

Biomass Utilization and Technology Development in China

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ABSTRACT

In this paper, issues related to biomass energy developed in China, on resources, technology, economy, environment, market, policy and regulation etc., are generally summarized. China is an agricultural country with a huge population and abundant biomass resources and facing increasing greatly energy demand and suffering serious environmental pollution. It is estimated that the total amount of biomass resources in 2001 was up to about 473 million ton-oe. The crop residue is the biggest biomass resource. So far, biomass utilization technologies mainly focus on biogas and biomass gasification and/or power generation. There is a huge market for biomass technology, especially for biomass power generation. But there is only some regulation, law and incentive policy on renewable energy development and environmental pollution control, which is not enough to promote development of biomass technology in large scales. In addition, financial shortage and technology drawback are another two barriers to be removed in the near future. So, there is big demand on financial aids and advanced technologies and an opportunity of cooperation on biomass energy between China and developed countries, like Germany.

Key Words: biomass, resources, biogas, gasification, power generation, market, pollution

1. Background

The first fuel for life was biomass fuel, firewood, in human history in thousand years ago, which comes from solar energy though photosynthesis by plants. In China, the biomass fuel is a traditional fuel, such as crop residues and firewood, which has been used for cooking and heating by burning directly in stoves. By now, the biomass is still playing an important role in energy consumption in Chinese rural areas, even though in most of countries in the world. Developing biomass energy is one of the most important energy strategies for China and also for the world, in which, a lot of benefits will be involved, not only energy supply, but also sustainable environmental improvement, ecology balance, social progress, and economy development. So it has contracted more attentions form the world.

1.1 Population

China has a hug population, which covers one fourth of the globe population. In the past 16 years, the population had been growing yearly at an average natural growing rate of 1.44%. By 1999, the population had been about 1.259 billions, of which about 69.1% was rural population, and the rate of population natural increasing rate kept at 8.77%. By 2000, the population was up to 1.266 billion, of which about 63.78% of its population was rural population and 36.22% was urban population.

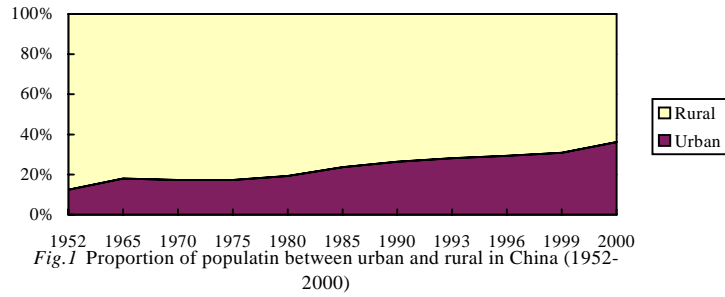
On the other hand, the proportion between the rural population and the urban population has been changing a great deal in recent years. From Fig.1, it is shown clearly that the proportion of population had a little change from 1952 to 1980, only 6% for 28 years, but it has been a great change from 1980 to 2000, up to 16% for 20 years. It is one of reasons that there is a quick population migration between rural areas and cities. The migration may be resulted from a great achievement on the national economy having been made in this period.

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Source: Statistical Yearbook of China, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

By now, Chinese population is still growing at a high rate, even though a population program in the whole country has controlled it for the last two decades. For instance, the natural growth rate of population was up to 1.145% in 1993. According to prediction in a report by the World Bank, Chinese population will be up to 1.55 billions (Table 1) and the proportion of rural population to total population will be changed greatly from 80% in 1985 down to 25-35% by 2050.

Table 1 Chinese population in the future (2000-2050)

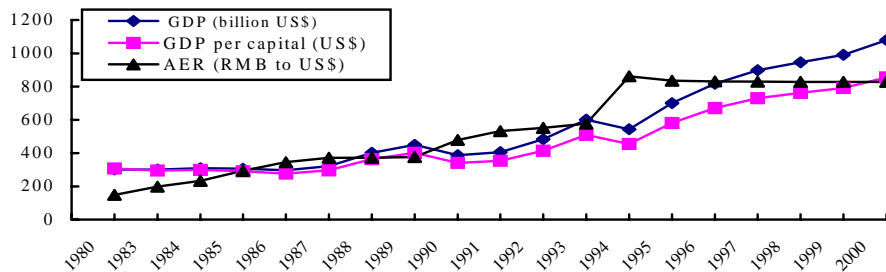
Years	Population (millions)	
2000	1,266	70
2015	1,396	65
2030	1,512	50
2050	1,550	25-35

Source: From a World Bank report in 1994

Comparing the figure 1 with table 1, it can be found that the change was more rapid than that of the prediction. In fact, the proportion of urban population was to 33.78% in 2000, but the figure should be by 2020 in the report and its figure for 2000 is 30%. This means that Chinese economy had been developed efficiently and the population migration form rural to urban was so fast that the fact take placed is over the prediction by those population experts in the world.

1.2 Economy

Since opening its door to the outside world in 1980's, China has been deepening process of economic and political restructure and marching towards to an establishment of a socialist market economy. By 2000, China had made a great achievement in its social and economic stability and sustained economic development. In this year, the GDP was up to 8940.36 billion RMB, about 10 times as much as that in 1985. The average annual increasing rate of GDP was over 7.9% from 1986 to 1990, and the rate was about 8.3% from 1996 to 2000 (Fig.2).



* Values in the figure are based on current prices and average exchange rates of RMB Yuans for 100 US\$ in these fiscal years respectively.

Fig.2 A curve of economy development in China from 1980 to 2000

Source: Statistical Yearbook of China, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

China is an agricultural country, that is, the rural economy is one of the most important sectors in the national economy. As shown in the table 2, the GDP of primary industry, agriculture, occupies about 15.9% of the total GDP in the country.

Table 2. Gross Domestic Production in 2000

Items	Total	Primary Industry	Second Industry	Tertiary Industry	Per capital (US\$)
GDP (billion US\$)	1080.0	171.7	549.5	358.8	855
%	100	15.9	50.9	33.2	

Source: Statistical Yearbook of China, the National Bureau of Statistics of China, China Statistical Publishing House, 2002

In the table 4, the primary industry means agriculture, including farming, forestry, animal husbandry and fishery; the second industry is composed of manufacture, mining, processing, construction etc.; and the tertiary industry is related to transportation, communication, commerce and other public service facilities.

A research result on the increasing of Per Capital GNP in the first half of the next century is shown in the table 3.

Table 3 A Prediction for Per Capital GNP (US\$) 2000-2050

Proposals\years	2000	2020	2030	2050
1	1,000	2,500	3,350	6,000
2	1,000	1,900	2,450	4,000

1.3 Energy

In recent years, China has paid more attention on developing its energy industry to meet more and more energy demand for the growth of national economy and the improvement of living level. In china, the coal mining industry is the most important energy industry and coal energy is the biggest part of energy sources, while the oil and natural gas energy industry and the electricity industry have been greatly developed only in the recent 50 years. By 2000, the primary energy production was decreased deeply, about 763 million TOE, in which there was 998 million tones of coal, 163 million tones of oil, 27.2 billion M³ of natural gas and 222.4 billion kwh of hydro-electricity (Fig.3).

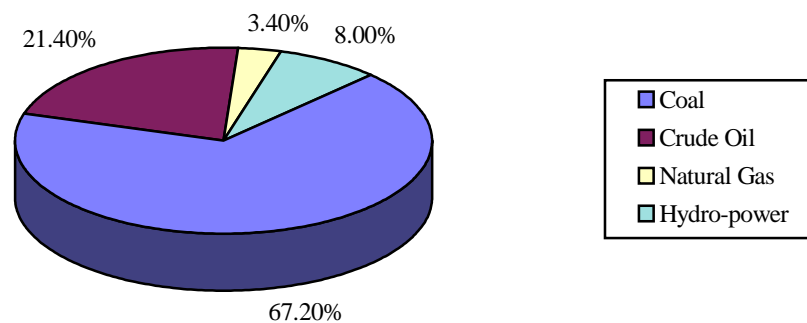


Fig. 3 Production and composition of primary energy (763 million TOE in total, 2000)

China has been consuming more and more the primary energy, which is prompted by the development of its national economy in recent 30 years. In 2000, the total consumption of primary energy was up to 896 million ton-oe, about 5 times of that in 1970 (table 4).

Table 4. The Primary Energy Consumption in China (1952-2000)

Years	Total MTOE	Proportion (%)			
		Coal	Oil	Nature Gas	Hydro-power
1970	205.0	80.9	14.7	0.9	3.5
1980	644.5	72.2	20.7	3.1	4.0
1990	690.9	76.2	16.6	2.1	5.1
1993	812.0	74.7	18.2	1.9	5.2
1996	972.6	74.7	18.0	1.8	5.5
1997	967.2	71.5	20.4	1.7	6.2
1998	925.5	69.6	21.5	2.2	6.7
1999	854.0	68.0	23.2	2.2	6.6
2000	896.0	67.0	23.6	2.5	6.9

Source: Statistical Yearbook of China, the National Bureau of Statistics of China, China Statistical Publishing House, 2000.

Because these clean energy sources are playing more and more important roles in the national economic actions, the proportion of coal in the total national energy consumption is reduced gently in recent years. By 2000, the proportion of coal energy consumption had decreased to 67.0%, but that of other primary energy sources, such as oil, natural gas and hydro-electricity had increased to 23.6%, 2.5% and 6.9% respectively.

But, in China rural area, the biomass energy is a main energy resource that is not included in all official statistics data. In fact, the total rural energy consumption was up to 462 million TOE in 1999, in which, about 282 million TOE came from he commerce energy, occupied 33% of the total commerce energy consumption in the country, and other 180 million TOE came from biomass energy (Fig.4).

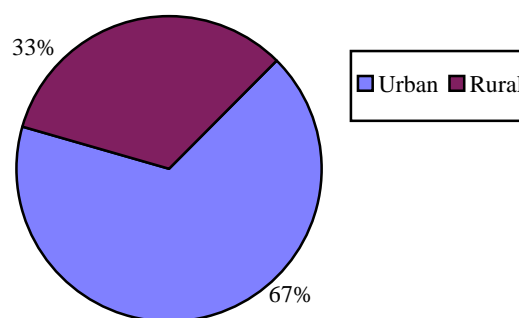


Fig. 4 Sectors of urban and rural commerce energy in 1999

Table 5. A prediction of total energy demand for 2000 -2050

Items\Years	2000	2020	2050
Population (million)	1,256	1,380	1,550
Per Capital GNP (US\$ in 1980)	1,000	2,500	6,000
GNP (billion US\$ in 1980)	1,250	3,450	9,000
Energy Demand (MTOE)	1,000-1,130	2,100	3,780
Per Capital Energy Consumption (Toe)	0.80-0.90	1.52	2.44
Energy / GNP (kgoe/US\$)	0.81	0.64	0.46
Energy Saving in Average (%/ year)	3.3	1.0	1.0
Elasticity of Energy Consumption	0.61	0.72	0.61

Source: From a World Bank report in 1994

In a long-term prediction of energy demand in future, it is reported that the energy demand will be

increased at a high speed as the growth of population and the development of economy in the country even though more and more new technologies will be used to save energy consumption. From Table 5, the energy demand will be up to 3,780 million TOE by 2050, about 4.4 times as much as that of in 1999.

1.4 Pollution from Energy Consumption

In fact, a process of energy consumption is a process of pollution formation, that is, when a kind of fuel is utilized as an energy source, it is always in company with varied pollution from waste gas or other pollutants. Coal and oil are two kinds of main energy sources in the world, which can cause very serious pollution on environments. Coal is mainly used to produce one or more kinds of second energy products, such as heat energy, gas fuel, liquid fuel and/or electricity, or burnt directly as a primary energy. Oil is mainly used to produce liquid fuels by a refining process, such as gasoline and diesel oil, or to generate electricity. From utilization of the two energy sources, air pollution by waste gases, such as CO, SO_x, CO₂ and NO_x, is one of the most serious effects on environments.

Table6. Waste gases from industry production

Years	Total waste gas (10 ¹² m ³)	Flue gas from fuel (10 ¹² m ³)	SO ₂ (million ton)	Soot (million ton)	Industrial Dust (million tons)
1990	8.54	5.95	15	13.2	7.8
1991	10.10	6.54	16	13.1	5.8
1992	10.48	7.20	17	14.1	5.8
1993	10.96	7.54	18	14.2	6.2
1995	12.34		19	14.8	6.4
1997	11.33	7.09	14	6.8	5.5
1999	12.68	7.59	15	9.5	11.8
2000	13.81	8.20	16	9.5	10.9
2001	16.09	9.35	16	8.5	9.9

Source: *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 1994-2002.

In 2001, the total waste gas from industrial production was up to 16,086 billion m³ and the flue gas from burning fossil fuels was over 9,353 billion m³, covering 58.16% of the total waste gas, by which, about 8.5 million tones of soot and 16.7 million tones of SO₂ was produced by burning fossil fuels like coal and oil, in China. As a result from a great amount of coal burnt directly, a study report appointed out that, as average values yearly, suspended particles in the air is up to 0.93 mg/m³/day in cities in North areas and 0.41 mg/m³/day in cities in south areas; SO₂ concentration in air is around 0.092 mg/m³/day in cities in North areas and 0.088 mg/m³/day in cities in south areas; and NO_x concentration in air goes to 0.054 mg/m³/day in cities in North areas and 0.048 mg/m³/day in cities in south areas.

It is estimated that the total CO₂ emission from fossil fuels was 2,279 million tones in China, equalized to 620 million tones of carbon and contributed 11.8% of CO₂ emission on the global GHG in 1990. By 2000, the total CO₂ emission from fossil fuels was up to 2824 million tones, about 790 million tones of carbon. Most of CO₂ emission, about 80%, was from industry burning fossil fuels as shown in the table 7, in the country.

Based on data in 1971, a prediction on the amount of CO₂ emission from using fossil fuels in the next century has been made by a research group in China. The result is shown in the table 8.

Table 7. CO₂ emission contributed by different energy sectors

Years	Total		Coal		Oil		Natural Gas	
	Energy *Mt-oe	CO ₂ Mt	Energy Mt-oe	CO ₂ Mt	Energy Mt-oe	CO ₂ Mt	Energy Mt-oe	CO ₂ Mt
1980	644.5	2114.45	465.33	1719.00	133.41	352.06	19.98	43.38
1985	536.8	1771.02	406.89	1503.14	91.79	242.23	11.81	25.64
1990	690.9	2279.02	526.47	1944.86	114.69	302.66	14.51	31.50
1993	764.2	2507.37	570.85	2108.82	139.08	367.03	14.52	31.53
1996	972.6	3184.06	726.56	2684.03	175.07	462.01	17.51	38.02
1997	964.6	3102.68	689.68	2547.79	196.78	519.28	16.40	35.61
1998	925.5	2948.90	644.15	2379.59	198.98	525.10	20.36	44.21
1999	910.8	2889.20	619.37	2288.05	211.31	557.64	20.04	43.51
2000	896.0	2824.34	600.32	2217.69	211.46	558.02	22.40	48.64

Source: Made by writers according to *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 2002 and 2002 World Energy Outlook by IEA

*Not: The total energy consumption includes the amount contributed by hydro-power

Table 8. A prediction on CO₂ emission contributed by different energy sectors in 2000 - 2030

Year	Total CO ₂ million tons	Coal		Oil		Natural Gas	
		Energy million t-oe	CO ₂ million ton	Energy million t-oe	CO ₂ million ton	Energy million t-oe	CO ₂ million ton
1971	812	192	681	43	124	3	7
2000	3,052	659	2,399	236	594	30	59
2010	4,155	854	3,169	336	862	57	124
2020	5,393	1,059	3,985	455	1,184	102	224
2030	6,717	1,278	4,869	578	1,518	151	330

Source: 2002 World Energy Outlook by IEA

By 2030, the annual CO₂ emission will have gone up to 6,717 million tones, about 1835 million tons of carbon, about 3 times as much as that in 1990 and 2.2 times as much as that in 2000. The increasing rate is over 7% yearly.

1.5 Environment Effects Caused from Biomass

In fact, the environment pollution is not only caused from burning fossil fuels, but also from unsuitable uses or treatments of biomass fuels. In China, biomass's effects on environmental quality can be contributed by four ways, biomass stove-burning or tradition combustion, open-burning crop residues in farmland, natural decomposition, and open-pile surround house, in which, the most harmful are stove-burning and open-burning in farmland.

As mentioned above, the direct stove burning is a traditional and major way in Chinese rural areas. By this way, about 200 million ton-oe of crop residues and firewood or wood waste are utilized at very low thermal efficiency, less than 10% or 1 – 5% some time, as fuel in each year. Such a way consuming biomass fuels not only squander too much energy resources, but also makes up a harmful living condition in farmer's houses, suffering from smoke, dust, ash and biomass wastes, which are the most harmful polluter for women and child in farmer families, causing some common respiratory diseases, such as tracheitis, pneumonia. Furthermore, rural families still fallen into dire straits of lacking fuels for 3~6 months per year. Furthermore, in some rural areas, mainly mountain areas, farmers are facing lack of fuels 3~6 months per year. They

have to make a over-cutting of forest, such as firewood forest, protect-forest and stand-forest, to meet their demand for fuels. It is a main factor on destroying ecological systems, losing water/soil, causing farmland degeneration and desertification in rural areas, especially in the northwest areas. It is estimated that about 3.9 million km² of farmland becoming desertification until 2001, and the farmland degeneration and desertification is occurring in a rate of 3,000 km² per years. In the North of China, most of cities, including Beijing, are suffering from sand-dust devil caused by the farmland degeneration and desertification.

Since 1991, the development of rural economy has brought a new problem that rural residents have begun to disuse their traditional fuel — biomass, but prefer to use convenient and clean fuels, such as coal and liquefied natural gas, because direct open-burning biomass fuels is less efficient, labored and too dirty. Thus, a great number of crop residues had to be burnt directly in farmland without any energy usage in order to reduce works on transportation and stockpile of these residues. It is roughly estimated that there was about 280 million tons of crop residues burnt on farmland in 1998.

Such open-burning caused serious air pollutions, damaged to human's healthy and hindered air and road transportation. A several events were reported in the year, such as traffic accidents on highways and airplane delay in some cities. For example, Capital Airport in Beijing and Shuangliu Airport in Chengdu had to be closed for several days, suffered from smoking by burning crop residues in the time of harvesting crops in 1997 and 1998 respectively. In recent years, the government has paid more attention on control the mistreatment of crop residues in rural areas and ruled out related regulations to forbidden burning crop residues on farmlands. So, the amount has being decreased deeply in recent years, but it is estimated that the amount is still up to about 10% of crop residues production in some areas being not good at managing the things. In addition, about 420 million tons of additional CO₂ emitted by the open burning, equal to 18% of the total CO₂ emission of China in this year.

Other environment effects caused from biomass include the natural decomposition and open-pile surround farmer's houses. The former is releasing fetor odor and the later uglifying village appearance, or create uncomfortable living condition.

By biomass power generation technology, such as biomass combustion, gasification and co-firing with coal, the thermal efficiency could be over 35% or more, in case of CHP systems, the efficiency might be up to 60% or more. It means that the biomass power plants applied these technologies could not only save much more energy resources and emit much less CO₂ than that by direct burning biomass, also improve ecological systems and protect farmers from smoke and dust pollution from biomass energy utilization in rural areas.

2. Biomass Resources in China

China is an agricultural country in which there are abundant biomass resources. From a theory estimation, its amount of biomass resources existing in cultivated lands, afforested lands and prairies in the country may be over 5 billion tons in dry weight that is equal to 1,700 Mt TOE. In fact, biomass resources available for energy mainly come from crop residues, firewood, forest wood residues and organic refuses, and the amount may be about 414 Mt TOE. China has paid more attention on developing new technologies for utilizing effectively biomass as energy and

will put these technologies into a popularized use in this new century.

In China, biomass resources that could be used as energy easily are mainly involved to four sources, i.e. crop residues, forest and wood residues, animal dung and organic refuses as following shown. Based on some related statistical data, an estimated amount of available biomass resources in the country will be calculated easily by simplified statistical ways.

2.1 Crop Residues

As mentioned above, the agriculture is one of main industries, which about In China, a great amount of crop residues can be produced from agricultural actions. These residues have been playing an important role in the rural energy in the Chinese energy history.

According to statistical data (2002), in 2001, there are 1.3 million km² of cultivated lands and 1.08 million km² of undeveloped land in which there are 0.354 million km² of useable land in this country. The total amount of grain products was 452.64 million tons, in which, the amount for rice, wheat and corn was 177.6, 93.9 and 114.1 million tons respectively.

Table 9. Production of Major Farm Crops (million ton)

Year	Rice	Wheat	Corn	Beans	Tubers	Oil-bearing Crops	Cotton	Sugarcane
1980	139.905	55.205	62.600		28.725	7.691	2.707	22.807
1985	168.569	85.805	63.826		26.036	15.784	4.147	51.549
1990	189.331	98.229	96.819		17.432	16.132	4.508	57.620
1993	177.514	106.390	102.704	19.504	31.811	18.039	3.739	64.194
1996	195.103	110.569	127.471	17.903	35.360	22.106	4.203	66.876
1998	198.713	109.726	132.954	20.006	36.042	23.139	4.501	83.438
1999	198.487	113.88	128.086	18.940	36.406	26.012	3.829	74.703
2000	187.908	99.636	106.000	20.100	36.852	29.548	4.417	68.280
2001	177.580	93.873	114.088	20.53	35.631	28.649	5.324	75.663

Source: Statistical Yearbook of China, the National Bureau of Statistics of China, China Statistical Publishing House, 1994-2002.

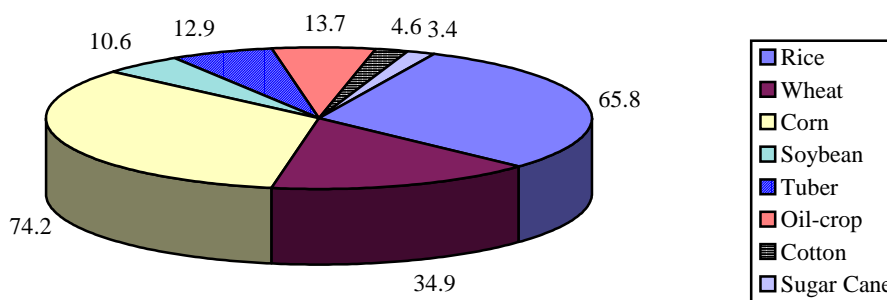


Fig. 5. Production of different crop residues in 2000 (Mtoe)*

* Sources: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.
Statistical Yearbook of China, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

In China, rice, wheat and corn are three kinds of main grain products; meanwhile, their residues are main biomass resources from agriculture production. In 2001, it is estimated that the total of

residues was 707.4 million tons, equal to 230.1 million ton-oe of biomass energy, in which, about 174.9 million ton-oe was from residues of rice, wheat and corn, covering 76.04% of total biomass energy from all crop residues in the country. Respectively, about 65.8 million ton-oe of biomass energy was contributed by rice residues covering 28.60%, 34.9 million ton-oe by wheat residues covering 15.16%, 74.2 million ton-oe by corn residues covering 32.25% and 55.2 million ton-oe by others covering 23.99% (Fig.5). Comparing the year of 2000, the amount had a little decreasing due to the grain production was decreased some in 2001.

In 1998, approximately, only 10 % of crop residues, about 80 million tons, was used as animal feeding, 20%, about 150 million tons, as industrial materials, 52%, 400 million tons, as fuels in rural areas and 18%, 140 million tons, burnt or disused directly in farmlands.

2.2 Forest Wastes

According the Fifth National Survey on Forest Resources (1994-1998) conducted in 2000, up to 1998, there are forestry lands about 2.63 million km² and forest lands 1.59 million km², in which Wood living stocks was about 12.49 billion m³ and forest stock over 11.27 billion m³ in China. Comparing with the Fourth Survey on National Forest Resources made in 1994, it is shown that the area of forestlands and the forest stock volume had been increased about 10%, due to maintain a greater growth rate of tree than consumption rate of wood.

Table 10. Area and volume of forest categories in the major forest regions in 1998

Regions	Total of stand		Timber forest		Protection forest		Firewood forest		Special forest	
	Area	Volume	Area	Volume	Area	Volume	Area	Volume	Area	Volume
	million km ²	million m ³	million km ²	million m ³	million km ²	million m ³	million km ²	million m ³	million km ²	million m ³
Northeast	0.3324	2,934.86	0.3056	2,651.89	0.009	95.22	0.0026	11.02	0.0151	176.72
Southwest	0.1902	3,455.65	0.1196	2,166.62	0.0581	1,067.91	0.0046	30.29	0.0079	190.83
South hill	0.3162	1,414.03	0.2657	1,202.54	0.0255	148.01	0.0215	20.65	0.0036	42.83
Northwest	0.0224	330.96	0.01	149.65	0.0085	128.69	0.0005	1.14	0.0034	51.48
Total	0.8612	8,135.50	0.7009	6170.7	0.1011	1439.83	0.0292	63.1	0.03	461.86

Source: China's Forestry (1949-1998), The State Forest Administration of PRC, China Forestry Publishing House, 2000

From distribution of Chinese forests, it is shown that the North Area is the biggest area of; the second should be the Southwest. But in the East as well as the Northwest, there are only some hundred thousands hectares of forestation, because of the East behaving such a special area, big population, many huge cities, spacious water, covering low and short plants; otherwise, the northwest region is much for the desert with the loess plateau the district, dry and little rain.

However, the forest cover rate was very low, only 16.55%, 10.5% less than that of the world's average rate, and the Capita Forest Area was 0.128 hectare, equal to 20% of the world's level; the capital forest stock was 9.05 m³, only equal to 12.5% of the world's level (72 m³). The firewood forest is the smallest forest, only 0.0429 million km², and 3.95% of the total. So Chinese Government has paid more attention on developing its forest industry and enlarges its forest area in the next few decades.

It is estimated that the yearly yield of firewood may be over 157 million tons in 1998, or equal to 67 million ton-oe (Fig.6).

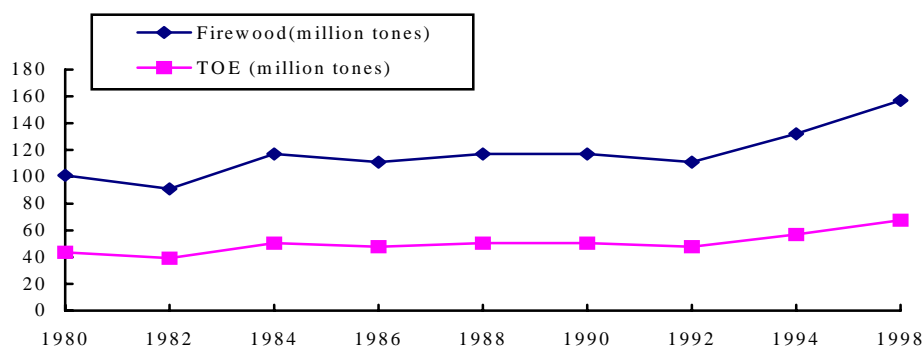


Fig.6. Production of firewood in China in several years*

Sources: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.

And Calculation based on information involved in:

1. *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.
2. *China Forestry Yearbook*, The State forestry Administration of China, China Forestry Publishing House, 2001.
3. *China Forestry Development Report 2001*, The State forestry Administration of China, China Forestry Publishing House, 2002.
4. *China's Forestry (1949-1998)*, The State Forest Administration of PRC, China Forestry Publishing House, 2000

From Fig.6, we can see that there is a little increasing of firewood production. But, it must be remembered that this estimation is made as a rational supply amount in theory, and in fact, the amount of firewood consumption is beyond these figures much, the shortage comes from over-cutting forest trees.

In China, the wood consumption primarily is divided into three greatest parts, one is the merchandise wood, roughly occupy 44.2% of the total amount, of which, about 2.9% is picked by the national selling plan and about 32.1% is sold in wood market; The second consumption is used by wood producers or farmers, of which, most is used by farmers for producing their facilities; the third is used for living fuels by a direct burning, roughly to occupy 28.8% of the total amount. Also, there is some other depletion of woods, about 3.5%, such as wood stolen, about 1.7%.

2.3 Dung

As livestock production and population in cities have been enlarged in recent years, the dung or manure has become a serious pollution source for the water body, meanwhile, it has been an important biomass resources contracted in a great attention by the government and experts in country.

In 1999, Chinese population was up to 1.27 billion, the numbers of livestock fed in farms was: large animals 151.5 million heads including houses, cattle, donkeys, mules and camels; hogs 447 million heads; sheep and goats 290 million heads; the poultry 5.28 billion heads in 2000.

Table 11. Number of Livestock (million heads)

Year	Cattle and Buffaloes	Horses	Slaughtered Fattened Hogs	Hogs (year-end)	Sheep and Goats(year-end)
1996	110.32	8.72	412.25	362.84	237.28
1997	121.82	8.91	464.84	400.35	255.76
1998	124.42	8.98	502.15	422.56	269.04
1999	126.98	8.91	507.49	431.44	279.26
2000	128.66	8.77	526.73	446.82	290.32

Source: *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

Table 12. Output of Livestock Products (million tons)

Year	Pork	Beef	Mutton	Milk	Sheep Wool	Goat Wool	Poultry Eggs	Honey
1996	31.58	3.56	1.81	7.36	0.30	0.035	19.65	0.18
1997	35.96	4.41	2.13	6.81	0.26	0.026	18.97	0.21
1998	38.84	4.80	2.35	7.45	0.28	0.032	20.21	0.21
1999	38.90	5.05	2.51	8.07	0.28	0.032	21.35	0.23
2000	40.31	5.33	2.74	9.19	0.29	0.033	22.43	0.25

Source: *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

Based on the data mentioned above and excretion rates of animal dung, it may be estimated that the biomass resource from the dung residue might be up to 320 million tons in dry weight, about 110 million toe in 2000. In Fig.7 it is shown that the yield of dung has increased in recent years as the development of livestock production and population enlarged in the country.

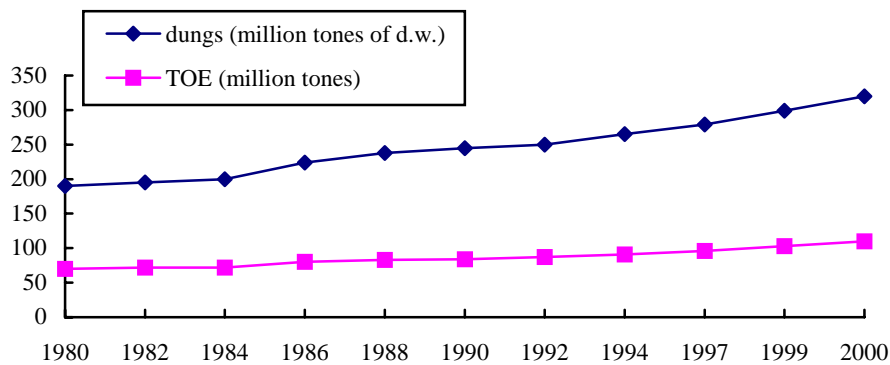


Fig.7. Biomass from animal dung (1980-2000)*

* Sources: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers. And Calculated result based on *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

However, there is a small amount of animal dung used as energy in China. The first use is the direct burning animal dung as energy occurred only in minority areas, such as Tibet, Qinghai and Ningxia, where a heavily shortage of energy sources and the amount might be 10 million tons. Secondly, there are some amount of animal dung has been used as materials for household biogas digester in rural areas, and the amount might be 7 million tons in dry weight.

2.4 Industrial Solid Wastes (ISW)

Industrial biomass resources include solid waste from industrial processes, such as distillery, paper, timber, grain, sugar and food industry production. It is estimated that the total annual yield of biomass residues from the industry may be up to 48 million ton-oe in cities of the country.

- **Crop Husk:** It is estimated that about 81.28 million tons of husk can be produced from rice and wheat processing. In fact, there are some husks lost and used as raw materials for some industrial production, such as cooking fuel, alcohol fermentation process and animal feed, may be up to 30%. So the available resource might be over 55 million tons, about 18 million ton-oe.
- **Biomass Wastes form Paper Mills:** In the whole country, the number of paper mills

operated may be up to 10,000 mills, of which, most of them are small in their production capacity, only one over 200,000 tons/year, including paper, paperboard and pulp, and 20 mills over 100,000 tons/year and 100 mills over 30,000 tons/year. Most of paper & pulp produced are made from herbage materials, such as rice & wheat residues, reed, sugarcane discard and so on, about 70%, only 30% from wood materials. It is estimated that this resource may be up to 3.20 million tons, or 1.1 million ton-oe, in which about 1.03 million tons from wood pulp production, or 0.3 million ton-oe, but there is a little amount of these refuses being used as energy.

- Wood Wastes from Timber Mills: According an estimation by some experts, the wood demand in the country must be up to 300 million m³ yearly, but only 150 million m³ can be supplied by domestic products at present, that is, the shortage should be over 50%. By 2001, the import of wood and wood products equal to original wood was up to 90 million m³, about 32% of total wood consumption in China. In 1999, the timber wastes produced from processing domestic wood material to wood products was over 37.03 million m³, or 18.5 million tons of wood. If the estimation can be made on base a prediction, the resource might be up to 100 million m³ or 50 million tons of wood by 2005, and 140 million m³ or 70 million tons of wood by 2015.
- Wastes from Other Industries Related to Biomass Resources: This part of biomass resources includes wastewaters from distillery, paper, sugar and food industry production. In a statistics based on data of 1990 for 230 cities in China, it is shown that about 6 billion tons of waste water containing a high concentration of organic matter was drained from distillery, paper, sugar and food processing, in which, about 2.5 million tons of COD* accounted for 33.2% of total amount of 7.2 million tons COD discharged from industrial production in the country. In addition, about 53 million tons of wastewater was excreted daily from daily life in these cities in the same year.

2.5 Municipal Solid Wastes

Municipal solid wastes (MSW) mainly come from daily life of residents in cities, of which some parts come from schools, hospitals, parks, and so on. The yield of MSW is depended on the enlarging and the civilization level in cities. Recently, the MSW is continually increasing yearly on its yield in China. The total amount of MSW collection had been up to 107.5 million tons in 1995 and 118.2 million tons in 2000. The table 23 shows the situation of MSW in 1985–2000, the increasing rate around 10% yearly.

Table13. The historical data of the MSW collection in China

Items	1985	1990	1995	1997	1998	1999	2000
MSW (million ton)	44.8	67.7	107.5	109.8	113.0	114.2	118.2

Sources: *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 1987-2002

The MSW amount yielded is mainly depended on some social factors, such as population, living condition, consumption structure, fuel structure, vegetable food structure and package food consumption and so on. By 1995, there were 640 cities in China, in which about 438 cities were the small city, population less than 0.2 million, 192 cities were middle city, population between 0.2 and 0.50 million, 65 cities were the big city, population between 0.5 and 2 million, and only 10 were the biggest city, population over 2 million.

The situation of MSW yield and treatment is very different in different cities as shown in the

following figure. It is clearly shown in the figure, the biggest cities are main sources of MSW in China, their amounts of MSW collection over 1 million tons.

The MSW is a complex mixture of different solid wastes from different sources, so its component is greatly depended on living condition, energy structure, city construction, and seasons etc. A component analysis for different cities is shown in the table 14.

Table 14. The component of the rubbish in several cities (%)

City\waste	Kitchen rubbish	Waste paper	Waste plastics	Fibrin waste	Furnace dust	Glass waste	Metal waste	Total organic
Beijing	27	3	2.5	0.5	63	2	2	33
Tianjin	23	4	4		61	4	4	31
Hangzhou	25	3	3		5	2	2	31
Chongqing	20				80			20
Harbin	16	2	1.5	0.5	76	2	2	20
Shenzhen	27.5	14	15.5	8.5	14	5	5.5	65.5
Shanghai	71.6	8.6	8.8	3.9	1.8	4.5	0.6	92.9

Sources: Partly from Strategy and Policy Study on Biomass Energy, Expert Group of Evaluation and Strategy Study on Commercialization of Biomass Energy Technology in China, MOA of China and MOE of U.S., 1995.

Form the table 14, it is can be see that the MSW components are very different in these cities each other, Generally, the more developed city is, the more organic waste in their MSW carried, and in cities of north, the organic wastes carried in MSW are less than that of in south. In addition, the heat value of MSW form different sources in a city is also very different to other sources. The table 25 shows a result from a heat value analysis made by an institute on different MSW sources.

Table15. Heat Values of the Different Kind of Rubbish (kJ/kg)

MSW sources	Values	MSW sources	Values
Residential area with Centralized heating and fuel-gas	4,500	Commercial area	8,200
Building for rich residents	900	Bungalow	2,800
Building for Enterprises	9,900	Dump	2,900
Hospital area	7,500	Big restaurant	10,900

Sources: Partly from Strategy and Policy Study on Biomass Energy, Expert Group of Evaluation and Strategy Study on Commercialization of Biomass Energy Technology in China, MOA of China and MOE of U.S., 1995.

In average, the heat value might be around 4,500 kJ/kg of MSW, so we can roughly estimate or calculate the amount of biomass energy carried in the MSW in China. In 2000, the total amount of MSW collection was about 118 million tons, that is, the amount of biomass energy was about 12 million tons of ton-oe in China.

2.6 Energy Plantation

Concerning on the limitation of fossil fuels, non-renewable, now, people have gradually paid more attention on renewable energy, especially on biomass energy. It is important for human society that some new biomass resources should be found to meet a great increase of energy demand and supply more fuel materials for energy industry in the near future. A possible way is to develop “energy plants”, including energy crop and energy trees etc.

The energy plants means such a plant to be planted for energy uses in farmlands, mountain areas and water bodies, such as firewood forests mentioned in the firewood sector of this paper, plants bearing oil, crops bearing starch or sugar and plants or microbe growing in water bodies. Most of

energy plants are growing in nature conditions so that they are very difficult to be collected for energy uses. By now, the people have to consciously cultivate these energy plants through some modern ways, such as engraftment, miscegenation, domestication and gene recombination, to try a great raise of biomass output for the increasing continuously demand of energy market in the future.

In fact, the government, institutes and experts related to biomass have been attracted by energy plants and paid a great attention on the concept of energy agriculture and energy forestry in China. The energy plants or energy crop means each kind of plants planted to be used as energy resources by anaerobic digestion or energy conversion technology, such as firewood forests at quick growing rates, plants or trees with high contents of oil or petroliferous juices, plants with high contents starch or cellulose, and others. Chinese government paid a great attention on developing energy plant, especially firewood forests. Some kinds of firewood trees are shown in the following table.

According to the survey of forest resources in 1998, China has about 0.0429 million km² of firewood forest occupied 3.95% of the total forest area in this year. In the national plan of planting trees, it is declared that China will plant 0.0603 million km² of firewood forest, that is, the area of Chinese firewood forest should have exceed 0.01 million km² by 2001.

Table 16. Some of popular firewood trees grown in Chin

Types of firewood trees	Heat Value (kcal/ kg)	Wood Yield (kg/ ha/ year)	Distribution areas
Horsetail pine	4822	625-750	Qinglin and South Huaihe
Black Pine	4180	1500	North and Northeast China
Hemp oak	4750	2000	Whole Country
Tussah tree	4530	350	North and Northeast China
Black Catalpa	4650	1000	South and East China
Silver matches	4100	1400	Tropical zone, subtropics
Yellow Hemp	4950	1000-2000	Guangdong, Fujian
Acacia		900	Whole Country
Blue Eucalypti	4800	1400	Sichuan, Yunnan

Source: Strategy Consideration on Developing and utilizing Biomass Energy in China, Wang Mengjie et al, a report by China Association of Rural Energy Industry, 2000

Afforest of firewood trees for energy purpose has been made for 20 years in China. In 70's, even though farmers used about 70% of crop residues as their daily life energy in rural areas, they had to face 30% of energy shortage so that they had to over-cut for their energy demands. In that time, the government carried out a national plant to develop firewood forest for resolving a series of serious problems, including energy shortage, forest over-cutting and ecological depravation. By 1995, the rate of forest covering had been increased to 13.9% from 8% in 50's, in which the area of wood forest was up to 5.4 million hectares. In the national plan, another 16 million hectares of forest will be built in the next 20 years, that is, about 300 million tons of firewood will be produced by 2020. By now, some institutes on support of national plans have developed several energy plants, such as sweet sorghum, sugar cane, sweet potato, etc.

2.7 Overview on Biomass

2.7.1 Basic Characteristics of Biomass

All biomass matters come from solar energy captured by plants through the photosynthesis so that

the biomass resource is a huge reserve or sink for solar energy in the global. Comparing fossil fuels, all biomass resources have some common characters shown as following:

- Biomass is a renewable and hug natural resource and provide a sustainable energy resource for most human activities through a successful management on it;
- Biomass features less content of toxic substances (S, N, Cl, heavy metals, etc.) than fossil fuel, < 0.1% of sulfur element, and the main constitute are carbon and hydrogen, similar to fossil fuels except oxygen, so it is a clean energy resource with a small environmental burden and could be used to replace fossil fuel in a large scale. However, MSW and industrial waste biomass produce Dxn (PCDDs), heavy metals, etc., and they give significant environmental burdens unless measures for eliminating them are taken.
- GHG reduction effect: Effects to fix, store and reduce CO₂ can be expected. Encouragement of recycling is possible by means of photosynthesis, and thus offering the GHG reduction effect.
- But its low density, 300~700 kg/m³ or 4.2 ~12.6GJ/ m³ and uneven distribution, due to different crop plantation and climate condition in different areas, may make it to be difficultly conducted an efficient collection and convenient transportation, that may raise its cost in energy systems. In most of cases, especially in mountain areas, biomass materials must be carried or burdened by man-labor to collection sites.
- And also, its low heat value, 14,000~18,000kJ/kg and high water content, 5~20% may make some increase of investment on building and operating the systems

2.7.2 Biomass Resources and Its Energy Potential

Overlooking some small biomass resources, like waste water, and, only from four resources, such as crop residues, firewood, animal dung and industrial solid wastes, a great amount of biomass can be used as energy sources, about 473 million ton-oe (Fig.8). It can be seen that the crop residue is the biggest biomass resource, covering about 51% of the total biomass resource in the country. In 2000, about 150 million ton-oe of biomass was used as energy, covering 14% of the total amount of biomass resources in the country (the total consumption was 1,074 million ton-oe, that is, 924 fossil fuels and 150 million ton-oe biomass).

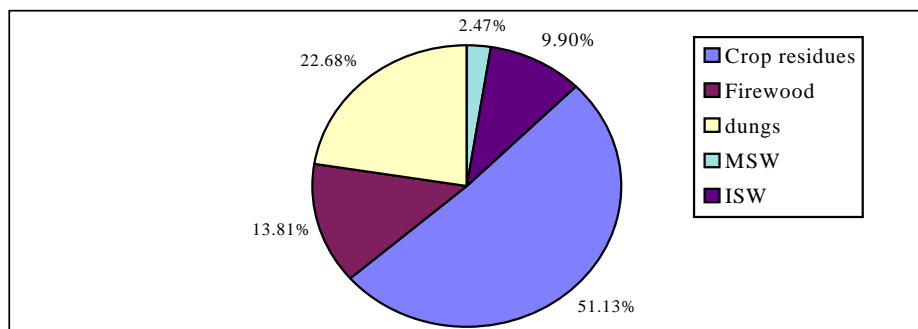


Fig. 8. The Constitute of biomass from different sources in China (473 million ton-oe)

Source: Calculation by writers of this paper based on related information

In order to make clear the energy potential of the biomass resource, we can do some suppose

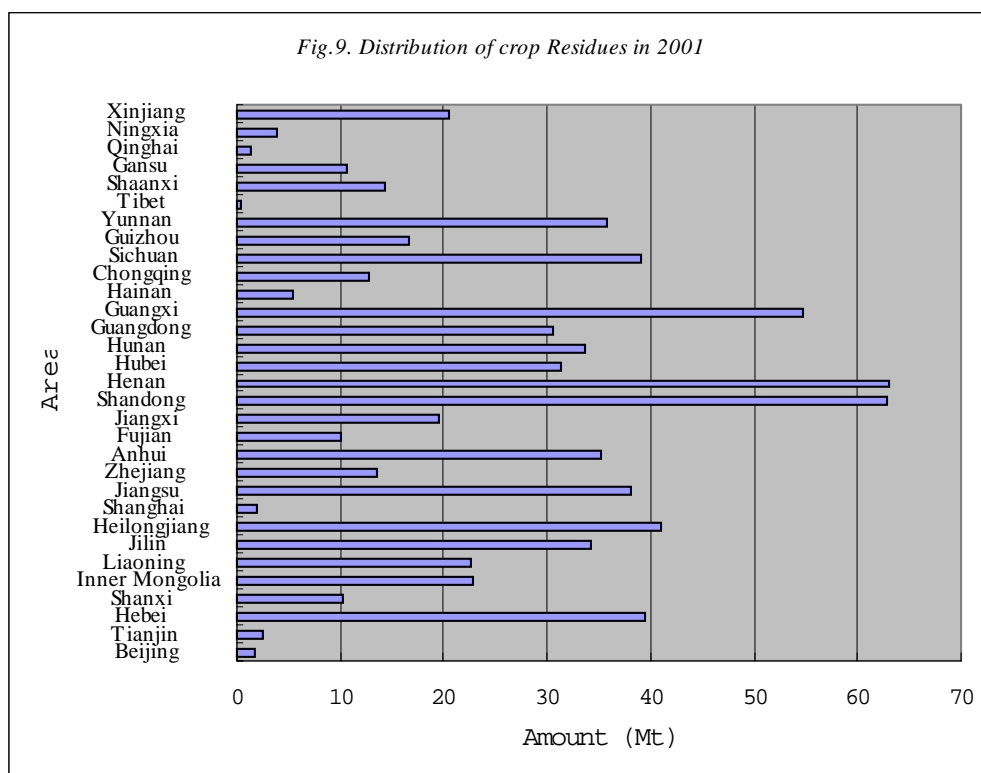
based on discussion above on its resources.

- If the biomass of 150 million ton-oe, used as energy in 2000, could be consumed as energy through some advanced technologies, modern combustion, co-firing with coal and /or gasification, for power generation, about 600 TWh of electricity could be generated yearly, equal to 44.54% of total electricity production in China in the year.
- If the biomass of 373 million ton-oe, generated in sectors of crop residues, wood residues, firewood and MSW in 2020, could be utilized for power generation, about 1,500 TWh of electricity should be generated yearly, equal to 43.34% of total electricity production in China in the year.
- If 700 million ton-oe the biomass in the future, generated in case of developing energy plants on 1.70 million km² of undeveloped land for forest and agriculture in the future, could be utilized for power generation, about 2,800 TWh of electricity could be generated yearly.

According to a predict study, the available biomass energy, only crop residues, will be up to 370 million ton-oe by 2020 and over 500 million ton-oe by 2050, when the grain production will be up to 1.6 billion tons. This prediction is based on a fact that China has 1.48 million km² of farmland for its agricultural production, but according to an update survey, the total area of farmland is up to 2.00 million km².

2.7.3 Distribution of Biomass Resources

Fig.9 shows the distribution situation of crop residues resources in 2001.



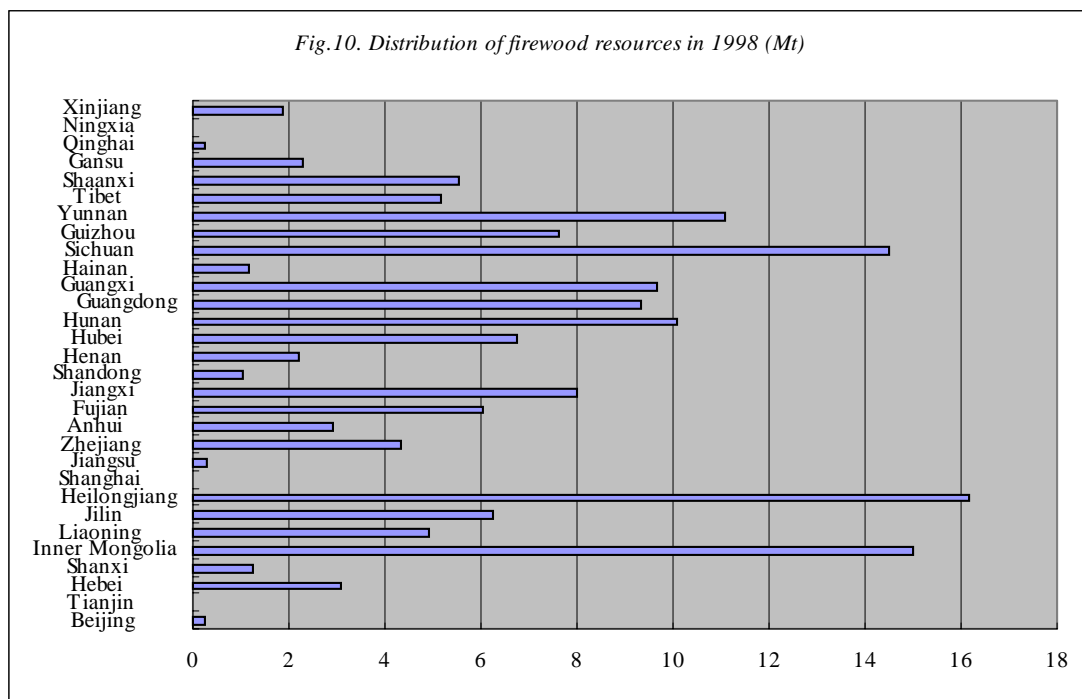
Source: Calculation by writers of this paper based on related information

Being different from other energy sources, biomass resource has some characters that should be

considered carefully for selecting ways of using it as energy. By its utilization as energy, not only a lot of fossil fuels will be saved, but also a great of benefits on environment improvement will be obtained. Of course, its distribution should be considered for collecting and transporting biomass materials easily in order to conduct such a project successfully.

In 2001, the total crop residues production was up to 730 million tons, including about 60 million tons of sugar cane residues produced in Guangxi, Guangdong and Guizhou provinces. The crop residues resources is distributed in some agricultural provinces, for instance, about 63 million tons in Shandomg, 62 million tons in Henan and 55 million tons in Guangxi (including 22 million tons of sugar cane residues), Other provinces with abundant crop residues are Heongjiang, Hebei, Jiangu, Anhui, Hubei Hunan, Guangdong and Tibet.

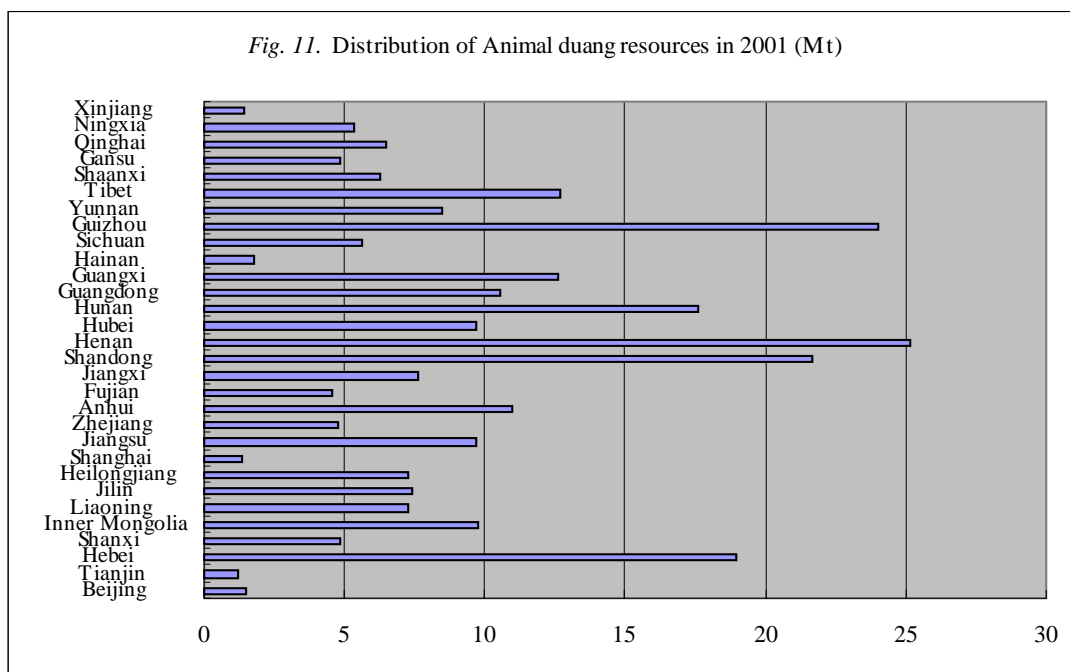
The fig.10 shows the distribution of firewood resources in1998 due to no available data in recent years. In 1998, the total firewood resource in China was about 160 million tons. From the figure, it is clear that there are three biggest firewood resources in China, that is Northeast region, including Helongjiang, Inner Mongolia, Jilin and Loiaoning Provinces, about 43 million tons; Southwest region, including Yunnan, Sichuan and Guizhou provinces, about 36 million tons; and South region, including Guangdong, Guangxi and Hunan provinces, about 33 million tons.



Source: Calculation by writers of this paper based on related information

The Fig.11 shows the distribution of animal dung resources in 2001. The total amount was about 280 million tons. Its main distribution region is some agricultural provinces, such as Hebei, Henan, Guizhou, Hunan and Shandong, each more than 17 million tons yearly; in some other provinces, such as Jiangsu Anhui Hubei, Guangxi, inner Mongolia Guandong and Tibet, the amount are over or near to 10 million tons yearly. Overall, in the Northeast, Southwest and South Areas, the firewood resources and in the North, and the two side-banks along the middle of the Yongze River, crop biomass resources are more abundant than other areas. In these areas, it is suitable to developing biomass power projects, such as combustion, co-firing with coal and gasification using

in large scales.



2.8 Rural Energy and Biomass's Role

In 1998, the rural energy consumption was about 316 million ton-oe, occupied 34.2% of the total commerce energy consumption in the country. In fact, the total rural energy consumption was up to 471 million ton-oe in 1998. The official statistics data is only for the consumption of commerce energy, but not include the amount of biomass used as energy in rural areas. To add the biomass energy consumed in rural areas, about 155 million ton-oe, into the counting.

For a long history, China has been using biomass as energy, especially in rural areas, biomass being utilized by a way of directly burning in a traditional stove, the heat efficiency only 10%. Before 1979, the biomass energy had covered about 70% of the rural energy consumption, occupying about 152 million ton-oe in the total energy consumption of 234 million ton-oe. Up to now, the biomass energy are still playing an important role on the rural energy, the total amount of biomass used as energy has been much changed in recent 20 year, still up to 155 million ton-oe, even though commerce energy sources, such as coal, oil and electricity, have been popularized and increased in rural areas (Fig.12).

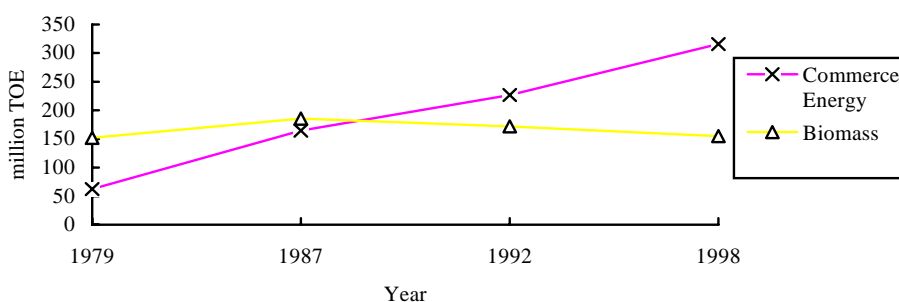


Fig.12. Changes of commerce energy and biomass energy in rural areas

In the fossil fuels, about 66.6% was the coal fuel, up to 209 million ton-oe and 21.9% was electricity from national grid, about 69 million ton-oe. In case of biomass, about 53.3% was crop residues, near to 87 million ton-oe and 46.7% was firewood, over 69 million ton-oe. In addition, there was about 1.9 million ton-oe from solar and biogas energy.

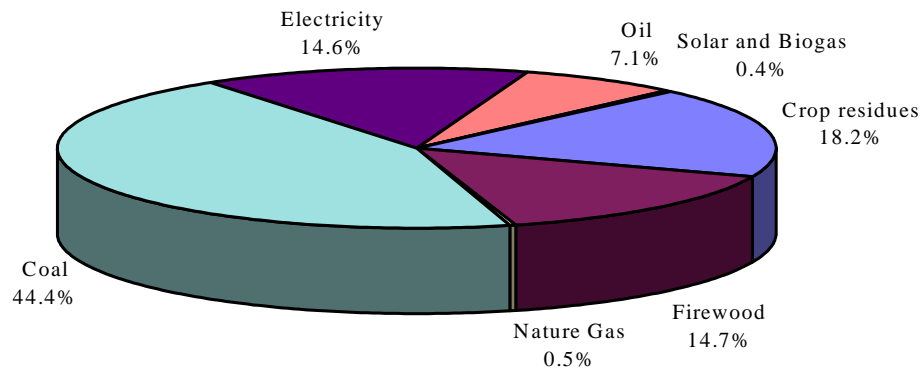


Fig.13. Constitution of the rural energy consumption in 1998 (471 MTOE)

Source: Rural Energy Development in China 1979-1999, China Energy Research Society and China Association of Rural Energy Industry, 2000

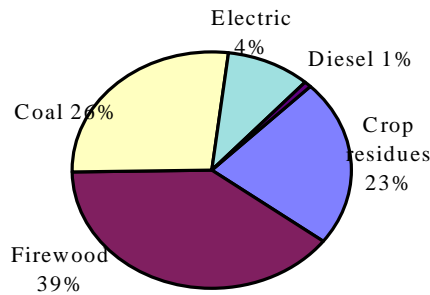


Fig.14 Constitution of household energy consumption in 1995 (224 MTOE)

Source: Research and Development on Biomass Energy in China, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.

In fig.14, it is shown that the energy consumption for rural household actually relies on biomass and coal, covering 62% and 23% respectively. It must be taken more attention that there was too much firewood consumed, up to 204 million tons, of which some parts consumed was from the over-cutting forest. In fact, firewood has been using as the main energy for household fuels as well as crop residues in rural areas, especially in provinces of the South China, for example, in Yunnan Province, about 70% of household fuels come from firewood, the figure is about 67.5% in Fujian Province, and 54.4% in Guangdong, 44.7% in Jiangxi, 40.6% in Hunan and 33.7% in Zhejiang. Also in some provinces of the North China, firewood is playing an important role on meeting for farmer's energy demand on household fuels, such as Helongjiang, Liaoning, Henan, Shaanxi and Guansu.

To consider the energy demand in rural areas, the energy shortage may be 10% in the whole rural areas. Some factories have to stop their operation due to the energy shortage. Actually, in some areas far from fossil fuels production sites, or undeveloped areas, such as provinces in the Western China, the shortage must be over 30%, thus cutting down forest has become a way to make compensation for the shortage. In other hand, in some areas closed to fossil fuels production sites, such as provinces in the Northeast, North and Middle of China, or developed areas, such as

provinces in the East and South of China, farmers are prefer to use fossil fuels, coal or LPG, for their life energy but disuse their traditional fuel, crop residues, as wastes and treat it by burning directly on farmland, that caused a serious air pollution and much energy squander in rural areas

3. Biomass energy and its utilization technologies

Biomass energy technologies may be roughly related to direct burning, physical process, biochemical process, and thermal chemical process. In the world, most of research works have been attracted into on the following technologies: anaerobic process for treating organic wastes and producing biogas for cooking and/or power generation, biomass gasification process for treating solid biomass residues and producing gas fuels for cooking, wood drying and/or power generation, landfill process for treating municipal solid wastes (MSW) and producing biogas for power generation, incineration process for treating wood and crop residues or MSW and producing heat for power generation, co-firing with coal process for treating solid biomass wastes, reducing environmental pollution from coal fuels and power generation, therm-liquefaction for converting solid biomass into liquid fuel, alcohol production for converting cellulose, sugar or starch materials into alcohol fuels and others, such as biomass briquetting and pylyolysis. These technologies, energy products and their final uses are shown in the fig.15.

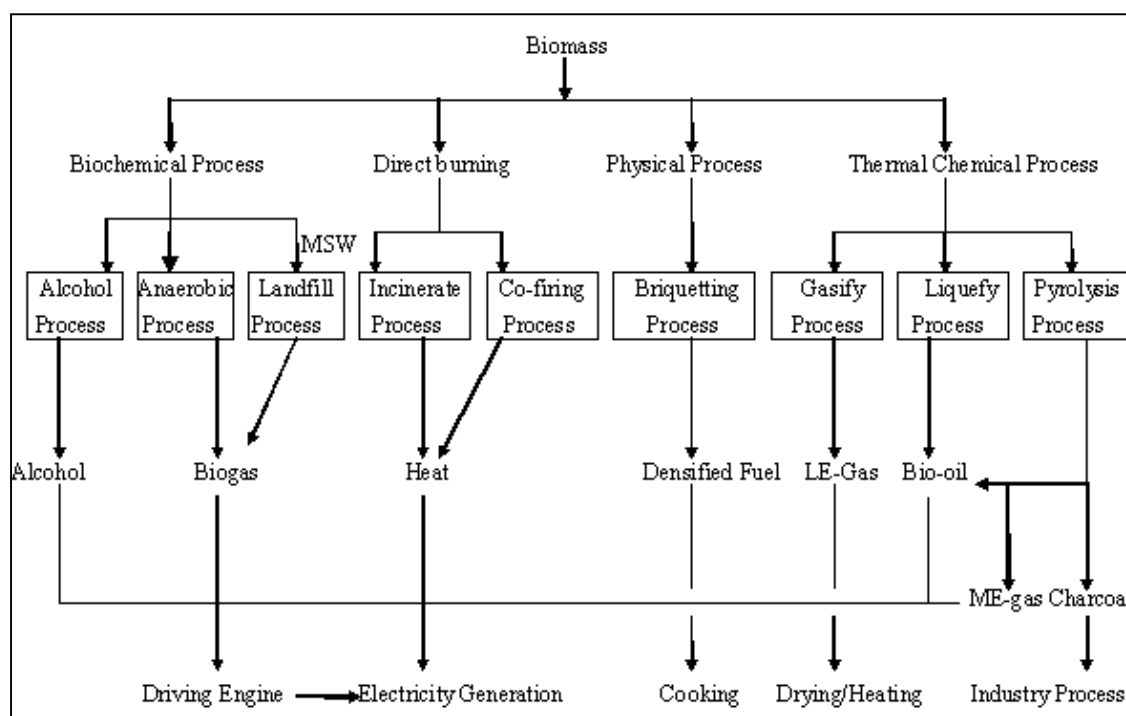


Fig.15. Biomass energy conversion technologies and their relations

Traditionally, biomass is a major energy source in China, especially in its rural areas. Crop and forest residues are two sources of biomass and mainly used as fuels for cooking food and/or warming room by a way of direct burning.

In 1979, there was a serious shortage of energy occurred in Chinese rural areas. The total energy consumption only 224 million TOE. Even though about 83.4% of rural energy was used as living energy, but about 47% of rural families still fallen into dire straits of lacking energy for 3~6

months per year. In order to resolve this problem, China government put the development of biomass energy utilization technology into the 6th Five Year Plan (1981-1985) and the 7th Five Year Plan (1986-1990). Since that time, China had begun to develop its biomass resources and energy conversion technology. Up to 1990, about 2.8 million hectares of firewood forest had been planted, 5 million sets of household biogas digesters had been built and operated, and a great amount of saving-fuel stoves had been used by 110 million of rural families.

Since 1991, the development of rural economy has brought a new problem that rural residents have begun to disuse their traditional fuel — biomass, but prefer to use convenient and clean fuels, such as coal and liquefied natural gas, because direct burning biomass fuels is less efficient, labored and too dirty. Thus, most of crop residues had to be burnt directly in cultivated land in order to reduce works on transportation and stockpile of these residues.

In China, there are still 110 million people who have no electricity supply, 70 million suffer from the severe shortage of firewood for cooking, and another 170 million people suffer from the threat of their land being reduced to desert. Moreover, the cost of the environment can not be neglected. Firstly, the environment has been severely destroyed, which results in the increase of land area of from 1.5 million km² in 1950's to 3.67 million km² being washed away. Secondly, the disorderly use and waste of biomass resources increases pollution. Thirdly, the environment quality deteriorates with the rapid development of village and town enterprises.

So, China has paid more attention on developing new technologies to convert biomass into convenient and clean energy products, such as low or middle energy gas fuel, biogas, briquette fuel and liquid fuel, in the period of the 8th Five Year Plan (1991-1995). During the 9th Five Year Plan (1996-2000) and the first decade of the this century, China will continue to develop its biomass energy conversion technologies and put more and more financial investment to support conduction of priority projects in this fields.

3.1 Biogas

The biogas projects on animal farms refer to the complete set of engineering equipment for anaerobic digestion with animal excrement as its raw materials for the production of biogas and the harness of the environment pollution.

The development of biogas projects on large- and medium-scale animal farms in China began in the late 1970s. By now it has a history of 20 years. The development is closely related to the development of the size and the level of concentration of the breeding industry in China and is related to the concern of the whole society over the environment protection. The development of biogas technology can be roughly divided into three periods:

The first period lasted from the late 1970s to the mid-1980s. The biogas projects on animal farms during this period were mainly built for the production of biogas to alleviate the severe energy shortage in rural area. As large- and medium-scale animal farms were not common, the materials for digestion of the projects were taken from animal excrement and sometimes from crop stalks. The rectangular or cylindrical digester was the major part in the project and was usually built underground. The digestion was performed under normal temperature and the volumetric biogas production only came to about 0.2m³/m³ per day. The digested residue was used as fertilizer with no treatment. Some types of digester developed in the period are shown in following table.

Table 17. Several kinds of household digesters and their performances

item name	Temperature °C	TS %	Adaptability	Pressure	Gas production rate m ³ /m ³ .day
Hydro-pressure digester	10-20	3-5	high	high	0.15-0.5
Cover-hold Digester	10-20	3-5	in south area	low	0.1-0.15
RM-PVC Digester	25-35	6-8	in south area	low	0.25-0.35
Solar-heating Digester	22-37	5-7	in north area	high	0.32-0.81
Two-step Digester	10-20	5-15	normal	high	0.3
High-efficiency Digester	20-30	6-8	high	high	0.3

The second period lasted from the mid 1980s to the early 1990s. During this period research was performed on digestion technology, construction of the digester and counterpart equipment in view of the problems in the large- and medium-scale biogas projects. The biogas projects were normally and steadily operating. The volumetric yield of biogas under normal temperature approached 0.5m³/m³ per day. The biogas projects on the Mianyang breeding stock farm in Sichuan and the Dengta chicken farm in Hangzhou are examples. Meanwhile advanced technologies were introduced from abroad and training and administration were enforced, which greatly promoted the technology for biogas projects. The promotion can be seen in the following:

Various types of technologies for anaerobic digestion had been employed, such as upper fluid, anaerobic filter, anaerobic contact, etc. Stirring devices were commonly adopted. Some projects used mid-temperature for the digestion to ensure the annual average gas production. The digesters were mostly built on the ground and concrete was taken as the construction material. The stirring became more and more standard. Pretreatment had been paid attention to. For example, there appeared special sedimentation tank, mixing boxes and dreg-filter, etc.

Special equipment for biogas storage and mostly wet tanks were adopted, and equipment for desulfurization of biogas was put into use. The issue that special attention should be paid to the benefit of the environment protection at the same time with the exploitation of energy resources, and that comprehensive utilization should be adopted was for the first time put forward. Administration was enforced. The design of most projects was standard. On-the-spot check before acceptance was performed after the construction of the projects and collections of drawings for reference had been made.

Table 18. Some kinds of typical anaerobic treatment system and there technical parameter

Item Type	COD Concentration mg/l	Temperature Condition °C	Load COD kg/m ³ .d	Retain Time days	Biogas Released m ³ /m ³ .d	COD Remove %
Anaerobic touching reactor	730	nature	2-4	10-20	0.5-1.0	80
Up-flow AF sludge bed	3000-10000	37	11-13.5	6-9	4.0-6.9	85
Up-flow fixes reactor	5000-20000	38±2	15-20	1-2	8.2	86

The third period began in the early 1990s and lasts till now. The progress in this period can be seen in three aspects: (1) more stress is put on the environment benefit of the projects; (2) the economic benefit of the projects is increased through comprehensive utilization; and (3) the comprehensive benefit of the projects is realized by way of excellent design, construction, and brilliant counterpart equipment, e.g., biogas projects on Xizi breeding farm in Hangzhou and Tangwan breeding farm in Shanghai. Table 18 summarizes the goals of the biogas projects in different phases, the raw materials, and the digestion technologies.

By now, the technology has been improved greatly and used widely in the country. For example, some new household digesters have been improved to be more efficient and more convenient, to get more biogas and to put smaller investment comparing old ones. The biogas production efficiency of old digester is only $0.1 \text{ m}^3 / \text{m}^3 \cdot \text{d}$, but that of these new digesters can be between 0.2 and $0.4 \text{ m}^3 / \text{m}^3 \cdot \text{d}$. Another example is anaerobic technology that many kinds of processes have been developed in China, such as mixing reactor, filter reactor, sludge bed reactor and fixed bed reactor. These reactors have been used widely for treating waste-water from food processing, fermentation processing, sugar fining and daily life, and animal dung from pig farms, cow farms and chicken farms. Their biogas conversion efficiencies can be varied from 0.5 to $6.9 \text{ m}^3 / \text{m}^3 \cdot \text{d}$ and rates of COD removed can be in range from 70% to 86% .

3.2 Gasification

China began very early to research biomass pyrolysis gasification. During the 1950s energy shortage, it began to use gasifiers to drive vehicles, rural drainage, and irrigation machines. There had formed some approved products. A set of timber-distillation production line was imported from Poland. For wood chip-fueled gasification technology, it had been used to produce gas to drive automobiles as earlier as the 1940s. Now it has been developed to circulating fluidized-bed gasifier from layer-mode gasifier with an improvement of gasification intensity of over 10 times. In the 1960s, the Institute of Forestry Chemical Industry, Chinese Academy of Forestry Sciences completed a half-mechanized industrial device with an annual disposal capacity of $3,000 \text{ m}^3$, using part-oxygenation method.

In the early 1980s, rice husk-based gasification device was developed in China, using a downdraft fixed-bed gasifier. It formed, finally, a series of products with a variable volume from 60 kW to 160 kW , which were applied in the food industry or exported. Model ND-600 biomass gasifier, using wood shavings, wastes, and chips as feedstock and developed by the Chinese Academy of Agricultural Mechanization Sciences, had been disseminated to tens of timber process factories. The Dalian Academy of Environmental Sciences had carried out the research and test about distillation gasification. After the 1990s, Chenglingji Food Garner in Hunan Province built a rice husk-fueled power generation station, which burns rice husks to drive steam turbine.

The research for crop stalk-based gasification technologies started later, from the mid-1980s. It aimed at building centralized gas-supply system for rural living. The Research Institute of Energy, Shandong Academy of Sciences developed a downdraft fixed-bed gasifier set. It can convert crop stalks to combustible gas with low caloric value. After cleaning the particulate and tar, the gas is delivered to rural households for cooking through centralized supply pipeline networks in a range of natural village. The feedstocks include the stalks of corn, sorghum, cotton, soybean etc. and woody wastes such as wood branch, wood chips, parings, bark, etc. The downdraft fixed-bed gasifier has a gasification temperature of over $1,000^\circ\text{C}$ and the gasification efficiency up to $72\text{-}75\%$. The gas productions with a caloric value of $4,000\text{-}5,200 \text{ kJ/m}^3$ of two models are respectively 200 and $500 \text{ m}^3/\text{h}$. Now the models have been demonstrated and applied in Shandong Province and rural areas in other northern provinces.

The Chinese Academy of Sciences (CAS) has carried out many experiments on circulating fluidized-bed gasification and the equipment. The Guangzhou Institute of Energy Conversion developed a circulating fluidized-bed gasifier using tiny woody powder produced in the process of

plywood as feedstock, and meanwhile did some research about the principle of gasification reaction. The equipment has consecutively operated for over 4 years in Zhanjiang plywood factories, and has been disseminated to Sanya of Hainan Province and the Wuyishan wood factory. The gasifier has a gasification intensity of over 2,000kg/m²/h, a tenfold improvement over the fixed-bed gasifier. The caloric value of gas is also improved by 40%. All these lay a good foundation for long-term and consecutive operation, and large-scale application of gasifier. The research results show that for biomass pyrolysis gasification circulating fluidized-bed, its technical indices have reached the requirement. The mid-caloric value of gas is 10,900-12,900 kJ/Nm³, gas production over 83 Nm³/h, gasification efficiency 62.8-65.3% and conversion ratio of carbon is over 74%. However, the research was just in the initial stage while not be pushed into industrialized stage because of shortage of research funds and some technical problems.

Table 19. Features of biomass gasifiers used in China

Type	Down-draft	Open-core fixed bed	CBF
Fuel type	Wood chips, Barks	Rice husk	Rice husk, wood wastes
Capacity	100-750kW _{th}	60-200kWe	400-5000kWe
Gas heat value	4,000-5,200 kJ/Nm ³	3,800-4,600 kJ/Nm ³	4,600-6,300 kJ/Nm ³
Temperature	1,000°C	700-800°C	700-800°C
Gasification efficiency	72%	55%	65-75%

Source: made by writer according to related information provided by Chinese experts

Table 20. Features of 200kW FBG and 1MW CFB gasifier

	Fixed bed	1MW CFB
Inside size of reactor	3m	1.8m
Productivity	400kg/h	1500kg/h
Production intensity	127kg/m ² .h	600kg/m ² .h
Gas heat value	3,800-4,600 kJ/Nm ³	4,600-6,300 kJ/Nm ³
Gasification efficiency	55%	65%
Generation efficiency	11.8%	16.5%
Feedstock consumption	2.2kg/kWh	1.7-1.9kg/kWh

Source: made by writer according to related information provided by Chinese experts

3.3 MSW energy technology

The municipal waste disposal is lately started in China, and the capacity of solid waste harmless disposal is still inferior. Now the common technologies, related to biomass energy utilization, are landfill and incineration. In recent years, the capacity and the rate of harmless disposal has increased significantly with the efforts of considering the local situation, utilization of research achievement during the “Seventh-Five-Year-Plan” and the “Eighth-Five-Year-Plan,” and a combination of domestic and foreign technologies and funds. By 1994, 609 sets of harmless disposal plants had been built, and the harmless disposal rate reached 35.7%. At present, disposal technologies such as the simple landfill has been applied in most of cities; some advanced measures such as harmless landfill and incineration are also adopted in some cities.

- Landfill :In recent years, a series of advanced landfill yards was completed. Many cities such as Hangzhou, Guangzhou, Suzhou, Beijing, Chengdu, Baotou, etc. had set up comparatively harmless landfill yards in accordance with their situation. Meanwhile, the technology for

collecting and using gas from landfill yards has also been developed. As an engineering technology, the harmless landfill technology is to put refuse into a comparatively enclosed system, to reduce its influence on the surrounding environment as little as possible. Normally, seamed development and cell separated landfill manner is adopted in a harmless landfill site to built a well infiltration-proof system. The fundamental process of infiltration treatment is “anaerobic sector blow and separate sector A/O biologic sector coagulate and sediment sector.” Moreover, complete underground water collection, sewage collection, and environment monitoring systems are also equipped in the whole system. Some new landfill yards are fitted out with methane collection and power generation system and had complete effective utilization of energy. Service the period of landfill yard is determined by the volume of storage and is generally longer than 10 years. At present, landfill is the primary method of refuse disposal in China and takes up 90% of the gross disposed volume.

- **Incineration:** Incineration is ranked as one of the main measures of refuse disposal prevailing in various countries, and because of thermal energy recovery and lack of land resources to build landfill plants in some metropolises and developed regions, it becomes almost the unique choice. Incineration measure just sprang up in China in recent years. Some pilot incineration power plants have been set up in cities such as Shenzhen, Leshan, and Xuzhou. Now these plants are running well, but their scale is not large and the daily capacity only ranges from 150 t to 300 t. Comparatively large-scale refuse incineration power plants are planned to be built in metropolises of Beijing, Shenyang, and Guangzhou. In the area of equipment and technologies of refuse incineration, China has obtained great achievements during the “Seventh Five Year Plan” and “Eighth Five Year Plan.” Partly domestic production has been realized in the manufacture of main equipment such as incineration furnace, ancillary machine, automatic control devices, refuse hoist, and air compressor, which have been successfully operated in refuse incineration plants, so the system cost is reduced greatly.

3.4 Others

- **Briquetting:** Due to natural solid biomass having a big volume and less energy density, its transportation is very difficult and costs too much. The briquetting process can compress its volume, 30 – 60%, and increase its energy density, 10-16 GJ/m³. The briquette fuel can be conveniently used as cooking fuel for special stoves and combustion fuel for boilers or furnaces. There are two kinds of briquetting processes being researched in China: one is screw pressing and another is piston ramming. The first one has been developed for 10 years and used in a small scale, about 600 sets of briquetting machines in operation in China. Presently, a research group in the Liaoning Institute of Energy Resources has resolved the key technological problem in the screw pressing process, that is, a new screw head has been made of a special material. The screw head has a long service life owing to its property of wear resisting, up to 500 hours. The second one is still at a research stage.
- **Pyrolysis:** Being undertaken a pyrolysis process, many kinds of biomass materials can be convert into three kinds of energy products: fuel gas, charcoal and bio-oil. By controlling reaction conditions, such as temperature, pressure and detained time in the reactor, we can change the proportion between the three products. In a typed process, 200~250 m³ of gas fuel, 250 ~600 kg of charcoal and 200~300 kg of bio-oil can be produced respectively. A

demonstration project was built in 1995 in Dalian City, Liaoning Province. The system can provide 1,000 families in village for cooking fuels with the heat value of 8,000 -10,000 kJ/m³, as well as some charcoal and oil by-products.

4. Biomass energy technologies applied in China

By 1998, a great achievement has been made by China on biomass as energy, especially on biogas technology, the application result is so good that the total energy production has arrived at 1.15 million TOE, providing 0.24% of the total rural energy (table 21). The second is the technology of improved stove and heat bed, about 0.525 million TOES saved yearly.

Table 21. Application of biomass energy utilization technologies in China

Technology	Scales	Energy Production	TOE	Note
a. Biogas		2090 million m ³	1,149,000	
Household digester	6,884,000 sets	1,984 million m ³	1,091,000	
Industrial digest system	753 stations	106 million m ³	58,000	
Domestic sewage digester	49,322 sets			
b. Direct burning			529,000	
Efficient furnace	200 sets	efficiency 80%	4,000	energy saving
Improved stove/heat-bed	184.7 millions	efficiency 25%	525,000	energy saving
c. Gasification	684 sets		23,000	
cooking by supply nets	164 sets	45.7 million m ³	5,600	330 working days
wood drying	370 sets	560×10 ⁹ kJ	13,400	330 working days
electricity generation	150 sets	15 Gwh	4,000	5 MW(capacity)
d. Briquetting	800 sets	200,000 tones	70,000	300 working days
Total			1,771,000	

Source: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.

As shown in the table, some new technologies have been developed in recent year and put them into a small scale of application. For example, about 700 sets of gasifiers have been operated for cooking by independent users or by centralized gas supply nets, wood drying processes and electricity generations; and about 800 sets of briquetting machines have been stalled for treating rice husks or stalks in the country. The total biomass energy output by these new technologies has been up to 1.77 million TOES.

4.1 Manufacturers

Under a strong support of the government, many bases or factories have been set up in recent years. It is estimated that there are more than 200 factories or enterprises that is working on manufacture of equipment and facilities for utilizing biomass as energy. At here, only a small part of them can be listed in the table 22.

Table 22. List of manufacturers of equipment and facilities

Manufacturers	Equipment /facilities	Location Areas
Shunsheng Gasifier and Heat Supply Equip. Factory	Gasifier	Beijing
Huairou Gasification Equipment Manufacturer	Gasifier	Beijing
Liaoning Energy Resources Co. Ltd.	Gasifier/briquetting	Liaoning
Beijing Tonghai New Energy Co. Ltd.	RM-PVC biogas	Beijing
Beijing Green Globe Energy Co. Ltd.	Gasifier/biogas project	Beijing
Hangzhou Energy and Environment Co. Ltd.	Biogas project	Zhejiang
Shanghai East New Energy Co. Ltd.	Biogas project	Shanghai
Shanghai Three Stars E& E CO. Ltd.	Biogas project	Shanghai

Botou New Energy Service Co. Ltd.	Biogas project	Hebei
Shijiazhuang Huadu Energy & Environment Co. Ltd.	Briquetg. machine/gasifier	Hebei
Yingkou Plastics Auxiliary Factory	RM-PVC biogas	Liaoning
Yiyang Biomass Fuel Co. Ltd.	Pyrolysis	Hunan
Nanyang Alcohol General Plant	Biogas project	henan
Yunnan Environment & Energy Co. Ltd.	Briquetting machine	Yunnan
Wugong Light Industry Machine Factory	Briquetting machine	Shanxi
Lanzhou Keneng Co. Ltd.	Briquetting machine	Ganshu
Beijing Suntrip Solar Energy Co. Ltd.	Biogas project	Beijing
Lianyungang Light Industry Machine Factory	Briquetting machine	Jiangshu
Dalian Energy & Environment Co. Ltd.	Pyrolysis	Liaoning

Source: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.

4.2 Demonstration projects

In past four successive national plans, 6th, 7th, 8th and 9th “Five-year Plan” (1980-2000), biomass energy technology had been playing an important role in the issue of renewable energy developments. Some excellent demonstration projects have been built up and operated successfully in the country.

Table 23. List of biomass energy projects typed in China

Projects	Materials	Scales	Capacities	Usage	Locations
a. Biogas projects		m ³	m ³ /d		
Fushan Chicken Farm(UASB)	dung	700	720	cooking	Zhejiang
Botou Distillery (UFB)	distilled waste	2,000	2,400		Hebei
Ziyang Sugar Refinery	distilled waste	1,400	4,000		Henan
Huabei Pharmacy Plant	waste water	6,000	4,000		Hebei
Huian Chemical Works	waste water	10,800	7,040		Fujian
Lezhi Distillery	distilled waste	600	3,600		Sichuan
Xinghuo Biogas Station	dung	2,700	2,700	cooking	Shanghai
Nanyang Distillery	distilled waste	10,000	40,000	cooking	Henan
Huian Chemical Plant Biogas Station	waste water	10,800	10,800	cooking	Shanxi
b. Gasification projects					
Huairou Wood Equip. Drying System	sawdust	ND600	620 MJ/h	wood dry	Beijing
Huantai Integrate Gas-supply System	crop residues	XLF	1,400 MJ/h	cooking	Shangdong
Shanya CFB Gasifier System	wood powder	CFB	2,900 MJ/h	cooking	Hainan
c. Pyrolysis Projects					
Dalian Biomass Pyrolysis Gas System	wood residues		1,000houses	cooking	Liaoning
Butoujiang Biomass Pyrolysis System	wood residues			charcoal	Hunan
d. Briquetting projects					
Jurong Briquette Fuel Producing Line	rice husks		1,000 t/y	solid fuel	Jiangshu
Wugong Grain Machine factory Line	rice husks		1,000 t/y	solid fuel	Shanxi

Source: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.

4.3 Institutes, universities and organizations

In 1987, the State Science and Technology Commission in Liaoning Province set up the China Biomass Development Center. The center is in charge of doing affairs related to development of biomass energy in the country, such as managing national projects, making national plans, conducting academic exchanges and cooperation between China and international institutes or organizations, and organizing and coordinating programs of research and development. Table 24 shows the members of the Center, including some institutes, universities and organizations involved in biomass energy.

Table 24. Members of China Biomass Development Center

Organizations or institutes	Research fields	Location area
1. China Biomass Development Center	all fields of biomass	Beijing
2. Beijing Solar Energy Institute	biogas\liquefaction	Beijing
3. Liaoning Institute of Energy Resources	biogas\gasifier\briquet.	Yingkou
4. Shandong Institute of Energy Resources	gasifier\biogas	Shanghai
5. Zhejiang Institute of Energy Resources	biogas	Hangzhou
6. Jilin Institute of Energy Resources	biogas	Changchun
7. Qinghai New Energy Institute	biogas	Xining
8. Institute of Energy Resources of Hebei	gasifier\briquetting	Shijiazhuang
9. Institute of Energy Resources of Jiangxi	biogas	Wuhan
10. Chengdu Institute of Biology, CAS	biogas	Chengdu
11. Institute of Engineering Thermo-physics, CAS	gasifier	Beijing
12. Guangzhou Energy Institute, CAS	biogas\gasifier	Guangzhou
13. Institute of Energy resources, CAAERP	biogas\furnace	Beijing
14. Institute of Energy & Power, CAAMS	Gasifier\briquetting	Beijing
15. Environment Science Research Institute of Shanghai	biogas	Shanghai
16. Institute of Forest Chemical Products of Nanjing	gasifier\briquetting	Nanjing
17. Chengdu Biogas Scientific Research Institute, MOA	biogas	Chengdu
18. Capital Normal University	biogas microbiology	Beijing
19. East China University of Science & Technology	alcohol from cellulose	Shanghai
20. Shanghai Institute of Industrial Microbiology	biogas	Shanghai
21. Technology R&D Institute of Jiangshu	biogas\briquetting	Wujin
22. Institute of Microbiology, Shangdong University	biogas microbiology	Jinan
23. Zhejiang Agricultural University	biogas microbiology	Hangzhou
24. Institute of New Technology of Changsha	gasifier	Changsha
25. Yunnan Normal University	briquetting	Kunming
26. Shenyang Agri- University	alcohol/liquefaction	Shenyang

Source: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.

4.4 Major Constraints

Even though, China has made a great achievement on utilization of biomass as energy, it is still facing some constraints in fields of technology, economy, finance, policy and others. These problems should be resolved in the near future so that its long term object could be achieved successfully.

- Firstly, some new technologies, such as biomass liquefaction, alcohol production from cellulose materials, gasification and pyrolysis, at low levels are a big constraint for their development. Main problems may be involved to low energy conversion efficiency, high energy consumption for system itself, low degree of automation and small capacity. These technical problems will cause a series of economical problems, such as a high operation and management cost on these biomass systems.
- Secondly, there is no an available policy to prompt the development of biomass energy conversion technologies in China, like in west countries.
- Finally, money is a big problem. Some biomass energy technologies could not be demonstrated and used in large scales and at high speeds due to a serious lack of financial input.
- All of problems mentioned above will hinder biomass energy going into energy markets and losing opportunities for its development. In order to promote the exploitation and utilization of biomass energy, it is important to get international technical and economical assistance

and to establish demonstration plant and production base of manufacture special equipment.

5. Past and ongoing efforts in China

It is well known; China is the biggest developing country in the world, about 64% of its population, more than 807 million (2000) in rural area. Traditionally, biomass, such as crop residues and firewood, is the most important part of the rural energy. Due to being utilized directly on fire, biomass is treated as a kind of inconvenient energy source, low efficiency (about 10%), laborious and dirty. So China does its best to develop the biomass energy technology for meeting its energy demand.

5.1 Government activities

As the development of national economy, China government has been putting a great attention on utilization of biomass as energy through developing new technology for long time. In past four successive national plans, 6th, 7th, 8th and 9th “ Five-year Plan” (1980-200), biomass energy technology had been playing an important role in the issue of renewable energy developments.

By hard works on biomass energy in the period of the last 20 years, an integrated management, development and research system net has been set up between the government, institutes/universities, manufacturers /users in China. The system net has been and will be operated to speed the development and popularization of the technology in the country. The relations of members in the net are shown as following:

- MOST → CAS, SEC, CBDC, local STC → institutes /universities
 |
 for **developing technology**
- SPC → Ministries of agriculture, forestry, electricity and other related →CAS,
 |
 SEC, local STC or REO → institutes /universities to set up bases
 for **technology demonstrations**
- SETC → Ministries of agriculture, forestry, electricity and other related →
 CAS, SEC, local STC→ institutes/universities→ manufacturers/users
 for **technology popularization**

In which, MOST is the Ministry of Science and Technology, SPC is the State Planning Commission, SETC is the State Economy & Trade Commission, CAS is Chinese Academy of Science, SEC is the State Education Commission, local STC is local science & technology commissions, CBDC is the China Biomass Development Center and local REO is local rural energy offices.

In the past 20 years, the net has put more attention on developing biomass energy and made a great achievement on putting the technology into a wide use, as mentioned in Part 2.2.2. Some excellent demonstration projects have been built up and operated successfully in the country and many institutes, universities and organizations have been involved in conducting these projects in national plans, by which, a big benefit has been obtained on popularizing biomass energy technologies, utilizing biomass energy efficiently and protecting environment.

Now, Chinese Government is drawing its 10th “ Five-year Plan”, in which the biomass energy development will be an important issue in the area of renewable energy.

5.2 The Agenda 21 of China

In 1992, just after the 92nd UN Environment and Development Conference, the government cleared

that “ clean energy sources, such as solar, wind, geothermal, tidal and biomass, should be exploited and utilized based on local conditions”.

In “the Agenda 21 of China” issued by the Management Center of “the Agenda 21 of China” in 1995, some biomass energy projects are confirmed as “ national priority projects” in the next century.

- Set up three biomass gasification systems with gas supply nets, to produce gas fuel, heat and electricity with an annual energy output of 3,000 TOE for 3,000 families in daily life use.
- Set up a biomass pyrolysis system to produce gas, oil and solid fuels, heat and electricity with an annual energy output of 7,000 TOE.
- Set up production lines to manufacture the two special systems with an annual capacity of 100 sets of gasification system and 5 plants of pyrolysis system.

The total input for this program is 22.25 million US\$, in which about 11.05 million US\$ from domestic sources and another 11.20 million US\$ from International sources.

5.3 The 9th Five Year Plan

From 1995 to 2000, the 9th five-year Plan had been conducted by MOST, in which the biomass energy technology was put on an important place. By 2000, most of these research works had been finished and a great achievement had been made (Table 25).

Table25. Research results on biomass energy in “the 9th Five-year Plan”

Projects	Scales	Institutes	Location
1. Gasification			
● An integrated system for converting crop residues to energy sources	480 Mwh, 1,500 tones briquette fuel, 300 tones charcoal yearly	Liaoning Institute of Energy Resources	Yingkou
● 1.0 MW electricity generation system by biomass gasification	3,000 Mwh electricity yearly	Guangzhou Energy Institute of CAS	Guangdong
● Integrated gas supply systems by crop residues gasification	500, 1,000 and 3,000 households	1. Shandong Institute of Energy Resources 2. Dalian Institute of Energy & Environment 3. Nanjing Institute of Forest Chemical Products	Shandong Dalian Shuzhou
2. Biogas			
● A large anaerobic system for treating pig dung	10,000 m ³ biogas daily	Shanghai Institute of Industrial Microbiology	Shanghai
● A anaerobic system for treating city refuses	100 tones refuses treated daily	Chengdu Institute of Biology of CAS	Mianyang
3. Liquid fuels			
● A pilot alcohol system from cellulose materials	2 tones materials be treated daily	East China Science and Technology University	Shanghai
● A research work on plant oil as energy	10 hectares of oil-forest for demonstration	Changsha Institute of New Technology	Changsha

Source: *Research and Development on Biomass Energy in China*, Yuan Zhenhong et al. International Journal of Energy Technology and Policy, Vol.1. Nos. 1/2, 2002, Inderscience Publishers.

5.4 The Key R&D Program of Biomass Energy in 10th “Five-year Plan”

In order to prompt the development of new and renewable energy resources, in 1995, three commissions, SSTC, SPC and SETC, drawn “ A Essential for Developing New and Renewable Energy Resources in China” to give outline for making plans “ Planning for 2010”. In these two documents, it is the object for 2010 that:

- firewood forest area will have been up to 1,340 hectares or produced 1 270 million tones of firewood by 2010;
- the total energy production will have been 4.9 million TOE by developing biomass energy technologies, such as efficient burning, brequitting, gasification and liquefaction, by 2010;
- the total amount of biogas users will have been 12.35 million households and biogas production will have been 4.0 billion m³ or 2.2 million TOE by 2010.

To arrive at this object, now, a developing plan is being drawn by CBDC under MOST for the 10th Five Year Plan (2000-2005). The table 26 shows the plan in details.

Table 26. Priority projects in “the 10th Five-year Plan”

Projects	Scales	Institutes	Location
1. Gasification			
● 4-5 MW electricity generation system by biomass gasification	12,000 Mwh electricity yearly	Guangzhou Energy Institute of CAS	Guangdong
Study on standardilization and commercialization of electricity generation system by biomass gasification	6 series 60-160kw	Liaoning Institute of Energy Resources Shandong Institute of Energy Resources Nanjing Institute of Forest Chemical Products	Yingkou Shandong Nanjing
2. Biogas			
● 2MW electricity generation by biogas	6,000 Mwh electricity yearly	Hangzhou Institute of Energy and Environment	Hangzhou

5.5 High technology development in“863” Research Program (2001-2005)

A high technology development program will be conducted in China from 2001 to 2005, named as “863”Research Program. In this program, some new technologies will be concerned as developing key biomass projects in next ten years. These research projects are shown in Table 27.

Table 27. Biomass research projects in 863 programs

Projects	Scales	Institutes*	Location
1. Biomass electricity generation			
● 5 MW electricity generation system by biomass IGCC	14,000 Mwh electricity yearly	Guangzhou Institute of Energy Conversion	Guangzhou
2. Liquid fuels			
● Biomass liquid fuel technology	Including alcohol, pyrolysis and plant oil fuels	East China Science and Technology University Changsha Institute of New Technology	Shanghai Changsha

6. Related policy in China

Chinese government pays much attention on the renewable energy, including biomass energy,

especially on its technology development and the industrialization, and has affirmed its role in the modern energy legally and has made enormous policies to promote its development in the whole country.

In the Energy Conversion Law of the People's Republic of China, the second item prescribes that the energy is the resource which can get usable energy directly or indirectly through some manufacturing processes or conversion processes, including coal, oil, nature gas, electric power, coke, coal gas, heat energy, refined oil, liquefied petroleum gas (LPG), biomass, and etc. And the eighteenth item points out that local governments should enhance the country's energy development and should explore and make use of the renewable energy, such as biogas, solar energy, wind energy, hydro-power and geothermal energy according to the guidelines including adjusting measure to local conditions, making mutual benefits among many kinds of energy, all-round utilization, and high efficiency.

In the Electric Power Law of the People's Republic of China, the fifth item prescribes that construction, production, supplying and using of the electric power should protect the environmental and reduce the harmful emission by using new technologies, and should prevent the environment from pollutions or other social effects. The government encourages and supports using renewable energy to generate electricity. And the forty-eighth item prescribes that the government advocates exploring the hydropower resources to build medium-sized or pint-sized hydropower stations and accelerating the electricallization in the country, and also encourages and supports the construction of the electric resources to increase the electricity supply in the country.

According to the national laws, China will conduct gradually a series of encouraging policies to develop the utilization of the renewable energy. The policies those are also suitable to the industrialization of biomass including items shown as following.

6.1 Subsidy Policies

The subsidy policies of Chinese renewable energy development mainly include the central government subsidies and the local government subsidies.

6.1.1 Central government subsidies

- **Subsidy of operating expenses.** In order to encourage the development and spreading of the renewable energy technology, the central finance offers the expenses not only for operating the central and local special administrations, but also for the activities of these departments.
- **Subsidy of study and development.** The central government offers the funds for talking the key problems of the renewable energy technology by the State Development and Planning Commission and the Ministry of Science and Technology (MOST). In the 9th "Five-year Plan", MOST offered about 60 million Yuan for the development of the renewable energy. And the average of it is about 15 million Yuan per year. In the 10th "Five-year Plan", key projects, the 863 Plan and the 973 Plan offered abandon of expenses for supporting the development of the renewable energy. And the total number of these funds is more than 300 million Yuan.
- **Subsidy of the investment loan subsidy.** The central government offers loan subsidy to the renewable energy projects from central finance by related departments. For example, the

State Economic and Trade Commission (SETC) have put 1.2 billion Yuan in supporting the development of renewable energy professions every year.

- **Subsidy of projects.** The central government also offers expenses to the renewable energy technology through different ways, such as spreading marsh gas system and firewood saving stoves, demonstrating and promoting small hydropower, small wind turbine, photovoltaic, and etc.

6.1.2 Local government subsidies

The local government subsidies play an important even majority role in the development of the renewable energy technology. It mainly includes management, spreading and demonstrating the local renewable energy. However, there are different recourse conditions and different level of people's knowledge on the development of renewable energy, so the subsidy policies of each local government have much difference.

6.2 Tax revenue policies

6.2.1 Tariff

China could consult the policies of wind power or other renewable energy technology, although China hasn't any formal texts prescribe that the biomass technology production can employ low tax policies when they are imported or exported. These policies mainly include: the imports tariff of parts or whole machines and photovoltaic components. In 1996, the tariff rate of equipments of wind power is 12% (not includes towers), but the actual imports tax rate is 3% and 12% (executive tax rate is 6%) for components or parts and generator groups respectively. In generally, it can apply for being tax-free if it is the photovoltaic system that accepted bilateral or unilateral supporting and was used in the rural area's power supply systems or in the aid-the-poor projects. Except the imports and exports tariff, some value-added tax and its surtax for the imports equipments should be collected. The highest tariff rate of the Chinese imports of the wind power turbines is 6%. And the highest rate of the total imports tariff is 26% •

6.2.2 Value-added tax and its surtax

At present, there is still no consolidated favorable policy for value-added tax, except three exceptions. The value-added tax rate is 13%, 6%, and 6% respectively for the man-made marsh gas, hydropower, and wind-power. The surtax of the value-added tax is a kind of tax that is imposed by locality. And it includes the additional tax of town construction and education. And the rate is from 8% to 11% commonly. Taking the wind power for example, according to the prescription of the State Power Company, the value-added tax of wind power adopts the policy of taxing except price. The formula is that the surtax of the value-added tax equals to the value-added tax multiply the rate of the surtax of the value-added tax.

6.2.3 Income tax

In order to encourage and support the development of some enterprises, the new statute of the income tax of enterprises prescribes two favorable policies. First, the enterprises which needs encouragement in the people's municipality can be authorized the priority of having reduction and exemption of taxes by local government. Second, the enterprises that adapt the reduction and exemption of taxes policy should execute according to the prescriptions of the lows or regulations

of administration or the State Council of China. For example, the rate of income tax in a high and new technological enterprises in the high and new technological development zone which is authorized by the State Council of China is 15%; the new high technological enterprises should be free-tax for two years since the year it puts into production; the enterprises which utilize waste gas, waste water and waste residues as their main materials should adapt the policy of reduction and exemption of taxes for five years. If the cooperative period of a joint venture lasts for more than ten years, according to the law of income tax, will be free-tax for two years and half tax for three years.

In general, the local government should impose the tax of renewable energy enterprises. The local government has authority of reducing or exempting taxes. The policy of “three years of reducing and two years of freeing” for solely investment companies, Chinese foreign joint ventures and Chinese-foreign cooperative enterprises is adaptive to the income tax. When these companies use the bank loan, they can repay the loan before or after the taxation. In fact, it is a way to reduce the income tax of enterprises that repay the loan before the taxation. And another way of reducing tax is to speed up the depreciation. And this way also can reduce the book rate.

6.2.4 Local tax

The local tax is mainly involves income tax, surtax of value-added tax, land occupy tax and etc. Nowadays, the policies of reduction and exemption of tax for the renewable energy enterprises are not on stage yet. But some localities are thinking about reducing the income tax of enterprises by speed the depreciation of the equipments. Inner Mongolia have carried out some measurements to reduce the surtax of the value-added tax (from 8% to 3%). And most areas take the policies of reduction and exemption of land tax or land allotment for the land occupation of wind turbines that is the fractional expenses in fact.

6.3 Policy of price

The price policy here is mainly about the price of electric power generated by renewable energy. In China, the price of electric power is enacting by the central government but not any other departments. The power plants supported by capital raising, Chinese-foreign investment or foreign investment may enjoy the power price policies of repaying capital with interest. And they can execute this policy after the consultation with the ministry of power industry and local government and after the approval of the price department in charge according to the cost, tax and duty, and reasonable profits of power. This policy makes it easy to attract the investment from all over the society, especially to improve the enthusiasm of the solely or joint power plants. For example, in 1995, the electric price of joint stock, joint venture or foreign-funded power plants is higher than the average price of whole country 4%, 38%, 197% respectively.

6.4 Low cost credits policy

In principle, the special loan subsidy of rural energy offered by the State Economic and Trade Commission can be used in the development of all the renewable energy industry. China have arranged more than 500 renewable energy projects used the funds of special loan of the rural energy utilization offered by the State Council since 1987. And these projects support following activities speeding the biomass energy industrialization and commercialization.

- **Large or middle sized marsh gas projects.** From the beginning to now, the fund had

contributed nearly 2 billion Yuan and had supported 100 middle-sized marsh gas projects and the production of their special equipments

- **The saving firewood and coal stoves.** The funds support more than 60 special factory of the stove, which can save firewood and coal.
- **Using bagasse to generate electricity.** It was involved in the 9th “Five-year Plan” of “••” loan that generate heat and electricity from bagasse. And the total investment will be more than 10 million Yuan. Besides these, the fund also supports the development of industrialization of biomass gasification, biomass compressing and other technological projects of biomass energy.

Except for the special rural energy loan, the loan of technology improving of the State Economic and Trade Commission can also be used in supporting the development of industrialization of biomass energy.

6.5 Credit Guarantee Policy

With the development of the application of renewable energy technology, the opportunities to use foreign fund and commercial loan are increasing. In many cases, the enterprise of renewable energy need loan to make construction. Under the circumstance of bank system gradually commercialized, enterprise credit guarantee will always be an important factor, which decides whether the bank loan will be gained. Especially, the capital system has been used in china in recently years, and it required the owner of the enterprise possesses 30 percent of the capital who wants to gain the bank loan. Government departments all make credit guarantee to these enterprises during the initial construction of wind power plants. Government departments can't make the credit guarantee for enterprise any more after the reconstructing of the bank system in 1994. And banks undertook these functions. But the governmental influence to enterprise credit guarantee is still very significant. For an instance, the fact that China purchased 30 Zond wind turbines using the loan from American Import and Export Bank was approved by the center government and guaranteed by China Bank.

6.6 Other policies

In 1997, the State Development and Planning Commission issued “Temporary Provisions of administration of capital construction projects for new energy resource”. It pointed out definitely the following contents:

- New energy resource refers to the electric power and clean fuel which was transformed or processed from renewable energy such as wind power, solar energy, geothermal, ocean energy, biomass energy and so on. All new energy installations projects (transforming or processing electric power or clean fuel) are capital construction projects.
- The exploitation and utilization of new energy resource is not only the supplement for the recently energy balance but also the hope of forward adjustment of energy resource structure • which meet natural industrial policies and it plays an important role for realizing the Sustainable Development Strategy. The nation encourages the development and utilization of new energy resource technology.
- The study of new energy resource technology and the manufacture of new energy resource

equipment should employ the style of autonomous exploitation with import, digestion, absorption and innovating, and conduct the integration of technology, industry and trade, and accelerate equipment's domestic-producing.

- The economic scale of capital construction projects for new energy resource is as follows: wind power, over 3,000 watts; PV installed capacity, more than 100 watts; geothermal installed capacity, not less than 1,500 watts; tidal power installed capacity, over 2,000 watts; waste power utilization installed capacity, over 1,000 watts; marsh gas projects, yield marsh gas more than 5,000 cubic meters, and other new energy resource projects which are invested over 30,000,000 Yuan.

In 1999, the State Development and Planning Commission and the Ministry of Science and Technology issued together "the notice about some concerned questions of further supporting on the development of renewable energy resource". It stipulates definitely:

- The SDPC and the MOST will support positively when arranging financial capital construction projects and national science and technology key problem projects.
- The renewable energy power projects can be supplied basic construction loan by bank in priority. In addition, the SDPC will give more 2% financial loan subsidy to the renewable energy power projects.
- The SDPC and the related banks will arrange loan subsidy in priority to construction projects that use domestic electricity-generating equipments using renewable energy. The deadline of repaying the loan should be extended accord to the approval of the bank.
- To the projects of grid connected power generation using renewable energy, the electric network manage department must permit using the net nearby under the circumstance of capacitance of electric network permission and purchase all electricity quantity of net-consuming.
- The price-fixing principle of repaying capital with interest adding reasonable profit will be put into practice during the course of paying the debt for the projects of grid connected power generation using renewable energy. The electric network shares the part higher than the average electric network price. The electricity price after the stage repaying capital with interest finishes will be decided according to the average electric network price.
- To the renewable energy decentralized power supply system, the nation encourages adopting the approach of installment payment or leasing.

7. Market for Biomass Power Generation

As Chinese economy development and society progress, its electricity and power demand will be greatly increased in the next few years. Now, it is the best time to make biomass power generation technologies going into the huge energy market. The market mainly include four sectors: (1) electricity production from renewable resources to makeup a full electricity supply in the whole country; (2) CHP production from biomass for reducing fossil fuel consumption; (3) reshuffle of small fire coal plants and (4) rural electricity demand.

7.1 Electricity Demand

In 2000, there was about 320 GW capacity of power generation and 1,387 TWh of electricity generated, 78% of it from coal-fired plants. According to International Energy Agency's (IEA) World Energy Outlook 2002, China's electricity consumption will grow by 4.2% per year on average over the Outlook (2030) period. The rate of growth will slow slightly as the years pass. Electricity's share of total final energy consumption will jump from 16% to 26%. The demand will be boosted by growth in personal incomes and by switching from coal and oil, as well as by rising output in industry and the commercial sector.

In order to meet the rapid growth of electricity demand and to replace plants that are to be retired, China will have to build 800 GW of new capacity by 2030, raising the total capacity to 1,087 GW. More than 800 billion USD investment will be needed for new generating capacity alone. The table 52 shows capacity additions by fuel in the three decades from 2000 to 2030.

Table 28. Electricity Generation Mix in China (TWh)

	1971	2000	2010	2020	2030
Coal	98	1,081	1,723	2,509	3,503
Oil	16	46	51	53	54
Gas	0	19	74	209	349
Nuclear	0	17	90	163	242
Hydro	30	222	333	511	622
Other renewable	0	2	10	16	42
Total	144	1,387	2,282	3,461	4,813

Source: International Energy Agency's (IEA) World Energy Outlook 2002,

The power sector's heavy dependence on coal will not change much over the next three decades due to China having abundant coal resources and low costs on coal-plant construction, so that, most of new generating capacity will be coal-fired. In the plan, the capacity of coal-fired plants will be increased three fold, to reach at 696 GW in 2030.

The GOC has paid great attention biomass power generation. Many power generation projects planned to use solid biomass waste are under preparation. Bagasse CHP, gasification and power generation based on biomass will be greatly developed. However, their portion in the total power generation is quite small. The major purpose of using renewable energy is to improve the situation of electricity supply and to protect the environment from coal combustion in the country.

7.2 CHP Market

Cogeneration plants were built for heating the industrial zone in northern cities and for heating the resident and public buildings. Government has made many policies to encourage the development of CHP. Local governments were requested to give priority to CHP projects when planning central heating systems and power projects. Utility company responsible for grid management should purchase electricity generated from CHP plants according to national related regulations, so as to ensure minimum purchase of electricity from CHP plants.

By the end of 2001, there were 1,583 CHP units with unit-capacity being over 6 MW. The total installed capacity of CHP was 28,153 MW (average unit size 18 MW), which is 12.6% of the total installed capacity of thermal power. In 2001, the total generation from CHP units was about 127 TWh.

Table 29. Classified CHP units in recent years

Capacity	Parameter	1999		1998		Growth	
		Units	MW	Units	MW	Units	MW
6-12MW	High pressure	1	10	1	10		
	Medium pressure	570	3456.1	541	3278.5	29	177.6
12-25 MW	High pressure	14	181.6	14	181.6		
	Medium pressure	455	5641.9	426	5252	29	390
25-50MW	High pressure	120	3015	120	3010		
	Medium pressure	81	2103.4	70	1823	11	280.4
Over 50 MW	High/super high pressure	161	13745	140	11372	21	2373

Source: Biomass Industry Survey, China Renewable Energy Scale-up Program, SPC, WB and GEF, 2002

The installed capacity of cogeneration was 12.6% (28,150 MW) of the installed thermal power in 1999. If cogeneration increases by 3,000 MW per year and the installed thermal power increases 5% per year, the total installed capacity of cogeneration will reach 43,100 MW by the year 2004 and cogeneration takes 14-15% of the installed thermal power, which still is not a high percentage. And if the percentage of 30-45% in the European countries is to be reached, the installed capacity of cogeneration should at least reach 85,000 MW. Therefore, the cogeneration market for biomass energy still has a large developing space in China.

7.3 Market in Reshuffling Small Coal Fire Power Plant

In China, there are great numbers of small thermal power plants firing coal, consuming coal at a low efficiency and making a serious pollution. For example, in Henan province, there are 92 such small power plants with capacities below 55 MW and 189 power plants with capacities below 130 MW by the end of 1999. According to the No.44 document launched by the State Council Official (1999), these small power plants should be closed down, besides they find ways to solve these problems. Since 1998, construction of small thermal power plants under 135 MW has required official permission from the government. In 2002, the government announced that loans and equipment would no longer be provided to existing small plants. So, there is a big market for biomass power generation technologies in China.

7.4 Rural Electrization

China is an agricultural country. The GOC has paid a great attention on developing rural economy and improving rural electricity supply. But the population is too huge, about 804 million, so that the development and improvement has been done very slowly. Until 1998, the total electricity consumption was 204 billion kWh in rural areas, in which, about 59 billion kWh for daily life and 141 billion kWh for agricultural production and rural industry. The capital electricity consumption for daily life was only 64 kWh/person/year and the electricity price was 0.67 Yuan/ kWh, 20% higher than that for urban residents. Now, the situation is still very serious that no farmer resident has been supplied with electricity in 8 counties and only 50% of farmer families have been supplied with electricity in 50 counties. The no electricity supply is involved to 364 towns, 14,000 villages, 8.8 million families and about 70 million population. So, there is a huge market for electricity production from biomass power generation.

8. Conclusion

Developing biomass energy is one of the most important energy strategies for China, by which, a lot of benefits will be involved, not only energy supply, but also sustainable environmental

improvement, ecology balance, social progress, and economy development. In fact, the biomass fuel is a traditional fuel in China. Crop residues and firewood has been used for cooking and heating by burning directly in stoves for a long time.

By now, the biomass is still playing an important role in energy consumption in rural areas. In the recent years, China has developed some new technologies, such as biogas, gasification, briquette and liquefaction. But there is still no advanced technology for using biomass as energy more efficiently low costly, environmental friendly and widely in China.

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