, (3) how to establish systems for early warning and contingency plans, (4) how to take part in an international cooperative framework that may facilitate the safeguarding of China's oil security, and (5) how to improve competitive strength of the Chinese oil enterprises to compete in the international markets. In addition, the Chinese government also needs to guarantee the supply security of power and natural gas, another facet of energy security.

[5] Only the capacity of sulfur dioxide was taken into consideration here based on the control of acid rain.

2. The sustainable development energy strategy should be regarded as the fundamental guideline for China's energy development in a new era promoting the concentrated development of the economy, society, and the environment

The goal of building an overall well-off society requires high demands on energy supply and its supply quality. Adopting the right energy strategies ensure energy supply, solves outstanding problems, and can meet challenges in the future. Two strategic issues for China's future development exist: (1) from the perspective of energy development trends in the world, especially in developed countries, energy consumption has gradually reduced its dependence on coal, and the majority of energy utilized is oil and gas, moving towards a larger proportion of renewable energy resources. **We can learn from this global energy development trend whether China will be able to incorporate it and implement a leapfrog strategy in the energy field.** (2) From the perspective of China's future development in the long term-- although it is still possible to achieve the goal of quadrupling the GDP in the first 20 years of this century while keeping the energy consumption increase doubled, **excessive dependence on fossil fuels (especially coal[7]) over time will severely weaken China's sustainable energy development.** Therefore, **the energy strategy for the first 20 years of this century should emphasize a "transformation" in the development** direction and approach to realize the long-term objectives. Though the tasks are arduous, there is the need to realize transformation in development and to promote development by means of transformation. Efforts should be made to set up new mechanism within the first 20 years to lay a foundation for far-reaching development in the future.

This transformation should include the following three aspects:

First, to achieve the goal of building an overall well-off society requires a shift from simply meeting the basic requirements of economic development to meeting the dual purposes of achieving environmental benefits while satisfying basic needs of realizing the coordinated development of economy, society and environment. **That is, energy development should shift "quantity" to "quality", making environmental protection central when formulating energy development strategy.**

Second, the energy development approach should be changed from governmental planning and regulation to market-oriented mechanisms guided by the government to overcome the drawbacks of planned economy that still exist in the field of energy. System reform should play a more important role in guaranteeing energy supply, efficiency improvement, and structure optimization.

Third, with economic globalization and China's entry into the World Trade Organization, **energy development should shift from relying on domestic resources to an international strategy, fully utilizing domestic and international resources and markets.** That is, China's energy strategy in this new era should be incorporate an international perspective.

To meet the challenges of energy development according to the above principles, **China should make a sustainable energy development strategy in line with the guideline of "energy saving as a priority, a diverse mix, and environment friendly" in the future 20 years. China should adopt an international energy strategy by system innovation and technological improvement, to carry out our international strategy and strive to realize the goal of maintaining energy consumption doubled while quadrupling the GDP. Energy demand by communities, especially by less affluent communities should be met first. China should try its best to effectively guarantee national energy security, to reduce to the extreme extent the effects of energy production on the environment and health, to form essentially a new initial mechanism of sustainable energy development and lay a foundation for future development.**

The ideal objective of sustainable energy development in China is to keep the demand for primary energy less than 2500 Mtce and 2900 Mtce at most. The proportion of coal consumption will be controlled to under 60%, the amount of renewable energy reaching 525 Mtce (among which new renewable energy generation up to 100 million KW), dependence on imported oil under approximately 55%, and the rate of reduction of major pollutants being 46–60%.

3.1 Energy saving as priority policy

Scenarios analysis shows that total energy consumption may decrease by 15-27% by 2020 if proper measures are taken to promote energy savings and energy efficiency. It is estimated that during the period of 2000 to 2020, we can achieve accumulated energy savings of 1040 Mtce valued at 932 billion RMB or an emissions reduction of 18.8 million tons of SO2 and 65.6 thousand tons of CO2. Energy consumption per unit GDP will decrease by 2.3 to 3.7% annually. Although the decline becomes slower compared to that in the past 20 years, it will be still higher than the world average dropping rate of 1.1%[8] for the same period. According to the current situation, the energy saving policies still have great effects on improving existing production capability and energy efficiency. The potential for energy saving can reach 150 to 200 Mtce with workable technology and a balanced economy.

From this we can see that there is great potential and possibility for energy saving and energy efficiency improvement. Whether the economic growth can be achieved at relatively less energy input depends largely on the utilization of energy saving potential. Energy saving may also bring obvious benefits to the guarantee of energy security and reduction in environmental pollution caused by energy production. Therefore, **energy saving should be put first place in the energy strategy. That is, energy saving should be given priority, and can contribute more than increasing energy supply in satisfying the increasing demand for energy. To establish the important strategic position of energy saving, it is suggested that resources conservation should be incorporated in to the country's basic state policies, thus "population control,**

resources conservation, and environmental protection" jointly as China's basic state policies for the new era[9].

The industrial sector is still the biggest energy consumer although its proportion in total energy demand falls from 72.7% in 2000 to 56.7 -58.7% by 2020 (see Table 5). At the same time, energy consumption by the transportation and buildings sectors will considerably increase. The proportion of energy consumption by the transportation sector will increase from 11.1% in 2000 to 16.3-17.1% by 2020, and the proportion of energy consumption by construction sector will rise from 16.2% in 2000 to 25 - 26.7% by 2020. It can be seen from the above that energy should be conserved in every field, and effective measures should be taken in the three sectors. The industrial sector, which takes up over half the total energy consumption, is still the key field for energy saving. **It is estimated that the potential for energy saving by industrial sector is up to 500 Mtce. Yet, the status should be changed as soon as possible where the emphasis is put on the energy saving by industrial sector, while ignoring the energy saving transportation and construction sectors. Effective measures should be taken as early as possible to implement energy saving construction and transportation sectors, which are under rapid growth and would require a high proportion of energy consumption.** If the gas tax and the fuel efficiency standards aimed at improving vehicle fuel efficiency could be implemented and enforced in the near future, and improvements can be made to optimize the transportation structure accordingly, 87 million tons of oil could be saved by the transportation sector by 2020, equal to half the total crude oil in domestic market. Great potential also exists in the buildings sector for energy savings. For China's existing urban buildings, only 2.1% have met the standards for energy saving of building heating. Compared with countries with similar climate in the same latitude, China's energy consumption by heating and air conditioning of per building unit is about three times that of the neighboring countries. About 160 Mtce could be saved in energy consumption in the buildings sector by 2020.

Table 5. Sub-sector's Demand for Primary Energy

Scenario		Total Energy Consumption (Mtce)			Average annual growth rate
		2000	2010	2020	2000~2020
C	Industrial sector	943	1239	1398	2.0%
	Transportations	145	246	409	5.3%
	Commercial/civil	210	374	659	5.9%

	Total	1297	1859	2466	3.3%
B	Industrial sector	943	1384	1664	2.9%
	Transportations	145	275	494	6.3%
	Commercial/civil	210	409	738	6.5%
	Total	1297	2068	2896	4.1%
A	Industrial sector	943	1429	1924	3.6%
	Transportations	145	282	535	6.8%
	Commercial/civil	210	426	821	7.1%
	Total	1297	2137	3280	4.7%

Note: End-use energy demand by the three sectors is converted into primary energy.

3.2 Diverse energy mix

Compared with the energy production structure, China's proportion of coal in primary energy consumption has declined significantly since 1990 (see the attached table). The proportion of coal in the total primary energy consumption fell from 76.2% in 1990 to 66.1% in 2002. Heavy dependence on coal in China's energy mix for such a long period of time has still not been resolved. The main reason for this is that no energy strategy and policies for optimizing energy mix exist. China's existing energy mix has caused serious environmental pollution and threatens the sustainable energy supply because of its unlimited consumption of fossil fuels. In addition, such an energy mix may impede energy efficiency. China's average utilization efficiency of natural gas is 30% higher than that of coal, which is 23% lower than that of oil[6].

Adjustments to the energy mix may have a great effect on the total demand for energy. According to sensitivity analysis, a drop of 1% in the proportion of coal in energy consumption mix, the total demand for corresponding energy may decrease by 20 Mtce. According to energy supply analysis, structural adjustments may save 128 Mtce by 2020.

From past trends, we can forecast that the consumption of superior energy such as oil and natural gas will rapidly increase, causing demand side motivated structural changes. Obvious structural changes have taken place in public energy consumption and in

[6] NIRA granted research project, Research of Northeast Asia Energy and Security Guarantee II: China Energy Environmental Issue and the Necessity of its International Cooperation with Northeastern Asian Countries, Executive Summary

developed areas, which has laid a good foundation for the adjustment and improvement of energy mix. **The following principles should be embodied in making policies for energy structural adjustment:**

1) The energy mix should be optimized to the fullest under conditions that international resources should be fully exploited based on domestic resources under the prerequisite of energy supply and economic acceptability

2) The state energy security should be guaranteed

3) Environmental quality should be improved and the capability of sustainable development should be strengthened

Recommendations for energy structural adjustment and improvement include gradually decreasing the proportion of coal consumption, speeding up natural gas development, satisfying the basic domestic demand for oil by using both domestic and foreign resources, aggressively develop hydros, nuclear power and renewable resources. Twenty years will be spent to create an initial diverse energy mix, making the proportion of superior energy increase obviously. The details are as follows:

Efforts should be made to gradually reduce the proportion of coal in primary energy consumption and to keep the proportion of coal under 60% by 2020. Coal still plays a critical role in China's energy mix because it is more abundant than oil; this situation may remain for a long time. Simply from the point of the quantity of resources, China's coal shows the potential to satisfy middle- and long-term needs. If 2.5 billion tons of primary coal was produced annually, it is estimated that the total conservation of coal can serve 80 years. If the restraints of water resources and environmental capacity were taken into consideration, the largest scale of coal development will be 2.8 billion tons for annual production. The key to guaranteeing coal supply is to increase production capability and the construction of infrastructure. The demand for coal by 2010 and 2020 will be 1.7 billion tons and 2.1 billion tons, respectively even if we adopt the plan demanding the least coal. From the perspective of the supply capability of registered mines and those under construction, it is estimated that the production capability will reach 710 million tons[11]. If production capacity of coalmines located in towns is still calculated as per 350 million tons, the net increase in annual average production capacity should be 50 million tons[12] from 2000 to 2020 to guarantee a stable coal supply. The task of constructing coalmines will be very difficult. If not handled properly, this problem may cause another shortage of coal supply.

The development of natural gas should be accelerated; it can play an important role in replacing coal consumption. As to oil, international resources and markets should be fully exploited to meet the basic domestic oil needs. Efforts should be made to improve the slow development of natural gas, and the proportion of natural gas in the primary energy consumption should increase from 2.8% in 2000 to 5-6% by 2010 and 6.7 -8.9% by 2020 respectively. The average annual consumption of natural gas should

increase by 9% from 2000 to 2020. The development of natural gas should be based on domestic resources and supplemented with foreign resources. The total demand for natural gas should amount to 160 billion cubic meters[7] by 2020, natural gas imports up to 50-60 billion cubic meters and the dependence on imports is about 34%. From the supply capacity of domestic resources, the reserves-mining ratio was 62.2 in 2001, much higher than 15.4 of oil (the world average reserves-mining ratio of natural gas and oil was 40.6 and 60.7, respectively). It is still in its growth stage with great potential for China's natural gas development.

The accumulated proved reserves may reach 4.9 trillion cubic meters by 2010 and 7.5 trillion cubic meters by 2020. That is, China's reserves of natural gas shall keep growing until 2020 at least. The development and utilization of natural gas has to be accelerated to realize the above targets. By 2020, the output of domestic natural gas should be 4 to 5 times that of 2002. At the same time large-scale transmission pipelines and other infrastructure should be built for using imported natural gas. Whether natural gas can replace coal depends on whether its price is competitive and acceptable. The development of a natural gas market has been impeded because of the existing prices and pricing systems, which have causes high prices for natural gas. Therefore, problems with pricing mechanisms should be solved as soon as possible.

The demand for oil by 2020 will amount to 450-600 million tons, which is 2-2.6 times that of 2000. Considering natural resources limitations, and the great pressure of dependence on imported oil and oil security, the goal should be set to meet the basic needs of domestic markets rather than to replace coal as main energy resource. Efforts should be made to keep the consumption of oil below 450 million tons by 2020. The peak time for crude oil production is predicted come after 2015 with the biggest quantity of 200 million tons and the output of crude oil by 2020 may reach 180-200 million tons. That is, even in the scenario with the least oil, oil imports will still reach 250-270 million tons, and dependence on imported oil will be up to 55-60%.

Efforts should be made to aggressively develop hydropower, nuclear power, and renewable resources. It is estimated that by 2020 the needed installation capacity will be up to 860-950 million KW (see table 5). That means about 29-33 million KW should be added to the existing installation capacity within the future 20 years. **By accelerating the construction and development of hydropower, its installation capacity should be not less than 200 million KW, striving to reach 240 million KW.** The proportion of hydro in the total power shall increase from 16.4% in 2000 to 19-22% by 2020. This would require annual hydro installation of 6.4-9 million KW. As far as hydro resources are concerned, reserves that could be recovered in terms of technology amount to 521 million KW. However, the rate of development is only 15% at present, much lower than

[7] Data on natural gas of base year was converted into heat value of 9310K/km3. According to such calculation, the total demand for natural gas is 160 billion cubic meters.

the world average level[8], even after such developing countries as India, Vietnam, and Brazil. According to the above tentative plan, hydropower development will reach 38-45%. In addition, great interregional differences exist in hydropower development. The degree of development in the eastern region is 68%, leaving little room to develop massive hydropower. It is only 8%, however, in western regions. From the above analysis, we can see that there is great potential for hydropower development, especially in western regions, and yet the difficulty and costs will be very high.

Table 6. Comparison of Demand for Power Generation and Different Power Mixes under Three Scenarios

Scenario		Installation Capacity？GW？			
		2000	2005	2010	2020
C	Total installation capacity	282	398	543	865
	Coal power	204	272	338	509
	Oil power	10	9	3	1
	Gas power	1	5	25	43
	Hydro	65	107	154	240
	Nuclear power	2	4	15	40
	New energy	0	1	7	30
B	Total installation capacity	282	407	551	867
	Coal power	204	281	361	568
	Oil power	10	10	4	3
	Gas power	1	3	26	39
	Hydro	65	108	146	211
	Nuclear power	2	5	10	34

[8] China's development rate is only 10% on the basis of power quantity, lower than the world average level 18.4%, ranking about the 80th in the world.

	New energy	0	1	3	13
A	Total installation capacity	282	402	559	947
	Coal power	204	285	384	661
	Oil power	10	10	4	6
	Gas power	1	3	28	46
	Hydro	65	100	132	191
	Nuclear power	2	4	9	31
	New energy	0	1	3	11

Efforts should be made to increase nuclear power installation capacity, through actively developing nuclear power, to 40 million KW by 2020 with annual growth of 15.9%. The proportion of nuclear power in total power generation should increase from 1.2% in 2000 to 7% by 2020. China's uranium resources are abundant in the short term and have potential for long term development of nuclear power. Input, technology, and environment are the key factors in developing nuclear power. Emphasis should be put on increasing the proportion of domestic production and realizing massive production, considerably strengthening the competitive strength of nuclear power.

Great efforts should be made to actively develop renewable resources and establish a certain scale to lay a foundation for future replacement of fossil fuels. The utilization of renewable resources may reach 525 Mtce by 2020, doubling the amount of 256 Mtce in 2000, and the proportion of the advanced utilization of renewable resources (such as wind power, solar power generation) in the total utilization of renewable resources will rise from 15% in 2000 to 73.5% by 2020. Installation capacity of renewable resources generation shall reach 100 million KW by 2000, in which hydropower comprises 70 million KW, wind power 20 million KW, and biomass power 10 million KW. From the perspective of quantity of resources, China has 7300 Mtce of new energy resources and renewable resources available for utilization. The quantity under development is not more than 40 Mtce, leaving sufficient resources for utilization. During the 9th Five-Year Plan period, the development and advanced utilization of renewable resources had reached an average annual rate of 11.2%. If this degree could be raised to 15%, the development goals set for 2020 could be realized. Despite its long-term objectives to replace fossil fuels with renewable resources, the short-term objectives should be taken into consideration to solve energy use problems in the remote rural areas that may arise in building a "well-off" society.

3.3 Environment friendliness

Environmental restrictions effect the energy strategy and the supply and demand technologies of energy during economic and social development in many parts of the world. Under many circumstances, environmental factors have a more decisive meaning than resources. In view of the severe destruction of environment, and the production and utilization of energy being the main reason for environmental deterioration in China, **it is recommended that environmental protection be at the core of energy strategy. When formulating energy strategy, one of the key decision-making variables is the environmental capacity and the environmental demand for a well-off society.**

Environmental restrictions on energy development are as follows.

(1) Environmental capacity. Based on acid rain controls, the amount of sulfur dioxide that China can handle is about 16.2 million tons. Based on the air quality requirements, however, the total amount of sulfur dioxide should be restricted to under 12 million tons to keep the density of sulfur dioxide for most cities in the country up to the national standard Grade II. The quantity of NOx that the country can handle cannot exceed 18.9 million tons.

(2) Reduction of greenhouse gas emissions. The CO2 emissions will increase to 1.3-2.0 billion tons in China by 2020 with carbon emissions per capita between 0.9 and 1.3 tons. If the U.S. signs on the Kyoto Protocol, China will be the next "target" which will be requested to limit GHGs. China would not be able to avoid limiting emissions after 2020. With the restriction CO2 emission, the marginal cost of reducing carbon dioxide will tend to be rising. Therefore, China's energy development in the future shall undertake the global environmental pressures. The economic input required by limiting emissions of greenhouse gases would force the Chinese energy sectors to re-position themselves.

(3) Making China environmentally well-off. Being environmentally well-off is an important aspect of China's overall well-off society and the environmental quality is also an important index evaluating the overall well-being of society. According to the indexes for the model cities of environmental protection and provinces and cities, and the experience of developed countries, indexes for China's environmental requirements are listed in Table 7.

Table 7. China's environmental requirement targets in the next 20 years

	Targets	Unit	2000	2010	2020
Air pollutants caps	Target of emission cap of SO_2	Ten thousand tons	1995	1600	1300
	Target of smog emission cap	Ten thousand tons	2257	1600	1000
	Target of emission cap NO_x	Ten thousand tons	1890	1800	1600
Air pollution control	Rate of industrial smog elimination	%	91.41	100	100
	Rate of smog reduction	%	91.8	95	97
	Rate of reduction in SO_2 (burning)	%	10.3	50	70
	Rate of reduction in industrial powder	%	82.1	90	95
	Proportion of desulphurizing units in coal fired units	%	2.1	38.4	80.2
	Emission compliance of industrial boilers' smog	%	91.0	94.0	97.0
	Emission compliance of industrial kilns' smog	%	70.3	80.0	90.0
Input to environmental protection	The proportion of environmental input in GDP	%	1.1	1.5	2
Air environmental quality	Days with air quality index better than grade 2	Day		200	300
	Average daily density of SO_2	$\mu g/m^3$	150	150	150
	Average daily density of in-breathing particulates	$\mu g/m^3$	150	150	150
Living environment in towns	Popularity of gas in urban areas	%	84.2	60.0	75.0

4. Adopt integrated measures to ensure oil security

4.1 Domestic and foreign oil resources, status of supply and demand, and the strategies for oil security are the three major factors influencing China's oil security.

From the long-term and global points of view, the so-called "Energy Problem", is nothing more than an "Oil Problem"[15]. Oil is the key factor in the creation of public wealth and also one kind of most important commodity influencing the global political pattern, economic order and military operations. Practically all the countries put the oil on the core position of energy strategy.

The three major factors constituting oil security China: (1) China's oil and gas resources, domestic output and import demand; (2) whether the supply and demand situation and the price volatility of oil in the world can meet China's demand or not; the strategies for oil security based upon the domestic and foreign supply and demand.

China is a big country in terms of its oil resources and it has a certain potential of development; however, at the same time oil and gas resources are relatively insufficient. The amount of resources, cumulatively proven recoverable reserves, residual recoverable reserves, and the output value (i.e. richness) per square km land area, are evidently lower than that of the world average level (for details, see Table 8). It will be increasingly difficult in the fields of oil and gas exploration, prospecting, and development in the future. As mentioned above, with a comparatively rapid increase of the oil consumption and by 2020, the external dependence of China's oil maybe exceeds 55% and the oil security problem will be a challenging and vital problem.

As viewed from the world oil resources and the situation of supply and demand, oil supply at the beginning of this century is in a relatively safe period. There are four reasons: (1) over the past twenty years, world oil output and the residual recoverable reserves have all been rising steadily; the residual recoverable reserves increased at an average rate of 2.2% with the accomplishment of "Balance of Revenue and Expenditure, slight surplus is attained" policy and the deposit-yield ratio of oil was kept at upward of 40; (2) Since the late 1980s, world oil was in limited production.

The Organization of Oil Exporting Countries (OPEC) adopted the general strategy of limiting production to maintain price, and acted as the adjuster of world oil supply; by reason of politics and economy, the oil yield of the countries in the Commonwealth of Independent States was reduced by significant margin; (3) world oil deposits could be doubled in about 30 years (by 2025); (4) before 2020, the oil yield will increase, and after 2020, owing to a bit slower development of alternative energy, the "Post Oil Times" will be the times of diversified energy, and the proportion of oil in the primary energy mix will also be significantly reduced. Therefore, in general, within the first 20 to 30 years of this century, either the oil consuming or exporting countries are in a relatively secure state, which can satisfy the global demand of oil inclusive of China's. However,

[15] Cite from the Research Report of the Research Institute for the Analysis of International Applied System on "Energy Resources in the Limited World", 1981.

the supply of natural gas will be more abundant than that of oil, and there will be great strides made in the development of international trade of natural gas.

Price trends in the international oil market will be characterized by long-term stability and short-term volatility by a big margin. Over time, the prices of oil and natural gas have become the monopolistic prices evidently higher than their costs; if calculating the prices according to the constant price of the US Dollar, the average value of long-term and multi-year oil prices is relatively stable; if calculating by the variable US Dollar, it has been slightly going up and it is estimated that by the year 2005 to 2020, the multi-year average price (calculate by the constant US Dollar in 2000) is more possible to rise from 23 per barrel to USD 25 per barrel. However, each factor influencing oil price can lead the price of oil to deviate from the average value and can be enlarged by speculative operation and human psychological factors, as a result, the price of oil will fluctuate accordingly. Among the various factors affecting the prices of oil are fluctuations in economic growth, change in supply and demand relations, and the impact of unexpected incidents.

4.2 The characteristic features of modern international oil market and oil geopolitics must be accurately grasped for acquiring the outlook on oil security.

The features emerged from the modern oil market and oil geopolitics are as follows:

1) Oil is regressed as a commodity. Oil's role as a political weapon has been considerably weakened as well as it being seen as strategic material. It has become an important commodity in the domain of society and economy has been more prominent. The law of market economy itself has had a greater impact on oil operations; **2) a new relationship emerged between the oil exporting countries and consuming countries**. Neither side in relation to OPEC and OECD can act independently and dominate the oil price; there are conflicting interests as well as mutual dependence and mutual infiltration between the two parties; **3) it is a complicated supply and demand pattern.** The non-OPEC-member oil exporting countries are playing an intensified role, and even more hot spots of oil exploitation and exporting countries emerged, new consumption hot spots emerged in Asia, and the global oil trade and flow direction tend to further complication, and both the consuming countries and oil exporting countries are diversifying the exporting (importing) countries to maintain the stable supply and demand relations and acquire still better economic benefit; **4) transnational corporations have become the major force in international oil markets.** The upsurge of privatizing oil companies is, to varying degrees, affecting all exporting and importing countries, and through the integration of North-South development and corporate mergers, a number of large-scale transnational corporations have rapidly emerged as principal exporting and importing countries. The combination of transnational corporations with international financial groups has become the major force in control of international markets.

As to China, the change of above-mentioned international oil market and oil geopolitics has both favorable aspect and a new challenge. The principal factors affecting China's oil security consist of the following: First, there is the possibility of temporary shortage of international oil supply. The dependence on oil import is constantly increasing, which increased the risks in supply of oil, and internationally, the short-term and partial shortage of supply may take place and the hostile forces will be possible threat for oil supply. Second, short-term fluctuations in international oil prices will possibly arise, and the excessively high price of oil can reduce the growth rate of GDP and the excessively low price will cause losses to the domestic oil sector. Third, as for domestic factors, the uncertainty of domestic oil and gas production exists to a certain extent, and the natural disasters will possibly produce a greater influence over production and transportation (specially over the transmission of natural gas). Fourth, the s China National Oil Corporation lacks both strength and international business experience. Fifth, there is an absence of a corresponding system of oil security.

4.3 Adopt integrated strategies to build up the safeguard system of China's oil security

The insecurity factors of oil can be minimized through comprehensive strategies. This is in addition to the implementation of the sustainable energy strategy as stressed above. With energy savings as the priority, comprehensive strategies also consist of the following:

First, accelerate the exploration and development of domestic oil and gas resources. The government should step up investment and support in the early stages of oil exploration to create conditions for opening up new regions and new fields. Through policy guidance, all domestic large-scale oil corporations have increased investments in upstream exploitation. And in line with key investments in the world oil industry, the investments have been turning to the upstream industry. The proportions of investment occupied in the upstream one were raised gradually from 40%~60% up to 78.5% (in 1995) and 82.9% (in 1998); carry out the practical regional strategy of oil and gas development and accelerate the development of oil science and technology.

Second, strengthen oil recovery and develop alternate fuels and technology. At present, the average recovery rate of oil fields in China is approximately 34%. If it were to adopt triple oil recovery technology to strengthen exploitation, the average recovery rate could be raised to 50%, thus greatly increasing the reserves for exploitation. In accordance with the American Geological Investigation Bureau and World Oil Association's "Resource Appraisal of World Oil and Gas" (in 2000) , if China adopts measures to intensify oil recovery and increase the recovery rate, the recoverable reserves could increase by 1.96 billion metric tons, equal to more than 80% of the residual recoverable reserves in 2000. The development of alternate fuel and technology (such as electric vehicles) is also an important step to decrease dependence on imported oil. Estimates

show that by 2020, the output of coal-liquefied products could reach 16 million metric tons and would need an investment of 145 billion RMB.

Third, as a big and rising international oil consuming country, China should make full use of the currently-formed international oil benefit pattern to carry out energy diplomacy and actively participate in the world and regional energy cooperation organizations. The government should: (1) participate in futures business and spot transactions; (2) take the markets as the principal means to acquire oil products; (3) take the quotient oil acquired abroad as the means to opening up the domestic oil futures market; (4) pursue more rights to speak in oil price negotiations; (5) and establish the laws/regulations system and a regulatory system favorable for entering the international markets.

Fourth, gradually establish and improve on the strategic oil reserve system and early warning system. Establishing a diversified and rationally-allocated strategic reserve system of oil to meet the needs of security at different levels, and in 2010 is the best way to acquire a strategic reserve equal to a 40 day oil supply. By 2015, we will have a reserve equal to 55 days and establish oil field reserves and energy-yielding reserve systems. Another important measure is to establish an early warning security and corresponding mechanism as well as the corresponding early warning program according to five grades (i.e. the oil shortage reaches 3%, 5%, 7%, 10% and 15% of the import amount respectively).

5. Improve the system, and push for the implementation of an energy saving strategy with governmental promotion

5.1 There are greater barriers to energy saving work at present

First, our energy saving sense is lagging behind. In the developed countries, from the early 1970s the energy saving sense that which was practicing economy and reduction only for dealing with the energy crisis has developed into the sense aiming at raising benefit, decreasing pollution, improving the living quality and the public relations. In our country, the sense of supplying the shortage and reduction still exists and this is the root cause of cognition to slacken the efforts in energy saving work so long as the energy supply is not in contingency state.

Second, the governmental energy saving body has been evidently weakened and a great number of energy saving managerial personnel have been laid off. This caused the decline of energy saving managerial work. In contrast, countries such as the US and Japan have strengthened state energy saving administration, for which there are 530 personnel working in the Energy Efficiency and Renewable Energy Bureau of the US Department of Energy and the annual budget for 2002 amounted to USD $1.3 billion.

Third, shortcomings exist in energy saving legislation and law enforcement. The Energy Conservation Law is not effectively carried out and the formulation of the complementary laws and regulations is slowing progress. An overall planning and decision-making system taking into account energy, the economy, and the environment still needs to be established. And there is a lack of energy decision-making and legislation capabilities.

Fourth, there is no effective economic incentive system. Since the reforming of the financial and taxation system in 1994, the original incentive policy and measures for implementing tax credits and preferential loans on energy saving projects and products have been significantly shrunk and/or no longer exist, which hinders energy saving.

Fifth, technical innovation is lacking in energy saving. Because there is too little investment put in the research and development of energy saving technology, it could not be listed as a national key scientific research plan of the 10th Five-Year Plan. It is difficult for enterprises to raise funds for energy saving technical retrofits and innovations. The quality of energy saving equipment is poor and some key technologies and equipment are imported.

5.2 The key links of energy saving work involve the governmental promotion and the establishment of effective economic incentive system

First, strengthen the building of the governmental energy saving management system and conscientiously transform the governmental accountability

Market drawbacks and obstacles are evident in the energy saving field. They are mainly reflected in the following points: 1) Market price can not give expression to long-term interests; 2) investors are partial to the energy development projects; 3) the environmental cost used by energy production is not included in the energy price; 4) consumers lack energy saving information and skills; 5) the government's irrational financial and taxation policy and control policy hamper energy savings potential. Energy saving is classified as a public issue. The function of market mechanism is rather limited, and according to the World Bank, the contribution rate of market power to the realization of energy savings potential is only 20%. In countries with market economies, energy savings work is the same as environmental protection: the government must play a leading role.

To put an end to weak government administration in the energy savings field, a Resource Office should be established under the State Council. There is for the State Council to set up the special purpose funds of energy saving management used for the following operations: energy saving policy, laws, regulations and standards.

Changing government accountability in the energy saving field is an important step. Currently, the government is responsible for formulating energy price and taxation policy, energy saving laws, regulations, and standards. Government offices also provide

information for energy auditing, energy efficiency labeling, public education and training as well as funding. Energy management carried out by the government should be turned from giving first place to energy supply to end use consumption and from relying mainly on administrative means to relying mainly on economic means. At present, the energy saving of governmental agencies should be taken as the breakthrough for carrying forward the nationwide energy saving work.

Second, establish and improve energy saving economic incentive policies

Energy saving is a highly dispersed secondary investment activity. Since energy expenses of most enterprises occupy make up a small proportion of the production cost, and higher energy costs can usually be recovered through product price, energy efficiency is usually not the decisive factor for consumers purchasing the energy-using equipment. Therefore, governmental economic incentive policies are essential for energy saving.

Pushing forward an energy price based on the market, and adjusting price and controls are recommended. Preferential policies for implementing tax credits or accelerating depreciation should be carried out in favor of energy saving investment projects; enterprises producing new energy saving products should be viewed as hi-tech enterprises and given preferential tax rates. Levying of gas taxes or raising the rates of consumption taxes on gasoline and diesel oil is needed. And the tax-bearing ratio of gasoline and diesel oil prices will be raised by about 60% within three to five years.

Third, establish an energy efficiency standards and labeling system for equipment
The formulation and implementation of energy efficiency standards and labeling of end use energy consuming equipment are one of the key measures for raising energy efficiency and of great significance for cutting down energy consumption, promoting market competition, eliminating international trade and technical barriers, and decreasing pollutant emissions. Taking into consideration energy efficiency and meeting international market standards, various end use energy-consuming equipment energy-efficiency standards and labeling need to be formulated along with their accompanying policy measures. If China formulates and implements new energy efficiency standards (such as household appliances, lighting fixtures, electric motors, fans, water pumps, compressors and transformers), it is estimated that by 2020, the electricity-saving potential will reach 254 billion KWH, energy saving potential of 128 Mtce (industrial boilers), the gross net benefit will reach RMB 506 billion, SO2 emission reduction 19.4 million tons and 97.6 million tons of CO2.

Fourth, establish new energy saving mechanism under the condition of market economy

Under a market economy, the crux of implementing strategy lies in creating a fair competitive playing field for conducting energy saving and development to give full play

to energy saving in the process of competition. Domestic and foreign experience clearly show that Demand Side Management and Integrated Resource Planning (DSM/IRP), energy service company, life cycle cost analysis, consumers' education, market pricing mechanism and the internalization of external cost and so forth, are the effective policy tools for bringing about the energy saving precedence. These series of new mechanisms should be gradually implemented within the whole country on the basis of pilots and models through working out the relevant policy, laws, and rules to remove obstacles.

5.3 Adjust the energy saving priorities and strengthen energy savings work in the buildings and transportation sectors; continue to promote industrial energy savings

The government has focused on industrial energy saving at the expense of buildings energy saving. This is a remnant of China's planned economy past. In addition, the dramatic increase in energy consumption in the transportation sector has been ignored. To address these emerging needs in the buildings and transportations sectors, energy saving priorities must be readjusted to strengthen energy savings in the building and transportation fields while continuing to promote industrial energy saving.

Industrial energy saving: As mentioned above, by 2020, the industrial sector will still be the biggest energy consuming sector as well as the sector with the most potential for energy savings. The energy saving amount realized through restructuring the sectors and readjusting product mix occupies about 70% to 80% of the energy saving potential in industrial sectors. Energy saving through technical advancement and reducing the energy consumption of unit product comprises 20% to 30%. Therefore, to realize energy savings industrial sectors should combine technical advancements with sector restructuring and adjustments of product mix through the following ways: revising energy saving design specifications; carrying out the corporate energy auditing and report/ standard-reference management; giving impetus to the energy saving technological advancement; establishing energy management information system; pushing policies and measures such as performance contracting; and promoting the energy saving of industrial sectors.

Buildings energy saving: By the end of 2002, only 0.23 billion square meters of energy saving buildings were constructed within China. This occupied 2.1% of the urban construction. Building energy saving should start with reforms in the heating supply system, including deregulation of the heating supply market and the promotion of retrofitting of older buildings. The State Council should formulate and implement building energy efficiency regulations, and design standards. Economic incentives are another way to encourage the production and the use of energy saving building materials and energy-consuming appliances and utensils. In addition, special funds should be made available for the existing structures for energy saving retrofits. The inspection and supervision of buildings should be strengthened. And energy-efficiency standards and labeling for energy-consuming equipment should be implemented.

Transportation energy saving: At present, the average oil consumption per 100 km is 20%

higher than that of developed countries. Provided the policy is properly carried out, by 2010, the oil-saving potential of highway transportation will be about 15%; by 2020, it will be 30%. A gas tax is recommended as well as fuel efficiency standards and standards for oil products quality. To improve urban planning, transportation systems should give priority to the development of high-speed and public rapid transit and establish intelligent transportation systems. The government should also encourage the development, ownership, and use hybrid-fuel vehicles to promote energy savings in transportation.

Demand Side Management should be implemented in the power sector, and the power grid company designated as main players for implementing DSM.

6. Implementing the environment-friendly energy strategy by means of governmental impetus, participation of the public, emissions caps and trading

A balance between energy and the environment is the basis of environmentally friendly policy. Energy is the core of environmental matters; energy production and use will produce significant influences local, regional and global atmospheric environments. Environment is key for energy policy making and environmental assessment should be the precondition for approving all the energy projects. The environment should be incorporated into the integrated resource planning. Energy is also at the center of environmental diplomacy and energy consuming products are also the objects of international trade green barriers. Energy production (particularly the nuclear power and hydroelectric power) and utilization (in the range of green lighting, green construction materials, energy saving air conditioners, energy saving refrigerators, green computers) are the principal goals of a green campaign.

The implementation of environment friendly strategy needs to be finalized in such four aspects as governmental driving, participation of the public, cap control and emissions trading.

Government driven: Environmental protection will fail if left to the market to decide; the government must take a stronger role. The government's role is not only to direct investment in environmental protection but also to formulate and execute laws, regulations, and standards. The government should also establish an economic incentive system to accelerate the development of clean energy and the elimination of industries and high consumption and polluting.

Participation of the public: The role of the public needs to be strengthened. Public education is needed to increase knowledge on environmental protection and improve awareness of the public's relationship to their local surroundings. Nongovernmental organizations should be brought into full play.

Cap controls: Environmental quality has been severely worsened. Cap controls on emissions are necessary to realize balanced development of the economy, energy and the environment.

Emissions trading: Trading low cost and highly effective way to protect the environment. It is also the most effective way to utilize environmental resources. International experiences have shown impressive results and should be referred to when applying emissions trading in China.

The following are policy recommendations:

(1) Develop environmentally- friendly energy

The development of clean energy and the energy clean utilization technology should be regarded as a central goal for the sustainable development energy strategy. In 2020, coal will still occupy about 60% of primary energy consumption; the development of clean coal technology is critical. By 2020, accelerating the promotion and use of clean coal technology can cut coal demand by 200 million tons and decrease emissions accordingly. It is recommended that the national clean coal technology commission established in 1995 should be resumed. The government should revise the promotion plan of national clean coal technology, strengthening the link between environmental protection means and the development of clean coal technology. In addition, incentive policies for technical research, development, promotion and utilization of clean coal technology should be formulated.

(2) Stricter cap controls will be carried out against principal pollutant emissions

Strict cap control over SO_2 have been carried out but in the next stage, great attention to the inhaled particulates is necessary since they have become the major pollutant in many cities. Significant increases in NOx make it necessary to gradually put them under cap controls. At the same time, still stricter standards of cap controls against the smoke dust and powder emissions must be implemented.

(3) Increase emission fee standard and carry out emissions trading

The emission fee standards should not be lower than the cost of pollution control, which should be incorporated into production costs. Pollutant emissions trading can reduce pollution emissions at minimal costs. The SO2 emissions trading system should be carried out nationwide. The current absence of laws, regulations, and on-line automatic inspection should be rectified; supervision and management must be enhanced.

(4) Implement environmental protection buy-downs and internalize the external costs of environmental pollution

Under the new power system of "separation from grid and bidding for access", to encourage clean power supply, more generation with renewable resources and priority

access should be implemented. As to price competition, not only the financial cost but also the external costs of environmental pollution should be incorporated into the total cost.

(5) Control the environmental pollution of urban transportation in the early stages

Environment-friendly transportation policies that give priority to public transportation, fuel consumption reductions, tailpipe controls and clean fuel vehicle development should be implemented. Reductions in vehicle tailpipe emissions should take into consideration: vehicles, fuel, and regulations. Fuel improvement measures include: prohibition of leaded gasoline, fuel improvements, alternative fuel and fuel quality improvements. The improvement measures for vehicles emission include: engine improvements, tailpipe purification, particulate collector, and motor vehicles maintenance. Developed countries have shown that total pollution emissions can be reduced by 30 to 40% by carrying out good service and maintenance. As far as rules and regulations concerned, traffic demand management policy, special laws and regulations to control gasoline and vehicle emissions and fuel efficiency standards should be finalized. In addition, gas tax reforms should be put into practice in the short term.

(6) Cancel production subsidies for high energy consumption products

Our country should stop supplying power at a favorable price, which encourages the production and export of high energy consumption products. In fact, this exported energy at a low price leaves China paying the environmental costs.

(7) Respond to global warming

Shortly before or after the year 2020, the negotiation of climate change convention with the reduction of greenhouse gas emission will exert great pressure on our economic and social development. We should take precautions and respond earlier.

7. Institutional reform and technical innovation are the core for finalizing sustainable development strategy

In the next 20 years, China will be confronted numerous change; some will impede sustainable energy development. To realize the goal of doubling energy consumption and quadrupling GDP, we must continue to carry on our experience of success in the past 20 years, and make breakthroughs in the aspects of institutional reform and technical innovation. This is the key to materializing our sustainable development strategy.

7.1 Accelerate the market-oriented reforms in the energy field

The energy sector was the last to go through the reform process. To a certain extent, it has become a restrictive factor in the development of the economy and deepening reforms. Market-oriented reform in the energy field has made some achievements, but it

still remains in its initial phase and the reform is still arduous. Moreover, a series of fundamental conflicts and problems have not been completely resolved, which impede further reforms and long-term development in the energy sector. The following are issues that still need to be resolved: (1) the coal price has not been completely market-oriented; (2) the reform of "separation from the grid and bidding for access" has just begun; (3) fairly strong regional monopoly in the oil sector; (4) the competition framework is being established and the main players of the competition, the market order, the market function and the pricing mechanism have not yet been put in place.

Experiences in the past 20 years indicate that the energy released by the economic institutional reform plays a very important role in the rapid economic development supported by a comparatively slower energy growth. In the next 20 years, China must further deepen institutional reforms, especially focusing on the relative delay in market-oriented reform in the energy field. .

The overall goal of our reform is: to ensure that China's overall energy strategy is carried out and the market competition is allowed full play in optimal allocation of resources. China also needs to improve the international competitive strength of its energy sector and satisfy society's daily increasing demand for energy. Additionally, it must meet all challenges in energy field and supply high quality, stable, sufficient, and clean energy products at a low price for the relevant industries and users.

The main content of our reform includes:

(1) Reform the energy management system

Because there is no central energy department government office to handle energy related issues, a unified governmental energy management department is needed to conform to our country's overall interest. This department could then plan the development and coordinate all energy sector to create an integrated national energy strategy and policy.

On the principle of "separation of regulation from administration", there is a need to establish a relatively centralized energy regulator, which separately regulates pursuant to our laws and regulations those sectors where monopoly (for example, power and natural gas sectors) features, and outstanding security problems (for example, coal sector) exist.

(2) Reform the administrative assessment and approval system and transform the government's accountability At present, issues such as monopoly and lack of market access in some industries are related to the current access control mechanism. In addition, government is guilty of intervention in enterprises. The following are recommendations: a) reform the current executive assessment and approval system; b) relax economic controls while enhancing social controls; c) encourage the government to shift its responsibility to protecting our national energy security and public interest as well as environmental protection; d) change our current investment management system to one of better transparency in the course of policy and decision making; e) encourage the

development of non-governmental enterprises in the energy field and introduce public auction and bidding invitation mechanism to the disposal of some energy resources at the proper time.

(3) Reform the current energy pricing system and price control approach

We should deregulate the price of those energy products in relatively full competition and allow supply and demand of the market to determine their prices. The government should create reasonable price controls over energy products with monopoly features, and use market acceptance as the main basis for price control (currently focus on solving of problems with natural gas price). We should form reasonable price parity among energy products through such measures as taxation policy, environmental protection buy-down and reform of price control approach so that energy restructuring can be smoothly carried out.

(4) Deepen the reforms of state-owned energy enterprises

We need reduce the number of state-owned enterprises in some sectors, accelerate the reform of property rights system, and encourage the development of mixed ownership. The state-owned assets management system needs to be improved to create good conditions for upstream and downstream integration among different regions and sectors.

Goals of sector reforms

Power sector:

1. Deregulate the market access of grid facilities and encourage social capital to invest in the construction of grid facilities
2. Realize the interconnections of regional grids
3. Improve on regulation mechanism
4. Establish a national integrated power market
5. Take the lead in introducing competition in generation connections
6. Realize separation from grid and bidding for access to establish a fairly competitive market mechanism
7. Introduce competition into power sales (retail market) gradually

Oil and natural gas sector

1. Accelerate pricing mechanism reform of oil and natural gas
2. Reduce the direct intervention from the government in the prices of oil products and natural gas
3. Break regional monopolies and encourage the three largest oil and natural gas groups to do business in other regions
4. Improve on the regulatory mechanisms and agencies of the oil and natural gas sector
5. Accelerate the pace of opening up to the outside world
6. Reduce trade and investment barriers

7. Encourage the involvement of social capital in the construction of natural gas pipelines while enhancing price regulations of pipeline facilities with monopoly characteristics
8. Establish an oil security early warning and strategic oil reserves system

Coal sector:

1. Improve international competitiveness of the national coal sector
2. Incorporate full competition in the coal market (through pricing reforms, deregulation, regulations, etc.)
3. Promote the optimization of supply and consumption mix related to the coal sector and other energy sectors,
4. Encourage the wide use of clean coal technology
5. Establish the fundamental role of our coal industry in the national overall energy strategy.

7.2 Technical innovations need to play a key role

Investment in energy research and development is far from adequate. In 2000, our national energy research and development investment was only 69.7 billion RMB (only 1.8% of Japan's), occupying 6.43% of our total research funds and 0.0068% of our GDP, while its percentage reaches 15.73% and 0.088 respectively in Japan. Within the energy research investment, the investment of enterprises occupy 53.6%, while their energy saving research investment only occupies 2% of their total investment on energy research. In addition, there are some obvious limitations in technical innovation mechanism. Because of the above reasons, the technical innovation makes a somewhat low contribution to energy savings and energy efficiency improvement. Without increased investments, our future goal of sustainable energy development can not be finalized.

The government needs to increase its investment in research investment in the energy field. According to end use energy demand, national key technologies should be chosen and brought into full play, incorporating all forces in terms of production, learning and research to handle energy issues.

The key to establishing an efficient innovation incentive mechanism is institutional reform, especially the market-oriented reform in energy field. We should establish an efficient incentive mechanism to promote continual enterprise innovations by shaping a normative corporate management structure and an effective competitive market structure, thus putting technical innovation on a good development path.

8. Promote massive development of renewable energy through legislation

8.1 Status of renewable energy

Internationally, renewable energy can be classified as conventional renewable energy and new renewable energy. Conventional renewable energy mainly includes large-sized hydro and biomass produced through conventional technology. New renewable energy mainly includes small-sized hydro generated through modern technology, solar energy, wind, biomass, geothermal, ocean energy, solid wastes and so on.

In 2000, global consumed renewable energy was 1960 Mtce[16], occupying approximately 13.6% of world supply of primary energy. Electric Power generated by renewable energy occupies 19% of the total, which is only second to the power generated by coal.

The improvement of energy efficiency and development of renewable energy have become two indisputable wheels for the sustainable energy development. **Strategically, the world will finally shift to renewable energy. Therefore, all countries around the world should take the promotion of renewable energy development as their basic option of energy development in the 21st century.**

The European Union (EU) stipulates that the percentage of renewable energy in primary energy needs to be increased from 6% in 1997 to 12% in 2010 and will reach 50% in 2050.

China develops renewable energy vigorously for the following reasons: **1) sustainable development; 2) adjust energy mix; 3) environmental protection; 4) develop the western regions; 5) supply energy for rural areas and power for remote areas as well as promote ecological construction; 6) enhance energy supply security; 7) find new growth factors for our economy.**

8.2 The reasons for slow renewable energy development and its related international experience

In 2000, China consumed 256 Mtce renewable energy, which occupied 19.7% of the total primary energy consumption, among which the new renewable energy, reached 37.2 Mtce, occupying 14.5% of the total, and small-sized hydros occupied 78% of the new renewable energy. New renewable energy generated 8.3 billion KWH power, occupying 6.17% of the total.

The reason for the slow development of renewable energy is: **The technical cost for most of power generation by renewable energy is too high and the market is too small.** Up to now, the cost of power generation by renewable energy is much higher than that of power generation by conventional energy, with the small-sized hydros as an exception. Obviously, the high cost will restrict the renewable energy market, and a

[16] The world Energy Survey, 2002 IEA

narrow market will handicap the cost reductions, creating a vicious circle, and making the development of renewable energy more difficult.

The experience of the international renewable energy development can be summed up as follows: **Compete with the cost of conventional energy; adopt economic incentive policies, mandatory market policies, and new technology.**

The competition with the conventional energy mainly means to reduce the subsidies for fossil energy and internalize its environmental cost.

Economical incentive policies include the subsidies to renewable energy and tax credit policies.

Mandatory market policy means to require renewable energy to occupy a certain proportion of the market through laws, regulations, and governmental decrees, and transfer the incremental costs to consumers in a fair approach. The following are policies.

(1) Renewable energy portfolio standard? RPS? : This is a quantity-based policy mechanism, which requires the power generated by renewable energy to occupy a certain proportion in the total power, and leave its price to be determined by the market. Generally, it is accompanied by issuing green energy certificates to generators and green energy certificate trading mechanism.

(2) Feed in Law: This is a price-based policy mechanism, which requires an electric company to buy the power of generators using renewable energy at a set price. The actual quantity of renewable power will be subject to the market.

(3) Competitive solicitation mechanism? NFFO? ? The government issues a tender and controls the whole process of competitive solicitation and realizes its goal by signing a long-term power purchase agreement with the generators using renewable energy. This is also a quantity-based policy and concession belongs to this mechanism.

Adoption of new technology: Many renewable energy technologies are still at their primary phase and immature yet, therefore, we need to tackle key problems and make pilots, reduce the cost and enlarge the market to realize their massive production.

8.3 The goal of the renewable energy development by 2020

The overall development goal by 2020: **1) develop renewable energy on a large scale; 2) have most renewable energy technologies will comply with international level; 3) reduce the cost and realize its commercialization; 4) promote the transform of rural fuel mix and optimize the energy quality in the rural areas; 5) solve the power supply problem in remote areas.**

The quantity goal is: By 2020, the renewable energy used by China will reach **525 Mtce,** and the total renewable energy will be about twice of the 256 Mtce in 2000, and the percentage of new renewable energy will increase to 73.5%.

Installation capacity of generators 100 million KW: Among them, small-sized hydro will occupy 80 million KW, wind power will occupy 20 million KW and biomass will occupy 5 million KW.

8.4 Renewable energy development strategy: (1) **government support,(2) legal guarantee, (3)introduction of competition, and (4)reliance on science and technology**

Governmental support: Domestic and foreign experiences indicate that renewable energy will not develop rapidly without governmental support. Government support includes carrying out mandatory market policies and economic incentive policies to promote renewable energy development.

Legal guarantee: In the early stage, in order to develop renewable energy, all countries would develop technology first. Once the technology became mature, they then shifted to focus on modeling and reducing the cost as well as opening up markets. In recent years, some countries require electricity companies to supply or purchase renewable power through legislation. Thus, they need not to follow the old sequence and leapfrog to the phase of creating markets directly.

Introduction of competition: The cost can be reduced only by competition; there is the need to enlarge the market further to realize its commercialization finally.

Reliance on science and technology: Fundamentally, the renewable energy development relies on the advancement of science and technology.

8.5 Policy recommendations

8.5.1 Enhance legislation: Make every effort to approve and issue the *Renewable Energy Promotion Law*

8.5.2 Enhance the construction and innovation of the policy system: (1) accelerate the pilot demonstration wind power concessions; (2) improve the investment and financing environment and attract foreign and non-governmental capital; (3) design public benefit fund plan for implementation; (4) accelerate the research and pilot of mandatory market policy for renewable energy

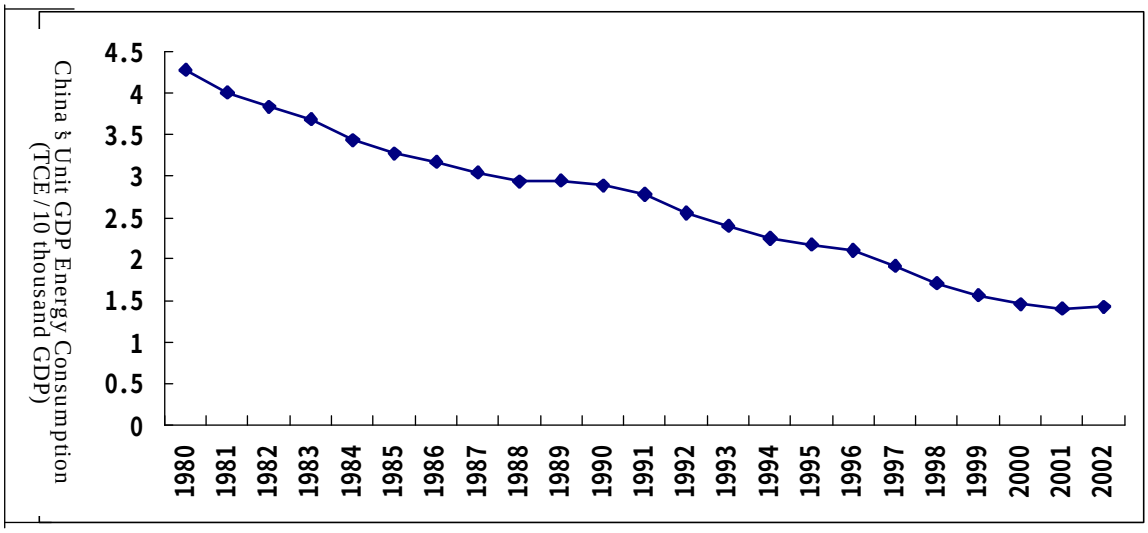
8.5.3 Adopt proper economic incentive policies: Since there is no fuel income deduction in the renewable energy generation system, it is recommended renewable energy such as wind, should have a value-added tax similar to small hydro should as well as the customs duty and income tax exemption.

8.5.4 Increase investment in renewable energy: We recommend that the development of renewable energy be listed in the plans of all levels of governments concerning industry development and scientific research to tackle these key problems, which will be incorporated in the financial budget.

8.5.5 Localize the manufacturing of power generating equipments using renewable energy? Foreign and non-governmental capital in the renewable energy industry should be encouraged as well as localization of equipment manufacturing to reduce costs.

Appendix

Chart 1 1980~2001 China's Unit GDP Energy Consumption Evolution



Source: China Statistics Abstract 2003, calculated on the basis of constant price in 2000

Table 1 Potential policy initiatives China based on the three scenarios

Transportation	Buildings	Industry	The energy shifting sectors
● Make gas tax of the vehicle ● Develop the public transportation mode, and set up intelligent traffic system (ITS) in the large and medium cities ● Work out measures to promote clean fuel automobile development ● Make relevant policies, encourage the international manufacturers with energy saving environmental protection type vehicles to enter the Chinese market ● Advance the formulation of the fuel efficiency standard	● Formulate building energy saving standards and implement heating price reform, to promote energy-conservation ● Formulate and implement of energy efficiency standard and labels of household appliances ● Implement new-type energy saving wall envelopes for buildings ● Promote and demonstrate large-scale projects such as green illumination projects, etc.	● Carry on the demonstration and popularization of voluntary energy saving agreements ● Revise the sector's energy saving design specifications ● Set up industrial products labeling and classification of energy consumption system ● Make the complementary codes of the energy saving law, and launch pilots for promotion	● Continue to push forward the system reform of electric power system ● National Electricity Co. eliminates overall the units under 100,000 kilowatts ● Generally install the desulphurizing device for newly-built thermal plants ● Develop the nergy with low carbon or no carbon, such as hydros, etc., ● Encourage the research and development and application of fuel cell, solar photovoltaic cell, etc.

Table 2 Factors included in the three scenarios and main differences among the three scenarios

	Scenario A	Scenario B	Scenario C
Population	The family planning policy has slightly been relaxed, the rate of natural growth of population is relatively high, national population is up to 1.485 billion by 2020.	Continue to carry out the state basic policy of the family planning, the rate of natural growth keeps relatively low-level, National population is up to 1.470 billion by 2020.	Carry out the family planning policy strictly, birth rate shows a trend to drop year by year, with 1.445 billion national populations by 2020.
Urbanization	Urbanizing progress is restricted by household register policy, resource and economic development level. The urbanization rate is 52.86% by 2020.	Giving priority to the development of small towns, give consideration to the mode of coordinated development of different kinds of cities. The urbanization rate is 55.78% by 2020.	Suitable for the needs of the development of western regions, all the small and medium-sized cities, big cities get rapid development. The urbanization rate is 58.29% by 2020.
Consumption trend	● The city builds houses fast, but energy efficiency level is not improved very fast. ● Rural housing construction will increase very fast. ● The popularity of the rural resident's ordinary household appliances will have improvement by a	● The housing and car consumption increase by a fairly big margin. ● Energy-consumption in big cities is mainly electric power and gas; communities rely mainly on electric power, coal, LPG in small cities. ● The demand potential of household electrical appliances is relatively great in small towns, the sales volume of ordinary home appliances increases	● Purchases of homes, automobile will increase very fast. ● Residents use high-quality energy, such as gas fuel and electric power, etc. Natural gas consumption increases by large margin in the city. ● Home appliances improvements accelerate; home appliances products' energy efficiency is improved.

	relatively large margin. ● The rural automobile upgrades, the motorcycle and automobile increase more. ● In leading civilians to choose the consumption pattern of high-efficient, environmental protection, the government's influence is relatively weak.	remarkably. ● Natural gas is widely used in the eastern area.	● The proportion of rural electric power and LPG use is raised, the renewable energy is commercialized and gets certain development
Adaptation degree to global economy	It is difficult for China to meet the challenges brought by global economic changes.	The global economic changes have a little effect on Chinese economic development.	The adverse effect of global economy is totally digested.
Industrial sector	● Small enterprise is difficult to implement close, stop, merge and shift, their competitive strength is relatively weak.	● The size and structure of the enterprise shift to economical size, tending to be rational.	● Enterprises seek to have large-sized corporate development, their international competitiveness is strengthened.
Transportation	● The small and medium-sized cities lack public transit mode of rational planning. Travel relies mainly on private vehicles; the urban public transit cannot meet the	● Focus on public transport and motorcycle for development. ● From 2005 to 2008, big cities and some coastal areas will implement Europe II standard mainly. After 2010, Euro-II implemented in small	● Large and medium cities residents' trips rely mainly on public transport, large and medium cities set up intelligent traffic system (ITS) ● The technological progress of the automobile trade is

	requirement. ● Vehicle energy efficiency raise relatively slower	and medium-sized cities. ● Some taxis for urban public transit will promote LPG in step by 2005-2010.	remarkable. Alternate techniques of clean fuel will be generally adopted for public transport and private cars. Euro III standard in the key cities.
Electricity generation	● Thermal power plants adopt desulphurizing device in step, the thermal power plants without desulphurizing devices occupy sizable proportion by 2020. ● Hydros, nuclear power, natural gas cogeneration and wind develop generation relatively more steady.	● For the newly- built thermal power plant, the proportion of the power plants with desulphurizing devices increases as soon as possible. The desulphurizing devices will be generalized by 2020. Begin and adopt clean coal generate electricity technology after 2010. ● Hydros, nuclear power, natural gas cogeneration and wind generation accelerate	● Thermal power plants adopt desuphurizing devices, with generally. More applications of the clean energy technology, ultra critical high-efficient generating set, IGCC, etc. ● Hydros develop smoothly, nuclear power, natural gas cogeneration develops on a large scale relatively, Wind electricity increases rapidly.
Energy saving policies	● Enhance the complementary codes *Energy Conservation Law* ● Lack valid policy means to guide the market. The implementation of energy saving goal is obstructed.	● Refine the complementary codes of *Energy Conservation Law* ● Energy saving policy, measures can be implemented more smoothly	● Refine the price mechanism of energy, and fiscal and taxation system that encourage energy saving. ● Energy saving policy, measure are successful.

Environmental protection policies	• Continue to use the current environmental protection standards • Before 2005, implement atmosphere pollution control for "two control regions" and key cities. • Before 2010, SO_2 emission cap and density will be in compliance in "two control regions".	• Continue to use the current environmental protection standard • PM10, PM2.5 are the focus of control measures • Improve air quality by increasing the supply of gas in the big cities. • Before 2005, implement atmosphere pollution control in "two control regions" and key cities. • Before 2010, SO_2 emission caps and density will be in compliance in "two control regions". • Before the 2020, "two control regions" policy will be carried out effectively, acid rain and SO_2 area will be controlled.	• Make efforts to implement emission standards in big cities. • Make stringent standard for NOx emission. • The substitution of coal not only takes place in the big cities but also happen in the rich medium-sized cities • Set up a stringent system of environment enforcement • Adopt the stricter SO_2 emission standards for power plants, force power plants to adopt desulphurizing technology
Energy resources	• The international oil resources will not become restraints over the next 20-30 years. • Chinese oil output has limited ability to increase production, but imported oil can satisfy oil demand growth • It is difficult for user to bear natural gas price; with slow exploration, and development of natural gas lines	• The international oil resources will not become restraint over the next 20-30 years. • Chinese oil output has limited ability to increase production, but imported oil can satisfy oil demand growth • The exploration and infrastructure construction of domestic natural gas is developed smoothly, the development of the natural gas market is good	• The international oil resources will not become restraint over the next 20-30 years. • Chinese oil output limited ability to increase production, but imported oil can satisfy oil demand growth • Natural gas price mechanism will improve, natural gas demand increase rapidly, import volume of natural gas increases.

	natural gas, line and slow construction of pipeline network, LNG and pipeline natural gas import are limited. ● The output of domestic natural gas is 80 billion cubic meters by 2020, import 40 billion cubic meters.	● The output of domestic natural gas is 120 billion cubic meters by 2020, import 50 billion cubic meters	● The output of domestic natural gas is 120 billion cubic meters by 2020, import 80 billion cubic meters
Energy security	● Based on domestic energy resources	● Utilize foreign high-quality energy, set up diversified energy import system.	● Diversify energy imports, pay attention to energy security problem
Energy sector reform	Progress of reform lags behind other sectors, monopoly continues to exist in some aspects.	Carry on restructure of the energy enterprises. Monopoly is broken.	The reform makes relatively fast progress. Energy enterprises have improved their international competitive strength
Energy efficiency level	● Because the objective condition makes the development of some technology obstructed, and due to some policy oriented disputes choose other options to comply with the objectives of international average level difficult to realize for technical equipment and the equipment	● Assume that the technology, the energy efficiency of unit products and equipment efficiency competence of unit product of trade of every department in China, reach the international average level when the time comes in 2030	● Assume the technology and energy efficiency, equipment efficiency level of different sectors and trades in China can reach the international average level by 2030

	operational performance.		
Public's awareness of energy saving and environmental protection	● Better	● Better	● Good

Table 3 The relation between the newly-increased GDPs and the newly-increased energy demands among three scenarios

		Unit	2000~2005	2005~2010	2010~2020
Scenario C	Newly-increased GDP	Hundred million RMB	39274	54798	174335
	Newly-increased energy demand	Mtce	277	285	607
	Newly-increased energy demand / newly-increased GDP	Tce /ten thousand RMB GDP	0.704	0.520	0.348
Scenario B	Newly-increased GDP	Hundred million RMB	39274	54798	174335
	Newly-increased energy demand	Mtce	375	396	828
	Newly-increased energy demand / newly-increased GDP	Tce /ten thousand RMB GDP	0.954	0.723	0.475
Scenario A	Newly-increased GDP	Hundred million RMB	39274	54798	174335
	Newly-increased energy demand	Mtce	374	466	1143
	Newly-increased energy demand / newly-increased GDP	Tce /ten thousand RMB GDP	0.952	0.851	0.655

Table 4 Energy consumption mix and its volatile trends

	Total energy consumption? 0.01 Mtce?	Proportion %			
		Coal	Oil	Natural gas	Hydros
1980	60275	72.2	20.7	3.1	4.0
1981	59447	72.74	19.96	2.79	4.51
1982	62067	73.67	18.91	2.56	4.86
1983	66040	74.16	18.14	2.44	5.26
1984	70904	75.27	17.45	2.37	4.91
1985	76682	75.8	17.1	2.2	4.9
1986	80850	75.8	17.2	2.3	4.7
1987	86632	76.2	17.0	2.1	4.7
1988	92997	76.2	17.0	2.1	4.7
1989	96934	76.0	17.1	2.0	4.9
1990	98703	76.2	16.6	2.1	5.1
1991	103783	76.1	17.1	2.0	4.8
1992	109170	75.7	17.5	1.9	4.9
1993	115993	74.7	18.2	1.9	5.2
1994	122737	75.0	17.4	1.9	5.7
1995	131176	74.6	17.5	1.8	6.1
1996	138948	74.7	18.0	1.8	5.5
1997	137798	71.5	20.4	1.9	6.2
1998	132214	69.6	21.5	2.2	6.7
1999	130119	68.0	23.2	2.2	6.6
2000	130297	66.1	24.6	2.5	6.8
2001	134914	65.3	24.3	2.7	7.7
2002	148000	66.1	23.4	2.7	7.8

From: Thomas B. Johansson and Peter A. Bradford
Subject: China's National Energy Plan: Observations from Meetings and Some Energy Strategy Considerations
Date: September 5, 2003

We held meetings at the Beijing office of the Energy Foundation during the week of August 18-22 with a group of researchers writing the Main Report and groups conducting work under 7 out of 11 sub-contracts. Each meeting lasted for around 3 hours, and was either conducted in English or interpreted by Fuqiang Yang. The researchers gave presentations followed by Q&A and discussions. With the exception of the "Comprehensive Report" on scenarios, no drafts were available, although in some cases brief synopsis were presented at the time of the session.

The presentations were uniformly of a high quality, and reflect significant achievements on key issues for China's future. We very much appreciate the time and effort made to give us insight into the directions and conclusions emerging in the preparation of the national energy strategy document. We intend the following comments not as criticism of the excellent work that is going on but as an opportunity perhaps to broaden its scope and to integrate its parts in a way consistent with the tremendous challenge faced by China's energy planners.

China intends to quadruple its economy by 2020 and is presently growing at a pace consistent with that goal. This means that one of the largest economies on earth will replicate itself three times over (three more economies the size of the present China) over the next two decades. This presents an immense environmental and national security challenge but also an immense opportunity.

China's energy system cannot continue to grow according to current patterns without substantial risk of:

- Becoming significantly dependent on oil –and perhaps gas –imports;
- Severe additional public health and environmental damage that will have very large economic consequences;
- Being unable to meet the challenges and economic opportunities likely to arise with regard to limiting green house gas emissions as climate change impacts become increasingly apparent[9];

[9] Although China does not have specific greenhouse gas reduction responsibilities under existing treaties, it has –like all signatories to the U.N. Framework Convention on Climate Change- committed itself to "protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities". United Nations Framework Convention on Climate

- The energy system becoming a constraint on economic growth if advanced technology projects do not come on line sufficiently quickly.

The briefings that we received show that the challenge is well understood. Realizing the opportunity will require that the energy system options be carefully analyzed in an integrated fashion. Such work is already underway at the Energy Research Institute of the National Development and Reform Commission. We urge that this important work be expanded into more fully integrated supply-demand scenario generation, expanding on the supply side options and exploring the implications in terms of cost, emissions and imports for various alternative futures, employing various levels of advanced technologies, and exploring what these would require in terms of institutional and policy change.

Such an approach would require an understanding in quantitative terms of where China desires to be in 2020 in terms of such goals as 1) level of oil and gas imports, 2) growth and composition of the economy, 3) regional development, 4) expanding access to electricity, and 5) controlling SO2 missions. Modeling could then identify alternative options and paths to get there as well as the institutional and policy changes that best supported these changes. The options that would be most compatible with future decisions to limit greenhouse gas emissions could also be identified.

There are strong reasons to base the energy economy on a policy of limited energy imports. The essence of energy security is to avoid depending for essential uses on supply and transportation methods whose performance, terms of delivery and environmental impacts can neither be predicted nor controlled. The failure of U.S. efforts to limit import dependency (which has grown from 19% of total oil imports in 1968 to some 58% today) has exposed the U.S. to unpredictable and often unpleasant shocks in recent years.

For China, the ERI and other modeling analysis suggests that the desired economic growth can be attained with a much lower growth in energy consumption and at lower cost if an optimal strategy and mixture of policies are chosen. Additional end use efficiency should be explored, using advanced technologies. This will leave coal and renewables - and gas in some areas - as the major domestic energy resources.

Change, Article 3. Energy sector development options that are compatible with future greenhouse gas emission reduction are likely to be less expensive in the long run than those that assume that no such limitations will be necessary or desirable for China.

These findings strongly shape the basic approach to import reduction: With aggressive deployment of advanced technology, coal has the long term potential to meet all China's need for clean fuels and environmental protection. However, not all technologies now labeled "clean coal" can achieve this. Coal can be used (if the CO2 is sequestered) in ways that are compatible with sustainable development requirements, through, for example, oxygen blown gasification to produce clean liquid and gaseous fuels as well as electricity and heat. Such facilities must be assured access to the grid for electricity sales and payments based on a market situation that either eliminates or charges for environmental and health impacts[10].

We offer some general energy strategy considerations based on international experience and on our own past work. Until we see drafts in writing, we cannot be sure of the extent to which these are already reflected in the ongoing work.

1) The principles underlying the plan must be articulated very clearly, as must conflicts among the constraints. For example, reducing oil imports, holding down China's total energy bill and protecting the environment will inevitably be goals of high importance. Nevertheless, a scenario in which a constraint against increasing China's total energy bill is more important than the other two may produce quite a different result than a scenario in which the highest priority is that the environmental burden must be no worse than it is today. And this in turn would be quite different from a scenario in which oil imports cannot exceed 100Mtoe or a specific percentage of total oil or energy consumption. If a preferred future scenario is chosen it should state what the highest priority constraints are. Too many energy plans –including the current U.S. plan –do not do this.

2) Between now and completion of the project, the challenges of integrating the work of the subgroups is immense. Without such integration, the Plan risks becoming a list of desirable items –of limited use in guiding government officials through the inevitable conflicts and competing resource claims that will arise.

3) China's extraordinary growth rate compels the inclusion of scenarios based on the employment of best available technologies and standards at

[10] The health and environmental impacts of burning coal in the Chinese electric sector are apparently very large, estimated at up to 7% of total GDP at present and likely to increase in the short term. Another study estimates the health impacts of coal burning at as much as 1.5 cents/kWh, see "Air Pollution in China: Health Damages and Policy Options", report by the Harvard Center for the Environment, China Project and the Tsinghua University Institute for Environmental Science and Engineering, 2003.

least by 2010. In a country that is doubling its economy every decade, the use of such technologies and standards in all fields –conventional supply, renewables and energy efficiency - can make a much greater difference than would be the case in societies growing more slowly. The retrofitting and reconfiguration of existing facilities that will occur in such countries as the U.S. and Japan will be of relatively little significance in China, which has more to gain from implementing the best proven technologies quickly. Of course, China also has much to lose with each year that goes by, because the added building stock will exist for decades. Every year's failure to use high building standards represents a commitment to build more power plants and to consume more fuel. In addition, higher standards create an opportunity for China to lead the region and perhaps the world in the manufacture of efficient appliances, as has already begun to occur with light bulbs.

It would be interesting to illustrate how far it is possible to go from a technology point of view in this respect, and then add economic, environmental, and security aspects, as well as an evaluation of institutional, policy, and regulatory measures that would have to be considered. E.g. would it be reasonable to enact fuel economy standards from 2010 at the level of hybrid vehicles now on the market in many countries? This would mean that the 50 million vehicles put on the road in the 2010-2020 period would require perhaps 50Mtoe less oil (out of a projected demand of 420Mtoe, 220Mtoe of which is expected to be imported) than without such standards. Emissions would of course be reduced correspondingly.

4) Once the scenarios are developed, the policies necessary to create the desired outcomes must be clearly stated from the beginning, and they must be adhered to and consistently enforced as long as they remain productive. Companies and investors and customers must be able to count on policy continuity and fair treatment for purposes of their own planning and investment decisions. When policies are set in this way, they will have great effect, but if they are frequently changed or abandoned, investment will be discouraged and results will be disappointing.

5) Whatever policies are chosen, substantial interests will quickly grow up around them and develop considerable governmental influence in ways that will make future change difficult. For example, an exemption granted to some older coal plants in U.S. air pollution legislation thirty years ago in the expectation that those plants would soon be closed has instead resulted in those plants staying open much longer because they operate

less expensively than their competitors. Indeed, the U.S. government has recently announced plans for further extensions and exemptions to them. Such stagnation –especially if it is reinforced by corruption –has been one of the greatest obstacles to sustainable development all over the world. This is another reason for the urgency of wise and vigorous energy policymaking in China at this vital time.

6) A policy favoring full scale, simultaneous pursuit of all options is likely to be expensive and self-defeating. In rapidly growing societies, there is a tendency to feel that all energy resources are needed and therefore to make large supply side commitments with promises of large demand side and renewable expenditures as well. This can lead to billions of dollars worth of waste, as it did with U.S. power plant construction in the 1970s. The U.S. found that the same $2-3 billion spent to build a nuclear power plant could –had it been spent on efficiency - have saved many more kWh than the nuclear station produced. Furthermore, once plants and transmission lines are built, they must be used fully to pay for themselves. Efficiency options that might have been cheaper at the outset will not look as desirable if they are conserving away the consumption necessary to pay for a completed program of massive investments. If aggressive efficiency commitments are designed in from the outset, this problem is less likely to arise.

7) Renewable energy options should be discussed in ways that make clear to skeptical decisionmakers what their real potential is. Renewable resources must overcome presuppositions that 1) they are too small or too unreliable to make much difference and 2) that they are too expensive. Resources such as the wind in Inner Mongolia, the volumes of agricultural wastes and existing uses of biomass should be presented in ways that make clear that they are can be developed on a large scale and at reasonable cost if China chooses to do so.

8) China's institutional and policy changes will take place in an environment that is moving towards increased market orientation and full enforcement of World Trade Organization obligations. The market mechanisms that China is embracing will continue to be a powerful source of enhanced productivity throughout its energy sector. However, market mechanisms will *always* drive prices toward marginal costs and will favor the producers with the lowest marginal costs. These marginal costs will not include environmental, social, reliability or national security impacts unless China takes steps to assure that they do so. This can be done by regulations that require elimination or mitigation of these impacts. It can sometimes be done by cap-and-trade mechanisms that enlist the market

on the side of abatement. It can also be done by tax policies that impose a charge on the undesirable impacts or that reward the output of more desirable technologies. The important point is that if it is not done, powerful market forces –far from improving the adverse social impacts of energy consumption –will in many respects make them worse, as competing companies seek to lower costs in every way possible.

9) The same point made in #8 with regard to energy markets is also true for tariffs that continue to be set by government. The financial incentives that are built into the tariffs will determine the behavior of the regulated entities –especially if privately owned –at least as powerfully as regulatory requirements. They will also shape the behavior of the customers. Even if energy firms are assumed to comply fully with regulatory requirements, their environmental and social performance will be much stronger if their financial interests are consistent with such conduct. The challenge of transforming electric (and also gas) utilities into proponents of cost-effective energy efficiency requires careful regulatory attention in tariff setting, because many methodologies reward transmission and distribution companies for selling more electricity rather than for lowering their customer's total electric bill. And, of course, subsidies have a similar effect on consumption by customers. International experience shows that when utilities are rewarded for programs that reduce customer bills, they will encourage conservation. As the CEO of one of the largest and most successful utilities in the U.S. (John Rowe of Unicom) often says in discussing the best way to encourage utility promotion of energy efficiency, "The rat must smell the cheese".

   In choosing pricing rules, China might benefit from the principle that companies whose performance is most beneficial to China and to their customers should be the ones that make the highest profits. Such a principle reward efficient and clean performance more than it will reward efforts to pass on increasing costs, engage in accounting gimmicks or skimp on environmental performance. A similar principle was endorsed by the U.S. National Association of Regulatory Utility Commissioners some 15 years ago.

10) With regard to China's desire to avoid becoming overly dependent on oil imports, several issues are important. First, during the years that China's import dependency is growing, the same phenomenon will be occurring in other major oil consuming regions, especially the U.S. and Europe. While most experts foresee no absolute oil shortage during this period, they also foresee a significant shift in world oil production in favor of OPEC, and especially in favor of the Middle East. This means that

increased market power will inevitably be lodged in fewer countries, increasing the likelihood both of price shocks and of long-term prices as far above production costs as producing nation cohesion and the price of alternatives will allow. Wars and embargoes in which a country like China has no direct part still have a greater likelihood of causing widespread economic damage than is the case today.

Under these circumstances, many of the measures that are desirable from an environmental standpoint (such as increased efficiency –especially in transportation - and use of renewable resources); serve the goal of increased energy security as well. Nevertheless, reduced oil consumption does not automatically translate into reduced imports or import percentages. Studies of this question in the U.S. in the 1970s and 1980s, as oil import prices and then dependence rose rapidly showed that imported oil from areas with low production costs would tend to displace high cost U.S. oil production (as well as other expensive energy sources).

A number of measures such as petroleum reserves and diversification of import sources among several regions of the world are also available to reduce both the cost of imports and their potential impact on China's national security. These measures can reduce the vulnerability of imports to threats of interruption for political, economic or military reasons. However, they do little to alleviate the impact of imports on the balance of payments, and of course they do nothing to mitigate the environmental impacts of oil-based transportation expansion in China's urban areas. The substantial gasoline taxes in effect throughout Europe are one example of a policy that addresses both import dependency and environmental impacts. Meaningful vehicle efficiency standards are another crucial measure. An oil import surcharge would also be effective (and has long been the preferred option of many U.S. national security analysts), but it may be impossible to implement in a manner consistent with WTO obligations.

11) In analyzing what can be expected from each energy source, it is important to include an estimate of the uncertainties involved. If two different electricity sources are each expected to cost $1000/kw but the possibility of a 100% cost overrun or a large fuel price increase or major new environmental requirements is 5% for one source and 50% for the other, they do not really have the same value. U.S. and British utilities wasted a lot of money by overlooking this principle in the 1970s and 1980s. In general, when uncertainties are taken into account, investment in energy efficiency looks more favorable because it does not take long to "build", and once in place its performance is quite predictable. Efficiency

is followed by renewables (which have little or no fuel risk) and proven fossil technologies. Nuclear power has tended to rank lower when uncertainties are taken into account.

12) Nuclear power is not projected to play a major role in China's power supply picture in the next twenty years. We think this is a reasonable conclusion for several reasons. First, no nuclear units have been ordered in countries that have chosen to use competitive markets and private capital as the basis for their future power supply. Although the existing plants (especially those in the U.S.) have substantially improved their operating efficiencies, the costs of electricity from a new nuclear unit are not competitive in any country with substantial fossil fuel resources or with substantial opportunities for energy efficiency. Second, existing designs have safety concerns that make siting them close to large populations problematic. Most countries with nuclear plants have adopted limitations on nuclear accident liability far below the potential cost of such accidents, a subsidy that cannot be reconciled with market principles. Third, the acceptability of nuclear power is to some degree at risk from possible accidents anywhere in the world, over which no individual company or government has control. Finally, no country has yet resolved the questions of how and where to dispose permanently of the waste products from the nuclear fuel rods.

    Some of the advanced reactor designs appear to offer considerable improvement over the existing plants as to safety, flexibility and waste disposal. However, their economics are unproven, and there are as yet no prototypes in commercial operation. Consequently, little can be expected from them in China between now and 2020. Should they prove successful elsewhere, China's go-slow approach to nuclear power deployment will leave it well positioned to take advantage of these advanced designs without becoming deeply involved with the difficulties of current designs.

    China's gradual approach to the question of spent fuel reprocessing will also serve the country well. The U.S. has rejected reprocessing as uneconomic (and unnecessary for waste disposal) for 25 years. Even when this policy has been relaxed from time to time, no private company has been willing to reprocess. In Great Britain, electricity market reforms have exposed the fact that reprocessed fuel is far more expensive than a once-through cycle. The closing in 2010 of the British reprocessing facility at Sellafield has just been announced. No new reprocessing contracts are to be signed. This appears to mean the end of commercial reprocessing in Britain.

If more information as to any of these points is desired, we will provide it. We would also be glad to review and comment on any drafts of this crucial work as they become available.

Overview and Evaluation of Energy Strategy and Policy (1980-2000)

Energy Research Institute
National Development Planning Commission

This project targets energy strategies and policies in the period 1980-2000 and divides the discussion into seven categories: comprehensive energy strategies and policies, coal, power policies, oil and natural gas, renewable energy, energy conservation, and energy environment policies. By collecting and sorting out numerous energy strategies and policies, selecting through expert-and-specialist consultation, and thoroughly analyzing and evaluating major energy strategies and policies, we classify the effects of energy strategies and policies into four ranks: excellent, good, poor, and not ready for evaluation. To evaluate the effectiveness of the energy strategies and policies the following criterion were used: (1) whether the formulation of the energy policy conforms to the overall requirements of energy in the support of national development; (2) the effects of the policy's implementation; and (3) the social and economic impacts of the policy's implementation on the economy, energy efficiency, the environment, and security.

Knowing the importance of energy to the national economy, the Chinese government places a high priority on energy issues and has laid a solid foundation for the development of the energy industry.

In 1996, the 9th Five-Year Plan and the Long Term Goals Through the Year 2010, for the first time, explicitly and systematically stipulated the energy development policy of "developing and economizing on energy at the same time and giving priority to energy conservation; stepping up the effort to readjust the structure of energy production and consumption; promoting advanced technology to improve the efficiency of energy production; persisting in synchronous advancement of energy development and environmental control, and continuing to rationalize the price of energy products; the energy structure should be centered around the electricity and based on coal, and great efforts should be made to exploit the resources of petroleum gas and to develop new sources of energy ". This policy was carried out with great interest.

In 2001, the 10th Five-Year Energy Development Priority Program further systematically stipulated the energy development strategy: "under the premise of safeguarding energy security and with top priority given to optimizing the energy structure, we make great efforts to improve energy efficiency, protect the environment, and accelerate the development of West China." This strategy pointed out the direction for future energy development.

1. Review and Evaluation of the Comprehensive Energy Policies

1.1 Accelerate the development of the energy industry to meet energy demands of social and economic development

In 1980, Deng Xiaoping stated, "The energy issue is of the utmost importance in the economy." In 1987, the 12th National Congress of the CPC made energy a strategic focus of social and economic development. A series of policies and measures have been successively adopted in order to give further impetus to the development of the energy industry, including: (1) constructing the heavy chemical industry base centered in Shanxi; (2) carrying out eight measures for building small coal mines; (3) encouraging communities and individuals in rural areas to operate mines; and (4) the complete contracting out of the mines. In addition, the Petroleum Ministry adopted a general rationing system for output quotas of 100 million tonnes of crude oil; and petrochemical companies were listed on the stock market. The government encouraged the practice of raising funds to develop electric power, adopted a multiple power pricing system and initiated the policy of "separating power plants from the grid, and setting up competitive bidding for electricity supply". These policies accelerated the development of the energy industry and thereby alleviated the severe shortage of the energy supply in the early 1980s.

1.2 Restructure government institutions to strengthen the macro-management of the energy industry

Since the Reform and Opening up, China successively established the National Energy Commission and the Energy Industry Commission. The former was merged into the National Economy Council in 1982 and the latter was established in June, 1988 and dissolved in June 1993. The governmental functions of the energy industry were decentralized in the comprehensive management departments of the national economy for most periods of times.

It was of great significance for the National Energy Commission and the Energy Industry Commission to centralize the governmental functions of the energy industry and strengthen the national macro-management and overall planning of energy. However, without enough attention, these Commissions only existed a short time. The governmental functions of the energy industry being decentralized and dispersed among many departments, the comprehensive research and overall planning of energy strategies and policies experienced increasing difficulties.

1.3 Establish the energy law and regulatory system

Since the Reform and Opening up, to establish and improve the socialist market economy and strengthen the energy law and regulatory system, China had successively formulated a series of laws and regulations, to establish, regulate and stabilize the market system. The following are major laws and regulations

related to energy: Mineral Resources Law (1986), the Key Points of National Energy Technological Policy (1986), the Law on the Prevention and Control of Air Pollution (1987), the Mine Safety Law (1992), the Electric Power Law (1995), the Coal Law (1996), the Law on Energy Conservation (1997).

The establishment of the energy law and regulatory system provided security for the energy development on a legal basis.

However, some provisions of the laws, which were subject to a long formulation period, are no longer applicable because China's dynamic energy industry has undergone significant changes. In addition, some departments have drafted their own department laws, which, as a result, inevitably favor the interests of those departments.

1.4 Improve the energy investment system

Before the Reform and Opening up, the government financed almost all the capital construction of the energy industry. Since 1980s, with the implementation of the reform and opening-up policy, and the progress towards reform of the fiscal, taxation, banking and pricing systems and of state-owned enterprises, the reform of energy investment system has been gradually extended.

The following aspects of the energy investment system have been reformed:

Developing a diversity of major investors: Cooperation in jointly developing oil resources started in 1982. In 1984, the government encouraged the villages and towns, groupsand individuals to invest in mining. In 1985, the government encouraged the practice of raising funds to develop electric power and adopted the system of multiple power prices. In 1997, the state-owned energy enterprises started to introduce a joint-stock system. The implementation of these policies brought about the diversification of major investors. The proportion of state investment in the coal industry dropped from almost 67 percent in 1981 to 54 percent in 1990 and 2.8 percent in 1998, while funds for other resources increased rapidly. And the proportion of state investment in the power industry dropped from 55 percent in 1981 to 13.5 percent in 1990, and 14.2 percent in 1998.

The contract system was adopted in the oil and coal industry. On June, 3, 1981, the State Council decided to adopt the general rationing system of contracting output quotas of 100 million tonnes of crude oil, which allowed contractors to export crude oil in excess of quotas or reserve quotas, and set aside the revenue from the gap between the domestic and international prices as funds for further developing energy resources. With the adoption of this system, the funds raised from 1981-1985 amounted to 11.7 billion RMB, equal to 93 percent of State investment in the corresponding period. In 1985, coalmines of unified distribution adopted the gross input-and-output contract system, contracting output, total investment of capital construction and scale. This policy played an active role in lightening the burden of the coal industry and encouraging the

improvement and upgrade of equipment, but was unable to solve all the problems the coal industry had accumulated over time.

The mode of investment in capital construction changed from state appropriation to loans. Since 1985, the most preferential interest rates and discounted interest were given to the coal industry, with 2.4 percent as the annual interest rate for project financed with loans instead of state proportion.

Financing for policy concerns

Relax the limits of authority on project evaluation and approval

Implement the liability system for projects, the tender system and the project supervision system

In line with international practices, the above-mentioned policies would intensify the efforts in supervision and management of energy project investment, relax the limits of authority of enterprises on project investment, and thuscould play a significant role in giving a further impetus to the development of the energy industry.

1.5 Construct major energy projects

Since the 1980s, manpower and material resources have been pooled in the construction of many major energy projects, including Shanxi Energy Base[Center?] (1980s) and Ge Zhouba Dam Hydropower Station (1970) with the damming beginning in 1981 and the generators going into operation in 1988. Other projects include the Ertan Hydropower Station, Three Gorges Dam, Daya Bay Nuclear Power Plant, Daqin Coal-Transportation Railway, Shanxi-Beijing natural gas pipeline, and electricity from West to East.

2. Main Policy Success

2.1 Stress the energy issue, make energy a strategic focus in the economic and social development, and thus, greatly promote the development of the energy industry

In 1984, the government promulgated the *Accelerating Electricity Construction policy*. I n 1985, the 7th Five-Year Plan explicitly stipulated that energy construction should be "centered on electricity" and the general principle of *Developing and economizing on energy at the same time and giving priority to developing the economy*. Senior level decision-makers corrected errors in judgment made in the past, and pointed out the direction for energy development. In spite of problems in the enforcement of specific policies, the principle of making energy a strategic focus in social and economic development is correct.

2.2 Bring into full play the initiatives of the departments, local areas and individuals and raise funds through diversified channels to develop the energy industry

The *Raising of Funds for Developing Electricity* and *Mining of Coal by the Masses* policies encourage governments at all levels and all circles of society to invest in the energy industry, which leads to the rapid growth of the energy production, the alleviation of energy shortages, and the transition of the energy industry from a monopoly to the multi-investment system. The policy-making direction remains correct and reasonable, but much room remains for improvement.

2.3 Intensify the efforts for the construction of energy bases

In line with China's current situation, the energy supply should mainly depend on large modern enterprises and the solution of transportation should be found at the same time. Concentrating on the construction of energy bases, the government decided to construct coal bases, such as Shanxi Coal Base, to exploit oil and gas fields in the Northwest of China and to construct key power plants, including the Three Gorges Project and nuclear power stations, and grids. From 1979 to 1998, Shanxi energy industry attracted the total investments amounting to 94 billion RMB, with the output of raw coal reaching 4.9 billion tonnes, coke 400 millions tonnes, electricity 611 billion kWh, exported coal 3.17 billion tonnes, electricity export 124 billion kWh. This productivity gave a powerful push to the region's economic development and played a significant role in promoting the development of the national economy.

2.4 Put a high priority on energy construction in rural areas

Rural energy, a weak link in China's energy development, was made a government priority in the early 1980s. In 1984, the State Council established an ad hoc group for rural energy and decided to set up 100 electrified pilot counties according to local conditions and with different methods. Because of rational policies and measures, great achievements were attained and thus acclaimed by organizations like the United Nations, and serious drawbacks ignored long in the past were corrected. The *123 Poverty-Alleviating Program on Rural Hydropower*, which was initiated in 1985, on the basis of building small power plants, solved rural electricity difficulties and accelerated the development of the rural economy. In 1978, nearly half of rural households across the country had no access to any energy source for 3-6 months, and 450 million people had no access to electricity; the number has been reduced to 22 million in 2000.

The actual effect is still not sufficient and more efforts need to be made, but the guiding ideology underlying the policy-making efforts is clear and rational.

2.5 Start paying attention to the development and utilization of quality energy resources such as nuclear power, hydropower and natural gas

Unprecedented success has been achieved in the construction and operation of the Qinshan Nuclear Power Station, the Daya Bay Nuclear Power Station, the second phase of Qinshan Nuclear Power Station, and the third phase of Qinshan Nuclear Power Station. Good results have been attained in the planning for the valleys of the Yangtze River and its branches, as well as the construction and operation of hydropower plants in this area. In addition, the active demonstration, construction, general survey of the oil and gas resources, and the unified demonstration for the Three Gorges Project produce good results and more emphasis is being put on the exploitation of energy resources. The facts prove that the policy of strengthening energy construction is totally correct. But because of the limits of the material and financial resources, energy development is still not sufficient.

2.6 Active cooperation with foreign countries

The energy industry remains a major attraction for foreign investment. In 1978, the State Council approved of the Petroleum Ministry's cooperation with foreign oil companies to jointly exploit offshore oil. In 1979, the National People's Congress approved and promulgated the Law on Joint Ventures, with the guidance of which, the energy departments actively cooperate with the outside world on large projects that generally are successful. It is necessary to introduce foreign investment, equipment, technology, and management modes to improve productivity and to withstand international challenges. The policy of *Encouraging the Use of Foreign Funds to Build Power Plants* for the power industry was initiated. The breadth and depth of cooperation with the outside world is increasing.

2.7 Promote energy conservation in accordance with market institutions and with the guidance of government

With the guidance of the government and in accordance with market institutions, the efforts of saving energy have been promoted in the establishment and improvement of the socialist market economic system. *The Green Lights Program* is an example of success.

2.8 Strengthen environmental laws and regulations and promote clean and efficient utilization of energy

The government has shown awareness of the environmental pollution caused by increasing development and energy use.

2.9 Actively cooperate with foreign countries

Promote international cooperation to attract foreign funds and introduce advanced technology and management methods. The exploitation of offshore oil has shown successful results.

3. Main lessons

China over the past 20 years has witnessed many successes in energy strategies and policies. Yet, not all energy strategies and policies attain desirable results in their implementation, and China still faces serious energy challenges for the present as well as for the future. Therefore, it is of important to summarize lessons from past implementation of energy strategies and policies.

3.1 Lack of national comprehensive energy strategies that have legal impacts

Because the comprehensive energy strategies have little legal impacts, a series of problems occurs in the implementation and management of energy policies: (1) rash and random policy-making, (2) lack of coordination in department policies, (3) barriers between regions and/or between departments, (4) serious controversies over certain energy policies, and (5) lack of strategic orientation in the selection of key technologies.

3.2 Lack of democratic and scientific policy-making institutions and processes

3.3 Sluggish transitions in the ideology of policy-making and planning

3.4 Weak supervision of law enforcement

Apart from a few articles, most articles of the *Energy Conservation Law*, which has been in effect for six years, are ineffective and some articles have not been implemented. Building Design Energy Efficiency Standards were promulgated in 1986. Up until 2000, only 2.3 percent of the area met these standards.

3.5 Lack of coordination and relevant policies supporting energy policies, such as for coal, electricity, and transportation

3.6 Lack of unified management and coordination in the implementation of energy policies, such as for clean coal technology

4. Recommendations

1. Push forward the democratic and scientific policy-making process, with legislation of the policy-making process and institution, submission of major policies to the National People's Congress for review, promotion of public participation, and formulation of the organization law on the government institutions.

2. Formulate national comprehensive energy strategies.

3. Set up a comprehensive policy-making and planning system for energy, the economy, and the environment.

4. Establish an energy policy-making system for unified management and coordination.

5. Enhance supervisory work and establish a liability system for erroneous policies to strengthen the supervision of law enforcement.

China's Energy Demand Scenarios to 2020

Beijing Energy Efficiency Center

1. Background

Last November, the Chinese Communist Party (CCP) held its 16th National Congress. It declared that, in the next two decades, China would concentrate on building a *Xiaokang shehui*, or "well-off society." This would be done in a comprehensive and coordinated manner to benefit all of China's people. One objective is to quadruple China's GDP by the year 2020. Optimizing the industrial structures, improving economic returns, and achieving nationwide industrialization will accomplish this.

To build a "well-off society" in a comprehensive way implies that more and more of the rural population will enter the urban areas; urbanization will be accelerated in the coming decades. The expansion of urban areas will also promote the rapid development of the service industry and transportation services. Increasingly, average urban families will be purchasing cars. Because of increased income, more and more rural households will be able to consume commercial energy instead of the traditional biomass.

To achieve widespread industrialization by 2020 implies that the manufacturing industry will continue to expand and the secondary sector will continue to play the primary role in China's future economic development. The proportion of secondary sector is still expected to be approximately 50 percent by the year 2020. Since the industry sector is expanding and much more energy-intensive, its energy demand will still be significantly increased in the next twenty years. According to international research, the future energy consumption in China's southeast coastal areas may exceed 4 billion tonnes of coal equivalent (tce) by 2020 as they strive for complete industrialization and a moderate standard of living.

Looking at the domestic resources available[11], China's future energy development will face great challenges in meeting the huge long-term energy demand with domestic resources. The measures and policies adopted to improve energy efficiency, strengthen the competitive power of the national economy, solve the domestic environmental problems resulting from energy use and global climate change issues will have significant impact on China's

[11] Crude oil production has nearly reached the upper limit of economically viable extraction; increased output in future will be difficult. At present, the natural gas yield is still low and on a per capita basis is far lower than the world average. Coal resources are abundant, but calculated on a per capita basis; coal availability is still lower than the world average.

sustainable development target. These efforts will affect whether the objective of building a "well-off society" can be achieved.

The current international experience is that no developing economy has been able to achieve a sustainable development path exhibiting low carbon emission rates while maintaining a high economic growth rate. Per capita energy consumption and carbon emissions in developed countries have reached very high levels, up to ten times that in developing countries. Even the developed countries, relying on their economic and technological advantages, have not yet successfully reduced their per capita energy consumption and per capita greenhouse gas (GHG) emissions.

The conclusion is that there is no existing development pattern with low carbon emission levels and high GDP growth rate for China to copy. On the other hand, China has great opportunities for future energy development. China's potential energy consumption pattern and energy demand trajectory as projected by research provide positive support for the Chinese government to implement relevant energy strategies, polices, and regulations.

2. Scenario Design

In 1999 the Energy Research Institute (ERI), which is affiliated with the China National Development and Reform Committee (NDRC), initiated an in-depth and systematic study of China's sustainable energy development scenarios with financial support from the Packard Foundation and Energy Foundation. The following three scenarios were designed in that project:

Scenario 1: If economic development can promote improved energy efficiency, the investment in energy efficiency by enterprises may be restricted to some degree because of competitive market pressures. In addition, clean fuel technologies cannot be widely applied in the next 20 years because of high costs, limited resources, etc.

Scenario 2: Based on the 10th Five-Year Plan and the outlook for the following 10 years, it was assumed that the social and economic development goals would be easily achieved. This scenario can be considered a detailed interpretation of the sustainable economic and energy development for the 10th Five-Year Plan and the following 10 years.

Scenario 3: This Optimal scenario assumes that many appropriate policies and measures were undertaken to improve energy efficiency and to adjust the industrial structure and energy mix. Significant impacts can be achieved by (macro regulation) and sustainable development policies. In the meantime, the

external environment will encourage China to make full use of its high quality energy resources in the international market. This will help adjust the energy mix, an essential step. Furthermore, China may introduce advanced technologies, equipment, and human resources so that by 2020 China's energy efficiency will be one of the best in the world).

At the 16th National Congress of the Communist Party of China (CPC) held on Nov. 8, 2002, the development goal of "building a (well-off society) in a comprehensive way" was proposed. Accordingly, efforts will be made to quadruple the 2000 GDP by the year 2020. China will have achieved almost total industrialization by then and the capability for sustainable development will steadily enhance. This development goal has enhanced the three-step strategy proposed by Mr. Deng Xiaoping. The earlier study of *Scenarios Analysis on China's Future Sustainable Energy Development and Carbon Emissions* is based on his three-step strategy and related government development plans. The scenario design for the social and economic development trend is quite similar to the goal for development proposed at the 16th National Congress. The scenario design in this program is based primarily on the earlier study. However, some scenario factors should be updated, such as the annual GDP increasing at a rate of 7 percent. In addition, in the earlier study, the scenario did not take into consideration that the sustainable development policy could not be implemented smoothly with the same increase in economic development.

Therefore, it is necessary to carry out a detailed analysis of quadrupling the GDP by 2020 and of *Building a Well-off Society* based on the earlier study. To compare the different results under different policy implementation possibilities, three scenarios were designed to study China's energy demand by 2020.[Why are scenarios given as B, C, A; rather then A, B, C? Suggest reordering. Yes]

Scenario A (without special policies): quadrupling the GDP by 2020, the scenarios on social / economic / energy are based on Scenario 1 of the earlier study and Scenario B of this study.

Scenario B: quadrupling the GDP for the year 2000 by 2020; the other factors are similar to Scenario 2 of the earlier study.

Scenario C (also called policy strengthening scenario): quadrupling GDP by 2020, emphasizing the influence of industry / energy / environmental policies; the other factors are similar with Scenario 3 of the earlier study.

3. Scenario results[12]

Before reviewing the scenario results, it is necessary to explain precisely the basic energy concepts involved and to analyze the parameters used in the model.

[12] The results in this paper do not include biomass energy.

Sector division of Final Energy Consumption: Includes agriculture, industry, construction, transportation, commercial, and residential sectors. The industry sector includes energy (coal production, oil refinery, electricity, etc.), steel, and iron, building materials, chemical, papermaking, manufacturing and light industries. In this study, the energy consumption of the energy producing enterprises is considered as the final energy consumption, including coal, oil and gas, and electricity production, oil refinery, coking, etc.。

Final energy consumption (demand): Includes the energy consumption of the agriculture, industry, construction, transportation, commercial, and residential sectors. Energy fuels not only include secondary energy (such as gasoline, jet kerosene, diesel, fuel oil, LPG , coke, and others), but also includes primary energy (such as the fossil fuels, raw coal, and oil) and renewable energy like solar energy, hydropower, wind power, etc.

Conversion of the final energy consumption to a standard unit: Electricity and heat are converted based on caloric value calculation, i.e. 860 kcal (or 0.1229 kgce) per kWh. Gasoline, kerosene, diesel, and LPG are based on 10000 kcal/kg. Coal related energy fuels are based on 5000 kcal/kg. Natural gas is based on 1.33 kgce per cubic meter.

Conversion of primary energy consumption: Primary power including hydropower, nuclear power, etc. is based on 860 kcal (or 0.1229 kgce) per kWh. Raw coal is based on 5000 kcal/kg. Raw oil is based on 10000 kcal/kg. Natural gas is based on 9310 kcal per cubic meter.

Data from the benchmark year: According to the 16th National Congress, in order to *Build a Well-off Society,* GDP of the year 2000 must be quadrupled by 2020. Therefore, the year 2000 is chosen as the benchmark year in this study. The statistic bureau has adjusted the energy consumption figures for 2000 compared to those for 1998 and 1999. But the energy consumption data issued by the statistics bureau are still inconsistent with those of related energy sector associations, especially for coal consumption. In this study, for those sectors that exhibit obvious differences, data used are based on the association numbers. Therefore, the adjusted final energy consumption for 2000 is 985 Mtce while that issued by the statistics bureau is 925 Mtce. And the adjusted primary energy consumption for 2000 is 1297 Mtce, while that of the statistics bureau is 1246 Mtce.

3.1 End use energy demand and final energy mix

In 2020, the final energy demands of the three scenarios are 2480 Mtce, 2250 Mtce, and 1910 Mtce, respectively. The energy demand of Scenario C is the least

because effective policies and measures were considered, including adjustments to the industrial infrastructure, technical improvements, and other similar measures.

The three scenarios show a similar trend; with the rate of increase in high quality energy will be greater than that of the end use energy demand. The energy fuel demand for natural gas, electricity, and oil consumption will increase rapidly, while the rate of increase of demand for coal will be lower than the average increase rate of final energy consumption.

The industry sector will continue to be China's main energy consumer in the next 20 years. However, the energy demand by the industry sector will be quite different under different development strategies. Regardless of which path is chosen, the portion of the final energy consumption by the industry sector will decrease while that by the transportation and building sectors will increase quickly.

3.2 Primary energy demand and primary energy mix

Scenario C assumes that more non-fossil fuels, such as renewable energy, will be used in power generation while in Scenario A it is assumed that fossil fuels will continue to dominate power generation and non fossil fuels will have no significant increase in their shares in power generation. In Scenario C, China's total energy consumption will reach 2470 Mtce by 2020,while in Scenario A, it will reach 3280 Mtce, 33 percent higher than in Scenario C.

The percentage of electrification provides an important indicator in assessing a country's living standard. The experience from the developed countries shows that the demand for electricity and heat in commercial and residential sectors will significantly increase when per capita GDP reaches middle-class standard of living. International experience shows that more coal should be used in transforming sectors in order to solve environmental issues. Considering the availability of various energy resources, even if non-fossil fuel sources are developed quickly, coal will still be the main energy source in China. And coal's proportion of total energy consumption cannot be dramatically reduced in the next 20 years. However, in Scenario C, in which most of the industrial boilers will still use coal, and more coal will be used for power and heat generation, the commercial and residential sectors will be consuming less coal and more electricity, natural gas, and oil. Even so, in Scenario C, China's annual coal demand in 2020 will reach about 210 million tonnes. According to the

assumptions of Scenario A, China's coal demand in 2020 will reach about 290 million tonnes, double the current coal consumption.

Looking only at the domestic oil supply capacity, Scenario C assumes energy-savings in transportation and strict fuel efficiency standards. The result is that energy consumption (converted to primary energy) in the transportation sector will drop from 373 Mtoe (533 Mtce) in Scenario A to 287 Mtoe (410 Mtce) in Scenario C. But in either case, the total nationwide oil demand in 2020 will exceed 450 Mtoe (643 Mtce).

Compared to oil, the exploitation and utilization level of natural gas is very low. It is assumed that in all three scenarios the demand for clean energy in the commercial and residential sectors will be inevitable. In the meantime, more natural gas will be used in the chemical industry to improve energy efficiency. In the power sector, besides using natural gas to adjust the peak demand for electricity, CHP (combined heat and power) and CHCP (combined heating, cooling, and power) systems will primarily be using natural gas. Based on the above assumptions, China's natural gas demand in 2020 will reach 16 billion cubic meters, which is 5 times the current level.

The portion of final energy consumption by the industry sector, based on primary energy consumption, will drop gradually with the rapid increase in energy consumption in the commercial, residential and transportation sectors. In Scenario C, the portion of total energy consumption by the industry sector will drop from 72.7 percent in 2000 to 56.7 percent in 2020, and in both the other two scenarios will also drop to less than 60 percent. This trend shows that after achieving industrialization, energy demand from the manufacturing industries will increase slowly, while demand from the buildings sector and transportation sector will increase rapidly.

3.3 Electric power demand and power generation structure

As there are some differences among the three scenarios on technological improvements and energy efficiency polices, the electric power demands in the three scenarios are also different. The power demand in Scenario C is 430 TWh higher than that in Scenario A.

The different assumptions were based on future power generation structure, energy efficiency of power generation, and transmission losses. According to the assumptions in Scenario C, if primary power, including hydropower, nuclear power, and wind power, is developed quickly and the energy efficiency of power generation is improved by eliminating low-efficiency equipment, the installed

capacity will increase from 282 GW to 865 GW. This means installing newly-built capacity of 29 GW annually. According to the assumptions in Scenario A, the annual (new-built) installed capacity must be 33 GW in order to meet the final electricity demand.

All three scenarios encourage significant exploitation of hydro resources. By 2020, the capacity of hydropower in Scenario A will be 190 GW and that in Scenario C will be 240 GW (including 40 GW of small hydro power). This means installing additional hydropower capacity of 6.3~9 GW annually over the next 20 years. Optimistic assumptions were also made regarding the development of nuclear power in C scenario where the installed capacity of nuclear power will increase from 2.1 GW in 2000 to 40 GW in 2020; an annual rate of increase of 15.9 percent.

Despite these predictions, fossil fuels, including an increase in coal, will still be the major source of future power generation. In Scenario C, the coal consumption used for power and heat generation will reach 1070 Mtce in 2020, accounting for more than half of the total coal consumption.

3.4 CO_2 emissions

By 2020, carbon emissions in scenarios C, B, and A will reach 1940 Mtoc, 1716 Mtoc and 1437 Mtoc respectively, representing a difference of 500 Mtoc between Scenario C and Scenario A.

Causes for such a great disparity include the total energy consumption amount and the energy consumption mix. For instance, the energy consumption in the three scenarios will be 3170 Mtce, 2780 Mtce, and 2320 Mtce. The portion of coal in the fossil fuel consumption will be 65.3 percent, 64.3 percent, and 63.1 percent.

According to the above results, without implementation of specific policies, per-capita annual CO_2 emissions will reach 1.33 toc by 2020, more than twice that in 2000. However, if appropriate policies optimizing power generation and improving energy efficiency are adopted and implemented, per-capita CO_2 emissions will increase at a lower rate. In 2020 they will be less than 1 toc annually, just 33 percent of current per-capita CO_2 emission levels in OECD (Organization for Economic Cooperation and Development) countries.

As energy consumption in the building and transportation sectors increases rapidly, so will the portion of carbon emissions from these two sectors. In Scenario A, the annual carbon emissions from the commercial and residential sectors increase from 130 Mtoc in 2000 to 490 Mtoc in 2020, representing an annual rate of increase of 6.9 percent. The portion of carbon emissions from

these two sectors also increases from 16.1 percent in 2000 to 24.9 percent in 2020. But because Scenario C assumes that many energy efficiency policies are implemented, the amount and trajectory of carbon emissions are reduced. In Scenario C, the annual carbon emissions from the commercial and residential sectors will only increase to 376 Mtoc in 2020, representing an annual rate of increase of 5.5 percent.

3.5 Influence of industrial infrastructure changes on energy demand

For a long time, an important role of industrial infrastructure changes has been to affect energy demand and carbon emissions. In the past 20 years, China's economy has allowed development to increase at a steady rate. As a result, there is high energy consumption and heavy pollution. With technological improvements, globalization and entrance into the WTO, China has the opportunity to realize rapid development with lower energy consumption rates. Hence, the economic development strategy will have an important effect on China's future energy demand.

Results show that if the industrial infrastructure is optimized and other conditions remain unchanged in scenario B, the final energy demand will only be increased to 2327 Mtce, which is 2.3 percent lower than in Scenario B. In analyzing the influence of this new type of industrialization on energy demand, assumes that: (1.) the structure patterns in the industrial sectors is unchanged, based on the GDP structure of 2000 in the industrial sectors; (2) there is improvement in the energy efficiency of the energy-intensive industries, light industry, and the manufacturing industry. Under these assumptions, the energy demand in the industry sectors in 2020 will reach 1260 Mtce, which is 7.7 percent higher than Scenario B (90 Mtce).

3.6 Influence of energy mix adjustment on energy demand

China's energy mix depends primarily on coal (about 70 percent). Calculations show that if China's energy mix were the same as the average world level, its energy consumption would be cut about 200 Mtce.

Of the three scenarios, Scenario C presents the strongest case for (energy structure optimization). Relevant policies suggested in Scenario C include increasing the share of oil and natural gas in the energy mix and developing non-fossil fuels like hydropower, nuclear power, and alternative sources.

Two additional schemes were designed in order to study the influence of energy mix adjustment on energy demand. In the first scheme, the energy mix of 2000 is retained and the other factors are the same as in Scenario B, resulting in energy

demand of 2980 Mtce in 2020, which is 86 Mtce higher than in Scenario B (3.2 percent). In the second scheme, the energy mix of 2000 is the same as in Scenario C and the other factors are the same as in Scenario B. The resulting energy demand in 2020 will decrease from 2980 Mtce to 2770 Mtce in Scenario B (4.3 percent change).

3.7 Influence of energy supply scheme on energy demand and carbon emissions

The energy supply scheme will affect not only the primary energy demand but also the GHG emissions. To meet a given final energy demand, energy transformations will play a decisive role on GHG emissions.

Scenario C assumes that the huge energy projects like West-east Power Project and West-east Gas Project can be implemented smoothly, the domestic natural gas market and hydro resources will be well utilized, and that coal based units will be improved. But in both Scenarios A and B, there are less optimistic assumptions about power generation infrastructure improvements. These different assumptions have resulted in different carbon emissions projections in the three scenarios.

Because the final energy demands in the three scenarios are different, it is difficult to directly compare the influence of power generation structure on carbon emissions. Therefore, an analysis of the power generation structure has been conducted that assumes seeking the same electricity demand. However, the share of non fossil fuels in the first scheme is 38 percent and in the second scheme is just 22 percent. The results show that carbon emissions in the first scheme are 1630 Mtoc which is 129 Mtoc (7.3 percent) less than in the second scheme.

In addition to economic development models and energy mix, energy efficiency policies and environmental policies have an important effect on the future energy demand and carbon emissions in China. The influence of these policies on energy demand includes: (1) newly built production capacity and people's lifestyles, primarily the energy consumption of buildings, cars, and appliances; and (2) energy efficiency improvements to the existing production capacity. Scenario results show that if relevant energy efficiency policies can be implemented smoothly, the above energy savings potential will be fully realized and the scenario of "increasing products without increasing energy consumption " may be realized by 2020 for some intensive industries like steel and iron, building materials, etc.

Environmental policies have important outside influences on energy technologies, energy policies, and industrial polices. This study considers primarily policies of regional environmental control and municipal air quality. Although the influence of international actions to reduce GHG has been considered, specific GHG indicators have not been designed in this study. Even so, results show that environmental policy has a great influence on carbon emissions.

4 Conclusions and recommendations

4.1 Conclusions

Scenario results show that:
Energy demand is related to many factors, including economic (industry and products) structure, technological improvements, energy efficiency policies and their implementation, and energy mix, among others. Different economic development models and different policies will result in a markedly different energy demand. The future energy demand cannot be considered a firm number; it may range from 2400to 3200 Mtce for primary energy consumption in 2020.

Even under the same rate of economic development, energy demand may vary up to 800 Mtce because of a difference in energy mix, energy efficiency, and related factors.

The energy demand that would result from Scenario C is an optimistic forecast based on the smooth economic structure improvements, well-implemented energy and environmental policies, etc. This Scenario offers the lowest estimate of future energy demand and significant efforts should be made to realize that goal.

The scenario results can be summarized as follows:
If the sustainable development strategy consisting of improving energy efficiency, optimizing the energy mix, and strengthening environmental policies can be fulfilled, China can realize “doubling energy demand to support quadrupling the 2000 GDP ” in the next 20 years.
Choosing the path of sustainable development is a decisive and critical factor for future energy development.

The rate of increase of energy demand from industry will be lower than that from other sectors and some energy-intensive industries may realize “ increased production without increased energy consumption ” at some point in the future.

Buildings and transportation will be the key factors affecting the energy demand in the next 20 years. Therefore, significant attention should be paid to the energy efficiency in the building and transportation sectors.
Energy mix optimization may greatly reduce future energy demand. Therefore, China needs to promote the optimization of the energy mix, especially the final energy mix.

Energy mix optimization is a long-term task. Therefore, it is important to regulate the mid-term and long-term energy development strategy and the energy supply scheme (including natural gas, oil, and hydro power) as soon as possible.

Strengthening energy conservation and improving energy efficiency will have considerable influence on the future energy demand.

4.2 Recommendations

In order to achieve the target of *Building a Well-off Society* the key recommendations are as followings:

- Utilize the government's powers to the fullest to guide and promote the energy market to realize the energy savings target of 500 million tce by 2020.
- Prepare an integrated energy strategy that includes the importation of energy and the development of renewable energy as soon as possible, in order to accomplish "adjusting the energy structure and expanding the proportion of high-quality energy in the energy mix."
- Change the economic development pattern to increase the importation of energy-intensive products and decrease or halt the export of energy-intensive products through general commercial trade, thereby lessening China's dependency on energy.

Restructuring and Optimization of Energy Supply Structure

Center for Energy Economics and Development Strategy of the Energy Research Institute

Challenges and opportunities for energy supply structure improvements and optimization

After 20 years of development since reform and opening up, China's energy industry has demonstrated great progress. The production of primary energy increased from 1039 Mtce in 1990 to 1390 Mtce in 2002, which made China the third largest energy producing country in the world, after USA and Russia. With rapid economic growth and further opening up, China's energy mix began to change dramatically, and a trend towards diversification has begun. The proportion of coal in conventional energy consumption is declining gradually. In 2002, the proportion had decreased to 66.3%. The proportion of oil and gas in energy consumption has increased and has reached 26.1%. The proportion of hydropower and nuclear power has increased rapidly and has reached 7.6%. Although the energy consumption mix has been improved after an effort of more than 10 years, China is still one of the few countries whose energy is based primarily on coal. An energy mix dominated by coal leads not only to low energy utilization efficiency, low economic benefit (especially in energy-intensive industries), and weak product competitiveness, but also significantly impacts the Chinese environment.

First, coal mining has seriously destroyed land resources that are already in very short supply in China. Statistics show that areas subsiding because of coal exploitation have reached 15,000-20,000 hectares, of which 30% is arable land. Second, coal mining has damaged groundwater resources. In 2000, wastewater emitted by coalmines reached 2.75 billion tonnes. Third, waste gas emissions from coal mining procedures have seriously polluted the atmosphere. Fourth, pollution caused by coal use has created heavy pressure for environmental protection in China. In 2002, sulfur dioxide emissions exceeded 19 million tonnes, of which 90% was caused by coal combustion. Fifth, the economic loss caused by environmental pollution is significant and the cost to reduce pollution is high. In 1998, the economic loss brought by acid rain has been calculated to exceed 150 billion RMB, which is about 2% of China's GNP.

Therefore, we can see that an energy mix dominated by coal is ill-suited for the coordinated development of the economy, energy, and the environment. Improving and optimizing the energy mix in China poses a serious challenge.

The 16th Communist Party Congress set the goals of *Building a Well-off Society* and quadrupling the 2000 GDP by the year 2020, based on optimized structures

and better economic returns. In order to achieve these objectives, China will take a new path to industrialization. Industries and manufacturing sector need to be updated and optimized, and energy consumption in the industrial field should aim for optimized development. Urbanization will accelerate. It is estimated that in 2020, the proportion of people in cities and towns will reach 53-58%. This approaches current levels seen in middle-income countries and will lead to a shift in energy consumption patterns. The quality of peoples 'lives will improve greatly, and the optimization of civil energy consumption will become a basic requirement and inevitable trend. All these factors will influence the optimization of our final energy consumption mix and lead to the gradual optimization of the primary energy mix in China.

With the acceleration of global economy and resource integration and China's entrance into the WTO, opportunities are available for China to utilize global energy resources and to optimize the domestic energy mix. Technological advancements will also provide safeguards for China's energy optimization. Therefore, improving the energy mix and taking a path towards optimized energy development have become inevitable choices for *Building a Well-off Society*.

Energy Supply Capacity of China in 2010 and 2020

1. Coal resources and supply outlook

Using international recognized methods, the Ministry of Land and Resources has recently made a techno-economic assessment of discovered coal resources. The assessment concluded that the recoverable reserve of coal resources in China exceeds 200 billion tonnes. And if estimated reliable coal resources below 1000 meters depth are considered, the total amount of remaining recoverable coal resources will reach 400 billion tonnes. With a recovery ratio of 50%, as calculated by the State Owned Mine, and an annual production of raw coal of 2.5 billion tonnes, the coal supply can last for 80 years. Therefore, the supply of coal in China for the medium- and long-term future can be guaranteed.

Based on the principle of sustainable development, the limitation on coal mining is how much abuse can the environment and water resources endure. As of now, however, there is no fixed conclusion on the maximum coal mining capacity for China. Based on the former research result, **the scale of coal mining cannot exceed 3 billion tonnes per year within the water resources limitation**. If additional environmental factors are considered, the coal mining maximum capacity should be far less than even this level.

By considering coal exploitation and environmental constraints together, we believe that **the maximum coal mining scale is 2.8 billion tonnes per year. Within this exploitation scale, the principle for identifying domestic coal production capacity will be "determined by demand, plus a little more". The**

key to the coal supply in the future will be the construction of the new coal production capacity and infrastructure.

In year 2020, the production capacity either existing or under construction will be 710 tonnes per year. According to the BAU (business as usual) Scenario, the annual energy demand at that time will be 230 billion tonnes. Including small coalmines, a total of **1.25 billion tonnes of coal production capacity needs to be built in State Owned Mines in the next 20 years. This means the heavy task of building 70 million tonnes of new capacity each year.**

2？ Oil and gas resources and supply outlook

Although it is commonly agreed that the total recoverable petroleum reserves are about 13~15 billion tonnes, some experts estimate as little as 11.5 billion tonnes. By the end of 2001, the cumulative]identified petroleum reserves in China were 21.8 billion tonnes, the cumulative recoverable reserves were 6.2 billion tonnes, and the remaining recoverable reserves were 2.4 billion tonnes. [

By analyzing the research results from the various domestic institutions, **we** estimate **that the peak of oil production in China will occur around 2015, with maximum crude oil production of approximately 200 million tonnes. In 2020, the annual crude oil production will be between 180 and 200 million tonnes.**

The total recoverable reserves of natural gas in China are about 10~13 trillion cubic meters. The rate of progress for the exploration for natural gas resources has grown relatively quickly in the last 10 years. By the end of 2001, the cumulative identified reserves of natural gas were about 3 trillion cubic meters, and the cumulative proved recoverable reserves were 2 trillion cubic meters. The remaining proved recoverable reserves were 1.7 trillion cubic meters. It is estimated that, between 2001 and 2010, the identified reserves and the proved recoverable reserves of the natural gas resources will increase to 2.3-2.6 and 1.5-2.0 trillion cubic meters respectively. The natural gas industry will develop rapidly in the next 20 years. It is estimated that annual 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 could be 2.24 trillion kWh. By the end of year 2000, the hydropower capacity in China reached almost 80 GW, which accounted for 24.8% of China's total power generation capacity. The exploitation rate of hydropower resources is rather low at present, about 15% in 2000, and is different in different areas.

According to current building projects and plans made by the power generation industry, hydropower will be developed rapidly. The hydropower generation capacity is expected to reach 125~155 GW in 2010, and the exploitation rate of hydropower resources should reach 24%~30%.

We estimate that the hydropower generation capacity in 2020 could reach 200~230 GW, with an exploitation rate of 38%~44%.

4. Nuclear development outlook

Uranium resources in China are generally regarded to be plentiful in the short-term, guaranteed for the mid-term, and potentially adequate for the long-term f**or nuclear development**. Since resources will be not be a problem, the barriers to the future development of nuclear power generation in China will be investment, technology, and environment.

In 2000, the nuclear power generation capacity was 2.1 GW. In the "ninth five-year" period, 4 nuclear power generation projects (8 units, totaling 6.7 GW) came under construction. These 4 nuclear power generation projects should be commercially operational by 2005. By then, the capacity of the nuclear power generation in China will reach 8.8 GW.

China has mastered nuclear power generation technology up to the size of 300 MW. We have mastered the design of 600 MW Pressurized Water Reactors, for which 60% of the parts and equipment can be manufactured domestically. But independent design and localized manufacture of large nuclear power plants (bigger than 1000 MW) still need to be developed.

Presently, China does not have the necessary design, manufacturing, or fuel supply capabilities for the large scale development of nuclear power plants. Four to eight units in the next five years are feasible. If the construction of nuclear power is started at once, **6~8 units could come into operation by 2010, with 14-16 GWs of nuclear power generation capacity. It is possible to achieve 32~50 GWs by 2020.**

5. Outlook for renewable energy development

The development and study of wind power generation began in the 1980s. By the end of 2002, the cumulative wind power generation capacity (peak) added to the grid reached 460 MW.

Currently, the technology for manufacturing 200~600kW wind turbines has been mastered. Wind turbines of 200kW, 250kW, 300kW, and 600kW have been developed and have been successfully operating for over two years. The comprehensive performance indexes have reached the level of foreign countries in the early 90s.

With the support of incentive policies in China, wind power generation will develop rapidly thanks to decreasing initial investments, increasing unit capacities, and domestic production of wind turbines.

Until 2010, the focus should be in the coastal areas. A series of wind farms of 100 MW scale will be built. Three GW of wind capacity will be built in Fujian, Guangdong, and Inner Mongolia Province. Therefore, by 2010, wind power generation capacity should reach 3~5 GW.

After 2010, the development of wind farms will be focused in Inner Mongolia, Hebei Province, the Northeast area, and Ningxia and Gansu Provinces. Wind farms of about 10 GW capacity are expected to be built. In addition, near-shore wind farms will be developed in the sea, hopefully up to 5 GW. In all, the wind power generation capacity could reach 10~30 GW by 2020.

Analysis of Energy Supply Scenarios in China

Scenario design

The objective of our scenario design is to describe possible trends in energy supply development and optimize supply alternatives for the next 20 years in China through quantitative analysis. The analysis and assessment has been carried out through different scenarios from different perspectives, such as resource availability, environmental impact, investment demand, and social costs.

In the subproject report, "Energy Demand Scenario Analysis up to 2020", the final energy demand in the next 20 years in China is analyzed and estimated for three scenarios. According to the results of that research, the final energy demands will increase from 985 Mtce in 2000, to 1424, 1580, or 1620 Mtce in 2010, and to 1905, 2252, or 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. A new Optimized Scenario has been designed in addition to the original three.

1) Business As Usual (BAU) Scenario

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

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

Based on the Business as Usual Scenario, the development and use of high-quality energy (natural gas, hydropower, nuclear power, and renewable energy) is strengthened. The possibility of optimizing the energy supply structure under the precondition of meeting the final energy demand is analyzed.

In this scenario, the development of hydropower and nuclear power is strongly promoted. In 2010, compared with the Reference Scenario, there is 30

GW additional hydropower capacity, 2 GW additional nuclear power capacity, 2 GW additional wind power capacity, and 7.6 GW additional natural gas capacity, based on meeting the final power demand. The coal-fired power generation capacity decreases by 30.8 GW. In 2020, compared with the BAU Scenario, there is a 30 GW additional hydropower capacity, 1.8 GW additional nuclear power capacity, 2 GW additional wind power capacity, 3.0 GW additional natural gas based on meeting the need of final power demand; the coal-fired power generation capacity decreases by 77.6 GW.

Moreover, natural gas is also used in town gas, industrial boilers, and petrochemical industry as a substitute for coal.

1. Assumptions

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

Capital cost. This assumption considers the location and type of new and potential energy production capacity for the exploitation of all energy resources. For the capital investment in all power generation technologies, not only are current technological achievements considered, but the impact of future technological advancement is also taken into account.

Import cost. The import cost of oil and natural gas is calculated by IEA's world oil and natural gas price projections for the next 20 years. These projections were made in 2002.

Environmental cost. SO_2 is one of the primary pollutants in China. Compared with other pollutants, SO_2 pollutes a large area and has serious consequences. Therefore, 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 emissions. Therefore, the direct economic loss from environmental and ecological devastation by SO_2 from coal mining and utilization is considered the environmental cost.

Environment impact. SO_2 emission limitations are used as key constraints for energy supply structure optimization. In the two scenarios, the assumed SO_2 emission limitations are 16 million tonnes for 2010, and 13.5 million tonnes for 2020.

Energy Security. Domestic resources support the coal supply in both scenarios. Reliance on oil imports in both scenarios is held below 45% in 2010 and below 55% in 2020, to ensure oil supply security. Considering the natural gas pipeline grid construction and LNG imports in the Reference Scenario, reliance

on natural gas imports in 2010 will be kept below 15%; in the Optimized Scenario import reliance is below 20%. For 2020, the reliance on imports in the Reference Scenario is held below 30% and below 40% in the Optimized Scenario.

Technology advancement. For renewable energy power generation technologies, only currently commercialized technologies or those that can be commercialized by the year 2010 are considered. Technological advancement will promote increased power generation efficiency. We estimate that the coal consumption per unit of electricity generated in 2020 will be three percentage points lower than in 2000.

2. Forecast results

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

3. Conclusions

The scenario analysis support the following conclusions:

1) Under the precondition of ensuring energy import security, energy production in China will be doubled to meet the energy demand for quadrupled GDP growth (Scenario 2).

The total supply of primary energy will increase from 1.30 billion tce in 2000 to 2.06-2.01 billion tce in 2010 and to 2.80-2.67 billion tce in 2020. By 2010, coal supply will reach 1.82-1.63 billion tonnes, crude oil supply 320 million tonnes (140 million tonnes imported), natural gas supply 90-120 billion m^3 (11-20 billion m^3 imported), hydropower 125-155 GW, nuclear power 14-16 GW, and new and renewable energy 2.3-3.9 million tce. By 2020, coal supply will reach 2.31-1.88 billion tonnes, crude oil supply 420 million tonnes (230 million tonnes imported), natural gas supply 180-250 billion m^3 (50-100 billion m^3 imported), hydropower 200-230 GW, nuclear power 32-50 GW, and new and renewable energy 7.6-22.8 million tce.

2) By 2020, the proportion of coal is expected to decrease to less than 60%. And if high-quality energy development is increased, the proportion could decrease to 50%.

Table1 Primary Energy Supply Scenario

	Reference Scenario			Optimized Scenario		
	Standard quantity	Physical quantity	Structure (%)	Standard value	Substance value	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	24.5	2.5			
Domestic production	32.6	245.0				

Hydropower Mtce (10^6kW)(Inc. Small Hydropower)	82.3	79.35	6.3			
Nuclear power Mtce (10^6kW)	6.1	2.10	0.5			
Renewable Energy Mtce	0.2	33.0	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	
Natural gas Mtce (10^9m^3)	119.7	90.0	5.8	159.6	120.0	7.9
Domestic production	105.1	790.0		133.0	1000.0	
Import	14.6	110.0		26.6	200.0	
Hydropower Mtce (10^6kW)(Inc. Small hydropower)	148.8	125.0	7.2	184.5	155.0	9.2
Nuclear power Mtce (10^6kW)	33.3	14.0	1.6	38.1	16.0	1.9
Renewable energy Mtce	2.3	300.0	0.1	3.9	500.0	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
Natural gas Mtce (10^9m^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 (10^6kW)(Inc. Small hydropower)	231.0	200.0	8.3	265.7	230.0	10.0
Nuclear power Mtce (10^6kW)	68.6	32.0	2.5	107.3	50.0	4.0
Renewable energy Mtce	7.6	1000	0.3	22.8	3000	0.9
Total ? Mtce?	**2795.5**		**100**	**2667.5**		**100**
2001~2020 total investment demand, 100 million RMB*		158901			229687	
2001~2020 Env. Cost		23814			21193	
Emissions in 2000						

SO_2, Mt	19.93	
NO_X, Mt	7.43	
CO_2, Mt	2939	
Emissions in 2010		
SO_2, Mt	16.16	16.01
NO_X, Mt	11.21	10.08
CO_2, Mt	4524	4254
Emissions in 2020		
SO_2, Mt	13.56	13.37
NO_X, Mt	14.22	11.62
CO_2, Mt	5945	5325

*Note: constant 2000 currency value. Environmental cost means the direct economic loss from environmental destruction brought about by coal mining and utilization.

According to the forecast, if policies are adjusted and measures are taken, the structure of primary energy supply in China is expected to change notably. Although coal will still be the dominant energy source, its proportion will decrease from 66.1% (biomass energy excluded) in 2000 to 50.2% (Optimized Scenario) or to 59% (Reference Scenario).

3) The amount of energy conserved is expected to reach 128 million tce thanks to increased high-quality energy development.

If the development and utilization of NG, hydropower, nuclear power, and renewable energies are strengthened, and capital investment for them is increased, the total demand for primary energy in the Optimized Scenario, as compared with the Reference Scenario, will decrease 4.6 percent, and the amount of energy conserved will reach 128 million tce.

4) To meet the objective of controlling environmental emissions, 100% of the newly installed coal-fired power capacity in the two scenarios needs to be equipped with Flue Gas Desulfurization (FGD) in both 2010 and 2020. In 2010, 70% of existing coal-fired power plants in the Optimized Scenario will be equipped with FGD, and 48% of the existing units in the Reference Scenario will be equipped with FGD. In 2020, 70% of the existing coal-fired power generation units in the Optimized Scenario will be equipped with FGD, and 86% of the existing units in the Reference Scenario will be equipped with FGD.

5) The direct economic loss and environmental damage from coal mining and coal utilization will be mitigated by the utilization of high-quality energy and the reduction of coal consumption. The analysis shows that the economic loss in the Optimized Scenario will be 10% lower than in the Reference Scenario.

6) A diverse high-quality energy mix should be sought after since it is difficult for China to rely on one type of energy to improve and optimize its energy mix.

7) Not only should the mix of primary energy supply be restructured and optimized, but the structure of end-use energy consumption should also be modernized. For example, the proportion of power generation in coal consumption should be improved. According to the analysis of the Optimized Scenario, if end-use coal consumption for electric power is significantly reduced, the ratio of power generation to coal consumption will increase from 50% in 2000 to 52% in 2010, and 77% in 2020. Practical, clean coal technologies should also be actively developed. The utilization of natural gas directly for end uses should be increased to reduce the proportion of coal used for heating and cooking.

Energy strategy

The energy supply strategy in China should be:

To guarantee the energy supply: provide sufficient energy to quadruple China's GDP and *Build a Well-off Society*, while making great efforts to enhance the security of energy supplies;

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

To be clean with high efficiency: be clean and highly efficient in exploiting and using energy resources: develop energy resources that are friendly to the environment; extend the utilization techniques of clean energy resources; protect and improve the environment; and increase energy efficiency and the resulting benefits;

To be economic and rational: allocate and utilize energy resources economically and rationally, provide superior services at the minimum cost.

Policy recommendations

1. Establish a risk fund, increase investment in basic exploration, improve the system of commercial investigation; and strengthen the security of backup energy resources, especially high-quality energy resources, by enhancing the exploration of energy resources.

According to the BAU Scenario, the demand for primary energy in China will reach to 2.8 billion tce in 2020, of which 2.3 billion tonnes are coal. However, the total production capacity of State coalmines in China, both existing and under-construction, will only be about 0.71 billion tonnes by then.

Considering the production capacity of small-scale coal mines, about 1.25 billion tonnes of production capacity from State coal mines should be added. According to the coal mining construction regulations, 175 billion tonnes of proven reserves for large and medium scale coalmines are needed. Currently, the undeveloped proven reserves are only 61.7 billion tonnes and some of them cannot be utilized due to geographic and mine engineering constraints of . Some others are only suitable for local small-scale mining; the proven reserves suitable for large-scale mining are only 30-40 billion tonnes. Therefore, the coal reserves appropriate for large and medium scale mining are not at all sufficient.

Since the 1990s, the investment system for coalfield exploration has changed significantly with the transformation of the economic system. The nation will be only responsible for payment for the initial exploration. The project owners must take responsibility for the exploration of proven reserves. However, the majority of coal corporations are still having problems since there is not sufficient capital for resource exploration. Therefore, the investment in coal exploration is very limited, and the geological work of necessary for coal mining is almost at a standstill. The exploration of coalfields should be intensified and the investment in government exploration should be increased. The investment system for commercial exploration should be improved, the proven rate of coal resources should be greatly increased, and the backup industrial reserves should be enlarged to meet the demand of the newly built mines.

The discovery rates of oil and gas resources in China are very low, only 23% and 10.7% respectively. However there is great potential for them to be increased. Unfortunately, since the restructuring of the oil industry, prospect investigation and the development of the strategic oil resources have declined. The oil companies are not willing to undertake the work of basic oil exploration. The government departments are in a transitional period of reformation and restructuring, and have not efficiently organized the national investigation and assessment of oil and gas resources. This has lead to a severe deficiency in backup oil and gas reserves. Currently, the identified recoverable oil reserves in China are 2.4 billion tonnes. But because the proportion of marginal resources is large, the backup reserves are seriously insufficient.

A new investigation for oil and gas resources in all of China should be carried out, based on new oil and gas geographic theories and assessment methods, to clearly identify strategic backup areas for oil and gas resources. Domestic oil and gas exploration should be strengthened, venture funds for exploration should be sought, and venture exploration by oil companies should be

encouraged and promoted. Policies should be established to encourage oil companies to set annual goals for the proportion of capital to be spent on venture exploration.

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

2. **Implement the capitalized management of energy resources, set preferential prices for high-quality energy sources, strengthen the monitoring of exploited resources, and improve the rate of developing the resources.**

When driven by economic profit, some of the coal production enterprises waste resources, such as "only mining the thick coal-beds and discarding the thin coal-beds." This is true especially in the areas with abundant coal supplies or excellent mining conditions. The resource recovery rate in some small mines is less than 20%, resulting in significant damage and waste of resources. Currently, the taxation policy is based mainly on the coal outputs in China, and the discrepancy in value for the differences in quality and recovery rates have not been considered. A market system approach should be applied to coal resources and the capitalized management of coal resources should be implemented. Rational prices for the resources should be set on the basis of coal quality, recovery rates, natural status, etc., with preferential prices set for the high-quality resources. Practical monitoring methods should be initiated; the basic management of the resource during the mining process should be enhanced; the law should discourage the waste of resources; and the resource recovery rates should be improved.

In the oil and gas industries there is also a problem with "different quality with same price". The proportion of heavy oil, dense oil, and low-penetration oil production will be increased. The proportions of the three types of natural gas resources will also be high. To effectively develop and utilize unconventional oil and natural gas resources, the resource taxes and mineral resource compensatory fees on heavy oil, high solidification oil, the third oil recovery / low grade oil and the "three low" types of natural gas should be reduced. The policies toward secondary recovery should be set to promote the development and utilization of old oil fields and low-penetration oil fields.

3. **The effective approaches for optimizing China's energy mix are (a) to give priority to the development of hydropower, (b) to accelerate the**

development of nuclear power, and (c) to actively develop new and renewable energy.

China should resume the work on hydropower, enhance hydropower planning and the exploration for water resources, and add hydropower backup projects. The medium and long-term plan for hydropower should be strengthened. From the standpoint of national economic development, energy mix improvement, and sustainable development, the western hydropower base should be combined in the electric power plan with the eastern power receiving areas. The local electric power market should be opened gradually to optimize the resources in the largest number of locations. Equity should be given to hydropower in taxation and other policies.

China should make medium and long-term plans for the generation of nuclear power. This is important from the standpoint of security of the energy supply, energy mix optimization, environmental protection, and retention of China's current advanced nuclear capabilities. During the construction of nuclear power projects, the government should give support in the areas of favorable financing policies, payback term, etc. The 1 GW grade Pressurized Water Reactor development plan should proceed; international technological improvements and renovation experiences should be applied; a group of 1 GW grade nuclear power stations should be constructed; and nuclear equipment supply, construction, and management should be designated as soon as possible. The monopoly 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 plants to help solve problems of the high cost of nuclear power plants and high grid prices in China. Specific organizations should be selected to coordinate and organize the important issues, such as the technical approaches, equipment localization, and inviting foreign public bidding.

The preparatory work on wind energy resources assessment and wind field construction should be accelerated and the wind power equipment manufacturing technologies should be improved to create favorable conditions for the development of wind power in China. Incentive policies of renewable energy development should be set; the development goal for renewable energy should be defined to give rational priority to the development of the renewable energy essential for the future. Specific renewable energy funds should be established, renewable energy investment channels should be established, and favorable tax incentives should be applied to renewable energy in China.

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

According to the BAU Scenario, in 2020 the reliance on imports of oil and gas in China will reach 54.8% and approximately 30% respectively. Therefore, the strategy of "going abroad" should be continued; entailing the acceleration of development and the encouragement of increasing participation of oil companies sharing overseas oil and gas resources. The approval procedure for oil companies to invest in the overseas oil resources should be simplified; the coordination of overseas business by the three big oil companies should be reinforced to avoid harmful competition among the national enterprises in the overseas market; and the government should give necessary diplomatic and military support and guarantees to oil companies for their overseas business. China should actively enter the international oil market, making participation the main approach for acquiring overseas oil and gas resources, and should participate in spot transactions and time-bargains in the international oil market.

In recent years, China has enacted some favorable policies encouraging coal export to help coal enterprises escape bad investment results of the past. However, from a long-term standpoint, China should not make exporting coal a development strategy for the coal industry. On the contrary, in the southeastern coastal areas, some coal imports from neighboring countries should be encouraged to help meet the demand of local economic development. Such imports would not only help mitigate the environmental pressure from the exploitation of domestic coal resources, but also reduce the growing pressure from the transportation of coal.

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

In the next 20 years, domestic oil and natural gas production can support the basic domestic.. Economic growth will allow China to import energy to make up for the deficiency in the domestic supply. In the future the problem of energy supply security will be caused mainly by the instability of oil supply countries and overseas oil transportation channels.

China should actively pursue the strategy of increasing oil imports. First, this strategy should increase and diversify import sources and import locations, take active measures to increase oil imports from Russia and Central Asia, and raise the proportion of crude oil imports from Africa and Latin America. Imports from the Middle East should be widely distributed among different countries. The dispersion / diversification of oil import sources and locations

will not only benefit China's oil supply security, but also help alleviate the price discrimination from importing crude oil from the Middle East. Second, the strategy should take advantage of the enthusiasm and expertise of local entities, enterprises, and nongovernmental organizations, and use various methods to establish a sound oil stockpile system to avoid accidental interruption. Third, area energy cooperation should be encouraged and reciprocal oil security systems should be established, in addition to participation in international and regional energy organizations. The Shanghai Cooperation Organization should be used to strengthen our energy cooperation with Central Asia and Russia. Mutual energy cooperation among the countries in Northeast Asia should be enhanced. The oil and natural gas import pipeline project should be regarded as an important component of our foreign trade and we should promote the construction of an oil and natural gas transportation pipelines through the countries in Northeast Asia. Dialog and cooperation with Southeast Asian countries should be used to help solve problems of exploitation of the oil and gas resources in the South China Sea and the security of the transportation channels at sea. If we can resolve current disputes, we should actively exploit the oil and gas resources in the South China Sea. And finally, we should not miss the opportunity of participating in the Energy Charter Treaty, which would increase the security of the cross-border oil and natural gas pipelines across China, Russia, and Central Asian countries.

Because the security of the supply of natural gas and electricity will directly influence the lives of all people, these security issues should be stressed. On the supply side, the supply sources of the natural gas should be diversified and the main pipelines and branch pipelines should be formed into a grid so the oil or gas in different pipelines can be flexibly adjusted. Underground gas storage of an appropriate scale should be established to mitigate the problem of meeting peak loads. For the demand side, a rational user structure for natural gas should be developed. Some gas air-conditioners and combined heating-cooling-power -systems should be developed to shave peaks and fill the troughs, which would help reduce the peak-trough differentials and improve the security of the natural gas supply.

The construction of the electric power grid should be developed well in advance and the planning for and control of the grid should be unified. The construction of the power sources should be completed well in advance to guarantee necessary backup capacity. The structure of the power grid should be improved to increase the capability of coping with accidents. In order to improve the reliability of the grid and optimize the use of resources, hydropower and thermal power among different grids should be exchanged. The security of power system should be considered of great importance.

New investment and financing mechanisms that resolve financial problems should be established for the development of the grid. A rational electricity pricing mechanism should be established. The prices for the different modes of generation and transmission of electricity should be rational, the situation of low prices in the transportation and distribution of power should be changed, and the allocations to the grid sector should be increased.

6. Implementing a clean coal utilization strategy and promoting industrialization of related clean coal technologies are the essential measures to guarantee sustainable development in China

Research results have shown that no matter which scenario is selected, coal will play an important role in the future of China's energy supply. Developing and promoting clean coal technologies is a critical strategy to guarantee sustainable development in China.

According to the demand forecast results, in 2020 coal demand will reach about 2.3 billion tonnes, 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 materials, and 3~4% for private use.

Therefore, clean coal power generation technologies will be very important to China's future. Super critical and ultra-super critical units should be promoted as the primary units for future power generation. Circulating fluidized bed coal (CFBC) combustion will be developed as complementary units. Integrated gasification combined-cycle (IGCC) and pressurized fluidized bed combustion (PFBC) demonstrations should be planned and arranged. Desulfurization technologies for flue gases and the low NOx combustion technologies should be promoted on a large scale. The retrofitting of industrial boilers should be encouraged, and advanced industrial boilers should be actively developed.

Coal washing and quality control (selection) contribute to clean coal utilization. The proportion of coal meeting international standards (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 from nearby big mines. Alternatively, many small mines could construct one coal selection plant together.

New clean coal utilization approaches should be actively researched, including coal slurry technologies, poly-generation technologies for coal

chemistry, coal liquefaction and gasification, and underground coal gasification technologies, and other new advances.

7. Apply economic principles to utilize high-quality energy rationally and appropriately

First, the monetary valuation of external damages caused by coal mining, transportation, and utilization (such as ecological losses, environment destruction, and heath impacts) should be gradually calculated into the price of coal. In order to promote the optimization of China's energy mix by raising the competitive position of high quality energy, the price of coal should be raised to a rational level. Second, a reasonable natural gas pricing mechanism should be formulated as soon as possible to promote the use of natural gas. The goal of natural gas pricing reform in China should be changed from one determined by cost to one determined by value. For different users, different alternative energies should be identified. This helps determine natural gas prices for different users. Third, the affordability for commercial and private use of natural gas will be greater in the future. Therefore, from the standpoint of long-term development, a higher priority should be placed on the development of the natural gas markets for these uses.

In the initial stage, in order to promote the development of the natural gas industry and accelerate the start-up of a natural gas market in China, the big and stable users, such as power plants and chemical plants, should be offered favorable gas prices or tax incentives. Fourth, inconsistencies between power generation and the coal industry should be reduced to make these two industries economical, rational, and equal. Coal and power generation enterprises can be combined to form a strategic alliance. Through holding, sharing, or controlling each other's stock, the capital from various enterprises could be combined, merged or re-structured to form mixed operations. In this way, coal prices can be stabilized.

On the one hand, such strategic alliances can solve the problem of coal enterprises offering only primary products and extend the scope of coal industry enterprises; and it can allow coal enterprises to use their resource advantages to expand into power generation. On the other hand, if the stability of coal prices and the supply of coal for power generation enterprises could be guaranteed, the risk of supply would be reduced. To achieve the goal of encouraging competition from the resource providers, power generation enterprises should expand into the coal industry by investing in new mines or merging with or purchasing existing coalmines. A reasonable pricing system should be studied and developed. Incentives such as price should be used to urge consumers to choose economic and proper end-use energy consumption devices. For example, gas-fired air-conditioners should

be used as much as possible to reduce the electric power consumption by air-conditioning.

China's Oil Supply Security and Countermeasures

China Society for Petrochemical Information

Background

This research report is a subproject of the *Research on China's Comprehensive National Energy Strategies and Policies*. Established in December 2002, the Project was organized and coordinated by the Development Research Center of the State Council and received funding from the US Energy Foundation. Apart from the general report to be submitted to government leaders, members of the Standing Committee of the National People's Congress, the State Council and its affiliated comprehensive departments and the authorities in charge energy, the Project has 11 sub-themes in it. This report is the Project's 4th sub-theme.

At a meeting held at the Development Research Center of the State Council on January 25, 2003, all the prospective members to participate in this sub-theme were present. The author then learned about the tenet, leading institution, working procedures and requirements of the project and took up the request to draw up the research outline of this sub-theme. The title of the sub-theme was preliminarily set as *The Status of Oil Security in China and its Countermeasures*. On February 22, 2003, the sub-theme research team reported to the Project's Core Group the outline and research schedule of the sub-theme and experts on the Core Group suggested valuable opinions for revision and gave approval to the formal establishment of the sub-theme.

Subsequently, research has been conducted in accordance with the requirements of the Project's Core Group and the prearranged schedule, and the current research has been gradually formed.

2. Research Schedule

2.1 Determination of research outline and theme title

As stated above, when the preliminary research outline and plan were made in February 2003, the Project's Core Group suggested a number of opinions. In particular, after the meeting, Mr. Yang Fuqiang made clear instructions on behalf of the Core Group, suggesting that: (1) Greater focus should be placed on the status of oil and natural gas resources in China. There are different understandings about the issue in the oil industry. Besides, many misunderstandings also exist among people other than oil or natural gas experts. Discussions of the impact of the US-Iraqi War on oil in China should be added. (2) More weight should be given to security countermeasures. The author therefore has fully revised the research outline of the sub-project and taken

"Analysis of Oil and Natural Gas Resources in China" as Section 1, stressing that the status of domestic resources and the demand for oil and natural gas in China are one of the bases determining the development strategy and security countermeasures. Section 2 is on "Oil Security in China", which describes foreign factors that affect China's oil and natural gas security and conducts analysis from the three aspects of oil and natural gas supply, oil price fluctuations and geographical distribution of oil and natural gas. There is an independent sub-section to discuss the impact of the US-Iraqi War. Section 3 is about oil security countermeasures in China, where the conditions for the formation of each countermeasure, experiences of its application abroad and its status in China are discussed. This avoided merely listing the countermeasures. Instead, a rather in-depth analysis is made. With these, the current report framework is formed. A suggestion is made to change the title of the report to *Oil and Natural Gas Resources and Security Countermeasures in China.*

3. Overview of major viewpoints

3.1. A view of oil security

In this new era in China, at the center of national security is assured sustainable economic growth. Oil security is an oil and natural gas supply that can meet, in terms of both quantity and price, the demand of sustained economic development. Major threats to China's oil security are emerging as the result of the country's oil and natural gas imports growing fast, while it lacks mechanisms and means to cope. When China establishes and improves a comprehensive response system, it will be possible to handle these threats to security and ensure economic development demands are met.

3.2. Overall view of oil and natural gas resources in China

An overall "two-point view" should be adopted to look at oil and natural gas resources in China. China is a major oil country, and it still has tremendous oil development potentials. However, in relative terms, oil and natural gas resources are lacking in China. In terms of resources volume, accumulated proven recoverable reserves, recoverable reserves remaining and output value (namely abundance) averaged by per 1,000m^2 of land, China is notably below the world average. In the future, exploration and development of oil and natural gas in China will become more difficult. Natural gas, which is in its infancy, will have greater development potentials than oil, which is now mature. But the equivalent values of natural gas 'various resource elements are lower than those of oil's.

3.3.Forecast for China's oil and natural gas demand and imports

Based on forecasts for oil and natural gas reserves and outputs in China, forecasts for their net imports are respectively made for 2010 and 2020. These are schemes of the average values of various forecasts under conditions of ideal progress.

Possible Schemes for China's Oil and Natural Gas Demand and Imports in Early 21st Century

	Oil		Natural Gas	
	2010	2020	2010	2020
Output / 10^8t, 10^8m^3	1.75	1.65	700～740	1,050
Demand / 10^8t, 10^8m^3	3.20	3.70	950	1,600
Imports / 10^8t, 10^8m^3	1.45	2.05	210～250	550
Degree of reliance on imports / %	45.3	55.4	22.1～26.3	34.4

3.4. The overall trend of the international oil market is a relative balance between supply and demand.

At present, due to various factors (war, political instability, etc.) many countries have reduced their output. Once these factors are removed or weakened, plus the expected new discoveries, there will be a more notable trend of the production capacity slightly being greater than the demand. However, this balance is relative. It is always interloped with imbalance between supply and demand and relatively short supplies in certain regions and during certain times. But such relatively short supplies happen to be the focus of attention for people. Future oil production can meet the demand of the world's growing economy. China's newly added imports are far from changing the overall trend of the world's oil supply and demand. Both oil importers including China and oil exporters as represented by OPEC are all in an overall state of relative security in the early 21st century. There is a more obvious case of natural gas having big supply potentials than oil. With the establishment of large-scale continental-level (intercontinental) natural gas pipelines an the great overall drop in LNG price, supply of natural gas will become more sufficient.

3.5. Features of today's world oil market

The two oil crises during the 1970s and the 1980s were major turning points in the histories of oil and oil market in the world. They make the international oil market in the 21st century greatly different from the early periods. The most important aspects are as follows: (1) Oil as a political weapon between countries has lost much of its effect. The aspect of oil as a strategic material has been weakened, while oil as an important commodity for the development of human society and economy is more salient. Its manipulation is more notably constrained by its own laws of the market economy. (2) It is very hard for either oil importers in the west or OPEC's oil exporters to relive the history of monopolizing the international oil market and deciding on oil price in the long term. The two sides have interests to fight for, but they also have their mutual interests. (3) The tide of privatizing the oil industry, by various degrees, affected oil exporters, and importers in all continents. A batch of large-sized multinational companies has seen their strength growing rapidly. In combination with financial syndicates, they have become a major force in controlling the international oil market. This trend will be clearer as the pace of economic globalization accelerates.

3.6. Oil price fluctuations

In the international oil market, the price of oil (including natural gas related to it) is still apparently higher than the monopolistic price of its cost. Affected by many factors, there have been apparent price fluctuations whose cycle and amplitude are irregular. In other words, big cycles of fluctuations are superimposed with multiple small cycles of fluctuations, thus leading to complicated and unpredictable phenomena. Alternate rebounds of high prices and low prices have appeared. In the process, there is also "artificial amplification" caused by excess speculative moves and psychological panic. However, the oil price averaged over many years in terms of an invariable US dollar is still very stable and slightly on the rise. This major trend is expected to continue for the next 20 years.

3.7. Features and focus of geographical distribution of oil and natural gas in China

In terms of geographical distribution of oil and natural gas, China has the following features: (1) It is a big country facing the sea in front and having land at the back. (2) There are potential factors of insecurity like regional military conflicts and natural disasters. (3) With a fast growing economy and rapidly expanding imports, it is a big consumer of oil and natural gas. (4) It is located in central East Asia, which lacks oil overall. (5) It is rather away from the Middle East, which is a major oil exporting area in the world. (6) It has a new base of potential supplies at the back. All these factors point to the fact that China should fully develop the world oil market. In terms of oil supply, the focus

should be placed on the Middle East and the Asian part of Russia. In terms of imports of pipe gases, the focus should be with the Asian part of Russia. As for LNG imports, the focus should be placed on Southeast Asia, Australia and the Middle East.

3.8. Main contents of China's oil security countermeasures

(1) Optimize the structure of energy consumption, conserve energy and oil; (2) strengthen exploration of domestic oil and natural gas; (3) fully enter the international oil market; and (4) gradually establish and improve oil and natural gas reserves and a pre-warning system. In simple terms, the countermeasures are: opening up new sources, regulating the flow, and establishing reserves. An important foundation for implementing this policy is to deepen institutional reforms and corporate restructuring and create a batch of large-sized multinational companies with strength and experiences of international operations.

3.9. Implement diversified imports and exports in a broad sense.

Upon full entry to the international oil market, make market operations as the major means of getting crude oil and oil products and even corporate profit. Resume China's oil futures market and actively get involved in spot and futures transactions in the international market. Expand import/export docks, special facilities, and ocean oil and gas fleets. Implement flexible scheduling of imports and exports of crude oil and oil products and make efforts to diversify the sources and regions, variety, ways and contract types for oil imports. The author generalizes these as "broad sense of diversification."

3.10. Combine oil and gas reserves and a pre-warning system

Reserves refer to the tactical and strategic storage of oil and natural gas. It is a "hard" measure. A pre-warning system refers to plans and mechanisms for monitoring, predicting, and responding to factors of insecurity. It is the "soft" measure. These two measures should be combined and made to complement each other. Neither can be missing. As for the strategic reserves, oil and natural gas fields are suggested to be one of the important forms. It is recommended that while importance is attached to oil security and reserves, attention should also be paid to the security and reserves of natural gas. At present, security assurance for the latter is even weaker. How to establish and operate reserve oil and natural gas fields and how to establish and improve the pre-warning system should be listed as important topics for research.

Energy Conservation and Energy Efficiency

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1. The strict enforcement of energy conservation is of vital importance to the achievement of the economic and social strategy targets

Energy is the moving force for prosperity of China. China is in the process of industrialization, which, in a developing country, depends on more energy for economic and social development than in developed countries. In 2001 the total cost of energy for China's final users was 1250 billion RMB, accounting for 13 percent of GDP. But in the US, energy only accounted for 7 percent. In the process of industrialization, rapid economic growth relies on the development of energy-intensive heavy industries, such as steel and iron, chemical industries, and building materials. In addition, China has been in an energy-intensive agricultural era and we must increase yield per unit area because of more people and less available arable land. The quickened pace of urbanization increases the per capita energy demand largely because urban energy consumption per capita is 3.5 times that of the rural population (including firewood and crop stalks). The use of personal cars is increasing rapidly, causing energy demand to exceed that predicted. Therefore, energy demand will inevitably continue to increase rapidly. Our studies predict that primary energy demand will reach 3300 Mtce by 2020, according to the business as usual (BAU) scenario. Of this demand, coal will be up to 2900 Mtce and oil up to 610 Mtce in 2020.

Such increased demand will raise serious issues. First, the demand for coal will exceed the limit of the domestic coal supply capacity (2700 Mtce). Second, the share of imports in total oil demand will reach 70 percent, creating enormous risk for China's oil security. Third, CO_2 emissions from fossil fuel may be highest in the world, exceeding the US 'in the early 2020s. This means that the developed countries will require China to assume more responsibility in controlling and limiting GHGs. If energy conservation is enforced, the primary energy demand will decrease to 2500 Mtce, coal to 2100 Mtce and oil to 480 Mtce. This will result in all the issues being significantly relieved and economic and social development being realized.

2. Energy conservation plays an important role in building a *xiaokang shehui* or "well-off society"

Between 2000 and 2020, the enforcement of energy conservation could reduce energy demand by 800 Mtce, of which 65 percent is from the industrial sector, 20 percent is from the household and commercial sectors, and 15 percent is from the transportation sector. This will help to ensure economic growth, reduce dependence on imported oil, improve environmental quality, and strengthen international competitiveness for energy-intensive products. The saved energy

amounts to 800 Mtce, valued at 756 billion RMB, and also results in reductions of 14.5 Mt SO_2 and 540 Mt CO_2. Energy conservation may create more employment opportunities; energy-saving investment creates twice the employment opportunities as mining oil and gas and power generation. It also contributes to an improved social environment and morals.

3. China has been the second largest energy consuming country, but the per capita consumption is far lower than the world average.

In 2002, the primary energy output in China was 1387 Mtce. Of this, 1380 Mtce was coal and 167 Mtce was oil, ranking first and fifth in the world, respectively. The electricity generated reached 1654 TWh, ranking second in the world. In 2002, China's consumption of primary commercial energy totaled 1480 Mtce, second highest in the world. Of this, 66.1 percent was coal, 23.4 percent oil, 2.7 percent hydropower, and 0.7 percent nuclear power. The consumption of firewood and crop stalks was 280 Mtce in rural areas.

In 2000, China's per capita consumption of primary commercial energy was 1050 kgce, only 9 percent of America's, 16 percent of OECD countries 'average and 50 percent of the world average. The annual per capita electricity consumption was 132 kWh in both urban and rural areas, only 3.1 percent of the per capita consumption in the US.

4. Energy conservation has achieved significant results

4.1 Rapid economic growth is ensured.
GDP growth rate on average was 9.7 percent annually during the period 1980 to 2000, but primary energy consumption grew at the rate of only 4.6 percent annually.

4.2 Energy intensity (consumption per GDP) declines sharply.
China's energy intensity dropped 64 percent, declined 4.6 percent annually during the period of 1980 to 2000. At the same time, the energy intensity of OECD and of the world dropped 20 percent and 19 percent respectively.

4.3 Energy conservation brings enormous economic benefits. During the period 1980 to 2000, the cumulative saved and unused energy amounted to 1145 Mtce, valued at 1082 billion RMB (fixed at 1997 prices). The investment for the energy supply system saved 327 billion RMB, calculated by integrated investment from the annual average saved energy and increased energy efficiency.

4.4 Energy conservation contributes significantly to ecological environmental protection. From 1980 to 2000, the cumulative savings of energy amounted to 20.8 Mt SO_2 and 722 Mt CO_2.

4.5 Energy conservation significantly narrows the gap between China and the high level for the international community.
In 2000, China's energy intensity was more than 60 percent higher than the average of non-OECD countries as well as 1.4 times that in 1990.
The gap in unit productivity energy consumption between China and the rest of the world narrowed dramatically, too. For example, in 1990 energy consumption of steel was more than 58.5 percent of the international advanced level, but in 2000 it declined to about 21 percent.

China's energy efficiency of processing, conversion, storage, transportation, and end-use was 33.4 percent in 2000, an increase of 5.4 percentage points compared to 1989, but still about 10 percentage points lower than international advanced levels.

5. Barriers to energy conservation
5.1 Purpose of energy conservation. In developed countries, the original purpose of energy conservation was to conserve and reduce energy use as a way of dealing with energy crisis in the 1970s. But now the goal has evolved to increase efficiency, reduce pollution, improve living quality, and improve public relations. However, in China, there is still the need to meet a deficiency, which is the reason for gaps in energy conservation when the energy supply is sufficient.

5.2 Government energy-saving management. China's administrative agency for energy-savings was significantly weakened when many of its personnel were cut.

5.3 Policy and regulation. The current capacity for energy conservation decision-making and legislation is weak. The *Energy Conservation Law* is poorly carried out because many relevant regulations have little enforcement. A system of laws and regulations should establish a decision-making system and a unified plan that affects energy, the economy, and the environment harmoniously.

5.4 Economic incentives. The 1994 reform in the finance and taxation system hurts energy savings because former policies and measures creating incentives for energy-saving projects or products, such as tax reductions and loans with favorable terms, have been weakened or cancelled.

5.5 Technological advancement. The investment in research and development of energy-saving technologies is so small that it was not listed in the 10th Five-Year Plan, National Science, and Technology plans. It is difficult to find necessary funds to promote and support energy-saving technologies and innovation by

enterprises. Furthermore, the quality of energy-saving equipment is poor as the key technologies and equipment depend excessively on imports.

5.6 Information services. Information services, including publicity, energy statistics, information networks, and consulting service, are very weak.

6. Energy conservation should be the first priority and core of the energy strategy

In order to implement market reform and a sustainable development strategy, a new energy strategy should be drawn up. The basic principles for establishing this energy strategy are to give first priority to meeting the energy demand of China's people, especially those in poverty, to ensure the security of the nation's energy supply, to utilize energy effectively, and to reduce to a minimum the influence on health and the environment in the production and utilization of energy.

The new energy strategy can be described as follows: energy conservation as the first priority, attention focused on the end-use, service oriented, and environmentally friendly.

Energy conservation as the first priority: This indicates that when making energy decisions, first priority should be given to providing high quality energy service at minimal cost.

Attention focused on the end-use, service oriented: the World Energy Council states, "the relationship between energy demand and supply is determined by end-use energy service." Energy supply, trade, and market used to be the determining factors. The Council also indicated that the energy system is service oriented. The more attention paid to the future energy system, the better the quality of the energy service. This means that there will be more opportunities for different energy services at an acceptable price based on end-user demand. This energy system will also lead to the development of more energy-efficient, less polluting products for customers. The focus of energy management should shift from energy supply to final consumption.

Environmentally friendly: We should support the coordinated development of energy and the environment, develop clean energy and clean utilization technologies, and promote national electrification.

7. Advancing market reform should require the government to change basic energy administrative functions

First, a planned economy in the energy sector has many defects. Significant reforms are needed to overcome the inertia of a planned economy. Central planning can t optimize resource allocation and separate government functions from the management of private enterprise. Moreover, energy decision-making and planning deal only with the quantity of the energy supply, not with its quality and benefits. The priority is to produce first and live second. Resources are precious and there is a price distortion of energy. Energy conservation is only a tool for making up for the deficiency. Energy pricing, finance regime and energy statistics disagree with prevailing international principles. And to some extent, there are deficiencies because of lagging transitional ideas and system reform in the energy sector. These are the most significant barriers to accelerating market reform in the energy sector.

In the market economy, energy conservation is different from energy development. The market determines price, quantity, and technology choices of the energy supply system. The government s role is limited to the area of market malfunction. There are more market deficiencies and barriers for energy saving than for energy development, so energy conservation is a common practice. But the role of the market is limited. According to a study by the World Bank, the contribution of the market economy to energy conservation is only 20 percent. At the same time, information from market economy countries where the government is a dominant player indicates that energy conservation makes the same contribution as environmental protection.

China must strengthen governmental energy-saving policies.

The fundamental governmental roles for energy conservation are as follows:

1. Make economic polices, such as energy pricing and taxation, strengthen the market signals;
2. Make laws, regulations, and standards for energy conservation;
3. Provide information services including publicity, energy audits, energy-efficiency labels, and education and training;
4. Subsidize and encourage research, development, and demonstration of energy-saving technologies;
5. Promote and coordinate all kinds of activities by energy-saving organizations;
6. Practice energy conservation in governmental agencies.
7. Readjust emphasis of energy-saving strategy and enforce energy savings in buildings

In 2000, the energy consumption for buildings was 350 Mtce, amounting to 27.5 percent of total national energy consumption.

The progress of building energy conservation is very slow. A total of 230 million square meters of energy saving buildings have been built as of the end of 2002, accounting for only 2.1 percent of the total urban building area. At present, China's energy consumption for heating buildings (based on floor space) was double that in the developed countries. This is because of the poor quality of thermal insulation in the building envelope. As a result, the potential for saving energy in the building sector is huge. Moreover, the energy consumption for heating and air conditioning buildings can be cut by over 50 percent. By 2010, the electricity savings for residential electrical appliances, such as refrigerators, air-conditioners, and color TVs, can reach 77.9, 38.5 and 34.2 TWh respectively.

For a long time, the government laid particular stress on industrial energy conservation, neglecting building energy saving. This reflects the prominent idea of planned economy, i.e., first produce, and then live. Energy savings in buildings has been a low priority. It becomes a weak link and difficult to accomplish, resulting in wasted resources. Building energy savings has a close relationship with the improvement of environmental quality and the standard of living. So we should adjust the emphasis of energy conservation from industrial energy conservation to building energy savings.

Measures taken to achieve more building savings include: reforming the heating systems, opening up the heating market and updating energy savings in existing building. The State Council should formulate building energy-saving regulations, develop strict design standards for building energy savings, implement economic incentives encouraging the production and utilization of energy saving building materials and energy-saving appliances, establish a special fund for improving existing building energy efficiency, set up and implement administrative and monitoring mechanisms for building energy saving, and draw up energy-efficiency standards and labels for end-use equipment.

9. Demand-side management (DSM) should be implemented in the electric power system

In 2002, the total installed capacity reached 353 GW with generated electricity reaching 1654 TWh. It is estimated that these will increase to 900~1000 GW and 4260~4600 TWh respectively by 2020.

By 2010, the potential savings of coal by improving power generation efficiency and reducing electricity transmission network losses will reach 110 Mt. The energy savings from electric use equipment will be 125 TWh.

The electric power system should take such measures as: Making efforts in electric power structure reforms to regulate rational power prices, implementing DSM, affirming the main body of DSM for electric network corporations, formulating incentive policies and measures for electric enterprises and users, developing technologies for clean power, consummating electric network structure to realize a trans-regional network, and establishing economic incentives and mechanisms promoting electricity savings and clean power.

10. Industrial sector energy savings comes from structure improvements

In 2000, the final energy consumption in China's industry sector was 497 Mtce, accounting for 55.8 percent of the total final energy consumption in China. Building materials, iron and steel, and the chemical industries were the major energy consuming industries in this sector.

According to scenario analysis of energy demand, energy savings from improvements in the trade and product structures accounts for 70 to 80 percent of the potential industrial energy conservation. Energy savings from technological advancements and reduction of unit product energy consumption accounts for 20 to 30 percent. In some trades (e.g., cements), the energy saved by changing the product structure is equivalent to energy saved by increasing energy efficiency. Therefore, technological advancement should be combined with trade structure and product structure improvements to produce more energy efficient products in industrial energy conservation.

The industrial sector should revise the design code, implement energy audits and reporting/benchmarking management, advance energy-saving technologies, build information systems on energy management, and implement energy-saving performance contracts.

11. Enforce highway transportation energy saving in the transportation sector

Demand for highway transportation and the consumption of oil products is increasing dramatically, causing significant atmospheric pollution. Highways should be the major focus for saving energy in the transportation sector. In 2000, the total energy consumption for transportation (including railways, highways, waterways, civil aviation, and pipelines) was 137 Mtce, accounting for 15.4 percent of the total final energy consumption, way less than the world average of 29.5 percent. It is forecast that energy consumption in transportation will reach 210~238 Mtce in 2010 and 308~440 Mtce in 2020.

In China the fuel consumption by motor vehicles per km is 20 percent higher than in developed countries. The main reasons for this are: for 10-20 years, technologies for vehicles lagged behind that in developed countries; old vehicles account for 25 percent of the country's total; 90 percent of trucks are medium-sized and there are few diesel cars; the quality of oil products is poor; the service load of cars is only 40 percent; road conditions are poor; and gasoline prices are low.

The potential oil savings by highway transportation is about 15 percent in 2010, and over 30 percent in 2020.

To accomplish these savings the following measures should be taken: impose taxes on fuel; formulate standards on fuel efficiency and oil products; improve city planning and the transportation systems; develop express public transit systems; setup an intelligent transportation system (ITS); and encourage the development, purchase and utilization of alternative fuel vehicles.

Policy recommendations

1. Make saving resources a basic national policy

General-Secretary of the CPC Hu Jintao stressed in the symposium held by the Central Committee on population, resources and the environment that it is vital to better manage the country's population, resources, and environment. To do so will promote a healthy, fast-growing national economy, gradually increase economic quality and efficiency, increase people's standard of living eventually, and promote harmony between man and nature.

Resources conservation, population control, and environmental protection are of equal importance. Moreover, they are closely related. Population control and environmental protection have been fundamental national policies calling for family planning, enhancing the awareness of the environment, and strengthening government management. In practice, the potential for saving resources is much less than for population control and environmental protection. Therefore the response of the general population in this effort is critical. It is recommended that resources conservation, population control, and environmental protection be considered equal and fundamental national policies.

2. Strengthen the governmental administrative system for energy conservation

The Central Committee emphasized many times that Party committees and government at various levels should do better in population control and resource and environmental protection and take responsibility for this work. It is better to strengthen capacity in integrated decision and coordinate management for leaders at various levels. We recommend setting up an office of resources saving and convene an official energy-saving institution in the State Council.

Measures taken should include establishing special funds for energy conservation administration. This administration should establish policies and standards, publicity, education, information services and encouragement for energy conservation. At the same time, the government's management priority should shift from energy supply to final energy consumption and from administrative means to economic means.

3. Formulate auxiliary regulations of the *Energy Conservation Law*
The *Energy Conservation Law* has been in effect for 6 years. Except for a few regulations, however, most of the law has been poorly executed - or worse unused. Relevant enforceable regulations were never promulgated or implemented.

At present, it is urgent that regulations be established for economic incentives, building energy-savings management, energy-efficiency labels for energy consumption equipment, government procurement for energy-saving products and energy conservation management by government agencies. In the meantime, we should strengthen enforcement capabilities and oversee relevant regulations.

4. Improve economic incentives on energy conservation
The measures taken should include: promoting energy pricing by market and scientific management; implementing preferential policies on energy-saving projects, such as tax reduction and exemption, and accelerated depreciation; adopting preferential taxes on enterprises which produce energy-saving products; and imposing taxes on automotive fuel or increasing the tax rate on gasoline and diesel. It is estimated that the percentage of taxes on gasoline and diesel will rise about 60 percent.

5. Increase investment on energy conservation R&D
In 2000, the investment on energy R&D was 69.7 billion RMB (only 1.8 percent of Japan's), accounting for 6.43 percent of total investment on R&D, 0.0068 percent of GDP, but 15.73 percent and 0.088 percent respectively in Japan. The investment by enterprises accounts for 53.6 percent of energy R&D investment. The investment in energy-saving technologies R&D is less than in energy R&D investment, only two percent of enterprise investment. Furthermore, the technology choices are out of line with the energy development strategy and planning, which lack unified management and coordination. The projects on energy R&D were duplicated and intertwined, which wasted limited resources.

Measures taken include: choosing key technologies based on the final energy demand, raising the proportion of energy-saving investment in energy R&D

sharply, arranging energy-saving R&D and expenditure rationally in the national plan, building a unified management and coordination mechanism, encouraging enterprises to develop energy-saving technologies, and promoting commercialization of products.

6. Establish energy-efficiency standards and labels on end-use equipment
It is one of key measures to make and implement energy-efficiency standards and labels in increasing energy efficiency for energy end-use equipments, which is important to decrease energy consumption, promote market competition, eliminate technology barriers of international trade and reduce emissions of pollutants. Make and implement new energy-efficiency standards for end-use energy equipment (including household electric appliances, lighting appliances, general equipment such as electric motors, air blowers, pumps, compressors and transformers, and industrial boilers). We estimate that until 2020, the saving electricity will reach 254 TWh, and the saving energy will be 128 Mtce (industrial boilers) with net benefit of 506 billion RMB. These measures also reduce 19.4 Mt SO_2 and 97.6 Mt CO_2.

Measures to be taken include: formulating energy-efficiency standards and labels for end-use energy equipment and relevant polices and measures based on potential saving of energy in end-use equipment, anticipated benefits, capacity of relevant organizations (test, manage, supervise, enforcing execute, assessment) and international uniform.

7. Take government agency energy savings as the breakthrough to advance energy conservation in the country
Energy conservation for government agencies has been paid more attention by the State Council. Premier Wen Jiabao made comments and gave instructions that the potential of energy savings by government agencies was so large that it is urgent to put this issue on the agenda.

Energy conservation for government agencies is a better breakthrough to advance energy conservation in the country. We should lay down administrative regulations and detailed implementation rules, formulate mandatory energy-saving targets, build administrative systems and draw up polices and measures such as financing mechanisms, economic incentives, building energy conservation and government procurement procedures.

8. Introduce new operating mechanisms of energy conservation.
In the conditions of economic market, the key to implementing the energy-saving strategy as the first priority is to create competitive market environments for energy conservation and energy development, which promote energy conservation to utilize its own advantages.

The experience from in country and abroad indicate that DSM / IRP (integrated resource planning), energy-service companies, life-cycle costs analysis, customers education, market pricing mechanisms and externality costs internalization are all effective policy tools for introducing energy conservation as the first priority.

We should lay down policies and regulations and eliminate barriers based on demonstrations, and then implement gradually throughout the country.

Energy, Environment, and Public Health

Chinese Academy for Environmental Planning
Chinese Research Academy of Environmental Sciences

Summary

1. Energy utilization activities have done great harm to environmental quality and public health

China's energy consumption structure, which is mainly composed of coal, will not be changed in the short term because of resource and energy conditions. Soot pollution will still be the major part of air pollution in China in the long run. This is due to the large amount of inefficient coal-burning equipment, traditional uses of coal, coal quality, and incomplete pollution control and treatment.

In 2000, total energy consumption in China was 130 million tce. The total amount of SO_2 emitted was almost 2 million tonnes; the total amount of soot discharged was 1.17 million tonnes; and the total amount of CO_2 emitted was 881 million tonnes. Based on the statistical data collected by the sections concerned, nationally 70% of soot, 90% of SO_2, 67% of NOx , and 70% of CO_2 emitted came from coal burning.

Suspended particles, which are related closely to coal utilization, were still the major air quality pollutant in China. In 2001, yearly concentrations of total suspended particulates (TSP) in 64.1% of China's cities exceeded Class II of State Air Quality; 29.2% of cities in the whole country exceeded Class III of State Air Quality. It is generally accepted that acid rain is mainly caused by SO_2 emitted by human activities such as coal burning. Areas affected by acid rain in the mid 1990s were extended more than 100 square meters beyond the areas of the 1980s. Thirty percent of the entire country had precipitation pH value lower than 5.6.

From various results made by many research organizations, economic losses caused by air pollution has already accounted for 2-3% of China's GDP. At the present rate, the economic costs for alleviating diseases for air pollutants emitted by coal burning will reach 390 billion U.S. dollars and account for 13% of China's GDP in 2020, as forecasted by World Bank. Therefore, the government of China should make air pollution a priority.

Human health is affected seriously by air pollution too. Both the incidence rate of and the death rate from respiratory diseases in heavily air-polluted areas are higher than those in areas of light pollution. In China's 11 biggest cities every

year 50 thousand people die prematurely and 0.4 million people are infected by chronic bronchitis because of soot and tiny particles in the air

2. Environmental Challenges under Energy Development Strategy

2.1 Challenge to meet the demand for Energy consumption and an environmentally improved society

Improvement to the environment is essential to realizing an improved society in 2020 in China. Indices to assess societal improvements should be comprehensive and include all aspects of the economy and society; environmental protection is undoubtedly the most important part of it. Standard indices of atmospheric environmental quality from China's energy consumption in the next decade are shown in Table 1.

Table 1: China's energy development and environmental requirement indexes system in next decade

Indexes		Units	2000	2010	2020
Air quality	Days of air quality Indexes > Class II	Days		200	300
	SO_2 daily concentration	$\mu g / m^3$	150	150	150
	Inhaled particles daily concentration	$\mu g / m^3$	150	150	150

Some estimates predict that China's coal consumption will reach 1.69-1.99 billion tonnes by 2010 and 2.05-2.90 billion tonnes by 2020. There will be a continuous increase in pollutants emitted from energy consumption and the goal of environmental improvement will not be achieved if effective measures are not taken.

Pollutant emissions from energy development and automobile exhaust are occurring primarily in metropolitan areas and people are the major casualty. Air quality in metropolitan areas will continue to deteriorate if effective pollution control measures are not undertaken during the development of energy sources. The result is that 340 million people will be affected by air pollution in metropolitan areas in 2010, and 490 million people will be affected in 2020. If the trend is not changed and air quality continues to deteriorate in the next decade, 380,000 people will die prematurely in metropolitan areas in 2010 and 550,000 people will die in 2020. The corresponding economic losses will be 28 billion RMB in 2010 and 41 billion RMB in 2020.

2.2 Challenge of environmental capacity to accommodate emissions from energy consumption

The research of Chinese Academy of Environmental Sciences indicated that the concentration of SO_2 in most of China's cities could attain Class II of State's Air Quality Standards if total emissions of SO_2 in China are held to approximately 12 million tonnes, based on the requirements of metropolitan environmental quality. If the requirement for critical load of sulfur sedimentation is attained, total emissions of SO_2 should be limited to approximately 16.2 million tonnes yearly. But, according to the forecast for pollutant emissions from energy development, SO_2 emissions will be 37 million tonnes in 2010 and 49 million tonnes in 2020, both of which exceed by an excessive amount the environmental capacity prescribed in the aims of environmental protection.

Compared with SO_2, there is much less research on NO_x and (total amount control) is still not prescribed or determined in China. NO_x emissions are forecast to increase from 19.8 million tonnes in 2000 to 28.9 million tonnes in 2010, and to 35.2 million tonnes in 2020. Therefore, measures to alleviate NO_x emissions should be much stricter than for SO_2.

2.3 Challenge to apply more stringent environmental requirements by enterprises

As China's environmental protection goals and requirements improve, the rules regarding environmental management by enterprises are becoming more rigorous. 'Total amount control 'on pollutants and emission standards are the two challenges faced by energy producing and consuming enterprises.

China will continue to implement 'total amount control 'on pollution emissions during the 10th Five-Year Plan period and SO_2 emissions will be decreased from 20 million tonnes in 2000 to 18.2 million tonnes in 2005. As for the power sector, measures to control pollutant emissions of old and new power generating equipment will be critical in realizing pollutant alleviation; SO_2 emissions will decrease by 10～20% from 2000 to 2005. To achieve the aims of 'total amount control', desulfurizing equipment should be applied to no less than 19% of all equipment used in the power sector. However, this goal will probably not be attained in the next two years.

For energy producing and consuming enterprises, major controlling sources are thermal power plants and pollutants emitted by them. Pollutant emission standards for thermal power plants, which refer to internationally advanced standards to be issued in 2003, will greatly enhance SO_2 emission standards. Newer thermal power plants have to desulfurize coal without consideration of the sulfur content in coal while older thermal power plants have to desulfurize, after a grace period, and conform to the same emission standards. NO_x alleviation is also required for thermal power plants.

2.4 Challenge to reduce abatement costs for pollutants with global significance

It is forecast that in 2020 CO_2 emissions will range between 1.3 billion and 2.0 billion tonnes and emissions per capita will be 0.9-1.3 tonnes. The promise to reduce green house gas emissions will be fulfilled and the marginal cost will increase with the improved mitigation of green house gases. The mitigation cost will be more than 50 billion RMB in 2020 even though the aim of CO_2 alleviation is just 10% of all emitted.

The primary responsibility and obligation for the control and mitigation of CO_2 emissions lies in the energy sector. In the near future the entire global community will put tremendous pressure on China to improve its development of energy sources. Investment in the reduction of green house gas emissions as well as the costs incurred because of pollution will compel China's energy sector to redirect its development plans and will also strongly influence the entire country's economic development.

3. Policy Scheme for sustainable energy and environmental development

3.1 Policy matrix for sustainable energy and environmental development

From the perspective of environmental protection, implementing a strategy of energy savings is the primary policy for the harmonious development of energy and environment. If the strategy of energy savings continues for the next 20 years, energy consumption per ten thousand Yuan in GDP will drop from 1.43 tce in 2000 to 0.79 tce in 2020. The resulting alleviation of SO_2, NO_x, and CO_2 emissions will be 30.6 million, 28.9 million and 1,380 million tonnes, respectively and the environmental benefits will be remarkable.

Energy structure regulation is a long-term task in China's sustainable energy development. It is also the essential key to China's social and economic development and environmental protection. The regulation of energy structure is very arduous and intricate. Energy structure should be regulated continuously over the next decade and be oriented toward "green power", which will improve environmental protection.

If energy savings and energy structure regulation are the two major policy considerations, China's energy and environment sustainable development matrix in the following 20 years is shown in Table 2.

Table 2 China's energy & environment sustainable development policy matrix

Policy and measures	**Coal**	Petroleum	Hydro -power	Renewable energy
Priority strategy of energy savings				
System and structure reform	++	++	++	++
Government's policy for	++	++	++	++

energy savings				
Cleaner production	++	++	+	
Energy structure optimization				
Reducing the proportion of coal	++			
Cleanly utilizing coal	++			
Promote environmental standard				
Standards of power generation performance and coal consumption	++	+		
Environmental labeling and energy utilization efficiency labeling	+	+	+	++
Automobile emission standards and fuel economy standards		++		
Technological progress in energy & environment				
Reducing coal pollution (at low cost)	++			
Reducing pollution from thermal power plants	++	+		
Environmental cost internalization				
Effluent charges	++	++		
Eco-compensation & environmental compensation	++	++	++	
Electricity price discounted for environmental costs	++	+		++
Environmental friendly energy fund	+			++
Utilizing market economy mechanisms				
(Emissions rights trading)	++	+		
Green electric power market			+	++
Quota credits of renewable energy			+	++

note：+the policy is applicable；++the policy is very applicable.

3.2 Implementation schemes for several policies

Accelerate coal desulfurization in the power sector

The power sector (especially the thermal power plants) will be developing with incredible speed in China in the next 20 years. China's realization of its goal to control the total amount of SO_2 will be influenced directly by the mitigation of SO_2 and NO_X emissions from thermal power plants in the next decade. Pollution control in thermal power plants is the key to control of China's acid rain and SO_2 emissions.

Based on current SO_2 emission controls and management status, and China's emission goals for the power sector, the technological route to reducing SO_2 is as follows: before 2005, the first stage of using low-sulfur content coal and beginning desulfurization of coal; 2006~2010, the second stage of using low-sulfur content coal and soot desulfurization; 2011～2020, the final stage of overall soot desulfurization.

As for environmental economic policies and management measures, we propose launching a pilot project involving the emissions trading rights. The purpose of this project would be: (1) to implement standards of electricity pricing discounted for environmental costs; (2) to implement stricter discharge standards in the power sector; (3) to introduce the emission performances management mechanism for power generation; (4) to pursue environmental information disclosure in power plants; and (5) to strengthen management and supervision and capacity building.

Implementing Green Projects in the Transfer Electricity from the West to East Policy

According to the strategic policy, *Transfer Electricity from the West to East*, more than 10 thermal power stations will be built in a long, narrow region between Yunnan and Guizhou province. Without any of mitigation measures, SO_2 emissions from thermal power projects in Guizhou Province will be increased 20.2 Mt and 13.6 Mt in Yunnan Province. To realize total emission goals during the 10th Five-Year Plan, the two provinces will spend 4 billion RMB desulfurizing.

So, it is recommended that investment in SO_2 emission treatments should be improved and vigorous measures taken to guarantee that SO_2 discharges meet the control requirements for total emissions during the period of the 10th Five-Year Plan. Air quality should be improved and the aim of the green project to *Transfer Electricity from the West to the East* should be accomplished.

Another recommendation is to promote a progressive range of charges for SO_2 and to implement an emissions trading system for SO_2 in Yunnan and Guizhou provinces. The desulfurizing feasibility studies of thermal power plants in the

project to *Transfer Electricity from the West to the East* in Yunnan-Guizhou should be developed, and reasonable and practical plans to alleviate SO_2 emissions should be established. With these measures, the goal of reducing SO_2 at the minimum cost will be realized.

Reduce traffic pollution

Environmental pollution in urban areas is caused primarily by exhaust emitted by motor vehicles. The purpose of auto emission treatments is to make it meet certain standards so that air quality will have as little harmful effect on human health as possible. To realize these goals, comprehensive strategic measures should be established considering social and economic enduring capability. The main features include: (1) playing the role of "three vehicles"; (2) reducing exhaust pollution from vehicles; (3) effectively controlling the development of transportation volume; (4) developing public transportation and pollution-free transportation; (5) controlling pollution of the entire range of vehicles and life cycle management; (6) instituting economic measures such as taxes to encourage the development of clean and energy-saving transportation; cooperating with concerned authorities to strengthen cooperative and comprehensive decision-making.

Develop renewable energy in rural areas

The goal of environmental protection in energy utilization in China's rural areas in the next 10 to 20 years is as follows: First, improve the peasant's living standard and promote social equity; Second, improve the rural ecological environment; Third, reduce the rural indoor air pollution and improve the peasant's health level.

A *National Rural Green Energy Plan* should be implemented based on several rural energy plans such as *Wind Planning*, *Green Lights Project*, *Synthesize Construction of Rural Energy*, *Marsh Gas Demonstration Project*, *Small Hydroelectric Project*, and *Improving the Ecological Environment of Rural Communities*.

In the *National Rural Green Energy Plan*, the emphasis is on improving the efficiency of energy utilization in rural areas; introducing irrigation techniques to save water; encouraging high-efficiency, low-toxicity, low-residual pesticides; and training the rural communities in technological advances. Based on the government's plan to improve the ecological environment in rural areas, China should actively develop sustainable agriculture. For instance, they should increase the use of marsh gas. In addition, while the renewable energy in China's countryside is being developed, corresponding policies should be made to stimulate and support the development of renewable energy in the rural areas, and allow rural communities truly develop and use this valuable, clean, and modern renewable energy.

Global Climate Change
Challenges, Opportunities, and the Strategy for China

Center for Energy, Environment, and Climate Change Research of the Energy Research Institute

Executive summary

Climate change is a global issue. As early as the 1970s, scientists had already pointed out that climate warming is a global environmental problem. Since the 1980s, the international scientific community and most countries in the world have grown concerned about global warming and its impact on economies and social development. Global climate change is an issue with a long history with various integrated concerns-- from climate, environment, economy, society, and politics, to science and technology. Therefore, China should formulate a climate change strategy from the starting point of national social and economic long-term development in an integrated framework of international politics, economics, and foreign policy in order to put climate change issues in the context of sustainable development. During the course of building a *xiaokang shehui*, or "well-off society" in a socialist market economy, China faces the significant task of deciding how best to respond to global climate change in the context of creating sustainable development.

Global Climate Change: Challenge, Opportunity, and Strategy for China is one of the seven sub-projects that compose the program of Strategy and Policy Research for China's Integrated Energy Development. The purpose of this sub-project is to find answers to the following questions, and formulate a feasible strategy framework and countermeasures for China to respond to the global climate change.

1. What is the basic carbon emission for China's well-off Society? Compared with other countries, does China bear any different features?

2. In order to contribute to global climate protection as well as promote China's social and economic sustainable development, China should deal with global climate change under the framework of sustainable development to achieve a win-win situation, but how can China do this?

3. In the past two decades, China has made remarkable progress on reducing carbon emissions per unit of GDP, which made a great contribution to global GHG mitigation. Can this positive trend continue in the next twenty years?

4. As one of the three mechanisms of Kyoto Protocol, the Clean Development Mechanism (CDM) has a dual-purpose: (1) to assist developed countries to carry out their commitment under the Protocol, and (2) to promote the sustainable development in developing countries toward the ultimate objective of the

Convention. Therefore, how should China utilize the CDM to promote sustainable development in its energy industry?

5. What is the strategic framework and basic countermeasures for China to address global climate change?

Up till now, this sub-project has generally met the requirements of the project contract. The following is the summary of the main conclusions from this sub-project.

I. Challenges imposed by global climate change to the development in China

As a developing country, China's first and overriding priorities are social and economic development and the elimination of poverty. In the long term, China will still keep up its rapid economic development and improve the living standard considerably. Therefore, China will inevitably increase its energy demand and greenhouse gas (GHG) emissions, thus making it a major GHG emitter and bringing severe challenges to China's social and economic development.

Developed countries will keep urging China to limit and control GHG emissions.

After the Kyoto Protocol, some developed countries claimed that the Kyoto Protocol stipulated mitigation targets for developed countries and urged major developing countries such as China and India to limit GHG emissions. Certain developed countries even declared that one of the preconditions for them to ratify Kyoto Protocol was developing countries 'meaningful participation and linkage with the Convention's financial mechanism. The reasons, the developed countries claimed, included considerations from the perspectives of environment, competition, and politics. Even though these reasons run counter to the Principal of "Common but Differentiated Responsibilities" and the *Convention's* particular emphasis--- "the extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology, will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties." But still it is difficult to lessen the pressure on developing countries to mitigate.

Climate change raises great challenges to China's current developing and consumption mode.

Natural resources provide the foundation for national economic development. Any countries 'industry structure and economic advantage are mainly

determined by the endowment and structure of its natural resources. As we all know, China has to carry on with the long-term goal of industrialization and urbanization with an enormous population base and low level of development. Therefore, China will suffer a long-term constraint from lack of natural resources per capita for its economic development. Even with a resource-depleting, unsustainable consumption and production mode, consumption and production has already seriously challenged China's social and economic development. With respect to the choice of development mode, every country is entitled to select its own mode based on its individual specific situation. But in the course of development, they have to follow some universal laws that few countries can make an exceptions for. The history and trends of development for all countries in the world have shown remarkable evidence that the commercial energy consumption per capita correlates with the level of economic development greatly. It can be predicted that if China continues its current level of technology development and consumption mode, its energy consumption per capita will inevitably reach a much higher level before it achieves full industrialization. Since there is no precedent of low energy consumption and emission level per capita with high GDP per capita for China to follow as an example. China is confronted with the challenge to initiate a sustainable consumption and production mode.

Global climate change raises great challenges to China's energy mix predominated by coal. China's energy consumption and CO_2 emissions will continue to increase because of rapid economic development and continuous population increase. It is predicted that China will surpass the United States and replace it as the top GHG emitting country after 2025. According to current development trends, China's CO_2 emissions per capita may be higher than the world average level after the year 2030 due to its faster rate of increase, even though the current value is still much lower. China is one of the few countries mainly powered by coal with a coal production of 1.393 gigatons in the year of 2002, accounting for nearly 30% of the world total coal consumption in 2002. Nevertheless, CO_2 emissions per unit heat value for coal is much higher than that of oil and natural gas by 36% and 61%, respectively. China is not only restricted by the mix of available energy resources for its energy mix, but also by the lack of technology and funding for its energy efficiency improvement. Hence, the prospect of CO_2 emissions control for China is bleak due to a combination of energy resources and consumption dominated by coal.

II. Opportunities for China's energy development

Global climate change raises great challenges for China. But it also brings new development opportunities for China as well. At present, the policies and measures formulated by the international community to mitigate CO_2 emissions are energy efficiency improvement and renewable energy development, which

not only meet China's need to transform its current extensive economic development to an intensive one, but also contribute to China's energy efficiency improvement and energy mix optimization by promoting international distribution of high efficiency energy technologies and products. As one of the major GHG emitting countries in the world, China enjoys many advantages in international cooperation on implementing the Convention. Therefore, China should take advantage of addressing climate change issues as a new development opportunity and act positively in concert with international cooperation, as well as fulfill its obligations consistent with China's economic development level. This will not only contribute to a favorable international image for China in global climate protection, but also promote international cooperation and push developed countries to fulfill their commitments of financial resources and technology transfer, as well as create a more favorable environment of international politics, economics, and technology for China's social and economic development.

Climate change favors China to carry out sustainable development strategy.

With the aim of dealing with the potential impacts that may be imposed by global climate change, China should adopt a wide range of climate change adaptation measures to gain the benefits and avoid losses. Examples of this are improvement of the environment and increasing carbon reserves in eco-system. These measures will all contribute to China's social and economic sustainable development. In the meanwhile, China should regard climate change as a global environment issue with a long-ranging and far-reaching impact and integrate it with China's sustainable development strategy to formulate and carry out the long-term climate change response strategy and action plan in the context of the United Nations Framework Convention on Climate Change. This strategy can further advance China's progress in family planning, energy conservation, and optimizing the utilization of energy resources.

China benefits from obtaining more advanced energy conservation technologies and other new energy technologies that will facilitate China's improvement of its energy mix. If developed countries have to carry out substantial domestic GHG mitigation, they will probably shift their energy mix from oil to natural gas, as well as developing all possible renewable energy resources. This will certainly impact the world's energy mix and technology development and provide opportunities for China to move from its current coal-predominated, high polluting and emission energy mix to the one with a greater proportion of oil and gas. On the other hand, the pressure for developed countries to mitigate GHG emissions will certainly boost technology innovation on energy conservation and new energy development[(such as coal bed methane and coal gasification)] and intensify the market competition of energy conservation and new energy technology. Therefore, climate change will doubtless bring opportunities for the development of a new generation of energy technology. In

the meantime, energy consumption in developed countries will suffer limitations, which to a certain extent will open up more opportunities for energy consumption for China's future development.

The adoption of GHG emissions mitigation policies and measures will contribute to the reduction of air pollution in China.

According to available research, at present, fuel combustion accounts for about 75% of China's total air pollutant emissions. This is a typical case of coal-fume pollution. In recent years, the Chinese government has been making great efforts to control air pollution, including legal, economic, and technical measures, but none of these measures have yet yielded obvious results. Therefore, the options to replace coal with carbon-free or low-carbon energy and improve energy efficiency are not only requirements for China's future CO_2 emissions mitigation, but also a requirement for local environmental protection and air pollution reduction.

Active participation in international cooperation for addressing global climate change can elevate China's international status and image.

Therefore, China should cooperate actively in the international climate change programs and observe obligations relevant to China's economic development level. This will not only contribute to a favorable international image for China in global climate protection, but also can help to promote China's international impacts and status. This will also induce the developed countries to observe their promise of financial resources and technology transfer, which can contribute to the demand for advanced technologies and funds for China's development.

III. The long-term strategy framework for China to address global climate change

Guiding ideology. The guidelines for China's response to climate change should be: (1) adhere to short-term countermeasures being driven by long-term strategy, the core is to ensure economic development with the fundamental starting point of accelerating the sustainable development via breakthroughs in energy efficiency improvement and environmental protection; (2) implement China's sustainable development strategy in all aspects with perseverance and continuously enhance China's capacity of mitigating and adapting to the climate change for the purpose of building up a concrete basis for the third goal of China's Three-Phase Strategy as well as for global climate protection.

Strategic objective. The overall objective of China's climate change strategy should be: (1) to slowdown the growth rate of net GHG emissions considerably and effectively, (2) to build up the capacity for adapting to climate change continuously, (3) to enhance public awareness of climate change protection, and (4) to strive for a leading level of research on the science of climate change.

Near term task is to reduce GHG emissions per GDP substantively. This process begins with the fundamental starting point of accelerating the sustainable development via breakthroughs in improving energy efficiency, the energy mix optimization, and environmental protection. The goal is to continuously enhance China's capacity on climate change mitigation and thereby make a positive contribution to global climate protection.

IV. Suggestions on carbon emission strategy for the future of China

China must recognize the inevitability of GHG emission increases resulting from the building a Well-off Society. China has been keeping a relatively high growth rate of economic development with low energy consumption per capita via the adjustment of energy and economic structures and energy efficiency improvements. However, China's energy demand will substantially increase and consequently CO_2 emissions will also inevitably increase in the coming 30 or 40 years due to the continuous increase of the population. This will occur even while other energy demand driving forces such as urbanization, living standards, and energy consumption per capita are kept at the current very low level. According to the Energy Information Administration (EIA) of US Department of Energy, China's CO_2 emission from fossil fuel combustion was about 832 million tonne of carbon in 2001 or 12.7 percent of the world's total, making China second after the US. Compared with CO_2 emissions of 394 million tons of coal in 1980, the average annual growth rate has been about 3.6 percent. Nevertheless, China's CO_2 emissions per capita in 2001 were 0.65 tonnes carbon / person, only 61% of the world average. According to the goal of "Building a Well-off Society in an All-Round Way by 2020," China will maintain a high growth rate for economic development and consequently carbon emissions will increase. According to the projections from *Scenario Analysis for China's Energy Demand in 2020*, as well as that of EIA, China's CO_2 emissions from fuel combustion in 2020 will reach 1,700-1,800 million tonnes of carbon in 2020, still ranking second just behind USA. But the contribution to the world total would increase to 18-19% bringing to China a more infamous image as a big emissions country. In the scenario of *Building a Well-off Society*, China's CO_2 emission per capita in 2020 will be up to 1-1.23 tonnes of carbon, though still lower than the world average of 1.43 tonnes of carbon per capita, gradually losing the advantage of low emission level per capita in international negotiations.

China should fully recognize the pressure and challenge to reduce the CO_2 emission intensity per GDP. Compared with other countries in the world, China's carbon emission intensity per GDP is at a very high level, even though it dropped by 52% during the period from 1990 to 2001. This high emission intensity may be the cause for some developed countries to press China to undertake emission reduction or emission control commitments. Nevertheless, China's energy consumption intensity and CO_2 emission intensity per GDP will keep dropping as there is still considerable room for industrial and production

improvements and technical energy conservation. According to the EIA projections, China's CO_2 emission intensity per GDP will drop to 0.40 tonnes of carbon / $1000 USD (48 toc / million RMB) by 2020, 47% from 2000, the fastest rate of decrease in the world. But many uncertainties exist in the driving factors such as technological progress, economic development, industrial improvements, industrialization and urbanization, energy resources, and lifestyle in the future. According the preliminary findings from scenario analyses for *China's Sustainable Energy Development and Carbon Emissions*, by the end of 2020, China's CO_2 emission intensity per GDP will be 56, 49 and 38 tonnes of carbon per million RMB respectively for the three scenarios in the research, decreased by 51%, 57% and 67% compared to 1998. If China can achieve the goal of quadrupling GDP by only doubling energy consumption as in past years, the decrease of CO_2 emissions intensity per GDP for the period from 1998 to 2020 will still be less than that for the period from 1978 to 2000. The decrease will also be less than the EIA estimates due to the slowdown in the annual decrease rate of CO_2 emission intensity per GDP.

The Chinese government should fully recognize the impacts of so-called GHG intensity targets on China. GHG intensity index is a new approach advanced by the US that has added new uncertainties to the validity and effectiveness of the Kyoto Protocol. The GHG intensity index not only has made equity, responsibility, and commitment the focal topics for international climate change negotiations, but also brought the negotiation goal under the *Convention* into a bilateral or multilateral commitment, which will certainly impact the direction of the *Convention*'s future development and to some extent on China's implementation of the *Convention*. This new approach provides China the choice of linking its political leanings if it commits to reducing its GHG emission intensity with the reduction goal that USA promised. It may also be regarded as an example and reference for China to make a certain commitment of emission control in an appropriate way and at proper time.

V. Recommendations for addressing climate change in the context of sustainable development

China should acknowledge the importance of global climate change from a sustainable development perspective. First, effective implementation of the *Convention* and Kyoto Protocol will contribute not only to the world's sustainable development, but also to China's long-term goal of economic and social development. Second, the implementation of the *Convention* and Protocol can actively push technical progress worldwide and create a brand-new sustainable development mode with low pollution and low resource consumption. Furthermore, the Kyoto Protocol has set quantitative, concrete and legally binding goals for the developed countries to reduce or control their GHG emissions. This can help to limit the virtual monopoly and division of international energy resources among the minority of developed countries and

provide equitable shares of resources for the majority of developing countries, as well as favorable conditions for China to utilize the world oil and natural gas resources. Therefore, China should recognize the benefits of the *Convention* and Kyoto Protocol and take advantage of them to create a favorable international environment for China's Three Phase Strategy.

China should establish a medium and long-term strategy to respond to global climate change within a sustainable development framework as soon as possible. The guidelines for China to respond to climate change should be: (1) adhere to the idea of short-term countermeasures being driven by long-term strategy, and (2) ensure economic development based on the fundamental of accelerating the sustainable development via breakthroughs in energy efficiency improvement and environmental protection. Implementing all aspects of China's sustainable development strategy with perseverance and continuously enhancing China's capacity for mitigating and adapting to climate change are the guiding principles. These actions support building up a concrete basis for the third goal of China's Three-Phase Strategy as well as for global climate protection. The overall objectives of China's climate change strategy should be: (1) to slowdown the growth rate of GHG net emissions significantly and effectively, (2) to build up the capacity for adapting to climate change continuously, (3) to enhance public awareness of climate change protection, and (4) to strive for the top level of research on climate change.

China can take an active role in global climate protection via sustainable development policies and measures. In the spirit of protecting the global environment, China should take advantage of the opportunities provided by global climate change issues and accelerate implementation of sustainable development policies and measures under the prerequisite of not impeding long-term social and economic development. In order to slowdown CO_2 emissions as much as possible, China should take full advantage of direct foreign investment to expedite the progress of technology development and transfer, to strengthen economic structure adjustment, and to improve energy efficiency and energy mix. The other option is to fully utilize the huge CO_2 absorbing capacity of forests by expediting the conversion of farming land to forest, strengthening forestation and reforestation, forbidding excessive deforestation, and similar measures.

China should take actions to control population growth, to enhance public awareness of global climate protection, and to build up a new style of living and consumption with lower GHG emissions. The huge population and its rapid growth rate have put heavy pressure on China's energy consumption and CO_2 emissions. Therefore, China should continue to carry on the State family planning policy to further control the population growth rate. At the same time, China should increase public awareness of the environment and environmental issues via the media (television, newspapers, books and periodicals, videos) to create a sense of participation in global climate protection and to guide people

towards a new way of living and consuming with lower GHG emissions. For example, the government could encourage people to use high efficiency household electric appliances, use public transportation, purchase and use recycled paper, and sort recyclables.

China objects to the proposal that developing countries should be committed to the climate change obligation of reducing or controlling their GHG emissions under the framework of sustainable development. The idea of response to global climate change under the framework of sustainable development, not only challenges the existing social economic development mode that relies heavily on natural resources to develop material wealth, but also shows clearly the direction for the coming negotiation under the *Convention.* However, the meaning of sustainable development is not the same for countries at different development phases. , The primary priority for developing countries is development, and their CO_2 emissions will inevitably increase in the future. At present, developing countries pay more attention to the challenge of meeting basic development demands instead of global climate protection. A relative easy step for most developing countries is to follow a more sustainable development mode starting from their development goal as along with the consideration of climate change. But this does not necessarily mean a decrease of GHG emissions, nor can it be a reason for developing countries to be committed to reduce or control their GHG emissions in the near future.

VI. Suggestions on China's participation in CDM (Clean Development Mechanism) activity

Apply CDM investment additionality principal to improve the efficiency of foreign investment use First, China should urge developed countries to carry out the relevant Conference of the Parties principles concerning CDM investment, which is the precondition to guarantee the additionality of CDM funds. Second, China should explicitly request the developed countries to support CDM projects with public fund additional to Official Development Assistance or other funding mechanisms in the Convention, at least the public fund for the CDM projects should be additional to the ODA which is at present more than 0.7% of the GDP. Third, China requires that the share of private investment in CDM project should be higher than that in a common commercial project, which is very important to minimize the incremental cost of reduce GHG emission.

Make use of the technological additionality of CDM projects to promote international technology transfer First, China should require the CDM executive board to establish the standard of advanced technology for sectors with large GHG mitigation potential, such as the thermal power sector. This can guarantee the technological consistency for the same type of CDM projects in different countries or regions, as well as avoid outdated technology being pushed by developed countries onto underdeveloped countries. This kind of CDM standard of advanced technology can help to guarantee those technologies with

actual GHG mitigation effect to be transferred to developing countries via CDM projects. Second, as CDM projects are bilateral projects between parties, the technological additionality of CDM project requires the developed countries not only to transfer public technology via CDM projects, but also require them to implement all kinds of policies and measures to stimulate the private companies to transfer those mitigation technologies for cars which can not be transferred by normal commercial means or the companies are not willing to transfer under other conditions. [Preceding sentence is too convoluted to follow –needs to be broken up into understandable components.] Therefore, in order to guarantee the technological additionality of CDM projects, developed countries should implement effective policies and measures and build up stable institutions to promote CDM technology transfers and to create a sound environment for technology transfers.

To strengthen the scientific assessment of CDM project for promoting sustainable development The decision preface concerning CDM project in COP7 restated that the host party is entitled to judge whether a CDM project can contribute to the national sustainable development, which is a significant principle for CDM. Therefore, China should start from the current situation and accept the sustainable development assessment index system including economic sustainability, eco-environmental sustainability, and social sustainability to judge a CDM project on whether or not it can contribute to China's sustainable development, especially in the energy sector. More specifically, China can assess a CDM project in the energy sector according to the following aspects: increasing economic output, increasing effective energy supply, advancing technologies, reducing local pollution, and increasing employment. The assessment index system can be: output / Cost Estimating Relations (CERs) , effective energy / CERs, CERs / emission baseline, pollutant emission / CERs, employment / CERs.

To strengthen institutional and capacity building, and prepare for CDM participation At present stage, participation in CDM project is an important way for China to take part in international cooperation on global climate change protection. Therefore, China should prepare in all aspects, such as institution, management, capacity building, and project assessment, for CDM participation. Since CDM participating countries are required to designate a national CDM authority to execute the responsibilities of the government of CDM parties, China should establish a special CDM administrative institute under the lead of a national coordination committee on climate change policy. Considering that some governments have already implemented procedures like biding and tendering to carry out CDM projects, China's authorities concerned with CDM should also take actions to assess potential CDM projects based on China's restructuring and Develop the West Strategy, and establish a concrete CDM project database which can act as a reference and menu of CDM projects for the negotiators.

Market-Oriented Reform in China's Energy Sector

Development Research Center of the State Council

I. Objectives of the market-oriented reform in China's energy field

1. Overall objectives

Through designing and carrying out a scientific and rational reform model and under the precondition of ensuring a smooth implementation of the overall strategy of national energy, China must bring the fundamental role of market competition into full play. This must be done with respect to the optimal allocation of resources, enhancement of the our internationally competitive strengths within the energy sector, constantly satisfy the increasing energy demand of the whole society, and cope with various future challenges in the energy field in order to provide related industries and users with low-price, high-quality, stable, sufficient, and clean energy products.

2. Goals for the short term

A. Sufficient energy supply at a low price and of high quality that can meet the energy demand arising from rapid national economic growth

B. Through implementing effective market regulation, prevent monopolization of any sector in the energy market, and at the same time, prevent disruptive fluctuations in the energy prices and energy markets, hence creating a stable economic and social influence

C. Reemploy elsewhere quickly the surplus labor force laid off by the state-owned enterprises because of reforms in the field of energy production

D. Control the financial pressure on the governments at different levels within acceptable levels

E. Policies will not remarkably increase the difficulty and cost of reform in days to come

3. The objectives in the mid and long term

A. Ensure national energy security and meet the energy demand for economic growth

B. Attract investors to the energy sector and maintain the capabilities for reinvestment or renovation and retrofit (such as the investment in power grid and retrofit capability) of the existing manufacturers

C. Guarantee complete and orderly competition through a separated and effective market regulation system, and avoid market monopolies.

D. Maintain a balance between the development of the energy sector, available resources, and the environment.

E. Make the governmental administrative system and energy policies more scientific and more effective.

F. Improve international competitiveness of the energy sector significantly

4. Industrial objectives

- Electric power industry---- (1) Open up market access to power grid facilities, and encourage non-governmental investment put in the construction of power grid facilities; (2) achieve the interconnection among the regional power grids via legislation; (3) improve the regulatory system; (4) on the basis of improving the regional electric power markets, gradually establish the nationwide unified market for electricity; (5) the power generation links should be the first to introduce competition, and complete the "Separation from grids, Bidding for grid access" to bring about a fair market competition system; (6) the electricity sale links (retail markets) will gradually introduce competitive mechanisms to allow end users to freely choose power suppliers; (7) power transmission and distribution links such as the retained links with the characteristics of networks in the electric industry, will still be regarded as natural monopolies, however, the power transmission and distribution should gradually be separated from each other, and at the same time, the governmental control must be strengthened accordingly, and (8) the power grid should provide necessary basis for ensuring the competition between the power generation and sales.

- Petroleum and natural gas industries----(1) Quicken the reform of pricing mechanisms for petroleum and natural gas, so as to decrease the direct governmental intervention in petroleum products and natural gas pricing; (2) break regional monopolies and encourage the three major petroleum and natural gas groups to enter other regions to develop business, and thus form a comprehensive competitive pattern; (3) improve the regulation system and institutions of petroleum and natural gas industries; (4) step up opening to the outside world by lowering the barriers to trade and investment, and gradually relaxing the restrictions on the foreign capitals and non-government funds entering oil exploration and exploitation, pipeline network transport, petrochemicals and oil products circulation (inclusive of wholesale and retail links); (5) encourage non-governmental funds to enter the construction of natural gas pipeline networks, and at the same time,

strengthen the price regulation over the pipeline networks with patterns of natural monopoly; (6) establish early-warning mechanisms for oil security and a strategic petroleum reserve system.

- Coal industry----Under the institutional circumstances of open, competitive, unified and effective regulation, our aims and objectives are: (1) to raise the internationally competitiveness of our coal industry, and form a fully competitive coal market; (2) through reorganizing market players, and the establishment, unification, and improvement of market system, reform of market pricing mechanism, normalization and regulation of market order, rules and regulations and guidance of market acts, bring into full play the integral role of the market mechanisms in the course of guiding the development of coal industry and enterprises; (3) push forward the optimization of supply and demand mix of coal and other energy sectors; (4) promote a wide utilization of clean coal-oriented technologies, so as to embody the fundamental standing of the coal industry of our country in the national overall energy strategy.

II. The basic principles for the market-oriented reform in China's energy field

Legal system paves the way for reform.

Establishing rules and regulations is a precondition and cardinal guarantee of market-oriented reform of the energy sector. The further improvement of current laws, such as the *Electricity Law*, *Mineral Resources Law*, and *Coal Law*; the *Petroleum Law, Natural Gas Law, and New Energy Laws* have not yet been developed.

Handling the balance between reform, development, and stability correctly.

The objectives of market-oriented reform are aimed at energy sector development; however, development cannot be separated from a stable external environment. Therefore, no matter what kind of reform model and policy initiatives China adopts, the reform cannot be considered a success if it causes instability, or fails to promote long-term development of the energy sector.

Implement plans and schedules in a systematic way

The market-oriented reform of energy sector involves many parties. It will meet with resistance from both the stakeholders with vested interests and competitors. The long and complicated process of balancing and adjusting these interests

cannot be accomplished through singular efforts. Thus, we must conduct overall planning at the higher levels of the national energy strategy that are oriented toward the 21st century, and carry out reforms one step at a time and by stages.

The government should provide support.

Market-oriented reform in energy sector requires that the government provide support. European and Japanese governments provided financial subsidies when reforms were carried out in their coal sectors, to alleviate social upheavals caused by the restructuring and the consequent impacts on declining mines.

Introducing market competition.

Government intervention must be executed under the prerequisite that the basic functions of competitive market mechanisms should not be damaged. We have adopted the following: (1) ease market access; (2) diversify property rights; (3) reduce financial subsidies; (4) reduce trade barriers, customs duties and non-customs duties; and (5) prevent market monopolies. All these initiatives are used to allow the market competition mechanisms to play their irreplaceable role in the following fields: Cost reduction, efficiency improvement, effective supply increase, and competitor selection.

The reform of energy sector should be combined with the reform of the governmental functional administration.

In the course of the market-oriented reform, besides the market-oriented reform of the energy sector itself, the reform of the administrative system and approach of the governmental functions should be carried out such as (1) to adjust the institutional framework and functional configuration of the governmental functional administration; (2) to reform and redefine the responsibilities and rights and benefits among the different government departments; (3) to reform regulatory institutions and mechanisms; (4) reform decision-making mechanisms; and (5) to allow for decisions to be made in a more democratic and scientific way.

The reform should be compatible with other complementary reforms.

The coal, electric power, and transportation reforms should be carried out in parallel. The other reforms should be promoted together and coordinated with one another, such as the enterprise, finance and taxation systems, investment and finance system reforms, as well as administrative framework reform.

III. Transitional arrangement and reform outline for bolstering the reform of the energy sector

(I) Transitional arrangement

Since market-oriented reform is a complicated and long-term process, its transition must be planned carefully. Easier reform projects should be done before difficult ones. During the transitional period, relevant arrangements should be made for the institutional framework and functional configuration of the government administration, legal oriented management system, and intensive management and more professional management.

Focus of reforms in the short term: (1) improve the legal system; (2) develop the national energy strategy; (3) strengthen market regulation; (4) reform the investment and financing framework; (5) deregulate the restrictions of market access; (6) adjust taxation policies; and (7) enterprise reform.

Focus of reforms in the mid and long term: (1) optimize energy and market structures; (2) improve energy markets and regulation system; (3) realize the separation of administration and regulation; and (4) promote the fulfillment of national energy strategy.

(II) Reform outline

1. Speed up the development of a relevant legal system ; develop a national energy strategy geared toward the 21st century; establish a strategic energy reserve system and an energy security early-warning system; and integrate energy supply with energy security, energy-saving, and environmental protection.

2. Improve and optimize the energy supply mix and regional structures; focus on the development of natural gas, nuclear, wind, and the other new sources of energy; reinvigorate our efforts in the area of the development and support of new and clean energies; encourage the research and development of the energies that are cleaner and more efficient.

3. Reform the institutional framework and approach of the government functional administration; separate the industrial administrative functions from the market regulatory functions; separate industrial policies from regulatory policies; when the requirements are met, consider separation of the market regulatory function to create a social regulatory institution.

4. Establish a modern regulatory system. In the short term, integrate administration and regulation; when the requirements are met, separate administration and regulation; strengthen the regulation of the monopolistic links and externalities.

5. Ease market access restrictions for the energy production sector; encourage the energy infrastructure and energy production sectors to attract all kinds of non-governmental capital. Select investors, builders, and operators of energy projects through public bidding invitations; the qualification of enterprises related to mining resources should be strictly authenticated to prevent excessive mining causing damage to the ecological environment.

6. Break regional and industrial monopolies and blockades; encourage competition to unify energy markets.

7. Speed up the reform of the state-owned assets management system and incorporate reorganization of the state-owned enterprises; make an energetic effort to foster a number of large-sized corporate energy groups, which are characterized by upstream and downstream cohesion, trans-industry and trans-region capabilities, and strengths to enhance our global competitiveness.

8. Speed up the relevant industrial reform process, and form an interactive mechanism that matches the reform of the energy sector, such as keeping up with electric power, coal, and railway reforms.

9. Raise funds from multiple channels, and establish a benign mechanism for the industrial transformation of cities based on coal and petroleum resources as soon as possible.

10. Adjust vehicle industry policies: encourage the development of clean fuels and vehicles using alternate fuels, as well as economical automobiles; increase the environmental protection standards for tailpipe emissions.

11. Adjust the taxation structure of the energy industry and cut down on its tax load.

Strategy and Policies for Renewable Energy (RE) Development

Center for Renewable Energy Development of the Energy Research Institute

Background

In 2000, the total world-wide consumption of RE amounted to nearly 1.96 billion tonnes of coal equivalent (tce), accounting for 13.6% of global energy consumption; 2.3% of which was hydro-electric and 9% coming from traditional RE sources.

By March of 2003, the global wind power capacity exceeded 40 GW (70% located in Europe), with the increasing rate in Europe more than 30-40% annually. Solar energy has also grown rapidly. Manufacturing capacity for PV generation manufacturing capacity has reached 400 MW annually, with a currently existing capacity of around 3 GW. By the end of 2002, the total capacity for biomass generation exceeded 50 GW with biomass liquid fuel exceeding more than 20 million tonnes. In terms of solar water heaters, the total world area accumulated to 91 million square meters, about 14 million tce.

2. What does the booming RE development in the world imply? And what can we learn from their experiences? What are the implications of the recent boom in RE development: What can we learn?

2.1 RE has become one of the most important choices for sustainable development.

International experience shows that no matter what the motives, governments give RE development legal and policy support. For example, Germany and Spain issued Feed-in-laws to ensure wind power development; Great Britain implemented (Non-fossil fuel obligation) this is also clearly to create opportunities for RE development; a number of states in the U.S., Australia and Japan issued renewable portfolio standards (RPS) to develop RE. They also formulated major development plans. The EU regards RE as the key to realizing three strategic goals: increasing the competitiveness of European energy, ensuring a stable and continuous supply of energy, and environmental protection. It is projected that by 2010 RE will occupy 12% of total energy consumption in the EU: PV reaching 3 GW, and wind power capacity reaching 60 GW, with a projected increase to 150 GW by 2020, 50 GW coming from offshore turbines.

2.2 RE is a growing industry with great economic potential.

Foreign experience shows that renewable energy, as an emerging industry, is increasingly playing an important role in national economies. The European

Wind Energy Association stated that a total of 5.8 billion pounds worth of wind power technology was installed in the EU in 2002. The electricity generated from wind power can meet the demand of more than 40 million people. The EU estimates that by 2020, the PV market will increase from 3 GW to 70 GW. Likewise, 30% of the electric power demand in Africa and 10% in OECD will be met by the use of PV technology. The U.S. is also strengthening its PV R&D and manufacturing capacity. It is estimated that by 2020, half of the PV market will be controlled by the U.S. The utilization of commercial biomass has already reached 140 million tce in the world. Aside from its benefit on economic and industrial development, the use of RE will create employment opportunities. The EU estimates that, if Europe can produce 40 GW of wind power, 3 GW of PV, a biomass capacity of 10 GW and 100 M m^2 of solar heaters, a total of 1.54-1.67 million jobs will be supplied by the RE industry.

2.3 Maintaining a technological advantage can help to control market share.

To maintain its status as a world leader, Japan continually increases its output of PV products, accounting for as much as half of the world's market. The best wind turbine manufactures are in America and Europe, namely Denmark, Germany, and Spain. Most of their products are for export, which covers more than 95% of the worldwide trade in wind power.

3. Four major reasons why China should develop RE

3.1 Compared with other countries, China has a less developed system for supplying sustainable energy

China's supply of high quality energy resources cannot adequately support China's immense population. China's per capita share of high quality energy resources such as petroleum and natural gas are respectively 17.1% and 13.2% of world averages. As most of the technologies for utilizing energy are out of date and inefficient, an energy crisis could erupt at any time.

The gap between the supply and demand of high quality energy may become larger and larger. By 2020, the national energy demand is forecast at 2.7 billion tce, 480 million tce higher than the supply. In 2050, primary demand will reach 4 billion tce, with the supply and demand gap widening to 1 billion tce, largely in terms of petroleum and natural gas.

China's energy system is overly dependent on coal, meeting almost 70% of China's primary demand, and causing severe environmental problems. Because of this heavy coal usage, 66% of cities exceed the Level II of national environmental standards in terms of atmospheric particle content, and 22% of cities in terms of SO_2 content. In winter the degree of pollution is higher, about twice the level of pollution during autumn. Environmental experts have

estimated that 90% of the SO_2 content in the atmosphere and 70% of the dust comes from coal burning.

The coal waste is also a big problem. Large amounts of polluted water, coal mud, and dust have become great sources of industrial and agricultural pollution. Coal waste is another factor that impedes regional sustainability.

3.2 Special Demands of China

Development of RE is urgently needed to construct a "well-off" rural society. In China, 80 percent of the total 1.3 billion population dwells in rural areas. Of the total 600 million tce consumed, about half comes from RE. Furthermore, there are still 7 million people without access to electricity, and extending the energy grid cannot solve this.

Another factor to consider is the creation of labor and employment opportunities. Experience demonstrates that RE development can meet both energy demands as well as help solve the employment problems. For example, in 1999 the wind power industry in Denmark supplied 12,000-15,000 jobs, while in Brazil the ethanol fuel industry created tens of thousands of new employment opportunities. In China the hydro industry has also supplied jobs to more than 500 thousand workers.

It is essential to protect the environment and improve the rural environment. Currently, there are 200 million people facing the threat of desertification. However, the consumption of conventional biomass in those areas to subsist means the environment is worsening. Building new and green energy use methods is an effective way to protect the environment.

3.3 RE Development is necessary to improve the safety of China's energy supply.

China has a shortage of petroleum and is becoming more dependent on foreign oil. In 1993, China became a net importer of petroleum. In 2001, 34% of China's petroleum had to be imported, and it is projected that by 2050, about 50% of China's petroleum supply will depend on imports. As a resource, RE can be transformed into electricity as well as liquid fuel such as liquid ethanol, biodiesel, and hydrogen.

3.4 RE development is needed to decrease the energy gap with foreign countries and maneuver into a strategic position in the future.

China is facing the following situation with respect to RE technologies and markets: China is already lagging behind America and a number of European countries, who continue to develop their RE industries. RE technologies are non-conventional; and make use of high technology. Long-term build up of this

technology and the RE market is necessary for RE development. Experience shows that the earlier RE is developed, the more advantages can be obtained.

4. The serious barriers for China to develop RE

Cost barriers. Compared with similar technologies, the cost of RE production is higher than that of conventional fuels. For example, if the production of one unit of coal-fired energy cost one unit, the relative equivalent cost of small hydroelectric power would cost 1.2 units. Biomass generation would cost 1.5 units and wind power would cost 1.7 units. The cost of generating PV would be between 11 and 18 units. There are numerous reasons for the relatively high costs of RE, such as limited markets and old manufacturing technology.
Market barriers. The main impediments for a strong RE market in China are, its small scale, uncertainty, and a shortage of relative development mechanisms.

Policy barriers. In the past ten years, relative Chinese authorities have formulated some incentives for RE. But with economic reform and development, some administrative sectors changed. Therefore some previous policies simply disappeared in the reform process (i.e. various provisions concerning wind power and access to the power grid), some polices are only nominal (certain regulations in the 44th document issued by SDPC and MOST in 1999), and some polices are just too difficult to implement in practice (regulations covering the half VAT for small hydro).

5. China has the basic capability to develop large scale RE.

5.1 Great market potential

China hosts a large population that is relatively deficient in energy. As the economy develops and society becomes more affluent, a larger energy supply will be required. China is also an agricultural country, with more than 80% of the population living in the rural areas. As much as 600 million tce energy will be consumed annually, half of which will come from biomass.

5.2 Strong resource base

The potential for small hydro is 120 million kW, but only one fourth of that is currently being utilized. The continental solar power potential is estimated at 2,400 billion tce per year. One percent of China's continental area, with 20% transformation efficiency, could supply 4.8 billion tce of solar energy. Wind power generation, including the onshore and offshore sources, could reach 1 billion kW. Biomass resources are also very large, totaling nearly 700 million tce annually.

5.3 The development of the RE industry is underway.

Utilization of RE in the past few years has greatly increased. In 2000 the amount of new RE utilized nationally amounted to 37 Mtce, 4.5 times of the value in 1990.

5.4 New progress in the technology R&D

- Some technologies have been commercialized, such as small hydro, solar heaters, passive solar homes, and household biogas etc.
- The following group of technologies is close to commercialization: large grid wind power, large and medium biogas etc.
- Some technologies are in the demonstration phase, such as biomass gasification technology.
- And some technologies are still being studied: i.e. hydrogen / biomass liquefaction etc.

6.China's Target for RE Development by 2020: a generation capacity of 100 GW, equivalent to 100-120 million tce

6.1 It is quite possible for China to realize a generation capacity of 100 GW by 2020

1) **Small hydro 60-70 GW**. The annual increase rate for small hydro of China is 1-1.5 GW. By the end of 2002, the total capacity for small hydro had reached 28.4 GW. In the coming 17 years, with the general idea of sustainability ingrained in people's minds, along with the development of China's west, an annual increase of 2 GW for small hydro is a reasonable assumption.

2) **Wind power 20 GW**. The national capacity for wind power at the end of 2002 was 400 MW. With a shorter construction period than small hydro, if there is a suitable policy in place, the wind power industry can develop quickly. Taking into consideration improvements in environmental policies, the strengthening of the national economy, and in reference to the increasing speed of foreign wind power development over the last 10 years, (more than 30%), it is likely that China will reach a similar rate.

3) **Biomass generation 10 GW**. Stalk generation (gasification mode) and municipal solid waste (MSW) generation both have large potential. MSW generation is estimated to increase from 150 MW to 2 GW by 2020 as the level of environmental protection becomes higher and higher. Biogas energy generation is estimated to increase to 1 GW, and the biogas generation should increase to 1.5 GW by 2020. The generation of energy from agricultural waste can increase significantly during the process of improving conditions in small rural towns. In concentrated agricultural regions, especially the commercial centers, energy generation from using stalks and rice husks could possibly reach a capacity of around 5-6 GW (including small coal-fired plants fueled by stalk usage).

6.2 It is possible that the total amount of RE produced will 500 million tce by 2020, amounting to 18% of China's energy supply.

The annual increase rate for utilizing new RE during the 9th Five-Year Plan is estimated at 11.2%. With a predicted annual increase rate of 10% and 15%, China's total energy capacity could reach 265 Mtce and 386 Mtce by 2010 and 2020 respectively.

Energy from conventional biomass will be 140 Mtce with an annual decrease rate of 2%.

7. New ideas and guidelines are needed to realize the strategic targets set for 2020

7.1 Basic concepts

1) Meet the total energy demand for an increasingly affluent society
2) Construct an energy supply system with sustainable safety in mind
3) Protect the environment and implement a strategy for sustainable development

7.2 Development strategy

There are four parts to the strategic guidelines that China needs to realize its RE targets:

1) **Government guidance**. According to foreign experience and China's actual conditions, the government should provide strong guidance and input in terms of policy, technology, and market management to develop RE. Also legal guarantees should be made to ensure that the government guidelines could take effect.

2) **Market regulation**. If RE wants to play a more important role in the sustainable energy system of the future, the use of government guidance should be fully explored to expand its role in the market. Doing so will improve technology, reduce costs, optimize deployment of resources, and enhance its competitiveness in the market.

3) **Emphasize innovation**. First, the government should increase technology input, focusing on the design and manufacture of key technologies. Second, innovation should be emphasized during the development process. Developers should not only follow the models of foreign technologies but make their own jumps in development thereby possessing the intellectual property rights to new RE technologies. Lastly, groups with a wide breadth of knowledge should be organized to work cooperatively, and enterprises in the private sector should be

encouraged to participate in development to raise the level of research. The main development path should focus on the generation of gas supplies and biomass liquid fuel.

4) **Scale up development**. RE technology must experience a shift in the scale of development, which is a basic way to reduce costs and promote commercialization. Large-scale production should be used to improve the development of the RE industry. In regard to mature and nearly mature technologies, larger scale production should be organized to expand actual functionality.

8. Ongoing work crucial to China realizing its targets

8.1 Strengthen legislation

Renewable Energy Promotion Laws should be launched quickly

Presently, there are neither special laws for RE nor necessary incentives. Therefore, it is necessary to formulate a set of laws. To begin the legislative process as soon as possible, laws to promote RE should be drafted immediately.

Strengthen policy

In tandem with legislative work, it is imperative to reinforce RE policies. An urgent task is to demonstrate wind concessions to get enough experience to expand throughout the country. Next the financing environment should be improved. Finally, a mandatory market share (MMS) policy study and demonstration should be speeded up.

Increase input, strengthen research on key technologies

The government should increase its input in projects: large scale biomass liquid fuel research, wind turbine research, introduction of PV production lines that can output more than 15 MW, electric power distribution into counties without access to electricity, wind power, biomass generation, and PV generation.

Outdated ideas of RE hindering China's economic goals need to be reevaluated

Compared with foreign countries, China still lags behind in terms of how RE is perceived. RE development should be made a high priority within the national development strategy and incorporated into the government's development plan and budget. Aside from long-term use and annual plans for developing RE, a detailed roadmap of how RE fits into overall development should also be formulated.

WTO's Impact on and Policy Analysis of Energy Technology Development

National Research Center for Science and Technology Development

Summary

This report discusses trends in China's energy R&D policy under new international and domestic circumstances in the 21st century. It mainly assesses the distribution and investment of energy R&D resources, the main elements affecting R&D outcomes, and the application thereof which promotes the advancement and improvement of energy technologies. The management of energy R&D programs (from establishment of projects to industrialization of R&D results) is evaluated in this paper, and as the goal of these programs is to stimulate the industrialization of R&D results, a policy analysis of energy R&D programs is also presented in this paper.

Pursuant to the functions of respective governmental departments and national fiscal budget, the assessment and analysis of the Chinese energy R&D policy hereby focus on the national Science and Technology (S&T) programs sponsored by the Ministry of Science and Technology (MOST), especially the R&D related programs, including High-technology Research and Development Program (863 Program), 973 Program and National Program of Key Science and Technology Projects.

Policy making in the energy field such as national and key innovation programs and projects coordinated and organized by the government are insufficient in China. Laws by some departments, such as the "Clean Vehicle Act" and "Purified Energy Act," rarely represent national objectives and the centralization of distributed resources. Moreover, they have no access to top-level guidance of national actions. Such actions are not included in this paper.

Research alike has seldom been conducted in China, and we are trying to fill the gap that exists in the science and technology policy research area. This is due in large part to the following: 1) the management of the development of China's energy industry has always been dispersed rather than centralized; 2) R&D programs have not received government allocations and investments of energy R&D resources.

Major issues indicated in this Research:

1. The energy R&D input is too low.

In 2000, investment in energy R&D was 5.78 billion RMB and accounted for 6.43 percent of China's total R&D expenditure and 0.06 percent of GDP, which is

much lower than the ratio of most developed countries 'energy R&D budget to GDP. Investment from the Chinese government accounted for almost 11 percent of the overall energy R&D input and accounted for 0.0068 percent of GDP. China's investment was less than that of most developed countries and amounted to only 1.8 percent of Japan's that year.

2. National Energy R&D Strategy Objective/Mission has not paid sufficient attention to the efficiency promoting technologies.

The 863 Program defined the strategy objectives of the energy technical field at the beginning of 2002. It concluded the following: (1) technology support should be provided for a sustainable, high-efficiency, safe energy supply, (2) efficient utilization of purified coal and coal-group liquid fuel key technologies should be improved, (3) the technical and cost problems involved in the application of nuclear energy and renewable energy on a large scale should be solved, and (4) innovative energy technologies should be developed. This represents China's energy R&D strategy objectives.

One major defect of China's energy R&D strategy objective is that the energy efficiency technology has not been strongly emphasized. This is despite the fact that the project *Major Scientific Issues within Energy Efficiency Conservation* was established in 2000 under the 973 Program, and one of the principle objectives of the coal purification technology under 863 Program is to realize the electricity generation efficiently by coal with low pollution. The energy end use efficiency technologies could also be enhanced by the transportation, manufacturing, and buildings sectors. The climate change caused by air pollution and greenhouse gas emissions could be effectively controlled by energy efficiency advanced technologies. In addition, the reliance on imported oil and the burden on enterprises and residents for energy consumption could be lessened. The enhancement of energy efficiency by innovative technologies is of great significance to raising production efficiency, lessening wastes, and lowering costs.

The development of sequestration technology should be deemed one of the major projects of Chinese energy R&D in the 21st century. If CO_2 could be separated and disposed of or utilized effectively, sustainable development of energy mainly consisted of coal could be realized. This significant issue deserves further research.

3. Energy technology selection is divorced from energy strategy projects.

Ministry of Science and Technology (MOST) guides energy development and research in China. Its consultant panel is comprised of the 863 Program energy expert and consultant committees, as well as the 973 Program expert consultant committee. Project applications are first reviewed and selected by technical experts (including a few technical economic experts and technical management experts). Generally, the experts make an evaluation of the applications based on their own working experience and knowledge and following the instruction of

the Project Office, which no doubt possesses some limitations. Our study indicates that the technology selection and the formulation of strategy objectives in the 863 Program and National Program of Key Science and Technology Projects have not been linked properly. For example, coal-burning pollution control technology projects are diverse and dispersed. The selection of new generation mainstream coal-generated electricity technologies also presents some disconnection as mentioned above.

4. Energy technical R&D projects are repeated and overlapping in the national science and technology programs.

The coordination and cooperation issues within the selection and management of energy projects under the 863 Program, 973 Program and National Program of Key S&T Projects have been prominent, since the 863 Program became a regular national S&T program from one of the tenth Five-Year Plan programs. It is difficult to divide an energy technology R&D project directly into basic research, applied basic research, applied research, technical innovation, and industrialization phases, and assign them to these different programs. Energy is a complex science and the R&D process of energy production and utilization technologies is an inter-locking chain. Moreover, it is not only a chain; its complexity makes it possess features of multiple chains linked. Then repeat and overlapping cannot be avoided when we try to use different programs to manage the R&D of a project in an energy technology sector, and limited resources including capital, technology and management manpower will be wasted.

Accomplishments that need to be further strengthened:

1. The investment in energy R&D by the 973, 863, National Program of Key S&T Projects has been stable.

Investment in energy R&D remains approximately 10 percent within the national science and technology programs framework and is higher than the ratio of energy R&D input in total national R&D expenditure. Although the input by the national science and technology programs takes a great part (approximately 60 percent) of the government energy R&D capital investment, most of which is from the central government and the insufficient contributions from other governmental departments and local governments will finally cause a low-ratio of government investment in energy R&D.

2. Independent R&D capabilities of enterprises in the energy industry have been strengthened.

In the last decade, the ratio of expenses on technology R&D and other technical actions (technical reform, technology import and domestic technology trade) of large and / or medium-sized enterprises in the energy industry to those in all-sector industries increased significantly. This indicates that the enterprises '

technological actions in the energy industry are more active compared with those of enterprises within other industries.

According to statistics, technical advancement in the energy industry relies more on external technologies (technical reform, technology import and domestic technology trade) compared with that of other industries. When we use the following formula:

(technology transfer cost +absorption cost) divided by (technology transfer cost + absorption cost + domestic technology cost +technology R&D costs)

to measure the degree of reliance of Chinese enterprises 'technical advancement on overseas technologies, the degree of large and / or medium-sized enterprises in the energy industry is much lower than that of enterprises within industries. Further, it has declined during the last decade.

Currently, government capital and bank loans account for 4 percent and 10 percent respectively of the independently raised funds for science and technology activities by the large and / or medium-sized enterprises, and the remainder is from enterprises 'own capital.

The data analysis indicates support for R&D projects to decrease energy consumption constitutes only a 2 percent share of the enterprises 'R&D expenditure, and accounts for 53.58 percent of the total investment for national R&D projects. Ignorance of R&D of efficiency improving projects is another feature of science and technology activities of enterprises in the Chinese energy industry currently.

3. The development of advanced energy technologies is encouraged by China's accession to WTO.

The energy R&D within the national science and technology programs studied here relates largely to the 863 Program, the 973 Program and the National Program of Key Science and Technology Projects (to a lesser extent, National Natural Science Foundation Projects, National Key Lab Construction Project Programs, National Mega S&T Projects, National Engineering Research Center Projects and Engineering Technology Research Center Construction Projects, etc.). There is no conflict between our government's funding of science and technology actions and requirements of the WTO's *Agreement on Subsidies & Countervailing Measures (SCM).*

From international cooperation in the 863 Program since the implementation of the 10th Five-Year Plan, cooperation and communication in various forms that combine independent R&D with technology import and absorption thereof have been further encouraged. Special funds for international cooperation have been established. Following the *Science and Technology Cooperation Agreement of China and EU*, the MOST opened some research projects under the 973 Program to OECD, one of which has been initiated. Most projects under the 973 Program

have established a broad and deep communication and cooperative relationship with countries worldwide in varying degrees.

We particularly investigated the coal direct liquefaction key technique project under the coal purifying technical theme in the energy field set in the 863 Program. It is a project in which Shenhua Group Ltd.'s imports AXENS Company's coal direct liquefaction technique demo production line; this is the first time technology imports support an R&D project in the energy field under the national high technology development programs.

With the assistance of the highly advanced technology import demo project, supportive system platforms for independently created technologies have been developed, and R&D improving techniques (such as solvent hydrogenation processes and high efficiency catalysts) have been implemented, thus the industrialization of advanced energy technologies has been promoted. The project aims to develop a Chinese Direct Coal Liquefaction (CDCL) technique, and achieve a CDCL technique package based on the process development unit (PDU) of 6 ton per day. The CDCL technique was defined and a patent application referring to it was filed correspondingly. More patent applications are being prepared and final achievements may be applied in consequent production lines (the 2nd and 3rd lines) in Shenhua First Stage Project. Undoubtedly, this is a unique mode for technical innovation deserving an in depth study.

Main recommendations:

1. Increase energy R&D investment

- Increase national R&D investment, especially the portion of energy R&D expenditure for national R&D investment and resolve the problem of insufficient investment in energy R&D. Also, energy R&D funding from the government should be increased. The share of energy R&D on national R&D spending should increase from 6.4 percent in 2000 to 7 percent in 2010 and to 8 percent by 2020. The share of government energy R&D spending of the total government R&D budget should increase from 1.9 percent in 2000, to 3 percent in 2010 and to 4 percent or 5 percent in 2020.
- In the funding of national S&T programs, an appropriate ratio should also be established for energy R&D. In specific science and technology programs, it is necessary to reasonably arrange the funding for energy R&D.
- In order to make the most effective use of the limited input, the government should identify limited goals, available resources, and define the most pivotal technologies in energy R&D in the formulation and implementation of national science and technology programs. The project selection and funding in science and technology programs should meet the

demands of national strategy goals of energy R&D priority areas and key technologies.

- To establish the partnership between government and enterprise, and the partnership among enterprises that act as bridges to national science and technology programs. Regarding the projects that have big investments and are long term and high risk, the R&D mode of sharing risk and benefit should be adopted. This is recommended for all engineering demonstration projects.
- Make full use of international resources, to extend the funding source for national R&D activities. After accession to the WTO, China has more opportunities to participate in international science and technology collaborations. Researchers and R&D institutes should be further encouraged to take part in international energy R&D cooperation. We suggest the government set up a special fund for international cooperation in national science and technology programs. Foreign multinational companies should be encouraged to establish energy R&D centers in China to engage in R&D for energy technologies.

2. Improvement in government management

The government should formulate national energy supply and consumption strategies, and energy R&D strategies to meet the national economic and social development based on the demand forecast. The energy R&D strategy should be based on regular technology planning practices to identify priorities and select national critical technologies.

Regarding national science and technology program management, government functions should be shifted from operating science and technology programs directly to taking charge of project selection and fund allocation, participating in evaluation and assessment, and consigning the implementation process management to intermediary agencies. In that way, the government not only plays a leading role in strategy implementation, but also avoids getting into operating details rather than high-level coordination and management.

The reform of research institutes in the past years has greatly promoted the process of R&D institutes transferring to technology-based firms. R&D institutes transferring to technology-based firms or merging with enterprises are effective ways to enhance enterprises 'R&D capability and accelerate commercialization and industrialization of R&D results. The Chinese government should strongly encourage energy enterprises to establish their own R&D centers. National science and technology programs provide a linkage and stage for cooperative research between firms and research institutes. The development and enlargement of Chinese-made FBCC is one of the best examples. In the future,

the government should play a greater role in the introduction and promotion of close linkages between R&D institutes and firms.

A united and coordinated mechanism on energy R&D should be set up between government sectors and within a ministry, including the formulation of the science and technology development and industry development plans, exchange and sharing of information, and the utilization and dissemination of R&D results.

3. Reinforce the construction of intermediary organizations

Industrial associations that consider it as their major responsibility to bridge enterprises and government with information exchanges and conduct academic activities and technology service, and other intermediary organizations should develop and enhance internal organizational operations within a broader of scope when the government sectors reform and China joins the WTO. Facing the challenge of international intellectual property rights (IPR) competition, two of the important tasks for the intermediary organizations are to coordinate member firms 'behavior, resolve common problems for the firms within their sector, and to formulate the sector's overall IPR planning for the interests of all firms within the sector. Industrial associations should play the role of promoting government investment of more money for protection of IPR, construction of IPR information networks, and support in applying for international patents for key technologies. Important coordination mechanisms and defined roles for industrial associations 'on settling intra-sector disputes and disagreements need to be set up.

Industrial associations should have *comme il faut* positions in the energy innovation system. All government sectors, enterprises, and R&D institutes should fully understand the important roles industrial associations play and make full use of them.

As an intermediary science and technology agency, the Innovation Foundation for Small Technology-based Firms has been playing a positive role in promoting small and medium sized enterprises (SMEs) energy development and energy saving technology development. It deserves further support under these new circumstances.

4. Further development of the market function

After China's WTO accession, the development of its energy industry will be shaped increasingly by the market economy system, and the market role on resources allocation will be continuously reinforced. The establishment of united market regulations compliant to the WTO and a supportive legal system is helpful for energy technology flow and R&D investment to energy firms. Energy

R&D policy-making must consider how to play the market function, and how to overcome the barriers to energy R&D through market mechanisms. The government should cultivate the new energy market. It can introduce the formation and development of the new energy market. Furthermore, government guidelines can encourage firms to invest on R&D in the field of clean energy through market mechanisms, that is by market pull and inner motivation of firms rather than by government pushes.

5. Enhancement of energy strategy development

The establishment of an energy development strategy should fully adapt to the needs of constructing a middle-class society. R&D and innovation of energy technology are essential to meeting such an enormous energy demand as the 2.4-3.2 billion tce in the year 2020.

The government should insist on conducting technology research based on key national technologies and priorities of energy R&D.

Strong attention should be paid to R&D of technologies that increase the energy efficiency of the end use consuming sectors (such as the transportation, industry, and construction sectors) and of clean energy producing and consuming technologies, including carbon sequestration technologies.

International energy R&D trends to develop clean energy technology are also useful for establishing a middle-class society and sustainable development.

Clean energy technologies can be defined as advanced, environmentally-friendly energy producing and consuming. One of the central missions of China's energy R&D should be to develop technologies with independent IPRs and suitable to China's situation. Development of clean energy technologies should be one of essential options for China's energy strategy and science and technology strategy. This report recommends enhancing continuous investment and policy support to clean and efficient energy technology R&D in national science and technology programs.

Development and Utilization of Clean Coal Technologies

Clean Coal Engineering & Research Center of Coal Industry

Background

The purpose of this subproject is to study the current laws, regulations and policies that are used to accelerate the development of clean coal technologies (CCT) in China, evaluate the implementation of laws and economic incentives, and find out the obstacles to the current development. Through the evaluation of clean coal technologies and development based on four main users of coal, i.e. power sector, industrial boiler, chemical production and fuel oil substitution, and household use, clean coal technologies suitable for Chinese situation are put forward. Based on the technical and economical evaluation, policy recommendations for the development of Chinese clean coal technologies are put forward, as well as the future development options.

1. China must develop clean coal technologies

China is a large energy consumer with coal as the dominant energy. The consumption of coal in China in 2002 was 1390 million tons, accounting for about 67% of primary energy consumption.

The energy resources and current economic foundation, as well as their future development, are sufficient to support the oil and gas to be used as the dominant primary energy to substitute for coal. All forecasts indicate that the proportion of coal in Chinese primary energy consumption will decline to 60% in 2020, but the total amount of coal consumption will rise to above 2000 million tons. The current situation and a forecast of coal consumption are listed in Table 1.

Table 1. Status and projections of coal consumption in China

Year	Total consumption (Mt)	Proportion (%)				
		Power	Industrial boiler	Coking & injection	Chemicals & fuel oil production	Household use
2002	1315	54.8	~27	9.1	3.0	6.0
2020	2480	68	14-15	8~9	4	5

The energy sources and economic development level in China determine that coal is the fundamental energy of China. Coal dominated energy consumption mix will not change for a considerable period in the future.

Coal plays an important role in the development of the national economy. Coal accounts for 72 percent of power, 50 percent of feedstock for chemical production, 90 percent of the fuel for industrial boilers, and 40 percent of household fuels.

However, large volumes of low efficiency coal use cause serious environmental pollution. Ways to control SO_2 and acid rain pollution caused by coal combustion have become the most pressing task in air pollution control in China.

Clean coal technologies are technical systems composed of new technologies including coal exploitation, combustion, conversion, and pollution control, all of which aim to improve coal utilization efficiency and decrease environmental pollution. The advantages of CCT are that they are able to ensure energy security, conserve energy, realize clean and high-efficient utilization of coal, and solve current coal and environmental problems, while efficiently utilizing abundant and cheap coal.

The development of clean coal technologies can be used at the source, using different methods to improve coal quality and reduce SO_2 emissions. They can also be used to improve the end energy consumption mix by increasing the conversion proportion from coal to cleaner electricity, gas, and oil to reduce the SO_2 emissions. Furthermore, a comprehensive process of pollution control from coal mining to utilization can be realized through a combination of different technologies. Vigorous development of clean coal technologies is a smart choice for balancing energy supply and demand in China, and a strategic and necessary choice for realizing the coordinated development of energy, environment, and economy in China.

2. The status of CCT development in China

2.1 Great progress has been made in Chinese CCT development

Chinese clean coal technologies are comprised of 18 different technologies within these five areas: (1) coal processing, (2) high-efficiency coal combustion and advanced power generation, (3) coal conversion, (4) clean and efficient comprehensive use of coal, and (5) pollution control and recycling. Among them, coal washing, blending, coal-water mixture (CWM), and circulating fluidized beds (CFB) have been put into commercial operation; supercritical units, flue gas desulfurization (FGD), and large coal gasification technologies with intellectual property rights are under development. Coal bed methane (CBM) development, integrated gasification combined cycle (IGCC), and coal liquefaction are mainly imported from abroad and have entered into commercial demonstration. Briquette, retrofitting of small-medium industrial boilers, comprehensive use of coal refuse and fly ash, and reuse of mine water are being improved and perfected.

China has promulgated many laws, regulations and policies related to clean energy sources / technologies and environmental protection. Unlike foreign

countries where CCT development is driven by environmental policies, the development of CCTs in China is, instead, significantly driven by the promotion of technical policies. Of the technical policies, industrial policies have been implemented more effectively than R&D policies due to more concrete goals combined with support. Increasingly strict environmental policies and measures have also played important promotional roles in CCT development in China.

The environmental measures (such as total emission controls, emission fees, control of key pollution sources combined with continuous emission monitors, and increasingly stringent emission standards) compel local cities and enterprises to use advanced technologies. This is reflected in the development of advanced power generation technologies and the use of low sulfur coal.

CCT development in China lags behind market demand and environmental demand so it needs to be accelerated further.

2.2 Barriers to CCT development in China

(1) No national energy department oversees the management and coordination of CCT development. Because multiple governmental departments manage energy, there is a lack in coordination among coal production, distribution, utilization, and environmental protection. China has not yet established a technical policy system that promotes CCT development. Current technical policies come from several governmental departments without an overall development plan, clear development emphasis, or development orders, which goes against comprehensive and effective promotion of CCT development and popularization.

(2) Environmental policies are not compatible with industrial and technical policies. Currently, most power stations have not installed FGDs because there are no incentives or mechanisms to encourage FGD installation. Environmental policies are usually carried out by command and control (C&C) measures. Some cities require units that have installed FGDs to use low sulfur coal, which results in increasing the operating costs for the enterprises and discourages the deployment of FGD.

(3) The enforcement of environmental laws is influenced by various factors. Laws, regulations, and policies lack corresponding detailed implementation requirements. Some of emission standards are not practicable. Major pollution sources have not all installed the continuous emission monitors. The great number of coal fired industrial boilers have become the second largest pollution source, second only to the power sector, but there is lack of effective management and monitoring of small-medium users. The level of SO_2 emission fees is still lower than the cost of SO_2 control. The phenomenon of paying emission fees through negotiation still exists.

(4) **There are few investments, favorable financing policies, and credit channels for CCT commercialization.** China invests too little in the development of new and key technologies. Commercial demonstrations mainly rely on enterprises to invest and take the risks, which influences the development and commercial application of new technologies to a considerable degree.

(5) **The energy plan lacks the integration of energy availability, economy, and environment.** There exist enormous differences of the energy availability among regions. Many regions cannot rationally choose clean energy sources / technologies based on the practical regional situation, such as forbidding the use of coal, which causes a series of problems.

(6) **High quality coal cannot be sold at a higher price without establishing a market mechanism to promote coal processing.** The coal supply system is uncontrolled and the quality of steam coal is very low. It is hard to establish that small-medium users should have a first priority on low sulfur and low ash coal and large coal fired units like power sector should use higher-sulfur coal because they have central desulfurization and continuous monitoring.

3. International experiences promoting CCT development

CCT development is generally driven by environmental regulations and policy incentives internationally.

First, special laws with strict legal requirements are established. The formulation of emission standards is in close combination with the economic and technical development level. The effect of enforceability is satisfactory because there is no limit on technology selection as long as emissions from this equipment complies with emission standards. For example, the Clean Air Act (CAA) in the U.S. and national policies for air pollution control in EU not only have the requirement of detailed time limits and standards for environmental control, but also provisions for criminal sanctions for non-compliance.

Next, the government invests significantly in the development of new technologies and offers multiple credit channels in order to promote the introduction of clean coal technologies. For instance, the total investment of the American CCT program is 7.14 billion dollars, of which, the proportion of government funding is about 35%. The Japanese government grants more than 57 billion yen every year to the "New Sunshine Program."

Effective enforcement of regulations is realized by adopting environmental protection measures, such as collecting fees on total emissions, imposing penalties on emission amounts exceeding regulations, emission trading schemes,

and collecting environmental taxes (such as sulfur tax). At the same time, incentive policies such as preferential taxation, low-interest loans, for introduction of advanced technologies encourage the enterprises to implement the environmental control technologies.

4. CCTs to be developed and potential for China in 2020

4.1 Recommendations for CCT development by 2020

1) **Power generation technologies**

- New coal-fired units: Internationally commercialized supercritical and ultra supercritical coal-fired units (equipped with FGD) should be taken as the main units supplemented by CFBC units. At the same time, IGCC and the second generation of advanced pressurized fluidized bed combustion (PFBC) should be demonstrated to accumulate experiences.
- Retrofit of existing units: Installation of FGD for the units is the most cost-effective way to reduce emissions. Taking a 30 MW power station as an example, the total investment, and operation cost of FGD installation accounts for 98 percent of the cost of switching to burning washed coal, and 10.5 percent of the cost of switching to burning natural gas after the retrofit for 15 years.
- China should introduce incentives to promote power stations to use high sulfur coal and install FGDs, at the same time it also should implement emission permits and SO_2 emission trading schemes so that enterprises with FGDs will be able to get more benefits.

2) **Coal-fired industrial boilers**

- Technical development: Energy availability, environmental demands and economic conditions in each region should be considered comprehensively to develop suitable industrial boiler technologies and systematically manage the retrofit of industrial boilers:
  - <10 t/h: switching to briquette and natural gas according to the local energy availability,
  - ≥10 t/h: implementing high-quality coal supply step by step, central desulfurization and de-dusting and developing gradually to large-scale technologies,
  - >35 t/h: introduction of CFB technology **and so on**, central heating, and combined heat and power (CHP).
- After considering the environmental factors, the ratios of operation cost of burning bulk coal, washed coal, briquette with desulfurization effect, CWM, heavy oil, and natural gas are 1:1, 1:1, 2:1, 45:2, and 3:3.1, respectively. Thus, it is inappropriate to burn heavy oil whether from reduction of fuel oil consumption or from the environmental effect.
- Improve the operating level and automation level of existing boilers and

accelerate elimination of the outdated coal-fired industrial boilers.

- Set up an energy contract management mechanism and socialization service system which accords with national situation, while gradually achieving professional and socialized management.

3) Chemical industry

- Technical development:
  - For the regions where natural gas is abundant and easily accessible, natural gas chemical engineering should be developed first. This will offer high-quality products and save investment. The cost of synthetic ammonia plants with the price of natural gas less than 1.0 Yuan/m^3 is lower than that with coal gasification.
  - Currently, coal gasification is mainly used for small and medium fertilizer production. Limited by resource and regional distribution, chemical production with coal gasification as the gas source still needs to be developed vigorously in the future.
  - Development of multi-product technologies should be encouraged for the long term in order to further decrease costs and reduce pollution.
  - Obsolete coal gasification technologies and small fertilizer enterprises should be eliminated.
- Accelerate R&D and commercial demonstration of large-scale advanced coal gasification technology to achieve independent intellectual property rights early. For the long term, coal gasification technologies provide not only the feedstock gas of chemical production but also gas sources for multi-product technologies and hydrogen production for fuel cells, so the development should be accelerated. The suitable technologies for China are advanced pressurized fixed bed technologies, pressurized entrained-flow technology, and pressurized fluidized bed technology.

4) Fuel oil substitution

- Technical development
  - CWM is the first choice for oil substitution technology in the near future. However, it is not economically competitive in the long term. Therefore, it just should be developed moderately.
  - Coal liquefaction technologies are suitable to develop as strategic technologies and for some fuel oil substitution technologies;
  - Using coal to produce methanol and dimethyl enther to substitute for fuel oil is under discussion. The technology development for the long term still needs comprehensive and comparative argumentation based on the energy system;

5) **Domestic fuels**

- Coal has an absolute advantage in price, while oil products, natural gas, LPG, and town gas rank second. The price of electricity is the highest in domestic energy, nearly 10 times of that of coal with the same heating value. Commercial and domestic energy structures should be adjusted according to economic capacity and energy availability.
- The energy for urban use: (1) gradually do away with the supply of bulk coal to form an energy supply system that commerce and domestic use, which has the priority on high quality energy; (3) further increase the proportion of natural gas, LPG, and electricity for household energy use; (3) popularize coal-fired CHP and central heating with FGD.
- The energy for rural use: (1) further increase the proportion of small hydropower, biogas, and firewood-saving stoves; (2) gradually increase the consumption of high quality coal (washed coal, low sulfur coal), and briquettes.

4.2 Potential for CCT development in 2020

Table 2. Clean Coal Technology Development Potential in China 2020

	Power sector		Industrial Boilers	Chemical production	Fuel Oil Substitution	Domestic use
Scale	New coal fired units 345 GW		Retrofit boilers based on different proportions at stages for Class I, II, III regions	New and retrofitted production capability of synthetic ammonia 8 Mt/yr	8.6 Mt/yr	Total coal consumption <80 Mt/yr
Technology options	10% sub critical, 80% supercritical, 10% ultra supercritical	Install FGDs for 80% of existing units (total 180 GW)	Combustion technologies using natural gas, washed coal, briquette, CFB, and desulfurizatin and de-dusting technologies	50% natural gas and 50% coal gasification	34.9% CWM substitute, 65.1% coal liquefaction substitute	Ratio of coal from current 37.9% to 15.5%. Forbid use of bulk coal and introduce briquettes and washed coal
Investment	4,743 billion Yuan		About 123 billion Yuan, increase of operating cost by ~29 billion Yuan per	Total investment for 20 years: 131 billion Yuan	Accumulative investment for 20 years: 103 billion Yuan	

		year after completion		
Benefit	Reduce SO_2 emissions by 3.93Mt Reduce CO_2 emissions by 4264 Mt	Increase average efficiency by nearly 12%. Reduce 2.85 Mt/yr of SO_2 emissions and 8.23 Mtoc/yr of CO_2 emissions.	Reduce SO_2 and CO_2 emissions	Emissions from coal combustion equal to current level

According to the forecast of coal demand in 2020 in Table 1 and considering national environmental demand, the developing potential of Chinese CCT is forecasted through technical, economic, and environmental evaluation as shown in Table 2. The development potential of Chinese CCT and corresponding comprehensive benefit will be huge if CCT are developed based on the above suggested technology development arrangement. Therefore, it should be developed as soon as possible.

5. Policy recommendations for future CCT development in China

Policy initiatives and mechanisms should be used to reach the goals listed in Table 2.

5.1 Policy requirement

1) Enhance unified management for CCT development

- The functions of "National Leading Group for CCT Popularization", which was set up in 1995, need to be renewed on the basis of Department of Energy of National Development and Reform Commission (NDRC).
- A National CCT Development Plan needs to be reformulated, specifying the focus and priorities of CCT development and uniformly arranging and managing national CCT development.
- The national unified CCT policy system should be formulated to organically combine CCT with environmental protection, energy conservation, and development and utilization of high technology.

2) Enhance the connection of environmental methods with CCT development

- Environmental standards should be used to promote the development of advanced technologies but not to limit the use of fuels or technologies.

- An emissions trading system should be popularized as soon as possible. Environmental capacity should be traded freely in the market as a kind of scarce resource to encourage polluters to utilize clean coal technologies actively.

3) Establish reasonable standards and detailed implementation rules for policies and enforcing environmental laws strictly

- As currently much coal-using equipment has used the general emissions standard, special standards for each coal-using unit should be formulated additionally. Current unreasonable standards should be revised and refined and the instructive standards for small users should be changed into mandatory standards.
- Raising the SO_2 emissions fees should be allowed in regions where environmental protection requirements are stringent. It is recommended that emissions fees be collected in several phases: (1) For enterprises that have used advanced technologies and currently have low emissions, the fee should be reduced (such as to 0.2 Yuan/kg SO_2 or less) to reward and compensate them for their beneficial influence on the environment. (2) For enterprises that currently do not employ emission reduction technologies and that have a relatively negative impact upon the environment, but whose emissions do not exceed regulations, the fee should be raised (such as to 1.0-1.2 Yuan/kg SO_2) as a way of encouraging them to use more effective emission reduction technologies. (3) For highly polluting enterprises whose emissions are in excess of regulations, punitive penalties should be continued (such as to 1.5 Yuan/kg SO_2 or greater).
- Continuous monitoring of large users and supervisory management of small users should be strengthened. During environmental enforcement, cooperation with industrial management departments should be enhanced; such as monitoring the operation of FGD units by large coal consumers and the introduction of in-bed desulfurization for CFB boilers in coal-refuse fired power stations. The professional technology and instruction capability of enforcement staff should be improved.
- Improve the environmental awareness, the knowledge level of CCT development, and the environment monitoring ability of the public.

4) Strengthen R&D, popularize technologies, and give necessary incentives

- China should boost R&D investment in CCT. The government needs to set up funds for R&D of basic and common technologies and build research centers. Competitive mechanisms should be introduced in different phases (R&D, laboratory test, pilot test, and demonstration) to fully exert the predominance of institutes, universities, and enterprises. Financing should be offered to purchase national equipment to support the equipment and technology of China. The government should arrange proper subsidies for diffusion of key imported technologies.
- Ramp up investments for demonstration projects. Financial support should be given to some projects, like coal gasification and coal liquefaction, which benefit the environment but need huge investment and have certain risks. Use policies to attract individuals and enterprises to invest. Special tariffs and value added import taxes should be given to the necessary imported equipment and

technologies for demonstration projects according to relevant rules.

- Set up special funds or fund channels for technical development and provide low interest loans for commercialized CCT projects. Some construction costs for projects with better economic benefits and obvious environmental benefits, that still need commercial popularization, can be furthered with funds and then paid back gradually from the benefit after its put into operation. Projects whose environmental benefits are better than the economic benefits should be listed in national major technical transformation projects, benefit from special energy conservation loans, technical innovation loans for enterprises, etc. or increase the proportion of the fund in the investment, broadening the payback period of the advanced fund.
- Preferential taxes should be given to SO_2 emission reduction technologies, which play an important role in environmental protection and social benefits. The major clean coal technologies to be developed should be given a zero percentage rate investment regulatory tax, transitional reductions, and exemptions from VAT and income taxes, as well as proper reduction in and/or exemption from land holding taxes.

5) Recognize the regional differences and draft development plans, choosing suitable technologies for that specific region.

- Each region should be required to draft realistic local energy development plans and clean coal technology development plans, and develop the technologies suitable for itself according to national environmental goals, local resource availability, and economic ability. Regions should not have national approaches imposed uniformly on all regions.

6) Actively build and refine coal supply market mechanisms

- The current coal supply system should be gradually changed such that industrial boilers, small-medium consumers, and domestic and commercial consumers have the priority on high quality coal with low sulfur content and low ash content, while the low quality coal will be supplied to power stations with central controls.
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5.2 Recommendations for CCT development

1) Recommendations for near term

- Supercritical and ultra supercritical units (with FGD) as the main-force units with supplementary CFBC units should be extended in the power sector. The FGD technologies should be extended overall for large coal users in power and non-power sectors.
- Pollution control of industrial boilers should be enhanced. Each region should be allowed to develop industrial boilers with different grades in combination with the local situations. It is suggested that natural gas or coal gasification should be mainly used in Class I regions; advanced industrial boilers firing briquette or low sulfur coal with S<0.5% and district heating and CHP with CFB technologies should be popularized in Class II regions; low sulfur coal,

washed coal, briquette as well as technical retrofit of boilers should be used to gradually realize central heating in industrial districts.

- R&D of large coal gasification and coal liquefaction technologies with independent intellectual property rights should be enhanced.
- Economic incentives should be used to encourage the application of coal processing technologies, such as steam coal washing, steam coal blending, industrial briquette, CWM, to control pollution at the source and improve steam coal quality. CFB technologies should be extended and CWM technologies should be developed moderately.

2) Recommendations for the development of CCT-related industries

- Integrated industries with comprehensive coal processing, distribution, and end-use services
- Clean coal technology-desulfurization environmental protection industries
- City heating-energy contract service industries
- Coal conversion industries jointly formed from coal liquefaction and coal-based synthetic substitute fuels
- CCT engineering service and consultation industries