A REVIEW OF CHINA'S RENEWABLE ENERGY POLICIES AND POTENTIALS

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CHINA'S RENEWABLE ENERGY POLICIES AND POTENTIALS REVIEW

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1. Renewables Potential in China

China has abundant renewable energy resources, including wind, solar, biomass, tide and wave, geothermal energy. The potentials of each renewable source of energy are briefly discussed below.

1.1Wind Energy

1.1.1 Resource Potential and Distribution

China has a vast territory, most of which is located within the sweep of the monsoon. Generally, in China's mainland, the Siberian and Mongolian high pressure during the winter season brings dry and cold wind from high latitudes, resulting in strong northwest winds. These winds influence most provinces in Northwestern, Southwestern and Northern China. Wet monsoon refers to the southeast wind from the Pacific Ocean and southwest wind from the Indian Ocean and Southern China Sea. Usually, the southeast monsoon influences the east half of China while the southwest monsoon influences southwest provinces and southern coastal regions, but its wind speed is far lower than that of southeast monsoon. Due to these climate characteristics, wind resources are quite abundant in China. The amount and distribution of wind resources have been basically identified through prospecting and investigation over recent decades, and those areas with plentiful wind and high exploitation potential have been further surveyed. The average yearly wind speed in all existing wind farms of China exceeds 6m/s (1999, White Book). The following figure 1-1 shows the wind resource distribution of China.

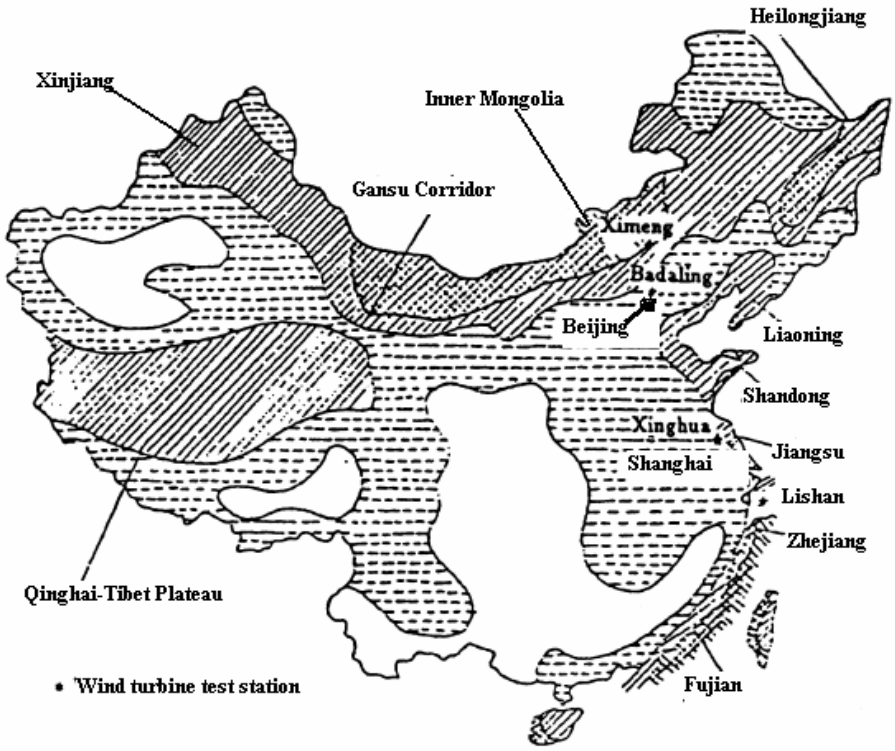


Figure 1-1 Division of Wind Energy Resource of China

Table 1-1 Criterion of Division and Percentage in Total Inland Area

Index	Abundant Area	Comparatively Abundant Area	Utilizable Area	**Shortage Area**
Annual effective wind energy density (W/m^2)	>200	200-150	<150-50	**<50**
Annual cumulative hours above 3m/s (h)	>5000	5000-4000	<4000-2000	**<2000**
Annual cumulative hours above 6m/s (h)	>2200	2200-1500	<1500-350	**<350**
Percentage in Total Inland area (%)	**8**	**18**	**50**	**24**

Resource: 1999 White Book China New & Renewable Energy

As the time distribution of wind resources, in the winter and spring season, the monsoon is heavy and the rain is small; in the summer, the monsoon is small and the rain is becoming heavier, which is proven complementarily to the low water period and high water period of hydropower. Figures 1-2 and 1-3 indicate, the wind resource in IMAR remains substantial in nearly all counties, while a smaller number of counties in Xinjiang and Qinghai offer promising resource conditions for wind market development. Only a few counties in the northern reaches of Xinjiang and even fewer counties in north and central Qinghai provide reasonably good wind resources (CEEP, 2000).

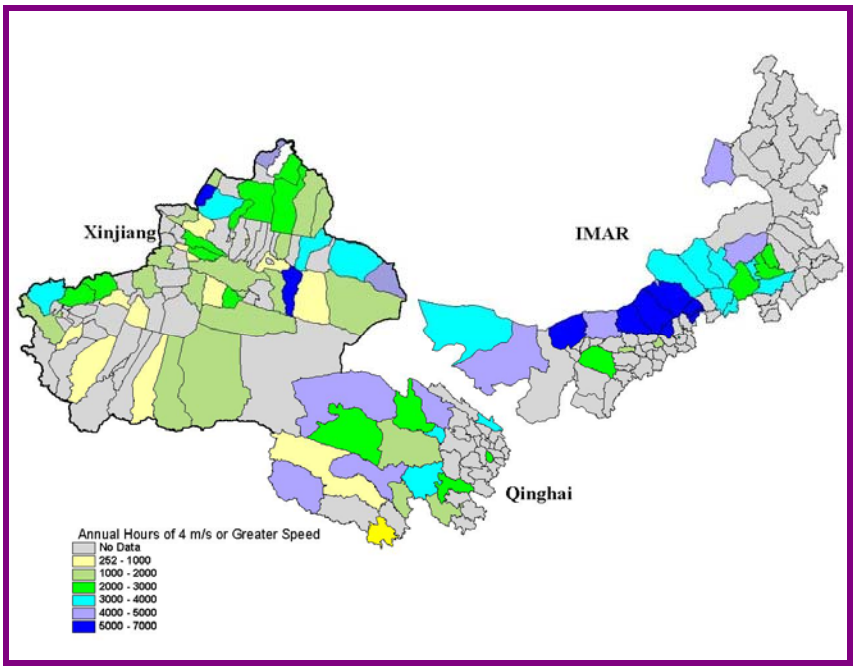


Figure 1-2 Annual hours of wind resource (≥ 4m/s) in the Inner Mongolia Autonomous Region (IMAR), Xinjiang, and Qinghai

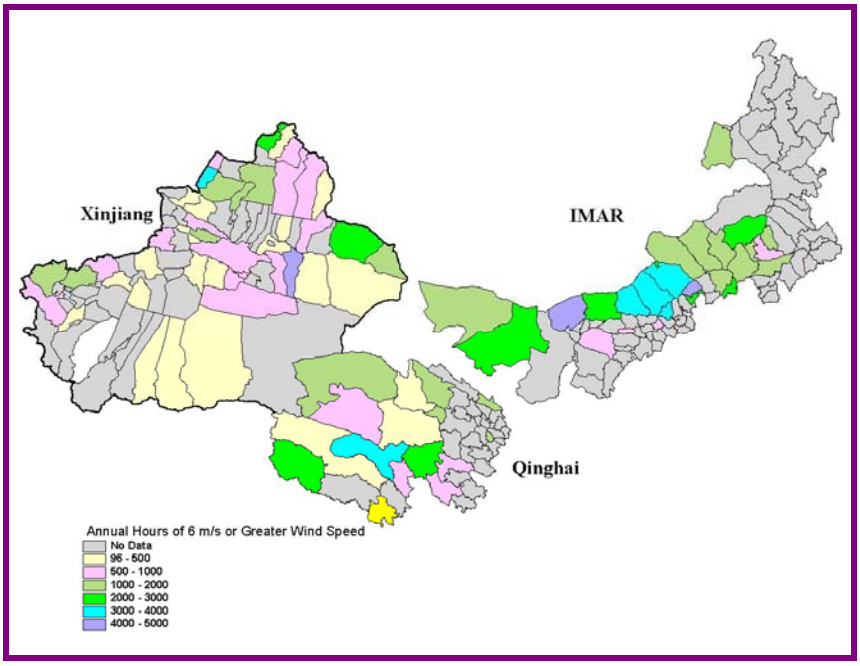


Figure 1-3 Annual hours of wind resource (≥ 6m/s) in the Inner Mongolia Autonomous Region (IMAR), Xinjiang, and Qinghai

In China, there are only a few regions (1% of China's total inland area) that have yearly average wind speed over 6m/s. These regions are mainly distributed in the southeast coastal areas and islands between Yangtze River and Nan'ao Island, which are the largest and the most abundant wind resource areas.

Bases upon Figure 1-1, it could be easily found that the areas affluent in wind energy mainly distribute in the grasslands or deserts in northwest, northern and northeast of China, and coastal areas or islands in east and southeast China where are generally absent of conventional energy such as coal. The abundant areas of wind resource in China includes: Shandong Peninsula, Liaodong Peninsula, Yellow Sea coastal regions, Southern Sea coastal regions, west of Nan'ao Island (Guangdong Province), Hainan Island and islands of Southern Sea, areas between Yinshan Mountain and Daxing' anling within Inner Mongolia, Danbancheng in Xinjiang Autonomous Region, Alashan Pass, Hexi Corridor, Songhuajiang Downstream, etc. Generally, China is endowed with large wind resources in the north, from Xinjiang Autonomous Region through Gansu Province to Inner Mongolia, and in the southeast, along the coastline. According to statistics, inland wind energy resources offer the

potential for supporting 253GW of wind generation. Plus the inshore (coastal sea areas with water depth of up to 15m) wind energy resources, the total exploitable wind power is estimated above 1TW. In other words, if wind turbines were installed to exploit all these resources, the current national installed power generation capacity could be more than doubled (Zhang, et al, 2002). Inner Mongolia, Qinghai, Heilongjiang and Gansu process topmost wind resources in China. The wind reserves in Inner Mongolia reaches to 40% of the total exploitable wind power of China.

The wind resources in some China's provinces are listed in Table 1-2.

Table 1-2 Wind Resource Capacity in Some Provinces

Provinces	Capacity(10,000kW)	Provinces	Capacity (10,000kW)
Inner Mongolia	6178	Shangdong	394
Xinjiang	3433	Jiangxi	293
Heilongjiang	1723	Jiangxu	238
Ganxu	1143	Guangdong	195
Jilin	638	Zhejiang	164
Hebei	612	Fujian	137
Lianning	606	Hainan	64

Sources: China Meteorology Science Institute

1.1.2 Current Status of Wind Power Utilization

By the end of 2003, there had been altogether 40 wind farms in China, with 1,042 sets of wind turbines and 567MW total capacity but only 0.14% of total electric power. Table 1-3 shows some wind farms of China. The majority of wind turbines have been installed in Dabancheng (Xinjiang), Nan'ao (Guangdong), Inner Mongolia, remote areas of the Northeast and on various islands.

Besides the wind farms, small wind power system is a great energy supply option for the unelectrified villages in remote regions and inshore islands of China. In China's wind-rich coastal island regions and northwestern areas, a number of wind generator systems have been installed over the last 10 years. Over 150,000 household wind systems (size is up to 1kW)

operate across the country (Guidebook, 2004). There is also large number of hybrid systems (wind/diesel; wind/PV) in China's remote regions.

Table 1-3 China's wind farm distribution (by 2000)

No.	Province	Name of Wind Farm	Number of Turbines in the Wind Farm	Capacity of Single Turbine (kW)	Installed Capacity (kW)	**Installed Capacity in Province (kW)**
1	**Hebei**	Zhangbei	24	275/300/600	9,850	9,850
2	**Inner Mongolia**	Zhurihe	38	100/120/ 250/300	7,500	56,905
3		Shangdu	17	55/300	3,875	
4		Xilin	10	250	2,980	
5		Huitengxile	61	550/600	36,100	
6		Keshiketeng	9		6,450	
7	**Liaoning**	Donggang	26	55/300/550	12,205	46,005
8		Hengshan	20	250	5,000	
9		Jingzhou	1		600	
10		Xianrendao	11		7,200	
11		Dandong	28		21,000	
12	**Jilin**	Tongyu	49		30,060	30,060
13	**Shandong**	Rongcheng	3	55	165	5,675
14		Changdao	11	55/600	5,510	
15	**Zhejiang**	Sijiao	10	30	300	30,355
16		Hedingshan	19	55/200/500/ 600	10,255	
17		Kuocangshan	33	600	19,800	
18	**Fujian**	Pingtan	16	55/200	7,055	13,055
19		Dongshan	10		6,000	
20	**Guang-dong**	Nan'ao	131	90/130/150/ 200/250/300 350/550/600	56,780	69,980
21		Huilai	22	600	13,200	
22	**Hainan**	Dongfang	19	55/250/600	8,755	8,755
23	**Gansu**	Yumen	4	300	1,200	1,200
24	**Xinjiang**	Dabancheng1	32	100/150/ 450/500/600	12,100	72,950
25		Dabancheng2	116	300/500/ 600	59,800	
26		Buerjin	7	150	1,050	
Total			727			344,790

1.1.3 Wind Power Industry

China's wind power industry has achieved significant progress. In China, the researches on the micro and mini wind turbines began in the 1950s and were applied on a large scale from the 1970s onwards. More than 170,000 micro turbines have been installed (20MW) and this is the largest number in the world. The development is speeding up in recent years. However, compared with those leading countries in installed capacity such as German, the US, Spain, Denmark, etc, China's wind power industry is relatively underdeveloped, especially in the area of grid-connected wind farms. China's annual rate of increase also lags behind those countries. In 2000, China's annual rate of increase of installed on-grid wind power capacity was 28.4% and this number is nearly 50% in recent years. But it is still less than some leading European countries such as Spain, France and Asian neighbor—Japan. On the other hand, the base of China's wind installed capacity is low, which makes the increase of wind industry lags behind those leading countries. In German, for example, it has been planned that the wind power would provide 10% of the electricity consumption of the whole country and 50% of that in 2050.

Recent years China is facing a salient problem—electricity shortage. In 2004, 24 provinces are reported to be in shortage of electricity and have a limit to electricity supply. The gap of electric power is 20GW-30GW in 2004 (State Power, 2004). Based upon the abundant wind resources, wind power provides a sustainable solution with strong feasibility. With the increase of the energy consumption, wind power has an increasing strategic position in China's energy supply, especially electricity.

Under the current technological conditions, the wind resource of the following regions can be exploited on large-scale: the coastal regions of Eastern and Southern China; Northern China (Hebei, Inner Mongolia, Gansu, Xinjiang); Northeast region; Part regions of Qinghai-Tibet Plateau, etc. All of these regions have the potential to install wind turbines at the level of several gigawatt, and these regions are near the locations where electricity is largely required or it is not difficult to transport electricity using the existed grid.

On-grid wind generation has become the main form of the exploitation of wind resource. With the constantly improving of requirement, throughput and turbine performance, the cost of wind power generation is steady declining and wind generation is becoming more and more competitive with conventional energy.

The scale of development reached a new level in China. As the result of government attention and support, China's wind power industry has entered a booming period since 1996. The rate of localization and the capacity for producing key equipment domestically both increased. In the past, depending too much upon imported wind turbines or key parts, such as blades, led to high wind power generation costs and hindered the commercialization of the industry. However, one of the key national research projects involved the research into large wind turbines and their connection to power grids (Zhang, 2002). The start of the industrialization of wind power technology has accompanied the establishment of specialized factories.

In recent years, the annual rate of increase of China's wind power generation is nearly or above 50% (China Power, 2005). Guangdong Province, Inner Mongolia and Xinjiang Autonomous Region are very promising regions of wind farms construction. In Guangdong Province, new projects with 260MW capacity are initiated recently, including the first wind farm on the sea in China (Nan'ao 20MW) and 100MW wind farm in Huilai. In Inner Mongolia, the largest wind farm will be built and some large-scale wind farms are under construction. Inner Mongolia possesses 40% of the total wind resource reserves and most of the Inner Mongolia is vast grassland with little population, which makes it suits construction of wind farms. The wind electricity in IMAR can be transported to Beijing conveniently and changes the electricity consumption structure of Beijing. And, wind power is very meaningful for the environmental protection of Inner Mongolia, which will decrease the sandstorm of Northern China.

In 2003, the National Development and Reform Commission (NDRC) brought forward the aim of wind power generation: the total installed capacity of wind generator will be 1000MW

and 4000MW in 2005 and 2010 respectively, and by the year of 2050, the wind power will provide 10% of the total electricity in China.

1.2 Solar Energy

Strictly speaking, solar energy is the most important basic energy among various renewable energies. As a kind of renewable energy, it means the direct conversion and the utilization of solar energy. It includes the photothermal, thermoelectricity and photovoltaic technologies.

1.2.1 Resource Potential and Distribution

China is one of the richest countries in solar energy resource in the world. The total radiation of China is 3,340~8,400 MJ/(m^2·year) and the average value is 5,852 MJ/(m^2·year). Two thirds of the total area of China has the sunshine time exceeding 2000 hours per year. In China, Tibet, Qinghai, Xinjiang, Gansu, Ningxia and Inner Mongolia have the highest annual solar radiation and sunshine hours and belong to solar energy rich areas of the world; Sichuan Basin, Hunan and Hubei are the solar energy poor areas (White Book, 1999). The other regions, such as South China, East China and Northeast China, have the moderate level. The solar energy resource distribution in China is shown in the following figure 1-4 and table 1-4.

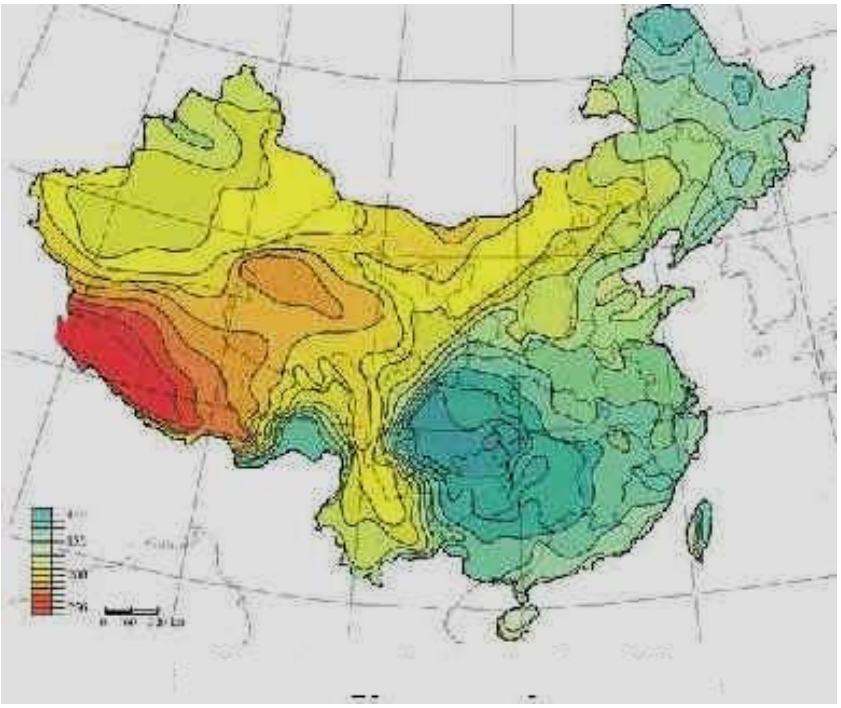


Figure 1-4 Solar energy resource distribution in China

The regions of category 1-3, with sunshine hours above 2,000 hours and radiation above 5,000 MJ/m^2 per year, have abundant solar energy and the total area is above two-thirds of China. These regions, as well as some areas in category 4 and 5, have good conditions for exploiting solar energy. Compared with the other regions of the same latitude in the world, except for Sichuan Basin and Guizhou, most of China have abundant solar energy, which is similar to the United States and far more predominant than Japan and Europe. Especially, Central and South Qinghai-Tibet plateau possess the richest solar energy of the world. Table 1-4 shows the solar radiation of main cities of China, compared with other cities of the world.

Table 1-4 Solar energy resource distribution in China

Category	Area	Annual Sunshine Hours	Daily Radiation (KWh/m^2)	**Annual Radiation (MJ/m^2·year)**
1	West Tibet; Southeast Xinjiang; West Qinghai; Northwest Gansu; North Ningxia	3,200-3,300	≥ 5.1	**6,680-8,400**
2	Southeast Tibet; South Xinjiang; East Qinghai; South Ningxia; Mid Gansu; Inner Mongolia; North Shanxi (Capital	3,000-3,200	4.5 – 5.1	**5,852-6,680**

	Taiyuan); Northwest Hebei			
3	North Xinjiang; Southeast Gansu; South Shanxi; North Shaanxi (Capital Xi'an); Southeast Hebei; Shandong; Henan; Jilin; Liaoning; Yunnan; South Guangdong; South Fujian; North Jiangsu; North Anhui; Southwest Taiwan	2,200-3,000	3.8 – 4.5	**5,016-5,852**
4	Hunan; Guangxi; Jiangxi; Zhejiang; Hubei; North Fujian; North Guangdong; South Jiangsu; South Anhui; Heilongjiang; South Shaanxi; Northeast Taiwan	1,400-2,200	3.2 – 3.8	**4,190-5,016**
5	**Sichuan; Guizhou**	**1,000-1,400**	**< 3.2**	**3,344-4,190**

Table 1-5 Solar energy resource in China cities and other big cities

Tibetan Region/ City	Annual Radiation (MJ/m^2)	City	Annual Radiation (MJ/m^2)	City	**Annual Radiation (MJ/m^2)**
Lhasa	7784.2	Beijing	5564.3	Paris	**4019.3**
Chamdo	6137.1	Shanghai	4672.5	Vienna	**3893.7**
Nagqu	6557.2	Harbin	4622.2	Stockholm	**3558.8**
Shigatse	>7500	Urumqi	5304.7	Moscow	**3726.3**
Ngari	7925	Golmud	7004.5	Hamburg	**3433.2**
Shiquanhe	7807.6	Lanzhou	5442.8	London	**3642.5**
Rongbu Temple	8369.4	Hohhot	6108.5	Venice	**4814.8**
		Yinchuan	6012.2	Tokyo	**4228.7**
		Chengdu	3805.8	New York	**4731.1**
		Kunming	5271.2	Singapore	**5735.9**
		Guiyang	3805.8	Seoul	**4016**
		Wuhan	4672.5	Pusan	**4930**
		Guangzhou	**4479.9**	**Sahara**	**>8373.6**

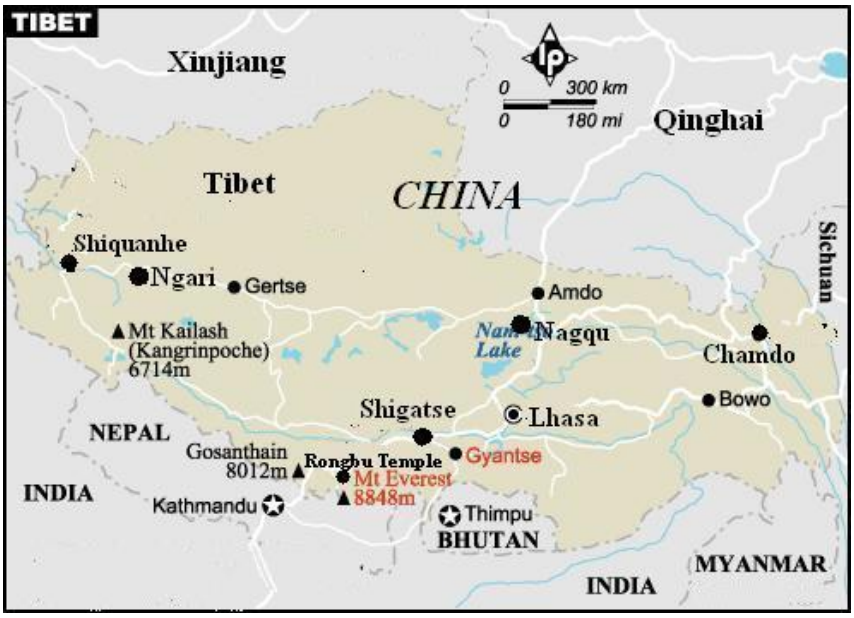


Figure 1-5 Abundant solar energy resource in Tibet

The main characteristics of China's solar energy distribution are: 1) between the latitude 22º～35º north there lie the maximum center and minimum center—Qinghai-Tibet Plateau and Sichuan Basin; 2) the solar radiation in Western China is higher than that of Eastern China; 3) the energy of solar radiation increases with the increase of latitude, except for Xinjiang and Tibet. Most counties in the IMAR have reasonably good solar radiation, with possibilities for some small-scale, complementary solar development in conjunction with wind. At the same time, nearly all counties in Qinghai receive significant solar radiation (>1,800 kWh per m²). Within the autonomous region of Xinjiang, solar potential appears especially encouraging. Its southern and western counties experience good to excellent solar radiation, with significant opportunities for developing solar PV home systems and community PV generation (See Figure 1-6).

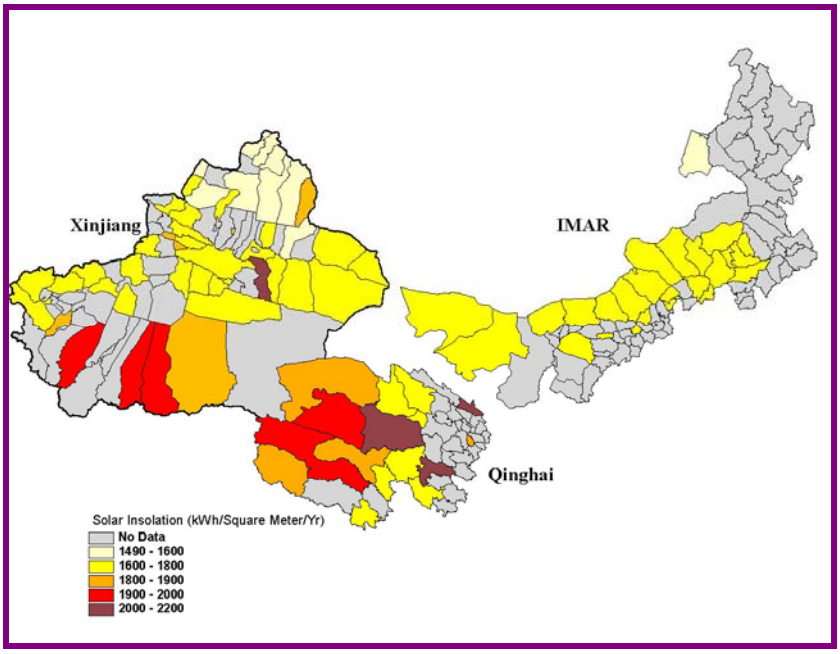


Figure 1-6 Annual solar insolation in the Inner Mongolia Autonomous Region, Xinjiang, and Qinghai (kWh/m2/year)

Source: CEEP, 2001.

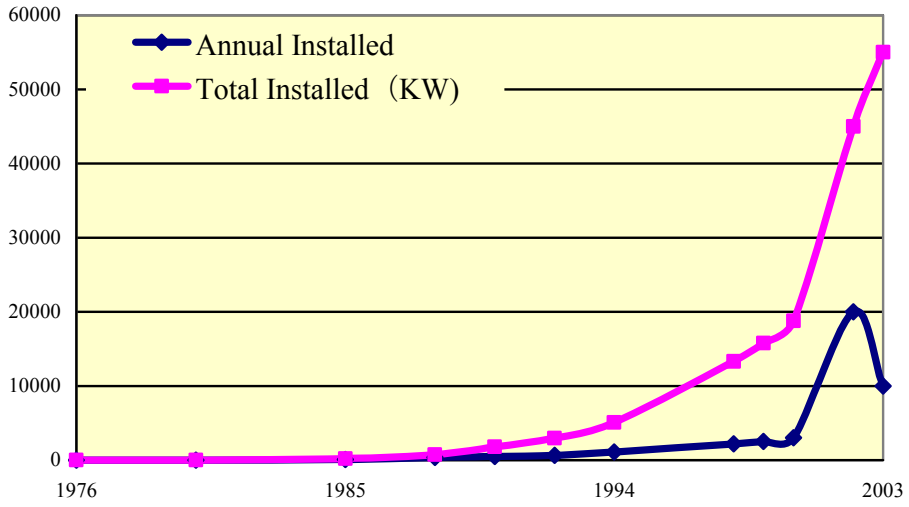


Figure 1-7 Installed capacity of PV in China

1.2.2 PV Market in China

The fast development since 2002 is largely due to Chinese government initiated the huge project to provide electricity for unelectrified villages in Western China — Township Program. Total installed capacity has reached 19.6MWp in this unprecedented project.

The following table shows the circumstance of China's PV market.

Table 1-6 China's PV Market

Market	**Total Installed PV（MWp）**	**Percentage（%）**
Rural Electrification	28 (Including Household System 7.8MWp)	51
Communication and Industrial Application	20	36
PV Commodities	5	9
Grid-connected PV System	2	4
Total	55	100

The fast development of PV industry and market in recent years is mainly due to the government's support and big programs initiated—to use PV or PV/Wind hybrid system to provide electricity for unelectrified villages in China. These regions is mainly distributed in Tibet, Xinjiang, Qinghai, Gansu, Inner Mongolia, Sichuan and Guizhou. The market for the PV household system is increasing. More than 410,000 household systems have been installed and it is estimated that the annual increase rate of household system in Western China is 10-20%.

China's PV industry and market will have a glorious future. First, the market of rural electrification is still very large—there are 28,000 unelectrified villages (more than 7,000,000 families and about 30,000,000 people) cannot get access to electricity in China by the end of 2003. The potential market for household system is 1400MWp—3000MWp. Before 2010, the PV market focus is indeed on small-scale, dispersed, stand-alone PV station, household system as well as small and medium-sized building-integrated grid-connected PV power

systems. According to official estimation, the PV market in China will begin to change from stand-alone systems to grid-connected systems, including very-large scale PV stations in Gobi or desert and city roof plan.

In the longer term, very-large scale PV system may represent a future option for photovoltaic applications and thereby contribute even more to the world energy supply. The feasibility and potential for very-large scale PV system in desert areas and city roof are beginning to be examined. The total area of the desert and desert soil in China is about 850,000 km^2, mainly distributed in Xinjiang, Ningxia and Inner Mongolia. On the other hand, total area of house roof is about 4×10^9 m^2. Both desert and house roof offer enough areas for very-large scale PV system. For example, total electricity generation in 2002 was 1650TWh. If it were provided by PV system, it would need only 1.3% of the total desert to install PV system (100W/m^2, 1500hours/year). Therefore, this technology is expected to generate a variety of advantages and will be one of the most attractive technologies for our future. An assumed case study of very large scale PV system installed in the Gobi (desert lies in both China and Mongolia) has been analyzed from technological, economic and environmental aspects. Results showed an attractive feasibility and a highly potential market.

PV systems play an increasing role for a sustainable energy future in China. It is estimated that the total installed capacity of PV system in 2010 will be 600 MWp, and this number in 2020 and 2050 is expected to be 30GWp and 100GWp respectively. It is expected in 2050 5% of electricity will be supplied by PV. Following tables show the forecast.

Table 1-7 China's PV market forecast

Year	2003	2004	2005	2006	2007	2008	2009	2010
Throughput (MWp)		20	29	42	60	88	126	180
Total Installed (MWp)	55	75	104	146	206	294	420	600
AIR	45%							

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Throughput (GWp)		0.28	0.42	0.62	0.92	1.36	2.00	3.00	4.40	6.60	9.80
Total Installed (GWp)	0.6	0.88	1.30	1.92	2.84	4.20	6.20	9.20	13.6	20.2	30
AIR	48.5%										

Source: NDRC/GEF/THE WORLD BANK, 2004

At the same time, the components of PV market will change dramatically, as following table shows.

Table 1-8 China's PV market forecast

Market	**Total Installed PV（GWp）**			**Percentage（%）**		
	2010	**2020**	**2050**	**2010**	**2020**	**2050**
Rural Electrification	0.36	3.0	5	60	10	5
Communication and Industrial Application	0.06	4.5	7	10	15	7
PV Commodities	0.06	4.5	8	10	15	8
Grid-connected PV System	0.12	18	80	20	60	80
Total	0.6	30	100	100	100	100

Source: NDRC/GEF/THE WORLD BANK, 2004

1.2.3 Solar Thermal Technology

1) Solar water heater

Solar thermal technology is one of the most commercialized and widespread technologies in the field of renewable energy utilization. In China, the main technologies of solar thermal application are solar water heater, solar house, thermoelectricity, etc.

Solar water heater has experienced rapid development, application and dissemination in China. There are more than 1000 water heater manufacturers and the total installed capacity has reached 40 million m^2. More than half of the solar water heater is installed in rural regions. At present, the leading solar water heaters on the market include vacuum tubes and flat-plate and the solar water heaters are mainly applied to families and factories, mines, governmental institutions and public places.

Solar water heater industry in China is well developed and commercialized. Apart from continuous improvement in technology and product quality, the national standard for several types of water heaters have been promulgated and implemented, such as "Testing Method for Property Evaluation on Flat-plate Water Heater" and "Heat Property Testing Method for Household Water Heater" (White Book, 1999). However, the market for solar water heater in China is still very large. The proportion of household users is very low. According to the forecast of Asian Development Bank, household user will take up 10% of the total population in 2010, and 75% of the hot water will be heated by solar energy. It means the saving of 10.5 Mtce and the decrease of 38.5 Mt CO_2 emission.

2) Solar Energy Architecture

Solar house is an important way to use the solar radiation energy directly. Combining solar house and architecture, Solar Energy Architecture technology is becoming the hot topic in the areas of both solar energy and architecture. This technology can save up to 75%-90% of the energy consumption of the architecture. China began the R&D and demonstration of this technology in early 1980s. An area of 10 million m^2 of solar house has been built in China, most of them located in the rural areas of Shandong, Hebei, Liaoning, Inner Mongolia, Gansu, Qinghai and Tibet. Passive solar houses were built for living community in Gansu Province. The technology of solar energy architecture in China lags behind developed countries. In the future, the design and construction of solar houses should be combined with the design of the architect and incorporated into the building specifications and standards. The commercialization of architectural materials is also a key issue for the fast development. 10%

of the civil architecture is expected to apply solar house technology by the end of 2010, and this number will reach 30% in 2030.

3) Thermoelectricity

China's thermoelectricity technology lags far behind the international level. Due to the lack of process, materials, parts as well as insufficient capital, this technology was once suspended and stopped. Currently, no sample machine has been manufactured. The R&D projects on small parts and materials have the nature of technical reserves (White Book, 1999).

A rough forecast and layout about thermoelectricity in China is that R&D and demonstration will be carried out before 2010; commercial demonstration with the power 10-100MW will be finished between 2010 and 2030; and it is expected that commercial application of thermoelectricity technology with the power 100MW can be achieved from 2030 to 2050.

1.3 Biomass Energy

As a kind of renewable energy, biomass energy accounts for 14% in the world energy consumption and 60% in the consumption of undeveloped regions, including wood and forest industry residues, agricultural residues, hygrophyte, energy crops, municipal and industrial organic waste and animal manure.

1.3.1 Resource Potential and Distribution

China is a developing country with large population, and more than 60% of China's population live in rural regions. Biomass energy development is very important for China because stalks and fuelwood are taken as the major residential fuel source for the daily energy consumption of the people living in rural regions (White Book, 1999). Although the utilization of coal and other commercial energy sources has a fast growth, biomass energy still plays an important role in China's rural areas. Straw, stalk and fuelwood are main resources for cooking and heating in China's rural families and therefore, developing biomass

technology to meet the residential and industrial energy demands is an important task in helping these areas alleviate poverty.

China's main biomass energy resources are showed in the following table 1-9:

Table 1-9 China's Biomass Energy Resources

	Straw & Stalks	Fuelwood	Animal Waste	MSW
Physical Amount (Mt)	720	127/year	1410	120
Standard Amount (Mtce)	360	74/year	130	-

Notes: The annual increase rate of MSW is 8-10%.

According to the investigation, most of the crop stalks can be used as energy resources. However, most of the stalks are used directly for stoves at low conversion efficiency. With the increasing use of commercial energy (e.g. coal), the conventional mode of stalk utilization is the first to be displaced and the amount of stalks abandoned in the fields is increasing, which leads to not only waste of energy resources but also environmental pollution. It is necessary to speed up the conversion of biomass energy into high-quality products. Urban refuse is composed of residential waste, business and service industry waste and a small amount of construction waste. The contents of urban refuse is influenced by people's living standard, energy structure, municipal construction, etc. And food waste is the major component of organic waste in China. If not processed and exploited appropriately, they will become a kind of organic pollution resource, threatening atmosphere, water resources as well as emission of greenhouse gas.

At present, the main utilization of biomass energy is in rural areas. With the development of economy and increase of living standard, the market for biomass energy is very large. The main reasons are:

- The total biomass energy resources will be 900-1,000 Mtce.
- Burning crop stalks directly for cooking and heating is displaced gradually by biogas and other fuels in rural regions, which means the improvement of the farmers' living standard and melioration of sanitation.
- There are many provisions, timber, tea, fruit mills and factories in rural China, which produce many castoffs such as chaff, sawdust, etc. Using biomass

gasification technology, they are good energy resources to supply high quality and clean energy.

- Animal dung will pollute the environment. With the development of large and medium-size husbandries, this problem is getting serious. Therefore, using anaerobic fermentation technology to process animal dung is meaningful for both environment and energy. This is also important for the process of increasing urban refuse.
- In remote regions short of electricity while have abundant biomass resources, biogas is an important option for electricity generation and heating supply.

Biomass energy in China has developed steadily and the main resources and technologies of biomass energy utilization are 1) Charcoal forest, 2) Biogas, 3) Biomass gasification, 4) Biomass solidification and other processes.

By the end of 2000, the total area of fuelwood forest had reached 5.4 million hectare, and according to the Chinese government's layout, this number will be 13.4 million hectare in 2010. According to the investigation on nationwide afforestation achievement, fuelwood forest area and annual biomass quantity per unit area, fuelwood annual increase is calculated as 20-25 million tons, which make great contribution in mitigating energy pressure in rural areas (White Book, 1999).

1.3.2 Status of Biomass Energy Utilization

Since 1990, biogas projects have developed steadily. In 2005, there will be more than 20 million household biogas pits in China altogether, and biogas will be used in near 10% of the rural households. By the end of 2010, it is expected that more than 20% of the rural households can use biogas for their daily energy consumption, which means more than 50 million household biogas pits will be built in China. One of the characteristics of China's biomass utilization is that the comprehensive utilization technology has achieved rapid development, such as "Four in One" model and "Energy-Environment Engineering", etc.

These technologies can not only solve the problem of pollution, but also have good energy, economic and social benefits. After this process, the manure can be used as source for methane and the residue is made commercial fertilizer.

Converting solid biomass energy into gas fuel can provide clean, convenient and high-efficiency energy, this technology—biomass gasification is widely emphasized in China. The R&D of biomass gasification has been carried out in some research institutes and universities of China. Biomass gasification generation is one of the key technologies of the "863" National Key Programs. For example, the gasification power generation system of 1MW has been developed by Guangzhou Energy Research Institute. The feasibility research of 4-6 MW demonstration project has also carried out. The total installed capacity of biomass power generation in 2002 was 800 MW—ranked No. 2 of all the renewable generation. The official forecast of biomass power generation installed capacity in 2020 is 10GW.

In future, biomass energy will play a more and more important role in the renewable energy. China's biomass energy application technology should focus on the following aspects (White Book, 1999):

1) High-efficiency direct combustion technology and equipment.

   High-efficiency direct combustion is very meaningful for China's vast rural regions. Improved biomass combustion will offer an ideal substitution of fossil fuel for township enterprises. Processing agricultural and forest residues into shaped fuel after extruding and classification and developing respective technology and equipment will have promising market in China.

2) Intensive and comprehensive utilization

   The construction of fast-growing fuelwood provides both energy and raw materials. Converting biomass energy into fuel gas and its transportation to residential consumers is viable, which also bring considerable economic and social benefits. On the other hand, take full advantage of abundant stalk resource of rural China

3) Innovative development & utilization of high-efficiency biomass energy

Fast development of science and technology can realize innovative utilization of biomass energy in high-efficiency and low-cost way. Technological breakthroughs such as liquefaction under normal pressure, catalyzing chemical conversion technology will largely promote biomass energy development.

4) Development and utilization of urban residential refuse

Residential refuse is increasing by 8-10% annually in China. Industrialized development and utilization of refuse has an enormous development potential. It can be used for power generation, centralized heating through combustion and coal gas production through gasification. Some institutes and laboratories of universities have been carrying out related researches for many years and many progresses have been achieved.

5) Energy plants utilization

Energy plants utilization includes developing all sorts of green oil-producing plants, such as oil palms and wood halberd plants, providing high quality resources for biomass energy utilization.

1.4 Geothermal Energy

Some regions of China lie in the borders of plates main geothermal belts such as the Pacific Rim Geothermal Belt and Mediterranean-Himalayan Geothermal Belt. The movement and collision of India, Eurasian and Pacific plates resulted in some geothermal areas in China.

1.4.1 Resource Potential and Distribution

China possesses abundant and widely distributed geothermal energy resources and the potential of Basin type geothermal energy resources can reach above 200,000Mtce. China has discovered 3200 geothermal areas and dug over 2000 geothermal wells, 255 areas among them have the potential of high temperature geothermal power generation. The total available installed capacity is 5.8GW. From 1970s, China began the development of geothermal application. Most of the installations are for space heating and cooling, direct hot water use, sanatoria and tourism. In 1970s, the geothermal wells began appear in Beijing city. Presently, Beijing have hundreds of geothermal wells, the growth rate of the geothermal application in

Beijing is around 20 per year (Gong, 2005). In Tianjin alone, there are 184 geothermal wells, which provide water heating for nearly 50 thousand households in the city (Xiao, 2005). For the Beijing 2008 Olympics, geothermal is also expected to provide heating and cooling in the Olympic park.

According to the formation cause, the geothermal energy resources in China can be divided into the following types (White Book, 1999):

1). Modern/neoteric volcano type

This type mainly distributed in Datun volcano area in North Taiwan (collision of Eurasian Plate and Philippine Mini-Plate) and Tengchong volcano area in West Yunnan (collision of Indian Plate and Eurasian Plate).

2). Magma type

The magma embedded 6-10km under the earth's surface becomes the heat source of high-temperature geothermal energy resources. The collision border of Eurasian and Indian Plates is a typical representative of this kind of formation, which, in China's territory, mainly distributed in South Tibet spread along the Yarlung Tsangpo (Brahmaputra) River. These regions such as Yangbajing and Yangyi in Tibet possess very rich geothermal energy resources.

3). Fault-rift type

This type geothermal energy resource is mainly distributed in the bedrock ridgy areas in the inner side of the plates or fault valleys and mountainous basins caused by fault, far away from the border of the plates. The geothermal resources in China's Liaoning, Shandong, Shanxi, Shaanxi, Fujian, Guangdong Provinces belong to this type. The area of geofields is usually several square kilometers, or ever smaller than 1 km^2. Heat is stored mainly at moderate temperature, individuals at high temperature. Individual geofields' heat storage is not high, but these geofields are widely spread in China.

4). Fault-subsidence and sunken basin type

Fault-subsidence and sunken basin type geothermal energy resources are mainly distributed in large fault-subsidence and sunken basins inside the plates, such as

North China Basin, Songhuajiang-Liaoning Basin, Yangtze-Hankou Basin, etc. The individual geofields have large areas of decades of or even hundreds of square kilometers. The geothermal energy resources are of high potentiality and great exploitation value.

255 places can be used for geothermal power generation with a total potential of 5800 MW, especially in Tibet, the total potential is more than 1GW. The medium and low temperature geothermal resources can be used for industrial use, drying, heating, medical treatment, agricultural irrigation, and so on. In China's territory, more than 2900 places can be used for non-power direct utilization. The number of hot well above 25°C is listed as following:

Tibet—283, Yunnan—820, Sichuan—220, Guangdong—257, Hunan—109, Taiwan—103.

1.4.2 Status of Geothermal Utilization

By the end of 2010, the targets for geothermal resources are: 1) Installed capacity of high temperature geothermal power generation achieves 75-100 MW. Mainly prospect and exploit the depth heat storage above 200-250℃ in Tibet and Yunnan Province, and the potential is expected to above 10 MW/well; 2) Geothermal heating achieves 22-25 million m^2, mainly distributed in Beijing, Tianjin, Hebei, Bohai Sea Economic Zone, Beijing-Jiulong industrial zone, Songhuajiang-Liaoning Basin, Mid-Shaanxi Basin, Ningxia Yinchuan Plain. Try to achieve the single well geothermal heating area of 150,000 m^2.

1.5 Small Hydropower

1.5.1 Resource Potential and Distribution

More than 290 GW economically exploitable hydro power potential ranks China No. 1 in the world in hydro power resource. Hydro power provides about 20% of total electricity and 8% of the total energy consumption of China.

As a sustainable rural energy, small hydro power is combined with the development of rural electrification in China. The concept of small hydro power has been changing. Typically, the small hydro power refers to the power generation which has the installed capacity less than 25 MW (In fact, the state's policies for small hydro power were specified for the generation with the capacity below 50 MW).

China possesses many rivers and water systems and the altitude is decreasing from west to east. More than 290 GW economically exploitable hydro power potential ranks China No. 1 in the world in hydro power resource. The total small hydro power resource is about 128 GW and 75 GW is technically exploitable, mainly distributed in more than 1600 counties in China and western China possesses nearly 70% of the small hydro power resource. The exploitable small hydro power resource in more than 1100 counties is above 10 MW (10-30 MW in 470 counties, 30-100 MW in 500 counties, above 100 MW in 134 counties). Following is the distribution in detail:

- The Yangtze Valley and its southern regions, including Fujian, Zhejiang, Jiangxi Hubei, Hunan, Guangdong, Guangxi, Sichuan, Yunnan, Chongqing and Guizhou, possess the richest resource—40 GW;
- Tibet and Xinjiang are sources of many rivers in China. The resource in these regions is very abundant—more than 20 GW;
- The region between the Yellow River and the Yangtze River, including Henan, Shandong, Anhui, Shaanxi, Gansu, Ningxia and Qinghai, has related small resource of small hydro power. The total exploitable resource in this region is about 6.5 GW;
- In the Northern China and Northeastern China, the small hydro power resource is mainly distributed in mountain areas and total amount is about 3.6 GW. But it is valuable for exploitation.

The most important characteristic of China's small hydro power resources is that it mainly distributed in remote and vast areas, where have sparse population and decentralized power load. It is not economical to use the grid to transmit electricity to these regions. Small hydro power is environmental friendly and has strong economic feasibility. It provides an ideal way to supplement state power grid. Also it needs small investment and provides fast benefit and low price of electricity. The most important is that they can form the local electric grid

and offer an ideal solution for China's rural electrification. The investigation in 1996 shows that 80% of the electricity in rural regions is provided by local electric grid. At present, small hydro power generation is providing electricity for one third of China and more than 800 counties mainly depend upon it for electrification. In 2003, 2.7 GW small hydro power was installed in China and the total installed capacity reached 31.2 GW, 40% of the total installed capacity of hydropower. The annual power generation of small hydro power was 110 TWh. Due to the large small hydro power investment and construction of rural electric grid, the unelectrified people in rural China has decreased dramatically in recent years.

The exploitation of small hydro power in China solve the problem of electrification in some rural regions. It also facilitates the development of agriculture, country industries and the protection of environment. But the exploitation of small hydro power is unbalanced in different regions—the development in Western China lags behind of Eastern regions. Currently, only about 35% of the small hydro power resource was exploited. Therefore, the potential for small hydro power is very large, and development of small hydro power plays an increasingly important role in China's sustainable energy future.

1.5.2 Status of Small Hydro Power Utilization

It is estimated that the total installed capacity of small hydro power will reach 35 GW in 2010 and 50-55 GW in 2020. At that time, small hydro power plant above 100 MW will be installed in more than 300 countries in China.

1.6 Ocean Energy

Ocean energy includes tidal energy, wave energy and ocean thermal. China has a long coastal line of 18,000 km. It is estimated that there is around 110GW ocean energy (Meishan Municipal Science and Technology Bureau, 2002), within which the exploitable energy is 28 GW (Chinese Public Network of Science and Technology, 2003).

With the fast development of coastal areas, the island exploitation is becoming pressing. The residents on the islands face energy shortage, especially the islands far apart from the

mainland. Ocean energy exploitation is an option to ensure the sustainable and fast development of the coastal and island economy.

1) Tidal energy

Tidal energy is mainly used for power generation. Investigation shows that there are altogether 424 dam sites with the recoverable installed capacity of over 200 kW. The total installed capacity is 21.79 GW and annual power generation approximately 62.4 TWh. These resources have an uneven distribution in China's coast and Zhejiang and Fujian have the richest resources—88.3% of the total in China and 10.33 GW and 8.91 GW respectively. Following regions include the north branch of Yangtze River estuary (Shanghai & Jiangsu, 704 MW), Liaoning (594 MW) and Guangdong (573 MW). The resource in other coastal areas is relatively poor. Recently exploitable tidal energy is mainly located at Zhejiang and Fujian.

2) Wave energy

Wave energy is another kind of ocean energy mainly used for power generation. The average annual wave power density in the majority of China's coastal areas reaches 2-7 kW/m.

2. Government Policies and Industrial Base

Since 1970s, for realizing the limitation of traditional energy and their negative impacts on environment, many countries began to develop various policies to spur the research and development of renewable energy. Chinese governments are taking efforts too. However, during the earlier stage, many of the regulations issued by the government are only general statements on the benefits of renewable energy and provide no legal changes that appreciably affect renewable energy development. So, if there are any major changes to be expected and concrete measures to be taken, those regulations must not only be plans approved by governmental agencies, but laws that have been fully reviewed and ratified by the State Council and/or the National People's Congress.

2.1 China's Current Renewable Energy Policies

The primary energy policies published by the Central Government to expand renewables are as follows:

2.1.1 By Laws

- People's Republic of China Electricity Law

This is China's first law on energy. The first Chapter, " general principles", states that the state encourages and supports renewable energy and clean energy based power generation. Chapter VI, "Power Construction and Consumption in Rural Areas", also stresses the importance of renewable energy.

In the 9th five-year plan for China's national economic and social development, the energy development strategy was defined as "centered around the coal based electric power with enhanced survey and development of petroleum and natural gas resources." The policy also stressed the necessity for developing small hydro power, wind, solar, geothermal energy and bioenergy. It was during this period of time, the renewables got a quick development and entered into a new stage.

- Energy Conservation Law

The 1998 Energy Conservation Law described the important role and strategic position of energy efficiency and renewable energy in bringing about emission reductions and environmental improvement. The Energy Conservation Law described the important role and strategic position of energy efficiency and renewable energy in bringing about emission reductions and environmental improvement. In its article 4, it emphasized that: "Energy conservation is a long-term strategy for national economic development" and "The state encourages the development and utilization of new and renewable sources of energy".

Although issued dozens of rules and regulations for energy conservation, the law didn't provide specific goals and operations methods for energy conservation, so the effects were limited. Nowadays, experts and policy-makers are making efforts to revise this law and to make it updated, more specific and operational.

- The Renewable Energy Law

On March 1, 2005, Chinese government passed the renewable energy law which is intended to increase production of energy from sustainable sources. Aims to increase the usage of solar and wind power to 10% of China's total energy consumption, this law will be in effective from early 2006.

The new law also provides a host of practices to ensure that renewable energy can be produced, marketed and used. It orders power grid operators to purchase "in full amounts" resources from registered renewable energy producers within their domains. It also encourages oil distribution companies to sell biological liquid fuel on the sidelines. According to the law, power grid operators should buy renewable-source-generated power at directed prices calculated by the government. The extra will be shared throughout the overall power network. The law also offers financial incentives, such as a national fund to foster renewable energy development, and discounted lending and tax preferences for renewable energy projects. Although some people thought some of the goals described in the law are ambitious, it has proved Chinese government's new efforts to pursue a sustainable energy path.

2.1.2 By Energy types

- Wind Power

One of the most concrete laws was the 1994 Regulation for Grid-connected Wind Power Generation Management. This document stipulates that wind power shall be allowed access to the nearby grid and the network shall purchase all output. The wind power tariff shall be

determined based on the cost (both principal and interest repayment) plus a reasonable profit. The incremental cost of wind power above the average electricity tariff is also supposed to be shared by the whole grid. Although this policy seems quite clear and straightforward, some utilities still got ways to get around this regulation, and this policy has not lead to greater wind development as it was expected for.

- Small Hydropower

In 1960s, the Chinese government issued the policy: "construct independently, manage independently and use independently" to encourage the local governments to develop the small hydropower and meet the energy needs of the local people. Thus, we should say that the fast growth of China's small hydropower industry comes from the direct policy support of the central government. Since 1960s, to further expand the small hydropower industry, the Chinese government adopted a series of policies benefiting the construction and development of small hydro generation. For example, small dams can be owned by private businesses, which can receive subsidies from the government. Also, the government provided discounted value added tax to the developers.

2.1.3 Other Local Policies

At present, about 10 provincial authorities such as those in Hebei and Shandong, have ratified laws related to renewable energy. These laws and regulations were shaped on the basis of existing problems and actual needs in the course of rural energy project construction and new energy development. These documents have played an effective promotion role in spurring renewable energy development in these areas.

As an example of local policy, the Shanghai municipal government allocated a financial appropriation of 10 million Yuan for a fund dedicated to the promotion of biogas projects using a market mechanism based on demand growth. Some local authorities such as those in Liaoning and Dalian provide 700 Yuan subsidy for farmers who used biogas to heat a

greenhouse or nursery. This is in addition to low-interest loans of up to 2000 Yuan for each system.

2.2 Legal and Institutional Base for Renewable Energy

2.2.1 Major agencies dealing with renewable energy

The government agency which engaged in renewable energy technology and development in China are: National Development and Reform Commission (NDRC) created by the recent government reform of 2003 which disbanded previous State Development and merged with former State Planning and Development Commission. Ministry of Science & Technology (MOST), Ministry of Agriculture (MOA), Ministry of Water Resources.

National Development and Reform Commission (NDRC) is the comprehensive economic management commission in charge of formulating the National Economic Development Plan, Five Years Plan and National Long Term Program. The Energy Bureau in NDRC which has two key divisions: Renewable Energy and Rural Power Division, Energy Efficiency Division under the department of Environment and Resource Utilization. NDRC is responsible for energy projects approving and planning, The division of renewable energy under Energy Bureau will be responsible for formulating the Renewable Energy Yearly plan, Five-Year plan, Long Term Program and for investment project approving, and is responsible for macro regulation on enterprises operation and approving the technology transformation project of enterprises. It is also responsible for formulating the Macro Investment Policy on Renewable Energy Development and Long Term Development Policy on Renewable Energy Industry.

- Energy Research Institute

Energy Research Institute (ERI) is a national research organization conducting comprehensive studies on China's energy issues. ERI is administrated by the National Development and Reform Commission. The main principles of research at ERI include: As a national research institute specialized in macro and comprehensive study on China's

energy issues, ERI employs in all the important fields of energy policy and economic research including the exploitation, utilization and management of different types of energy, etc. ERI provides the government with advises, policy suggestion, and information in the development of energy strategies, policies, standards, plans, and administration programs. The institute also provides energy consultation service to businesses working closely with the central government; ERI has good relation with the local governments, as well as the enterprises.

- Center for Renewable Energy Development

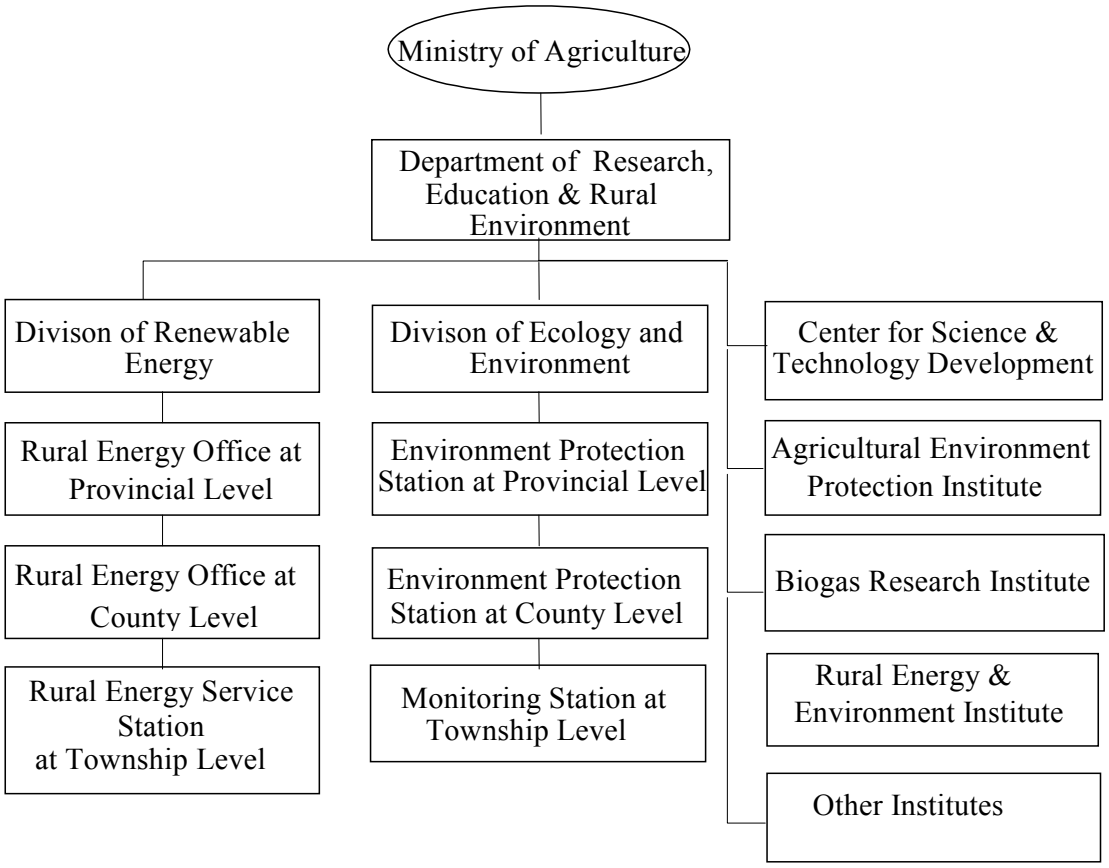
Center for Renewable Energy Development (CRED) is subordinate to the Energy Research Institution (ERI). As a non-profit research and development agency headed directly by ERI, the Center's main duties are: engaging in research activities on technologies and strategic policies of renewable energy and rural energy; promoting the process of commercialization of renewable energy technologies.

Ministry of Science & Technology (MOST) is the comprehensive management ministry on national significant science and technology research. The Energy Division of New and High Technology Department is in charge of regulating and organizing the significant science and technology project concerning renewable energy technology. MOST and SDRC jointly formulate the Five Years Plan on science and technology and are responsible for organizing and implementing the renewable energy science and technology research project.

Ministry of Agriculture (MOA)

The Ministry of Agriculture (MOA) is responsible for implementing rural energy programs and demonstration projects to improve agricultural production capacity, promote the rural economy and increase farmer's income. It is also responsible for technical assistance and training services for farmers to enable them to utilize renewable energy technology efficiently in farm operations.

The framework of rural energy service and assistance provided by MOA is illustrated in the following Figure. The local rural energy offices (REOs) and service stations play a key role in rural energy development in China. Together the REOs and service stations provide technologies and products, installation services, technical assistance and support, local technician training and maintenance services .



Former **Ministry of Electric Power,** changed to State Power Corporation, handles business aspects of the industry, with generation and transmission the responsibility of regional subsidiaries. Now it was restructed into two Transmission System Operators (State Power Grid and Southern Power Corporation) and five generation companies (Guodian, Huadian, Huaneng, Datang, China Power Investment) and four auxiliary engineering and service companies. Recent reforms have also included the creation of a new regulatory body, the State Electric Regulatory Committee.

The Ministry of Water Resources (MOWR) is of the view that the overall concepts of the recommendations are of high value for enhancing water resources management in China, resources and regulates China's hydropower production. Bureau of Hydro Power under MOWR is working on renewable energy – small hydro power, and responsible for hydro power planning and development, coordinate with related official departments for rural hydro power development, investment and construction, operation and management.

- **Chinese Renewable Energy Industries Association**

The Chinese Renewable Energy Industries Association (CREIA), established through the UNDP and Global Environmental Facility (GEF) project, is a business-led, independent, and self-financed association, working for the interests of its industry members. CREIA serves as a liaison between regulatory authorities, research institutes and industry professionals. It provides a forum to discuss renewable energy development at the national level and subsequently to advise the central government on strategic policy formulation. CREIA is intended to be a window bringing together national and international project developers and investors. It plans to promote technology transfer and raise awareness of renewable energy investment opportunities through the development of an online Investment Opportunity Facility, and through regional networking meetings and training activities.

- **China Association of Rural Energy Industry**

The China Association of Rural Energy Industry (CAREI) has been established to support the development of rural energy industries. This institution takes responsibility for supervising and providing production support to rural energy industries, and ensure quality control. Other services include investigation, data collection on rural energy industry, cooperate with governmental agencies on decentralized area-based rural energy planning, co-ordinate the development of all possible alternative sources of energy concurrently, but with priority given to the renewables.

2.2.2 Major investment Programs

- **Integrated Rural Energy Development in One Hundred Counties**

During the Eighth Five-Year Plan period, ‘‘Integrated Rural Energy Development in One Hundred Counties’’ was organized as one of national construction programs by the Ministry of Agriculture, State Planning Commission, State Economic and Trade Commission, State Science and Technology Commission and four other ministries or commissions. As a result, large-scale integrated rural energy systems were built up in one hundred counties. The selection of the counties was based on indicators of local natural resources, population, economic development status and availability of funds. Under the leadership of the county government, researchers used the methods of systematic engineering to scientifically evaluate and analyze various energy construction projects on the basis of resource investigation and planning. They drew up comprehensive plans in accordance with the principles of rural energy development, and set up the systems in line with local economic and social development targets. While executing the projects, the idea was to rely fully on the progress of science and technology to apply various advanced technologies, exploit local resources, effectively utilize and conserve energy resources, gradually establish a system of mutual complementing of multiple energy resources so as to suit a market-oriented economy in rural areas, strengthen the establishment of industry and the development of energy-saving products, establish and perfect the energy management and service system, and ultimately, ensure the achievement of integrated results in energy, economic, environmental and social aspects.

After five years of efforts, the 100-county rural energy development program has achieved the following obvious fruits.

- Various kinds of renewable energy resources available locally were exploited, including forests of 1.70 million ha area, over 20,000 household biogas digesters, 500 MW installed capacity of small hydropower, with solar water heaters of 386,000 m2 collector area, passive solar houses of 1.83 million m2 area, 3,000 small household wind turbines and 99 geothermal wells. These resulted in annual exploited energy

capability of 316.4 PJ. After completion of different kinds of technological innovation projects there was established an annual energy conservation capacity of 333.1 PJ.

- Multi-purpose utilization and renewal of resources were realized. For example, agricultural wastes such as livestock excrement were disposed of by anaerobic digestion technologies, and transformed into biogas as fuel and efficient organic fertilizer. Thus, integrated development and utilization of biomass was put into practice so as to promote the development of ecologically efficient agriculture.
- The rapid development of electricity utilities raised the proportion of towns, villages, and rural households connected with electricity grids to 99%, 97.9%, and 94.7% in 1995 respectively from 93.5%, 88.9%, and 85.4% in 1990. (Ma, 2004)

❖ Ride the Wind Program

NDRC initiated a market model of "demand created by the government, production by joint venture enterprise, and ordered competition in the market." Wind farm projects approved by NDRC during the Ninth Five-Year Plan (1996-2000) required that wind turbine generator (WTG) equipment purchased for these projects contain at least 40% locally-made components. Under this program, several international and Chinese companies capitalized on this requirement and formed joint venture companies for 600 kW and 660 kW WTGS (NREL, 2004).

The following results have been achieved as the part of first stage of Brightness Program:

- Installed 1,780,000 household systems, 2000 village systems, and 200 station systems;
- Established national and local government bureau financing approaches and practical financial mechanism;
- Established industrialized production enterprises which can fulfill the demand of the market;
- Set up a distribution and service network and marketing mechanism;
- Installed a technical training system providing different levels of training for local technicians and engineers.

Progress toward reaching the goal of Brightness Program include: signing of a project agreement between three provincial planning committees and National Development and Reform Commission/Chinese Academy of Sciences (NREL, 2004).

- 863 Wind Program

During the Tenth Five-Year Plan (2001-2005) MOST is supporting R&D programs to develop megawatt-size wind turbines, including technologies for variable pitch rotors and variable speed generators, especially on clean coal and new energy sources such as fuel cells

- Brightness Program

It was launched by the Chinese Government during 1996 till 1999 . The plan is to speed up the activity of decentralized electrification of remote rural areas; it is also a positive response to the proposal of the world solar summit in Zimbabwe. It is planned that 23 million people in remote area shall be electrified by wind and PV technologies till 2010 with an average capacity of 100 W per capita. The total installed capacity will reach 2,300 MW then.

Under the leadership of SDPC, the pilot projects were lunched in March 2000. Inner Mongolia, Gansu and Tibet were selected as pilot provinces. SDPC allocated RMB 20 million grant for the projects and installed a executing system. About 5500 sets of Wind/PV hybrid home systems, 1 village system were installed in Inner Mongolia by end of 2003. And about 10,000 solar home systems and 3 PV mini-grid village systems were installed in Gansu by end of 2002. Six PV village systems around 6 kW were installed in Tibet by end of 2001(Ma, 2004).

- Capacity Building for the Rapid Commercialization of Renewable Energy in China

In March 1999, amidst a growing recognition of the contribution that renewable energy can make to sustainable development, the Government of China launched the project, *Capacity*

Building for the Rapid Commercialization of Renewable Energy in China. The Project supports a market-oriented approach to increasing the more widespread adoption of renewables, addressing a number of critical issues holding back the commercialization of renewable energy in China today. Strong international support from the Governments of Australia and the Netherlands, and from UNDP/GEF, has made possible an ambitious programme of activities. The project's targets are:

- To develop national capacity for identifying, developing and implementing commercial renewable energy projects and to assist in accelerating the commercial adoption of these technologies.
- To lower existing technical, institutional and policy barriers to the commercialization of market-ready renewable energy technologies.

❖ Township Electrification Program

In late 2001, China's State Development and Planning Commission (renamed the National Development and Reform Commission [NDRC] in 2003) launched an ambitious renewable energy-based rural electrification program known as Song Dian Dao Xiang, literally "Sending Electricity to Townships." The objective of the program is to supply power for the basic needs of the 1,065 not-connected township locations, which are distributed in 12 provinces, by use of small hydropower, PV and PV/wind hybrid systems under consideration of the actual resource-situation of the location. 688 PV or PV/wind hybrid mini-grid systems with a total capacity of 20 MW will be installed by the end of 2004, most of them have been in operation; 377 small hydropower mini-grid systems with a total capacity 264 MW will be installed by the end of 2005; The total investment was RMB 4.7 billion; All of the townships of China are supplied then; More than 1 million people benefits from the program.

In just 20 months, the program electrified more than 1000 townships in nine western provinces—Xinjiang, Qinghai, Gansu, Inner Mongolia, Shaanxi, Sichuan, Hunan, Yunnan, and Tibet—bringing power to nearly one million people and providing the basis for rural economic development. Installation was completed in June 2003 and consisted of 20 MW

from PV, 840 kW from wind, and 200 MW from small hydropower (in Hunan and Yunnan provinces). The government provided 240 million U.S. dollars, or 2 billion Chinese Yuan, to subsidize the capital costs of equipment, and is now drafting guidelines for tariffs and system ownership.

The next phase of this initiative will be the Village Electrification Program, which is targeted for 2005-2010 and will electrify another 20,000 villages in China's off-grid western region. Capacity building will be an important component of this phase, and NDRC will work with Jikedian Renewable Energy Development Center, National Renewable Energy Laboratory, Institute for Sustainable Power, and international and local agencies to develop and implement a training program for national- and local-level engineers and technicians. The training certification system has been an integral part of China's 1998 Brightness Program, and indeed human capital is the key to the sustainability of rural electrification initiatives.

Other inputs that will be critical to overall program sustainability include system design, productive use components, load management, system monitoring, reliable batteries, and appropriate tariffs. The Township Electrification Program is one of the largest renewable energy-based rural electrification programs in the world, and it has enough critical mass to create a truly robust and sustainable renewable energy infrastructure in China, especially for PV. The program represents an important launch point, as the lessons learned will have an immediate impact not only on future objectives of rural electrification, but also ostensibly on renewable energy programs worldwide. As commercialization of renewable energy technologies advances in China, market opportunities will be considerable for joint ventures between Chinese and international companies. Such ventures provide a powerful tool for meeting China's environmental challenges.

2.2.3 Renewable Energy Industry Structure

- **Solar**

Currently China's solar industry is mainly government program driven – that's to say, that the industry is still not commercially built up. Most of the PV projects are either government sponsored with international aides or within the framework of government programs at national or local levels. Major programs such as the Brightness Program and the Township Electrification Program are still the dominating solar photovoltaic power businesses for local and international companies, see details as follows.

- **Wind**

The exploitation of wind energy began in the early 1970s and it initially focused on the development of small wind turbines. The primary purpose of exploiting wind energy was to supply electricity to those people who live in poor rural areas without a grid connection, such as herdsmen and residents in remote pastoral areas or isolated islands. After 30 years of effort, small-scale wind generation technologies have matured and more than ten types of wind generation units with a range of capacity between 100 W and 10 kW can be manufactured in China. Over 170,000 sets of small-sized wind turbine generators with a capacity of 100Ws and a few off-grid hybrid generation systems with a capacity of 1kW–10kWs have been installed, around 80% of which (140,000 sets) were installed in Inner Mongolia Autonomous Region .

The development of grid-connected wind power started in the late 80s and the first wind farm was built in Rongcheng County in eastern China's Shandong Province in 1986 using equipment from Denmark. In the same year, another pilot wind farm was built in Pingtan County in Fujian Province in southeastern China, supported by a grant from Belgium. After these two pilot projects, wind farms began to be built throughout the country, mainly using imported wind turbines. The installed capacity of wind power increased rapidly.

- **Small hydropower**

Since 1950s, the small hydro power (SHP) business in China has developed rapidly. With its development, the design capability and production capacity has also developed very fast.

China's first 800 kW water turbine unit was manufactured in 1952. During1960s, ten special water turbine manufacturing units were formally established with annual production capacity of 100 MW. With the advent of 1970s, the number of special factories reached 60 with annual production capacity of nearly 1 GW. The industry was able to manufacture a series of products and to realize automatic speed-regulation operation of units. Up to date, there are more than 100 SHP equipment manufacturers with annual production capacity of over 1.5 GW. In order to expedite the development of SHP in China and to meet the demand from rural electrification, the related sectors have researched and laid down the standards for seriation and uniformity of SHP equipment. There are now 26 standard types of water turbines with 83 varieties of products. The range of water head goes from 2.5m to 400m. The capacity of a single unit ranges from several kW to 10 MW. The fact that the existing power stations are operating well shows that various types of hydroelectric generation machinery designed under unified standards give satisfying performance and fulfill the requirements of design. These products have good stability in operation and are attractively designed too. Moreover, they are highly generalized in applicability, seriated, and standardized and have uniform installation dimensions and uniform standards for wearing parts.

3. Market Perspective

In this section, several renewable energy types will be examined from the perspectives of current development status, technology and barriers. They are mainly solar PV, solar thermal (solar water heater), wind and small hydro. Other renewables such as geothermal and ocean energy are also briefly mentioned in the text. But due to the available literature information, they will not be described in details.

3.1. Current Development Status

Over the past decades, the Chinese renewable energy industries have made significant achievement but also confronted with challenges. In 2003, the annual production of solar PV cells is 15 MW with 53 MW of cumulative installed capacity. The annual production of solar water heater in 2005 is 1.1 million m^2, the cumulative installed area size is 64 million m^2.

On-grid installed wind power capacity is 1.2 GW in 2005 with the annual power generation of 150~2000 MWh. There is about 2 billion m^3 biogas produced yearly, and 20 million m^2 heating area with geothermal utilization in 2005.

The "Tenth Five-Year Plan and Regulation by 2010 on Chinese New and Renewable Energy" formulated by the National Development and Reform Commission (NDRC) indicated that, in 2005, the use of new and renewable energy (excluding small hydro and conventional biomass) is 13 million TOE with significant emissions reduction (10 million tones of CO_2 and 600,000 tones SO_2 and dust), providing electricity to 1.3 million households (approximately 5 ~ 6 million population) and creating about 200,000 jobs. In order to achieve the goal set above, investment into research, development and demonstration (RD&D), and technology transfer is needed. According to expectation of NDRC, most of the investment will come from private channels and commercial loans while few available from governments. Self-financing is mainly used for project construction, equipment purchasing, installation and operation while governmental investment primarily focuses on technology transfer and capacity building such as standardization, quality control, personnel training and project demonstrations.

Table 3-1 Demand on Investment for the Tenth Five-Year Plan and Regulation (2010)

	Baseline			Policy Scenario		
	10th Five-Year (2001~2005)	11th Five-Year (2006~2010)	Total (2001~2010)	10th Five-Year (2001~2005)	11th Five-Year (2006~2010)	Total (2001~2010)
Power Generation						
Small Hydro	182.99	192.4	375.39	190.17	120.75	310.93
Solar PV	15.8	16.01	31.8	20.35	29.65	50
Wind	9.01	20.21	29.22	20.71	32.6	53.31
Geothermal	0.4	2.8	3.2	1.2	2.8	4
Biogas	0	0	0.01	0	0.01	0.01
Paddy Hull	0	0.01	0.01	0	0.01	0.01
Bagasse	0.32	0.6	0.91	0.68	0.75	1.43
Sub-total	208.52	232.02	431.53	233.12	186.57	419.69
Thermal Utilization						
Solar Water Heater	38.84	45.06	83.9	71.92	118.7	190.61
Solar Heating	0.86	1.12	1.98	1.19	2.77	3.96
Thermal Heating	2.83	4	6.84	3.76	6.86	10.62
Thermal Cultivation	1.11	2.3	3.41	2.5	3.45	5.95
Solar Stove	0.02	0.03	0.05	0.03	0.04	0.07
Large scale Biogas	0.62	1.28	1.9	0.98	1.55	2.54
Household Biogas	2.1	3.92	6.02	4.47	4.91	9.38
Straw Gasfication	0.04	0.09	0.14	0.07	0.11	0.18
Sub-total	46.42	57.81	104.23	84.92	138.39	223.32
Total	254.95	289.83	535.76	318.04	324.96	643.01

Source: http://www.chinamining.com.cn/news/listnews.asp?classid=154&siteid=2167

Since 1996, with the implementation of the "Ride the Wind" program and "Brightness Program", the national government gradually enhanced its investment on renewables. In 1998, the National Planning Commission appropriated 5 million Yuan to support the biomass project in Lanzhou city. In the end of 1999, the National Planning Commission appropriated 7.5 million Yuan for the "Ride the Wind" program to support the development of domestic wind turbines. And, for the "Brightness Program", the accumulated investment during the past years will amount to 36 billion Yuan.

NDRC also estimates the investment in new and renewable energy from 2000 to 2010 by two scenarios, see details in the Table 3-1.

The current market status and domestic investments of different energy type will be described by renewable energy (solar, including PV and thermal utilization, Wind, Biomass, small hydro and ocean energy)

3.1.1 Solar PV

It is for several decades that China has used solar PV technologies. In 1973, solar PV was, for the first time, been used for a lighthouse in Tianjin harbor. At that time, the production of PV cells was rather low — annual production was less than 10 kW, while the price was extremely high. Due to the low production and high cost, the expansion and penetration of PV products was very slow. Only a few of the small power PV products were used for lighthouses, railway guidance, etc. During the period of China's sixth and seventh Five-Year Plan (1981-1985 and 1986-1990 respectively), central government has begun to recognize the importance of solar PV development. Since then, both central and local governments have invested a lot of money and human resources into PV industry, by researching and setting up demonstrations in various fields such as micro-wave relay stations, cathode protection system of oil pipes, carrier telephone systems, small home systems (SHS) and village PV stations. In the seventh Five-Year period, several production lines of PV products were introduced into China. Except there was one production line with the capacity of 1 MWp for amorphous silicon production, others were mono-silicon production lines. Then, the annual PV production in China reached 4.5 MWp and the actual sales at that time reached 0.5 MWp. Meanwhile, the initial price for PV cells had dropped from 80 Yuan[1]/Wp to 40 Yuan/Wp. The combined effect of improved production and reduced cost made it possible for PV market to grow. As a consequence, solar PV has been largely used for communications, transportation, oil transmission, rural electrification and household products. Solar PV was not only listed among the prior national

[1] The exchange ratio of US$ and Chinese Yuan is roughly: Year 1988， $1=￥3.5--3.8；1989—1993，$1=￥5.3--5.7； 1993—date，$1=￥8.3—8.9.

research programs, but also been included in some important constructive projects such as the Brightness Program etc. In year 2001, the actual sale of PV cells was 4.5 MWp, and the cumulative PV installation was over 20 MWp by then.

In 2002, the NDRC launched the Township Electrification program, which aimed to use solar PV and small wind as ways for providing electricity in nearly 800 townships in seven western provinces (Tibet, Xinjiang, Qinghai, Gansu, Inner Mongolia and Sichuan). Under this program alone, 19.6 MWp PV cells and 840 kWp wind turbines were installed. Incited by governmental programs and the successful application, the whole PV industry was boomed. Soon the annual domestic production capacity reached 100 MWp. The real sale in 2002 was 20 MWp. By the end of 2003, the cumulative installation of solar PV was 55 MWp. Meanwhile, not all of the solar PV products were supplied in the domestic market. After 1995, most of the amorphous PV products were exported. From 2003 on, a small part of crystalline silicon was exported.

Table 3-2 shows the historical statistics of annual production, price and cumulative installation of solar PV in China. Along with gradual growth of annual production, the price dropped significantly. Nowadays, the price for amorphous-silicon solar cell is 20 ~ 25 Yuan per peak watt, for crystalline silicon solar cell is 25 ~ 30 Yuan per peak watt. The cumulative installation grow slowly until 2001, when Township Electrification program initiated, there is a big surge of PV installation.

Table 3-2 Annual Production, Prince and Cumulative Installation of Solar PV Products (1976 ~ 2003)

Year	Annual Production (KWp)	Price (Yuan/Wp)	Cumulative Installation (KWp)
1976	0.5	400.0	0.5
1977	1.0	200.0	1.5

1978	2.0	120.0	3.5
1979	5.0	100.0	8.5
1980	8.0	80.0	16.5
1981	15.0	75 - 80	31.5
1982	20.0	70.0	51.5
1983	30.0	60.0	81.5
1984	50.0	50.0	131.5
1985	70.0	45 - 50	200
1986	80.0	40 - 45	280
1987	100.0	40.0	380
1988	a-Si 200.0 c-Si 150.0	a-Si 21-23 c-Si 35-45	730
1989	a-Si 300.0 c-Si 250.0	a-Si 23 c-Si 35-37	1280
1990	a－Si 100.0 c－Si 400.0	a－Si　22－25 c－Si 38－40	1780
1991	a-Si 100.0 c-Si 450.0	a-Si 23-25 c-Si 38-40	2330
1992	a-Si 150.0 c-Si 500.0	a-Si 25 c-Si 40-42	2980
1993	a-Si 250.0 c-Si 650.0	a-Si 25-27 c-Si 40-47	3880
1994	a-Si 200.0 c-Si 900.0 imported 100.0	a-Si 25-27 c-Si 40-47	5080
1995	a-Si 200.0 c-Si 1000.0 imported 350.0	a-Si 25-27 c-Si 40-47 50-60	6630
1996	a-Si 450.0 c-Si 1420.0 imported 300.0	a-Si 25-27 c-Si 40-47 50-60	8800.0
1997	a-Si 500.0 c-Si 1500.0 imported 300.0	a-Si 25-27 c-Si 42-47 46-60	11100.0
1998	a-Si 430.0 c-Si 1670.0 imported 200.0	a-Si 25-27 c-Si 40-45 45-60	13300
1999	a-Si 500.0 c-Si 2000.0 imported 200.0	a-Si 22-25 c-Si 38-45 45-60	16000
2000	a-Si 600.0 c-Si 2200.0 imported 500.0	a-Si 20-25 c-Si 35-45 45-60	19000

2001	a-Si 300.0 c-Si 4000.0 imported 200.0	a-Si 20-25 c-Si 35-45 40-50	23500
2002	a-Si 300.0 c-Si 15000.0 imported 5000.0	a-Si 20-25 c-Si 30-35 30-40	≈ 45000
2003	a-Si 1000.0 c-Si 7000.0 imported 2000.0	a-Si 20-25 c-Si 25-30 25-30	≈ 55000

* Year 1988， $1=￥3.5-3.8；1989 —1993，$1=￥5.3-5.7； 1993—date，$1=￥8.3-8.9

Source: REDP, 2004.

By the end of 2003, the market share of solar PV products in China. Rural electrification is the largest field in which PV is applied. 51% of all PV products (28 MWp) go to rural electrification. Communications and industries now become the second major application, having 36% of the whole market, namely, 20 MWp. Commodities take up to 9% of PV market (5MWp), and 4% of solar PV products (2MWp) contribute to on-gird generation (see details in section 1).

3.1.2 Solar Thermal

In terms of solar water heating, China has been the world's biggest producer and consumer for many years. Annual growth in the solar water heater market in China was about 27% in average between 1998 and 2002 in terms of square meters installed. By the end of 2003, the cumulative installed area was 52 million m^2 (Hua, 2005), and there are over 1,000 factories and dealers in the solar water heater industry in China. This industry employed 200,000 people in 2002 with an annual revenue of 11 billion Yuan ($1.3 billion) and 80 million Yuan ($10 million) revenue from export. The top eight manufacturers each have an annual turnover of more than 100 million Yuan ($12 million) (Hua, 2005). The Chinese government sets a national target for 65 million m^2 of cumulative solar collector area by 2005, while there is a further target for 230 million m^2 by 2015 (NDRC, 2003).

The solar water heaters in China are mainly for residential use, including urban to rural areas. Nowadays, solar water heater is a hot sale product, especially in the provinces of Jiangsu,

Zhejiang, Shangdong and Yunnan, where most of the manufacturers are, and penetrates to mega cities such as Kunming, Shanghai and Tianjin.

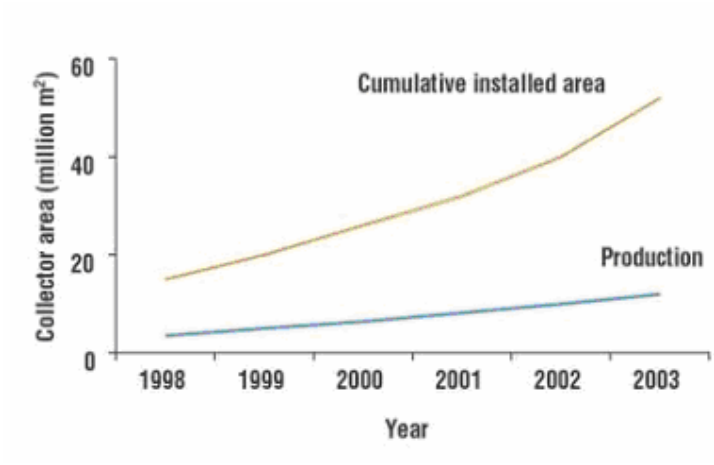


Figure 3-1 Market development of Solar Water Heater, 1998-2003 (Hua, 2005)

A new application of solar water heaters is building-integrated SWH system, which would be installed on building's rooftop or wall. It would provide hot water service to the buildings. However, it is not yet being adopted in China due to the challenges, including the shortage of perception and motive in properties' owners, real estate developers. In the long run, the further development of SWH should be integrated with the real estate industry. And the public preference has an influence on the market already. For example, in the southwest Kunming city, houses without solar water heating are not attractive to buyers due to the high energy costs. Therefore, most of the new buildings in the city are incorporated solar systems.

The application of SWH in China is becoming larger and larger. From the perspective of utilization areas, the development of solar water heater has from small coastal towns to large cities; from traditional residential use to commercial utilization and from distributed system to integrated water heating system. Now the market share of solar water heater is keep growing.

3.1.3 Wind Power

China started the wind power generation since 1980s. The wind energy is exploited in two ways, off-grid small turbine and on-grid large-scale wind farm. Small turbines are mainly

employed to provide rural people electricity service in remote areas. Why small turbines in Inner Mongolia wildly spread is due to local governmental great support and market demand. Since early 1980s, Inner Mongolia government has launched financial subsidies to households whoever purchases a small turbine, say, 200 Yuan per 100W. The small wind turbines produced in Inner Mongolia are reliable and of high quality, now Inner Mongolia becomes the largest small turbine manufacturing center in China and world as well.

Large-scale wind energy application started from the beginning of 1980s. However, it was in the 1990s that wind energy began its commercialized development. Until 1994, when the Ministry of Electricity published relevant regulations of on-gird wind power generation, wind energy began to attract attentions. Xinjiang, Inner Mongolia and some coastal areas in southeast China are the three places with early application of wind energy. By the end of 1996, the installed capacity of wind generation was 60 MW. The largest wind farm is located at Dabancheng in Xinjiang province, of which the capacity was 12.1 MW by the end of year 2002 (Xinjiang Wind Company, 2003).

The "Riding the Wind" program initiated in 1996 advocates local manufacturing technology of large- and medium- scale wind turbines. In the period of the Tenth Five-Year Plan, it is planned to invest 1.5 billion Yuan into wind industry (Xu, 2003). Currently, the cumulative installed small turbines across the country is nearly 200 thousand sets, which play an important role in rural electrification. 26 wind farms were constructed in Guangdong, Fujian, Zhejiang, Liaoning, Inner Mongolia and Xinjiang with single turbine capacity range from 200 kW to 1300 kW.

The Tenth Five-Year Plan (2001 ~ 2005) calls for a wind capacity boost, 1.5GW by 2005. With proper financial incentives and policy support, China could easily surpass this target. The short-term objective is by year 2005, the capacity of on-grid wind generation to be 1.2 GW (Xu, 2003).

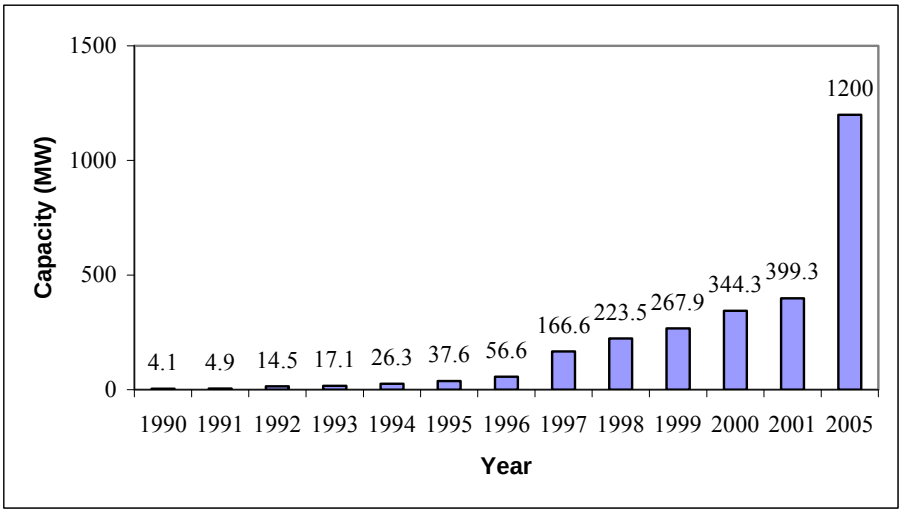


Figure 3-2 Installed Capacity of Wind Power in China

Source: http://www.newenergy.org.cn/energy/wind/read.asp?id=611

According to Wired news (2004), the world's largest wind power project was initiated in October 2004 near Beijing, which will bring green energy and cleaner air to the 2008 Summer Olympics and city residents coping with some of the worst air pollution in the world. The new wind power plant in Guanting, 60 miles away from Beijing downtown, will provides 400 MW at its full capacity, nearly doubling all wind power capacity in current China. In the summer of 2004, at a climate change conference in Bonn, Germany, China surprised many by announcing it will generate 12 percent of its energy from renewable sources such as wind by 2020.

3.1.4 Biomass

China is a big country where agriculture constitutes the very foundation. Poverty alleviation and the satisfaction of basic human needs remain as urgent priorities. For a long time, the straw firewood and other biomass waste were main fuel for the rural residential energy consumption. The rural economy and living standard are restricted by the shortage of the energy supply. Rural energy development is related to the upgrading of people's living

standards, the improvement of ecological environment and the sustainable development of rural economy.

The biomass energy is the most important rural energy resource in China. There are abundant biomass resources in China including crop residues, firewood and various kinds of organic wastes. Biomass accounts for about 70% of the energy consumption of rural household (China Rural Energy Statistical Yearbook 1997).

China rural energy development started from the application of biogas digesters. Small and medium scale anaerobic digester system has been applied in China for several decades. Biogas was first introduced in China in the 1930s.With individual household-scale biogas digester technology developed in the early 1950s, a series of programs about development, technical support, and assisted technology dissemination were implemented in China, which resulted in biogas digester (simplified as biodigester) technology being widely adopted to provide fuel gas for rural household heating, lighting and cooking.

Since 1980 the GOC has launched RD&D to further improve the biomass and bioenergy technologies, notable achievements include the large and medium husbandry farm biogas engineering technology, straw and stalk gasification technology for central gas supply and refuse landfill power generation. (Zhang et. al., 1999) By year 2000, there are 7.6 million Chinese households with biogas digesters already, which can generate nearly 200 million cubic meters of biogas annually, and 748 large and medium-sized digesters treating 20-million-ton waste nationwide. The country has also set up over 500,000 sewage treatment facilities, with an annual treating capacity of 200 million cubic meters (CEEP, 2004).

In the practice of biogas multiple use it appeared different modes focusing on the biogas utilization in rural China. “Energy environment projects” and “ecological garden projects” are combined with biogas technology, agricultural production and environmental protection. (Wang, 2001) Integrated biogas use has become very popular. Ecological model for integrated biogas use — "pig-biogas-fruit" was developed in South China, and in North China, "4-in-1" model (pig, biogas, latrine and greenhouse) was dominating (Lu, 1998)

3.1.5 Small Hydro

Though, with the best hydraulic resources in the world, the percentage of power generated from hydro is very low in China. In 2001, the power generation from hydro was only 24.5% Usually in China, small hydro refers to hydro power plant with capacity less than 50 MW (Department of International Cooperation, MWR, 2003). For a long time, more than 1,000 hydro power stations have been constructed annually in china. Historical data of small hydro capacity and generation is shown as below.

Since 2001, the Department of Water Resources has arranged preparation for the Small Hydro as Fuel program. Principal aims of this program are to better the living and production life in rural areas, and also prevent the deterioration of ecology and environment. More than 1600 counties across China have launched the Small Hydro as Fuel Program. Most of them are located in western areas, while the exploitable small hydro is 80.61 million kW and expected annual generation is 2,749,000 GWh, thus could completely satisfy people's need for living fuels (Department of International Cooperation, MWR, 2003). The map of the program is attached below. According to the regulation, 28.3 million households (104 million people) will be electrified after the Eleventh Five-Year Plan (2006-2010).

Table 3-3 Historical data of installed capacity and annual generation of small hydro

	Small Hydro		Ratio of small hydro in hydro	
	Installed Capacity (Mw)	Annual Generation (TWh)	Ratio of Installed Capacity (%)	Ratio of Annual Generation (%)
1950	3.70		2.20	
1955	7.00		1.40	
1960	251.40		13.00	
1965	330.00		10.90	
1970	1019.00		16.40	
1971	1536.20	3.00	19.70	11.80
1972	1830.80	3.40	21.00	11.60
1973	2200.70	4.10	21.40	10.40
1974	2593.50	4.90	21.90	11.80
1975	3083.20	6.70	23.00	14.10

1976	3601.40	7.10	24.60	15.70
1977	4315.20	8.50	27.40	17.90
1978	5266.50	10.00	30.50	22.40
1979	6239.50	11.90	33.10	23.80
1980	6925.50	12.70	34.10	21.90
1981	7573.60	14.40	34.50	22.10
1982	8079.70	17.20	35.20	23.20
1983	8504.70	19.90	35.20	23.10
1984	9066.60	20.80	35.40	24.00
1985	9521.00	24.10	36.00	26.10
1986	10095.10	24.40	36.60	25.90
1987	11106.30	29.10	36.80	29.00
1988	11792.30	31.60	36.10	29.00
1989	12934.30	34.70	37.40	29.30
1990	13180.00	39.30	36.60	31.10
1991	13853.40	37.30	36.60	29.80
1992	14419.10	44.20	35.40	32.20
1993	15055.30	47.00	33.80	35.70
1994	15776.60	50.90	32.20	30.50
1995	16646.10	55.40	32.70	32.60
1996	19201.80	62.00	34.50	33.20

Source: http://www.cws.net.cn/water-power/anli-001.asp

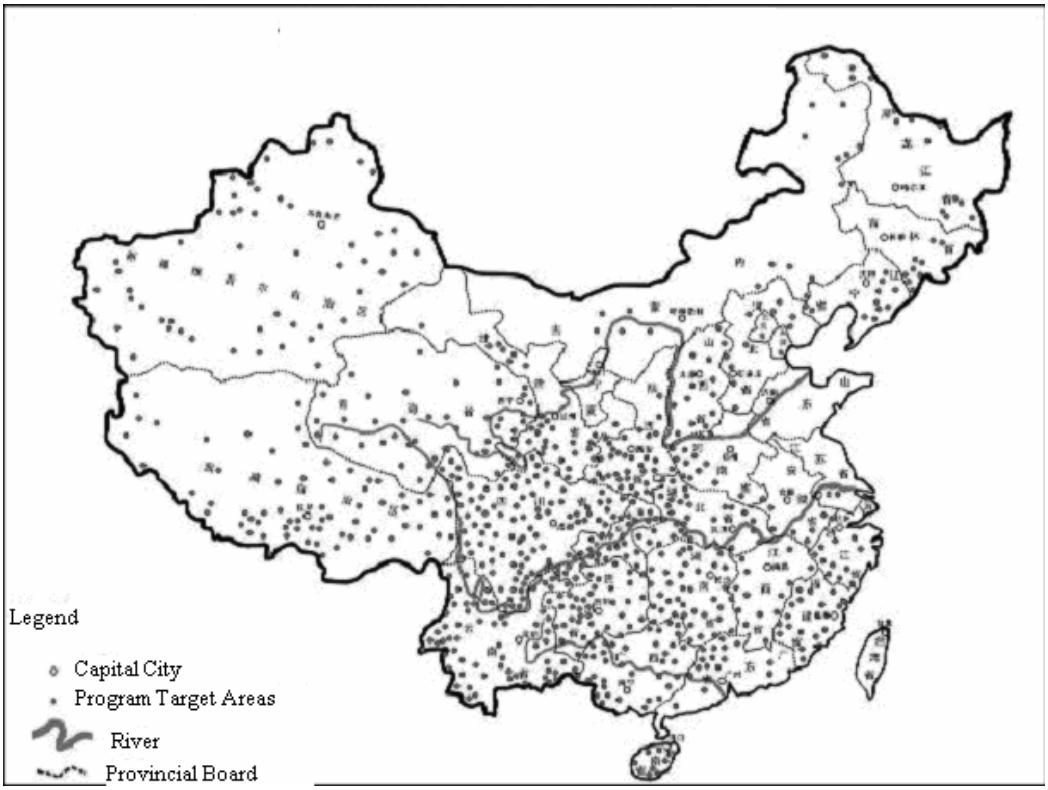


Figure 3-3 Map of Small Hydro as Fuel Program

Source: http://www.shp.com.cn/dairanliao/ziliao/showcontent.asp?id=8574

In 2004, China National Development Bank loaned 542 million Yuan to Guangxi for the province's Small Hydro as Fuel program, which will invest totally 778 million Yuan, benefiting 12.04 million people (Li & Zhang, 2005).

3.1.6 Geothermal and Ocean Energy

Geothermal

The development of geothermal power generation is relatively slow. The total installed capacity of geothermal generation in China is 35 MW (Sinoline Network Information Service Co., Ltd., 2005). The largest power complex is located at Yangbajing, Tibet. At the end of 1999, its total installed capacity was 25.18 MW (gross), generated by nine single flash, double flash and hybrid cycle power plants (World Energy Council, 2001; Xinhua Agency, 2004 and Gong, 2005). The primary development has been in the growth of geothermal energy used

directly. In 1998 it was reported that there were in excess of 1,600 sites being used for installations as diverse as drying, fish farming, irrigation and earthquake monitoring, etc (World Energy Council, 2001). Tibet, the region with the richest geothermal energy, has more than 700 geothermal sites, 342 of which are exploitable and contain energy equal to 31.53 billion TCE (Xinhua Agency, 2004). Geothermal energy resources in this region have the capacity of no less than 1 million kilowatts of electricity (Xinhua Agency, 2004). In its application document for Olympics in 2001, the Beijing government planned to invest 1 million US dollars within 7 years to construct 160 geothermal wells for heating (Gong, 2005). The whole construction is expected to be finished in 2006. It has been projected that 13.4 million TCE will be displaced by geothermal over the period 2001-2010 in China (World Energy Council, 2001).

Ocean Energy

China's utilization of tidal energy with modern technologies began in 1956: several small-scale tidal plants were built for pumping irrigation water. Thereafter tidal energy began to be used for power generation. Starting in 1958, 40 small tidal power plants stations with a total capacity of 12 kW were built for the purpose for power generation. These were supplemented around 1970 by much larger stations, of which the 3 MW Jiangxia and the 960 kW Baishakou schemes were the largest (World Energy Council, 2001). The majority of the early plants have been decommissioned for a variety of reasons, including design faults, being found to be incorrectly located, etc.

Since the beginning of the 1980s China's wave energy research has concentrated mainly on fixed and floating oscillating water column devices and also the pendulum device (World Energy Council, 2001). After more than 10 years in demonstration and application, along with the development of technology in wave, marine engineering and turbine generator sets, the utilization cost of wave energy is likely to be lessen 2-4 times than the present situation in 6 to 10 years, which may reach the cost lower than 10,000 Yuan for per kW (Guangzhou

Institute of Energy Conversion, 2001). Fundamental research is continually supported by the Nature Science Fund of China and the Chinese Academy of Sciences.

3.2 Foreign Investment and Investment Strategy

The major foreign players in the Chinese renewable energy market are international organizations such as the World Bank, the Asian Development Bank, the United Nations Development Programme, the United Nations Foundation and the Global Environmental Facility. These organizations have largely involved in the infrastructure construction of China's renewable energy industry. For example, In year 2000, NDRC, Ministry of Finance (MOF), the World Bank and GEF established a partnership to have a long-term cooperation on Chinese renewables. It is agreed that within 8~10 years after 2000, GEF and the World Bank will provide US $80 ~ 100 million for the development of renewable energy in China (NDRC, State Power, 2001). However recently, many foreign governments are also interested in investing on renewables in China. Many of these investments are through the approach of bilateral or multi-lateral projects and programs.

Besides governmental activities, foreign companies and enterprises are also active in the market. International corporations, such as GE, Shell, BP and Siemens, have son-companies in China. Others like Vastas (Denmark) are selling their equipment to China. In recent years, through the "Ride the Wind" program and "Brightness Program", the absorbed foreign funds is near US$ 0.2 billion (1999 White Book). 19 large scale wind farms are established, with a total installed capacity of 130 MW, account for about 60% of the total funds.

Generally, for foreign investments to enter Chinese market, probably one of the four forms should be taken: wholly foreign-owned enterprises, China-foreign joint ventures, China-foreign cooperative enterprises and Cooperative development. Usually, propositions for establishing enterprises, feasibility study and contracts and statutes should be submitted and approved before a license from the approving administrations is issued. Then investors

may begin formalities with industrial and commercial administrations. Some foreign firms may have been willing to take an initial loss in order to break into the Chinese market.

Usually, the time limit for a foreign invested enterprise is 10 ~ 30 years but it is negotiable according to national regulations for specific industries and items. The Chinese government has worked out a list for preferable areas of foreign investment, among the categories are: energy, comprehensive resource and renewable resource utilization and environmental pollution protection. Foreign investment enterprises will be terminated at the end of the specified time limit. If investors want to prolong the time of operation, they may apply to approving authorities for permission at least 180 days before the enterprise is terminated. If the foreign investment is less than US$ 30 million, local government (provincial, municipal, or autonomous regional government) could have the authority to approve otherwise the investment should be approved by the Foreign Trade and Economic Cooperation Administrations (NREL, 2003).

As the Kyoto Protocol finally came into effect early this year, a more flexible investment strategy is provided through the clean development mechanism (CDM). CDM is one of the three major mechanisms endorsed by the Kyoto Protocol, which uses the low cost green house gases (GHGs) emission reductions in developing countries to offset the GHGs emissions in developed nations, thus offer a win-win strategy for both annex 1 countries and non-annex 1 countries.

The first CDM project in China is a wind farm located in Huitengxile, Inner Mongolia. The Netherlands government would invest 5.4 Euro for per ton Certified Emission Reductions (CERs). Total CERs for this project is 54,000 tonnes with an effective period of 10 years (CREIA, 2003). For another CDM project, Xiaogushan Hydro Power Plant, the investor is Prototype Carbon Fund (PCF) from the World Bank. The CERs would be 3,723,000 tonnes and the price is $4 per ton CO_2 reduction (Lei & Zhao, 2005).

China is one of the few countries in the world to have delinked, on a long-term basis, its economic and energy emissions growth rates. CDM projects in China, in particular, promise to generate revenue and other benefits for companies from industrialized countries that invest in qualifying projects. The priority of CDM projects will lie in the areas of energy efficiency, renewable energy, and the substitution of fossil fuels. On June 30, 2004, a formal regulation drafted by NDRC, MOST and MOF came into effect. NDRC is the national autheroritity for CDM project approval and the governmental process time is 20 working days.

With its thirst for foreign investment and its dependence on carbon-intensive coal as a primary source of energy, China may become the largest single recipient of CDM projects (Szymanski, 2002). The Asian Development Bank estimated that the Chinese market for carbon emissions reductions could amount to $13 billion per year.

3.3 Status of technology development by renewable energy type.

3.3.1 Solar PV

There are basically two sources of the silicon materials of solar cells: one is come from the semi-conductor industry and the other is from the specialized production for solar PV products. In China, proximately there are 50 ton of silicon come from the semi-conductor industry annually, which is equivalent to 3 MW of PV products. Most of the silicon used for solar cells is imported from abroad. One production line with annual production of 1000 ton of Electrical Grade silicon is in construction now. It is possible that in the future, this plant could provide part of silicon needed for solar PV industry. However, even so, the domestic production of silicon cannot meet with the continuously increasing requirements from the demanding side. Suppose if, that in 2010, the annual production of solar cells in China achieve 100 MW, then the consumption of silicon would be 1100 tonnes. It is almost impossible to supply this much of silicon domestically without new production lines. Fortunately, building a manufacturing factory with production capacity of more than 2000 tonnes silicon is already listed on the agenda.

In the year 2003, 63.5 MW mono-crystalline silicon was produced domestically. However, since some plants with larger production capacity are mainly foreign controlled plants and most of their products are sell back to these foreign countries, the production of mono-crystalline silicon can barely satisfy the domestic demand.

For the poly-crystalline silicon, there are only one company in the country are currently producing poly-crystalline silicon. The production capacity is 2 MWp and most of the products are sold directly into the foreign market. Another production line of 6 MWp capacities is in debugging period now and it will soon put into operation. It is obvious that the domestic supply of poly-crystalline silicon is far less than the demand from the solar PV industry.

Battery is the single part that consumers mostly complain about. It is an important factor in solar PV systems. The relative lack of effectiveness and short life-span of battery is also among the primary reasons that impede the further development of solar PV industry. Currently in China, most of the batteries used in solar PV systems are lead-acid batteries, with some small amount of CdTe batteries applied in high altitude areas against the extremely cold weather there. The life time of lead-acid battery is normally 10 ~ 15 years, and the price is ranged from 0.8 to 1.2 Yuan per Wh. There is no specialized battery especially for solar PV systems in China. And because of the short life span, most of the end users cannot afford the expenses to replace batteries.

Because power controllers for solar systems cannot be used by other industries, there are only handful factories producing PV controllers. The price of domestically produced PV controllers are normally 1 ~ 2 Yuan per watt.

Inverters can apply not only for solar systems, but also comprehensively used for communications. It is also the core for Uninterrupted Power Services (UPS). Therefore, the production of inverters is mainly from UPS factories.

Chinese market for DC lights is rather narrow. There are not so many factories engaged in this business. Most of the existing factories that producing DC lights are small plants and some of them are even small workshop with hand-made techniques. The majority of DC lights have the characteristic of energy saving. Recently the high illumination LED lights came into Chinese market. DC lights have the shortage of short life cycle while LED lights are expensive, which are both the factual cumbrances of PV systems expansion.

3.3.2 Solar Thermal

For more than twenty years' research and development, China has made impressive progress on solar energy utilization, especially in the field of solar thermal application. Since 1991, a number of standards relating to solar water heaters have been developed. Now China has a series of standards on testing, designing, manufacturing, installation, operation and maintenance.

Presently there are three types of solar water heater in Chinese market: vacuum, flat plate and combined storage tank. The vacuum tube is currently the most popular type of collector in China. In 1996, the flat-plate collector was still dominant, with a market share of about 70%. However, the market for vacuum-tube collectors grew so quickly from 1999 that it soon took the lead, with an 85% share in 2002 (see Figure 3-4).

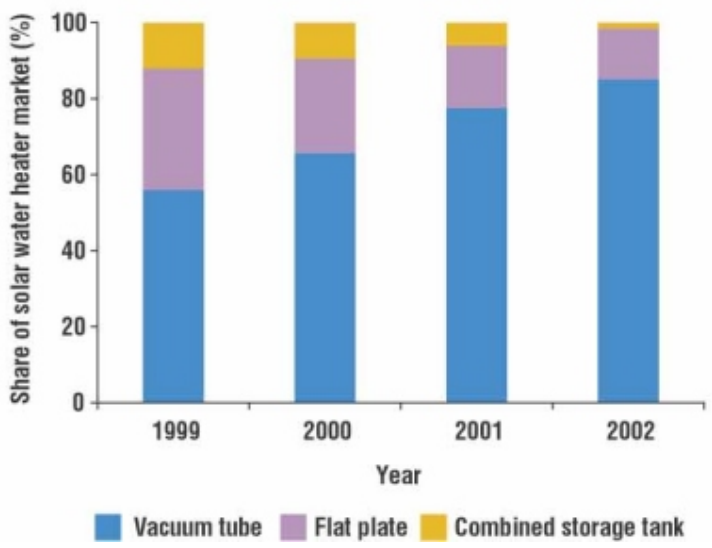


Figure 3-4 Product Segment (1999-2002)

Sources: China Solar Water Heater Industry Development Report, NDRC, 2003

According to Hua (2005), in warmer regions, typical solar water heater comprises 2 m2 of solar collectors, a 180-liter storage tank and an open circulation system, simply provides hot water and the price is very competitive, for less than 1500 Yuan. In a relatively cold region, a better level of comfort is provided in the system with a total price range from 2200 to 3000 Yuan. The top-quality systems usually consist of a 4-6 m^2 collectors, forced circulation and a back-up electrical auxiliary system, which will cost 10,000-15,000 Yuan.

About 80% of the solar water heaters in China use natural circulation (thermosyphon) systems with vacuum tube or flat-plate collectors (Hua, 2005), which means they cannot be directly used for space heating or cooling. A number of manufacturers, often working together with universities, are developing suitable new products and technologies. The main focus is to develop systems for industry; and for heating and cooling applications, improve productivity and efficiency by automating production and develop systems suitable for building integration.

3.3.3 Wind Power

The wind power generation is particular originating from its randomness of wind force, so it is necessary to study the new methods and technology of random power of the generator in the aspects of wind power field decision-making, trend analysis, stability calculating, trouble shooting in the power system, etc. In addition, it still required to investigate centralized monitoring of wind power fields, its interference on telecommunications, and varied interface technology between the wind field and power systems, and the impact of wind power generation on the environment.

One of the key issues of China's wind power development is the localization. Depending too much on imported wind turbines or parts will limit the development of the wind power industry. This leads to the high wind power generation costs and hindered the commercialization of this industry in China. In terms of equipment technology, China now can manufacture more than ten types of various small turbines ranged from 100 W to 1 kW. For turbines on 200 – 300 kW, 90% are produced domestically. In terms of 600 kW turbine, 80% are produced domestically. Large-scale wind power generators in foreign countries are comparatively advanced in integral technical level, which have been realized its microcomputer control and no man on duty with high reliability. But the value to introduce generators is rather high, over 10,000 Yuan per kW. In order to develop the wind power sector, it is imperative to be innovative in approaching to realize the industrial production in China on the basis of digestion and absorption of the introduced technology.

The development of wind power generation technology is very fast in China. Under the assistance of introducing technology and capital from foreign countries, Chinese manufactures have begun to master the related technologies of wind power generation. The rate of localization has increased dramatically and Chinese manufactures can now produce the main equipment for wind power generation. Some of the products have been exported to many countries. Domestic manufactures have developed 250 kW and 300 kW wind turbines, which can perform very well in practical operation. In terms of wind turbines of 600 kW,

China can produce the main components, including the generator, gearbox, control system, blade, yawing system, hub, tower, etc (Zhang et al, 2002). Some joint ventures can manufacture 600 kW and 660 kW wind turbines, which have a high localization rate. Tests show that these turbines have strong reliability and suit the domestic market very well.

Wind power generation is viewed as the most promising technology among the renewables. The fast construction of wind farms in China facilitates the industrialization of wind power generation. Some foreign companies and multi-organizations have invested in China's wind farms. The wind power industry has begun to influence the social and economic life of Chinese people, especially in some provinces where possess large-scale wind farms such as Xinjiang, Inner Mongolia and Guangdong. In these regions, the wind-generated power has a strong potential to provide a considerable proportion of the electricity on their local grid and electricity for the nearby cities which needs large energy consumption.

Domestic wind turbine manufacturing industry is the key for strengthening the domestic wind power industry. China now possesses many domestic components manufacturers and some of them also deal with the development of wind farms. Large-scale domestic production of wind blades will be achieved in the near future.

3.3.4 Small Hydro

Many rivers and streams in China are suitable for small hydro. However, in order to make the project profitable, the location of small hydro should be economically attractive. High water head and close to end users are two important requirements for small hydro construction. Therefore, the exploitation of small hydro is not limited to areas with very rich hydraulic resources. The efficiency of small hydro is twice as much as of thermal power plants on the same scale. Currently, rural and remote areas are in desperately need of power supply.

Compared to other power plant types, the construction of small hydro is relatively simple and less time-consuming 1~2 years. In addition, there is no problem of population displacement

(Cheng & Li, 2003). The initial investment is lower and the overall impact (displaced population, environment and ecology) is small. Because the small hydro is usually near to the end users, simple transmission and distribution equipments are enough and the overall T&D loss is small. The prestige of small hydro make it developed rapidly in China and in other developing countries, small hydro becomes one important method for rural electrification.

China developed a series of standard for small hydro on rural electrification including annual power consumption 200 kWh per capita every year (Guangzhou Energy Research Institute, 2005). It is a different method away from the traditional electricity development plan because the development of small hydro is mainly for rural electrification. Therefore on the balance of power supply, there would be extra power during summer, which is the season there are most rainfalls and lack of power during winter, when the water is also in shortage. Therefore, in almost every county, people are encouraged to use electricity for cooking productive activities in summer while in winter just guarantee the power supply for normal living energy demand. If there is still lack of energy, considering to purchase power from large grids. In the first batch of 100 counties that launched the rural electrification, they adopt the mutual adjustment, and 0.4 GW was installed and the energy consumption is 15% higher than regulated. Billions of dollars are saved from this strategy.

When developing small hydro for power supply, China builds up a lots of local small grids. The scale is usually 200~300 MW. So now in rural China there are three types of power supply: small hydro, national grid and combination of these two. Currently two thirds counties are supplied by national grid. However the extension of the grid caused high cost at the end users. In some places even there is a national grid available; people cannot afford the power. When the power generated from small hydro cannot meet with the requirements of local people, national grid will supply the balance.

3.4 Major barriers to renewables expansion/penetration in China

The development of renewable energy in China is quite different from that in developed countries. In China, remote and poor areas have the richest renewable energy resource, and these places are also in need of renewable energy for their daily life. Practically, it is feasible to provide basic energy supply to local people through renewable energy and China relies largely on these renewables for its rural electrification.

Since 1990s, many national and international programs aimed at using renewable energy for rural electrification are conducted. And the results are impressive, 5~6 million people are dependent on renewables for daily energy use. However, for further development of renewable energy, there are also barriers, both technical and non-technical, that limit further development.

3.4.1 Solar PV

China has very plentiful solar resources and potential huge market. During the past decades, solar PV industry reached great development and application. However, the solar PV industry is still far away from full commercialization. To further explore the market and identify possible use of solar systems, industry needs to remove the barriers that restrict the development. The barriers are high production cost, shortage of effective regulations and financing support and so on.

A corresponding development of all components for solar PV systems will maintain the PV industry in a reliable road. However, this is not what happened in China. As mentioned before, there is no balance at all for the PV system components. The silicon supply, the fundament of solar cell manufacturing, cannot meet the demand of PV industry development. Most of silicon needed is imported. And there is almost no specialized silicon production of solar PV industry. Currently the total production of mono-crystalline silicon is 63.5 MWp, but only 20 MWp is available for domestic market, cannot meet with the requirements of solar cell manufacturers. The production for poly-crystalline silicon is 8 MWp annually, far less than what needed for manufacturing demands even all of them are supplied. By the end of 2003, the annual production of crystalline solar cell is around 45 MWp, less than one tenth of the

world's production that year (the total world production in 2003 is around 732 MWp). Because of the small production scale, when the Township Electrification program started, 18 MWp installed solar systems of that year are provided from foreign products.

Production scale is one essential factor that will influence the cost. Many factors may influence the enlargement of production, one of which is the market development. Presently the PV market in China is small and unstable. Without supportive strategies from the governments, it is very hard for the industry to expand their business by themselves.

Some corresponding components such as batteries, inverters and DC lights need to be improved too. Both production equipments and measurement facilities are not advanced, they need to be upgraded.

The biggest difference of PV development between China and abroad lies in the policies and regulations toward the development objectives. There are currently no feasible benefits and subsidy policies in China. Although in 1999, NDRC and Ministry of Science and Technology (MOST) announced that power generation from renewable energies must be allowed connecting to the nearest electricity grid and purchased by utilities. There is no tangible subsidies. Therefore, though the central government has a positive attitude to support PV on-grid application, in fact the grid-connected application of PV systems couldn't be demonstrated in large scale. Relevant policies need to be offered in the future.

Although a lot of funding flows into PV industry, further development requires more effort, including research and development. The national investment on R&D of solar PV is not enough and cannot provide sufficient technical support to manufacturing industry.

3.4.2 Solar Thermal

China is now the largest producer and consumer of solar water heater in the world, with a high possession and growing development rate. However, in order to expand the industry, there are several challenges, both technical and non-technical. The overall technical level and product quality need to be improved. The current products are not good enough on durability and stability, therefore not very convenient for end users. In order to directly heat or cool the space by SWH systems, a circulation other than natural circulation should be used.

The ideal building-integrated solar water heater system, which would be easy to install, elegant, practical, and serve directly as the roof or wall of the building with which it is integrated, is not yet being produced in China. Though several demonstration projects have been completed, the industry faces a challenge to persuade real estates and building developers to integrate SWH into the building to guarantee safety and also no negative atheistic problem. It also need educate property owners, real estate developers and other relative parties on the development of integrated building SWH system from economic, energy and environmental and social perspectives.

3.4.3 Wind Power

Despite considerable progress has been achieved in wind technology, there are a wide variety of barriers to wind power development in China. The main barriers are related to resource assessment, equipment manufacturing, wind farm construction and operation, cost and pricing levels, and government policies (Zhang et al., 2002).

The most important thing is the shortage of reliable wind resource data. This led to the difficulties in wind farms planning, site choosing and scale design. The current wind data is national level wind resource distribution at the height of 10 meters, which is not enough for the construction of wind farms. Secondly, the wind resource data quality is low. This will also negatively affect the construction of wind farms. Additionally, the assessment of inshore wind resource is quite limited. These regions have rich wind resource and undoubtedly, will be

developed into the national center for wind power generation in the future. In summary, further work and research should be carried out on the resource assessment.

In terms of equipment manufacturing, the main problem is that nearly 95% of the wind turbines in wind farms of China are imported from foreign countries. Although the imported wind systems have excellent performances and high efficiency, they also lead to high price and a low rate of domestic manufacturing. Another problem is that the scale of production is too small and it also results in high prices of products.

Many barriers exist for wind farm construction. The scale of wind farms is too small. And the layout of wind farms is dispersed. China lacks experienced developers, which is very important for assessment of wind resources, the design of the wind farms, the selection and installation of equipment, the O&M of wind farms, etc.

The main characteristics of China's wind power generation are high generating costs and high on-grid power prices. These became the obstacles to the widespread utilization and commercialization of wind power. The investigation shows that the average price for wind power generation is about 33-60 percent higher than coal-fired power plant and the on-grid price is 68-94 percent higher than coal-fired power generation (including value-added tax) (Zhang et al., 2002). From an economic perspective, the burden of tax and loan make the price of wind power very high, although the O&M costs are higher for coal-fired power than for wind power. It shows that the tax on wind power can constitute up to 27 percent of the total price (with VAT and related taxes of up to 15.4 percent), which is 8 percent higher than the tax on coal-fired power in China (Zhang et al., 2002).

There are several problems about the policy for China's wind power industry. First, although Chinese government shows interest to the renewable energy and has made up plans for renewable energy development in recent "Five-year Plan", the objective of development is not clear. There is no clear definition of the status and role of wind power in the current power system.

3.4.4 Small Hydro

Financing is the biggest barrier for small hydropower development in rural China. For household who use small hydro for fuel, they need to buy wires, meters, switchers, electronic cooking appliances, the initial investment would be 300~400 Yuan (Zhan, 2003). Moreover, they need to pay for the electricity. If peasants will use electricity for cooking, their annual usage would be 800 ~ 1200 kWh, plus the heating in winter, power usage would be 1400 ~ 2000 kWh each household yearly. Based on the current electricity price of small hydro, it is very difficult for common peasants to afford. Government should have favorable policies for people to make the small hydro affordable. Good location and reasonable policies could low the construction and operation cost. More advanced technology will lower the cost and guarantee the supply is reliable.

3.4.5 Solving Problems for Further Development on Renewable Energy

The importance of developing renewable energy is not so highlighted. There is no clear and effective objective and strategy. The importance of renewable energy development to sustainable energy is not recognized by the whole country. People simply just don't think that it is necessary to develop renewable energy. A common impression about renewables is that they are too expensive, and the potential to replace conventional energy is very limited. Although the central government has a long-term objective and strategy for renewable energy development, some local (provincial, municipal or autonomous regional) governments are not serious about renewables, their enforcement of central government's strategy is not enough. In some places, development of renewable energy is not in local government's agenda; in other places, there is no long-term regulation or planning about renewable energy development. Or, although there is such a regulation or planning, no supportive strategies back up for them.

There is no complete market competition mechanism and systematic economic incentives. Renewable energy industry is a rather new field. From the past experiences we know that whether it is a developed or developing nation, the development of renewable energy is

greatly supported by government, through a series of preferable policies such as financing, tax credit, subsidies and market exploration. These preferable strategies are the important incentives for the industry. In comparison to other countries, the renewable industry in China is generally remote and poor areas oriented, where the renewable energy resources are most rich. In other words, the development of renewable energy in China is primarily in remote and poor areas, to provide power to meet with local people's basic energy demands. The social benefit of renewable energy in China is prominent but the economic benefit is not very high. Under such a situation, the policy intention and support are become more important.

The formation of industry is slow and the corresponding management level lags behind. In China, most of the companies in renewable energy are small business. The technology is backward, the product quality is not stable and the economic benefit is low. The cost of manufacturing is high and the supply of components is not in time because they may be made somewhere else rather locally.

The support for renewable energy from government is not enough and the input is not sufficient. By now, in China, the construction of renewable energy projects hasn't been listed on government's budget and financial plan. There is no routine financing for renewable energy development as that for other conventional energy construction projects. It blocks renewable energy development. Limited by financing mechanisms in China, the investment and financing channel for renewable energy are very limited. The companies are not able to attract finance. Therefore lack of capital funds severely embarrassed development of renewable energy and the industry cannot achieve an economic scale.

Because of the low input, there is no sufficient research and development; the technology transfer from laboratories to industries is slow. Some research results lay there for a long time, and could not make any use. At the same time, many important components are imported for a long time, such as large- and medium- scale wind turbines, which cause the domestic

development slow. In addition, some renewable energy-based projects have a good market potential. However, due to the lack of information and funding, there is no effective market for these projects.

There is a very complicated bureaucratic administration system in China. For a long time, the administration of energy is distributed in many ministries and departments. The Ministry of Agriculture, the Ministry of Water resources, State Power, the Ministry of Forest, National Development and Reform Commission all have responsibility for part of the energy development. The overlap of management and multi-head administration causes the scattered funding and repeating construction. The management from more than one ministry is, to some degree, weakened the macro adjustment ability.

4. Renewable Energy Financing and International Cooperation

4.1 Incentives and Subsidy for RE

In 1999, the State Council, the State Development Planning Commission (SDPC) and the Ministry of Science and Technology issued the "Further Supporting Renewable Energy Development." The statement stressed that renewable power projects can have priority for state bank loans. The National Development Bank is the leading institution providing such loans and would encourage the involvement of other commercial banks. The SDPC assists the developers to request banks loans for projects above 3MW. These types of loans have low interest rate, two percent below the commercial rate, which is a discount subsidized by the national or local government.

There are several other direct economic incentives provided by the Chinese government.

- Customs tariff relief

With the gradual opening of Chinese markets, customs duties have dropped for many imports. In 1996, the average customs tariff level has dropped to 23%. Concerning about renewable energy, there are no clear written regulations for its imported tariff. However, in real practice, the duties for wind turbines and PV equipments are much lower than the average. So, the real duty for wind turbine components is 3%, for the complete wind turbine is 6%, and the duties for PV equipment is 12%. (10th five-year renewable energy development report, 2001, SDPC)

- Value added tax relief

The value added tax was a kind of tax shared by the central and regional government. In it, 75% will be submitted to the central government, and 25% submitted to the local government. In China, the value added tax could be grouped into three categories: the average one is 17%, the lower one tax for small-scale taxpayers could be 6%. At present, there are still no standard written favorite regulations for renewables, so most renewable energy products are taxed at the full value added tax (VAT) level (the unified current VAT is 17%). The two exceptions are the VAT on biogas at 3 percent and the one on small hydropower generation (less than 25MW) at 6 percent.

- Enterprise income tax

The common rate is 33%. It is zero for these certified enterprises by the Chinese government in the new and high-tech industrial zones for the first two years and 15% is applied in the following two years. Enterprises using wastes as main raw materials are free from income tax within five years after operation.

Enterprise income tax for foreign investors is different. Starting from January 1, 2000, for foreign-funded enterprises in the middle and western areas of the country, tax rate of 15% will be applied within three years after the current tax concession policy expires. If foreign-funded enterprises in eastern areas of China reinvest in the central and western areas of the country, they shall be regarded as foreign-funded enterprises if the investment proportion exceeds 25% and enjoy the corresponding treatment.

- Discount price

Local authorities have some measures for pricing of certain renewable energy applications. For example, Shanghai authorities have defined a higher price of biogas for cooking at 1.2 Yuan/m^3 while other provinces such as Sichuan and Guangdong have offered discount prices for the cement used in biogas digesterconstruction.

- Pricing of renewable energy based electricity

The electricity price is fixed by the Pricing Department and the pricing system is very complicated. Before the mid-1980s, power plants (including hydropower stations) were built with government appropriations and the power generation cost and price were very low. Later on, state financing was changed into bank loans and principal and interests have to be paid. The electricity price for independent power plant (IPP) was fixed by cost plus tax and profits during the period of repaying principal and interests.

At present, the prices of grid-connected electricity generated by most hydropower stations are slightly higher than cost, 0.10 Yuan/kWh, which is lower than thermal power. In 1994, the former Ministry of Power Industry provided that all power grids must purchase the electricity generated by wind farms and the electricity must be priced according to the repayment of principal and interests. The portion above average electricity price is shared by the whole power grid. In 1999, the State Development Planning Commission and the Ministry of Science and Technology confirmed this policy. The problem is that it is hard for small power grids with a bigger proportion of wind power to bear the higher cost.

- Preferential loans

The Chinese Government created low rate loans dedicated to rural energy development in 1987. These loans supported big and medium size biogas projects, solar thermal applications and wind power generation technology. In 1996 the total fund hit 130 million Yuan. The government offered a 50 percent discount on regular commercial bank loan interest to investors to support renewable energy development projects, including small wind generator manufacturing (the accumulative amount of loans of 50 million Yuan) and wind farms construction (850 million Yuan in 1996), photovoltaic cell assembly line (10 million

Yuan), solar energy heater production, and power generation by sugar cane sludge (100 million Yuan planned for 1996-2000 annually). In addition, the government has made a limited number of low rate loans available for small hydro project. In the document "Further Supporting Renewable Energy Development" collectively issued by the State Council, SDPC and the Ministry of Science and Technology, it stated that a 2% discount could be offered to the renewable electricity generation projects.

In 1994, China's commercial banks went commercialized and the State Development Bank and Agricultural Development Bank were opened as policy-based banks. At present the policy-based banks provide low rate loans.

- National Debt input

To use national debt to support the development of some of the renewables. For example, the wind electricity project supported by the Ministry of Economic and Trade, was to use the national debt to construct an 80 MW wind farm.

- Other Subsidies

The central government's subsidies in renewable energy are mainly offered for research, development and site demonstration projects. The local governments also provide some subsidies on research projects, but most of the subsidies from local governments goes to solar energy and wind power.

In China, subsidies mainly come from the government. Because China has limited financial revenues and the demand for subsidies comes from so many sectors of the economy, the dependence on public funds is not a long-lasting strategy. To be effective, subsidies have to be well designed. Who should be subsidized and with what type of mechanism are key issues. Direct subsidies to users may not reach the target. When investors are subsidized together with fair competition, the dual objectives of production expansion and cost reduction can be achieved. Three key targets of subsidies include:

- Subsidies paid to investors. The Chinese government's investment in the construction of local small hydropower stations is an example. The U.S. government provided 15%

investment subsidies for wind power investors, although the policy has expired. Investment subsidies can be used to mobilize investors and increase production capacity.

- Output subsidies. At the present time, there is no such policy in China. Generally speaking, these kinds of policies can have a dramatic effect on production increase, cost reduction and economic benefit boost.
- Consumers' subsidies, a widely applied incentive in China. In addition to its extensive application in solar energy equipment and small wind generators, these subsidies are widely used for improved cooking stove and other bioenergy technologies. The objective is to spur the expansion of production capacity and thus reduce the cost.

During the past years, the major subsidy program from the central and local governments could be summarized as the following:

Subsidy by the central government

-Overhead expenses for management organizations in demonstrative projects and training. It amounted to 9.2 million Yuan in 1990-1996.

-R&D subsidy. 500 million Yuan were used for this purpose in 1996-2000.

-Investment discount. At present, the State Economic and Trade Commission provides 120 million Yuan of low rate loans for renewable energy and the Ministry of Water Conservancy provided 300 million Yuan of low rate loans for small hydropower projects per year.

-Funds for poverty alleviation and rural electrification. In 1991-1995, 7 million Yuan were invested in Tibet, which were used to build four photovoltaic power-generating systems, with a total capacity of 85kW.

Subsidy by local governments:

-R&D subsidy: 300,000 Yuan in Inner Mongolia; one million Yuan in Xinjiang and 500,000 Yuan in Qinghai yearly.

-Subsidy to users. Inner Mongolia subsidizes 200 Yuan to a set of 100W wind generator or 16W photovoltaic system. The total subsidy in 1996 was 1.5 million Yuan. Xinjiang subsidizes 50-200 Yuan to a set of photovoltaic system. The subsidy comes from the fund

raised by collecting additional charge of 0.02 Yuan/kWh on grid power. In Gansu, the subsidy for the purchase of each set of photovoltaic system is 300 Yuan, coming from the local finance and photovoltaic funds.

-Rural energy construction. In 1981-1996, provincial, county and township governments spent 2.06 million Yuan in total.

4.2 Research, Development and Demonstration Funds

The major stakeholders in international cooperation programs are the World Bank, UNDP, UNF, GEF and ADB. There are also some foreign government invested programs.

China Renewable Energy Development Project (REDP)

Time line: December 2001 ~ December 2006

Sponsors: GEF, the World Bank, NDRC

Funding: IBRD loan US$ 10 million; GEF grant US$28 million; Chinese co-financing

The Project aims to use PV technologies and wind to supply electricity in an environmentally friendly way to provide energy to dispersed rural households and institutions. A direct subsidy of US$1.5 per Wp would be provided to PV system companies to assist them for marketing 10 MWp of PV in Qinghai, Gansu, Inner Mongolia, Xiajiang, Tibet and Sichuan. A technology improvement would also be provided to strengthen institution capabilities for PV quality assurance and project management. Wind power companies will install 20 MW of wind farms, mainly to promote the technology in locations with public visibility.

Capacity Building for the Rapid Commercialization of Renewable Energy in China

Time line: From1999

Sponsor: GEF, Australia, The Netherlands, NDRC

Funding: GEF US$ 8.5 million, AusAid US$3 million, Ministry of Foreign Affairs, the Netherlands, US$2.53 million, Chinese co-financing: US$ 11.5 million.

The project covers several renewables: wind, solar water heater and biomass. A series of technology application projects (for industrial application of biogas technologies, hybrid

village power systems, and bagasse co-generation) are addressing issues presently inhibiting widespread commercialization in these particular market sectors. The Project will also contribute to the development of national policies for renewable energy development, through its own activities and in cooperation with other groups working with the Government of China.

Improvement and Expansion of Solar Water Heating Technology in China

Time line: 2002 ~ 2005

Sponsor: UNF, UNFIP

Funding: UNF US$1.8 million, Chinese co-financing US$ 9.6 million

A set of technology standards and building codes has been promulgated with a guidebook and design model for integrating solar water heaters into buildings. As a result, 100,000 m^2 demonstration buildings has been constructed in Beijing, Shanghai, Yunnan, Anhui, Shangdong and Tianjin under the UNFIP programme in the last two years (Office of National Coordination Committee on Climate Change, 2005).

China's Rural Renewable Energy Project

Time line: From 2002

Sponsor: Asian Development Bank

Funding: US$ 33.1 million

This project aims to integrate biomass-based renewable energy generation technology into the existing agricultural production system for improving the environment and promoting economic growth and poverty reduction in rural areas. The project is to turn the waste into renewable energy for rural households and to use the residues as organic fertilizer by using biogas digesters to produce biogas, thus reducing the dependence of farm households on coal, straw, and firewood for heating and cooking. It also promotes a better living environment, and causes less stress on forest resources.

US/China Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Technology Development and Utilization

Time line: Since 1995

Sponsor: US

Funding: NA

The US/China Protocol has three main objectives: to mitigate environmental damage through deployment of renewable energy and energy efficiency measures, to build partnerships between US and Chinese industry, and to advance world energy security by helping China develop more diversified energy resources. Five of its seven annexes pertain to renewable energy: rural energy, wind energy, geothermal energy, policy and planning, and business development. The project has identified twelve potential geothermal heat pump projects, three of them totaling $5.3 million (NREL, 2003). It will leverage in several projects to expand the market for geothermal energy. Partnering, training, and monitoring potential sites have led to a rapidly growing Chinese market for geothermal heat pumps.

A summary of other major programs are provided in the below table:

Table 4-1 Summary of Major Programs in China

Project	Sponsor	Funding	Contents	Time line	Target Areas
Silkroad Brightness Program	The Netherlands	Euro 13.79 million	Subsidy for solar home systems	2002 — 2006	Xinjiang
Solar PV Program in West China	Germany (KFW)	Euro 26 million	Establishment of Village Power Station	2003 — 2005	Xinjiang, Yunnan, Qinghai and Gansu
Renewable Energy in Rural China	Germany (GTZ)	Euro 4.6 million	Technical support and Training	2003—	Qinghai, Yunnan, Tibet and Gansu
Solar PV Program	Canada (CIDA)	Canadian $ 3.43 million	Power station demo. And management training	2003 — 2005	Inner Mongolia
NEDO Program	Japan (NEDO)	RMB 38.53	Establishing demonstration	1998 —	Xinjiang, Tibet, Gansu,

		million	power station and laboratory	2002	Shanxi, Ningxia, Inner Mongolia, Sichuan, Qinghai, Yuannan, Guangdong, Zhejiang & Hebei

4.3 Chinese governments' strategies toward international cooperation

The Chinese government attaches much importance to the renewable energy development. The Renewable Energy Law was just passed at the beginning of 2005 and will be put into enforce on January 1, 2006. The law requires all electricity grids, heating gas grids and fuels companies must allow renewable energy to enter the market through their network if the renewable energy owners require so. The price difference between renewable energy and conventional energy will be distributed to the whole network, which guarantee the market for renewable energy development.

China also encourages foreign investment into the renewable energy market. Chinese government has listed a number of fields that need foreign investments and renewable energy is on the list. China has adopted favorable taxation policy for foreign investments through a combination of income tax and value-added tax (VAT) incentives. The government collects business income tax from foreign investment enterprises at the rate of 33%, but collects only 15% from enterprises in special economic zones, the national hi-tech industrial zones, and national-grade economic and technical development zones. Foreign investment enterprises may also be eligible for a business income tax waiver during the first two years after they begin to make a profit and for a partial waiver during the next three years. Additionally, foreign investment enterprises in less developed regions may apply to the relevant State Council tax authority for a favorable tax policy after the initial tax exemption and reduction period. After approval, they can enjoy a 15-30% reduction in income tax over the next ten

years. Enterprises in the biogas and wind energy fields are eligible for an income tax rate of 15%.

In addition, many of the main components of wind turbines, the turbines themselves, and Photovoltaics modules enjoy favorable import duties compared with the average rate of 23%. Further more, China approved efforts to reduce or exempt imported wind turbines and related equipment from import duty so that the actual duties paid were very low. For bio-energy equipment, if it is considered to be a high-tech product, it could be exempt from import duty.

Although without obligations to Kyoto Protocol, China is the only country by now that has a long-term emission reduction objective. Due to the serious environmental problems and governments' awareness of the importance of renewable energy development, China views CDM as an effective solution to deal with domestic environmental problems.

4.4 Prospect of future development

Under the background of international crude oil price instability and limits on usage of electric power domestically, Chinese energy experts agreed that China has great potential to develop renewable energy.

According to the plan by 2015, China will annually develop new and renewable energy resources amounting to 43 mtce, or 2 percent of the country's total energy consumption (Source: http://www.electricityforum.com/news/aug04/chinarenew.html).

In north China's Inner Mongolia autonomous region, which boasts rich wind power resources, the largest wind power generation station in Asia will be built before 2008.The project, with generating capacity of 1 GW and US$1.2 billion of investment, according to the agreement signed recently between Erenhot city of the autonomous region and the Avalon Power Corporation of Canada.

The development of renewable energy will provide nearly 500,000 job opportunities and can help solve power shortage for 5 million people in remote areas, according to the China Energy Research Association.

Solar PV

Presently the main markets for PV systems are communications, commercialized power sources and household systems for remote areas. The demand for communication industry is very stable, around 10 MWp. For commercialized power sources, the demand is also about 10 MWp; for Solar Home Systems in western areas, it is expected that the demand is less than 10 MWp annually.

In China, PV systems have contributed significantly to rural electrifications. Due to the unavailability and prohibited cost of conventional electricity girds, solar PV is much more cost-effective to meet people's basic energy needs in the western areas, where minority people usually live. Potential of PV market is enormous. China has electrified about 800 unelectrified townships by PV systems under the Township Electrification program. But there are still about 28,000 unelectrificed villages, or 7 million rural households without access to electricity. Therefore the potential of this market is expected to be at around 3000 MWp. For those established PV stations, there are some problems, such as, who would be responsible for the PV stations after its operation, who is going to take care of the daily maintenance and management; Who will collect the fees for using electricity and if these fees are not enough for the replacement of broken components like batteries, who is going to pay for the differences and guarantee the PV station will still in operation properly.

On-grid generation is the final goal of PV development, and it is also the largest PV market in the future. However, nowadays, there is no initiative in this aspect. Whether PV could be used for on-grid generation largely depends upon the governments' attitude. If China wants to start this market, several factors need to be considered carefully: technical standards, market permission, generation ratio of PV systems and objectives (for peak-shaving, emergency or

greenhouse gases emission reduction), incentive policies and on-grid electricity price; research and developments on components (solar cells, inverters and controllers and so on.)

Large scale application and long-term usage of PV systems including: PV stations in deserts, PV in spaces, PV in automobiles and so on. But China has not begun its research on this yet.

Solar Thermal

The Chinese Government set a national target for 65 million m^2 of cumulative solar collector area by 2005, while there is a further target for 230 million m^2 by 2015 (NDRC, 2003). In the long run, the further development of SWH should be integrated with the real estate industry. And the public preference has an influence on the market already. The market prospective of renewable energy in China is promising and Chinese government is positive in international cooperation in this field, either through establishing enterprises, conducting programs or by CDM projects.

4.5 National Promotion Programs for Renewables

Since 1996, with the implementation of the "Ride the Wind" program and "Brightness Program", the national government gradually enhanced its investment on renewables. In 1998, the National Planning Commission appropriated 5 million Yuan to support the biomass project in Laizhou city. By 1999, the National Planning Commission appropriated 7.5 million Yuan for the "Ride the Wind" program to support the development of domestic wind turbines. The accumulated investment in "Brightness Program" amounted to 36 billion Yuan.

APPENDIX Other Major Laws /Regulations and Policies Associated with Renewable Energy

Name	Highlights
1. Energy conservation law (promulgated on Nov.1, 1997 and implemented on January 1, 1998)	*Article 11: The State Council and provincial governments shall take out energy conservation funds from funds for capital construction and technical transformation for use to support the rational utilization of energy and the development of new and renewable energy. *Article 37: The designing and construction of structures shall adopt energy-efficient structures, materials, appliances and products to raise heat insulation performance and reduce consumption in heating, refrigerating and lighting. *Article39: Governments at all levels shall strengthen rural energy construction, develop and utilize such new and renewable energies as biogas, solar energy, wind energy, water energy and geothermal resources according to the principle of proceeding from the actual local conditions, mutual supplementation among different forms of energy, comprehensive utilization and practical results.

3.Power Law (promulgated on Dec28, 1995 and effective on April1,1996)	Article5: The state encourages and supports the use of renewable energy and clean energy to generate electricity. Article 22: When power production enterprise with independent legal person status demand the on-stream of power, power-handling enterprises shall accept. Article37: Power going on stream shall be the same price in the same power grid, of the same quality. Article47: The state shall grant preferential policies to rural electrification.
3. Air pollution prevention and control law (promulgated on Sept.5.1997 and revised on Aug.29, 1995)	Article15 Enterprises shall give priority to the use of clean production technological processes that are energy efficient and discharge less pollutants to reduce air pollution. Article 24 Coal washing and processing. The lowering of sulfur and ash contents shall be protected and mining of coal with high sulfur and ash contents shall be limited. Article 27 Areas where acid rain has already or is likely to occur or other sulfur oxide pollution is serious shall be demarcated as acid rain or sulfur oxide control zones. Article 28 It is encouraged and supported to produce and use lead-free gasoline and limit the production and use of leaded gasoline.
5. Water pollution prevention and control law(promulgated on May 11, 1984 and revised on May 15,1996)	It provides the formulation of water environment quality standards and standards for discharging pollutants, the supervision and management of water pollution prevention and control and the prevention of ground and underground water from being polluted. It is associated with hydropower projects, the utilization of geothermal resources and the treatment of animal and poultry drops and urban sewage water and the not wastewater discharged by the thermal power plants.

6.The State Council set up creation funds for science and technology-oriented medium-sized and small enterprises (Feb, 1999)	It is a specially earmarked government fund, totaling one billion yuan. The ways of support include free assistance, discount loan, capital input, targets include energy efficiency and new energy. 1000 projects were approved in 1999, totally 820 million Yuan and 460 million have already issued. Local watching funds were 850 million and bank loans were 3.75 billion yuan.
7. Catalogue of industries, products and technologies encouraged for priority development by the State at present and indicative catalogue of industries for foreign investment worked out by the State Development Planning Commission and approved for issue by the State Council (issued on Dec.31, 1997 and for trial implementation on Jan. 1, 1998)	Catalogue of industries, products and technologies emphatically encouraged: ● Protection and development of water energy resources; ● Solar energy, geothermal energy, marine energy, garbage, biomass energy generation and large wind generators; ● Key technologies for energy conservation in buildings; ● Comprehensive utilization of resources; ● Comprehensive utilization of solid wastes; ● New energy(solar energy, wind energy, geothermal energy and tidal energy) power stations construction and operation; ● Energy conservation technologies; ● Technologies for regeneration and comprehensive utilization
Policies	
1. State energy technology policies approved for issue by the State Council (1996)	● Actively develop and utilize new energy; ● Set up a rational rural energy structure and end serious energy shortage in rural areas as soon as possible.

2. Outlined Program for the Development of New Energy and Renewable Energy for 1996-2010 and Priority Development Projects for New Energy and Renewable Energy formulated by the State Development Planning Commission, the Science and Technology Commission and the Economics and Trade Commission.	Put forward the objectives, tasks and priority development projects for renewable energy for 1996-2010.
3. Standards and specifications	By the end of 1996, China had promulgated 30 state standards concerning renewable energy and rural energy, 6 trade standards and 3 sectoral technical specifications, including home biogas pits, large and medium-sized biogas projects, solar energy water heaters, solar house, solar dryers, solar stove, wind power generation, mini hydropower and energy-efficient stoves.
4. Integral construction plans for rural energy at the county level	With county as the basis unit, work out plans for energy, economy and environment and fix execution plans and technical line in the light of local conditions and promote a coordinated development between energy and economy, society and environment with focus on the development and utilization of renewable energy. Achievements are good. In 1998, there were 204 counties investing 3.85 billion yuan, including 310 million appropriated.

5. Training	Established a rural energy-training network, with training centers in North China, Northeast China, East China and Central China, which trained 378000 people in 1997 and 1998.
6. Displaying the role of non-governmental organizations	Non-governmental organizations associated with renewable energy include: the China Rural Energy Industry Association, Rural Energy Sub-Committee, New Energy Sub-Committee and Geothermal Sub-Committee of the China Energy Research Society. Chinese Solar Energy Society, China Hydropower Society, China Forestry Sciences Society and the China Biogas Society. These organizations play a role in advising on policy decision-making, project assessment, publicity, education and training, information service and international exchange.
9. Public involvement	To enhance the understanding of the public of renewable energy through publicity activities and large scale training; develop technologies best suited to China's conditions (energy efficient stoves, home biogas pits, ecological agricultural mode with biogas as the bond and mini-hydropower) on the basis of technical creation by the people; a successful case of direct participation of residents in working out renewable energy development plans is the 12 types of comprehensive construction of rural energy in 1986-1990, which had the participation of thousands of farmers and rural technicians.

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