Research and Development on Biomass Energy in China

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Abstract

Like developed country, China is facing two serious constraints, energy shortage and environment pollution, which will hinder the development of national economy and improvement of living standards. It is estimated that the total biomass resources is up to 5.2 $\times 10^8$ TOE in which crop residue resource is up to 2.7×10^8 TOE, firewood over 5.2×10^7 TOE and animal dung about 1.0×10^8 TOE. Meanwhile, Biomass is a clean energy resource and can explored as a convenient energy in the next century. Since 1980, several institutes have developed various biomass energy conversion technologies and applied successfully in rural areas. Up to 1999, there is about 1.58 million TOE of energy came from biomass energy through energy saving technology and biomass energy conversion technology. In the future, China will develop biomass energy in a large scale. By 2010, energy provided by these technologies will have been up to 14.1 million TOES. Through these technologies, biomass will give us more benefits on energy, environment and economy. Of course, we should resolve some problems, such as technical, economical, political and financial problems.

Keyword: biomass, gasification, liquefaction, brequitting, biogas, alcohol, energy, environment, greenhouse gas, CO_2, crop residues, sawdust, firewood, animal dung

1. Introduction

1.1. Related position of agriculture and rural sector in the national economy

1.1.1 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 nature increasing kept at 8.77‰.

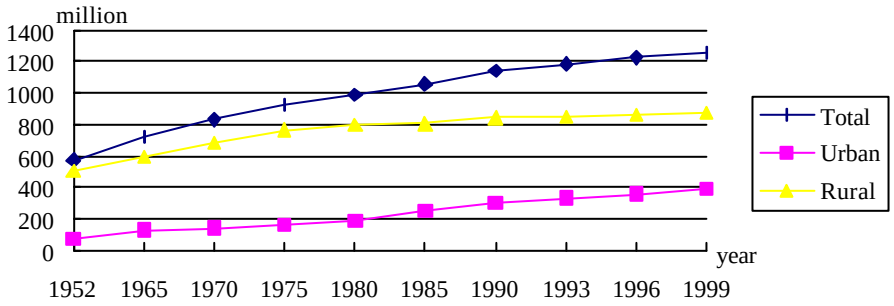


Fig.1 Population and its distribution in China (1952-1999)

China also is an agricultural country that about 69.1% of its population was rural population and 30.9% was urban population in the same year (Fig.1).

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.2, 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 1999, up to 10% 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.

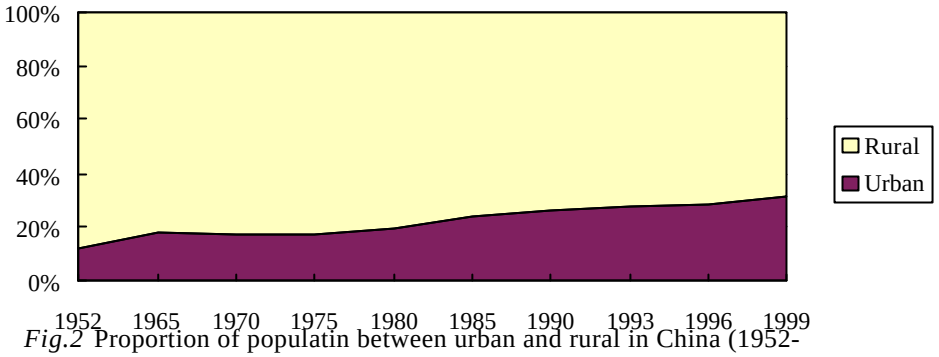


Fig.2 Proportion of populatin between urban and rural in China (1952-1999)

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. By 2050, Chinese population will have been up to 1.55 billions (Table 1) and the proportion of rural population to total population will have been changed greatly from 80% in 1985 down to 25-35% (Table 2).

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

Years	Population (millions)
2000	1,248
2015	1,396
2030	1,512
2050	1,550

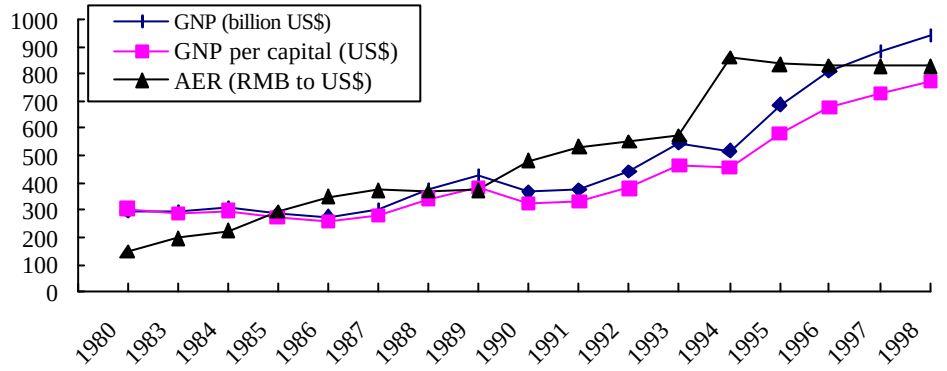
*From a report by the World Bank.

Table 2. Proportion of rural population to total population (%) (2000-2050)

2000	2020	2030	2050
70	63	50	25-35

1.1.2. Status of the national 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 with Chinese Characteristics. By 1998, China had made a great achievement in its social and economic stability and sustained economic development. In this year, the GNP was up to 7800 billion RMB, about 3 times as much as that in 1985. The average annual increasing rate of GNP was over 6.6% from 1978 to 1993, and the rate was about 10.5% from 1991 to 1998 (Fig.3).



* 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.3 A curve of economy development in China from 1980 to 1998

In Fig. 3, there are three peaks of economy growing, but there is no decreasing clearly. One exists between 1988 and 1989, annual increasing rates of GNP are 25% and 14% respectively in these two years, second one is between 1992 and 1993, and annual increasing rates of GNP are 17% and 23% respectively in these two years, the third one is at 1997-1998. In China, the rate is mainly contributed by three economic sectors, primary industry, second industry and tertiary industry. In 1988, for example, the rates for the three sectors are 25.7%, 44.1% and 30.2% of the total GNP respectively. In the second peak, they are 21.8%, 43.9% and 34.3% respectively in 1992, and 19.9%, 47.4% and 32.7% respectively in 1993. In the third peak, they are 19.9%, 50% and 30.1% respectively in 1997, and 18.6%, 49.3% and 32.1% respectively in 1998.

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

1.1.3. Position of agriculture and rural economy in the national economy

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 4, the GNP of primary industry, agriculture, occupies about 17.7% of the total GNP in the country.

Table 4. Gross National Products and National Income in 1999

Items	Total	Primary Industry	Second Industry	Tertiary Industry	Per capital (US$)
GNP (billion US$)	1011.3	178.5	499	333.8	807
%	100	17.65	449.34	33.01	

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. In fact, the so-called rural industry involved in the second industry and tertiary industry has become an important sector in the rural economy since 1980's (Fig. 4). Since 1994, there have not been any official statistics data on rural industry in the country.

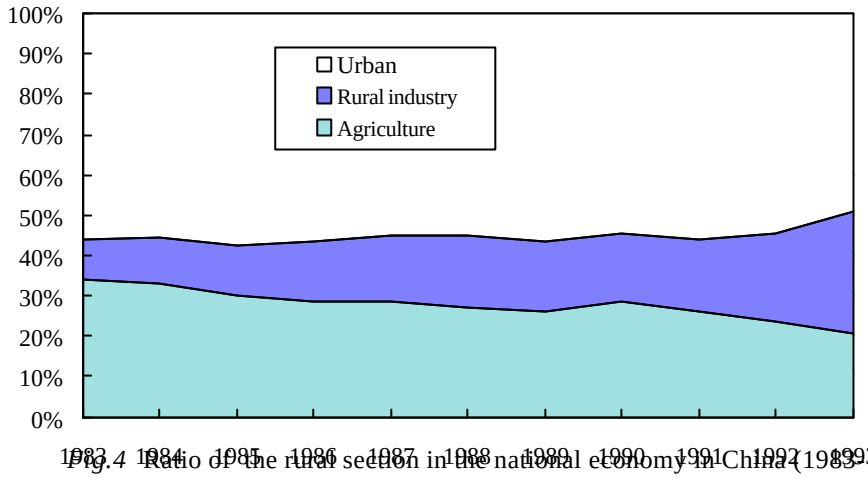


Fig. 4 Ratio of the rural section in the national economy in China (1983-1993)

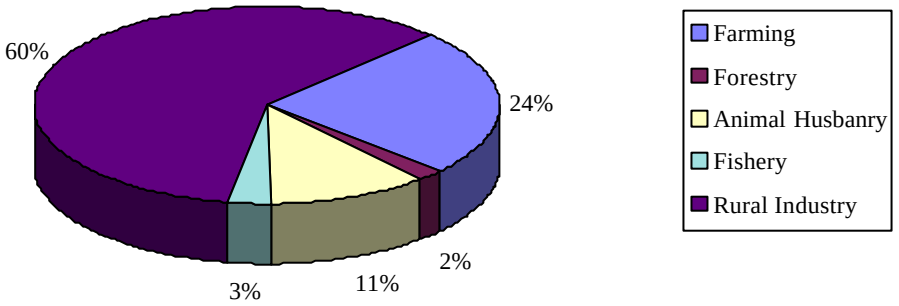


Fig. 5 Composition of the rural economy in 1993(GNP of 277.9 billion US$ in total)

From Fig. 4, the rural industry had been growing at a high speed in the decade. In 1983, the rural industry occupied only 9% of the national economy, however, by 1993, its sector had gone up to 30% of the national economy. Concerning the rural industry, the rural economy had covered about 51% of the total national economy in 1993, about 277.8 billion US$ of GNP.

In the rural economy, there was about 60% from the rural industry, but farming, forestry, animal husbandry and fishery was 24%, 2%, 11% and 3% respectively in 1993(Fig.5).

1.2. Energy supply situation in the country

It is well known that the growth of national economy and the progress of society must rely on the development of energy industry. In nowadays, commerce energy is mainly composed of fossil fuels, however, fossil fuels, such as coal, petroleum and natural gas, is limited greatly by their resources and will be used up in the future.

1.2.1 Energy production

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.

In 1953, about 70 million of coal, 0.62 million tones of oil, 11 million M^3 of natural gas and 1.5 billion kwh of hydro-electricity was produced and occupied respectively about 97.88%, 1.73%, 0.03% and 0.36% of total primary energy production, 35.76 million TOE. From 1985 to 1997, the total primary energy production had been increased by 5.7% yearly. In 1985, the primary energy production was 599 million TOEs, in 1993, the primary energy production was 779 million TOEs, in 1997, the primary energy production was up to 927 million TOEs, but in 1999, the primary energy production was decreased deeply, about 770 million TOE, in which there was 1,072 million tones of coal, 161 million tones of oil, 26.5 billion M^3 of natural gas and 203 billion kwh of hydro-electricity (Fig.6 and Table 5).

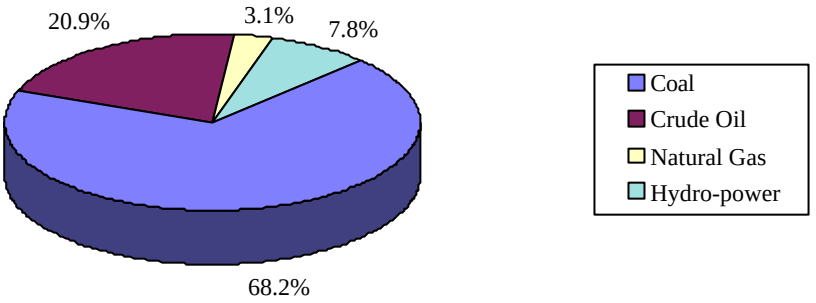


Fig. 6 Production and composition of primary energy
(770 million TOE in total, 1999)

Table 5. The Primary Energy Production in China (1952-1999)

Years	Total MTCE	Proportion ( )			
		Coal	Oil	Nature Gas	Hydro-Power
1952	48.71	96.7	1.3	...	2.0
1962	171.85	91.4	4.8	0.9	2.9
1970	309.90	81.6	14.1	1.2	3.1
1975	487.54	70.6	22.6	2.4	4.4
1980	637.35	69.4	23.8	3.0	3.8
1985	855.46	72.8	20.9	2.0	4.3
1990	1039.22	74.2	19.0	2.0	4.8
1993	1110.59	74.0	18.7	2.0	5.3
1996	1326.16	75.2	17.0	2.0	5.8
1997	1324.10	74.1	17.3	2.1	6.5
1998	1240.00	72.0	18.5	2.4	7.1
1999	1100.00	68.2	20.9	3.1	7.8

Note: MTCE means million tones of energy equal to standard coal

1.2.2. Primary energy consumption

As a developing country, 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 1970,

the total consumption of primary energy was only 205 million TOE in this country, of which about 81% came from coal energy. After 28 years later, in the year of 1998, the amount was up to 925.5 million TOE, about 5 times of that in 1970. From Fig.7 and table 6, it can be seen that consumption increasing rates of oil, natural gas and electricity is steeper than that of coal. It means that more and more clean energy, such as oil, nature gas and electricity, have been used in modern industries and daily life.

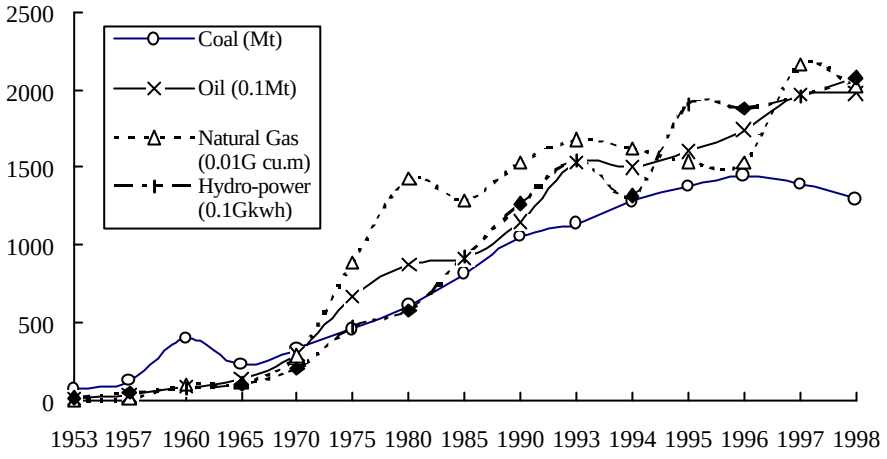


Fig.7 Consumption of primary energy in China

Table 6. The Primary Energy Consumption in China (1952-1999)

Years	Total MTCE	Proportion (%)			
		Coal	Oil	Nature Gas	Hydro-power
1957	67.5	92.3	4.6	0.1	3.0
1962	115.8	89.2	6.6	0.9	3.2
1970	205.0	80.9	14.7	0.9	3.5
1975	318.0	71.9	21.1	2.5	4.6
1980	644.5	72.2	20.7	3.1	4.0
1985	536.8	75.8	17.1	2.2	4.9
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	67.1	23.4	2.8	6.7

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 1999, the proportion of coal energy consumption had decreased to 67.1%, but that of other primary energy sources, such as oil, natural gas and hydro-electricity had increased to 23.4%, 2.8% and 6.7% respectively (Fig.8).

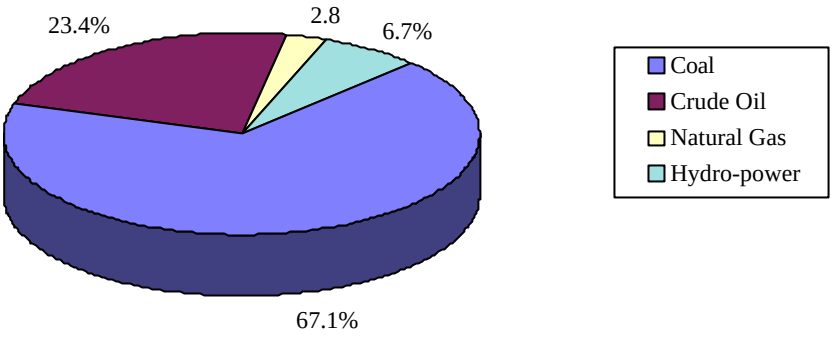


Fig. 8 Consumption and composition of primary energy in China (854 million TOE in total, 1999)

In order to produce the clean energy, a great amount of coal have been converted to second energy products, such as electricity, charcoal and coal oil. In 1993, about 335 million tones of coal, equal to 239 million TOEs, were used for power generation. The amount is about 29.4% of the total coal consumption of 1,140 million tones or equal to 570 million TOEs in this year.

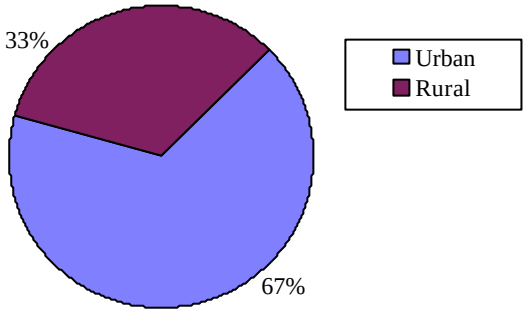


Fig. 9 Sector of rural commerce energy in 1999

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.9).

1.2.3. Energy balance

In fact, there is a big shortage in the energy providing market, even though China has done its bet to develop its energy industry in the recent years, that is, the energy production can not be enough to meet the energy demand due to a poor base facility and an investment shortage for developing energy industry in China.

In 1993, there was a shortage of 3 million TOE between energy production and energy consumption, that is, China has become an energy imported country which the amount of energy imported will be more than that of energy exported (Table 7).

Table 7 Primary Energy Balance in MTCE in China

Items	1985	1990	1995	1997	1998
Total Providing Energy	**77603**	**96138**	**129535**	**133724**	**128368**
Primary Energy Production	85546	103922	129034	132410	124250
Energy Saving			2312	467	1920
Input	340	1310	5456	9964	8474
Output (-)	5774	5875	6776	7663	7153
Deferent Yearly	-2509	-3219	-491	-1453	878
Primary energy Consumption	**76682**	**98703**	**131176**	**138173**	**132214**

To consider the energy demand in rural areas, the shortage may be 10% in the whole country. Some factories have to stop their operation due to the energy shortage. Actually, in rural areas, the shortage must be over 30%, thus cutting down forest has become a way to make compensation for the shortage.

1.2.4 Prediction of Energy in the future

It is well known that the energy consumption in a country is greatly related to the size of population and the scale of economic action in the country. According to some research works on population and economy in the future, the energy demand will be increased steeply in the next century. 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 7, the energy demand will be up to 3,780 million TOE by 2050, about 4.4 times as much as that of in 1999.

Table8 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

By survey data from related government divisions, it has been estimated that the total oil reserve may be up to 60 billion tones, the recoverable oil reserve will be 15 billion tones and the explored reserve is 3.3 billion tones in China in 1992; the total natural gas reserve may 30×10^{12} M^3, the recoverable reserve can be 6.4×10^{12} M^3 and the explored reserve is 1.4×10^{12} M^3 in 1992; The total coal reserve may be 450 billion tones and the explored reserve is 985 billion tones. Based on these data and planning rates of economic growing, some research work has been made and several energy experts have obtained a similar

result. In a report, it is pointed that the oil resource will have been exhausted by 2040, natural gas by 2060 and coal by 2300.

1.3. Utilization of agricultural/ forestry residues and other biomass as renewable energy source

For a long history, China has been using biomass as energy. Especially in its rural areas, biomass can be 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. Up to now, the biomass energy are still playing an important role on the rural energy, even though commerce energy sources, such as coal, oil and electricity, have been popularized in rural areas in the country (Fig.10).

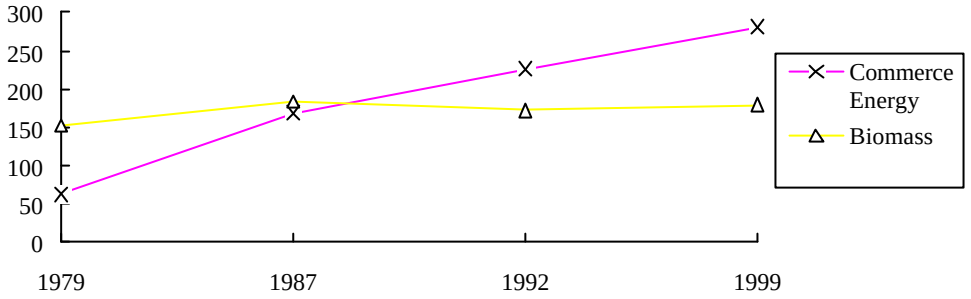


Fig.10 Changes of commerce energy and biomass energy in rural areas

In 1993, the total energy consumption in rural areas was 4.10 $\times 10^8$ TOE, of which 2.46 $\times 10^8$ TOE was for the household energy consumption and 1.64 $\times 10^8$ TOE for the rural industry energy consumption, respectively occupied 60% and 40% of the total amount.

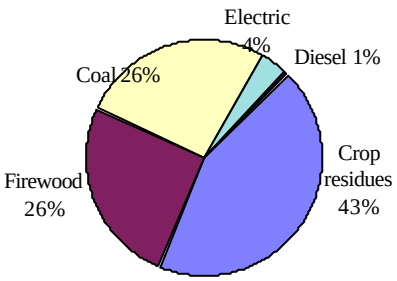


Fig.11 Consitution of household energy consumption in 1993 (246 MTOE)

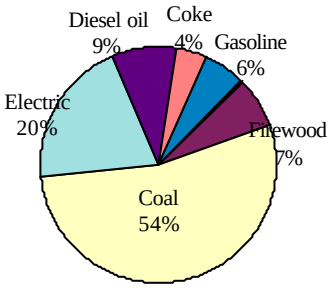


Fig.12 Consitution of rural industry energy consumption in 1993 (164 MTOE)

Furthermore, about 69% of the household energy consumption came from biomass, up to 1.70×10^8 TOE, of which 1.06 $\times 10^8$ came from crop residues and 6.4 $\times 10^7$ TOE from firewood (fig.11). In fig.12, it is shown that the rural industry energy consumption actually relies on coal and electricity, covering 54% and 20% respectively, only 7% came from biomass-firewood, about 22 million tones being equal to 1.1 $\times 10^7$ TOE, which occupied 14.7% of the total amount of firewood consumed in the country.

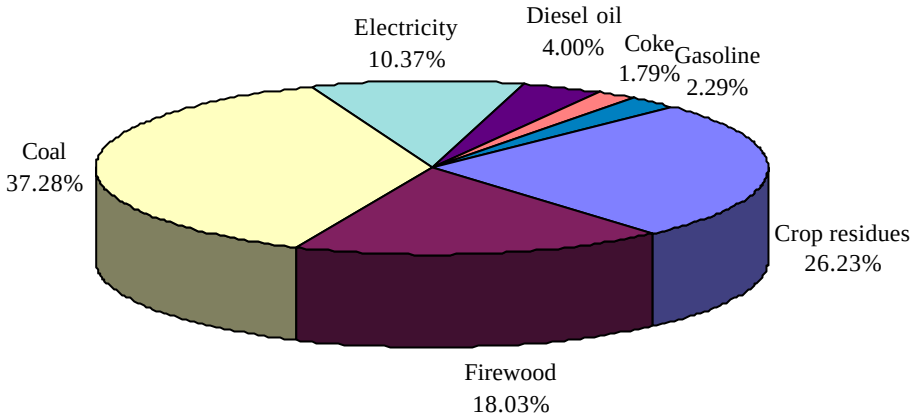


Fig.13 Consitution of the total rural energy consumption in 1993 (410 MTOE)

As shown in fig.13, the biomass energy consumed for household uses and industry occupied about 44% of the total energy consumption in rural areas in 1993. Recently, in the rural energy consumption, the proportion of commercial energy including coal, electricity, oil and natural gas etc. has been going up in a large scope, although their prices are always much higher than that of biomass fuels. . In 1999, the total rural energy consumption was up to 464 million of TOEs, of which, about 30% came from biomass, mainly crop residues and firewood. Thus, it has become urgent to develop some advance processes for conversion of biomass to clean and convenient fuels in the country.

In the part 1.2 of this paper, the biomass energy is not included in the national energy consumption, that is, the statistical data is only for the commerce energy. If the biomass energy consumed in rural areas can be counted into the statistical data, the total energy consumption in the country could be about 1034 million TOEs in 1999. Thus the total consumption and composition of energy in China can be shown in the Fig. 14.

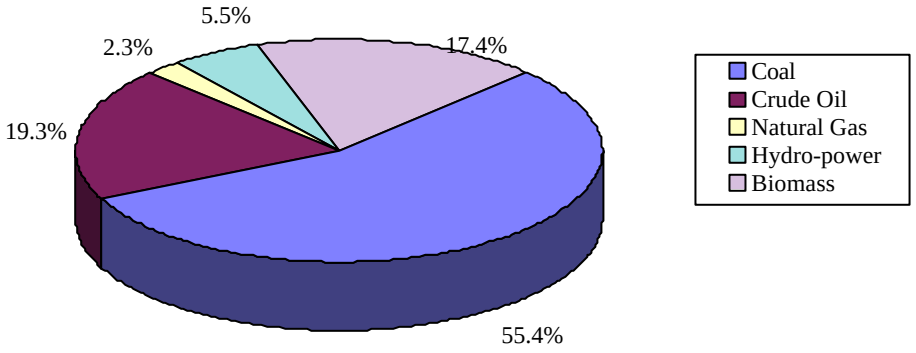


Fig. 14 total energy consumption and its composition (1034 million TOE in total, 1999)

1.4. Environment impacts of energy production and use

It is well known that the production and consumption of energy is one of the most important human actions and is a prerequisite for the progress of human society. Meanwhile, the production and consumption of energy must cause a harmful pollution on the human living environment. In recent years, environment pollution has become a hot topic in the world due

to its seriously limited effects on most of human actions, especially on the development of economy and the progress of society. In the modern human society, coal and oil are two important energy resources and their production and utilization in a large scale can bring a serious pollution on the globe environment, especially a great contribution to the GHG. As a developing country, China uses coal as its main energy source, over 67% of its total energy consumption in 1999, from which serious environment pollution has been caused in the whole country in recent years.

1.4.1 Environment impacts of energy production

Any kind of energy source, including coal, oil, natural gas, even though, and new and renewable energy, like hydro-electricity, nuclear energy, biomass, wind energy, terrestrial heat and solar energy, can cause more or less environmental effect when it is explored as an energy source.

In case of **coal,** its exploration in a large scale can cause a series of critical effects on environment:

- Causing earth's surface drooping down or earthquake by mining coal underground;
- Destroying earth's surface structures and bioecological systems by mining coal on the ground;
- Polluting underground water system;
- And producing many kinds of wastes, such as CO, SO_x, CO_2, CH_4, gangue, coal powder and others, to pollute atmosphere layer and water system.

In case of **oil** and **natural gas**, their exploration can also cause a serious pollution on environment like the case of coal:

- Polluting waster system including underground water system and on the ground water system by waste oil;
- Destroying farmland and agri-ecological distribution by trilling mud and oil-bearing water;
- Making air pollution by water, gas and solid wastes from refining processes;
- Harming fishery production and maritime ecological systems by oil escaping from oil tankers or offshore oil fields.

Finally, some environment effects can be caused from explorations of other energy sources, for example:

- To build a hydro-electricity plant, a big water reservoir is needed certainly so that a large area of farmland, and/or forest will be inundated, natural ecological systems of agricultural and/or forest will be destroyed;
- To get enough wood energy, an over-cutting down of forest may be conducted;
- To explore geothermal energy in a long time, an earth's surface drooping down or earthquake may be caused from a change of geological structure;
- To operate a nuclear generation plant, radiation pollution may be caused from a nuclear escaping occasionally.

By 1999, the area of earth's surface drooping down caused by mining industry had been up to 2 million hectares, the area of farmland polluted by industrial wastes had been 10 million hectares, and the area of losing soil and water had been 150 million hectares. According a statistics, the area of farmland is reduced by 0.3 million hectares yearly.

1.4.2. Environmental impact of 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, CO_2 and NO_x, is one of the most serious effects on environments. In 1989, about 13.6 million tones of soot and 14.8 million tones of SO_2 was produced by burning coal, which may contribute respectively 62% and 93% of their total emissions in the whole country. The table 9 shows levels of air pollution from industrial waste gases from 1990 to 1999.

Table 9 Waste gases from industry production

Years	Total waste gas (10^{12} M^3)	Flue gas from fuel (10^{12} M^3)	SO_2 (Mt)	Soot (Mt)	Industrial Dust (Mt)
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

It is clear that the pollution has been increasing with annual rates of 8.67% for the total waste gas and 8.21% for flue gas in China. For example, in 1999, the total waste gas from industrial production was up to 12,680 billion m^3 and the flue gas from burning fossil fuels was over 7,590 billion m^3, covering 59.9% of the total waste gas.

In China, caused from a great amount of coal burnt directly, as average values yearly, suspended particles in the air is up to 0.93 mg/m^3/day in cities in North areas and 0.41 mg/ m^3/day in cities in south areas; SO_2 concentration in air is around 0.092 mg/m^3/day in cities in North areas and 0.088 mg/ m^3/day in cities in south areas; and No_x concentration in air goes to 0.054 mg/m^3/day in cities in North areas and 0.048 mg/ m^3/day in cities in south areas.

In general, fossil fuels, like coal, oil and natural gas, are called as carbon-hydrogen energy from which waste gas emitted is mainly composed of CO_2 that is a kind of greenhouse gas (GHG). It is estimated that the total CO_2 emission from fossil fuels was 2,270 million tones in China, equalized to 620 million tones of carbon and contributed 11.8% of CO_2 emission on the global GHG. Based on data in 1985, a prediction on the amount of CO_2 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 10.

Table 10 Prediction for emission of CO_2 from fiscal fuels in China

Fossil fuel	CO_2 Emission (10^6t carbon/year)			
	1985	1990	2020	2025
Coal	530	540	1,150~1,350	1,670~1,940
Oil	76	100	190~220	320~370
Natural gas	7	8	60-70	90~110
Coal gas	9	12	40~70	70~80
Total	622	660	1,570*	2,220*

* An average value.

By 2025, the annual CO_2 emission will have gone up to 2,220 million tones of carbon, about 3.36 times as much as that in 1990 and 1.41 times as much as that in 2000. The increasing rate is 7.17% yearly.

China government has paid a great attention on reducing its contribution of CO_2 emission on the global GHG through ways as following:

- To improve energy efficiencies of fossil fuels for saving energy sources, reducing consumption of fossil fuels and controlling CO_2 emission;
- To develop new and renewable energy, such as solar energy, wind energy, biomass energy, tide energy and nuclear energy for changing its energy consumption composition, that is, reducing consumption of fossil fuel, especially coal;
- To protect and develop forest resources, increase forest-cover rate, turn the land green with park and trees for speeding the absorption of CO_2 and improving environment.

2. Current Status and Future Prospects of Utilization of Agricultural and forestry Residues and Other Biomass as Energy Source

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, afforestated lands and prairies in the country may be over 5 billion tones in dry weight that is equal to 1.7×10^9 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 4.37×10^8 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 the next century.

2.1. Availability of agricultural and forestry residues and other biomass

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. Based on some related statistical data, an estimated amount of available biomass resources in the country will be calculated easily by simplified statistical ways.

2.1.1 Crop residues

In China, a great amount of crop residues can be produced from agricultural actions. According to statistical data (1994), in 1993, there are 95.1 million hectares of cultivated lands and 108 million hectares of undeveloped land in which there are 35.4 million hectares of useable land in this country. The total amount of grain products was 456.5 million tones, in which, the amount for rice, wheat and corn was 177.7, 106.4 and 102.7 million tones respectively.

a. Statistical method

The total biomass production of crop residues is related to amounts of crop-products, rates of residues produced from crops and heat values of residues. Thus, the amount of crop residues can be expressed by the following formula:

$$\tilde{S} = \sum_{i=1}^{n} S_i \cdot d_i \quad \text{.....(1)}$$

In which $\tilde{S}$ means the total amount of biomass from crop residues in the country,

S_i is the amount of grain produced from a special crop,

d_i is the rate of residues biomass produced from the special crop,

And i=1,2,3……n for a special crop.

Table 11 Rate of Residues Produced from a Special Crop (kg/kg)

	Wheat	Rice	Corn	Soybean	Tuber	Sorghum	Millet	Cotton	oil-crop	Others
Rate of residues	1	1	2	1.5	1	2	1	3	2	1

In case of the amount expressed as TOE of energy, the formula can be:

$$\tilde{E} = \sum_{i=1}^{n} \alpha_i \cdot S_i \cdot d_i \quad \text{.....(2)}$$

in which $\tilde{E}$ expresses the total biomass energy from crop residues in TOE,

and α_i is the heat value at a low level (LHV_i)of a special crop residue and it can be treated as a constant value (LHV_o) in order to simplify calculations. Thus, the biomass energy can be expressed as:

$$\tilde{E} = \alpha \cdot \tilde{S} \quad \text{.....(3)}$$

In case of crop residues, α may be 14,630 kJ/kg, because most of crop residues have their LHV_i around LHV_o, that is $\frac{LHV_i}{LHV_o} \approx 1$.

b. Results

In China, rice, corn and wheat are three kinds of main grain products, meanwhile, they are main biomass resources from agriculture production. In 1998, It is estimated that the total yield of residues was 772 million tones, equal to 270 million TOE of biomass energy, in which, about 200 million TOE was from residues of rice, corn and wheat, covering 74.3% of total biomass energy from all crop residues in the country. Respectively, about 69.3 million TOE of biomass energy was contributed by rice residues covering 26%, 38.2 million TOE by wheat residues covering 14%, 93.1 million TOE by corn residues covering 34% and 71 million TOE by others covering 26% (Fig.15).

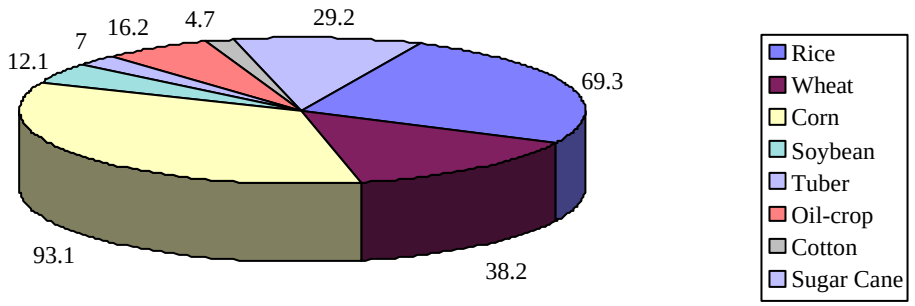


Fig.15 Production of different crop residues in 1998(million TOE)

In 1998, approximately, only 10 % of crop residues, about 80 million tones, was used as

animal feeding, 20%, about 150 million tones, as industrial materials, 52%, 400 million tones, as fuels in rural areas and 18%, 140 million tones, burnt or disused directly in farmlands.

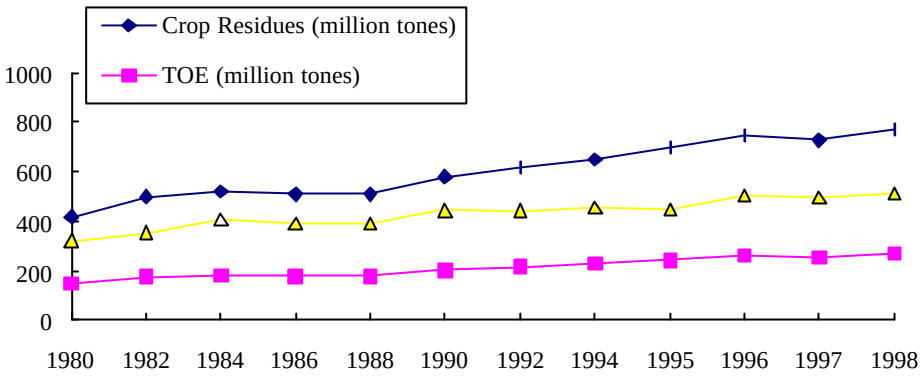


Fig.16 Production of crop residues in China (1980-1998)

As development of economy in China, the yield of crop residues is still increasing at an increasing rate of 2.4% yearly in recent years (Fig.16). For example, in 1980, the biomass energy resource was 150 million TOES, and in1994, the amount was 216 million TOES, by 1998, the amount had become 270 million TOES. If the rate can be kept at a level of 1.5% in the first two decades of the next century, the biomass energy will have been 370 million TOE by 2020, and if the rate can be kept at a level of 1% at the next 30 years, 2020 - 2050, there will be 500 million TOE of biomass energy resources in the year of 2050 in China. This prediction is based on a fact that China has 148 million hectares of farmland for its agricultural production in 1993, but according to an update survey, the total area of farmland is up to 200 million hectares(1996). The total amount of crop biomass was only 1,200 million tones including about 600 million tones of agricultural products and about 600 million of crop residues. By a theoretical estimation, the total biomass production can be up to 3,000 million tones on the 200 million hectares of farmland, that is, the maximum biomass production from crop residues can be 1,500 million tones, equal to 525 million TOES.

2.1.2 Firewood and forest residues

In China, there are about 128.6 million hectares of forest area and a forest cover rate of 13.4%. According to statistical data, the total amount of growing stock is about 10.8 billion cube meters. According to a survey of forest resources in 1989, China has about 4.44 million hectares of firewood forest occupied 3.72% of the total forest area in this year. In the national plan of planting trees, it is declared that China will plant 6.03 million hectares of firewood forest, that is, the area of Chinese firewood forest will have exceed 10 million hectares by 2001.

a. Statistical method

Because of the lack of further detail data, it is very difficult to calculate the yield of firewood and forest residues accurately. As we know, the yields of firewood and forest residues are variable to different forest types in different areas, depending on their productivity and collect ability. For example, the average yield of firewood forest can be over 7,500 kg/ha in south mountain area, but only 3,750 kg/ha in North mountain area, while, that of shrub

forest may be 750 kg/ha in the country, but the collected coefficient is 0.5 in plains area, and 0.2 in mountain area.

The total biomass production of firewood and forestry residues is related to types of forests, areas of forests, amounts of trees inside and along side farmland and rates of biomass production in different forests and different areas. Thus, the amount can be expressed by the following formula:

$$\tilde{S} = \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \eta_{ij} \left(A_{ij} \cdot r_{ij} + T_i \cdot d_i \right) \right] + 1/3W \quad \text{.....(4)}$$

in which $\tilde{S}$ means the total amount of biomass from firewood and forest residues in the country,

A_{ij} means areas covered by different forests(j) in different regions(i),

r_{ij} means rates of biomass produced from different forests(j) in different regions(i),

η_{ij} means collectable coefficients of biomass from different forests(j) in different regions(i),

T_i means amounts of trees inside and along side farmland are in different regions(i)

d_i means rates of residues produced from trees inside and along side farmland in different regions(i),

i=1,2,3.....n, regions,

j=1,2,3.....m, types of forests.

Table 12 Rates of biomass from different forestry in different regions

Regions / Types of forestry	Mountain Areas in the South		Plain and Hills		Mountain Areas in the North	
	ç	*r* or *d* (kg/ha.)	ç	*r* or *d* (kg/ha.)	ç	*r* or *d* (kg/ha.)
Firewood forestry	1.0	7,500	1.0	7,500	1.0	3,750
Protection forestry	0.2	750	0.5	750	0.2	750
Shrub forestry	0.5	750	0.7	750	0.3	750
Depleted forestry	0.5	1,200	0.7	1,200	0.3	1,200
Trees inside and along side farmland	1.0	2kg/tree	1.0	2kg/tree	1.0	2kg/tree

In case of the amount expressed as TOE of energy, the formula can be revised as following:

$$\overline{E} = \alpha \cdot \tilde{S} \quad \text{.....(5)}$$

in which $\overline{E}$ expresses the total biomass energy from firewood and forest residues in TOE, and α is a constant value and expresses an average heat value at low level (LHV_o), 18,000 kJ/kg for crop residues, because most of these biomass fuels have their LHV_i around LHV_o, that is $\frac{LHV_i}{LHV_o} \approx 1$.

b. Results

There is no official statistical data in hand for recent years, therefore, all works on calculation on firewood biomass is based on statistical data provided by Ministry of Forest Industry (MOFI) in 1994, it is estimated that the yearly yield of firewood may be over 120 million tones in 1993, or equal to 52 million TOEs (Fig.17).

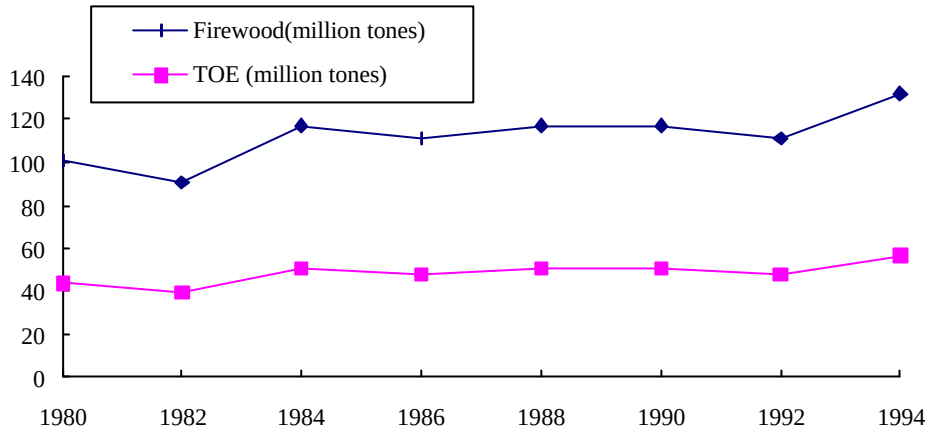


Fig.17 Production of firewood in China in several years

From Fig.17, 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 fact, the total consumption of firewood and forest residues was about 64 million TOEs in 1993 that was reported by the MOFI.

2.1.3 Dung

Dung or manure is an important biomass resources and its year yield of manure is concerned to the population and livestock production in a country. In 1999, Chinese population was up to 1.26 billion, the numbers of livestock fed in farms was: large animals 150 million heads including houses, cattle, donkeys, mules and camels; hogs 520 million heads; sheep and goats 279 million heads; the poultry 5.28 billion heads in 1999.

a. Statistical method

The total animal dung biomass is related to the size of population in the country, Animal husbandry production and rates of dung excreted from different individuals. Thus, the amount can be expressed by the following formula:

$$\tilde{S} = \sum_{i=1}^{n} \boldsymbol{h}_i \cdot d_i \cdot M_i \quad \text{.....(6)}$$

in which $\tilde{S}$ means the total amount of biomass from animal dung in the country in the dry weight,

M_i means sizes of population in the country or different groups(i) of husbandry animal,

$\boldsymbol{h}_i$ means rates of animal dung excreted by individuals from different groups (i),

d_i means age coefficients of individuals in different groups,

and i=1,2,3……n.

Table 13 Rate of dung excreted by different individuals in different groups

Items	Human being	Pig	Cattle	Horse	Goat/sheep	Poultry
$\boldsymbol{h}_i$ (kg/ones/yr, dry weight)	33	300	1,000	750	150	5
d_i	0.9	0.8	0.7	0.7	0.8	0.9

In case of the amount expressed as TOE of energy, the formula can be:

$\overline{E} = \alpha \cdot \tilde{S}$ .....(7)

in which $\overline{E}$ expresses the total biomass energy from animal dung in TOE,

and α is a constant value and expresses an average heat value at low level (LHV_o), 14,000 kJ/kg for animal dung, because their LHV_i is around LHV_o , that is $\frac{LHV_i}{LHV_o} \approx 1$.

b. Results

Based on the data mentioned above and excretion rates of animal dung (table 13), it may be estimated that the biomass resource from the dung residue might be up to 299 million tones in dry weight, about 103 million of TOE in 1999. In Fig.18, it is shown that the yield had of firewood and forest residues has been increased in recent years as the development of livestock production in the country.

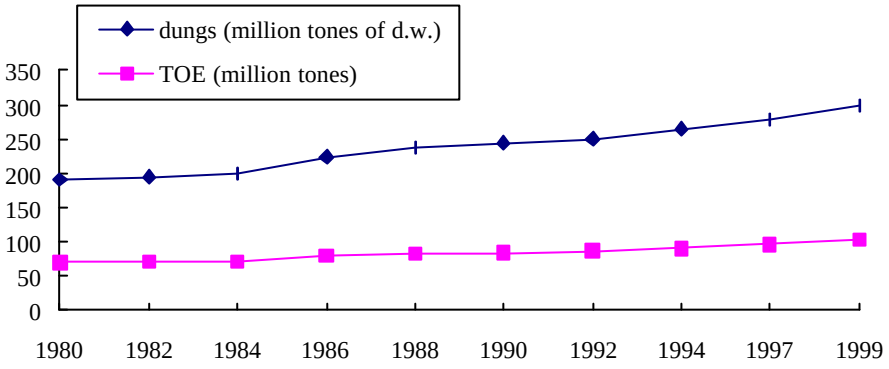


Fig.18 Biomass from animal dung (1980-1999)

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 tones. 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 tones in dry weight.

2.1.4 Others

Others of biomass resources include wastewaters from distillery, paper, sugar and food industry production, solid organic wastes from daily life and agricultural industry, and waste water from daily life. In a statistics based on data of 1990 for 230 cities in China, it is shown that about 6 billion tones 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 tones of COD accounted for 33.2% of total amount of 7.2 million tones COD discharged from industrial production in the country. In addition, about 53 million tones of wastewater and 2.5 million tones of solid wastes were excreted **daily** from daily life in these cities in the same year.

It is estimated that the total annual yield of biomass contained in these solid wastes may be up to 92 million tones of TOE in cities of the country. By now, the amount have been

increasing yearly at 8% of growing rate, but there is a little amount of these refuses being used as energy.

2.1.5 Total production of biomass yearly

Overlooking some small biomass resources, like waste water and industrial solid wastes, only from four resources, such as crop residues, firewood, animal dung and solid wastes from daily life, a great amount of biomass can be used as energy sources, about 520 million tones of TOEs (Fig.19). From Fig.19, it can be seen that the crop residue is the biggest biomass resource, covering about 52% of the total biomass resource in the country. In 1999, about 140 million TOE of biomass was used as energy, covering 27% of the total amount of biomass resources in the country.

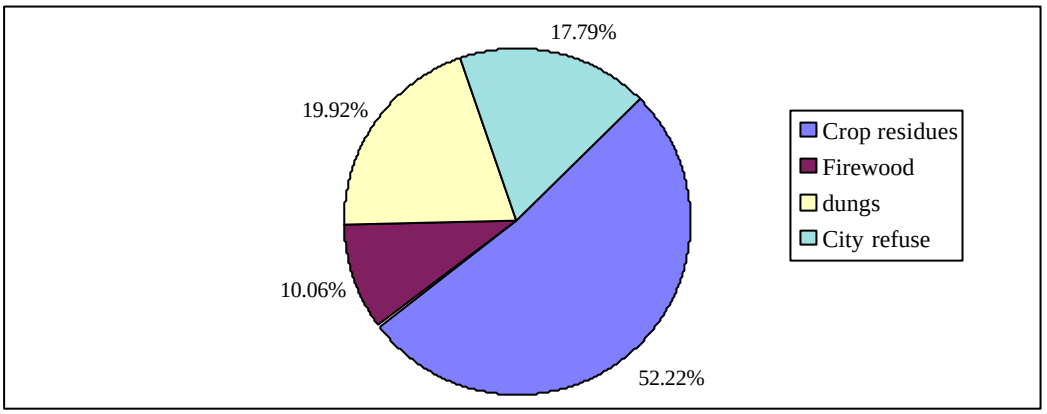


Fig. 19 The Constitute of biomass from different sources in China (1999)

2.1.6 Biomass distribution in China

Being different from other energy sources, biomass resource has some characters that should be considered carefully for selecting ways of using it as energy. These characters are shown as following:

- a renewable and hug natural resource;
- low sulphur, < 01%, and low ash, <15%;
- low energy density, 300~700 kg/m^3 or 4.2 ~12.6GJ/ m^3;
- low heat value, 14,000~18,000kJ/kg;
- high water content, 5~20%.
- uneven distribution in different areas;
- difficult for collection and transportation;
- low per capital resource, about 0.36 TOE/person.

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. Table 13 shows the distribution situation of biomass resources in China.

Table 14. Contribution Densities* of Biomass in Different Areas

Areas	Crop residues	Dung**	Firewood
Northeast	++++	++	++++
Inner Mongolia	++	++++	+
Huangtu Mountain	++	+	+
End-middle of the Yongze	+++	+	++
Southwest	+	++	+++
South of China	++	+	+++
Ganshu-Xinjiang	+++	++++	+
Qinghai-Tibet	+	++++	+

* biomass distribution is expressed by degrees of comparing the annual yield of biomass with rural population in a given area, that is, the unit is kg biomass/year/per capita.

a. Crop residues (+)<500, (++)500~525, (+++)625~750, (++++)>750;

b. Animal Manure (+)<200, (++)200~300, (+++)300~500, (++++)>500;

c. Firewood : (+)<100, (++) 100~200, (+++) 200~300, (++++) >400.

** not including human manure resource in cities

In the northeast area and the end-middle of the Yongze River, crop biomass resources are more abundant than other areas; in the Inner Mongolia area, the Ganshu-xingjang area and Qinghai-Tibet area, the most plentiful biomass resource comes from animal dung; and the firewood and forest residues are mainly distributed in the northeast area, the southwest area and south area.

2.2. Current status of biomass energy conversion technologies

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.

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, briquetting 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 next 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.

2.2.1 Biomass energy conversion technologies and their relation

These new technologies developed in China are involved in:

- anaerobic digestion, including household digester and industrial anaerobic system, for treating animal manure, waste water to produce biogas;
- thermal pyrolysis, including gasification, liquefaction and carbonization, for treating crop and/or forest residues, industry organic wastes to produce gas fuel, bio-diesel and coke fuel;
- alcohol process for treating lingo-cellulose-wastes to produce ethanol fuel;
- briquetting process for identifying incompact biomass materials;
- efficient burning furnace and saving fuel stoves.

These new energy products and their final uses are shown as following:

- **biogas:** cooking by independent users or centralized gas supply nets, electricity generation or boiler fuels in factories.
- **low energy gas**: cooking by independent users or centralized gas supply nets, drying wood or other products in factories, electricity generation;
- **middle energy gas**: cooking by independent users or centralized gas supply nets, drying wood or other products in factories, electricity generation or synthesize liquid fuels, like methanol;
- **bio-diesel**: driving engines;
- **alcohol**: driving engines;
- **briquetting fuel**: cooking by direct burning in a special stove, pyrolysis for producing charcoal, gas fuel and bio-oil;
- **hot air**: drying processes in factories.

These technologies, energy products and their final uses are shown in the fig.20.

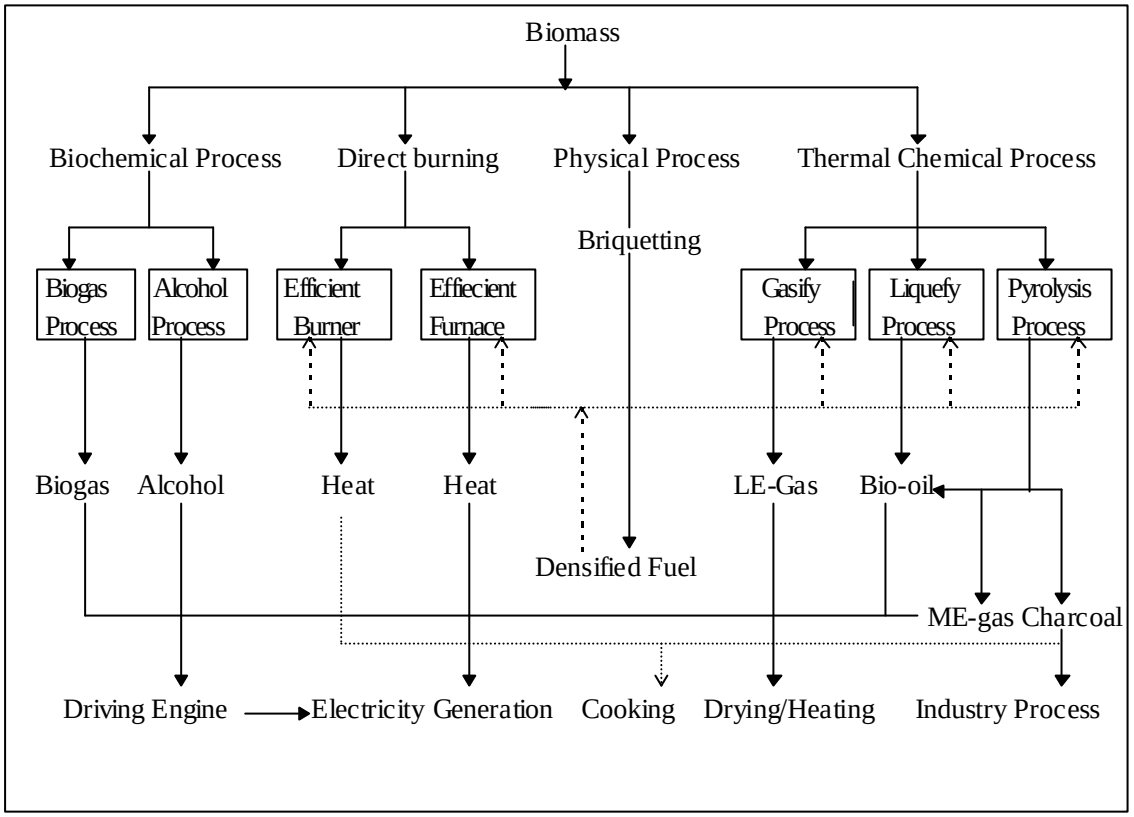


Fig.20 Biomass energy conversion technologies and their relations

2.2.2. Status of biomass energy conversion or utilization technologies

a. Biogas

The technology has been developed for 20 years in China. 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 m^3/ m^3.d, but that of these new digesters can be between 0.2 and 0.4 m^3/ m^3.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 m^3/ m^3.d and rates of COD removed can be in range from 70% to 86%.

b. Gasification

In recent years, the gasification technology has got a great progress in China. Three processes have been developed for treating different materials and different usage. First one is the up-draught fixed bed gasifier. Its gasifying efficiency is 75% and maximum energy output is about 1,400 MJ/h. The system can convert crop residues into gas fuel and one system can provide 800 m^3 of gas fuel to 90 rural families daily by a gas supply net. Second one is the downdraught fixed bed gasifier. Its gasifying efficiency is over 75% and maximum energy output is 620 MJ/h. The system is mainly used for treating wood wastes and supplying 2,600 m^3 of gas fuel to wood drying process in a factory. Third one is down

draught recycle fluid bed gasifier. Its gasifying efficiency also is 75% but its maximum energy output is up to 2,900 MJ/h. The system has been operated successfully for treating wood powder and providing gas fuel in a factory.

c. 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 m^3 of gas fuel, 250 ~600 kg of charcoal and 200~300 kg of bio-oil can be produced respectively.

d. Briquetting

There are two kinds of briquetting processes being researched: 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.

e. Others

Several research groups in China have researched some new technologies, such as biomass liquefaction by thermal-chemical processes and alcohol from sugar or cellulose materials. These technologies are still at a research stage.

2.2.3. Application of biomass energy conversion or utilization technologies

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 6). The second is the technology of improved stove and heat bed, about 0.525 million TOES saved yearly.

As shown in table 15, 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.

Table 15 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	

2.2.4. 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 16.

Table 16 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 Energy & Environment 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

2.3. Past and ongoing efforts of the government and universities and other private research institutes/organizations

It is well known; China is the biggest developing couture in the world, about 75% of its population, more than 880 million (1999) 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%), labored and dirty. So China does its best to develop the biomass energy technology for meeting its energy demand.

2.3.1 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.

2.3.2 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 17 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

3.3.3 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 18 shows the members of the Center, including some institutes, universities and organizations involved in biomass energy.

Table 18 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\briquett.	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 Academy of Science	gasifier\briquetting	Shijiazhuang
9.	Institute of Energy Resources of Jiangxi Academy of Science	biogas	Wuhan
10.	Chengdu Institute of Biology, Chinese Academy of Science	biogas	Chengdu
11.	Institute of Engineering Thermo-physics, Chinese Academy of Science	gasifier	Beijing
12.	Guangzhou Energy Institute, Chinese Academy of Science	biogas\gasifier	Guangzhou
13.	Institute of Energy and Environment Protection, Chinese Academy of Agri-Engineering Research and Planing	biogas\furnace	Beijing
14.	Energy and Power Research Institute, Chinese Academy of Agri-Mechanization Science	Gasifier\briquetting	Beijing
15.	Environment Science Research Institute of Shanghai Academy of Agri-science	biogas	Shanghai
16.	Research Institute of Chemical Processing and Utilization of Forest Products	gasifier\briquetting	Nanjing
17.	Chengdu Biogas Scientific Research Institute of the Ministry Agriculture	biogas	Chengdu
18.	Renewable Energy Institute, Capital Normal University	biogas microbiology	Beijing
19.	Department Chemical Engineering for Energy Resources, 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 Province	biogas\briquetting	Wujin
22.	Institute of Microbiology, Shangdong University	biogas microbiology	Jinan
23.	Microbiology Laboratory, Department of Environmental Science, Zhejiang Agricultural University	biogas microbiology	Hangzhou
24.	Institute of New Technology of Changsha	gasifier	Changsha
25.	Solar Energy Research Institute, Yunnan Normal University	briquetting	Kunming
26.	Energy & Environ. Enginrg. Research Department, College of Agri-Enginrg. for Shenyang Agri- University	alcohol from sugar materials liquefaction	Shenyang

3.3.4 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 19).

Table 19 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	Shandong
		2. Dalian Institute of Energy & Environment	Dalian
		3. Nanjing Institute of Forest Chemical Products	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	Wuhan
● A research work on plant oil as energy	10 hectares of oil-forest for demonstration	Changsha Institute of New Technology	Changsha

2.4. Future prospects for use of biomass energy source

2.4.1 the Agenda 21 of China

In 1992, just after the 92' 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.

2.4.2 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 m^3 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 20 shows the plan in details.

Table 20 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 Liaoning Institute of Energy Resources	Guangdong Yingkou
● Study on standardilization and commercialization of electricity generation system by biomass gasification	6 series 60-160kw	Shandong Institute of Energy Resources Nanjing Institute of Forest Chemical Products	Shandong Nanjing
●		Secretary Office of China Biomass Development Center	Beijing
2. Biogas			
● 2MW electricity generation system by biogas	6,000 Mwh electricity yearly	Hangzhou Institute of Energy and Environment	Hangzhoui

2.4.3 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 21.

Table 21 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	East China Science and Technology University	Shanghai
2. Liquid fuels			
● Biomass liquid fuel technology	Including alcohol, pyrolysis and plant oil fuels	Changsha Institute of New Technology	Changsha

*Note: Institutes in table are bodies that give out related proposals.

2.5. 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.

3. Suggestions for Priority activities for inter-country/regional Cooperation

For developing biomass energy in a large scale, it is necessary and possible that some international and/or regional cooperation activities be conducted by countries in the region of Asia and Pacific in a wide field. Most of these countries, including China, are developing countries and they have a common situation on prompting economy growth, developing new energy resources, improving environmental quality. In these countries, biomass resources are used as a major energy source, especially in their rural areas. I am certainly believing that the more such activities we do, the more benefits will we share on energy and environment.

By considering Chinese experiences in developing biomass energy, its constraints in fields of technology and economy and its requirements for international aids, priority activities on inter-country and regional cooperation could be suggested as following:

- to set up a regional foundation by a cooperation between governments of countries in the region;
- to set a development center by experts from countries in the region;
- to exchange information between these countries through international meetings, magazines and visiting activities;
- to confirm priority projects and technologies being suitable for these countries;
- to helping those countries being lack of experts by making plans on utilization of biomass energy;
- to conduct cooperation research works between experts from these countries, if necessary, to provide financial aids for supporting research cooperation between these countries and developed countries;
- to build some demonstration projects for selected technologies in selected countries and transfer technologies to them;
- to provide technology aids for biomass energy projects and apply financial aids from international organizations or institutes for biomass energy projects.

Some priority technologies are as following:

- biomass gasification and power generation;
- biomass briquetting technology;
- biogas technology for treating animal dung and waste water;
- daily life refuses as energy by biogas, gasification or direct burning;
- biomass liquefaction by a thermal-chemical process.

In addition, an integrated plan should be drawn for developing biomass energy in the region, which will be combined with a national planning by a special country.

China is a developing country. It will do its best to prompt the development of biomass energy technology in the whole region.

References

1. *Statistical Yearbook of China,* China Statistical Publishing House, 1994.
2. *Rural Statistical Yearbook of China,* China Statistical Publishing House, 1994.
3. *Statistical Yearbook of China,* China Statistical Publishing House, 1998.
4. *Rural Energy Statistical Yearbook of China,* China Statistical Publishing House, 1998.
5. *Statistical Yearbook of China,* China Statistical Publishing House, 2000.
6. *Rural Energy Statistical Yearbook of China,* China Statistical Publishing House,2000.
7. *New and Renewable Energy - Technologies and Products in China,* State Science & Technology Commission of China, 1995.
8. *A report on development of energy in China,* Yan Changle et al, Economy Management Press, 1994.
9. *A Essential Workframe for Developing New and Renewable Energy Resources in China,* SSTC, SPC and SETC, 1995.
10. *Priority Projects on Developing New and Renewable Energy Resources in China,* SSTC, 1995.
11. *A Prediction Research Works on Energy Demand for 2050 in China,* Zhou Xiaoqian et al, the Integrated Planning Division of Ministry of Energy, 1990.
12. *New and Renewable Energy Technology and Products in China,* SSTC, 1995.
13. *An Index of Institutes for New and Renewable Energy in China,* SSTC, 1996.
14. *Biomass Gasification in China,* Yuan Zhenhong, Workshop on Biomass Production and Utilization, Trieste, Italy, 1996, 5.
15. *A Strategy Evaluation Research on Solid Fuel Technology from Biomass in China,* Lin Guofen et al, Research Report for the National Planing by SSTC, 1995.
16. *Research and Development Works on Biomass Energy Conversion Technology in China,* Yuan Zhenhong et al, A Report to SSTC, 1994.
17. *A Strategy Research on Liquid Fuels from Biomass,* Yuan Zhenhong et al., A Research Work in the "8th National Five-year Plan for the Development of Science & Technology" 1995, 6.
18. *A Feasibility Research on Priority Projects of Biomass Energy Technology,* Yuan Zhenhong et al, A Meeting Report for the Priority Project Plan by SSTC in the Period of the "9th Five Years Plan", 1996,3.
19. *A Recycle Fluid System for Gasification of Biomass,* Xu Bingyan et al., A Research Work put in the "8th National Five-year Plan for the Development of Science & Technology" 1995, 12.
20. *A research Work on Catalysis Gasification and its Kinetics for Wood Materials,* Jiang Jianchun et al., A Research Work put in the "8th National Five-year Plan for the Development of Science & Technology" 1993, 7.
21. *ND-600 Gasifier for Crop and Forest Residues and its Utiliztion,* Yang An et al., A workshop on Technologies for Development of New Fuels, the Ministry of Agriculture, 1992.
22. *Exploitation and Utilization of Biomass and the Establishment of Demonstration Project,* Yuan Zhenhong et al., Proposal Submitted to priority Projects of "21st Century Agenda of China" 1995.
23. *Research Works on Gasification of Biomass and its Key Technology in China,* Xu Binyan et al., New Energy, 1995,17(12).
24. *The Status of Biomass Energy Technology and its Utilization in China,* He Yuanbin et al., a Workshop on Biomass Utilization, AIT, Bangkok, 1995, 9.
25. *Present Situation and Research on Fuelwood Forest in China,* Guo Huairang, Research and Development of Biomass Energy Technology in China, China Science & Technology Press, 1992
26. *Present Situation of Biomass Resources and Their Utilization in China,* Xiong Chengyong et al., Research and Development of Biomass Energy Technology in China, China Science & Technology Press, 1992, 7.
27. *Evaluation and Utilization of Biomass Energy Resources in China,* Wang Mengjie, Research and Development of Biomass Energy Technology in China, China Science & Technology Press, 1992, 7.
28. *Biomass Pyrolysis Gasification Technology and Gas Supplying Network in a village, Sun Li et al.,* Research and Development of Biomass Energy Technology in China, China Science & Technology Press, 1992, 7.