The Role of Renewable Energy Options in China's Present and Future Energy System

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ABSTRACT China's population has reached 1.25 billion, ranking No.1 in the world. Along with rapid economic increase during the past 20 years, there is increasing pressure on the energy industry from limited mineral energy resources and regulations for environmental protection regulations. The development and utilization of renewable energy is becoming one important option to realize sustainable development of the energy system. This paper firstly introduces current status of renewable energy development in China. Although renewable technologies have failed to emerge as a prominent component of the China's energy mix in the past two decades, the development of renewable energy is expected to reach expectations of 87.50 Mtce, 4.2% in 2015's energy mix of China. The formulation of industrial and market scale renewable energy will lay a solid foundation for realizing the target of a share of 5% in 2020's energy mix. In the paper, the authors also focus on the institutional problems blocking the development of renewable energy technologies, and try to put forward some policy recommendations so as to put into force renewable energy development strategy.

Key Words: Renewable Energy, Energy System, Development Strategy, China

1. Background

1.1 Rapid increase of energy consumption and low efficiency of energy use

During the past 20 years, China's GDP increased by 5.5 times in terms of comparable prices (from 1980's 451.7 billion yuan to 1998's 7939.6 billion yuan), while total primary energy consumption also increased by 1.26 times from 603 Mtce in 1980 to 1360 Mtce in 1998 with an annual growth rate of 4.62%, as shown in table 1. China's energy consumption amounts for 10% of world consumption, ranking No.2 after the USA.

Table 1 Primary Energy Consumption in China

Year	Consumption (Mtce)	Proportion (%)			
		Coal	Oil	Natural gas	Hydropower
1998	1360	71.6	19.8	2.1	6.5
1980	6028	72.2	20.7	3.1	4.0

Source: China Statistical Yearbook (1999).

Among the total energy consumption, rural commercial energy consumption increased much faster from 1980's 100 Mtce to 1998's 448 Mtce. Its proportion in the total commercial energy consumption increased from 16.6% to 32.9%, correspondingly, as shown in table 2. Traditional biomass consumption is gradually replaced by commercial energy.

Table 2 Commercial Energy Consumption in Rural Areas of China (Mtce)

	1998			1980		
	Total	Production Consumption	Residential Consumption	Total	Production Consumption	Residential Consumption
Total	672	307	365	330	69	261
Commercial	448	292	156	100	59	41
Non-Commercial	224	15	209	230	10	220

Source: China Rural Energy Yearbook (1998 1999).

However, energy consumption per capita in China is still very low. In 1997, average energy consumption per capita was only 1.12tce, about 54% of the world average level, i.e. 2.08tce, 1/10 of USA, as shown in table 3. Average electricity consumption per capita was much lower. Much worse, there were over 40 million people without power supply in 1998.

Though energy consumption per capita is very low, low energy efficiency causes very high energy intensity. In 1996, China's energy intensity was 1.67kgce/US$, about 2 times of the world average level, i.e. 0.58kgce/US$, 7.2 times of Japan, as shown in table 3. The dual characteristics are becoming a serious problem in China's Energy consumption and utilization.

Table 3 Energy Consumption Level in China

	China	USA	Japan	OECD	World Average
Energy Consumption per capita in 1997 (tce)	1.12	11.53	5.82	6.58	2.08
Power generation per capita in 1997 (kWh)	919	12739	8130	8021	2090
Average GDP per capita in 1996 (US$)	671	22676	36575	21359	5845
Energy intensity in 1996 (kgce/US$)	1.67*	0.55	0.23	0.44	0.58

Note: *--in 1987's price.

Source: IEA, Coal information in 1997, OECD, 1998.
US DOE/IEA, International Energy Development in 1999, March 1999.
Japan's Institute of Energy Economics, Japan Energy and Economic Statistical Handbook (1999), Feb. 1999.
China's National Bureau of Statistics. China Statistical Yearbook (1998).

1.2 Limited fossil energy resources

The proven reserve of coal in China ranks third in the world with total amount of 114.5 billion tons, accounting for 11.1% of the global reserve. However, this is only 95 ton per capita, 52% of the average level of the world, i.e. 182 ton [11]. The proven reserve of natural gas is about $1.37*10^{12}m^3$, averaging $1000m^3$ per capita, only 4% of the average world level[12]. Therefore, the reserve is not sufficient to meet domestic demand, and some import from abroad, such as Russia, is needed. China's proven oil reserve ranks No. 10 in the world, with total amount of 3.3 billion ton, and average per capita of 3 ton, 12% of the world average value[12]. From 1993, China has become an oil-importing country, with net imported oil of 40 million ton. It is estimated that net import of oil in 2010 will reach 80 90 million tons[8]. From above, the deficiency of fossil fuel will result in threat to the security of energy supply.

1.3 Coal-dominated energy structure becomes a strict challenge for sustainable development

As the largest coal-consuming country in the world, China consumed 1.23 billion tons of coal in 1998[11], 71.6% of the total primary energy consumption. Coal-dominated energy structure brings a great pressure for environment and transportation. In 1999, emissions of smoke and dust and of SO_2 were respectively 11.6Mt and 18.5Mt[13], among which 70% and 85% came from coal burning. CO_2 emission was estimated to be 840 Mt-c, and 82.8% was emitted from coal combustion[10]. Mass consumption of coal also aroused vast transportation burden. Among the total freight transport in 1998, about 44.2%, i.e. 1.61 billion tons, was from coal[1]. This indicated that the use of coal would directly influence other economic sectors such as communication and transport.

1.4 Restricted supply of commercial energy in rural areas results in degradation of ecological environment

Because of limited supply of commercial energy in rural areas (especially in the western part of China), 900 million rural residents are still depending on biomass. In 1998, crop straw consumption and firewood consumption were respectively 286 Mt and 147 Mt [3], accounting for 57.4% of the total rural residential energy consumption. Large amounts of crop straw and firewood are used as residential fuel resulting in extraordinary consumption of crop straw, and over- cutting of ecological vegetation in some regions, especially western areas. Water loss and soil erosion occur not only in the

Yellow watershed but also in the Yangtze and Zhu river basins. The area of water and soil loss has increased to the current 3.67 million km^2 from 1950s' 1.50 million km^2. The area of desert land has increased to 153 million hm^2, resulting in a decrease of organic substance content in the land and of productivity. Degradation of the ecological environment will bring about frequent natural disaster. Compared with 1950s' situations, the area of disaster-stricken region in China increased by 6% and the disaster area increased by 90% in the 1980s, and climate changed frequently. Much seriously, it brought about forming the bad cycle of natural resource shortage and environmental deterioration.

1.5 Renewable energy development is a strategic option for China's sustainable development

During the first 20 years in the next century, China's population will break through 1.5 billion, and China's economy will keep an annual growth rate of 6 7 , so energy demand will be doubled to reach about 2.2~2.5 billion tce[8]. Therefore, the requirements for China's future energy strategy are very clear, that is:

- ✧ Increasing energy supply, improving energy efficiency and cleanly using fossil energy;
- ✧ Changing energy structure, gradually decreasing coal's proportion and increasing the supply alternative energy;
- ✧ Strengthening international cooperation, and expanding energy supply sources;
- ✧ Protecting environment to realize sustainable development.

Renewable energy will be a major option to ensure the implementation of the above energy strategy. Furthermore, China is endowed with rich renewable energy resources, and has the technical foundation to develop and utilize renewable energy resources on a large scale.

2. Current situations of renewable energy development

2.1 Resources

Table 4 shows China's renewable energy resources. According to the statistics, over 2/3 of the whole country has solar radiation of over 5.02GJ/m^2 and annual sunshine hours of 2200 hours. Therefore, it provides a good resource condition for development and utilization. The theoretical reserve of wind energy is 3226 GW while the exploitable reserve is 253 GW. Long-range prospective medium and low-temperature geothermal reserves are over 2000 billion tce, and the recoverable reserves in more than 40 medium and low-temperature geothermal farms are proven to be 3.16 billion tce. High-temperature geothermal reserves, which can be used for power generation, are equivalent to 5800 MW. China also has very rich biomass energy resources. The annual production of crop straw is about 700 Mt, among which 280~350 Mt can be used for energy. The rational yield of firewood is about 158 Mt, while currently 182 Mt are actually exploited, over-cutting 15%. Furthermore, there are large amounts of livestock feces and industrial organic wastewater, which can be used to produce biogas. Among the total livestock feces from intensive livestock farms, dry materials are 37.155 Mt. The amount of industrial organic wastewater is 22.25 billion ton (not including township and village industry). The theoretical reserves of small hydropower are about 1800MW while only 75 MW is actually exploitable.

2.2 Technology, cost and market

As a type of new and high technology, renewable energy technologies have the features of new-tech products and are in different stage of development. Most renewable products don't have a mature, normative market and price system in China. Only a few technologies are basically mature and some applied products are produced. They have initial profitability and a certain market scale. This lays a primary basis for industrial development of the technologies. However, these technologies need to further reduce costs so as to compete with conventional energy. Currently, there are some products with a certain scale of production such as solar PV systems, solar water heaters, grid-connected wind farms, off-grid wind generation systems, geothermal heating, geothermal power generation, large and medium-sized biogas engineering (using agricultural waste and industrial organic waste water as raw material), biomass gasification, small hydropower, and so on.

Table 4 Summary of renewable energy resources and utilization

Category	Total reserves	Utilizable reserves[1]	Annual exploitation[1]	Annual energy substitution (10^3tce)	Major technologies
Solar energy	$5.02*10^{22}$J ($1.7*10^{12}$tce)	[2]	Solar PV:13MW Solar water heater: 15 Mm^2	6.6 1950	Solar PV system Solar water heater
Wind energy	3226GW	253GW	Grid-connected: 224MW Off-grid:17MW	223.6 20.4	Wind power generation system
Geothermal Energy	200 Gtce	[5]	Geothermal heating: 8Mm^2 Geothermal generation: 25MW[3]	224 60	Geothermal heating Geothermal generation
Industrial organic waste water	22.25Gt Organic substance: over 5Mt	6000Mm^3 (Biogas)	320Mm^3	274.2	Biogas Engineering
Livestock feces	403Mt dry substance: over 37Mt	9000Mm^3 (Biogas)	59Mm^3[4]	7.55	Biogas Engineering
Agricultural crop straw	700Mt	280 350Mt	Traditional use: 280Mtce Gasification: 70 Mm^3	2.09	Crop straw gasification
Firewood		158Mt	182Mt (Over-cutting)		
Small hydro power	180GW	75GW	22GW	26.40	Small hydro power generation

Note [1]data in 1998; [2]depending on technical level; [3]mainly from Tibet's Yangbajin geothermal power generation station; [4] not include gas supply from over 6 million household-sized biogas digesters (about 1.6 billion m^3); [5] low and medium-temperature reserves in over 40 geothermal farms are proved to be 3.16 billion tce. High-temperature geothermal reserves, which can be used for power generation, are equivalent 5800 MW.

1) Through 20 years' R&D, solar water heater technology has gradually become mature in China. Currently the solar water heater is one product with great development potential in the renewable energy industry in China. Since 1995, sales of solar water heaters have increased very rapidly by 20%~30% annually. A household solar water heater with an area of 1.5 m^2 costs 1200~1800 yuan in the market. Compared with gas-fueled or electric water heaters, solar water heaters are competitive from the viewpoints of both economics and safety. It results that solar water heaters account for a certain proportion of household water heaters. By the end of 1998, the total amount of solar water heaters in the whole country reached 15 million m^2 (counted by area), ranking No.1 in the world. The whole industry has formed a production capacity of 4 million m^2 and gross output value of over 3.5 billion yuan. It is predicted that the demand for solar water heaters will increase along with the improvement of people's living standards. Furthermore, solar water heaters will gradually be used for providing hot water or heat for commercial usage and industrial or agricultural production. Therefore, there will be much more of a chance for the market to expand. A kind of new technology combining solar water heaters with building will become another direction of its development. Solar water heaters made in China have also begun to export to other countries, and will expand to a much larger overseas market if the quality of products can be improved further.

2) Solar photovoltaic conversion technology includes the production of solar PV cells and the application of solar PV systems. Single crystalline and amorphous silicon cells produced commercially in China have an efficiency of 12~13% and 4~6%, respectively. There are some poly crystal silicon solar cells with an efficiency of 10~12% in pilot-production. Compared with international advanced production levels, there exists a big gap for efficiency of solar PV cell. Except for solar cell products, the solar PV system includes the inverter, controller and storage battery. Though these products can be produced locally, there are a few products which are designed especially for solar PV system and for renewable energy. There has also been a big gap between these products and international products. Since 1990, solar cells have been not only used as small-sized power sources in China, but also for communication, transportation, oil, rural electrification, and residential use. Production has increased by more than a20% annually by the end of 1998, accumulative amount of solar PV was over 13 MW, as shown in figure 1. However, the high production cost of solar PV cell seriously impedes large-scale dissemination and application of the solar PV system. Productivity of solar PV cells reached about 4.5 MW in 1998 while actual production was about 2.1 MW. Currently, the cost of Solar PV systems is about 80~100 yuan/kWp

while the cost of PV power generation is more than 2.5yuan/kWh. It is estimated that the PV system's cost will decrease by 50% before 2015 (as shown in figure 2) so that it brings a great market potential for large-scale application of solar PV generation system.

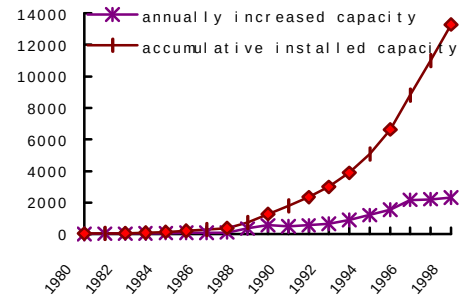

Fig. 1 Installed capacity of Solar PV (kWp)

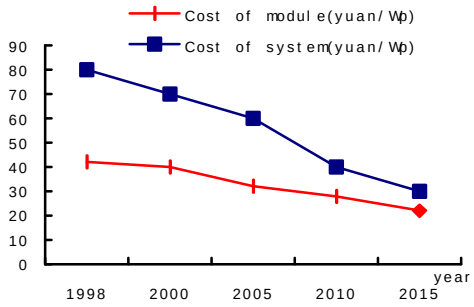

Fig. 2 Decrease trend for Solar PV's cost

3) During the period of 1990-1998, grid-connected wind power generation increased by over 60% per year. By the end of 1999, there were 24 wind farms with a total installed capacity of 262 MW, as shown in figure 3. Although wind generation cost has already decreased to about 0.05 US$/kWh in some countries, it is still the most important barrier in China. Because almost all large-sized wind generation turbines were imported from abroad, this resulted in much higher investment and higher generation costs. It will be, therefore, one key issue for the development of wind power to set up a kind of mechanism to promote the localization of wind generation equipment.

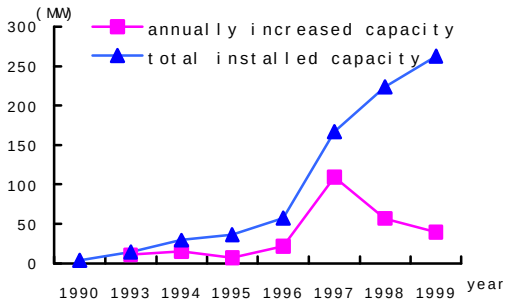

Fig. 3 Wind power development in 90s in China

After 30 years of effort, small-sized wind generation technology has become very mature. China is able to manufacture over 10 types of wind generation units with a range of capacity between 100 W to 10 kW. Total installed capacity of wind generators added up to 17 MW by the end of 1998. Compared with similar foreign wind generators, Chinese products have features such as low start-up speed, high generation in low wind speed, reliability at limited speed, stable operation, etc. More importantly, they have a much lower cost and price. However, there are still some gaps in turbine appearance and blade power quality. The difference between units with a capacity of tens of kilowatts is also apparent. There are wide areas without power supply and lack of conventional energy resources in China that will be a major market for small-sized wind generators and hybrid systems such as wind/solar PV, wind/diesel and so on.

4) A complete set of criteria for the exploitation and assessment of geothermal energy has been set up in China. Equipment and monitoring instruments of geothermal energy utilization can basically be manufactured completely in home, and are developing towards the directions of specialization and normalization. A demonstrated geothermal power plant with a capacity of 28 MW in Lhasa of Tibet is operating commercially. In 1998, the total area of low-temperature geothermal heating reached to 8 million m^2. Currently, it needs to further expand the market. In particular, it will provide a great development prospect using geothermal hot water for medical care and tourism.

5) Large or medium-sized biogas engineering is one type of important biomass energy conversion technology which can use industrial and agricultural organic waste and livestock fence resources as raw materials so as to bring environmental and energy benefits through anaerobic digestion. By the end of 1998, there were over 200 and 540 industrial wastewater and livestock fence biogas engineering projects respectively, with annual biogas production of 320 and 60 million m^3. China has

mastered mature anaerobic digestion technology used for biogas engineering, and is able to design and construct biogas engineering according to different features of raw materials. The pressure of environmental protection will greatly drive the market of biogas engineering. Centralized gas supply or power generation combined with crop straw gasification is another important biomass conversion technology, which is mainly used for converting crop straw or agricultural wastes into valuable product. The key of the technology lies in the gasifier, gas purifier and power generator. Currently, there are over 200 village-sized demonstration projects with a centralized gas supply combined with crop straw gasification. However, gas produced in the process of gasification has less combustible contents, low caloric value but high tar content. At present, gas produced through crop straw gasification is mainly used for cooking, while a much more effective option will be used for power generation in the future, which can provide scattered and stand-alone power systems for rural areas. Large-scale dissemination of crop straw gasification technology will not only effectively alleviate the shortage of high-grade commercial energy, but also be beneficial to prohibit the burning of crop straw and comprehensively make use of it. It will play a positive role in promoting sustainable development and environmental protection. The technology, therefore, will have a huge market potential though currently it is urgent to improve the technical level so as to become much mature, practical and reliable.

6) The first hydro generation turbine with a capacity of 800 kW in China was manufactured in 1952. During the 60s, there were 10 enterprises in the whole country with an annual productivity of 100 MW manufacturing specialized hydro generators, while it increased to 60 manufacturers and 1000 MW in the 70s, correspondingly. Meanwhile, a series of products with automatic speed control systems could be manufactured. In the 80s, the small hydropower industry had a drastic development, along with the implementation of a program of rural electrification in 600 counties. By the end of 1998, China had built up more than 44000 small hydropower plants with a total installed capacity of 220 MW and annual power generation of 60 billion kWh. About one-third of the counties in the whole country, i.e. about 700 counties, mainly depended on small hydropower supply to meet electricity demand. The whole small hydropower industry had fixed assets of 100 billion yuan, annual sales of 25.3 billion yuan and annual profits of about 2 billion yuan. Meanwhile, the number of small hydropower equipment manufacturers had increased to over 110 with an annual production capacity of over 10 MW. A series of standardized small hydropower generators could be manufactured so that 21 types and85 brands of equipment with water heads of 2.5 ~400 m could be chosen by users. Some products manufactured according to international standards had been exported to the USA, Indonesia, etc. The power industry and equipment manufacturing industry of small hydropower had greatly contributed to China’s economy.

3. Industrialization of renewable energy development

3.1 Overall development targets

The renewable energy development plan put forward by China's State Economic and Trade Commission (SETC) requires increased application and dissemination of technology and products, enhanced productivity of equipment, complete industrialization support systems and regulation, mechanisms, and finally realized commercialization of renewable energy. By 2015, renewable energy will reach 87.50 Mtce, accounting for 4.2% of total amount of national energy consumption.

3.2 Development strategy for various technologies

Various strategies and action plans in term of renewable energy technologies will be as follows.

1) Expanding production scale and regulating the market of solar water heaters

In 2015, China will have 20-30% of families in the whole country using solar water heaters so that total area of installed solar water heaters will reach a scale of 232 million m^2, as shown in Figure 4. The realization of the goal is based on the fact that solar water heating systems would be able to supply hot water in any climate and any season, and have a much lower or equivalent cost for hot water supply than conventional energy. The government will support several backbone enterprises with good equipment situations, strong technical power and high-grade products so as to make them reach a scale of annual production of about 2-3 million m^2 and have the ability of new product

development. Furthermore, in order to normalize the market, the government should formulate the quality norm of products and set up a national testing and measuring center so as to test, supervise and certify the quality of various products or components of solar water heaters.

2) Setting up a complete production system of solar PV cells and application devices, and further lowering costs

Base on the current scale of production and application, the solar PV industry in China should firstly follow the development trends of international PV technology, and break through stagnancy with annual production of 2 MW relying on the power of enterprise groups. The government will support several important factories with good production and management levels to build advanced technology solar PV product lines. Several PV factories with production capacities of 2-5 MW will be expected to be set up or expand in the next 5 years, and those with a capacity of 10 MW will be developed after 2005. In 2015, the total installed capacity of solar PV systems will reach 320 MW, as shown in Figure 5. The share of communication and industrial use will decrease from current 40-50% to 20-30% of 2010. Civil usage such as household-sized PV systems will increase from current 30% to 40-50%. China will begin to develop roof solar PV systems on a large scale from 2015.

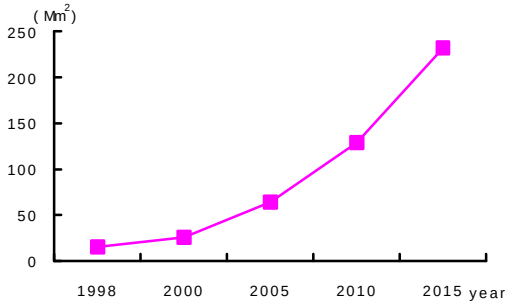

Fig. 4 Development of Solar water heater in China

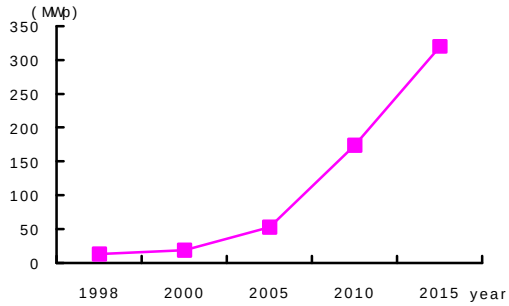

Fig. 5 Development of solar PV system in China

3) Accelerating the development of wind farms and progress of localization of wind turbine production as well as the commercialization of wind power generation

In the next over 10 years, wind power in China will increase by over 20% annually. The development targets of installed capacity of wind turbines will be 3000, 4900 and 7000 MW respectively in 2005, 2010 and 2015, as shown in figure 6. One main objective of industrial development of wind power generation is to improve domestic production capacity for wind generation equipment and realize localization of wind turbine manufacture, so as to meet domestic demand caused by high-speed increases of wind farm construction. Domestic wind turbines should also aim to export. To realize the above targets, it should enhance R&D of domestic wind generation technology, improve the domestic production capability of most components, and create a few famous brands of wind generator with self-owned intelligence. China will use other countries' experiences in wind generation turbine production for reference, break through the borderline of sector and support assembly factories and components manufacturers through public biding so as to lower prices of wind turbines and the wind power generation cost. During this process, it should accelerate formulating quality norms and build testing and measuring system for wind generation turbines.

4) Continuing dissemination and diffusion of small-sized off-grid wind generation

It should strengthen technical innovation of enterprises engaged in small-sized wind generator manufacture, and promote application and dissemination of small-sized wind generator-based hybrid generation systems. It is expected to form an annual production capacity of 50000 sets and a total installed capacity of 105 MW in 2015, as shown in figure 7. One important measure of small-sized off-grid wind generation development is to introduce, digest and absorb oversea advanced technology and experiences and to enhance R&D of small-sized wind turbines with capacity of tens of kW. The technical criterion, standard and test methods of off-grid wind generation should be revised according to international general norms. Guarantee, supervision, testing and measurement systems for product quality should be set up and completed, too.

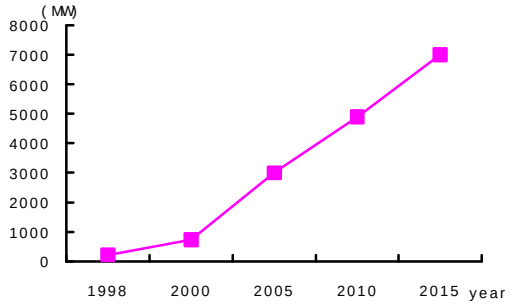

Fig. 6 Grid-connected wind geneartion

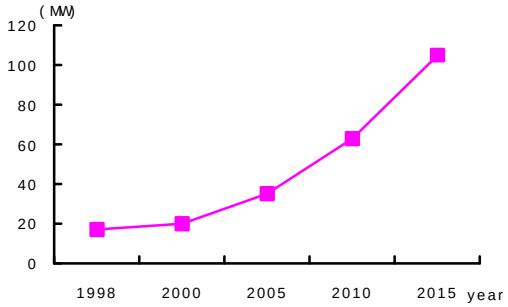

Fig. 7 Off-grid wind generation

5) Developing geothermal heating and power generation technologies to solve the problem of regional space heating or power supply

It should pay much attention to water-restoring technology of geothermal exploitation and production of geothermal equipment so as to realize provision of a complete set of equipment and to avoid environmental pollution caused by geothermal utilization. It should speed up R&D of geothermal pulp technology and the progress of localization of equipment manufacturing. The market for geothermal space heating is expected to develop to the scale of 9.50, 15.00, 22.50 and 30.00 million m^2 respectively in 2000, 2005, 2010 and 2015, as shown in figure 8. The short-term targets of geothermal generation are to use high-temperature geothermal energy in Yangbajin geothermal well in Tibet, and to build Yangyi geothermal power plants in Tibet and Tengchong geothermal power plants in western Yunan Province. Installed capacity of geothermal power generators will reach 30 MW, 40-50MW, 87.5 MW and 110 MW in 2000, 2005, 2010 and 2015, as shown in figure 8.

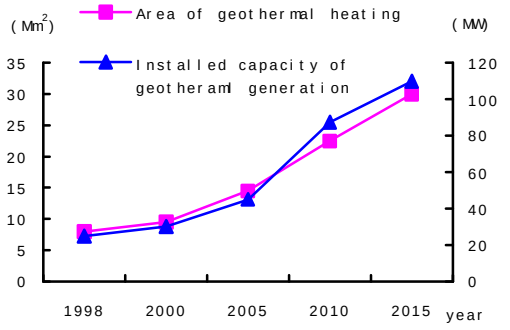

Fig. 8 Geothermal generation and space heating

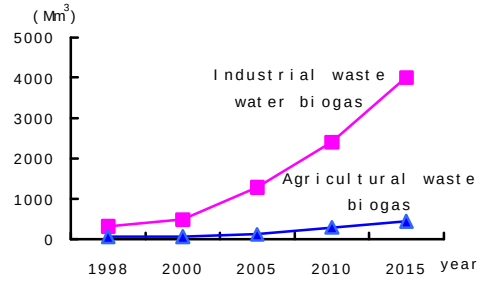

Fig. 9 Large and medium-sized biogas engineering

6) Promoting large and medium-scale biogas engineering construction, developing efficient biomass utilization equipment

It should further improve design, technique and automatic control level of biogas engineering based on current basically mature technology. In 2015, there will 2500 large and medium-sized biogas engineering projects utilizing industrial organic waste water in the whole country, with annual biogas production of 4 billion m^2, equivalent to 3.43 Mtce, as shown in figure 9. Annually, 375 million m^2 industrial organic wastewater will be expected to be disposed. As for agricultural waste biogas engineering, it will increase to 4100 plants, forming an annual biogas production capacity of 0.45 billion m^2, equivalent to 0.58 Mtce. Therefore, 123 million tons of livestock feces will be disposed annually so as to greatly alleviate environmental pollution caused by intensive livestock farms in the whole country. Crop straw gasification technologies need to be improved further, so it will firstly focus on 200 gasification central gas-supply demonstration plants to promote the technology. After the technology becomes mature, it can be further disseminated and applied. It is estimated that until 2015 there will be 4500 gasification plants in total, with a total gas supply of 2 billion m^3, equivalent to 570,000 tce, as shown in figure 10.

7) Speeding up the exploitation of small hydropower

Because small hydropower technology is very mature and the industry has a certain scale in China, future action is to further increase its development. It is estimated that in the next 10 years installed capacity of small hydropower will increase by 800~1000 MW annually, so that it will increase to 37GW in 2015, as shown in figure 11. At that time, it will reach 50% of national exploitable reserves of small hydro energy, and there will be over 1100 counties in the country, especially in the southwestern China, primarily depending on small hydropower to supply power. The development of small hydropower will greatly promote the process of rural electrification.

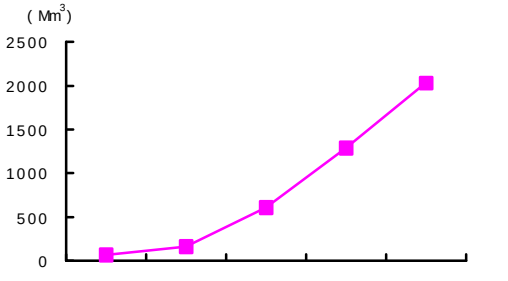

Fig. 10 Gas supply from crop straw gasification

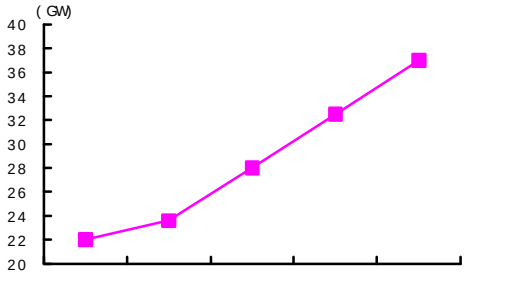

Fig. 11 Installed capacity of small hydro power generation

It summarizes industrial development targets for renewable energy in China in table 5.

Table 5 Industrial development targets for renewable energy in China (1998-2015)

Year	1998	2000	2005	2010	2015
Installed capacity of solar PV(MWp)	13	18.5	53	174	320
Installed capacity of solar water heater (Mm^2)	15	26	64	129	232
Installed capacity of grid-connected win turbine (MW)	223.6	740	3000	4900	7000
Installed capacity of off-grid wind turbin (MW)	17	20	35	63	105
Total area of geothermal space heating(Mm^2)	8	9.5	14.5	22.5	30
Installed capacity of geotherma generation(MW)	25	30	45	87.5	110
Gas from industrial waste water bioga engineering(Mm^3)	320	480	1280	2400	4000
Gas from agricultural waste bioga engineering(Mm^3)	59	65	120	290	450
Gas from crop straw gasification(Mm^3)	700	160	610	1290	2030
Installed capacity of small hydropower(MW)	22000	23600	28000	32500	37000

3.3 Strategic role of renewable energy

The above-mentioned industrial development of renewable energy will bring obvious energy, economic, environmental and social benefits.

In 2015, the total amount of end-use energy products such as electricity, heat water and gas will reach 87.50 Mtce, as shown in figure 12. Energy supplied by renewable energy will be equivalent to about 4.2% of the national energy consumption. Figure 13 shows the make-up of various renewable energy technologies. According to estimates, oil and gas is expected to account for over 30% of the total energy consumption in 2020, while renewable energy will be over 5%, and the coal proportion will have an obvious decrease to about 50%, as shown in figure 14. Therefore, it can be said that renewable energy as an alternative option will play an important role for changing China's energy structure.

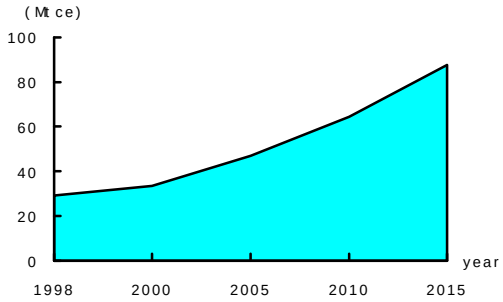

Fig. 12 Renewable Energy supply

As for economic benefits from the renewable energy industry, the total amount of annual benefit of energy supply and equipment production including electricity, gas and hot water in 2015 will be about 111.4 billion yuan, accounting for 10% of the whole electricity, gas and hot water sector, and 1% of the national industrial output value.

Including driving the development of related sectors, renewable energy will also bring obvious environmental benefits. In 2015, renewable energy will substitute 123 million tons of coal, so as to reduce emission of CO_2 by 89 Mt-c, and SO_2, dust and smoke by 4.2 million ton.

Because the utilization of renewable energy will reduce the consumption of coal, it will protect the coal resource. According to the standard coal resource tax levied by Chinese government, i.e., 40 yuan/ton, annual reduction in coal consumption of 123 Mt will bring an economic benefit of 4.9 billion yuan for protecting coal resources. Similarly, if estimated using the marginal exploitation cost of coal, it will bring economic benefit of 24 billion yuan for saving 123 M tons coal.

The development of the renewable energy industry will bring many social benefits, among which the most obvious being that 1 million jobs are estimated to be newly created and the problem of power supply for about 25 million farming or husbandry households will be solved by 2015.

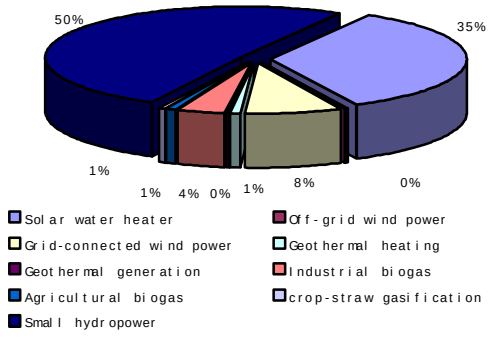

Fig. 13 2015 shares of renewable energy supply in China

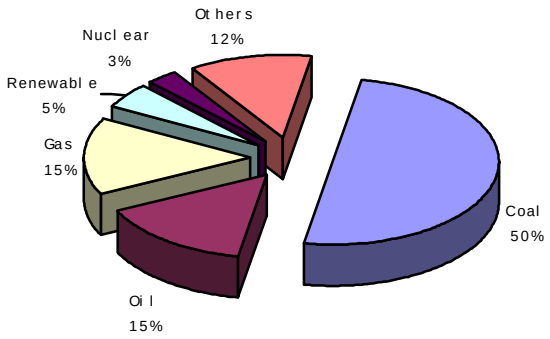

Fig. 14 2020 shares of China energy consumption

4. Barriers, policies and measures to realize the strategic target

China's rich renewable energy resources, huge potential market and current rapid development establish a solid basis for realizing the above strategic target. However, it still needs to get rid of some barriers to technology, market, mechanism, financing and so on.

4.1 Encouraging technological improvement and innovation

Compared with some developed countries, the technical level of most renewable energy industries in China is more backward, the quality of products is poorer, and the production scale of enterprises is smaller. Some raw materials have to be imported, preventing increased levels of localization in domestic production. All these factors increase the production cost of renewable energy so that it cannot compete with conventional energy.

Important measures adopted by Chinese government are to enhance the import of foreign technologies and domestic R&D of new techniques and new products, to promote mechanisms for technology creation and innovation, to provide support for organizations engaging in renewable energy R&D, to build demonstration projects, to support technical renovation and expansion of

production scale in key sectors and a batch of renewable energy backbone enterprises, and to accelerate localization and commercialization in the process of production.

4.2 Building up polity incentive mechanism for renewable energy

Under the current technological level, the cost of renewable energy products has no competitive power with conventional energy. If there were suitable incentive policies to induce the market to a certain scale, it would be able to accelerate the progress of industrialization and commercialization of some of renewable energy products. Renewable energy policy should overcome two bugs: discontinuity and a lack of competition mechanisms. Discontinuous policies will result in a fluctuation of the market, while a lack of competition mechanisms will create a type of purely protective policy and make enterprises heavily dependent on government preferential policies. The government will pay much attention to combining competition with policy support so as to make enterprises continuously lower costs under the government's support policy, and finally have the ability to compete with conventional energy. Therefore, it needs to formulate or perfect long-term and continuous incentive policies and measures on the aspects of investment, tax, credit, price and management. Through these policies and measures, it should create a fair competitive environment between enterprises as well as between the renewable energy sector and other sectors.

Currently, the main supporting policies in China are subsidies, duty exemptions, etc. However, according to international experiences, it is perhaps a more effective measure for the development of renewable energy to implement an offset tax policy for renewable energy power generation, a renewable energy portfolio standard or a carbon tax and transacting system. China should enact suitable policies and measures based on China's situations and other countries' experiences.

4.3 Developing and regulating market

As a whole, renewable energy products have no systematic technical standard, or any national quality norm and corresponding regulation and rule, and quality-supervision system. The whole market is in such disarray that it impedes the development and expansion of the market. Furthermore, though renewable energy projects have very good market potential, it doesn't create effective a demand due to a lack of information and advertisements about renewable products.

The government should strengthen regulation and control of the market through the following: enacting standards for products, perfecting quality-control and authentication regulation, establishing national and regional-level product quality testing and detection centers, putting into enforcement inviting public bidding and engineering quality supervision, control and evaluation rules, and carrying out government purchasing system for renewable energy products. Through these measures, it can create incentives for demanding renewable energy products and promote the growth of the market.

4.4 Expanding financing manners

As a rising industry, the scale of renewable energy is small and enterprises have a low profitability at present. Capital shortage and a lack of effective financing mechanisms are therefore important barriers for industrialized development. According to estimates, it will need a total investment of about 16.4 billion yuan to realize the target of 2015, annually averaging about 10 billion yuan. In 1997, total social investment of China was 2494.1 billion yuan, so average annual investment will be expected to account for about 0.4% of the total social investment. It needs to set up effective domestic and international investment channels and different financing modes (including risk investment) to attract domestic enterprises, international organizations and developed countries to take part in the construction of the renewable energy industry.

4.5 Setting up sound management systems, clearly defining authority and enhancing coordination

Classified by energy type, the management of most renewable energy products is subordinated to different government sectors or departments. For example, the authority and leadership for renewable energy has fallen within the competence of the State Development and Planning Commission (SDPC), State Economic and Trade Commission (SETC), Ministry of Science and Technology (MoST), Ministry of Agriculture (MoA), etc. Therefore, it is very difficult to reach an agreement on

development planning, policy and implementation of projects because different agencies have various thinking from the viewpoints of their own interest. Such institutional systems not only have very high social costs, but also cannot adapt to the requirements of a market economy, and it is very difficult to form unified policies and measures.

It would be ideal for there to be a special government agency established to engage in all aspects of management and decision-making related to renewable energy development. For example, India has set up a similar agency, e.g. Ministry of Non-conventional Energy Sources (MNES). However, China already reformed government agencies in 1998, and reduced its size. It did not set up such an agency with a special responsibility for the management of renewable energy. It therefore does not seem possible to set up such agency now. Therefore, a more feasible solution may be to enhance the unified leading of renewable energy management under the current agency system, and to clarify the function and authority of all related agencies, especially their authority and obligations for policy formulation.

4.6 Strengthening law and rule formulation

The coordination of all related governmental departments should promote the formulation of unified policies and measures, as well as basic laws and rules for renewable energy and related management regulations.

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