Economic Development and Energy Issues in China

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Abstract

The paper presents current economic and energy situation in China and projections of economic and energy development up to the year 2020. China's per capita GDP reached US$ 1,090 in 2003 and it is targeted to quadruple GDP during 2000-2020. Featured by limited per capita energy resources and using coal as a dominant fuel, energy conservation, development of alternative energy and renewable energy, coordinative development between energy consumption and environment protection are key issues facing China. Response strategies of developing clean energy including energy conservation and energy substitute is the proper way to solve energy supply issue for supporting sustainable development in China.

Keywords:

GDP, energy conservation, renewable energy, alternative energy, global climate change, sustainable development

1. Introduction

Since the opening and reform in China in late 1970s, great progresses have been achieved in social and economic development. During 1980-2000 period, national economy had a continuous rapid expansion, the average annual growth rate of GDP was 9.6%, which was much higher than the world average level at the same period. The GDP increased by 6.3-fold during two decades.

After entering the new century, GDP still kept strong development trend, growth rates were 7% in 2001, 8% in 2002. Though affected by SARS for several months national-wide, GDP growth rate went up to 9.1% in 2003, the highest rate in past six years. Furthermore, per capita GDP reached at 1,090 US$, given the total GDP 1,400 billion US$ (current price), it was the first time per capita GDP of China over 1,000 US$. It shown that China has fully broken away from influences of Asia finance crisis and come into a new economic development period.

High economic growth rate in 2003 was mainly due to the high development of industry sector whose contribution as higher as 79%. Industries of manufacture, metallurgy, machinery, chemical accounted for more than 50% of total 39 industrial sectors, it implied that China's industry entered a Heavy and Chemical Industry stage, which is an important sign of new economic development phase of China.

It is well-known energy industry played a very important role in supporting national economy development. But, as the real situation — China has 1.3 billion population, lower per capita energy resources is a key factor in a long term to restrict social and economic development in China. And, with increasing consumption of energy and natural resources, pollutions to air, water, land result in environmental deterioration in China, how to provide sufficient quantity and good quality of energy to guarantee rapid social and economic development should be studied seriously.

Thus, energy exploration and process especially developing clean energy, energy conservation and environmental protection are the major issues facing China in next decades, and ask for a better solution to realize a sustainable development.

2. Energy consumption

(1) Current situation

Commercial energy consumption and its mix in past 15 years in China are briefly shown in Table 1. Total commercial primary energy consumption was 912 Mtoe (million tons of oil equivalent) in 2000, which ranked the second top position in the world since early 1990s onward and hence energy related CO2 emission also did the second place.

Table 1 Energy consumption in China

	Energy consumption	Shares (%)				
	(Mtoe)	coal	Oil	N.G.	hydro	nuclear
1985	599	72.8	20.9	2.0	4.3	0
1990	691	76.2	16.6	2.1	5.1	0

1995	918	74.4	17.4	1.8	6.0	0.4
2000	912	65.9	24.5	2.5	6.7	0.4

Energy consumption in China ever went up to a maximum in 1996, and then relationship between energy supply and demand had an obvious turn over, there was a surplus coal supply and a released tension of electricity supply since 1997 and had a maximum energy supply capacity (except oil) in 1998. Some economic and energy experts thought that Asia finance crisis might be one of the reasons for the energy consumption decline in this short-term period until the year 2000.

Entering the twenty first century, energy consumption rebounded owing to starting a new economic development period. Energy consumption increased to 924 Mtoe in 2001, 1,015 Mtoe in 2002, and as high as 1,080 Mtoe in 2003. (Number in 2003 is estimated by an institute, as official statistical data is not announced yet).

Besides, just passing a few years after a relatively ease energy balance period, energy supply tensions came back in China in the year 2003, especially electricity shortage, diesel shortage and even coal shortage for power generation. Electricity generation can not sufficiently meet the demand for industrial production and people's daily life in more than 20 provinces, the situation of demand over generation existed in five of six regional grids all over China except the North-east regional grid. Power grids in provincial level had to shut down power transmission to enterprises sometimes at the priority of guaranteeing residential use.

It is not surprised to have a serious power shortage because of some reasons. First, since 2000 power demand growth rate increased greatly, they were 11.3% in 2000, 9% in 2001, 11.6% in 2002. Moreover, the power demand monthly growth rate has been kept continuously over 15% in past 17 months. However, new power generation capacity was greatly dropped behind the demand, their growth rate were 6.8%, 6.3%, 5.3% in 2000, 2001, 2002, respectively. Effect accumulated in past years results in an insufficient power supply.

Second, production investment increased rapidly, of which investment was centralized in energy intensive sectors, i.e. metallurgy, building materials, chemical industries to support boom expansion of automobile and construction sectors. Now, the production output of steel (210 million tons in 2003), coal (1,400 million tons in 2002), cement of China has jumped up on the first place in the world.

Third, there existed water shortage in recent years especially in 2003, it, in turn, reduced hydro power generation, which accounted for 16-20% of total generation.

Forth, in the reform in China coal trade has been really put into market economy started since 2002, the State gave up the guidance to the coal price, which will be determined by the market in a short time period. And, coal price has rose up by average 10-15 yuan per ton recently because of the increasing demand and transportation cost. On the other hand, thermal power price is still guided by the State instead of being flexible with the variations of demand and coal price, this hinders development of coal-fired power generation (accounts for 80-90% of thermal power generation).

Along with power shortage, coal and diesel shortages were accompanied. Extreme example of coal shortage was that even in the Shanxi province (one of the biggest coal production sites in China) coal-fired power plants suffered difficulty from purchasing sufficient coal, and some iron & steel plants suspended production for a short period in 2003 because of being unable to obtain coal as fuel and raw materials. Analyzed by energy experts, one principle explanation to coal shortage is to close down small-scale coal mines resulting in reducing coal production capacity. Oil production was less than demand in China and the deficit expanded since mid 1990s, this is the essential cause in oil supply, but the status in 2003 was indirectly worsened by power tension as many enterprises stored diesel for generating power themselves to keep normal production going on.

(2) Main characteristics of energy supply and demand

(2.1) Lower per capita energy resource

As China has a huge population, China's figures of whatever indicator are always smaller while making about per capita comparison.

Known from the resources survey as of the end of 1996, China has proven coal reserve of around 200 billion tons ranking the third top place in the world, however, per capita exploitable reserve in 2000 was 90 tons, 55.4% of the world average.

The national oil and natural gas resources assessment completed in 1994 revealed that China has a total oil resource of 93 billion tons and a total natural gas resource of 38 trillion cubic meters. But it is known that, per capita exploitable oil reserve and natural gas reserve in China in 2000 were 2.6 tons and 1,074 cubic meters, corresponding to 11.1% and 4.3% of the world average, respectively.

Finally, though the exploitable hydro power resource in China is 1,980 TWh annually, ranking the first top place in the world, its per capita hydro power 1,530 KWh per year is lower than the world average 1,750 KWh per year.

All in all, China is a big developing country with low income now, development is the primary task in decades, lower per capita energy resource is a vital factor to limit social and economic development of China.

(2.2) Coal as a main fuel

Coal is a major energy source for a long period. In 2002 coal accounted for 65.9% of total primary energy consumption, whereas shares of oil, natural gas, hydropower and nuclear power were 23.3%, 2.7%, 7.7% and 0.4%, respectively. Huge amount of coal production and consumption has put much more pressures on transportation and environmental protection.

(2.3) Lower energy efficiency

The effectiveness of energy use is quite lower, energy intensity per unit of GDP in 2001 was 0.82 kgoe/US$ (at 1995 prices), more than 4-fold higher than the average energy intensity 0.19 kgoe/US$ (1995 prices) in OECD countries. In addition, energy intensity of unit product is also at a higher level in China, it is roughly estimated that average energy intensity of industrial products in eight energy intensive sectors now is 47% higher than the world advanced technologies.

(2.4) Fewer renewable energy use

Renewable energy means hydro, solar, wind, geothermal, biomass energy etc., the renewable energy except hydro and biomass energy is mentioned here. By the year 2002 in China, wind power capacity was 468 MW, solar PV capacity 30 MW, solar thermal capacity 40 million square meters, geothermal power capacity 32 MW. Renewable energy contributed about 3.2 Mtoe, accounted for 0.3%, a very small part in total commercial energy consumption.

(2) Energy demand projections

Facing the serious electricity shortage in a wide range across China in 2003, energy experts, managers and energy development program makers should think about what can be learn from that? They summarized that inaccurate forecast affected by the circumstance of surplus power supply in some years in late 1990s is one of the principal causes. Energy facilities need quite a long time to be built for providing consumption centers and end users with energy (coal, oil, natural gas, electricity etc.) and services. A good energy demand forecast could give useful information and consultation for arranging energy projects in advance to avoid insufficient energy supply, and in some cases could also avoid from surplus production capacity.

Several key factors in social and economic development, such as population, urbanization, GDP, national economy structure, technology progresses etc., are of important functions on energy demand forecast. Before making energy demand projections, these factors should be studied well.

Because of the large population pressure, it is no doubt that China will continue to implement its family planning policy in a long period, which has been one of the national basic policies and led to obvious achievements to all. It is supposed that population would slowly increase from 1,266 million in 2000 to 1.475 million in 2020 at an annual average growth rate 0.77%. And, proportion of urban population would increase from 36% in 2000 to 52% in 2020.

Regarding to economic development, a grandiose medium term target was set up in late 2002, i.e. China's GDP would be quadrupled in the period 2000-2020, this would the second round to quadruple GDP in China in close wake of the first round in 1980-2000. To reach the target, annual average growth rate of GDP should be kept over 7.2% in 20 years. Following this target, China's GDP in 2020 would rank the third top place in the world (behind USA, Japan), and increase per capita GDP up to 2,945 US$ (estimated at constant price and exchange rate in 2000), approaching the bottom-bound of up medium income country (defined by World Bank).

At present time, proportions of primary, secondary, tertiary industries in China's GDP is 15%, 51%, 34%, respectively. This GDP mix will vary with two obvious changes in both primary and tertiary industries. Referring the structure in developed countries, GDP mix evolvement of China is supposed as decreasing primary industry share and increasing tertiary industry share evidently. A reasonable GDP mix in 2020 is assumed to be 8%, 49%, 43%, respectively. It is known that energy intensity per GDP in secondary industry is much higher than that in tertiary industry (about 4-6 folds in China), so such a GDP mix adjustment will slow down increase rate of energy use.

Technology progresses are generally reflected by the indicator of energy intensity per GDP, and compared with advance levels in OECD countries, there are rooms in China to reduce energy intensity in future. It can be assumed that energy intensity will go down continuously, and decrease by 40-50% in 2020.

Based on the assumptions of population, economic development and technological progresses in medium term periods, energy consumption demand projections of China up to 2020 are studied. Among the factors that influencing energy demand, GDP growth is of the most important role. Study results provide that primary energy demand of China would reach to 1,281 Mtoe in 2010 and 1,717 Mtoe in 2020 (see Table 2).

Table 2 Energy demand and structure

	2000		2010		2020	
	Mtoe	(%)	Mtoe	(%)	Mtoe	(%)
Coal	601	65.9	763	59.6	927	54.0

Oil	223	24.5	285	22.2	420	24.5
N.G.	22	2.4	112	8.7	182	10.6
Hydropower	61	6.7	84	6.6	102	5.9
Nuclear power	4	0.4	23	1.8	53	3.1
Renewable	1	0.1	14	1.1	33	1.9
Total	912	100.0	1,281	100.0	1,717	100.0

In this energy demand projection, the energy elasticity of GDP in 2000-2020 would be 0.45 given the annual average growth rate of GDP and energy consumption 7.2% and 3.2%, respectively. Coal share will decrease from 66% in 2000 to 60% in 2010 and 54% in 2020, but coal is the major energy in China. At the same time, clean energy and non-carbon energy especially natural gas, nuclear energy and renewable energy will have a great development, their share in total primary energy will increase from 2.9% in 2000 to 15.6% in 2020, and make contributions of expanding energy resources and protecting the environment.

3. Energy conservation

(1) Overall survey

Experienced by electricity, diesel and coal shortages in last year, people understands again the basic situation, i.e. natural resources including energy are not sufficient in supporting long-term social and economic development at a higher growth rate. Actually, China did constitute the energy development strategy in 1981, the strategy could be briefed as “to produce and save energy simultaneously, with priority on saving energy”. In the “Proposal to Formulate the Ninth Five-year Plan and the Long-term Target of Social and Economic Development of China” in 1995, this energy development strategy was repeated it again. Recently, there are appeals from research institutes and energy experts to upgrade energy conservation strategy into a much higher level of being a basic national policy, i.e. to form a so-called basic national policy “Controlling Population, Conserving Resources, Protecting Environment” in the coming new round development period to guarantee a sustainable development in China.

Energy conservation could be considered in a broad sense way as a strategy to improve energy system efficiency, to save raw materials of production, labor force and funds, to slow down population expansion, to increase productivity and benefits of industrial enterprises, to make reasonable adjustment and optimization of industry mix and product mix etc. It is estimated that 60% of energy conservation potential in

China exist in industrial sector, so that emphasis of carrying out energy conservation strategy should be put on enterprises' production.

Since 1980 great achievements in energy conservation in China were obtained, owing to great efforts by central and local governments, industrial sectors, and energy end users. During the period of 1980-2000, annual average growth rate of GDP and energy consumption were 9.6% and 3.9% respectively, hence the energy elasticity of GDP was 0.41. At the same period energy efficiency indicated by energy intensity per GDP (EIGDP) decreased by 64% or so, thus the average annual decline rate of EIGDP was 5% that was the highest rate in the world and being 2.7-fold over OECD countries. In other words, it resulted in energy saving and/or energy use reduction of 773 Mtoe in 20 years, furthermore in a better environmental protection to reduce roughly 20 million tons of SO2 emission, 263 million tons of cinders, 13 million tons of ashes and dusts, 440 million tons of carbon emission.

Studies on the situation of energy conservation in the years of 1996-2000 reveal some preliminary findings that about 80% of energy saving and energy use reduction were attributed to effective measures: reconstruction of national economic structure (i.e. industry adjustment, sector adjustment, product adjustment), enhancement of energy management, imports of energy and energy-intensive products etc. Besides, 20% of energy saving were directly derived from construction of new large-scale power generation units, cogeneration for district heating, technical renovation in energy intensive sectors of iron & steel, building materials, chemistry etc., retrofit of power grids in urban and rural areas.

In obtaining great energy conservation achievements, certain useful experiences are briefly summarized as below:

- A comprehensive national energy strategy including energy conservation need be formulated early to guide energy development in a correct way. Long before, China government promulgated an overall energy strategy in 1981.
- China government formulated and implemented Five-year plan and annual plan of energy conservation along with the state Five-year Plan of national economy and social development since 1981.
- Established and perfected systems for energy conservation management, supervision and testing, and technology service.
- Worked out policies, regulations and standards of energy conservation, executed quote management, award and fine in order to standardize energy use behavior.
- Provided more input on energy conservation to promote technological progresses in terms of developing, importing and diffusing advanced energy utilization technologies, retrofitting existing enterprises, and stoutly phasing out production of energy-intensive products especially in five categories of small town-village enterprises (blast iron, building materials, electrolytic

aluminum, coke, synthetic ammonia).

- Established China Energy Conservation Investment Corporation (CECIC) and Energy Conservation Information Dissemination Center (SECIDC) to initiate lease business of energy conservation equipment. They have promoted the retrofit of common-used equipment such as pumps, fans, motors etc.
- Established Energy Saving Corporations (ESCO) to provide effective helps to users in Integrated Resources Program (IRP), Demand Side Management (DSM) and others.

(2) Energy conservation potential

In the past time energy conservation has achieved huge fruits and played a very important role in China's economic development. In order to know does there still exist energy conservation potential in future, analysis could be made through two aspects.

First, a comparison on energy consumption of unit product is made between China and advanced level in the world. For thermal power generation (supply), it is 283 kgoe/kWh in China, the world advance level is 222 kgoe/kWh, 27% higher in China. Steel manufacture (comparable energy intensity), it is 676 kgoe/t in China, the world advance level is 459 kgoe/t, 47% higher. Clinker production, it is 119 kgoe/t, the world advanced level is 75 kgoe/t, 58% higher. On the average, energy use per unit of major industrial products in China is 25-90% higher than those in developed countries. It is estimated that energy saving potential could reach to 70 Mtoe in near term by means of technology renovation.

Second, a comparison on EIGDP is done. In 2001 it was 0.82 kgoe/US$ in China, 0.09 kgoe/US$ in Japan, 0.15 kgoe/US$ in France, 0.30 kgoe/US$ in Korea, 1.08 kgoe/US$ in India. And the world average is 0.29 kgoe/US$, so China is higher by 2.3-fold. Though there are some incomparable factors such as different stages of economic development, primary energy mix, exchange rates etc., it is true that the energy efficiency of producing value added is lower in China. Rough estimation indicates that energy conservation potential of China derived from adjusting structures of industries, sectors, and products, could be 210 Mtoe in near term.

(3) Energy conservation barriers

At present time, there exist some problems that do not have positive influences in achieving the potential energy conservation in the future.

First, macro management on energy conservation is being weakened gradually. This is because many measures and instruments that were more suitable for the central planning economy ever being in China in past decades seem to be less effective to market economy during the current economic reform in China. In addition, the management is greatly lessened due to some relevant agencies and departments were dismissed in the restructure of ministries of the state council for several times in the past. And some statistical agencies in various levels gave up statistics and public announcement of energy conservation indicators.

Second, shortage of preferential policies in financial subsidy, tax reduction and exemption, low interest loans, fund support for R&D, funds utilization, etc. All policies encouraging energy saving and environmental protection effectively should be worked out well.

Third, though the “Energy Conservation Law” has been promulgated in late 1990s, a complete and perfect system of rules and regulations on energy conservation, i.e. new regulation system and rules on criterion, standard, technology, have not yet established. Thus, management for reasonable energy use can not be fully implemented in terms of legislation function.

Fourth, Energy-Saving Service Company (ESCO) is proven to be an effective way for promoting energy conservation in many other countries. But, in China there are a lot of problems for ESCO accessing into the market, such as lack of initiating funds, shortage of integrated information service system when analyzing and assessing energy-saving projects, no enough running experiences in the market, insufficient project managers who possess pretty experiences of market and business operation etc.

For overcoming current barriers in realizing energy conservation potentials in a great extent, corresponding options might be adopted.

- To establish the market-oriented incentive mechanism and energy audit system for encouraging enterprises to obtain their economic benefits through efficient energy utilization. In addition, to improve government’s regulations and controls on enterprises’ energy activities in terms of supervision, evaluation and verification on enterprises’ energy consumption.
- To set up the energy statistical system adapted to market economy and international methods, by means of increasing input of labor and funds.
- To formulate a complete legal system for promoting energy-saving according to relevant laws and regulations.
- To work out relevant favorable financing and tax polices for encouraging energy suppliers and users to actively join and implement energy saving actions.
- To strengthen government’s management of examination, approval and implementation on capital construction projects and technical transformation projects of energy-saving, especially those projects initiated by state preferential polices. In order to get maximum benefits of energy conservation,

the management should be focused on the project selection, bidding, examination of engineering construction and operation management.

- To enhance fundamental work of energy conservation, such as standardization, propaganda and training. And to promote commercialization of ESCO by referring successful operation experiences of other countries in the world. Enterprises can ask for helps of ESCO in order to excess technology market.

In past few years, one new type of financing institution was introduced into China, i.e. EMC (energy management contract). It implements energy efficiency projects through setting contracts on energy management and producing profits. Actually, EMC is commercial firms instead of financial organizations, because it provides a series of business management services and guarantees of certain quote of energy saving besides project funds to the clients. In the functions of EMC, financing, design, equipment installation etc. are just small part of the work, management, energy audit, monitoring, operation and maintenance after equipment put into effectiveness are the most important part of the work, which would lead to the projects success or not. Hence, EMC is a commercial body under the market economy, and substantially different with ESCO.

In practice, EMC and its client enterprises are linked by an Energy Performance Contract. The cost of services provided by EMC can be recovered from the energy savings, and the service fees can only be charged when energy savings are actually achieved. At present time, there is few EMC in China, they are all shareholding corporations, one example of them was established in Liaoning province. EMC is at the very beginning stage of demonstration in China, its role in promoting energy saving, experiences in practical business etc. need be summarized and assessed for better development and dissemination in future.

4. Energy substitution

Oil resources in China is very limited considering rapid increase demand in past decade, oil import occupied about 30-40% in recent years, and the proportion will go up continuously, e.g. 52% in 2020 assuming domestic production capacity 200 million tons and consumption 420 million tons. Thus, in substituting coal for improving energy efficiency and reducing pollutant emissions, natural gas and nuclear power are the most feasible options besides renewable energy in China.

(1) Natural gas

China's total natural gas (NG) resources are estimated to be 38 trillion m^3, of which 30 trillion m^3 in the mainland, 8 trillion m^3 in the sea. Although the NG resources are abundant, the proven reserves is less than 3% of total resources, it shows a bright perspective for developing NG in long-term period. NG industry in China is just in the initial stage, but in past decade it grew rapidly. NG output increased from

15.3 billion m^3 in 1990 to 32.7 billion m^3 in 2002. Now, there are four major NG fields (Shanganning, Chuanyu, Qinghai and Xinjiang) in west China. Besides, there are a few NG fields in east China where the NG is formed and produced closely together with crude oil.

China expects to expand its NG output to 70-80 billion m^3 in 2010, and 100-110 billion m^3 or as high as 150 billion m^3 in 2020, if the NG pipeline framework is constructed well, to meet immense demand. From the point view of demand forecast, NG consumption is expected to 220 billion m^3 in 2020, it is sure that domestic NG production can not satisfy the rapidly growing demand of economic development and environmental protection.

On one hand, following the national strategy of “Developing the West”, China has approved a project of “Transporting NG from West to East”, actively build NG production fields in the west region and long distance pipeline to transit NG to consumer centers in east China. This west-east pipeline could be westward extended in future to connect NG fields in countries in the central Asia for importing NG to China. The main west-east pipeline will start from Xinjiang Uygur Autonomous Region (XUAR) and end in Shanghai, total length is 4,200 km, annual transiting capacity is 20 billion m^3.

This strategic energy project needs a big amount of investment, in order to raise enough funds through every potential ways, the project asked for foreign businesses bidding and carried out new measures different from previous ones. For constructing this pipeline, foreign investors can enjoy new special favorable rules besides original favorable conditions for infrastructure construction. These favorable rules were summarized as following 6 items:

1) Foreign investors can be the majority stock controller.
2) There is no restriction to the cooperation modes. Joint venture, cooperation, and other modes are all permitted.
3) Urban NG network construction is permitted to be put into the content list of international cooperation. (It was not included in the list in the past).
4) Custom duty and import VAT of imported equipment for self-use are exempted within the total amount of investment according to relevant rules and procedures.
5) The business scope can be expanded by approval, according to the existing “Provisional Regulations on Oriented Guidance to Foreign Investment” if big investment is put towards construction and management of infrastructure projects on energy and communication.
6) Land-levied use right could be solved by ways of approving the right of underground pass, and special solution for special case.

In the project of “Transporting NG from West to East”, there are two obvious new changes in the policies for international cooperation. First, Chinese stockholders have to be the majority stock controller in past rules, but now these rules are removed. Second, urban NG network construction was not in the “Guideline Content of Industry for Foreign Investment” issued before, but now it is listed.

The phase-I construction of the project started in 2001 and is expected to supply NG in 2004, its total investment is around 120 billion yuan (14.5 billion US$), life time 30 years, and annual transiting capacity 12 billion m^3, of which 10 billion m^3 to Shanghai and 2 billion m^3 used by provinces on the way.

On the other hand, China carried out international cooperation for NG exploitation and later on to import NG. For example, China has signed a government agreement with Russia to import NG and to build pipeline started from the NG fields in keweikejin of Irkutsk (north Siberia of Russia) to China. This project will build a north-south backbone pipeline through China with a NG transiting capacity of 20-30 billion m^3 per year, of which 10 billion m^3 per year will supply to Korea from the pipeline. The project construction is expected to start in 2005 and will be completed and put into operation in 2010.

(2) Nuclear power

Though China started its nuclear power construction in late 1980s, nuclear power development is still in an early stage, now there are three nuclear power plants put into operation with total capacity 6,100 MW. All the existing nuclear power stations are located in east coastal areas, where the economy is well developed but poor energy resources is a major barrier for further rapid development. So that there is a potential demand to build nuclear power plants for easing serious power shortage there.

According to the estimation made by domestic energy experts, total capacity of nuclear power would be: 15-20 GW in 2010, and 35-45 GW in 2020. Recently, the nuclear power forecasts are proven to be consistent with the nuclear development program supposed by state leading ministries. Several months ago, the National Development and Reform Commission (NDRC) promulgated a long-term program of nuclear power development, in which a target of total capacity 36 GW in 2020 is set, that means about 2 GW new nuclear station should be completed each year in next 16 years. This program will express the efforts and make contribution to reduce the dependence upon coal towards a more clean energy structure.

In China nuclear power mainly replaces coal-fired power. Comparison between nuclear and coal power in special region in east China shows that the grid-in price of nuclear power now is higher than that of coal power. But, considering new coal power plants to install de-sulphur equipment (cost about 20% of total investment) and coal price increase, the large grid-in price gap would decrease and then nuclear power can enhance its competition ability with coal power in those region.

In order to reach the tough target of nuclear power in 2020, proper strategic measures need be adopted:

- Nuclear power is a fund- and technology-intensive sector, it is accordingly to put priority on east coastal region as it possesses conditions of strong economic and technical strength, shortage of energy, high power demand for developing nuclear power.

- Nuclear power plants could be located in a concentrated place at the first stage, i.e. the existing three nuclear power plants could be well used as the bases. More generators might be further built in those plants to share the common infrastructure and to accumulate operation experiences for spreading nuclear power plants to south central China in following stages.

- Technology development path should be based on the most economic and mature types of reactor. At present time PWR (pressured water reactor) is the type widely used in the world, China has adopted this type in all current nuclear power plants. The further task in future is to make efforts on localization of 600MW PWR and preparation for batch production at the first step; and to establish R$D on advanced technologies of enriching nuclear fuels, large scale of PWR and other new types of reactors, and/or to import advanced nuclear power equipment at the second step.

- As nuclear power is a high investment industry, the state should involve the construction funds of nuclear power into the state energy construction investment scope to help overcoming barriers in raising enough funds.

Actually, because of gross fund limitation, thermal power and hydropower are always put into top priority during developing national power capacity in China. But nuclear power has a much higher unit investment than traditional types of power, so financing issue hindered nuclear power development from the beginning. In the early stage, there were three financing modes in China for nuclear power construction.

First, state grant was provided for building the first China's nuclear power station in early stage, the grant was shifted to state loan during late period of the construction and till the completion of the plant. This financing approach is actually the financing pattern adopted for large national engineering projects by the state in central planning economy.

Second, both domestic and foreign stockholder funds were used. The typical example is the construction of the second nuclear power station (900*2 MW) in early 1990s. Investment was shared by China and Hong Kong power companies. The deficit of total construction investment was complemented by foreign loans through

Bank of China, who bears the third part guarantee.

Third, for building the second phase (600*2 MW) of the first nuclear power plant, a board was established, it consisted of the China Nuclear Company, the State Power Investment Company, governments of three provinces and one city. Each stockholder contributed financing based on the shares they promised. Investment deficit was complemented by seeking state financial supports.

The three modes for financing mentioned above were mainly dependent on domestic investment, but they are not suitable to current situation partly. Because domestic funds are continuously shortage, foreign funds become a very important financing source. Besides the original financing ways, some other approaches are considered. One mode could be designed as “Full Foreign Funds”, i.e. foreign investors build nuclear power plants in China by their own funds under the conditions: they would own the plants and business income in a certain period (e.g. 10 or more years, and then the plant will be fully handed over to China), and the business income would be taken as the guarantee. In such a financing mode, the state bank would no longer provide any guarantee, otherwise it needs the state bank to provide necessary guarantee if Chinese enterprises apply for loans of foreign investors.

In brief, this mode could be imaged that foreign investors would only concern to investment, return of capital cost, interest and profits, whereas all other matters such as project preparation, design, procurement, construction, operation and management etc. could be relegated to China. How long for the certain period is reasonable before the nuclear plant is handed over to China? Foreign investors and China partners thought that 15 years would be a proper time duration after many discussions. Foreign investors own the plant for 15 years and then hand the plant ownership, spent-fuels, out of commission over to China, the plant could then continue to run for 30 years or more. Foreign investors considered that this pattern might be better than they deal with everything of the plant and are responsible for management and post-retired treatments within the whole lifetime of the plant by themselves.

5. Renewable energy

(1) Overall status and perspectives

As an important kind of energy, renewable energy has great positive effects on the mitigation of greenhouse gas emissions. Chinese government has paid great attention to the research and application of new and renewable energy, which has been developing rapidly since 1980s.

In order to promote the development of renewable energy in China, three former commissions (State Development Planning Commission – SDPC now State Development Planning Commission – SDPC; State Science & Technology

Commission – SSTC now Ministry of Science & Technology – MSOT; State Economic & Trade Commission – SETC now dismissed) jointly formulated the "Guidelines on Renewable Energy Development Program (1996-2010)" in 1995. The Guidelines described main tasks of renewable energy development in China, i.e. to raise conversion efficiency, to reduce production cost, to expand the proportion in energy constitution, and to develop new technologies. By using mature techniques, large scale and modern production could be realized, and relatively perfect production and service system would be established. This will contribute to environmental protection and sustainable development of national economy.

By the end of 2002, China has constructed around 30 wind farms, mainly in Xinjiang Uygur Autonomous Region (XUAR), Inner Mongolia Autonomous Region (IMAR), Guangdong province. Total wind farm capacity was 468 MW. If small wind turbines are also accounted (their unit capacity is generally around 100 W, and the current number is roughly estimated to be 170,000 in islands, rural and remote areas), total capacity of wind power was about 485 MW, equivalent to 0.25 Mtoe of energy.

There are two major types to use solar energy, one is solar thermal, and the other is solar PV. By the year 2002, the tenure areas of solar energy water heaters are estimated to be 40 million m^2. Supposing energy derived from solar heaters per year is 0.07~0.10 toe/m^2, total solar thermal energy use was about 3.4 Mtoe. By the year 2002, total installed capacity of PV was 30 MW (peak), producing a neglected amount of energy in national primary energy.

Currently, total annual output of agricultural residues is 700 million tons (equivalent to 210 Mtoe), 51% of which is used for fuel, now 250-300 million tons are consumed per year in rural area mainly for space heating and cooking in rural households. In addition, proper exploitation of firewood can reach to 140 million tons, equivalent to 56 Mtoe. Among them 26% was from firewood forest, 37% from timber industry residues. In recent years, agricultural biomass energy use and firewood use are estimated around 84 Mtoe and 70 Mtoe per year, repectively.

Though renewable energy now accounts for a very small proportion, its important role in improving environment quality and people's living standard of rural areas is deeply recognized by government officials, researchers, enterprises etc. By the end of the 20th century, relevant agencies made new targets for renewable energy development in medium term (see Table 3), based on the "Guidelines on Renewable Energy Development Program (1996-2010)".

Table 3 Targets of renewable energy development

	2010	2015
1. Solar energy		
(1) Solar thermal		232 million m^2 [1]
(2) Solar PV		320 MW (peak)

2. Wind energy		
(1) Grid-connected (MW)	4,900	7,000
(2) Stand-alone (MW)		105
3. Geothermal energy		
(1) Thermal use (Mm^2)	22.5	30
(2) Power generation (MW)	87.5	110
4. Biogas		
(1)From industrial organic waste water		4,000 Mm^2 (2.4 Mtoe)
(2)From Agricultural Residues		450 Mm^3 (0.41 Mtoe)
(3)From gasification of Straw		2,000 Mm^3 (0.4 Mtoe)

Notes [1]: 20-30% of total national households will install solar water heaters.

(2) Institutions

As there is no unified management organization and shortage of unified coordination, the phenomenon of overlapping, restricting each other happens sometimes. It is suggested to establish an integrated and coordinated organization comprising the departments currently concerned to renewable energy development or to designate an agency holding leading power in renewable energy management. In addition, integrated commercialized companies or organizations should be formed to promote the commercialization of renewable energy in China. Finally, operation mechanism on the basis of market and the appropriate price system, policy framework and law system of renewable energy should be established.

(3) Development policies

Chinese government highlights the roles of new and renewable energy in easing energy tension, promoting rural development and environmental protection, and pays a priority to the development of renewable energy resources in national energy development strategy. Key points for main types of renewable energy are as below:

1) Expedite the development of hydropower resources

Speed up the development of small- and medium-scale hydropower, which have few impacts on the environment and are located near demand centers and end-users, and finally can be built by local people.

2) Enhance the development and utilization of biomass energy

Popularize technologies for converting biomass into biogas for daily life and commercial use. Develop the production of biomass energy and reduce the proportion of biomass used directly.

3) Develop technologies for both direct and indirect use of solar energy

In the near term, encourage the development of photovoltaic devices, so as to improve conversion efficiency and reduce costs. In the long term, establish large-scale solar power stations.

4) Expand utilization of wind power

Enlarge the scope of utilization of wind power so as to provide remote areas with electric power. In the near term, emphasize research on the development of large wind power generating units and costs reduction. In the long term, make emphasis on the establishment of large wind power stations.

(4) Financing framework

For developing renewable energy, apart from strong unified leadership, overall planning and coordination given by the governments, some suitable financing policies should be formulated, such as increasing financial support and investment funds, expanding scope of credit, providing low interest loans, stipulating policies for tax reduction, price subsidies, incentives and so on.

1) Tax

There are two different kinds of tax policies in practice. One is favorable tax policy, such as deduction for custom duty, property tax, value-added tax (VAT) and income tax. This policy just reduces government's financial income instead of spending many funds for subsidy. The other is mandated tax policies, for example, polluters have to pay for their pollution to the environment. By using tax policies properly, renewable energy development can be encouraged, advanced technologies, especially those with high standard and high performance, can be speedily adopted.

The income tax system in China is generally complete and canonical, and the average rate of income tax for industrial enterprises is 33% now. For promoting renewable energy development, e.g. the wind power, some local governments, such as IMAR, XUAR, have formulated policies of tax exemption and partly exemption.

In past years, the custom duty has been adjusted for several times. In order to promote renewable energy development, China government provides some favorable custom duty for expensive foreign equipment, e.g. the customs duty rate was 3% for spare parts of wind turbines and zero for the whole generation units. Some energy experts argue that though the reduction of custom duty is good, it still possesses unreasonable structure. Because the price of wind turbine manufactured in developed countries is generally much higher, hence the way to develop wind power in a large-scale in China should encourage domestic turbine production. Based on this target, the zero custom duty should be given to spare components of wind turbine instead of the whole generators.

At present time, the VAT is 17% in China. In practice, VAT of most products can be offset by the taxes of raw materials. But for wind power generation, because no raw material and fuel tax can be offset, VAT rate of 17% is considered too heavy for wind power enterprises. The uniform tax policy does not reflect the developing strategy for renewable energy exploitation, it is supposed to revise the tax in a reasonable range. Some actions have been made in certain regions to reduce VAT in a large amount.

2) Financing and investment

In the first stage of renewable energy development, fund shortage is a major constraint, and lack of financial channels contributes to fund shortage. Financial funds mainly come from domestic organizations and abroad. Take wind energy as an example, except a few wind farms invested by domestic loans for special projects, most others are built by using foreign favorable and soft loans.

Since 1997 bank system reform was conducted in China, governments could no longer assign project investment from the commercial bank directly. Only the National Development Bank can provide loans indicated by government, but in many cases wind power projects do not attract commercial banks very much, because high initial unit investment results in a very limited benefit for the investors. Furthermore, the commercial banks also require that all the projects have to be guaranteed by qualified enterprises or others in applying loans, it is often difficult to satisfy this precondition for many large-scale projects.

In the beginning of 1999, MOST and SDPC made policy for helping renewable energy projects to raise funds. SDPC will assist proprietors to get domestic bank's loans if they intend to build medium- or large-sized renewable energy power projects, whose capacity need be over 3 MW. If the funds come from the state capital construction loans provided by domestic banks, 2% of financial interest discount will be granted. For applying the interest discount, equity input of the renewable energy projects have to account for 35% or more of the total investment of the project.

Private sectors would gradually play important role in developing renewable energy according to the experiences and situation in China and abroad. Experiences in Europe, India, North America show that limited funds can not match great potentials of developing renewable energy of wind, solar and others. Only private sectors have big funds supporting huge renewable energy development. In China, during the economic reform, more and more private sectors show interests in and start entering the fields of renewable energy. In general, private sectors' involvement in China is just in the very beginning stage and there is very few cases happened. But the government encourages private investment and provides guidance in financing performance and pre-project work.

3) Subsidy

To promote renewable energy development, subsidy is often used as an economic incentive measure in both China and world. Generally, there are three kinds of subsidy. The first one is the subsidy for investment. It has two effects, the advantage is to strengthen production ability and expand industry scale. But the disadvantage is that the enterprises do not have pressures to update technologies and reduce production costs because of no competition. The second is subsidy for production output. It has a lot of benefits: expanding production, reducing costs, increasing economic profits, etc. Some experiences can been seen abroad, but no such policy is implemented in China so far. The third is subsidy for consumers. This subsidy was implemented in local regions, and helped to solve electricity supply for surviving needs in daily life of headsmen households. However, subsidy for consumers has many uncertainties in practice, sometimes it could not reach the targets of some policies and cost reduction.

Though subsidy policies have been proven to be an effective instrument in some specific cases and periods, there still exist some issues to be addressed. One is the fund source for providing subsidy. Foreign experiences showed system benefit charge and fossil fuel tax are the major fund sources. However, the subsidy is mainly dependant on government finance in China, it could not be expected to be a policy for a long time, because many other matters need be subsidized by the limited finance of the country. The other is to whom the subsidy should be given and what performance mechanisms are established to guarantee the achievements of the subsidy, otherwise the expected goals can not reach.

Currently, subsidies from central government for wind power are mainly used in R&D and demonstration projects. Subsidies from local governments are partly used in R&D and the most is used for diffusion and application of wind generation technologies.

4) Price

Price is one of key factors to impede renewable energy development. For example, wind power price is always higher that of conventional electricity (thermal power), e.g. around 2-fold.

For encouraging wind power and overcoming the barrier of high price, Chinese relevant administrative agencies promulgated the “Regulation of Large Scale Grid-in Wind Farm” in 1994. The regulation requires power grids should allow wind farms to connect into the grid as near the farm as possible, and then purchase all wind power they generated. The pricing principle of wind power should be based on the generation cost, capital payback, and plus rational profits of investment. The price gap between wind power and conventional power should be shared by whole grid.

The regulation and policies are good, but there is an uncertainty, i.e. no region scope is clearly indicated. So that the power purchase price (PPA) varies from province to province, even resulting in PPA can vary by a factor of two in the same provinces. Each PPA has to be negotiated individually. Because of shortage of the standardized PPA, it is very difficult for private investment entering wind power projects.

To reduce the high price of wind power, one effective way is to speed up local manufacture ability. For example, the price of imported equipment is about 670 $/kW and the overall cost of wind farms is 8,800 yuan/kW, two times higher than thermal power plants. It is estimated that local manufacture could result in about 30% cost reduction of wind farm equipment and about 20% grid-in price reduction of wind power.

And, one incentive financial policy was issued by SDPC in 1999 for encouraging use of China made facilities. The marginal investment profit of renewable energy power projects during the loan payback period could not exceed the loan interest in the same loan payback period by 3% if the project uses imported power generation equipment. However, the marginal investment profit could exceed the loan interest during the same loan payback period by 5% if using domestic equipment.

6. Chinese efforts in addressing environmental protection and global climate change

Coal is a dominating energy in China, a huge quantity of coal production and consumption has resulted in serious damage on environment. Air pollution is caused by SO2, CO2 and dust, studies show that 85% of SO2 emission and 76% of CO2 emission are from coal combustion. Acid rain influence increases now, area affected by acid rain in China has reached to about 40% of total territory, China is one of the three main heavy acid rain regions (the other two are Europe and North America). About one third of coal is consumed by thermal power plants, but only a few percentages of total coal-fired power plants has accessed to de-sulphur facilities. In addition, China is now the second biggest CO2 emission country in the world, and many studies indicated that China would most likely become the country to lead the world in emissions of CO2 in next few decades. In the efforts to reduce SO2 and CO2 emissions, energy conservation, clean coal technologies, and clean fuel alternatives are proven to be the most effective approaches.

In recent years good coordinative development of energy and environment is paid more attention by various departments, enterprises, people etc, and preliminary achievements are obtained owing to a series of well carried out policies and measures, including:

- Emerging environmental protection into energy expansion program, forming a sustainable development strategy
- Perfecting environmental protection laws and regulations, enhancing management on environmental protection
- Giving priority to energy conservation and optimizing energy mix
- Establishing comprehensive utilization of natural resources
- Introducing and disseminating clean production in industrial sectors
- Making great efforts in developing rural energy and improving rural ecological environment
- Improving utilization efficiency of energy and other resources in terms of technical progresses
- Implementing various economic approaches for promoting environmental protection
- Increasing forest for creating better environmental self-clean ability
- Making awareness of environmental protection to all people
- Expanding international cooperation for environmental protection capacity building through funds and technologies of developed countries

China has done a lot to the environment protection and the global climate change, and it actively takes many response measures in cooperation with other countries to combat the global climate change. China compiled the “China's Agenda 21” (i.e. the “White Paper of Population, Environment and Development of China in the 21st Century”) and the documents of “Priority Program for the China's Agenda 21”. The Priority Program aims at disaggregating action plans suggested by the “Agenda” into concrete operationable projects.

Almost all projects in the Priority Program are included in the national or local governments’ plans for social and economic development (e.g. Five-year plans). Many projects clearly reflected the important strategy of “Developing the West” formally promulgate by the state government in 1999, which aiming at helping the less-developed regions in middle and western China in capacity building, sustainable development, and avoidance of the bad development path of “production first and environmental protection followed”.

The priority projects listed in the Program are distributed in 9 areas:

- capacity building for sustainable development
- sustainable agriculture
- clean production and environmental protection industry
- clean energy and transportation development
- conservation and utilization of natural resources
- environmental protection control
- poverty abatement and regional development
- population, health and human settlement
- global change and biodiversity conservation

In the list, clean energy and production are obviously put in an important position. The projects are more executable and attractive to industry and business for future participation and investment.

Many studies have revealed that energy efficiency improvement is the most important strategy to abate GHG emissions. Another important strategy is energy substitution, especially renewable energy development. For a long period these are the two main areas, where technical options for GHG mitigation should be focused on. In energy conservation area, priority options might include: high efficiency boilers, high efficiency electric motors, power and heat cogeneration, green lighting, energy saving buildings, waste heat and energy recovery, central heating, large thermal power generation, etc. In energy substitution area, wind energy, solar thermal heat, combined cycle natural gas power generation, coal-bed methane recovery and utilization, biomass gasification, and nuclear power are considered as priority options.

7. Conclusion

(1) China's energy consumption ranked the second top position in the world since early 1990s onward. With continuous increase of energy consumption, it is most likely that China will become the country to lead the world in fossil fuel consumption and emissions of CO_2 in next few decades.

(2) China has been paying more attentions to reduce the growth rate of energy consumption and emissions as far as possible, and developing feasible and effective measures and strategies based on its own domestic situation to guarantee the realization of its social and economic development goals and, at the same time, to reach protecting global climate target.

(3) Apart from other major strategies (e.g. population control, etc.), strategy of promoting clean energy is the most important, because 85% of SO_2 emission and 76% of CO_2 emission are contributed by coal combustion. To realize clean energy strategy, efforts should be focused on energy efficiency improvement, energy substitution, and renewable energy development.

(4) In past two decades, great progresses have been achieved in energy conservation, and big potential still exists in future. Studies show that energy saving potential in near term could reach to 70 Mtoe by means of technology renovation, and 210 Mtoe in terms of adjusting structures of industries.

(5) In energy substitution, NG and nuclear power are the most feasible options for replacing coal in China. According to studies on energy demand forecasting, share of NG in total primary energy would increase from 2.4% in 2000 to 10.6% in 2020, and share of nuclear power from 0.4% in 2000 to 3.1% in 2020.

(6) Renewable energy will increase its role not only in addressing global climate change but also in solving energy supply shortage in China's vast rural areas and remote regions. Share of renewable energy in total primary energy will increase from 0.1% in 2000 to 1.9% in 2020 according to many study results. Solar

thermal utilization and wind power will be the major renewable energy in a quite longer period in China.

(7) There are many GHG mitigation options in clean energy field, China should focus on the most priority technologies and fields by using limited resources, funds and labor force. For example, motors and drivers, industrial boilers, thermal power generation by advanced clean coal and NG technologies, wind farm, and biomass gasification etc.

(8) During the transition from central planning economy to socialist market economy in China, some new mechanism, rules and policies play a role to promote clean energy development. But those are not enough, mechanism, institution, policies in financing, tax, subsidy and prices, laws and regulations still need be further completed and perfected to realize the sustainable development in China.

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