GoC/ World Bank /GEF

China Renewable Energy Scale-up Program (CRESP)

CONTRACT FOR CONSULTANT'S SERVICES

(Consultation on Biomass Power Generation Technology Improvement)

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Content

Preface

Biomass resources are very abundant in China, with great energy potential. Energy utilization from biomass is an important way to national economic sustainable development on renewable energy, as well as reducing pollution to environment. Renewable Energy Law has been legislated in February 2005 in China, in which the development and utilization of renewable energy ranks priority item among Chinese energy development. And the China Renewable Energy Scale-up Program (hereinafter referred to as CRESP) cooperated between the State Development and Reform Commission of China and the World Bank aims at expanding and developing China's renewable energy utilization to accelerate technological scale-up and industrialization process.

CRESP office has entrusted and supported Guangzhou Institute of Energy Conversion (GIEC), CAS to make an elaborate analysis and assessment of cogency on the application of biomass electricity generation technology in China, which constitutes part 1 of this report, and is submitted to the Expert Workshop on "Analysis of Potential in China for Improvement in Biomass Power Generation Technology" of CRESP in April 2005. Based on the analysis and assessment, Experts and researchers participating in the conference discussed and expressed various opinions on some important points such as foreign and domestic relevant technologies and future development trend, biomass energy technological industrialization and which technologies are priority of industrial support and special measures. Everyone has the consensus that energetically developing biomass power generation technology is of importance to national sustainable development, particular to the wide rural and remote areas in China. The meeting summary constitutes part 2 of this report.

As described in part 1, present key problem of scale-up utilization for biomass power generation technology is that China is very weak in general manufacture and production ability of biomass power generation related equipment. In order to advance China's biomass power generation technology level and relevant energy equipment manufacturing ability, CRESP office particularly set up the Competitive Grant-in-aid Project according to GoC/ World Bank/ GEF, and entrust GIEC with the project implementation scheme, including the emphasis of technology advance items to be supported by ESCRP, qualifications for supported objectives and examination standard. These constitute part 3 of this report.

For a further necessary environment to support biomass power generation technology development, CRESP office still set up the Technology Improvement Project, and entrust GIEC with the project implementation scheme, including financing channel, operable and supportive policies, economic promotion measures and fair market competition mechanism. These constitute part 4 of this report. The Technology Improvement Project will work together with the Competitive Grant-in-aid Project.

Part 1: Analysis of the Application of Biomass Power Generation Technology in China

1. Introduction

Before accomplishing this report, according to requirements of the project, we have carefully read up and analyzed two research reports - "Biomass Industry Survey" prepared in Finland and "Biomass Co-firing, Combustion, Gasification and Utilization" prepared by Mitsubishi Corporation, Japan. We think they provide abundant information on biomass energy utilization and power generation, which is very beneficial for realizing the status of biomass energy in the world and in China, especially for comprehending the general situation of biomass energy resources and its utilization in China, and for studying the application direction of Chinese biomass power generation technologies for the future. Of course, these two reports have their advantages and, accordingly, deficiencies respectively, and followings are their main characteristics:

1.1 Research report "Biomass Industry Survey"

- The description of biomass utilization technologies in Finland is relatively comprehensive, especially in detail for wood disposal equipment.
- The structure and economic analysis of investment on projects of biomass power generation are illuminated in detail, but most of which are made on basis of overseas economic environment and relatively earlier situation, as a result, there is a great gap between its conclusion of economic analysis and reality in China.
- It analyzes the characteristics of wood-type biomass material in detail, but it is not sufficient in depth for the material nature and supply characteristic of biomass resource of China in which the agricultural offal is dominating.
- It obviously overestimates the manufacture technology and capability of biomass boilers in China. There are lots of boiler factories in China indeed, but most of them only manufacture coal-fired boilers. There is hardly any biomass boiler put into service for power generation except some simple bagasse boilers.
- The conclusion on comparison between various biomass utilization technologies is relatively inexplicit.

1.2 Research report "Biomass Co-firing, Combustion, Gasification, and Utilization"

- It describes the China biomass resources in detail, but still doesn't explain characteristics of their supply.
- It describes various biomass utilization technologies in all rounds, especially the status of China biomass utilization.
- The analyses of the price and cost of biomass material are relatively detailed,

but the transport costs are overestimated while the storage and management costs are not considered.

- The economic analysis of various technologies and comparison between them are relatively particular, but there is an obvious deviation to the reality at present.
- Although there are some comparisons between characteristics of various technologies, the conclusion is incomplete.
- It is inadequate in the analysis of the characteristic of capital utilization in construction items of biomass power generation projects.

Considering the characteristics of these two reports, this report will not repeat the discussion on issues such as technology, international development survey, and the potential of biomass resources in China, which have been discussed clearly in above entioned reports. This report put emphasis on analyzing the status and problem of electric power supply, the supply characteristic of biomass resource, the economy of biomass power generation, and other specific problems. On the basis of these analyses, this report analyzes different characteristics of various biomass power generation technologies in China, and consequently presents the idea for development of scale utilization of China biomass power generation technologies in the future.

2. The present situation in supply of electric power of China

2.1 The structure of electric power of China

Table 2-1 shows the increase and structure of the installed capacity of power generation and the output of electricity of China (1990-2003). The table contains the data of thermal electricity and hydropower. For years, coal steam electricity dominates in power source structure, and except hydropower, the proportions of nuclear and renewable energy resource for generation is small. In addition, the proportions of both oil and natural gas electricity in thermal electricity are very small too. Fig. 2-1 shows the structure of annual electricity output of China, in which renewable energy electricity other than hydropower accounts for 0.1% of the total generation only.

Table 2-1 The increase and structure of the installed capacity in China during past years

Year	**Installed Capacity** (GW)		Proportion (%)		Output of electricity (TWh)		Proportion (%)	
	Hydro	Thermal	Hydro	Thermal	Hydro	Thermal	Hydro	Thermal
1990	36.05	101.84	26.1	73.9	126.3	495.0	20.3	79.7
1991	37.88	113.59	25.0	75.0	124.8	552.7	18.4	81.6
1992	40.68	125.85	24.4	75.6	131.5	622.7	17.4	82.6
1993	44.89	138.02	24.5	75.5	151.6	686.8	18.1	81.9
1994	49.06	148.74	24.5	74.4	166.8	747.0	18.0	80.5
1995	52.18	162.94	24.0	75.0	186.8	807.4	18.6	80.2
1996	55.58	178.86	23.5	75.6	186.9	878.1	17.3	81.3
1997	59.73	192.41	23.5	75.6	194.6	925.2	17.2	81.6
1998	65.07	209.88	23.5	75.7	204.3	938.8	17.6	81.1
1999	72.97	223.43	24.4	74.8	212.9	1004.7	17.3	81.5
2000	79.35	237.54	24.9	74.4	243.1	1107.9	17.8	81.0
2001	83.01	253.14	24.5	74.8	266.1	1204.5	17.6	81.2
2002	86.07	265.55	24.1	74.5	274.6	1352.2	16.6	81.7
2003	92.17	285.64	24.0	74.3	283.0	1580.0	14.8	82.8

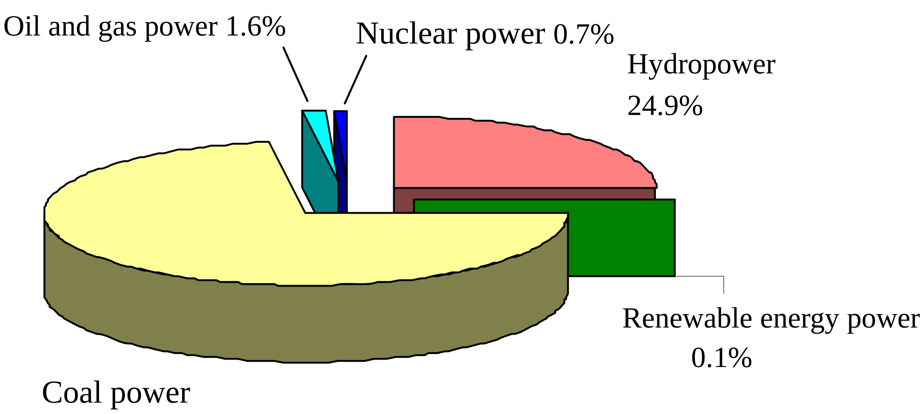


Fig. 2-1 The electric power structure in China in 2000

2.1.1 Coal steam electricity

Energy resource structure of China, dominated by coal, determines that most of electricity power is produced by coal-fired plants for years. It is estimated that the proportion of coal steam electricity will fall gradually in the future 20-30 years with the establishment of structure on diversified energy resources, but it will still dominate in the electricity structure. China will develop coal-fired power generation technology and large-scale gas-steam combined circle technology with high efficiency and cleanness, and improve utilization efficiency of energy resource and restrain environmental pollution from coal-fired power generation in maximum by choosing power generation method with higher economic efficiency and better benefits of environmental protection. China plans to reduce the proportion of coal steam electricity to less than 50% in 2050.

2.1.2 Hydropower

There are plentiful water resources in China, at the first place all over the world. China government always attaches importance to build water conservancy and hydropower, and the installed capacity of hydropower increases year by year, especially rapidly after 1990s. At present, hydropower generates more than 25% of electric power of China, and the contribution of hydropower in the consumption of primary energy resource is about 7%. Hydropower holds the balance of energy supply in China. However, more than 3/4 water resources concentrate in the western China, of which only less than 10% are exploited in order to transmit electric power to economic advanced regions in the eastern China where the potential of hydropower exploitation is very small.

2.1.3 Oil and gas electricity

The installed capacity of oil-fired power generation in China is very small, and they are mainly some small-scale oil-fired generators in various regions. With continuous rise and long-term turbulence of crude oil price, and rapid increase of energy consumption in transportation in the future, it’s estimated that the possibility of increasing oil-fired power generation is very small.

The electricity generation with natural gas possesses advantages of generation efficiency and environmental protection, and it’s the trend of development of electric power industry in the world at present. China also actively develops the utilization of natural gas, and experts estimate that the proportion of installed capacity of natural gas electricity generation will exceed 10% after 20-30 years in the future. The natural gas resources required in the future will partly come from domestic natural gas and coal bed methane resources, and in addition, a great lot of natural gas will be imported. Since coal is the main part in the energy supply of China, to develop natural gas electricity generation will be a complicated systems engineering, which will relate to many fields such as transmission pipeline, electricity generation equipment, investment and financing, economic capacity for acceptance of consumption areas, and need all-round supports from various area such as electricity generation technology, equipment manufacture technology, and policy.

2.1.4 Nuclear power

At present, the proportion of nuclear power in the electricity structure of China is less than 1%, and the installed generators are mainly in Daya Bay and Qinshan nuclear power plants. However, in comparison with the advanced levels in the world, there is still a quite big gap in nuclear power technology and its equipment. Considering the rapid increase in demand of energy as well as continuously increasing shortage of coal resources and electric power, China will develop nuclear power more rapidly and increase its proportion as an alternative energy resource,. Especially in eastern and southern China where economy develops fast, nuclear power is considered as supplement to ease the demand for electric power.

2.1.5 Renewable energy electricity

The development objective brought forward in **the Development Program of New and Renewable Energy Resources of China (1996-2010)** is: improve the conversion efficiency, reduce production cost, increase the proportion of renewable energy in the structure of energy resources, and make contribution to environmental protection and constant development of national economy. Both the Tenth Five-Year Plan and the 2015 Long-range Plan built by State Economic and Trade Commission put emphasis on taking great efforts to develop small hydroelectricity, wind, biomass, solar, and geothermal energy, and all these strategic plans guide development of renewable energy in China. In the field of electricity generation on renewable energy, the installed capacity of small hydroelectricity at the end of 2003 has been up to 30 GW, which is at the first place in the world, and wind power of 560 MW, as well as 170 thousand subminiature off-grid wind power generators, biomass generators of 1 GW, solar energy PV of more than 40 MW, and geothermal energy of 280 MW. However, the contribution of electricity generation on renewable energy is less than 10% of the total generation output, and most of them come from small hydroelectricity. In order to increase the proportion of electricity generation on renewable energy in the structure of electric power rapidly and to develop green electric power with great efforts, besides constantly developing small hydroelectricity, electricity generation on biomass energy and wind power are the primary direction of development for a long period in the future.

2.2 The price system of electricity power inChina

2.2.1 Power production cost

Fig. 2-2 shows the average electricity prices of some power grids and regions of China in 2003. The variation of electricity prices between power grids of various regions or provinces is relatively large, and the same case occurs between coal and renewable energy electricity.

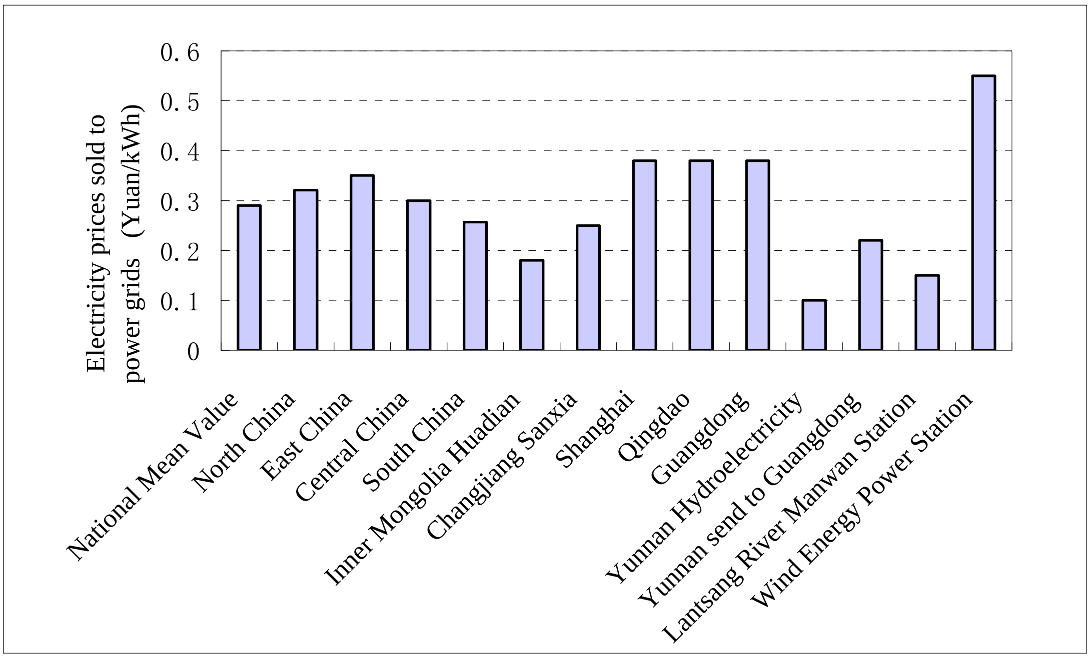


Fig. 2-2 the average electricity prices of some power grids and regions in 2003

Sources: Sum-up of data of various local electricity prices sold to power grids.

Fig. 2-3 shows the sale prices of some province and city power grids in 2003. The price for the voltage less than 1kV is usually 0 ~ 0.02 Yuan/kWh higher than that of 1 ~ 10 kV, and that for 35 kV or above is 0~0.02 Yuan/kWh lower than that of 1 ~ 10 kV; the price of regions that do not levy city utility additional tax is generally 0 ~ 0.02 Yuan/kWh lower than those of regions in the same province that levy this tax. It is obvious from Fig. 6 that the prices for various kinds of consumers in a province may be quite different, for example, the variation is about 0.58 Yuan/kWh in Fujian and 0.57 Yuan/kWh in Hunan; the prices for the same kind of consumers differ obviously in different provinces, for example, the difference in price of commercial electricity between Hunan and Xinjiang is up to 0.421 Yuan/kWh. Although there are differences between electricity prices (such as electricity for resident living) of cities in a province, they are close to above prices basically and don't vary too much.

From Jan. 1, 2004, according to F.G.D. No. (2003) 124“The Notice of National Development and Reform Commission on Adjusting Electricity Price”, all the grid prices of coal-fired power units controlled by power grids on provincial or higher level increases by 0.7 Fen/kWh (including tax) to deal with the influence of increase in electricity generation cost due to the rise of coal price in 2003 and 2004. The sale prices are adjusted accordingly. All sale prices to consumers, set by corporations managing power grids of provincial or higher level, are increased by 0.7 Fen/kWh (including tax) on basis of the State listed price issued by the National Development and Reform Commission except for that used in resident living, agricultural production (including agricultural drainage and irrigation in depressed counties), and chemical fertilizer production.

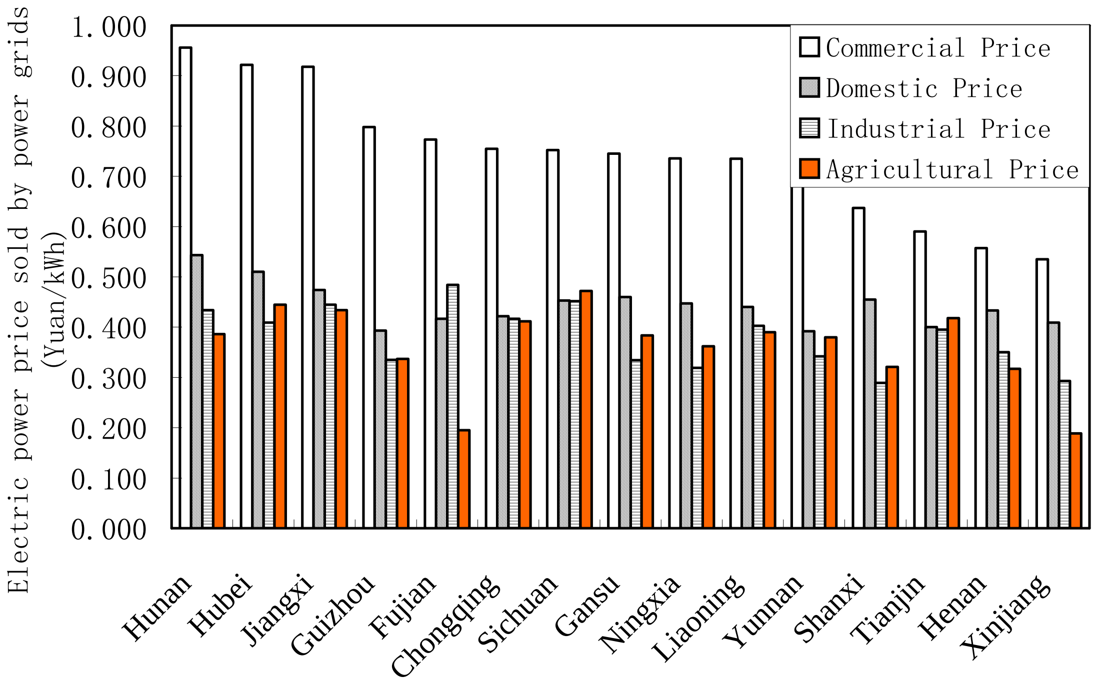


Fig. 2-3 The sale prices of some province and city power

Sources: Sum-up of data from China Price Information Network

2.2.2 The transmission and distribution costs

According to the Law on Electric Power and principles of economics, the price of transmitting electricity should be equal to the summation of transmission cost of electric power, profit, and tax. The transmission and distribution costs include depreciation of equipment for transmitting electricity, maintenance cost, material cost, overhead, power grid loss, expenses for resettling electricity generation plan and economic dispatch, reliability expense, and other costs; profit and tax should be calculated according to relevant State regulations. In electric power market of China, the transmission market is absolute monopolistic, which means that all power grids, auxiliary equipments, and safety control devices belong to power grid corporations who take charge of the safe and stable operation of power grids and open this market to all market members, such as power producers, power suppliers, and large consumers.

China has implemented the electric power system reform of "division between power plant and grid, and introduction of price competition in selling power to grid." However, since the electric power system with the pattern of integration of electricity generation, transmission and selling has been performed for a long time, the electricity price system of China only formulates terminal selling price and top wire electricity price but no transmission and distribution price. The transmission and distribution price (equal to selling price minus average top wire electricity price and grid loss) in China is 1.02 US cents/kWh computed based on selling and top wire electricity prices, while it is more than 1.67 US cents/kWh in Brazil, Britain, Canada, German, and Australia. In listed prices of State power corporation system, the top wire electricity price accounts for 77% and the transmission and distribution price -- for 23%, while the latter overseas generally accounts for 50~60%.

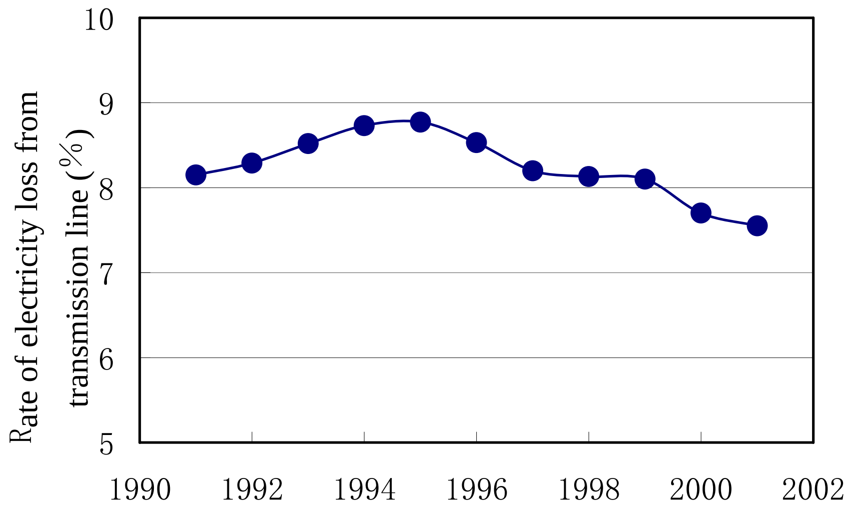


Fig. 2-4 Variation of loss of electricity in transmission in past years

On the other hand, in order to guarantee the electricity supply, the installed capacity of electric power will increase continuously for the coming years. Taking 1:1 or so as the reasonable ratio of investment in power grid to that in power source in China for calculation, the investment in power grid will be as high as up to 580 and 900 billion Yuan in order to realize the investment plans for power sources construction in the periods of national Tenth and Eleventh Five-year respectively, including 470 and 720 billion Yuan from State Power Grid Corporation respectively and corresponding capital in cash will be 94.0 and 144.0 billion Yuan respectively. The ratio between investment in electricity generation, transmission and distribution in the West developed countries is about 1:0.5:0.7, while it is 1:0.23:0.2 in China. In comparison with electricity generation, the proportions of investment in electricity transmission and distribution are obviously on the low side. It is obvious that the demand of huge investment in power grid cannot be satisfied if merely depending on power grid corporations' own accumulation.

According to analysis above, the rise of electricity price not only lies on the factors of the rise of fuel price or inflation, other factors such as power grid construction and management, and line loss from long distance transmission of electricity will also result in the trend of price rising. Table 2-4 shows the variation of the ratio of electricity transmission line loss past years in China.

2.2.3 The gross profit of electric power selling

For instance, the data released by State Power Grid Corporation show that it sold electric power 1120.2 TWh and accomplished selling income of 427.7 billion Yuan and profit of 4.16 billion Yuan in 2003, and in the first half of 2004, they are 609.2 TWh, 277.8, and 3.3 billion Yuan respectively. This means the profit of selling electricity is 0.0038 and 0.0054 Yuan per kWh respectively, which is about 1% of electricity price if calculated by average electricity price in that year. The capital return ratio and selling profit ratio of State Power Grid Corporation are 0.49% and 1% respectively, which is lower than 7.1% and 18.9% of electricity generation corporations, as well as industrial average level (3.5% and 5.1% respectively in 2001) in China.

2.3 The characteristics of investment in China electricity market

2.3.1 The procedure of project approval

Since the adoption of the reform and opening policy in the late 1970s, China has executed an investment system characterized by examination and approval system. On July 25th, 2004, the Chinese government promulgated Decision on Reform of the Investment System, which is considered as the speed-up signal of reform of general adoption of the market principle in investment field. This means that reform of electric power investment system with deep characteristics of planned economy and government administration will be accelerated in the direction of general adoption of the market principle.

The Decision stipulated clearly that enterprises shall be in principal status in investment and they can make their own decisions on investment. For electric power investment, most projects will need only to be authorized by relevant government authority in charge of investment except the projects funded by government investment that need still to implement the examination and approval system. For the project application reports submitted by corporations, the government authorizes them mainly from these aspects such as maintaining economic safety, exploiting and utilizing resources reasonably, protecting ecological environment, optimizing important layout, guarantee public benefit, preventing the emergence of monopoly and so on, and no longer supersede the investor in auditing for the projects of market foreground, economic benefit, capital source, and product and technique scheme. Changing the examination and approval system to the registration and recording system and "examination and approval" to "authorization", the market degree of electric power investment and the basic role of the market in resource allocation will be improved greatly, and the application procedure of electric power projects will be simplified too.

Investment system reform will bring special right to large-scale electric power groups which possess solid strength and lead the market. The "Decision" mentions to give large enterprises greater power to make investment decisions and to basically set up large enterprises group with modern enterprise system. To invest and build the projects on the "list", the investors can make medium or long-term plans of development and construction. When the plans are authorized by the State Council or the authority in charge of the investment, the projects in the "list" only need the procedure of recording and no longer need to be declared and approved in addition. All these will greatly boost up the feedback and expansion speed of large electric power groups for market. Currently, although the trend of diversification of subject of investment in field of electric power is evident, the large state-owned enterprises are still the mainstay of the electric power industry of China. The “Decision” has a policy support to the large state-owned enterprises, which indicates that the State expects they could play greater role in the sustainable development of electric power.

2.3.2 The primary investors

From 1980s, China began to reform its investment and financing systems of electric power and electricity price. As a result, diverse investment subjects, capital channels, and power development patterns are emerged, and the capital channel is broadened. A pattern of diversification in investment subjects appears preliminarily.

At present, there are five main subjects in investment and operation of electric power industry:

(1) Five large state-owned power corporations regrouped from former state power system, each of them possesses installed capacity of about 30 GW and assets of dozens of billion Yuan;
(2) China Three Gorges Project Corporation, SDIC Huajing Power Holdings CO., Ltd., and GuoHua Electric Power Corporation, which are still state-owned enterprises;
(3) Local state-owned enterprises, 43 local power investment corporations all over the country possess assets of 175.2 billion Yuan and generation capacity of 55.39 GW, which accounts for 17% of total installed capacity in China;
(4) The projects of total 37 GW invested by foreign merchants directly;
(5) Private capital, for example, one of China private corporations, Chengdu LinFeng Group has purchased 51% stock right of Sichuan Jialing Electric Power Co., Ltd. whose investment was 3 billion Yuan.

2.3.3 The capital scale

Depending on type of electrical sources, the structures of investment would differ slightly. The source of investment fund in hydroelectric projects has three characteristics: (1) Loans from commercial banks and development banks are still the main capital source, but the proportion of the former falls to 24.8% and the latter has become the uppermost capital source, up to 26.8%, and the summation of both accounts for more than a half of the total investment; (2) the hydroelectric corporations have abundant own funds, and their investment accounts for more than 20%; (3) the foreign capital utilized in hydroelectric investment is very small, only 3.15%, obviously because of long cycle of hydroelectric investment and relatively long period of payback.

In the capital structure of thermal power investment, loans from commercial banks are is the main source, accounting for 35% of total thermal power investment, far higher than other sources. In addition, foreign capital, loans from development banks, and corporations own capitals are important sources of thermal power investment too, and the proportions of these three sources are 19.75%, 17.16%, and 12.68% respectively. The summation of the four investments above accounts for about 85% of total thermal power investment.

Unlike the investment in hydroelectricity and thermal power, the foreign capital dominates in nuclear power investment absolutely, up to 54.87%, because large nuclear power equipment and key technologies need to be imported from other countries and the import credit loan and other foreign capital are obtained at the same time.

As for the investment in power grid engineering, more than a half of it comes from bank loans (including loans from commercial banks and development banks), while the foreign capital and corporations own funds are relatively less. However, Three Gorges Project Fund contributes 7.28% for building the transmission engineering of Three Gorges Project.

2.3.4 The Return and Risk

2.3.4.1 The Return

The first characteristic of electric power industry is intensive capital, For example, the comprehensive cost of hydroelectric or thermal power generator set is up to 6000~7000 Yuan/kW, and if to build a conventional hydropower plant or thermal power plant of 100 MW, it commonly needs total investment of several hundred million Yuan; the second characteristic is relative long construction cycle, for instance, for 2 thermal power generator sets of 300~600 MW, it needs 2-3 years from starting building to putting into production, while the time limit for a large or medium-scale hydroelectric project is 4~8 years.

But of the return on capital, in comparison with other industries, it is relatively stable in electric power industry, and its rate could be up to about 10%~12%. Investing in electric power industry can gain profit stably as long as following national technology and equipment policy of developing electric power industry and affirming with sufficient market survey (actual electric power demand in investment region) in advance that there has enough market space to develop. At present, the electric power market in China is still in growing stage, and the power supply is not superfluous but insufficient in consideration of medium or long-term demand. Therefore, the investment risk in electric power industry is much smaller than in other industries whose market varies greatly.

On main financial indices, the asset-liability ratios for these three electricity generation modes are basically the same. On indices such as break-even cost rate and profit rate for output value, hydroelectricity and nuclear power has average profit level higher than that of entire electric power industry. Especially for nuclear power, its profit rate for output value is retained at over 30%, much higher than 9% for thermal power and 10% for entire industry. Both coal steam and wind power plants are of short-term investment projects. Despite of heavy preparatory work, large investment and long construction term, the market risks of hydropower and nuclear power are smaller and their financial returns are generally quite optimistic.

2.3.4.2 The Risk

With reform of general adoption of the market principle in electric power industry, the power corporations have to face various market risks and the investors should make out reply strategy to evade risks:

(1) The risk of electricity supply--forecast properly the electric power demand in the regions where the plant is planned to build;

(2) The risk of financing--ensure reasonable structure of financing;

(3)The risk of technology and equipment--optimize equipment selection and purchase;

(4) The risk of construction and operation--manage them very well.

Brief summary

- China energy resource structure dominated by coal determines that most of electricity power is produced by coal-fired plants for years. At present, hydropower generates more than 25% of electric power of China. The proportion of nuclear and renewable energy resource for power generation is very small.
- It is the strategy of energy development in China to establish multi-outlet energy resources structure. The proportion of coal steam electricity will fall gradually, but it will still dominate in the structure of electricity power. And the proportion of hydropower and renewable energy power will increase. China plans to reduce the proportion of coal steam electricity to less than 50% in 2050.
- Of renewable energy power, electricity production from biomass and wind is primary development directions in a long period for the future.
- The difference of electricity prices between each regional or provincial power grids in China is relatively large, and the same between coal and renewable energy electricity. The main influence factors on electricity price are fuel price, network construction and management cost, electricity transmission cost, etc. Present renewable energy power cost is higher than coal electricity, so state policy is necessary to support renewable energy development to realize national energy plan.
- The electric industry of China is administrated by the state, with the characteristics of high capital intensity and high admittance conditions. So presently the main investors are still large national enterprises.

3. Strategic significance of biomass power generation

3.1 Facing challenge in Chinese electricity production

3.1.1 Rapid increasing in electricity demand, high pressure in supply

With the development of economy and society of China, electricity demand from living and production is rapidly increased year by year. As shown in Fig. 3-1, though electricity supply has been increasing with years, it cannot keep up with the increase of demand. There sometimes have the phenomena of controlling the electricity consumption by switching off in China. Twenty-two provinces have to control the electricity consumption with this way in 2003, 10 provinces more than previous year. Some regions not only lack electric power, but also begin to be short of installed capacity. It is predicted that the supply and demand balance in electricity can be attained in 2006. However, the long-term phenomenon of lack of electricity will exist in jumping-off region. As 1999 white book of new energy and renewable energy in China, there are 76.56 million populations with no electricity, 16 counties, 828 townships and 29783 villages where no electricity is available. Because these spots locate in remote areas, being far from the grid, having small demand for electricity and dispersed, it is impossible by extending the grid to supply electricity for them.

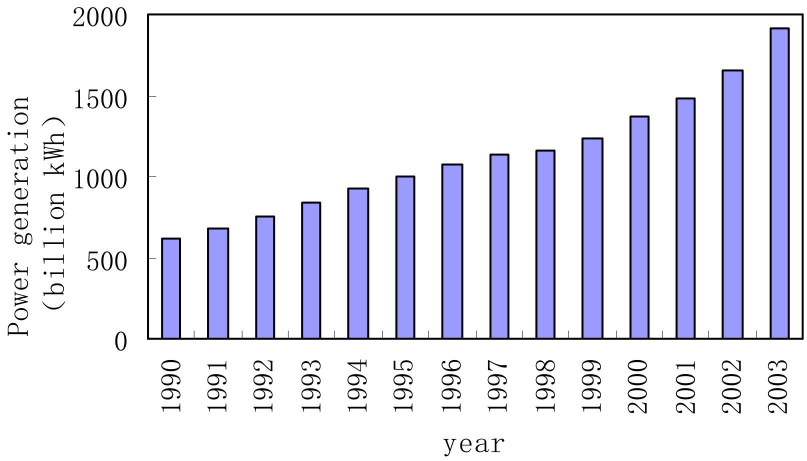


Fig.3-1 Electricity generation in recent years in China

Sources: *Electricity Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 2004.

3.1.2 Proportion of electricity from coal is kept on high level, and pollution is serious

The characteristics of energy resource, i.e. abundant in coal deposit, lack of oil and scarce natural gas, determine the electricity supply structure in China, in which coal has large proportion. By the end of 2000, the electricity installed capacity reach 319 million kW, including hydroelectric power of 79.3 million kW, accounting for 24.9%; coal power of 237.5 million kW, 72.8%; oil and gas power of 5.12 million kW, 1.6%; nuclear electric power of 2.1 million kW, 0.7%; renewable electric power, such as wind, solar electric power accounts for 0.1%only. The amount of electric power generated with fossil fuel is as high as 81% of total amount.

The coal-dominated energy structure results in so-called soot-type of atmospheric pollution in China. According to statistics, 90 percent of sulfur dioxide and 70 percent of soot in emission comes from coal combustion, and the emission of sulfur dioxide higher than the limit specified in related regulations occurs in over a half of northern cities and 1/3 southern cities, and about 1/3 land of China suffers from acid rain. In 1998, the emission of sulfur dioxide from the industrial section was 20 million tons, in which the emission from fire power plants beyond 6000 kW level was up to 7 million tons, accounting for 33 percent of total emission from industrial section, with a great amount of ash and sediment and waste water as well. Therefore, the emission of contaminants during the use of coal has become the fatal pollution source to environmental quality in China, and the reduction of the proportion of fire power in power structure will be related to the restoration and improvement of the ecology and environment in China.

3.1.3 Distribution disproportion of primary energy resource, long distance transmission of electric power

China is one of a few countries that depend heavily on coal as main energy. Coal plays important role in the development of economy and society. But the distribution of coal resource in China is concentrated. In northwest areas coal resource is abundant. However it is scarce in developed coastal southeast regions. In regions north to Dabie Mountain- Qinling Mountain-Kunlun Mountain, the coal resource amounts to 2.45 trillion tons, accounting for 94% of total coal resource in China, and in regions south to this mountain line, their coal resource only accounts for 6%. In four provinces, namely Xinjiang, Inner Mongolia, Shanxi and Shaanxi, their coal resource accounts for 81.3% of total in China; in three provinces of Northeastern China, the corporation is 1.6%; in seven provinces of Eastern China is 2.8%; and in nine provinces south of Yangtze is 1.6%.

Fig. 3-2 shows the distribution of grid net in China. And Fig. 3-3 shows coal resource proportion of coal resource to total reserves of China in several representative grid net covering areas, and proportion of regional power output to the total output in China. As shown in the Fig., the areas with abundant coal don’t accord with ones with great demand for power supply. The disagreement between energy resource and energy demand induces the measures, such as “transporting coal from north to south” and “transmitting power from west to east”, to ensure electricity energy supply. As result, large scale DC power grid interconnection was established between Eastern China and Central China, AC interconnection -- between Northeastern China and Northern China. Long-distance transmission of electricity between provinces and regions has to be built up. At the same time, security problems of power grid become serious, and the transmission loss of power becomes a indispensable problem.

Long-distance transportation of coal for electricity is one of main loads for railway transportation. At peak of electricity consumption in summer, transporting coal to ensure power supply becomes the bottleneck of railway transportation, using large proportion of the railway transportation capacity. This summer, because railway transportation capacity cannot cope with the demand for coal transportation, some regions have to adopt high-cost vehicle transportation. The coal storage in some plants fell beyond alarm limit.

Fig.3-2 Power Network in China

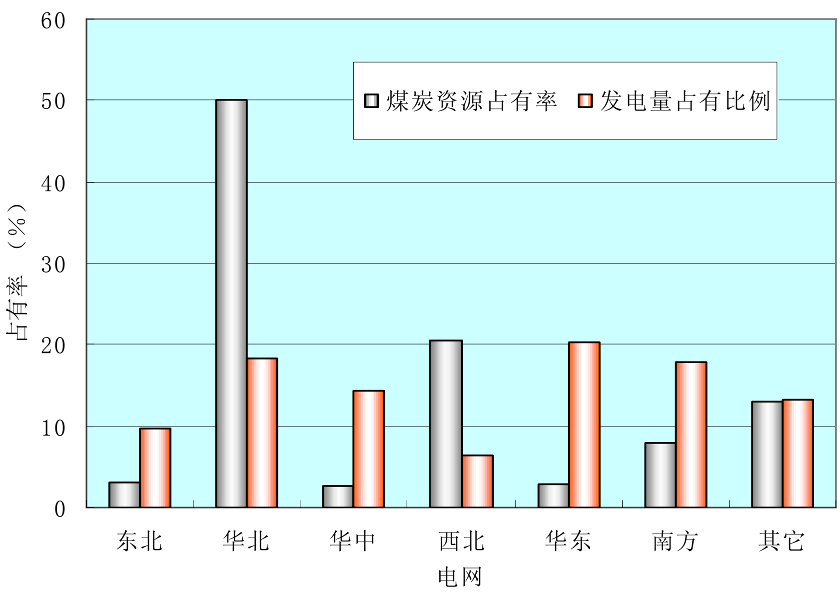


Fig.3-3 Distribution of Coal resource in China

3.1.4 Larger scale, stricter security problems

With the rapid development of economy in China, especially in its inshore and inland areas, the demand for electricity will be greater and greater. The pattern-“transmitting power from west to east”, “south-north cooperation”, and “interconnection all over the country”-devote itself to achieve optimizing configuration of resource in broad range of all over the country, and to meet the demand for electricity. Main projects include: power transmission and transformation system in the Three Gorges, 100,00MW transmission project from west to Guangdong, large capacity hydroelectricity in Southwestern China and upper-middle reaches of the Yellow River and large capacity power generation unit near pithead, transmitting power from west to east under construction. By the end of 2000, the total transmission length reached to 72617km, transforming capacity was 99612MVA. With development in interconnection of power networks, however, the hazard to stability and power cut accident in extensive areas will become greater, security and stability problems in big power network will be stricter. The characteristics- power industry's public and synchronization of power system-induce that the impact of power network accidents will be greater, higher speed, and more serious aftermath. Besides great economic loss to the power plants, the accidents also bring tremendous impact on politics and economy. 220KV power network are being improved and extended.

In view of the problems existing in big power networks and under the joint effect of progress in power generation technology, policy of public environment, enlargement of power market and other factors, it is the small scale distributing power generation system being close to user's spot that will be one of important selections of energy in the future.

3.2 Object of development of renewable energy power in China

For sustainable development of economy in China, installed capacity of power generation will be added, and electricity generation will be enlarged. But in 2002, installed capacity already has been 357 GW, electricity generation 1652 TWh, including hydroelectricity of 16.60%, nuclear electric power of 1.02%, and fossil-fuel electricity of 81.74%. It is predicted that anticipated installed capacity in 2020 will be 1000 GW, annual electricity generation 4600 TWh. On the basis of the electric power structure and SCE (standard coal equivalent) consumption for power supply-383gce/kWh in 2002, it is estimated that coal consumption for power generation is nearly 1.4 billion tce in 2020, and will greatly threaten coal supply in China. On the other hand, as an indispensable restriction, it is the substantive emission of greenhouse gases and heavy pollution resulted from the consumption of fossil fuel. Now, CO_2 emission in China ranked second in the world, while USA is the first. We will confront with the pressure from international society. For the sustainable development of energy in China, China Government has established sustainable development strategies of energy, namely priority to energy saving, ensurence to supply, Structure optimization, and friendly to environment. Actively promoting development of renewable energy is one of important policies.

Furthermore, for undeveloped rural areas in China, especially remote mountainous areas and pasturing areas, it will take huge investment and long time to establish powerful central network of electricity supply and distribution with certain scale. The local economic development is greatly restricted by the supply of energy. We can fully make use of local renewable energy to generate power, such as biomass energy, wind energy and so on. It will greatly promote modernization in China's rural areas, and successfully accomplish the goal of building a well-off society.

It is anticipated that new energy and renewable energy consumption (not including traditional biomass) in China by 2020 will reach to 300 Mtce, about 10% of primary energy supply. And the installed capacity of renewable energy will amount to 120 GW, accounts for 12% of total installed capacity all over the country, of which small hydroelectricity of 80 GW, wind electricity of above 20 GW, biomass electricity of 20 GW, and solar electricity of 1 GW. At that time, its contribution to total electricity generation will reach to 6%. Compared with developed countries, such as European Union, Japan and so on, this proportion is small. But it should be considered that we leave behind the top lever in the world now, moreover on the basis of the same proportion, the actual installed capacity would be large. It is an arduous and compulsory strategic task to develop renewable energy power generation technology actively and increase the proportion of renewable energy power generation in total electricity generation.

3.3 The significance of biomass power generation

3.3.1 Abundant resources, huge potential for development

There is abundant biomass resource in China, and great potential can be explored for development by 2050, the price of biomass energy will be equal to or lower than the price of fossil fuel in the world. So it can provide the whole world with 60% of electric power and 40% of the fuel, and the emission of CO_2 will cut down by 5.4 billion tons (now the annual emission from fossil-fuel all over the world is 6 billion tons of CO_2).

Beside traditional agriculture on existing arable land, woodland and grassplot, there are about 100 million hm^2 of forest and land that can be used to develop energy agriculture and energy woods. So in next 30 years, for the development of energy agriculture and energy woods, the potential of biomass resource in China will be great. The available biomass resource is at least 1.5 billion tce, of which 30% comes from traditional agriculture and 70% is from energy agriculture and woods. For instance, planting of 20 million hm^2 of energy woods can produce biomass resource 1 billion tons annual (equivalent to 500 Mtce). In addition, combined with West China development, desert management, conceding the land to forestry and the construction of “three-north protecting forest”, at least 20 million hm^2 of energy woods can be planted, so 400 million tons biomass resource can be produced. To energy agriculture, high-energy species, such as sugarcane, sorgo, cassava, and vetiver, will be developed. With the methods of gene modification, species of energy crops with very high photosynthetic efficiency. For instance, energy sugar cane can have the yield of 55 tons per hm^2, 10 tons seeds and 100 tons stalks can be harvested in the sorgo. If 2000 hm^2 of energy crops are planted, available biomass resource would be 600 million tons (equivalent to 300 Mtce). Therefore, in the next 30 years, at least 2 billion tons biomass resource can be developed; it is equivalent to 1 billion tce.

3.3.2 Suitable for developing distributed power system and close to end-user

In comparison with fossil fuel such as coal, oil, and natural gas, biomass resource is distributing, which determines distributed utilization of biomass energy. Just because of this characteristic, in the areas where biomass resource is relatively concentrated, the type of biomass power generation technology could be selected reasonably according to resource amount and corresponding scale of biomass power plant could be set up, and the electric power generated by the plant could be provided to nearby consumers directly or merged into power gird. This kind of distributed electric power system has many advantages such as feasible technology, less investment, close to end-user, free of the effect of power grid, direct power supply, and convenient and reliable operation. Since there is a great gap in the electric power supply in China, so it has a broad market prospect to utilize biomass energy resource according to local conditions and build off-grid or on-grid disperse and independent distributed biomass power plant. If 40 percent of current agricultural and forestry offal is used as power plant fuel, then 300 GWh electric power could be generated, which accounts for more than 20% of present total electric power consumption in China.

3.3.3 Improve ecological environment, develop agricultural production and rural economy

Biomass energy is a clean energy, which is helpful for environmental construction and CO_2 emission reduction. The content of deleterious substance in biomass such as sulfur and ash is only 1/10 of those in medium quality soft coal. In addition, the emission and absorption of CO_2 by biomass make up of carbon cycle in nature, so the utilization of biomass could realize zero emission of CO_2. Expanding the utilization of biomass energy is the most important approach to reduce CO_2 emission. The practice has proved that the function of reducing CO_2 emission by biomass energy is quite significant. Therefore, biomass energy resource is a kind of highly clean energy technology, and is a scientific selection for reducing greenhouse gases emission and preventing global environment from deterioration.

Through introducing biomass power generation technology, biomass energy could be transformed into high-grade electric energy to satisfy rural urgent electric power demand and to improve the inhabitation environment and living standard of peasants. Moreover, the thermal efficiency could be improved to 35~40%, which saves resource. On the other hand, utilization of biomass power generation technology could solve the “stalk problem” thoroughly which exists generally in China country and could not be solved completely. In recent years, with the development of rural economy and the improvement of peasants’ living standard, a great amount of crop stalks are abandoned in the field and burned on the spot, which causes serious smoke gas pollution and threatens the transportation safety seriously. Biomass power generation technology could transform agricultural and forestry offal into electric power and form industrialized utilization to consume a great deal of stalks and eliminate their harms finally.

Energy utilization of biomass could bring a series of ecological, social, and economic benefit. The development of biomass power generation technology could not only solve electric power shortage in countryside, but also drive development of energy agriculture and forestry in large scale, which could afforest barren hills and fields efficiently, alleviate soil erosion and water losses, control desert, protect biological diversity, promote favorable ecological cycle, accelerate the development of modern plantation industry, become new rural economic growth point, increase employment opportunity in countryside, improve living environment, increase income of rural inhabitant, and develop rural economy.

3.3.4 The direct effect of biomass power generation

Biomass power generation is a new technology that uses offal of agriculture and wood industry, municipal living waste or biogas to generate electricity through combustion or gasification. It has already been emphasized widely in China and the main technique is biomass power generation by direct combustion or gasification.

There are many kinds of boilers of firewood (wood crumb), bagasse or paddy chaff developed by Chinese boiler manufacturers and used for power generation or heat supply with biomass combustion. The 1500 kW power plant of paddy chaff combustion, which was built by a rice mill of Chenglingji Grain Depot in Yueyang, Hunan province in 1990s, can generate electricity of 7.20 million kWh annually, and as a result, the electricity fee of 0.72 million Yuan and 4320 tce can be saved and additional profit of 0.6 million Yuan can be obtained annually. The Shengrong Rice Refining Factory in Shucheng county, Anhui province, which could refine rice 2010 tons and cost electricity fee of 98000 Yuan at past annually, produced more than 800 tons of paddy chaff without utilizing, which became serious pollution source. However, after the factory generated electricity by combustion of paddy chaff, 80 kWh of electricity could be generated per hour, which could support 50 kW processing machines as well as living electricity for 100 families. A double 12 MW power plant of and a 25 MW heat and power plant of straw combustion will be built in Jinzhou city, Shijiazhuang, Hebei province and Shanxian county, Heze city, Shandong province respectively, and the former project, which is planned to put into production in October 2005, will introduce straw power generation technology of BWE corporation, Denmark and could generate electricity 120 GWh and burn straw more than 0.2 million tons annually.

The research of biomass gasification power generation technology in China began in 1960s, and its representative equipment was the 60-kW power generation equipment by chaff gasifying. The technology experiences a rapid development in recent years and medium-scale biomass gasification power generation technology of MW level has been developed successfully. The first power generation equipment of paddy chaff gasification with capacity of 160 kW was operated successfully in Bazhe Rice Mill, Suzhou city, Jiangsu province in 1981. This type of equipment has been commercialized gradually subsequently, and mainly of two specifications of 160 and 200 kW, and more than 300 sets have been made until the end of 1998. The main furnace type of these equipments is fixed-bed gasification furnace (layer down inhale type), and cycled fluidized-bed gasification equipment with high production intensity and gasification efficiency was devised along with the rice mills centralized and being large-scale. The first 1MW power generation equipment of cycled fluidized-bed gasification of paddy chaff, which was developed and set up by Guangzhou Institute of Energy Conversion, was operated in the rice mill of Huagang Corporation in Putian, Fujian province in 1998. In 1999, 0.4 MW and 1.2 MW power generation equipments of cycled fluidized-bed gasification of wood powder were put into service in Burma and Sanya, Hainan province respectively, and nice social and economic benefit has been obtained already.

The power generation by waste and biogas combustion in China began in 1980s, and great improvement in technology and application has been obtained for curent years, which begins to progress gradually from depending on import to researching and developing independently. For example, the integrated disposal factory of Shenzhen Municipal Environment and Health built the first city waste power plant of China by introducing waste combustion technology of MITSUBISHI Corporation of Japan. The plant had installed steam power generators of 6000 kW successively, and 85 percent of the facilities of the third furnace were made in China. In addition, city waste combustion power plants have been built in Zhuhai, Ningbo etc. The biogas power generation technology is mostly applied in three aspects: domestic birds and animal plants, disposal plants of industrial wastewater, and waste filling plants. Not long ago, a 50 kW ‘biogas-diesel’ double-fuel generator set, installed by Tianpeng Stock Raising Co. Ltd. of Jiangshan city, Zhejiang province, generated electricity successfully using biogas. Changle Alcohol Factory of Shandong province installed two 120 kW biogas generator sets, which could generate electricity of 8640 kWh daily using 4800 m^3 biogas produced by 170 m^3 lees, and the biogas electricity could meet all the producing consumption of the factory basically. The first biogas power plant of waste filling field in Taohuashan of Wuxi developed and built by China independently began to generate electricity in August 2004, and its annual production of electricity is up to 15.30 GWh. The project of biogas electricity generation of Xingfeng waste filling field in Guangzhou city was operated successfully in August 2004 too. It could generate electricity more than 50 MWh daily, and its maximum annual production of electricity will reach 167 GWh of which about 75 percent sold on grid besides satisfying the consumption itself.

Utilizing biomass resource to generate electricity by combusting or gasifying resolves both the environmental pollution of offal and the electrical problem of the corporations themselves as energy resources. Therefore, biomass power generation has become an important way of the industrialized application of biomass energy.

Brief summary

- Power production and supply situation in China is very severe: power supply cannot keep up with rapid increase of power demand; power structure is unreasonable, and production process results in serious pollution; electrical source distribution is not seasoned with economic development, and electricity transmission cost is high; large power network hides safety trouble.

- There are abundant biomass resources in China, which possess great energy potential. Energy production from biomass has strategic significance in resolving some problems of electricity supply and environment to some extent.
- Biomass power generation has the following characteristics: suitable for developing distributed power system and close to end-user; improve ecological environment, and develop agricultural production and rural economy.

4. The characteristics of biomass resources of China

Since biomass is treated as non-commercial energy, China has not kept official records regarding its biomass resources, characteristics or geographical distribution. However, there still is adequate information from various sources (e.g., Statistical Yearbook of China, China Forestry Yearbook, Ministry of Agriculture, Ministry of Industry, State Forest Administration and China's Association of Rural Energy Industry) to estimate the biomass resources.

4.1 The structure and energy potential of biomass resources in China

There are various types of biomass in China. They come mainly from crop residues, firewood, forestry residues and organic refuses, such as animal dung and municipal solid wastes. Also, industrial wastes from rice mills, paper mills, timber mills, sugar and beer and food production can be used for energy. They contain a great amount of energy. It is estimated that a total amount of over 487 million tons of oil equivalent (toe) from biomass is available annually for energy use in China, of which about 370 million toe or 76% could be utilized for electricity and heat production and the remaining (approximately 117 million toe) could be used for agricultural applications (e.g. animal waste for fertilizer) in rural areas.

4.1.1 Crop Residues

China is a big agricultural country. A significant percentage of biomass comes from agricultural crops such as rice, wheat, corn, beans, tubers, cotton and sugarcane. In 2001, for instance, residues from these crops were about 715 million tons having energy equivalent of 250 million toe. Fig. 4-1 shows the breakdown of the energy available from crop residues. Rice, wheat and corn are three major grain products in China, biomass from their residues account for a high percentage, i.e. 70% of total agricultural residue.

However, sufficient utilization of these crop residues as energy source has not been realized. In 1998, about 10% of them were used as feed, 20% for industrial materials, 52% as rural daily energy through direct combustion with low efficiency, and the remaining 18% were discarded or incinerated in the field.

4.1.2 Forestry Residues

Forestry residues constitute another very important biomass source. China's most important forest regions are in northeast, southwest, northwest and southern undulating terrain. According to the 5th national forest resource survey (1994~1998) finished in 2000, the timber reserve was 12.49 billion m^3, increasing by 4% than previous survey. Wood consumption in China is classified under three general categories: a) commercial wood, which is 44.2% of the total amount consumed and sold mainly in the wood market; b) 32.1% used mainly by wood producers and farmers; and c) the remainder for direct burning in households. Firewood and forestry residues in 1998 were estimated to be 157million tons (67 million toe), but actual consumption should be higher due to overcutting.

At present, there is no energy crops industry in China. Based on national statistics, there were 1.3 million km^2 of cultivated lands and 1.08 million km^2 of undeveloped land, the latter containing 0.354 million km^2 of useable land. If the 0.354 million km^2 land is used for developing energy crops, 177 million tons of biomass could be potentially produced annually, that is about 80 million toe.

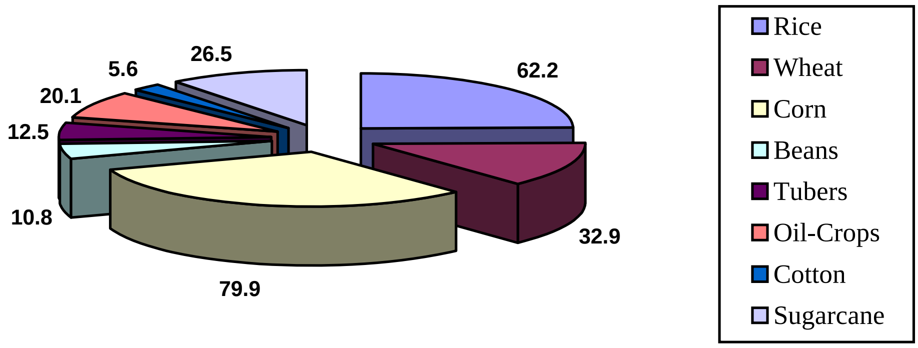


Fig. 4-1 Production of different crop residues in 2001 (million toe)

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, Interscience Publishers; and calculation results based on *Statistical Yearbook of China,* the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

4.1.3 Animal Dung

In 2000, farm livestock in China was comprised of: 151.5 million large animals such as horses, cattle, donkeys, mules and camels; 447 million hogs; 290 million sheep and goats; and 5.28 billion poultry. Biomass resources in the form of animal dung reached 320 million tons in dry weight having energy equivalent of 110 million toe. Fig. 4-2 shows that dung is growing constantly.

Besides a little amount being burned directly on farms, most animal dung has been utilized as material for biogas, a clean energy product supplying fuel, electricity and heat. But the comprehensive utilization rate of biogas is low at present, since only 700 of the 17000 medium and large animal production farms, have been commercially developed.

4.1.4 Municipal Solid Wastes

Municipal Solid Waste (MSW) is the compound of daily refuses from citizens, commercial, service and small amount of waste from construction activities. Its composition and amount depend on various factors, such as population, resident income, fuel structure, food preferences, urban construction and seasonal influence, etc. There is very considerable variation in composition of MSW, especially the percentage of organic material, from city to city. In general, the more developed a city, the more organic wastes in its MSW; also, cities in the south have more organic materials than those in the north. Hence, their heating value varies significantly from city to city. Developed cities of Beijing, Guangzhou, Shanghai and Shenzhen, etc. have a heating value over 4500 kJ/kg, others around 3400kJ/kg. The annual MSW yield in China has reached 150 million tons (15 million toe), which continues to increase at approximate rate of 10% per year.

Thought landfill treats most of the MSW disposal in China, with relevant environmental protection standards becoming stricter, land-saving development and the much attractive social and economic benefit of MSW energy utilization, new technologies such as electricity generation from MSW have been emphasized.

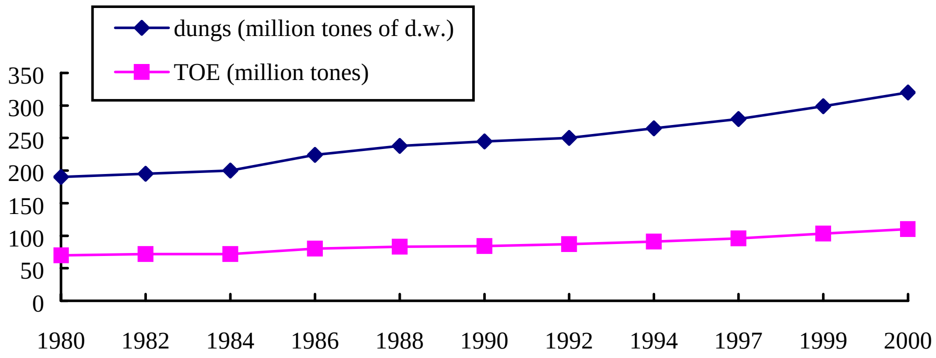


Fig. 4-2 Increasing trend of biomass energy from animal dung

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, Interscience Publishers; and calculation results based on *Statistical Yearbook of China*, the National Bureau of Statistics of China, China Statistical Publishing House, 2002.

4.1.5 Industrial Wastes

Industrial biomass resources include solid waste from industrial processes, such as production in grain, paper, timber, distillery, sugar and food industry. It is estimated that the total annual yield of biomass residues from these industries may have energy equivalent up to 48 million toe.

Crop Husks:

Crop husks come from grain processing, such as rice and wheat, and could be up to 30% of the weight of crops. About 81 million tons of husks is produced annually, of which 30% are used as fuel, fermenting ethanol and feed. So, there are still 55 million tons having energy equivalence of 18 million toe.

Wastes from Paper Mills:

The paper industry in China expanded rapidly from a total capacity of 13.72 million tons in 1990 to 28.12 million tons in 1995 and declined to 24.87 million tons by 2000. There are about 10,000 paper mills, most of which are small. About 70% of the pulp and paper produce comes from agricultural materials such as rice and wheat residues, reed, sugarcane discard and so on. Only about 30% comes from wood.

It has been estimated that there are about 3.20 million tons of biomass or about 1.1 million toe that can be produced from the paper mill industry. Of this amount of biomass, about 1.03 million tons come from wood pulp production having energy equivalent of 0.3 million toe.

Wood Wastes from Timber Mills:

A large amount of leftover material and wood powder occur during timber processing. In 1999, wood wastes from timber mills reached 37 million m^3, that is about 6 million toe. Annual wood demand of China is estimated to be over 300 million m^3, of which only half can be supplied domestically and the remaining has to be imported. The wood demand is to increase continuously.

4.1.6 Composition of Biomass

The total biomass energy potential is about 487 million toe per year, the breakdown of which is shown in Fig. 4-3 below. It can be seen that crop residues comprise half of all residues, followed by animal dung, then firewood, industrial wastes and municipal solid wastes.

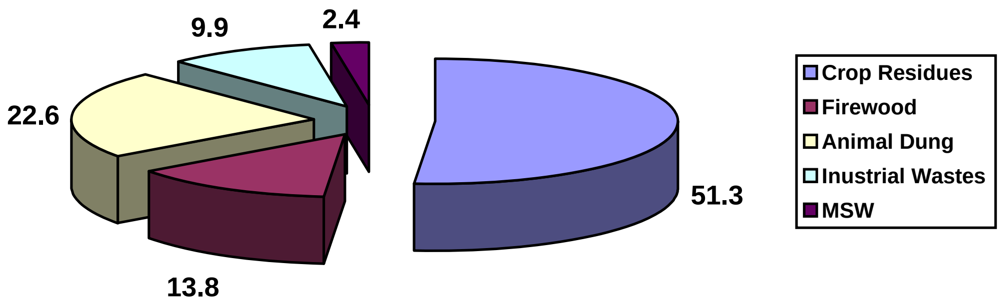


Fig. 4-3 Composition of biomass resource in China (%)
(487 million toe)

Source: Calculation based on related information

4.2 The distribution of the biomass resources in China

The abundant biomass resources in China feature in dispersive distribution, presenting obvious regional characteristics. Additionally, the production of crop residues, the primary biomass resources in China accounting for over 50%, is greatly influenced by agricultural production and seasonal activities.

4.2.1 Brief on Distribution of various biomass resources

Fig. 4-4 shows the biomass distribution of crop residues, firewood and animal dung resources in various areas of China.

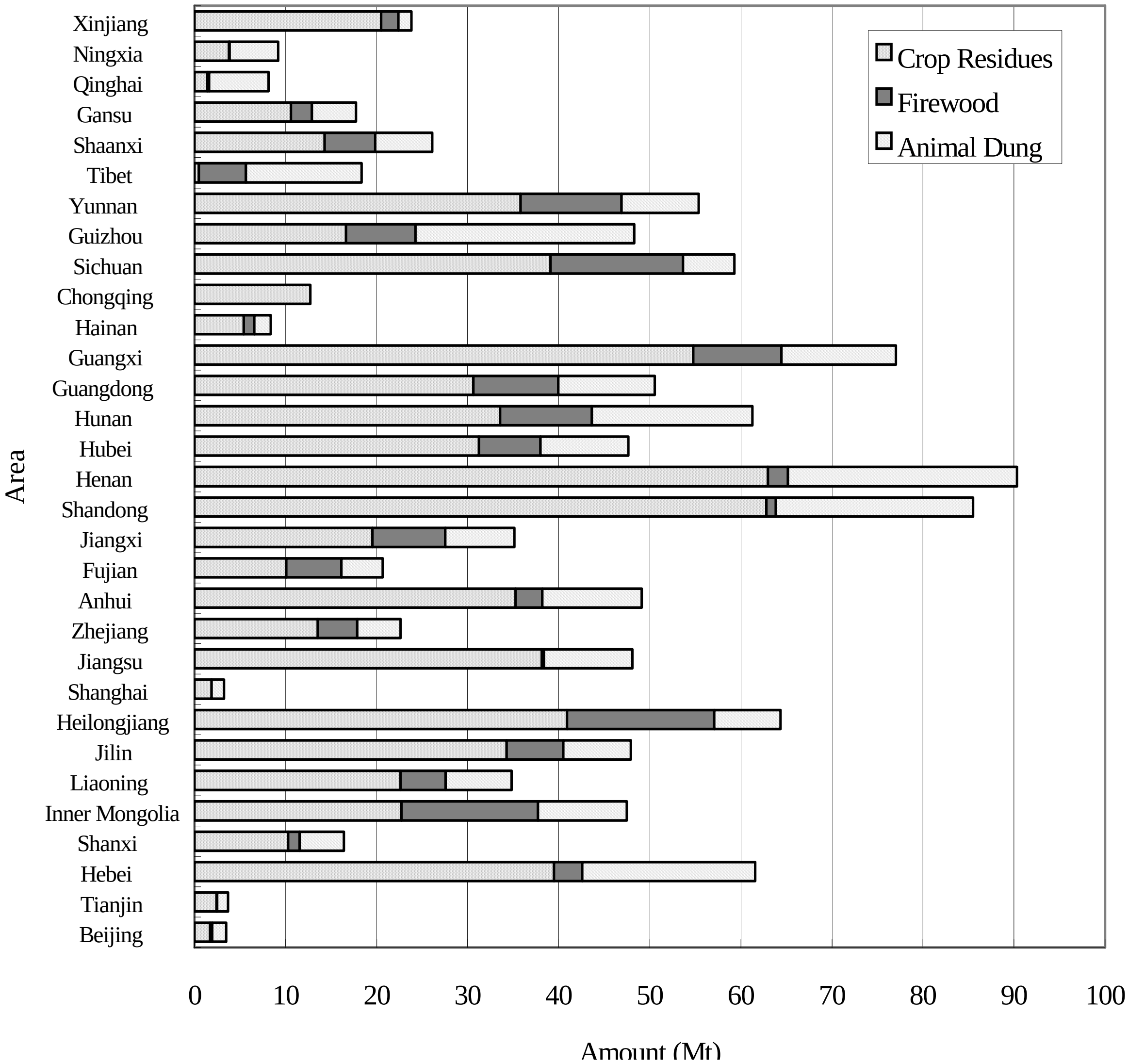


Fig. 4-4 Distribution of crop residues, firewood and animal dung resources

Source: Calculation based on related information.（Note: Figures of crop residues and animal dung are based on the statistics in 2001. Figures of firewood are based on the statistics in 1998. No latest figures were available.）

Crop residues in Shandong, Henan and Guangxi provinces are of higher output with productions of 63 milltion tons, 62 million tons and 55 million tons respectively, including 22 million tons of bagasse in output of Guangxi. Firewood resources are richest in the Northeastern areas, especially in Heilongjiang, Inner Mongolia, Jilin and Liaoning provinces, in approximate 43million tons. The next is Southwestern areas with output of 36 million tons and the Southern area of China with output of 33 million tons. As for animal dung, it comes mainly from agricultural provinces, such as Hebei, Henan, Guizhou, Hunan and Shandong, each having an annual output of over

17 million tons, and it is around 10million tons for each other provinces. In 2001, the total dung output in China reached 280 million tons.

As described above, crop residues account for over half of the whole biomass energy of China. Rice, wheat, and corn are the three main crops of China. They produce 70% of crop residues in China, indicating important influence on biomass distribution situation. In fig. 4-5, the three crops' residues were calculated based on their crop productions in 2002 and plotted to show the distribution situation, together with the production of wood (including firewood). Rice straw mainly is distributed in the regions along Changjiang River and of its south, accounting for 77% of the total output, and about 9.6% yield is in the three northeastern provinces. The wheat cultivation area in Hebei, Henan and Shandong provinces in the middle and lower regions of Yellow River accounts for 45% of total cultivation area the country, with about 54% of the output of wheat straw. The corn straw mostly is distributed in the three northeastern provinces and Inner Mongolia as spring sowing regions and Hebei, Henan and Shandong provinces in Yellow River, Huaihe River and Haihe River plains as summer sowing regions, accounting for about 35% and 30% of output respectively. Wood (including firewood) concentrates in east and middle areas.

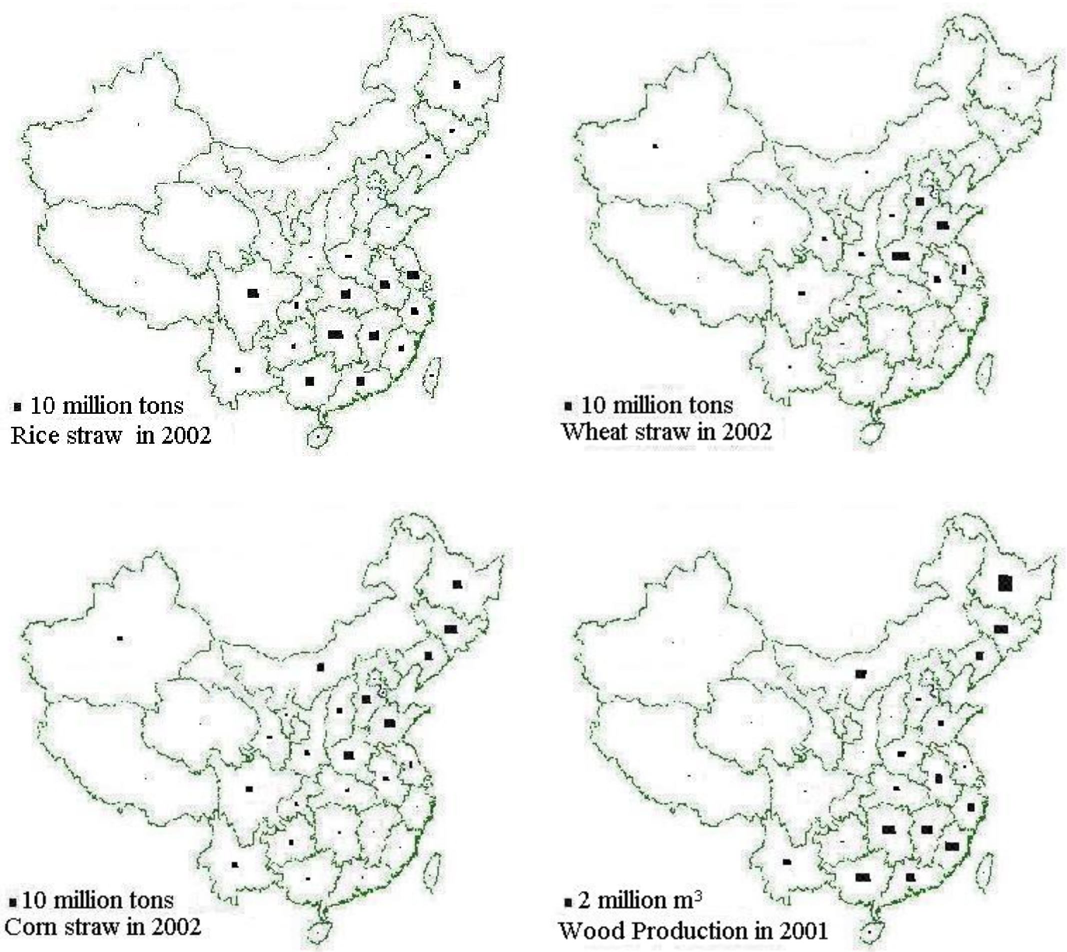


Fig. 4-5 Distribution of primary agricultural and forest biomass in China

Sources: Calculation according to *Rural Statistical Yearbook of China*, 2003 and *Forestry Yearbook of China*, 2002.

The output of municipal solid wastes (MSW) varies in a wide range, depending on their population and living level. Some representative cities in China have daily output as shown in table 4-1. At present the output per capita in China is about 440kg.

Table 4-1 Daily MSW production of some representative cities

Citiy	MSW（tons/day）	Citiy	MSW（tons/day）
Haerbin	3500	Nanning	800
Beijing	11000	Chengdu	2400
Shanghai	12000	Xi'an	3400
Guangzhou	6000	Wuhan	5000

Sources: Sum-up of data of cities' MSW production.

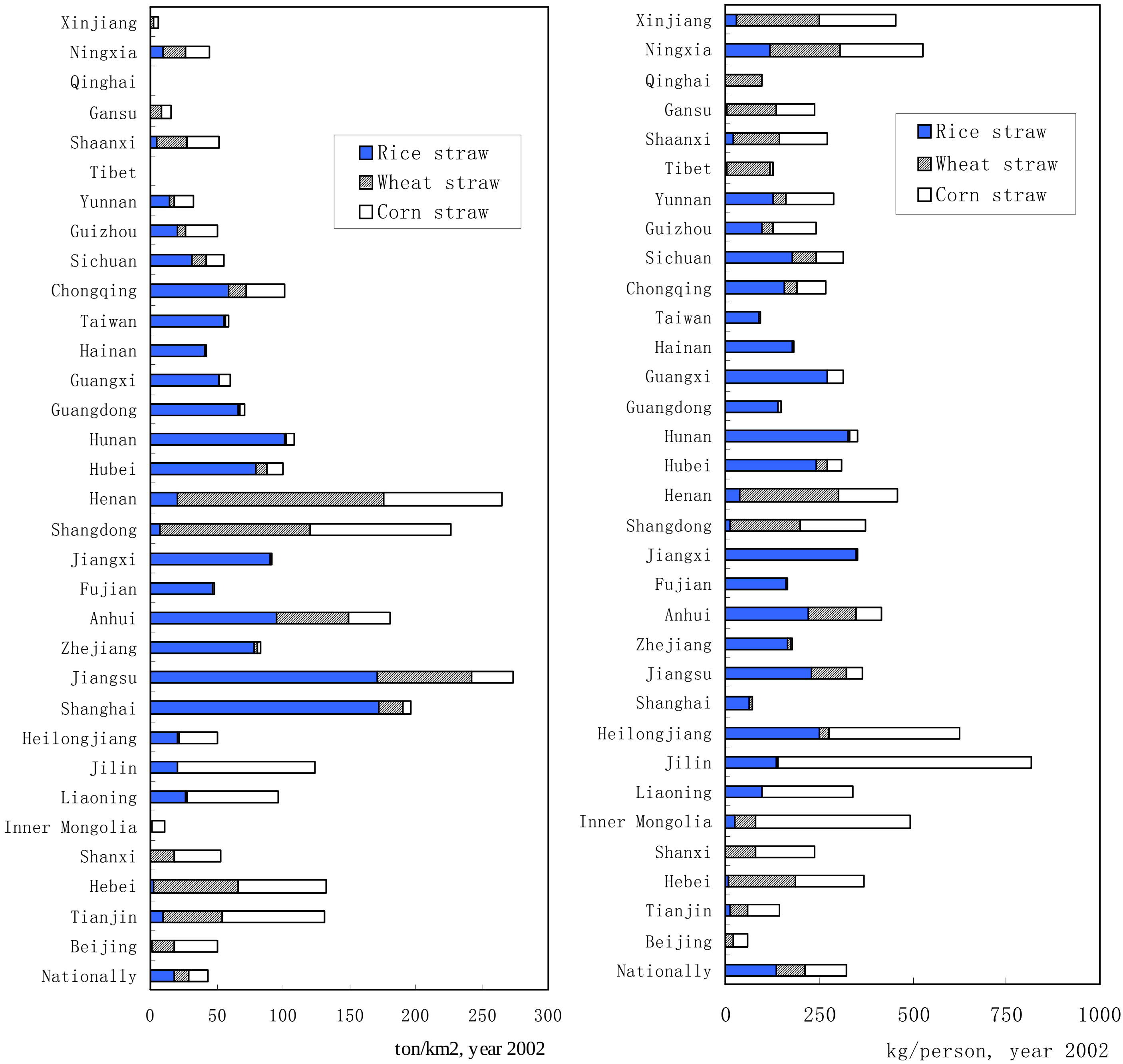


Fig. 4-6 Distribution density of biomass

4.2.2 Distribution density of biomass resources in areas

Biomass distribution densities per area and per person in areas are calculated out based on the distribution of various resources, and illustrated in fig. 4-6. The distribution density depends on local cultivating technology level and cultivated land as well as area and population of the region.

If the theoretical straw output is calculated according to one growth per year, the biomass density in plough of agricultural areas is about 750 ton/km^2. And if according to 1.5 growth per year, it's about 1000 ton/km^2. In fact, the proportion of plough even in areas where agriculture is concentrated very much is not high. For example, if calculated by entire soil area, the topmost biomass density of Henan and Jiangsu is only 280 ton/km^2, while the average density in most areas is about 100 ton/km^2. If considering the collection proportion and waste problem, the density of applicable biomass resource will be much lower.

4.3 The collection and transportation of biomass resources in China

4.3.1 The volume densities of various biomass

The specific gravity of biomass is small while the volume is large. The natural stack density of the material with higher stack density such as wood and cotton straw is between 200 ~ 350 kg/m^3, wood powder is 180 kg/m^3, rice hull is 90 kg/m^3, and natural stack density of crop straw with lower stack density is usually 30 ~ 50 kg/m^3.

4.3.2 Collecting methods for various biomass

At present, most of agricultural residues is discarded or burned in the field without utilizing, and only a small part is crushed to put back to fields, or utilized as feed, living energy for cooking or heating in countryside, or material for paper making and so on. There is no special vehicle to transport straw, and it is drawn away by oxcarts or carriages after simple packing by users, or collected and carried by tractors or boats if the conditions allow.

The city waste is gathered in collection spots set up specially and transported by special obturating condensation vehicles, and the charge is paid by residents.

4.3.3 The requirements for transportation of various biomass

The natural stack density of residues from agriculture and forestry is quite low usually so that it's unreasonable to transport so fleecy light matter with low efficiency and high freight. Therefore, the key to solve the transportation problem is to compress the residues into high-density matter on the spot. For example, in Luquan straw exploitation experiment field of Hebei province, the straw such as corn straw is compressed with high pressure and temperature into block shape with high density of 0.8 ~ 1 t/m^3; the technology and equipment for pressing straw into block exploited and developed by Liaoning Institute of Mechanization of Agriculture and Stock

Raising compresses the straw to 1/6 ~ 1/8 of its original volume and the Water content less than 14%, through which the cost of store and transportation is reduced greatly.

To city waste, it's necessary to avoid secondary pollution along the road during transportation besides reducing volume by compressing.

Because of low stack density, transportation difficulty, and high freight of residues from agriculture and forestry, the cost of their collection and transportation makes up of the main part of biomass price, which increases the operation cost of biomass power generation. If the scope of collection and transportation is too large, the increase of the cost of power generation will induce the price of power generation higher than grid price, thus the biopower will lose its economical advantage and competition power. Therefore, it's necessary to utilize the biomass material on the spot to reduce the cost of collection and transportation.

4.4 The instability of biomass resources of China

4.4.1 Influence of season on various biomass resources

The harvest of crop is the time of production of crop residues. So agricultural season influences the stability of the supply of agricultural biomass resources.

Table 4-2 The sowing and harvest time of crops

Crop		Sowing Month	Harvest Month
Rice	Early	4	7
	Middle	5	7
	Late	6	11
Wheat		10	5
Corn		5	9
Rapeseed		10	5
Cotton		3	11

As table 4-2 shows, the straw is produced mainly in lunar summer and autumn and not supplied continuously all year, so it needs to store adequate biomass fuels for continuous production of biopower in order to reduce or avoid the seasonal influence.

The production of other biomass such as forestry residues, animal dung and municipal solid waste is hardly influenced by seasons, so the supply is relatively stable.

Fig. 4-7 shows the output of straw and the seasonal influence in several typical agricultural counties in China.

4.4.2 The storage characteristics of various biomass

The storage of biomass fuels has very important significance of stability of fuel supply and continuity of biopower generation, so it's necessary to take measures on its storage. The straw collected should be piled up separately based on the degree of dryness or wetness: the dry straw should be piled up and covered by plastic or mud roof to prevent it from exposing under rain or snow and keep clean and dry to avoid mould development and decomposition, in addition, it must satisfy the fireproofing requirement to prevent self-ignition; the damp-dry straw needs to dry entirely and then be piled up for standby. The storage of firewood and forestry residues needs to prevent from exposing under rain and fire too, and the animal dung and municipal solid waste need to prevent their secondary pollution to ambience.

4.4.3 The influence of agricultural production on the supply of biomass resources

The relationship between the production of crop straw and agriculture, mainly the plant production is quite close. In recent years, China enhances the adjustment strength on plant structure in agriculture and many regions increase the planting area of economy and feed crop, which results in the decrease of the total area for foodstuff. According to the statistics of Ministry of Agriculture, in the first year of the new century, the specialized area of high quality winter wheat was more than 5.8 million hectare, 0.8 million more than in previous year; the area of “double-low” rapeseed is 4.67 million hectare, more than 0.67 million hectare increased; but the area and output of rice descend year after year with the rapid extension of high quality rice. As a result, the output of rice and rice hull reduces while that of straw of wheat and rapeseed and wheat hull increases accordingly, which influences the supply amount of various biomass resources.

The seasonal nature of agricultural production is very obvious and the time of triple-autumn is very long. As table 4-2 shows, the fresh materials of straw resource, which is affected remarkably by season, is provided gradually only in second half year, and according to Fig. 4-5, the stable supply of straw depends on transportation and storage because of the regional distribution of various straw resources. So biomass power generation equipment is required to be suitable for various biomass materials, and these biomass resources are complementary to each other.

Table 4-3 Straw production in several typical agriculture areas

Xinghua County, Jiangsu Province

(Million ton)

Item	Yr.2002	Yr.2003
Rice straw	64.1	42.2
Wheat straw	25.7	31.2
Cotton straw	3.3	2.7
Cole straw	0.6	0.7
Total	93.7	76.8

County cultivated land:

1.92million mu

Sources: Calculation according to local statistical yearbooks and consultation.

Jiedong County, Guangdong Province

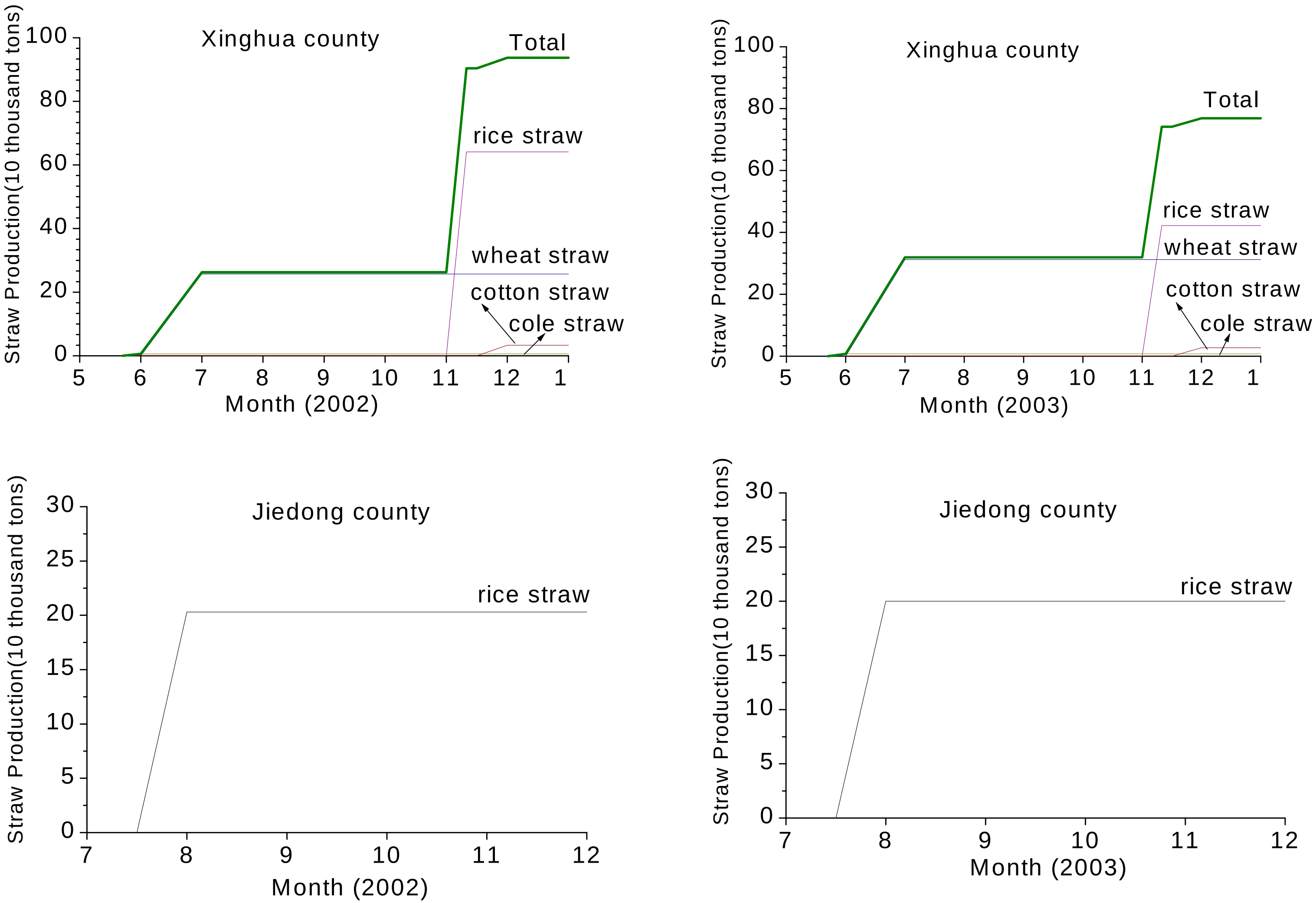
(Million ton)

Item	Yr.2002	Yr.2003
Rice straw	20.3	20.0
Total	20.3	20.0

County cultivated land:

0.57 million mu

Fig. 4-7 Seasonal influence on straw production in several typical agriculture areas



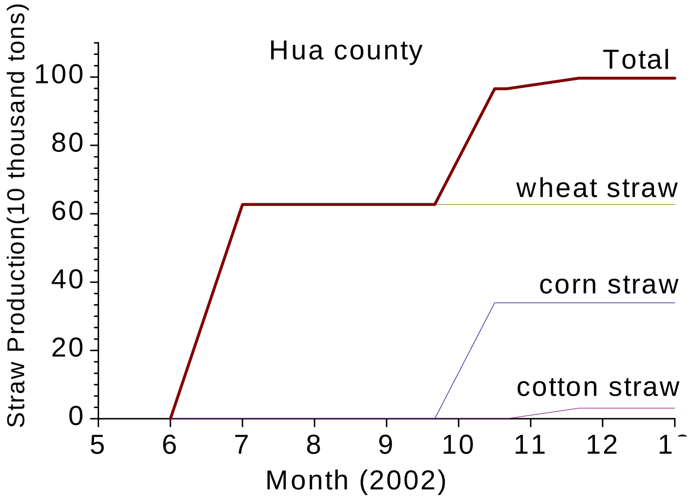
Hua County, Henan Province

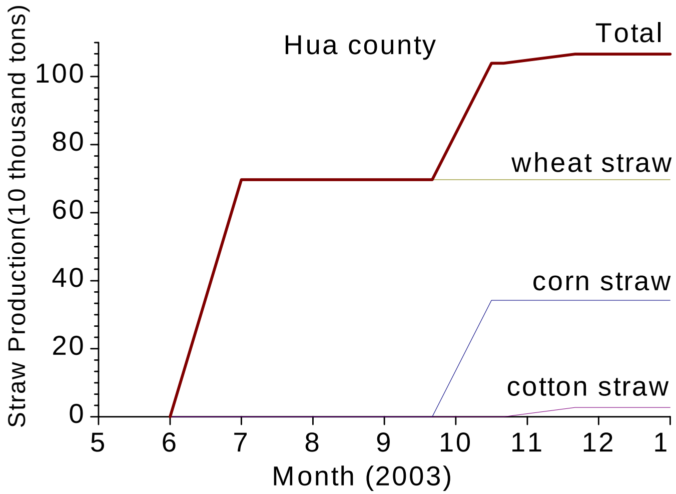
(Million ton)

Item	Yr.2002	Yr.2003
Wheat straw	62.7	69.7
Corn straw	33.9	34.2
Cotton straw	3.1	2.7
Total	99.7	106.6

County cultivated land:

1.7 million mu





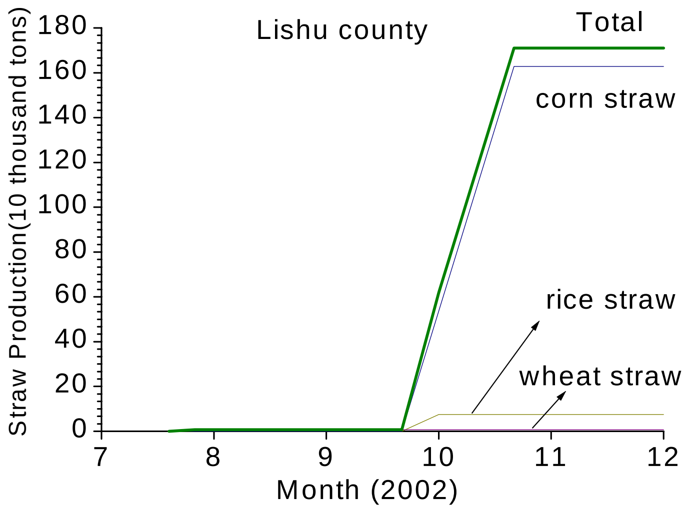
Lishu County, Jilin Province

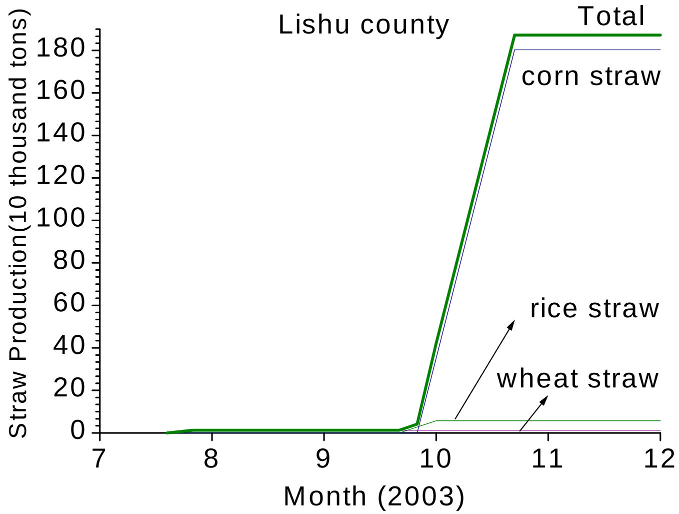
(Million ton)

Item	Yr.2002	Yr.2003
Corn straw	162.8	180.3
Rice straw	7.5	5.7
Wheat straw	0.7	1.3
Total	171.0	187.3

County cultivated land:

2.6 million mu





4.5 The cost structure of biomass material of China

4.5.1 Investigation on biomass material costs

In order to well understand the cost of biomass in China, we have made investigations on biomass cost of various areas in China.

4.5.1.1 We investigated several primary straw production areas in China, and see table 4-4 for the results.

4.5.1.2 Analysis of the collection and storage costs of straw

The collection and storage of straw are always difficult problems to solve till now. The following are some results of investigation we made on mass collection and storage of straw in Xinghua City, Jiangsu Province. In February 2005, Guangzhou Zhongke Huayuan Science & Technology Co., Ltd. Subordinate to Guangzhou Institute of Energy Conversion, CAS, managed to purchase cotton straw and rice straw in the City.

The first purchase was completed with cotton straw of 3026.58 m^3 (approx. 200 tons) transported in 100 times by tractor, 30 m^3 (approx. 1.8-1.9tons) for each time in average. The cotton straw storage occupied a area of 2500m^2, and the stack height was 3-3.5 m (initially 4m). Turning over the cotton straw costs 20Yuan/man-day× 13man-days. The cotton straw is difficult to pile high and requires a lot of area. So mass storage is impossible if without mechanical operation.

The first purchase was completed with rice straw of about 250 tons transported to factory's dock by boat. Then the rice straw was moved 200 m from the dock to storage site, costing 20Yuan/man-day×100man-days. There it cost 20Yuan/man-day ×130man-days to pile the rice straw to height of 6.4 m on an area of 400m^2 (10m× 40m).

The tractor loading has a maximum width limit of 3m and height limit of 3.5m (1m for vehicle + 2.5m for cargo). And the tractor has to pass through a toll-gate about every 20km in the transportation. Therefore, the tractor transportation is infeasible here. On the contrary, the boat has a carrying capacity of 40-50tons, and has a smooth way. Consequently, the boat transportation is best.

Based on the investigation above, we analyzed the characteristics of costs of mass straw collection, transportation and storage.

- Purchase cost of cotton straw: about 200 Yuan/ton (including transportation fee) Because of the bulking property of the straw, it is too difficult to pile them. Mechanical operation is necessary for mass collection, or the cost will be too high due to large area requirements.
- Purchase cost of rice straw: 80－100 Yuan/ton

Transportation cost of rice straw: 20 Yuan/ton for collection radius within 10 km and about 40 Yuan/ton for over 10km

- Cost for carrying and piling rice straw: 20 Yuan/ton
- Total cost of rice straw is 150－180 Yuan/ton

4.5.1.3 Results of investigation on cost of straw in Rudong County, Jiangsu Province by certain institution

- Average purchase cost: 97.5Yuan/ton
- Triming and packing cost: 32 Yuan/ton
- Transportation cost: 25 Yuan/ton for collection radius within 15 km and 50 Yuan/ton for 15-25 km
- Total cost: 154.5 Yuan/ton for collection radius within 15 km and 179.5 Yuan/ton for 15-25 km
  Average cost calculated on basis of area: 170.5Yuan/ton

4.5.2 Cost structure of biomass material

For biomass power plant, the material cost means all expenses before material delivered to power plant, including direct production cost, collection cost, transportation cost, and storage and pretreatment cost.

4.5.2.1 Direct Production Cost

It's the material own price. Because of the complexity of the category of biomass material, the prices differ greatly. The direct production price of agricultural residues applied most widely in China is about 40~100 Yuan/ton, including all kinds of straws, rice hull, and peanut hull etc; the price of forestry residues, mainly wood crumbs, is about 40~80 Yuan/ton; the price difference of industrial residues is relatively great, for example, the prices of combustible inorganic matter such as bagasse, waste wood and paper are close to the price of wood crumbs, while the organic waste water of butcher factories and animal dung of breed farms are regarded as waste and have no cost generally; the aim to utilize municipal solid waste is mainly for disposal, so some disposal fees should be got from government during the utilization process.

4.5.2.2 Collection Cost

Because of the characteristics of agricultural and forestry residues, the collection of material is very complicated, so the collection cost accounts for quite a proportion of total cost. Moreover, it is related to the equipment used, categories of straws, and local labor cost level very much. In general, the more straws disperse, collection method is backward, and collection radius is large the higher the collection cost is, so the power plant scale is an important factor affecting its economy. At present, the biomass collection cost is 20 to 60 Yuan/ton in most agricultural areas of China. The industrial residues and municipal solid waste are relatively concentrative, so the workload is not too heavy, and the cost is rather low so that it's only a small part of total material cost.

4.5.2.3 Transportation Cost

Material transportation is an indispensable part in the utilization process of biomass energy. The transportation cost is closely related to the collection radius. The larger the collection radius is the higher the transportation cost is. Generally, the transportation cost has no relevance to transportation distance under short distance, which is about 20 Yuan/ton within collection radius of 5~10 km. When transportation distance is over 10 km, the transportation cost is related to the distance. Because of low mass density and energy density of biomass, the transportation cost of biomass material is higher than that of fossil fuel such as coal and oil if accounted by per ton and per kilometer. Within 50 km management range, the transportation cost accounts for more than 1/3 of the total material cost. The organic waste water of butcher factories and animal dung of breed farms are inconvenient for transportation, so they should be utilized near material production place to reduce transportation and avoid secondary pollution.

4.5.2.4 Storage and Pretreatment Cost

The aim of storing material is to ensure the system normally continuous run, and the amount of storage relates with the system scale. Because of low density of biomass, the field required for storage is larger, and the related cost increases accordingly. Considering the flammability of biomass material, the fireproofing measure needs to be reinforced correspondingly. The storage cost mainly includes two parts: field rent and material management fee.

Different technology types and systems need biomass material under different conditions. Material pretreatment is to make the material meet system requirements, and its process includes cut up, drying etc. The pretreatment costs of different materials differ greatly. Some materials don't need pretreatment, such as the organic wastewater of butcher factories and animal dung of breed farms; some materials need complicated pretreatment process, which results in higher cost, such as municipal solid waste.

Brief summary

- Biomass resources for energy come mainly from crop residues, firewood, forest wood residues and organic refuses, such as animal dung and municipal solid wastes. Also, industrial wastes from rice mills, paper mills, timber mills, sugar and beer and food production can be used for energy. Total amount of biomass over 487 million tons of oil equivalent (toe) is available annually for energy use in China, of which about 370 million toe or 76% could be utilized for electricity and heat production. Agricultural residues are the most primary biomass resources in China.

- Dispersive distribution and obvious regional and seasonal production are the characteristics of biomass resources in China. Therefore, biomass material transportation and storage for material complementarity are two important factors that determine biomass power generation capacity and production cost.
- Biomass material cost includes direct production cost, collection cost, transportation cost, and storage and pretreatment cost. Usually, biomass price is 150-200 Yuan/ton if with no consideration of storage cost. The storage cost is related to the scale of biomass power plant. Normal average biomass piling area needs $2m^2$/ton.
- Collection radius of biomass determines its cost. The biomass material cost difference between within and beyond 15km is about 25 Yuan/ton.

Table 4-4 Investigation results of the prices of biomass resources

<table>
<tr><th rowspan="3">No.</th><th rowspan="3">Biomass material</th><th colspan="6">Liaoning</th><th colspan="2">Shandong</th><th colspan="2">Rudong, Jiangsu</th></tr>
<tr><th colspan="2">Dandong</th><th colspan="2">Dalian</th><th colspan="2">Yingkou</th><th rowspan="2">Net price (Yuan/ton)</th><th rowspan="2">Trans. fee</th><th rowspan="2">Net price (Yuan/ton)</th><th rowspan="2">Trans. fee</th></tr>
<tr><th>Net price (Yuan/ton)</th><th>Trans. fee</th><th>Net price (Yuan/ton)</th><th>Trans. fee</th><th>Net price (Yuan/ton)</th><th>Trans. fee</th></tr>
<tr><td>1</td><td>Corn core</td><td>160</td><td></td><td>300</td><td>Included (30-50km)</td><td></td><td></td><td>250-300</td><td rowspan="14">The trans. fee of 100 km for a truck with a normal load of 3 tons is about 300 Yuan. As for larger trucks, the fee is calculated by 0.6-0.7 Yuan/ton.</td><td></td><td rowspan="14">25 Yuan/ton for collection radius within 15km;
50 Yuan/ton for radius of 15-25km.</td></tr>
<tr><td>2</td><td>Corn straw</td><td>60</td><td></td><td>150</td><td>Included (30-50km)</td><td></td><td></td><td>100-150</td><td>82</td></tr>
<tr><td>3</td><td>Rice husk</td><td>30</td><td></td><td>150</td><td>50 Yuan/ton (30-50km)</td><td>250</td><td></td><td>150-200</td><td></td></tr>
<tr><td>4</td><td>Bean straw</td><td>100</td><td>Included (30-50km)</td><td></td><td></td><td></td><td></td><td></td><td>150</td></tr>
<tr><td>5</td><td>Chestnut hull</td><td>160</td><td>Included (30-50km)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Rice straw</td><td></td><td></td><td></td><td></td><td>300</td><td></td><td></td><td>96</td></tr>
<tr><td>7</td><td>Wheat straw</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>104</td></tr>
<tr><td>8</td><td>Firewood</td><td>220</td><td>Included (30-50km)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>Durra straw</td><td></td><td></td><td>200</td><td>70-80 Yuan/ton</td><td></td><td></td><td></td><td></td></tr>
<tr><td>10</td><td>Tree pruning</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>11</td><td>Wood powder</td><td></td><td></td><td>350-400</td><td>Included (30-50km)</td><td>400</td><td>Included (30-50km)</td><td>about 300</td><td></td></tr>
<tr><td>12</td><td>Peanut hull</td><td></td><td></td><td></td><td></td><td></td><td></td><td>about 300</td><td></td></tr>
<tr><td>13</td><td>Cotton straw</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>196</td></tr>
<tr><td>14</td><td>Cole straw</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>84</td></tr>
</table>

5. Present situation of biomass power generation technologies

5.1 Various technologies of biomass power generation

There are mainly four kinds of generation technologies of biomass: combustion, mixed burning, gasification and biogas power generation.

5.1.1 Biomass combustion and power generation technology

Biomass is directly combusted in boiler specialized for biomass, providing high pressure and high temperature vapor for steam turbine unit to generate electricity. Key points of this technology include biomass pretreatment, boiler’s adaptability to multiple biomass resources, high efficiencies of boiler and steam turbine.

5.1.2 Biomass mixed burning and power generation technology

Generation with mixed burning is to use biomass to coal-fired power plants, which uses both coal and biomass as their fuel to generate electricity. There are two kinds of mixed burning modes: (1) Biomass is directly mixed with coal to burn in boiler of coal-fired power plant. (2) Biomass is first gasified and then the gas is introduced into boiler to burn together with coal. Both have to pretreat the biomass fuel to meet the requirement of boiler or gasifier. This is the key technique. The utilized technologies for efficiencies of boiler and steam turbine are also important.

5.1.3 Biomass gasification and power generation technology

Biomass is gasified in gasifier to produce combustible gas. After cleaned, the gas is burned in internal combustion engine unit or small gas turbine unit to generate electricity. Key points of this technology include biomass pretreatment, high efficiency gasification technology and suitable internal combustion engine or gas turbine, of which the gasifier needs to adapt to different kinds of biomass; the internal combustion engine is usually rebuilt from diesel engine or natural gas engine; the gas turbine is required to be small capacity to suit the low heating value gas from biomass gasification.

5.1.4 Biogas power generation technology

Biogas obtained through anaerobic fermentation from organic liquid waste or dung is utilized as fuel gas for internal combustion engine, gas turbine or boiler to generate electricity. Key points include high efficiency anaerobic fermentation technology and biogas engine technology.

5.2 Present situation on application of biomass power generation technologies

5.2.1 Present situation on application in foreign countries

As a kind of clean renewable energy, biomass energy utilization has been a consensus over the world. In European and American countries, biomass energy R&D is supported by incentive policies and finance. European Union has funded many projects to accelerate European biomass energy industry.

5.2.1.1 Foreign biomass combustion and power generation application

The technology has been very mature in European countries. Here, the wide application of crop straw combustion and power generation technology of Denmark is recounted to indicate importance of direct combustion in power generation with biomass.

Before 1973, Danish energy only depended on importing oil, but after oil crisis, it urged positive development of renewable energy, including biomass energy. In order to make use of the abundant straw resource in Denmark, BWE Co. first developed straw combustion and power generation technology. The company still keeps leading position in this field over the world since its first straw power plant founded in 1988. For example, adapting BWE technological design and boiler equipment, Danish National Power Company invested 230 million krones to a straw power plant in South Denmark, with installed capacity of 12MW, straw consumption of 7.5tons/h, providing heat and electricity for 50,000 people continuing 5,000 hours/year. Another power plant of 850MW in Copenhagen, the capital of Denmark, is a multi-fuel plant combusting straw and timber chip besides coal, oil and natural gas.

Presently, there have been 130 straw power plants all over the country. Some timber and municipal solid waste power plants also combust straw together. In Denmark, electricity consumption from renewable energy has accounted for 24% of total national power consumption or more.

United Nation has regarded the straw combustion and power generation of Denmark as key project to expand its application in the world. European countries, such as Britain, Sweden, Finland, Spain and etc. have set up their own straw power plants adapting Danish BWE technology and equipment. And the one in Chambers, Britain is the largest one in the world, with installed capacity of 38MW, investment of 500 million krones.

5.2.1.2 Foreign Municipal Solid Waste incineration and power generation application

MSW combustion and power generation appeared first in Germany and USA. Since 1970s the technology has been developed rapidly in developed countries. Main incineration equipment include grate, fluidized bed, rotary kiln and module type, of which grate incinerator is the current dominant equipment, but fluidized bed technology has better potential. In USA, there are hundreds of MSW power plants disposing 40% rubbish of the country; disposal capacity of the MSW power plant in Detroit reaches 4000 tons/day. In Japan, MSW incineration rate had approached 75% in middle 1990s, and that in many European countries it has approached or exceeded landfill rate.

Simultaneously, MSW pyrolysis and gasification technology has well development in these countries, such as MSW thermoselect gasification technology of Switzerland and rotary kiln PKA gasification technology of Germany.

5.2.1.3 Foreign biomass mixed burning and power generation application

Centralized large biomass power plant is infeasible due to the characteristic of low bulk density of dispersive biomass resources. But the good adjustability of large

coal-fired power plant makes it feasible for biomass to mix and combust together with coal in existing traditional power plants. In Scandinavia and North America, this technology has been widespread. For example, more than 300 coal-fired power plants in USA adapt the technology, their total installed capacity reaches 6000MW.
VERBUND, the largest power provider in Austria, has studied following four modes of this technology:

a) Biomass combusts in a separate combustion system the heat generated is used to the existing boilers in power plant;
b) Biomass burns on grate set in coal boiler;
c) Biomass, Pulverized in specialized crusher, burns together with pulverized coal in boiler;
d) Biomass is first gasified, and then the fuel gas is introduced into boiler.

Studies indicated that c) and d) have better practicability.

Though simple the technology, but following problems exist:

- Generally, boiler is designed for certain special fuel, so its flue gas production should be constant to some extent. But the high content of water in biomass increases flue gas volume. If the increase exceeds limit, heat exchanger would overload. Therefore, biomass proportion in mixed burning should not be too high.
- Original stable burning in boiler would become complicated due to instability of biomass fuel.
- Slag-bonding is easy to occur due to low melting point of biomass ash.
- Chlorine biomass such as straw, straw, will result in high temperature corrosion on heat exchanger surface when surface temperature exceeds 400℃.
- Alkali resultant of biomass combustion will devitalize denitration catalyst.

5.2.1.4 Foreign biomass gasification and power generation application

Small biomass gasification and power generation systems are usually referred to gasification and generation systems with fixed bed gasifier and generation capacity less than 200kW. Most of them are used in developing countries, especially in Africa, India and South-East Asian countries such as China. Though small biomass gasification and power generation technology is very mature in USA and European countries, application is very limited because of relatively high biomass energy cost and existing perfect power supply system, and only a few apparatuses for research and experiment were established.

Medium biomass gasification and power generation systems are usually referred to gasification and generation systems with fluidized bed gasifier and generation capacity from 400kW to 3000kW. They were earlier applied in some developed countries. As its equipment investment is very high, unable to reduce generating cost, it is used less in developed countries. Currently, there are only a few projects in Europe.

Large biomass gasification and power generation systems, generally with generation capacity more than 3000kW or IGCC system, have not maturated so far, being in research and demonstration stage. Owing to its achievable systematic efficiency >40%, advanced biomass IGCC technology has gained great attention since 1990. Many developed countries have devoted to the research, such as demonstration projects in Battelle, (63MW) and Hawaii (6MW) ofUSA, Britain (8MW) and Finland (6MW) in Europe. Presently, it is still under development because its economical efficiency is not good enough to enter into market. For instance, according to an Italian 12MW IGCC demonstration project, investment cost is up to 25000RMBYuan/kW, and generating cost is about 1.2 RMBYuan/kWh. In Sweden, Varnamo biomass IGCC demonstration power plant aims to establish a perfect B/IGCC system for investigating its various key processes. The investment and running cost are very high. So it is more suitable for R&D. It uses all presentlatest biomass gasification and power generation technologies in Europe such as pressurized circulating fluidized-bed (18MW), high temperature filtration, gas turbine (4.2MW) and exhausted heat power generation.

5.2.1.5 Foreign biogas power generation application

Developed countries primarily use anaerobic technology to disposal animal excrement and concentrated organic liquid waste. India, Philippines and Thailand also constructed large and medium biogas demonstration projects.

As to biogas power generation, USA, Britain and Italy apply to biogas disposal in refuse landfill dumps. Internal combustion engines adopted are Otto engine and Diesel engine, with power/mass of 27kW/t. Gas turbine and steam turbine also have utilizations but with power/mass respectively of 70～140kW/t and 10kW/t. USA keeps ahead in the field of biogas power generation. USA, with its mature technology and engineering, is in the world leading level. There had been 61 refuse landfill dumps introducing internal combustion engine system at the end of the 20th century. Together with turbine generation, the installed capacity had been 340MW in the country. Otherwise in cattle farms, farmers generate electricity from cattle dung biogas. More than ten cattle farms in California are in construction of biogas power generation. In Europe, internal combustion engines used for biogas power generation have capacity of 0.4～2MW and power generating efficiency of 1.68～2kWh/m^3. Application in Britain is only inferior to USA. At the end of the 20th century, Britain had benefited power of 18MW from refuse biogas. In the next decade, ￡150 million are to be invested in more biogas electricity projects.

5.2.2 Applications in China

5.2.2.1 Biomass combustion and power generation application in China

Key points of this technology are on biomass boiler and small steam turbine unit. China has mature small steam turbine technology with low cost but low power generating efficiency, as shown in table 5-1.

Table 5-1 Characteristics of small condensing steam turbine

Capacity (kW)	Inlet steam parameters (MPa)	Inlet steam parameters (℃)	Total inlet steam (t/h)	Steam consumption rate (kg/kWh)	Generating efficiency (%)	Reference price ($\times 10^4$Yuan)
1500	2.35	390	8.4	5.60	20.0	130
3000	3.43	435	14.8	4.93	22.1	180
6000	3.43	435	28.5	4.75	22.9	290

12000	3.43	435	55.6	4.63	23.5	480
25000	3.43	435	111.0	4.44	24.5	900
25000	8.83	535	91.0	3.64	28.5	–

Sources: Design standards and consultation.

China has produced special boiler for biomass of timber, bagasse and rice husk etc. to combust and generate electricity. Because biomass resources are very dispersive, Biomass boilers available in market are very few. Furthermore, most in domestic market are boilers with medium and small capacity. Large ones basically are exported to international market where biomass supply is mass. For example, facing environmental pollution from rice husks, rice mills developed rice husk combustion and power generation plants, simultaneously improving its own electricity cost. But these rice husk power generation projects are all small, without large biomass power generation plant for centralized disposal.

Fig. 5-1 Timber Boiler

In addition, it has been well recognized to use the abundant straw resource in China to generate electricity, but most are small gasification application, without special straw boilers. So several straw combustion and power generation programs have planned to introduce foreign technology and equipment. For example, Jinzhou City of Hebei Province is to adapt related technology of Danish BWE Co. to construct a 2×12MW plant, burning more than 200,000 tons of straws and generating electricity 120 million kWh every year. Another plant of 25MW is in Shandong Province.

Here are some Chinese boiler enterprises' biomass boilers.

Shanghai Sifang Boiler Works:

Manufactured multiple scale timber boilers with capacity of 4t/h、6t/h、10t/h、15t/h、20t/h、25t/h、30t/h、35t/h.

Table 5-2 Specification of timber boiler

No.	Type	Boiler name	Fuel
1	DZG4-1.25-M	Package fixed grate timber boiler	Timber
2	SZW10-1.25-M	Package fixed grate timber boiler	Timber
3	SZG10-1.25-M	Package fixed grate timber boiler	Timber
4	SZG10-1.76-M	Package fixed grate timber boiler	Timber
5	SHG15-1.76-M	Double lateral canister fixed grate timber boiler	Timber
6	DHG20-2.5-M	Corner tube fixed grate timber boiler	Timber
7	SHG30-2.5-M	Double lateral canister fixed grate timber boiler	Timber
8	DHL35-3.82/450-(A+M)	Corner tube chain grate coal-fired mixing timber boiler	Soft coal and Timber

Sources: http://www.sfbw.online.sh.cn/crfm.htm

Wuxi Huaguang Boiler Co., Ltd:

In 1993,exported the first 60t/h high pressure (100kg/cm^2) timber boiler to Indonesia。Also produces bagasse boiler of 35t/h、65t/h、130t/h etc.

Fig. 5-2 60 t/h timber boiler exported to Indonesia

Wuhan Boiler Works:

The bagasse boiler designed has very good fuel adaptability, not only burning bagasse, heavy oil, coal dollop or coal power, but also mixed burning of bagasse with heavy oil, coal dollop or coal power. Equipment and technology were exported to Europe, Asia and Africa in the past decades of years. But recent years, many sugar refineries use bagasse as material of high quality paper. Combustion proportion of bagasse has decreased. Consequently, bagasse boiler production also decreased. Table 5-3 is specification of bagasse boiler.

Wuliangye Group Co., Ltd:

In order to solve the rice husk pollution problem of the Company, it cooperated with Shanghai Sifang Boiler Works in manufacturing rice husk boiler, and succeeded in July, 1999.

Hangzhou Boiler Works:

Manufactured rice husk boilers typed as SHSL10—25/400—D, and exported one of 12.5 t/h to Thailand in 2001.

Yingkou Luyan Boiler and Crane Co., Ltd:

Mainly exported biomass boilers to Malaysia, Singapore, Thailand, Ghana etc. which were fueled with timber, bagasse, rice husk, palm ear, cacao hull and etc.

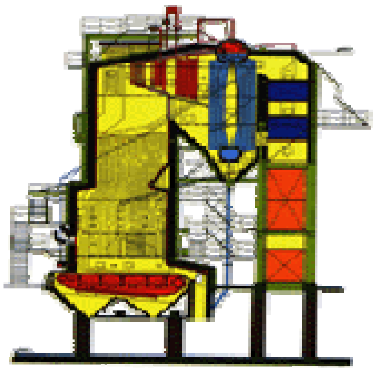


Fig 5-3 Bagasse boiler: WGZ65/3.82-16

Fig 5-4 65 t/h Bagasse boiler

5.2.2.2 Municipal Solid Waste incineration and power generation in China

Municipal Solid Waste (MSW) incineration and power generation in China started in medium 1980s. Some cities with higher heating value MSW have devoted to application. For example, in 1988, Shenzhen City of Guangdong Province introduced Mitsibishi MSW technology to build the first MSW power plant in China, with total generating capacity of 6000kW so far. And in its No.3 unit, 85% of utilized devices are home -made. Other cities, such as Zhuhai, Ningbo etc., also constructed their own MSW power plants. Though landfill is still the main method for refuse disposal in current China, with more and more limit to newly-build landfill field and increase of MSW heating value, power generation from MSW is sure to be an important disposal technology. Simultaneously, small-scale refuse gasification technologies are under development.

Table 5-3 Specification of bagasse boiler

Type	Rated Evaporation (t/h)	Outlet Vapor Pressure (MPa)	Outlet Vapor Temp. ℃	Feed-water Temp. ℃	Fuel	Combustion Method	Dimension L*W*H m*m*m
WGZ65/3.82-16	65	3.82	450	105	Bagasse+ Anthracite	Fire bed and suspending	12*8*20
WGZ60/2.45-1	60	2.45	360	104	Bagasse+ Oil	Fire bed and suspending	15*8*21
WGZ35/3.82-22	35	3.82	450	105	Bagasse+ Anthracite	Shaft coal power grate-fired boiler	11*6*20
WGZ35/3.82-24	35	3.82	450	105	Bagasse+ Lignite	Spreader stoker boiler	11*6*17
WGZ35/2.45-2	35	2.45	400	80~85	Bagasse+ Soft coal	Spreader stoker boiler	11*6*17
WGZ20/2.45-6	20	2.45	400	105	Bagasse+ Soft coal	Spreader stoker boiler	12*5*15
WGZ20/2.45-8	20	2.45	400	125	Bagasse+ Oil	Roll-over grate-fired boiler	—
WGZ15/2.45-1	15	2.45	400	105	Bagasse+ Heavy oil	Roll-over grate-fired boiler	10*5*12

Sources: http://www.chinaboiler.com.cn/boiler/whd.htm

Table 5-4 Biomass boiler price

Rated capacity (t/h)	Biomass combustion boiler (million Yuan)	MSW incineration boiler (million an)
35	6. 5	8. 5
75	13	17
130	30	35

Note：Including the boiler main body, water treatment, dust collector, deaerator, control system etc. and installation.

5.2.2.3 Biomass gasification and power generation application in China

Related research and application in China began in early 1960s. Then, based on early rice husk gasification and power generation technology, further research was focused on various generating capacity and biomass resources, finishing manufacture of various generation sets with capacity from 2.5kW to 200kW. In recent years, medium and small systems have been emphasized under development due to low investment and flexibility tallied with Chinese basic conditions. Developped power generation sets are of generating capacity from several kW to 4000kW with gasifier structures of open-center style, down draft style, CFB etc. and internal combustion engines (unit max power 200kW) for single gas fuel and dual fuel. For example, Guangzhou Institute of Energy Conversion (GIEC), CAS has developed series of circulating fluidized bed biomass gasification and power generation system of 200kW, 600kW, 800kW, 1000kW, 2000kW, 3000kW, 4000kW etc. The investment cost is controlled under 5000 Yuan/kW, and generating cost is 0.3~0.5 Yuan/kWh. With its remarkable economical efficiency and potent competitiveness, these products has are welcome and applied widely in China, and become the most applied medium biomass gasification and power generation technology in the world.

Because of severe difficulty in tar disposal and gas turbine reconstruction, biomass IGCC application faced with a number of problems such as immature system, high cost and low practicability. Under present conditions in China, development of BIGCC under the same technical approach as in foreign countries will be of more difficulty in capital and technology.

5.2.2.4 Biogas power generation application in China

The technology mainly is applied to biogas from animal excrement, industrial liquid waste and refuse landfill.

At present, researches on biogas engine mainly focus on dual-fuel type of biogas and diesel oil. Not long ago, a 50kW dual-fuel biogas engine unit succeeded in power generation in Zhejiang Province, equipped with a biogas supply system of 800m^3/day.

Changle Wine Works of Shandong Province installed 2×120kW biogas units, generating electricity 8640kWh every day from 4800m^3 biogas of ferment of 170m^3 lees. This biogas power generation system can supply all electricity the Wine Works needs, saving 290,000 Yuan of energy cost every year, and recovering investment only within one year.

Landfill dumps contain tremendous biogas resource. In August 2004, China's first independently developed MSW landfill biogas power plant, invested 20 million Yuan by private enterprise, was put into service at Taohua hill refuse landfill dump in Wuxi, Zhejiang Province,. It is estimated to generate electricity 15.3 million kWh/year. The electricity price to power grid is 0.527 Yuan/kWh. The Project is a part of China National Action Program to Collect and Utilize Refuse Landfill Biogas promoted by China and UNDP. In October 1998, the first landfill biogas power plant in mainland of China, Hangzhou Tianziling landfill biogas power plant, was built under cooperation with USA. In addition, other cities such as Guangzhou, Nanjing also have similar plants.

As to research on advanced biogas power generation technology, large and highly effective anaerobic biogas power generation technology and demonstration, the Key Science-Technology Project of the National 'Tenth Five-Year-Plan' of China, has been finished by Chengdu Biogas Scientific Research Institute of Ministry of Agriculture in January 2004. Its ferment capacity reached over 40,000m^3, and biogas production rate $\geq$4.0m^3/m^3. They newly developed 600kW biogas power generation set.

Fig.5-5 highly effective anaerobic biogas power generation unit

Application of biomass power generation technologies has been commercialized on fairly large scale in China. The total installed power capacity of bagasse, rice husk and biogas has been over 800MW.

5.2.3 Conditions for application of biomass power generation technologies

In fact, biomass power generation has two main modes: combustion directly to produce steam and gasification. The former has been basically mature and obtained extensive application, with relatively high efficiency and rational investment under large scale. But it requires centralized mass biomass resources, e.g. modern large farms and processing mills that discharge biomass residues. Considering its high collection and transportation cost, this mode is not suitable for developing countries with dispersive distribution of biomass resources.

The latter is more environmentally friendly, nearly without harmful gas emission. Medium and small biomass power generation technology in developed countries is mature but no competitiveness with other energy due to small capacity and complex process, it is also difficult for this technology to enter developing countries because its construction cost (more than 1200$/kW) and running cost are high. However, that developed by China features in low investment and cost and is flexible in capacity. Small biomass power generation application has been commercialized.

As to BIGCC, though has high power generating efficiency, its generating cost is closely related to biomass cost and generating capacity. For 70MW BIGCC, if biomass price is 250 Yuan/t, generating cost is about 0.35 Yuan/kWh, almost same as that of small coal-fired power plant. For 70MW BIGCC, large amount of biomass resources (2000 t/day) is needed, and its investment is high, too. Countries or enterprises with ability to meet these conditions are finite. If decreases the capacity, economical efficiency will obviously decrease too. Therefore, it is impossible for the technology to obtain practical application in the near future. Table 5-5 is the comparison of biomass power generation modes.

Table 5-5 Comparison of biomass power generation modes

Mode	Combustion	Gasification-Combustion	Mixed Burning	Gasification-Mixed Burning
Technological Characteristic	Biomass burned directly in boiler to produce steam to generate electricity	Biomass gasified first and then fuel gas burned in gas turbine or engine	Biomass mixed with coal and burned in boiler	Biomass gasified first and then fuel gas burned with coal in boiler
Main Advantage	Mature technology, relative large scale, simple biomass pretreatment, reliable equipment, low running cost	Low emission pollution, high efficiency at small scale, flexible in capacity, low investment	Simple and convenient operation, the least investment if no reconstruction of existing device	Universal application, low impact on original coal-fired system, obvious economic benefit
Main Disadvantage	High emission pollution, low efficiency at small scale, single biomass fuel, large investment	Complex equipment, immature large system, high maintenance cost	Strict biomass quality and pretreatment, some impact on original system	Append gasification system, complex management, certain metal erosion problem
Application Conditions	Large scale power generation system (>20MW)	Medium and small system	Suitable for timber biomass and special boiler	Power generation system for mass biomass

5.3 Development trend of biomass power generation technology in China

Based on the characteristic of biomass resources and national conditions of China, development trend of biomass power generation technology may be in three forms: miniaturization and close to end users, comprehensive utilization and CHP, distributed power system.

5.3.1 Miniaturization and close to end users

This technology utilizes dispersive biomass to set power plant near end users. For example, in small rice mills where rice husk production is not much, there is very good economical efficiency to establish power generation plant according to its rice husk production scale. Electricity produced can be used by rice mill to reduce its running costs. Potential end users include medium and small sugar-refinery, animal production farm, timber mill etc.

5.3.2 Comprehensive utilization and CHP

Enhancing system efficiency is the basic way to utilize biomass energy in maximum. According to different biomass resources and user requirements, large-scale biomass power generation system can combine multiple technologies such as CHP to enhance system efficiency. Potential end users include large animal production farm, timber mill etc.

5.3.3 Distributed power system

From the view of power network safety, distributed power system is regarded as the best way to enhance safety of electricity supply. In the future, power system should be a combination of centralized power system with distributed power systems, which has an integrated structure consisting of central power generation and teletransfer skeleton network, regional power transfer and distribution network, and micro power network. Biomass power generation system is a convenient, realizable, distributed renewable energy system, offering clean, effective and reliable electricity to end users.

Brief summary

- Biomass power generation technologies have been maturely applied in the world, mainly including direct combustion, gasification-combustion, direct mixed burning with coal and gasification-mixed burning with coal.
- Foreign countries have much successful experience of biomass direct combustion and power generation technology, and China has well accumulated in biomass gasification and power generation technology but less in biomass combustion experiences. Because China’s industrial manufacture level is relatively low, the manufacture capability of integral biomass power generation equipment is not strong. So in the future, equipment manufacture must be strengthened to reduce project investment cost.

- Development trend of biomass power generation technology is miniaturization and close to end users, comprehensive utilization and CHP, distributed power system.

6. Economic analysis of biomass power generation technologies

There are three main kinds of biomass power generation technologies: mixed burning, gasification and combustion power generation. Mixed burning technology is the most complex one, whose economical efficiency is related to the capacity of coal-fired power plant, combustion equipment and power generation equipment, besides its mixed mode. Because the requirements for biomass mixed burning are high, it is not feasible for all coal-fired power plants. Moreover, original plant efficiency and output will be influenced. Therefore, it is difficult to evaluate its economical efficiency.

Here, biomass gasification-mixed burning power generation technology, which is of higher versatility, is selected as the basis of analysis. All technologies are assumed to enjoy government's protective electricity price. Accordingly, their generating cost and investment recovery period are analyzed.

Because about 30—50% of biomass cost is for transportation and storage, while calculating generating cost, that cost for all plants with different scales will obviously increase. Therefore, biomass prices of different scale biomass power plants are assumed respectively, as shown in table 6-1.

Table 6-1 Biomass price calculated

Capacity（MW）	1-2	5-10	10-20	>20	Remark
Biomass supply (×10^4ton/year)	1	5	10	>20	Dry material
Average collection radius (km)	1-4	5-10	10-20	>30	Calculated on basis of 30% biomass production
Biomass cost (Yuan/ton)	100	100	100	100	Purchase from farmers
Collection and handling cost (Yuan/ton)	40	40	40	40	Labor cost for collection and handling
Transportation cost (Yuan/ton)	10	15	20	25	1Yuan per 1km increased
Storage management cost (Yuan/ton)	10	15	20	25	Considering quantity and time
Comprehensive cost (Yuan/ton)	160	170	180	190	

Note: Calculation is based on biomass heating value of 3250 kcal/kg.

6.1 Biomass gasification-mixed burning power generation

Its basic assumption is that a set of biomass gasifier is added to a small coal-fired power plant. Gas from gasifier is directly led into boiler and burned together with coal. Calculations are based on two coal-fired power plants with capacities of 12MW and 25MW, generating efficiencies of 20% and 25% respectively.

Table 6-2 Investment estimation of 20MWt and 40MWt biomass gasification-mixed burning power generation systems(×10^4Yuan)

No.	Item	20MWt	40MWt	Remark
1	Gasification system	245.0	2×245.0	Gasifier
2	Feedstock supply system	195.0	255.0	Dry, shatter and convey
3	Gasifier monitoring system	15.0	15.0	Gasification and combustion control system
4	Installation material and fitting	27.0	47.0	Equipment installation
5	Workshop and civil work	52.0	82.0	Workshop, foundation and stock field
	Total	534.0	889.0	

Table 6-3 Estimation of economic benefits for 20MWt and 40MWt straw gasification-mixed burning power generation projects

Item	Unit	20MWt	20MWt	40MWt	40MWt
Straw consumption rate	t/h	5.0	5.0	10.0	10.0
Gasification efficiency	%	90.0	90.0	90.0	90.0
Straw HV	kcal/kg	3100.0	3100.0	3100.0	3100.0
Straw price	Yuan/t	170.0	170.0	180.0	180.0
Generating efficiency	%	20.0	25.0	20.0	25.0
Gasifier running time	h/y	6000	6000	6000	6000
Straw consumption	t/y	30000	30000	60000	60000
Salary	$\times 10^4$Yuan/y	42	42	57	57
Maintenance cost	$\times 10^4$Yuan/y	20	20	30	30
Management cost	$\times 10^4$Yuan/y	10	10	20	20
Total cost	$\times 10^4$Yuan/y	582	582	1127	1127
Power production	$\times 10^4$kWh/y	2160	2700	4320	5400
Direct generating cost	Yuan/kWh	0.260	0.208	0.254	0.202
Electricity price*	Yuan/kWh	0.5	0.5	0.5	0.5
Gross profit	$\times 10^4$Yuan/y	498.0	768.0	1033.0	1573.0
Investment recovery period	year	1.07	0.7	0.86	0.57

* The electricity price after deducting relevant taxes

According to the above calculation, the economical efficiency of biomass gasification-mixed burning power generation technology is related to original plant’s generating efficiency, namely increases with the latter increases. Moreover, investment recovery period is less than one year, so the technology has very good economic benefit, but this conclusion is based on the preconditions of national protective electricity price of 0.5 Yuan/kWh and separation of biomass electricity price and coal electricity price. However, in practical operation, it is not easy to distinguish biomass electricity from coal electricity. Additionally, due to the lack of effective supervisory means, specific subsidy support or protective policy is unavailable. This is why the technology has not been widely utilized though it has good economical efficiency.

6.2 Biomass gasification and power generation

There are two types of biomass gasification and power generation technologies. One is of small scale usually <3MW, adapting simple combination of gasifier-internal combustion engine, with power generating efficiency of 18-20%. The other is of medium scale adapting exhaust-heat boiler and power generating system in addition to gasifier- internal combustion engine (or gas turbine), with generating efficiency of 25-45%. Since the key technology of IGCC with gasifier-gas turbine combination is not mature, here only analyze the relatively low efficiency gasifier-internal combustion engine system.

6.2.1 Economic analysis of ≦3MW biomass gasification and power generation technical and economic indicators

According to developed MW scale biomass gasification and power generation technology and distribution characteristic of user’s electricity load, tthe following indexes are possible to obtain:

- Installed capacity: 1000-3000kW;
- Long-term average running load accounting for design capacity: 85%;
- Failure rate of system: <15%;
  Usage rate of system: 75%;
- Biomass consumption rate: 1.7kg/kWh (dry).

Investment budget:

Table 6-4 Investment budget for MW scale biomass gasification and power generation plant(×10^4Yuan)

Item	3MW	2MW	1MW
1.Equipment	850.7	612.2	316.5
2.Installation material and fitting	36.3	28.0	18.3
3.Building and civil work	139.0	119.0	80.8
4.Equipment installation and commissioning	82.0	77.0	63.0
5.Support equipment and fitting	80.5	66.5	30.5
6.Others and unpredictable cost	260.0	186.0	102.3
Total cost	1448.5	1088.7	611.4

Cost analysis:

Table 6-5 Running cost of MW scale biomass gasification and power generation plant(×10^4Yuan/year)

Item	Basis	1MW	2MW	3MW
1. Salary		**59.4**	**81.0**	**87.0**
1）Management cost	45000 Yuan/person.year	9.0	9.0	9.0
2）Operators	30000 Yuan/person.year	36.0	48.0	54.0
3）Other workers	24000 Yuan/person.year	14.4	24.0	24.0
2.Maintanence cost		**29.4**	**55.6**	**79.1**
1）Gasifier		1.8	3.6	4.5
2）Gas engine set	3000 Yuan/month.MW	3.6	6.0	9.0
3）Gas engine set fitting	10000 Yuan/200kW.Year	6.0	12.0	18.0
4）Lubricating oil	0.02 Yuan/kwh	12.0	24.0	35.6
5）Others		6.0	10.0	12.0
3.Management cost		**6.0**	**6.0**	**6.0**
1）Supplies Expense	3000 Yuan/month	3.6	3.6	3.6
2）Unpredictable cost	2000 Yuan/month	2.4	2.4	2.4
Total		**95.8**	**142.6**	**172.1**

Table 6-6 Economic benefit estimation

Item	Unit	Capacity			Basis for calculation
1）Design load	MW	1.0	2.0	3.0	
2）Running days	day/y	287	287	287	
3）Running time	hour/day	24	24	24	
4）Self-use load	kW	60.0	100.0	120.0	
5）Electricity output	×10^4kWh/y	594.0	1188.0	1782.0	24×275×(1)×0.9
6）Self-use electricity	×10^4kWh/y	43.2	72.0	86.4	24×300×(4)

7）Sold electricity	$\times 10^4$kWh/y	550.8	1116.0	1695.6	（5）-（6）
8）Electricity price*	Yuan/kWh	0.5	0.5	0.5	
9）Output value	$\times 10^4$Yuan/y	275.4	558.0	847.8	(7)×0.5
10）Running cost	$\times 10^4$Yuan/y	95.8	142.6	172.1	Table 6-5
11）Biomass price	Yuan/kg	0.16	0.16	0.16	
12）Biomass cost	$\times 10^4$Yuan/y	166.2	332.6	499.0	（5）×1.75×（11）
13）Total cost	Yuan/kWh	262.0	475.2	671.1	（10）+（12）
14）Generating cost	Yuan/kWh	0.476	0.423	0.396	（13）/（7）
15）Gross profit	$\times 10^4$Yuan/y	13.4	82.8	176.7	（9）-（13）

* The electricity price after deducting relevant taxes.

6.2.2 Economic analysis of >5MW biomass gasification and power generation

According to feasibility study of 6MW scale biomass gasification and power generation technology (under construction), the following indexes are possible to obtain:

Technical and economic indexes:

- Gasification efficiency: 78%
- System total efficiency: 28%
- Plant self-use electricity rate: 10%
- Biomass consumption rate: 1.03kg/kWh
- Operation worker: 60 persons

Investment budget:

Table 6-7 6000kW project's investment budget ($\times 10^4$Yuan)

Item	Cost
1. Gasification system	420.0
2. Gas engine generation system (4500kW)	900.0
3. Exhausted heat utilization system	220.0
4. Steam turbine generation system (1500kW)	200.0
5. Biomass supply system	200.0
6. Ash discharge system	50.0
7. Chemical water system	30.0
8. Water supply system	50.0
9. Electricity power system	150.0
10. Thermal control system	120.0
11. Building and land	350.0
12. Substation combination system	500.0
13. Others	150.0
14. Unpredictable cost	600.0
Total	**3940.00**

Cost analysis:

Table 6-8 6000kW project's economic benefit estimation($\times 10^4$Yuan)

1.	Capacity	kW	6000
2.	Running load	%	90
3.	Running time	h/y	6200
4.	Self-use electricity rate	%	10
5.	Sold electricity	$\times 10^4$kWh/y	3000.0
6.	Gasification efficiency	%	78.0
7.	Internal combustion engine efficiency	%	30
8.	General efficiency	%	26.5
9.	Biomass consumption rate	kg/kWh	1.05
10.	Biomass price	Yuan/t	170.0
11.	Biomass consumption	t	34560.0
12.	Biomass cost	$\times 10^4$Yuan/y	587.5
13.	Salary	$\times 10^4$Yuan/y	180
14.	Material	$\times 10^4$Yuan/y	150
15.	Maintenance	$\times 10^4$Yuan/y	50
16.	Management	$\times 10^4$Yuan/y	25
17.	Total cost	$\times 10^4$Yuan/y	992.5
18.	Generating cost	Yuan/kWh	0.331
19.	Electricity price*	Yuan/kWh	0.50
20.	Output value	$\times 10^4$Yuan/y	1500.0
21.	Gross profit	$\times 10^4$Yuan/y	507.5

* The electricity price after deducting relevant taxes.

According to the above analysis, unit investment on equipment for small biomass gasification and power generation system is relatively low. But when biomass price is high, the investment is hardly recovered (at protective electricity price of 0.5 Yuan/kWh) since generating cost becomes high due to low gasification efficiency, particularly for very small projects. Consequently, small biomass gasification and power generation technology is suitable to cases with relatively low biomass price and difficult financing.

For medium scale project, the power generating efficiency is high and generating cost is relatively low. But its unit investment on equipment is high because of its complex system. Generally, medium scale biomass gasification and power generation technology has good economical efficiency (at protective electricity price of 0.5 Yuan/kWh), and is suitable for case with relatively high biomass price and sufficient investment.

6.3 Biomass combustion and power generation

Technical and economic indexes

According to foreign experiences of biomass combustion and power generation plant and existing technology in China, the technical and economic indexes are closely related to plant's capacity. Following data are the indexes of 6MW and 25MW biomass combustion and power generation plants.

Table 6-9 Technical and economic indexes of 6MW、25MW biomass combustion and power generation plants

Technical and Economic Index	**6MW**	**25MW**
Steam parameter	3.43 MPa/435℃	8.83 MPa/535℃
Long-term running load rate (%)	95	95
Running time (h)	7500	7500
Boiler efficiency (grate furnace)(%)	85	90
Steam turbine efficiency (%)	22.9	28.5
System generating efficiency (%)	19.5	25.6
Fuel consumption index (%)	1.48	1.04
Self-use electricity rate (%)	10.0	10.0
Operation worker (person)	60	150

Economic benefit analysis:

Table 6-10 Economic benefit estimation of 6MW and 25MW straw combustion and power generation projects

Item	Unit	6MW	25MW	25MW
Origin of equipment		Domestic	Imported	Domestic
Equipment unit investment	Yuan/kW	6500	10000	6000
Total investment of project	$\times 10^4$Yuan	3900	25000	15000
System thermal efficiency	$\times 10^4$Yuan/y	19.5	26	22.1
Self-use electricity rate	%	10	8	8
Straw HV	kcal/kg	3100.0	3100.0	3100.0
Straw consumption rate	t/h	1.42	1.11	1.26
Straw price	Yuan/t	170.0	190.0	190.0
Running time	hour/y	7500	7500	7500
Electricity output	$\times 10^4$kWh/y	4275	17812	17812
Sold electricity	$\times 10^4$Yuan/y	3847	14250	14250
Straw consumption	t/y	60705	197713	224431
Straw cost	$\times 10^4$Yuan/y	1032.0	3756.5	4264.2
Salary	$\times 10^4$Yuan/y	240.0	360.0	360.0
Maintenance cost	$\times 10^4$Yuan/y	60.0	250.0	150.0
Material cost	$\times 10^4$Yuan/y	215.0	890	890
Management cost	$\times 10^4$Yuan/y	50.0	50.0	50.0
Total cost	$\times 10^4$Yuan/y	1597.0	5306.5	5714.2
Generating cost	Yuan/kWh	0.415	0.372	0.401
Electricity price*	Yuan/kWh	0.5	0.5	0.5
Output value	$\times 10^4$Yuan/y	1923.5	7125.0	7125.0
Gross profit	$\times 10^4$Yuan/y	326.5	1819.0	1411.0
Investment recovery period	year	15.5	18.7	13.5

* The electricity price after deducting relevant taxes; capital interest rate of 3%.

Biomass direct combustion power generation system has relatively high generating efficiency and low running and generating cost. But if adopts foreign generation equipment, it has very high equipment investment and long recovery period. If adopts domestic equipment, the investment becomes low, however generating efficiency decreases. Large-scale (>20MW) biomass direct combustion projects can still keep fairly good economical efficiency at high biomass price, because generation equipment of high parameters is available. But the generating efficiency and economic efficiency of small ones (<10MW) decrease due to limit of generating parameters. Consequently, biomass combustion and power generation technology is suitable for cases with mass biomass areas and large investment.

Brief summary

- The economical efficiency of biomass gasification-mixed burning power generation technology is related to original plant's generating efficiency, namely increases with the latter increases. But the technology has not been widely utilized though it has good economical efficiency, because it is not easy to distinguish biomass electricity from coal electricity in practical operation.
- The equipment unit investment of small biomass gasification and power generation system is relatively low. But when biomass price is high, the investment is hardly recovered (at protective electricity price of 0.5 Yuan/kWh) since generating cost becomes high, particularly for very small projects. Consequently, small biomass gasification and power generation technology is suitable for case with relatively low biomass price and difficult financing.
- The power generating efficiency of medium scale biomass gasification and power generation system is high, and the generating cost is relatively low. But its equipment unit investment is high because of its complex system. Generally, medium scale biomass gasification and power generation technology has good economical efficiency (at protective electricity price of 0.5 Yuan/kWh), and is suitable for case with relatively high biomass price and sufficient investment.
- Biomass direct combustion power generation system has relatively high generating efficiency and low running and generating cost. But if adopts foreign generation equipment, it has very high equipment investment and long recovery period. If adopts domestic equipment, the investment becomes low, however generating efficiency decreases.
- Large-scale (>20MW) biomass direct combustion projects can still keep fairly good economical efficiency at high biomass price, because generation equipment of high parameters is available. But the generating efficiency and economic efficiency of small ones (<10MW) decrease due to limit of generating parameters. Consequently, biomass combustion and power generation technology is suitable for cases with mass biomass areas and large investment.

7. Comprehensive comparison of biomass power generation technologies

7.1 Basic requirements to biomass power generation technologies in China

The primary biomass resource of China is still crop residues at present, and this situation will continue for a fairly long time. Used as fuels for power generation, crop residues have the most obvious characteristic of dispersiveness, which results in difficult biomass collection and transportation. Additionally, biomass supply ability is greatly influenced by crops' planting scale, presenting obvious seasonality. Therefore, practice of biomass power generation technologies in China has its special requirements.

7.1.1 Biomass power generation technologies must have good adaptability to most biomass fuels

Due to the seasonal effect of agricultural production, most crop residues are produced only in a certain period of a year. And crop residues almost feature in low bulk density and large volume. So it is very difficult to mass-deposit and o high cost. In order to guarantee year-round production of biomass power generation plant and improve equipment utilization, the most reasonable way is that biomass power generation technologies must have good adaptability to most biomass fuels.

7.1.2 Biomass power generation technologies should offer flexible scales for different areas.

China has wide rural areas, but natural conditions vary in different areas. As a developing country, China is still at a low agricultural modernization level, and large and modern farms or agricultural productions are scarce but medium and small contracted managements or family operations alone instead in most rural areas. Consequently, it is necessary to decide the size of power generation system according to local biomass characteristics. For example, it is better for plain areas where agriculture is relatively well developed to adapt large size system, but biomass dispersive areas must utilize effective small ones, otherwise economic benefits will not be good.

7.1.3 Biomass power generation project has to match different capital status

It isn't easy to attract big companies and investment into biomass power generation industry, because the scale of biomass power generation project is relatively small, profit is fairly influenced by policies, and the instability of biomass supply increases the difficulty to predict long term profit of investment. Particularly, because biomass power generation project has relatively small investment compared with unit project of other type power generation, there are a lot of units need to be organized for large capital investment (for example, capital of a 1000MW biomass power station have to be allocated for 100 units). Under this condition, capital management is complex and management cost is very high. So large company's enthusiasm for heavy investment in biomass power generation is not high. Instead interested investors should be medium and small enterprises and individual investors, however, insufficient capital is their common difficulty currently. Development of biomass power generation technologies is seriously restricted by lack of funds.

From the analysis in section 2, it is known that present electric industry of China is specially administrated by the State. Besides strict approving procedure, basic characteristics include big enterprises almost dominating the whole industry, intensive capital, steady return on capital, low risk, capital mainly coming from banks or financial institutions, and a little equity capital. These characteristics are in conflict with those of biomass. Therefore, development of biomass power generation must take into account these non-technological factors that will not have considerable change in the near future, and try to select biomass technologies that can meet different capital investment.

7.2 Comparison of biomass power generation technologies

In order to understand the characteristics of various biomass power generation technologies, the inner rate of returns (IRR) of them have been compared here from their biomass material cost, pool electricity purchase price, equipment investment and running time. The economic efficiency of investment is reflected through some comprehensive financial indicators, such as project's IRR and investment recovery period that depend on technical characteristic, local electricity price, biomass price, financing cost and local tax etc. In the following, four technologies have been compared. Table 7-1 shows their basic indicators. Table 7-3 to table 7-6 are their cash flow statements.

Table 7-1 Comparison of biomass power generation technologies

Indicator	Biomass power generation technology route			
Installation capacity	24MW	6 MW	6 MW	3 MW
Power generation mode	Combustion (imported)	Combustion (domestic)	Gasification (High eff.)	Gasification (simple)
Power generation efficiency (%)	25.6	19.5	25.6	18.0
Running time (hr./y)	7500	6500	6500	6000
Self consumption (kW)	2400	600	600	150
Power production (kilo kWh/y)	180000	39000	39000	18000
Biomass consumption (kg/kWh)	1.05	1.37	1.05	1.48
Biomass material price (Yuan/ton)	171	155	155	155
Expendable cost (Yuan/kWh)	0.0265	0.0265	0.045	0.05
Selling electricity (kilo kWh/y)	162000	35100	35100	17100
Fixed number of persons	150	60	60	35
Labor cost (Yuan/person. year)	25000	25000	25000	25000
Equipment maintenance rate (%)	1.5	1.5	1.5	1.5
Self-capital (kilo Yuan)	92400	13650	13650	4725
Loan (kilo Yuan)	171600	25350	25350	8775
Theoretic electricity price sold to network (Yuan/kWh)	0. 600	0. 574	0. 535	0. 551

Note:

1. Data of 24MW derived from the feasibility study report of Rudong, Jiangsu project; data of gasification projects derived from national 863 project research materials; the other was estimated according to present domestic technology possibility.
2. Biomass material prices were calculated based on 155 Yuan/ton for collection radius within 15km and 171 Yuan/ton for over 15km.
3. Self-capitals were all calculated by 35%, and the others were loan with interest rate of 5%.
4. Theoretic electricity price sold to network was calculated based on total investment's inner rate of return of 10%.

7.2.1 Influence of biomass material cost on IRR

Power generating efficiency, directly affecting the biomass material consumption (kg/kWh), primarily influences the evaluation of a technology. Generally, for one kind of technology, the larger the scale, and the higher the generating efficiency is, the lower the biomass material consumption for unit electricity. But on the other hand, large scale project requires much more biomass materials, resulting in high cost of biomass collection and storage. So comparison among different technologies should be emphasized on the influence of biomass material cost on IRR. Table 7-1 indicates that, for large scale system, generating efficiency of combustion technology is higher; for medium scale system, IGCC has much higher generating efficiency; and of same technology imported equipment have higher generating efficiency than domestic ones due to difference in equipment manufacturing.

From the comparison of existing technologies, it is known that power generation system of lower efficiency is very sensitive to the variation of material price (fig. 7-1). Higher efficiency ones can accept relative high cost material. To sum up, when the electricity price sold to network is 0.52 Yuan/ton, the material price for technologies except for biomass gasification-exhaust heat utilization technology must be controlled at about 175 Yuan/ton to assure 10% IRR, which is, however, difficult for most areas in China, especially impossible for large power generation system required mass material collection and storage (collection radius of 24MW reaches 30km, and storage capacity surpass 90000 tons).

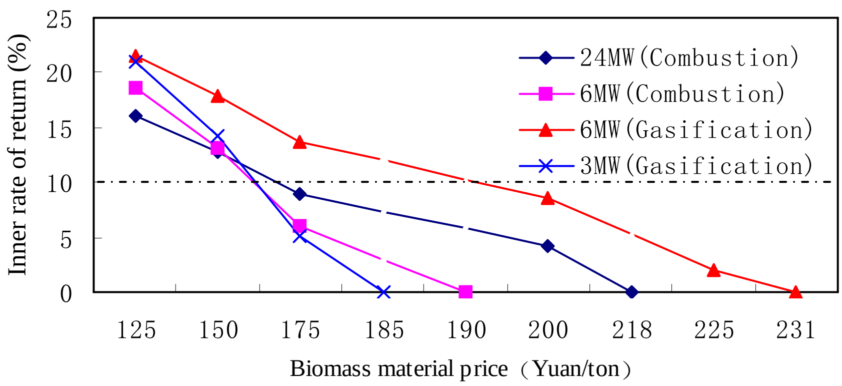


Fig. 7-1 Relationship between biomass material price and IRR

7.2.2 Influence of equipment unit investment on IRR

Unit investment of equipment is a primary parameter that indicates a technology's economic efficiency and market competitiveness. Usually, technology of low efficiency has low investment, and for same technology, the larger the scale, the lower the equipment unit investment. Noticeably, the investment of imported equipment goes far beyond that of domestic ones, which seriously influences the economic efficiency of project.

It can be seen in fig. 7-2 that, with the same investment, imported equipment for 24MW have the highest inner rate of return. However, according to present market price, namely 11000 Yuan/kW of imported equipment and 6500 Yuan/kW of domestic equipment, the domestic equipment has stronger market competitiveness than the imported one because of its higher inner rate of return even though it is not greater in power generating efficiency.

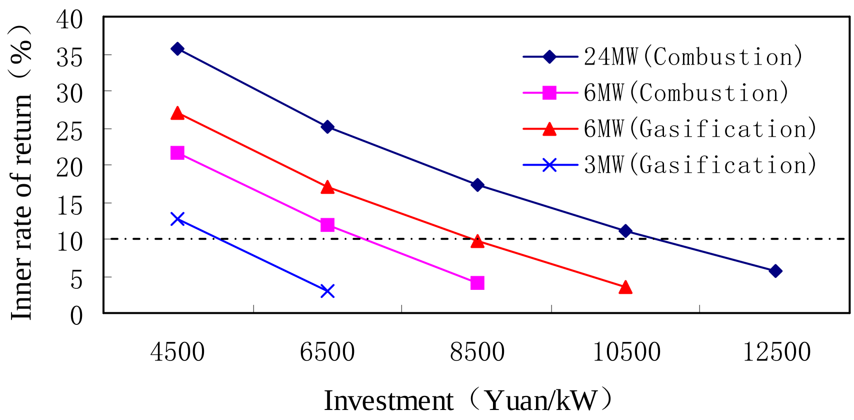


Fig. 7-2 Relationship between equipment unit investment and IRR

7.2.3 Influence of electricity price sold to network on IRR

The electricity price sold to network directly relates to power generating cost. Projects of lower generating cost may accept lower electricity price than that of higher generating cost. Generally, technology with higher generating efficiency has lower running cost, and for same technology, the larger the scale, the lower the running cost. But it should be noticed that running cost of mature technology is lower due to its low equipment maintenance rate, and that imported equipment have higher running cost due to their expensive fittings.

Fig. 7-3 indicates that in order to assure total investment's inner rate of return at about 10%, the electricity price of biomass power generation projects with imported equipment should be around 0.6 Yuan/kWh, but that of biomass gasification-exhaust heat utilization project is only 0.535 Yuan/kWh. And low efficient equipment are much more sensitive to electricity price.

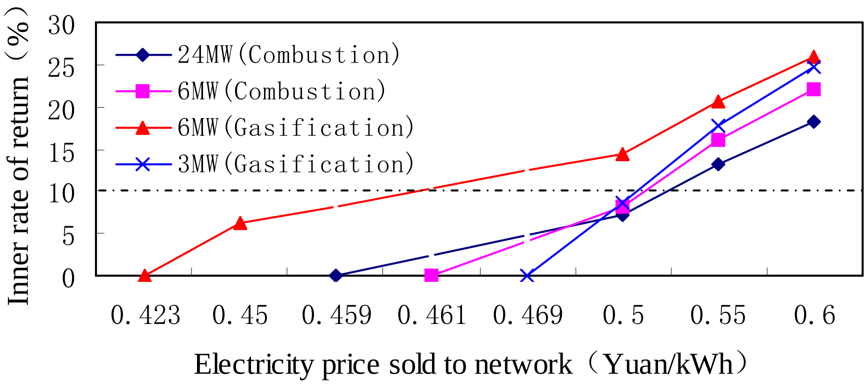


Fig. 7-3 Relationship between electricity price sold to network and IRR

7.2.4 Influence of operating rate on IRR

Operating rate mirrors the maturity character of a technology. High operating rate or long running time relate to mature technology. But the higher the operating rate designed, the higher requirement for technological reliability and stable biomass material supply.

In fig. 7-4, in order to assure 10% IRR, the running time of 24MW project has to be no less than 8000 hours per year, that is to say that the operating rate reaches 91.3%, which is very difficult to realize. Particularly for agricultural straw, complex composition, frequent alternation of available material, wide collection range and large storage make it difficult to provide stable biomass material to assure the operating rate over 90%.

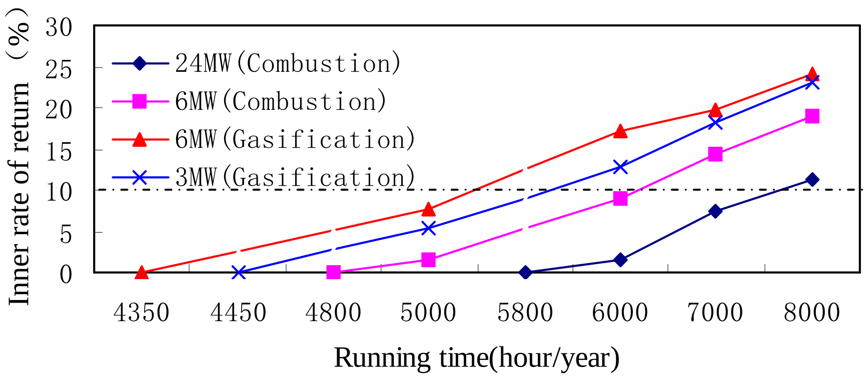


Fig. 7-4 Relationship between operating rate and IRR

From the analysis above, conclusions are made as follows:

a) According to the comparison of projects' inner rate of return, high efficient and medium scale biomass gasification power generation technology has the best economic efficiency; the worst belongs to high investment biomass direct combustion technology and low efficient small scale biomass gasification power generation technology.

b) Large-scale direct combustion technology owns higher technical efficiency and strong capability of anti-price variation of biomass material by dense capital. But it requires large biomass material supply, and the transportation cost and storage cost are high. So the material supply is difficult to manage.
c) Small-scale power generating technology owns lower technical efficiency and weak capability of anti-price variation of biomass material. However, the biomass material demand by it is not much, so relatively easy to supply.
d) Imported equipment has high generating efficiency, but the comprehensive cost is too high, seriously influencing economic efficiency. In order to enhance economic efficiency under the same technical efficiency, imported equipment price has to be reduced to about 8500 Yuan/kW, the point with possible market competitiveness.
e) Under the condition of biomass material cost of 100 Yuan/ton (excluding transportation cost and storage cost), the electricity price sold to network from biomass power station must be about 0.55-0.60 Yuan/kWh, and medium and small gasification technology or medium and small direct combustion technology are prior choices. When the previous cost is higher than 150 Yuan/ton, the electricity price must be higher than 0.60 Yuan/kWh, and medium scale gasification technology or high efficient direct combustion technology are prior choices. Based on project's scale, it is the first thing to consider the stable biomass material supply and the capability of anti- low operating rate.
f) Generally considering the factors of power generating efficiency, investment, material supply stability, etc. the scale of biomass power plant should be as small as possible under same generating efficiency. Though small station is difficult in capital management and has low investment efficiency, it is excellent in anti-risk from material supply instability, and in fact it has a low long-term investment risk.

7.3 Principles for selection of biomass power generation technology

Generally, biomass power generation project of large scale and high generating efficiency of course has good technological characteristic, but biomass material cost of too large-scale project is high and accordingly economical efficiency decreases and investment risk increases. On the other hand, too small project has bad comprehensive economical efficiency because of no scale merit. Therefore, there is an optimal economical project scale from integration of effects of these factors, and the optimal economical project scales are different for different regions and conditions. While comprehensively evaluating technologies for a certain region, it is indispensable to analyze the optimal economical scale to select the one of rational technical characteristic and economical indicators. For scale>10MW, gasification technologies have not been mature, so combustion and power generation technology is a fairly good selection; for scale<10MW, gasification technologies have advantages, especially for projects of around 5MW. Considering the above mentioned, applicability of biomass power generation technologies in China has been known as listed in table 7-2.

Table 7-2 Applicability of biomass power generation technologies in China

Scale / Technical order / Application order	**<5MW**	**5~10MW**	**>10MW**
1.Mixed burning and power generation	1. Gasification-Mixed burning 2.Combustion	1. Gasification-Mixed burning 2. Mixed burning	1. Gasification-Mixed burning 2. Mixed burning
2. CHP	1. Combustion 2. Gasification	1. Combustion 2. Gasification	1. Combustion 2. Gasification
3. Individual power generation	1. Gasification 2. Combustion	1. Gasification 2. Combustion	1. Combustion 2. Gasification

Brief summary

- Various biomass power generation technologies were compared by their inner rate of return. High efficient and medium scale biomass gasification power generation technology has the best economic efficiency. Large scale direct combustion technology owns higher technical efficiency and strong capability of anti-price variation of biomass material by dense capital. But it requires large biomass material supply and costs high. Small scale power generating technology owns lower technical efficiency and weak capability of anti-price variation of biomass material. However, the biomass material demand of it is not much, so relatively easy to supply. From the view of anti-risk from material supply instability, the scale of biomass power plant should be as small as possible under same generating efficiency.
- While comprehensively evaluating technologies for a certain region, it is indispensable to analyze the optimal economical scale to select the one of rational technical characteristic and economical indicators. For scale>10MW, gasification technologies have not been mature, so combustion and power generation technology is a fairly good selection; for scale<10MW, gasification technologies have advantages, especially for projects of around 5MW.

Table 7-3 Cash flow statement of 24MW biomass combustion power station（capital 35%, discount rate 9.76%）

Financial year	Cons.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Electricity price (Yuan/kWh)	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52
Biomass material price (Yuan/ton)	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
Running time (hour/y)	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
Income (kilo-Yuan/y)	0	84240	84240	84240	84240	84240	84240	84240	84240	84240	84240	84240	84240	84240	84240	84240
Fixed assets recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		13200
Cash flow recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1000
Cash inflow（kilo-Yuan/y）	**0**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**	**84240**
Fixed assets (kilo- Yuan)	92400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow (kilo-Yuan/y)	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Material cost (kilo-Yuan/y)	0	32130	32130	32130	32130	32130	32130	32130	32130	32130	32130	32130	32130	32130	32130. 0	32130. 0
Expendable cost (kilo-Yuan/y)	0	4770	4770	4770	4770	4770	4770	4770	4770	4770	4770	4770	4770	4770	4770. 0	4770. 0
Maintenance cost (kilo-Yuan/y)	0	3960. 0	3960	3960	3960	3960	3960	3960	3960	3960	3960	3960	3960	3960	3960. 0	3960. 0
Labor and mgt. cost (kilo-Yuan/y)	0	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750. 0	3750. 0
Loan payback (kilo-Yuan)	0	11440	11440	11440	11440	11440	11440	11440	11440	11440	11440	11440	11440	11440	11440. 0	11440. 0
Sales tax (kilo-Yuan/y)	0	7160	7160	7160	7160	7160	7160	7160	7160	7160	7160	7160	7160	7160	7160. 4	7160. 4
Interest (kilo-Yuan/y)	0	8580	8008	7436	6864	6292	5720	5148	4576	4004	3432	2860	2288	1716	1144. 0	572. 0
Cash outflow (kilo-Yuan/y)	**93400**	**71790**	**71218**	**70646**	**70074**	**69502**	**68930**	**68358**	**67786**	**67214**	**66642**	**66070**	**65498**	**64926**	**64354**	**63782**
Income tax (kilo-Yuan/y)	0	1867	1953	2039	2125	2211	2296	2382	2468	2554	2640	2725	2811	2897	2983	3069
Accumulation (welfare) fund (kilo-Yuan)		1867	1953	2039	2125	2211	2296	2382	2468	2554	2640	2725	2811	2897	2983	3069
Net cash flow after tax (kilo-Yuan/y)	−93400	8715	11068	11555	12041	12527	13013	13499	13986	14472	14958	15444	15930	16417	16903	17389
NPV after tax (kilo-Yuan/y)	−93400	7864	9013	8491	7985	7496	7027	6578	6150	5743	5356	4991	4645	4320	4014	3726
Accumulative net cash flow after tax (kilo-Yuan)	−93400	−84685	−73617	−62062	−50022	−37495	−24481	−10982	3003	17475	32433	47877	63808	80224	97127	114516
Financial NPV after tax (kilo-Yuan)	−93400	**−85536**	**−76523**	**−68032**	**−60047**	**−52551**	**−45524**	**−38946**	**−32796**	**−27053**	**−21697**	**−16706**	**−12061**	**−7741**	**−3727**	**−1**

Table 7-4 Cash flow statement of 6MW biomass combustion power station（capital 35%, discount rate 11.86%）

Financial year	Cons.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Electricity price (Yuan/kWh)	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Biomass material price (Yuan/ton)	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155
Running time (hour/y)	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500
Income (kilo-Yuan/y)	0	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252
Fixed assets recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1950
Cash flow recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1000
Cash inflow（kilo-Yuan/y）	**0**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**18252**	**20202**
Fixed assets (kilo- Yuan)	13650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow (kilo-Yuan/y)	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Material cost (kilo-Yuan/y)	0	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7	8281.7
Expendable cost (kilo-Yuan/y)	0	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5	1033.5
Maintenance cost (kilo-Yuan/y)	0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0	585.0
Labor and mgt. cost (kilo-Yuan/y)	0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0
Loan payback (kilo-Yuan)	0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0	1690.0
Sales tax (kilo-Yuan/y)	0	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1551.4	1717.2
Interest (kilo-Yuan/y)	0	1267.5	1183.0	1098.5	1014.0	929.5	845.0	760.5	676.0	591.5	507.0	422.5	338.0	253.5	169.0	84.5
Cash outflow (kilo-Yuan/y)	**14650**	**15909**	**15825**	**15740**	**15656**	**15571**	**15487**	**15402**	**15318**	**15233**	**15149**	**15064**	**14980**	**14895**	**14811**	**14892**
Income tax (kilo-Yuan/y)	0	351.4	364.1	376.8	389.5	402.1	414.8	427.5	440.2	452.8	465.5	478.2	490.9	503.5	516.2	796.5
Accumulation (welfare) fund (kilo-Yuan)		351.4	364.1	376.8	389.5	402.1	414.8	427.5	440.2	452.8	465.5	478.2	490.9	503.5	516.2	796.5
Net cash flow after tax (kilo-Yuan/y)	-14650	1640.1	2063.3	2135.1	2207.0	2278.8	2350.6	2422.4	2494.3	2566.1	2637.9	2709.7	2781.6	2853.4	2925.2	4513.7
NPV after tax (kilo-Yuan/y)	-14650	1445.5	1602.9	1462.0	1331.9	1212.2	1102.1	1001.1	908.5	823.8	746.4	675.8	611.5	552.9	499.6	679.4
Accumulative net cash flow after tax (kilo-Yuan)	-14650	-13010	-10947	-8811	-6605	-4326	-1975	447	2942	5508	8146	10855	13637	16490	19416	23929
Financial NPV after tax (kilo-Yuan)	-14650	-13204	-11602	-10140	-8808	-7595	-6493	-5492	-4584	-3760	-3013	-2338	-1726	-1173	-674	6

Table 7-5 Cash flow statement of 6MW biomass gasification power station（capital 35%, discount rate 17.15%）

Financial year	Cons.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Electricity price (Yuan/kWh)	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52
Biomass material price (Yuan/ton)	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155
Running time (hour/y)	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500
Income (kilo-Yuan/y)	0	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252
Fixed assets recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1950
Cash flow recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1000
Cash inflow（kilo-Yuan/y）	0	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	18252	20202
Fixed assets (kilo- Yuan)	13650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow (kilo-Yuan/y)	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Material cost (kilo-Yuan/y)	0	6347	6347	6347	6347	6347	6347	6347	6347	6347	6347	6347	6347	6347	6347	6347
Expendable cost (kilo-Yuan/y)	0	1755	1755	1755	1755	1755	1755	1755	1755	1755	1755	1755	1755	1755	1755	1755
Maintenance cost (kilo-Yuan/y)	0	585. 0	585	585	585	585	585	585	585	585	585	585	585	585	585	585
Labor and mgt. cost (kilo-Yuan/y)	0	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Loan payback (kilo-Yuan)	0	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690
Sales tax (kilo-Yuan/y)	0	1551	1551	1551	1551	1551	1551	1551	1551	1551	1551	1551	1551	1551	1551	1717
Interest (kilo-Yuan/y)	0	1268	1183	1099	1014	930	845	761	676	592	507	423	338	254	169	85
Cash outflow (kilo-Yuan/y)	14650	14696	14612	14527	14443	14358	14274	14189	14105	14020	13936	13851	13767	13682	13598	13679
Income tax (kilo-Yuan/y)	0	533	546	559	571	584	597	609	622	635	647	660	673	685	698	978
Accumulation (welfare) fund (kilo-Yuan)		533	546	559	571	584	597	609	622	635	647	660	673	685	698	978
Net cash flow after tax (kilo-Yuan/y)	−14650	2489	3094	3166	3238	3310	3382	3453	3525	3597	3669	3741	3813	3884	3956	5545
NPV after tax (kilo-Yuan/y)	−14650	2062	2124	1801	1526	1292	1094	925	783	662	559	472	399	337	284	330
Accumulative net cash flow after tax (kilo-Yuan)	−14650	−12161	−9067	−5901	−2663	647	4029	7482	11007	14604	18273	22014	25827	29711	33667	39212
Financial NPV after tax (kilo-Yuan)	−14650	−12588	−10464	−8663	−7138	−5846	−4752	−3827	−3044	−2383	−1824	−1351	−953	−616	−332	−2

Table 7-6 Cash flow statement of 3MW biomass gasification power station（capital 35%, discount rate 12.70%）

Financial year	Cons.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Electricity price (Yuan/kWh)	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52	0. 52
Biomass material price (Yuan/ton)	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155
Running time (hour/y)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Income (kilo-Yuan/y)	0	8892	8892	8892	8892	8892	8892	8892	8892	8892	8892	8892	8892	8892	8892	8892
Fixed assets recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		675
Cash flow recovery	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1000
Cash inflow（kilo-Yuan/y）	**0**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**8892**	**9567**
Fixed assets (kilo- Yuan)	4725	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow (kilo-Yuan/y)	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Material cost (kilo-Yuan/y)	0	4129	4129	4129	4129	4129	4129	4129	4129	4129	4129	4129	4129	4129	4129	4129
Expendable cost (kilo-Yuan/y)	0	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
Maintenance cost (kilo-Yuan/y)	0	202. 5	203	203	203	203	203	203	203	203	203	203	203	203	203	203
Labor and mgt. cost (kilo-Yuan/y)	0	875	875	875	875	875	875	875	875	875	875	875	875	875	875	875
Loan payback (kilo-Yuan)	0	585	585	585	585	585	585	585	585	585	585	585	585	585	585	585
Sales tax (kilo-Yuan/y)	0	756	756	756	756	756	756	756	756	756	756	756	756	756	756	813
Interest (kilo-Yuan/y)	0	439	410	380	351	322	293	263	234	205	176	146	117	88	59	29
Cash outflow (kilo-Yuan/y)	**5725**	**7886**	**7857**	**7828**	**7799**	**7769**	**7740**	**7711**	**7682**	**7652**	**7623**	**7594**	**7565**	**7535**	**7506**	**7534**
Income tax (kilo-Yuan/y)	0	151	155	160	164	168	173	177	182	186	190	195	199	204	208	305
Accumulation (welfare) fund (kilo-Yuan)		151	155	160	164	168	173	177	182	186	190	195	199	204	208	305
Net cash flow after tax (kilo-Yuan/y)	−5725	704	880	905	929	954	979	1004	1029	1054	1079	1103	1128	1153	1178	1728
NPV after tax (kilo-Yuan/y)	−5725	615	670	602	540	484	433	388	347	310	277	248	221	197	176	225
Accumulative net cash flow after tax (kilo-Yuan)	−5725	−5021	−4141	−3237	−2307	−1353	−374	630	1659	2713	3792	4895	6024	7177	8355	10083
Financial NPV after tax (kilo-Yuan)	−5725	**−5110**	**−4440**	**−3838**	**−3298**	**−2814**	**−2381**	**−1993**	**−1646**	**−1335**	**−1058**	**−810**	**−589**	**−392**	**−216**	**9**

8. Influencing factors in Chinese biomass power generation development

8.1 Limiting factors

There are three limiting factors: technological, economic and policy factors. This is different from that of other countries due to Chinese national situation and conditions.

8.1.1 Technological limiting factor

Research on biomass power generation technology in China is few due to short fund input to research and weak development ability of energy equipment enterprises. Recent over ten years, related research basically focused on medium and small biomass gasification technology, and combustion technology was developed independently by boiler or other pyrolysis equipment enterprises. In Present China, a few biomass gasification and power generation systems are being demonstrated, but other technologies, such as biomass combustion and mixed burning, have very little practical application. So that there is a lack of mature technologies, and the whole R&D is weak.

Singly depending on domestic technology is insufficient to extensively expand biomass power generation utilization. Simultaneously, relatively weak machining and manufacturing of industrial equipment makes it difficult to absorb foreign advanced technology. In addition, crop residues as the primary biomass resource of China and components different from foreign biomass result in obvious difference in requirements for equipment and generating conditions. These factors indicate that when introducing foreign advanced biomass power generating technologies, China must select those suitable to local biomass characteristics, control level and technology absorbing capability, and should not unilaterally aspire after large scale, high efficiency and full automation, preventing unnecessary waste and inadaptation.

8.1.2 Economic limiting factor

Biomass power generation projects are all small compared to other types of power generation projects, besides relatively high generating cost, difficult financing and low capital intensity. Large companies and investors usually keep cautious to its dispersive capital and difficult management. Though investment in biomass power generation project is around several or tens million Yuan RMB, that is not very easy for most medium and small enterprises, especially those in agricultural area, to finance at present. Biomass power generation technology has not been well socially known, and banks also keep cautious to provide loans for bad investment risk (particularly without policy support). Under this circumstance, capital lack will continue to hinder the technology from expansion in short period if no relevant measures are taken.

8.1.3 Policy limiting factor

There are some policy supports from governments for development of renewable energy in China, but there are still many undefined points in these support policies that are difficult for most local administrations to bring into effect. Biomass power generation technology is facing the same problem too. Moreover, these incentive policies are based on previous planned economy, and feature in guidance and support but not compulsiveness, and without effective economic measures to complete them. These cause difficult operation of renewable energy power generation project. For example, the preferential electricity price for renewable energy is at the cost of benefits of local power grids, the influence was not obvious before when all grids belonged to the State, but now this price policy markedly damages local interests when the grids become independent accounting system. The difficulty for local grids to apply for national subsidy directly influences their enthusiasm for developing renewable energy electricity. Though biomass power generation capacity is relatively small, but it deals with much more project items in wide scope. So it is impossible to mass utilization of the technology if the policy's limiting factor unresolved.

8.2 Policy requirements for biomass power technology development in China

At Present, the development of renewable energy generation technology, especially biomass energy, in China is obviously limited by lack of effective policy and social consciousness. Because in many people's mind, biomass is more close to traditional energy, so many local administrations have little awareness of its available preferential policies. Another reason is that biomass power generation projects are almost small ones, even relative to wind energy. According to existing national policy, biomass power generation project of several hundred kW must go through the approved procedure of initialization, feasibility study and preferential electricity price application etc. Cost of time and expenses for the procedure is a heavy burden for biomass project's capacity and benefit. These are disadvantages to social investors' enthusiasm. Therefore, specific and feasible supporting policies are required to be established.

8.2.1 Standardized project initialization procedure

Under general circumstance of support from State legislation, operable project initialization management measures must be established for biomass power generation project and put into effect through all level finally to local administrations. Especially in agricultural areas, authorities of administration and coordination should be defined, and it is necessary to make investors know clearly the application procedure and requirements.

8.2.2 Normative qualification certification procedure

There are great difference in technical indicator, capital required and economic benefit among various projects of biomass power generation technologies because of their great difference in biomass material, capacity and technological process. As a result, it is not easy to have a simple standard. So administrations must set strict and specific qualification certification and admittance conditions related to environmental impact and other social benefits. Particularly for gasification-mixed burning and power generation technology, which has good economical efficiency, these normative certification and supervision will promote its application.

8.2.3 Market environment of fair competition

The cost of biomass power generation depends upon local characteristic of biomass resources and technologies. It is higher than the cost of traditional electricity, and even higher than wind energy power generation. Besides the common advantages of renewable energy, biomass energy still belongs to rural energy. Power generation from biomass has special meaning in China for promoting rural output and improving rural economy and providing employment for farmers. Administrations should consider these social and environmental benefits when they constitute incentive policies for renewable energy power generation in a market environment of fair competition.

Brief summary

Application of biomass power generation technology in China is limited by technological, economic and policy factors. Technological factor: in Present China, a few biomass gasification and power generation systems are being demonstrated, but other technologies, such as biomass combustion and mixed burning, have very little practical application. So that there is a lack of mature technologies, and the whole R&D is weak. Economic factor: Biomass power generation projects are almost of small scale, and investment is relatively high. Big investors are not very willing to support financially, and little investors have limited capital. It is also difficult to obtain loans. Policy factor: State policy of renewable energy features in guidance and support but not compulsiveness, and without effective economic measures to complete it. These cause difficult operation of renewable energy power generation project.

9. Ways for China to develop large-scale biomass power generation

9.1 Development of multiform biomass power generation technologies

In China, diverse crop residues as the primary biomass resource and the imbalance in economic development among wide rural areas determine that biomass power generation technology must develop in multiple forms: various scales develop together according to biomass resources supply; technologies of combustion, gasification and mixed burning develop together for different purposes. While evaluating the adaptability of biomass power generation technologies, following aspects may be considered.

9.1.1 Purpose of project

Technologies have their own advantages for certain purpose. It must be clear that the project is single power generation or CHP, and the biomass is utilized alone or mixed with other fuels. Usually, CHP project prefers combustion technology; mixed burning project prefers gasification technology; single power generation project still needs to analyze local resource characteristic, scale required and economic level etc.

9.1.2 Types and characteristic of biomass resources

Different types and characteristic of biomass resources have different requirements for power generation technologies. High water content biomass is suitable for combustion technology, the dry for gasification; single biomass utilization prefers combustion and power generation technology, and multiple resources utilization prefers gasification and power generation technology because of its built-in material pretreatment system and simpler design of gasifier than that of boiler.

9.1.3 Project scale must be suitable to local biomass and industrial level

Under same technological level or economic benefit, the smaller the project scale, the lower the investment risk, and more feasible the operation. Therefore, smaller project is preferential under same conditions. Particularly, too large-scale biomass power station should not be set up at areas with low economic level and dispersive multiple crops even widely varying every year. Large biomass power station is only suitable for areas with high agricultural modernization, convenient transportation, mass agricultural planting and high economic and management level, though their cost of biomass storage and supply is higher. Otherwise, there will be problem of biomass supply for large project.

9.2 Diversification of investment on biomass power generation project

Due to the characteristic of biomass, China should develop small biomass power generation principally. Hence, the projects are dispersive and the investment is usually not big. Biomass projects distribute in rural areas, tying up with agricultural development. They can be regarded as a part of rural economy in a long view. It is unpractical to depend on investment only from large companies or State. It should be right to create conditions for diversification of investment such as from township enterprises, individual enterprises and other social capital. Policy establishment and management related to biomass power generation is obviously different from that of wind energy: on the one hand, it would be emphasized that biomass power generation is a part of modern agriculture and an important way to promote economy of rural areas, since it is combined with modern agricultural economy; on the other hand, administrations should strengthen guidance and management to attract social capital to biomass project to form a booming industry with diversification of investment.

Brief summary

The economic development level and other conditions in different areas of China are not the same. So biomass power generation technology must develop in multiple forms. On another hand, biomass stations are dispersively distributed, and investment of them is usually small. Therefore, it should be right to create condition for diversification of investment such as from township enterprises, individual enterprises and other social capital.

10. Conclusions

(1) The most emergent problems of China's power system include unreasonable electricity structure, serious pollution from production, electrical source distribution incommensurate to current economic development, high electricity cost and hidden troubles of power grid safety.

(2) The electricity supply situation in China is very severe at present. Energy production from biomass has strategic significance in resolving some problems of electricity supply and environment to some extent. But the electric industry of China is administrated by the State, with the characteristics of high capital intensity and high admittance conditions. So presently the main investors are still large state-owned enterprises. Therefore, developers will face difficulties from related system structure in development of biomass electricity.

(3) China has tremendous biomass resources, but with crop residues as the primary in a long time. Therefore, there exist obvious difficulties in biomass supply, such as dispersive distribution of biomass, high collection cost and transportation cost, and seasonal influence on stable biomass material supply.

(4) Dispersive distribution of crop residues determines that medium and small power stations will be primary application for biomass power generation in China. But they have low efficiency, scattered capital and management difficulty, which are inconsistent with present electricity status. So, biomass power generation technology must develop according to these characteristics to maximize benefit, but can't fully copy traditional or foreign energy technologies.

(5) Biomass power generation technologies have been maturely applied in the world. Foreign countries have much successful experience in biomass direct combustion and power generation technology, and China has well accumulated in biomass gasification and power generation technology but less in biomass combustion experiences. Because China's industrial manufacture level is relatively low, general manufacture and production ability of biomass power generation related equipment is not strong. So in the future, equipment manufacture must be strengthened to reduce project investment cost.

(6) The general economical efficiency of biomass power generation technology is still low. The most competitive one among them is the technology of biomass gasification- mixed burning with coal. Its running cost is 0.25—0.3 Yuan/kWh. But there is management difficulty in practice. Other's running cost is 0.3—0.4 Yuan/kWh (excluding depreciation). This means that national special policy support is necessary to rapid development of biomass power generation technology.

(7) Through analysis of the influence of biomass material cost, pool electricity purchase price, equipment investment and running time on the inner rate of returns (IRR), followings are found: high efficient and medium scale biomass gasification power generation technology has the best economic efficiency. Large-scale direct combustion technology owns higher technical efficiency and strong capability of anti-price variation of biomass material by dense capital. But it requires large biomass material supply and costs high. Small-scale power generating technology owns lower technical efficiency and weak capability of

anti-price variation of biomass material. However, the biomass material demand of it is not much, so relatively easy to supply.

(8) Considering the general economic development status and biomass power generation characteristics, China should improve policy conditions for biomass power generation development, and simultaneously encourage development of multiform biomass power generation technologies and diversification of investment.

Part 2: Expert Workshop Report on "Analysis of Potential in China for Improvement in Biomass Power Generation Technology"

Based on the previous report and other reports of the project of Analysis of Potential in China for Improvement in Biomass Power Generation Technology, experts and researchers specializing in biomass energy utilization assembled in the Expert Workshop on the subject to discuss on some key questions of Chinese biomass power generation technology route, develop mode and measure, etc.

1 The evaluation of the report

The report of "Analysis of Application of Biomass Power Generation Technology in China " is a detail consultation report on the development of biomass power generation technology as one important type of renewable energy in China. While ***"Law on Renewable Energy"*** is about to take effect and the clarified price of electric power generated by biomass has not been regulated, it is important and timely to carry on the study of "Analysis of biomass power generation technology and its utilization in China". Biomass power generation is a huge impetus to utilize residual and wasting biomass resources in the country or forest field sufficiently, develop biomass energy, improve environment, develop rural economy; biomass power generation fits the development of distributing energy system rightly, approaching terminate consumer closer, and having great positive effect on both energy saving and emission reducing of CO_2. In a word, developing biomass power generation technology will take effect on supporting agriculture, saving energy, developing renewable energy, protecting environment and decreasing green house gas, which has a huge strategic meaning of China economic development.

The report - 'the Analysis of Biomass Power Generation Technology Applied in China' has reasonable structure. The composition of ten sections is suitable. With abundant content, correct point and plentiful proof, this report is very adapted to Chinese own conditions. The report thoroughly analyzed the problems presenting in biomass power generation in China such as the shortage of the traditional energy resources, unreasonable electrical structure, severe pollution, generation and transportation with high cost, hidden trouble in electric meshwork security and the strategic meaning of biomass energy as an important segment of energy strategy in China.

Comparatively comprehensive analysis is given on physical character，distribution situation and supply feature of biomass resources taking agricultural residue as important resources. A great deal of investigation and analysis on Chinese biomass resources has been carried on. In addition, the storage, distribution, collection and transportation of biomass resources are evaluated in detail, which can provide the quantity gist for industrial development of Chinese biomass power generation. The investigation has largely updated and structured the information base for biomass based power generating technology market analysis and public policy design.

Component of biomass power generation items and economic performance of different scale of biomass power generation items are analyzed in detail and rightfully, comprehensive comparison is given on all kinds of biomass power generation technology. This report plays a guide role in developing Chinese biomass power generation technology. From the analysis on the factors that are restricting the development of biomass power generation in China nowadays, the existing problems in power generation by biomass are found. To a certain extent, the research object of the technology and stratagem of biomass power generation is confirmed. The conclusion of the report will be the important guidance for government to the constitution of policy on biomass power generation.

Encouraging technologies of biomass power generation towards multi-technology routes, establishing the fair rivaling market and realizing multi-investing, those suggestions given by this report is adapted to Chinese condition and they are very important to boost the industrialization of biomass power generation. This conclusion is especially important for China's biomass power generation development considering the biomass power generation is just at its starting-up stage in China.
The technology assessment and financial analysis of alternative biomass based power generating technologies carried out in this study have provided important information for the determination of the feed-in tariff levels of the major biomass based power generating technologies, thus could contribute to the coming up of implementing regulations of ***"Law on Renewable Energy"*** which was passed in February 28, 2005. The content in the report including the economic data, lately electric rating on the network, the study about the obstacle of electric project management on the development of biomass power technology can be used as the reference to making the encouragement policy by government.

Biomass power plant has the significant meaning for adjusting peak-valley of electric network. For the flexibility of the biomass power generation and storability of biomass resources, the biomass power generation would play a role of variable load plant for the Chinese electric network with several-ten-million kilowatts capacity, which can save the investment on the stand-by equipments and build up the biomass power plant or variable load plant in the Chinese style.

2 The discussion about key problem

There are the key problems of technical progress in the expert workshop as following:

2.1 Total quantity of biomass resource

China is rich in biomass resources and has a huge reservation. But the resources mainly come from agricultural residuals in long term. So, there exist a distinct shortcoming in feedstock supply, with features of decentralization, high cost in collection and transportation, big changes in different seasons round year and instability. The situation in China is not the same as abroad: annual trading volume of straw is small since the farmers perform their production in household basis. For large-scale biomass power generation, its cost might be high. Besides, crop rotation system in agriculture of China is not the same as that of abroad, resulting in problem of collecting straw. One of preconditions for biomass power generation in future China is to have ample resource for it.

To utilize the biomass energy, it is very important to carry out investigation and make our fundamental resources known clearly. And utilization of biomass should be on basis of regional planning. Utilization may be considered only with resource evaluation having made. The supplying maximum of biomass resource should be forecasted. Except narrow straw resource, other biomass resource should be taken into consider. The abundant forest resource has not been utilized. According to the latest statistics, growing stock volume on forestland in China was about 8 000 million solid –m^3 in the year 2000. There are about 7,000 sawmills producing about 17 million m^3 of sawn goods in 1999. According to the consultant's estimation, sawmilling by-products would annually include 20 million m^3 of wood processing waste with a total energy content of about 37 TWh. Only a small fragment of this biomass potential is currently utilized in energy production. Forest resource will be dominant in biomass energy. The density of forest resource is higher than straw resource and is easy to be transported and stored.

One of preconditions for biomass power generation in future China is to have ample resource for it. The development of biomass resource should be noticed to sustain the large-scale development of biomass power generation industry. Based on the prediction of biomass resource, to display the status of biomass power generation industry in the future energy structure, the predicting contribution of biomass power generation to China power should be made. By the prediction, we can also know whether biomass power generation industry agrees with energy development strategetic objectives of country. Power plants of biomass could not control the price of straw. It is necessary to consider the industrialization of biomass power generation in framework of entire industrial system. It is feasible only if its fuel purchase and cost mechanism is stable.

Energy plantation is a right measure to magnify the supply of biomass resource and valorize. Energy plantation can decrease the market risk and the passive situation of purchasing biomass from farmers will be ended. Energy plantation can do good to circumstance and desert management. I hope that more energy wood would be planted in the next five years. The industrialization of biomass energy will accelerate the development of energy agriculture, energy plantation and energy industry.

2.2 Price of the biomass resource

Collection of straw is one of problems appearing in approved projects. Collection direct from farmers means high cost, resulting in increase of electricity price and decrease of income. The first problem should be resolved is the collection of biomass resource before the technical progress. It is necessary to research the method of biomass collection.

The development and utilization of biomass energy will change the products made by peasants into valuable resources and enrich the rural areas. Once the peasants' products that are discarded in the field before are purchased as materials, the price will soar.

According to expert opinion, we should not only consider interest of power plant in the collection of resource, it is necessary to consider interest of farmers too. It is possible to transfer some interest onto farmers. If the peasants realize that the utilization of agricultural residue resources will benefit themselves, they will have a good mood in the purchasing of biomass resource and be honest. The collaboration module for ages of biomass collection is more important than the research on transport costs, and should be established before technical progress.

The price of biomass resource will rise from 400 Yuan/ton to 600 Yuan/ton with the change of the peasant's idea. It is difficult to deal with the problem of peasant. The market is the only measure. Only if the stalk is waste and valueless, can we build power plant. Timber mills have plenty of wood wastes to develop autarkic power plant. In addition, many corporations have enough biomass resource to built a power plant. Energy plantation is a right measure to deal with the problem of energy resource and decrease the market risk.

It is advised by some experts that the peasant can change stalk for power generation to avoid the purchase by money? For example, the peasants maybe barter 2kg stalk for 1kwh electricity. The forest mills have adopted the measure. Peasant can exchange wood crumb for biomass coal. The measure is appropriate to a little-scale biomass plant, but it cannot be used in large-scale power plant.

2.3 The biomass power generation technology options

Encouraging technologies of biomass power generation towards multi-technology routes, establishing the fair rivaling market and realizing multi-investing, those suggestions given by this report is adapted to Chinese condition and they are very important to boost the industrialization of biomass power generation.

The environment inside and outside is so good to develop regenerated energy. There are several technology mode, such as mixed burning, direct combustion and biomass gasification. Different person has different idea, and different selection of different lines. Technical line will be selected based on local particular situation. This is important for reducing risk in deciding policies and for avoiding miscarriage in policies.

There are very different situations in various parts of China. Therefore, it is not possible to utilize a single technology for all cases. In terms of the character of the biomass resource and present biomass technology, there is the contrast of mixed burning, direct combustion and biomass gasification as followings:

Technical feasibility required that biomass power generation with direct combustion should be in certain larger scale or larger. Cost is one of important factors. Biomass fuel requires collection of biomass in large scale with higher transportation cost. It is still not feasible to utilize technology of direct combustion in small-scale systems. It is not possible in the near future to develop technology of direct combustion in China. In future, development of direct combustion is promising if there is sufficient biomass resource available. Moreover, developing direct combustion will take effect on protecting environment. Power generation technology by straw direct combustion has characteristics of technical maturation, huge consumption of straw, no pollutant in the whole production process, realization of zero emission of CO_2 in energy utilization, so it's perhaps a feasible technical route of conversion from much residual crop straw to biomass energy.

It was expounded that China has gotten well technology accumulations in the field of power generation from biomass gasification. However, in order to reduce the cost of investment, we should energetically strengthen the capability of equipment manufacture. There is the opinion of some expert as following: While evaluating gasified power generation technology in China, the major technology problems of tar handling and secondary pollution are not introduced. However, it's really a technical and financial problem needed settling in developing power generation technology by biomass gasification. According to the commercialization demand, combined with constructed projects, the technical route of power generation by straw gasification and its economic feasibility, especially include the problems of tar and secondary pollution, should be further post-estimated. Without complete solving these problems, it is very difficult for the power generation by biomass gasification to gain industrial support and to make a big progress in China. Experts expounded that the tar technology had been mature, but its cost is too high. The disposal of tar will influence seriously the earnings of little-scale biomass power plant. But the operation cost of a large-scale power plant will not increase a lot with the adoption of corresponding equipment to resolve the problems of tar and secondary pollution.

Under existing technology, it is hard to say which technique is good and which one is bad. Fluidized bed would be good choice for cotton stalk, which is of high density, while fixed bed----for lighter straw. There is the opinion of some expert as following: On diversification of technical lines, it is mentioned that gasification power generation is suitable to medium and small scale. It is also important to consider which technology has more promising prospect. Professor Zhang have a technical line for the experts' consideration, i.e. alteration of small thermal power plants with following technical line: gasification of biomass - power generation with mixed and supporting combustion in small thermal power plants. Supporting combustion with product of gasified biomass will enhance combustion efficiency in addition to low initial investment. Small thermal power plants use chain boilers in size of tens of tons. This will solve the problem of cost for biomass raw material. It is suggested that gasification of biomass - power generation with mixed and supporting combustion will be a technical line supported by CRESP.

At present, for small-scale power plant that is appropriate to current resources, such as power generation with gasification and proper mixed combustion with mixture proportion of 5%~10%, raw material of biomass for its development may be ensured. For 60 MW of mixed combustion generation with biomass proportion of 10%, the equivalent generation with biomass is 6MW. The fuel will be sufficient under this condition. The bigger biomass energy system (the capability of generating electric power is 1 to 10 MW) should use the technology of mix burning of biomass with coal and be combined with the coal-fired plant in the county. There are several advantages as followings:

(1) The fuel will be sufficient.

(2) Removing the process of combustible gas cooling and purifying, which will increase the efficiency and avoid problem comes from tar.

(3) The equipment can be installed flexibly.

At present, generator sets in power plants of county level is small, and of low efficiency and high coal consumption. With support from State policies, mixed combustion with gasified biomass would be a good choice. Its scale may be large or small. For power plants of county level, it is possible to solve problem of fuel for mixed combustion: less mixture may be used in seasons when biomass resource is less and more mixture-- in seasons when biomass resource is more. Installed capacity for mixed combustion of gas and coal may be between 10-15 MW. Generating efficiency of small power plants is too low. Very large power plants of direct combustion are not suitable to China.

Whether the power generation technology of gasification or direct burning, both can be spread though China only after being tested and identified fully. All rash or blind advances would bring on the numerous waste of the social resource.

This Report considers the reality of China and does not simply "move" technologies for plants of large scale into China. The report indicated that according to the analysis of material cost, electrical price in the grid, equipment investment and the run time etc. which influenced the yield of the interior investment, the high efficiency, middling scale biomass power generation technology is economically optimized; the large scale technology of direct combustion bear the higher efficiency, but material demand is huge, cost is high; though the efficiency is relatively low in mini-scale, the material demand is small, supply is easy to ensure and the cost of fuel can be decreased.

In European, projects of small scale are out of their consideration. For China, investment is an important factor to be considered. Transportation of fuel is another restriction. However, although the biomass resource is abundant in China, the resource is distributed widely over the country. The difficulty of collecting the separate resources is a hurdle in developing the technology. Dispersive agricultural wastes determines to develop biomass energy stations in middle and small scale in China, but it’s low efficiency, dispersing invest and management in middle and small biomass energy stations, and faces with convention with big demands of electric power in China. In other words, to use biomass power generation is good for building separated energy plant. It should be built in remote areas where have plentiful biomass resources but lack power.

The purport of mini-type power plant is to provide distributed energy. Distributed power plant has finite capacity, but disperses widely. It is an appropriate measure for the problem of rural economic and energy. The society benefit brought by biomass energy is more important than the large scale and high efficiency. The large-scale of biomass power generation does not mean the capacity of every individual power plant, it means the total number of applications.

Some expert suggested that the positive effect of small-scale biomass power plant should be properly identified. To the economic analysis on the biomass power generation, the gasification biomass power plant below the capability of 100KW should be treated actually. It is needed that the specific discussion on the economy and feasibility of the small-size power plant that is self-supplying and self-capitalizing. In this way, On the one hand, the biomass resources can be utilized efficiently, On the other hand, it will persuade the government to give up the regulation on the restriction to the small-size power plant accessible to the main electric network.

But the conclusion was opposed with the following opinion. The large-scale projects of biomass power generation are a key problem the experts should focus. As rural energy, biomass energy will have no chance to be a member of mainstream industry. The stagnancy of technical progress of biomass energy should be ended and enters into the industrial mainstream. A rising industry will die on the vine without the entrance to industrial mainstream.

In Europe, wheat stalk is dominating in agriculture waste, but wheat stalk is valuable in Jiangsu (wheat stalk can be used in paper making). The biomass fuel is multiform in China, but the oversea product is designed for simplex biomass fuel. During the introducing of oversea product, it is important to pay attention to the difference of fuel. So, if China wish to develop electric power by biomass, it should aim at developing owe technologies by applying agricultural residuals. It couldn’t copy traditional and oversea technologies at all.

The application of compression-molding technology of biomass will expand its collection radius. The biomass fuel can be used as coal sometime because of the development of compression-molding technology. Compression-molding technology has been developed since twenty years ago. The method of the utilization of biomass resource is as important as the technology. The biomass resource can be processed in removal. After the straw has been baled in local, it will be transport to the destination. The compression-molding technology of biomass should be supported by CRESP for it can provide service for the fuel of biomass power plant.

The report has not mentioned the disposal of ash. The report should put much emphasis on the ash produced by the biomass power generation and study its synthetic disposal and utilization for the several tens to thousands of cubic metric ash generated by the power plant would leave terrible influence on the environment. Especially to the technology of mix burning of gasification with coal, the ash disposal must be studied first to avoid an ash pileup.

2.4 Economic analysis

There is an opinion as following: Cost analysis and investment estimation are relatively utopian and some data need be adjusted. For example, the unpredictable cost plus cost for others is two million, accounting for 6.2% of total budgetary estimate. In accordance to stipulation on Required Budgetary Reserves specified by State Development and Reform Commission, a part of it, namely the Basic Budgetary Reserves, should account generally for 10~15%, and in no circumstance less than 8%. Another part of Budgetary Reserves, namely Budgetary Reserves for Rise in Price, accounts for 5%. These two items together should account for about 20%. In addition, the cost of half million for "Others" is underestimated, too. Finally, it is reasonable for these two items together to account for about 20~25%.

The labor expenses in the report need to be modified. There are 10 persons for control the set divided into 4 shifts with average 2.5 persons for each shift. Operation should be in standard mode.   For example, it is necessary to take the system of "four group in three shifts", 3~4 persons in a group. In addition, 10 laborers will be needed for preparation of raw material and warehouse management. In a word, this number of operators is far from enough. I hope this will be modified in follow-up work of this Report.

2.5 Incentives to support biomass energy

Actively participating in the work of constituting the rules on encouraging biomass power generation. Nowadays, The problem to be solved principally, which affecting large-scale development of biomass power generation, is how to make the encouragement policy take effect. ***"Law on Renewable Energy of People's Republic of China"*** will be executed on 1.1.2006, in which has the clauses on encouraging biomass power generation that need detail rules to put into practice. It is a very emergent problem. Based on the reference of foreign policies and practical steps, the detail operating rules matched with ***"Law on Renewable Energy"*** should be designed and established. Once the encouraging policies take effect, the problems of economy, fund and industrialization that restrict the development of biomass power generation in China will be solved easily.   The content in the report including the economic data, lately electric rating on the network, the study about the obstacle of electric project management on the development of biomass energy technology can be used as the reference to making the encouragement policy by government.

Generally advising situation in economic developments and technology in biomass energy, China should consummate conditions in policy and special technology adapted to rural development. At same time, China should encourage biomass energy technologies towards diversified technology routes and multi-invests during developing and actualizing biomass energy.

The formulation of favorable electricity price in the grid is the most important encouragement policy. Generally, it's low in economy and high in cost for generating electricity by biomass, except technology of mix burning of gasification with coal; the running cost is 0.25 to 0.30 RMB Yuan, even though having some problems in practice operations. The running cost in other methods of biomass energy almost is over 0.30 RMB Yuan (excluding equipment depreciation). Therefore, it needs policy protectionisms from Government, especially at beginning, if China wants to develop electric power by biomass quickly. The formulation of favorable electricity price is a prior condition.

This Report may serve as a basis for formulating policies on biomass power generation. It was suggested that the way to determine scale of biomass power generation by its value of kW is not advisable. 200 kW is possibly quite enough for a village, without need of translation of raw material and with saved land for stack. Farmers can take the ash back for fertilization. Ordinary fireproofing and moisture proof is the only thing that needs to take care. In case it is OK in economy, even system of 100 kW is suitable choice, and farmers can become its owners. If possible technically, little-scale power plant can be connected with electricity network, or an isolated can be built in remote rural area. This does not mean large scale is not good, it do mean no restriction would be set up. Anybody who can invest and obey the rule of market economy should be allowed to establish power his plant or station, at the same time he must assume sole responsibility for profits and losses.

2.6 Financing and investment

The Report of "Analysis of Application of Biomass Power Generation in China" analyzed the influencing factors of developing biomass power generation technology，and proposed development direction of technical course variety and investment main body plurality. The conclusion accords with Chinese conditions.

The situation of power supply is so grim, so development of bio-power can delay the stress from electric power supply and environments. Even though it is very important in stratagem, electric power industry is controlled by the government with characteristics of dense capital and high admittance, which determine that main invest body is state industries and it is difficult to develop bio-power in national systems. Financing is an emergent problem should be faced up to. If an investor has not enough capital and has no chance to receive a loan from bank, a favorable environment of financing is required.

The competitive capital donation will encourage the improvement of technology and equipment manufacture. At the same time, the introduction of foreign technology through international intercourse is necessary to accelerate the development of biomass electricity in China. For instance, Europe and American is in the highest flight in biomass combustion, and their technical experience can be use for reference in China. We can introduce the key equipment manufacture and try to make such device in our country gradually. Then the introduction of foreign experts is a useful approach too.，Some portion of capital can be invested to improve environment. China has some experience on Biomass gasification. A portion of capital invested in manufacture can be used in the project of technical progress.

2.7 The improvement of industry manufacture

Biomass technology is mature and has wide use in China and other countries. Among of them, successful biomass technology is direct burning abroad and gasification in China. Owing low level in industry manufacture as well as poor experience in generating electric power by direct biomass burning, China should strengthen ability construction in electric power equipments and reduce production cost.

CRESP office will not support the commercial investment of mature technology or essential research. The technical progress is the focus. World Bank will provide 2 million dollars to stimulate the industrialization of biomass power generation and improve the technology of equipment manufacture.

2.8 Donation scheme of CRESP

CRESP office plans to sustain more than 20 projects in the next 3 years, and the dotation of each project is about 10-300 thousand dollar. The experts concluded a common understanding that the technical progress will consume high outlay, but the capital supplied by World Bank is not enough to support all projects. So the essential weakness and key point of the technical progress should be found out and resolved. The technical improvement will be optimized and the key project can enjoy priority. The foreign experience, the enthusiasm of corporation and existing technology maybe useful to the improvement of biomass power generation. We can utilize the mature technology and experience, and avoid useless work.

Experts expounded that tar is not an obstacle for biomass gasification power generation. And the technology of mixed burning is feasible now. But the quantum computation of biomass resource consumed in mix burning is difficult to resolved. A good method to supervise the proportion of biomass power generation is necessary. The aim of CRESP is to inspire the enthusiasm of the corporation. The rest of technical problem can be solved by the corporation itself.

The integration of the technical progress and market is the main problem nowadays. The mode of the technical progress in the future should be the cooperation between institute and corporation to avoid the waste of manpower and resource. The thinking method should be directed by market. An appropriate environment of market is necessary for the development of biomass energy.

Some expert expounded that more kinds of unit can be supported by CRESP. Except the large institute, the private corporation is a good choice for its applicability to market. At the same time, the participation of design institute can accelerate the industrialization of biomass energy project. It will do good to the standardization and scale-up of biomass power generation. Before the startup of biomass project, the feasibility study and environment assessment should be accomplished by institute, corporation and design institute. The design institute is absolutely necessary for the industrialization of production of scientific research. But some experts did not agree the opinion. Because the standardization of biomass industry is just at its starting-up stage，design institute can not complete the design solely.

China has gotten well technology accumulations in the field of equipment manufacture of biomass power generation. Many works have abundant professional ability to participate in the Technology Improvement Project of biomass power generation equipment manufacture. On the basis of professional ability of such corporations, the technical progress will be easily completed. Some expert concluded that what large corporations want were encouragement policy, money is subsidiary. The support of the government and World Bank will inspire the enthusiasm of corporation. CRESP can disperse the donation of World Bank and support more projects. With the symbolistic donation, the corporation supported by CRESP will be easy to get a bank loan. Some experts emphasized that the undertaking of CRESP project is more important than donation.

3 The coming task

3.1 Environment benefit

To country, macro indexes of evaluation, such as society, environment, and strategy, must be paid attention to. So, as a consultant reporting for the country, the environmental impact of biomass power generation should be made and numerically analyzed, to elucidate environmental benefit of the development of biomass power generation industry for environment improvement in China. The Kyoto Protocol has come in effect. It will have great influences on sustainable development in China. Reduction emission of greenhouse gases inevitably will be China’s duty. So, the reporting, connected with plan analysis, should foresee the reduction emission of GHGs contribution of biomass power generation industry. Some expert mentioned that report should gather all the issues relating to environment and add one “environmental evaluation of biomass power generation” which could include the environmental evaluation of producing biomass, transforming energy from the heat to power and terminal energy utilization.

With fast development of Chinese economy, including Chinese rural economy, the crop straw left in country will get more and more. Incinerating straw has been an important reason of air pollution in China, and it has cause serious attention of Chinese government. Project CRESP can integrate the industrialization of biomass power generation and settlement of hundred millions of residual crop straw in China, which can not only control efficiently environment pollution resulted from combustion of lots of residual crop straw, but also accelerate the industrialization of renewable energy in China, it will be a huge promotion to Chinese rural economic development.

3.2 Society benefit

It is not strong enough to emphasize development of biomass. It should emphasize the necessity of biomass power generation, so as to attract concern of entire country. For persons who are engaged in research in energy strategy, it is necessary to change their idea and to establish thinking of sustainable development. Utilization of biomass involves many aspects. There was a opinion in discussion of ***"Law on Renewable Energy"*** that the development of biomass is advantageous for energy security of the State. At the same time, the industrialization of biomass energy will cultivate enormous society benefit. Biomass power generation is close related to agriculture and totally realizes the productive value of peasants. It is a measure to help farmers to become rich. So, this reporting should involve in functions of the development of biomass power generation industry, such as the leading function to other industries, the contribution to the development of rural area economy, the opportunities for job and so on.

The report scarcely mentions "person". Because biomass power generation has important influence on the future of China, the report should take a necessary look at those people who are spreading the technology of biomass power generation, operating the equipment of biomass power generation, and benefiting or losing from biomass power generation. That will help to spreading technology of biomass power generation successfully.

This Report should emphasize that biomass is, in the State Renewable Energy Planning (wind, solar biomass), one and only energy that has the function to support agriculture. This is where the most strategic significance of biomass power generation is. Therefore, this Report should emphasize biomass as a renewable energy most suitable to real situation in China. At least 50% of money spent on wind and solar power generation flows into pocket of foreign equipment manufacturers, only biomass power generation gives the price difference back to farmers. Biomass energy changes the wastes straw into useful things and creates a new way for agriculture and provides conditions for farmers to increase their income. It serves as a demonstration of adjustment of agricultural industries. It promotes other industries, promotes employment and agriculture. Biomass will give an impulse to the development of the economy in rural areas. Farmers grow paddy rice, originally, they have only a single product—rice. With development of biomass, straw of paddy rice, discarded in the past, becomes an output. For instance, output of straw is 600 kg per Mu with price of 0.6 Yuan/kg. So, farmers increase their income in 360 Yuan per Mu. Farmers do not change their cultivation, but now they have one product more. If this is supported by environmental projects and needy-help projects, its prospect will be more promising. This Report should emphasize that biomass will promote economic development of China.

3.3 Evaluation of quantity and cost of biomass resource

The quantity and cost of biomass resource should be investigated totally before the industrialization of biomass energy. Quantity evaluation of crop straw should analyzing and calculating respectively according to different concepts on theoretic corn-grass rate, actual reachable corn-grass rate and affordable quantity of straw resources, etc. In fact, value of actual affordable straw is much lower than that calculated by general theoretic corn-grass rate for biomass power plant, especially for power plant using technology of straw direct combustion. For any straw power plant, straw resources affordability must be investigate before project designing. Any inaccurate investigation data of straw resources affordability will affect both the operation of straw power plant and reach-factory price of crop straw, so it need more attention.

Because China is a big country, it exists many differences in residual crop straw resources, including actual reachable amount, actual affordable amount, reach-factory price of resources. So what is very important is the further local investigation and calculation, grasping fully the situation of Chinese residual straw resources, main effective factors and further developing trend. It can establish the foundation of the national governmental constitution of development plan on biomass power generation, the foundation of the calculation of electricity price, the foundation of the analysis of commercialization and investment of all the projects on biomass power generation.

3.4 The standard establishment of design and evaluation

In the process of industrialization, preparative work for project is as important as the technical progress. The date derived from scientific research is not measure up to the standard of substantial project. The cost or price should be selected strictly at the standard of engineering project while carrying economic evaluation on the biomass power generation in order to make the results of economic evaluation be more accordant with the demand of industrialization. It is also suggested that more promising technologies not being industrialized, such as power generation by biomass gasification in fixed-bed, power generation by straw direct combustion, substituting straw for coal in small coal-fired power plant, should be studied and analyzed more.

There is no criterion for testing system of power generation. The establishment of testing system is necessary for the economic evaluation. It is a real technical progress to establish a new accurate testing method. The date of technology evaluation finished by institution is much better than actual date used in engineering.

3.5 Overall arrangement of China biomass power generation scale-up program

The experts concluded a common understanding that the evaluation of biomass resource and cost is absolutely necessarily. With the evaluation of feedstock supply and different technology, the power generation project should be designed according to local circumstance. The social benefit and environment should be taken into account. The public understanding of the benefit brought by biomass power generation is valuable. The report need include an overall arrangement on choosing technology in different areas where enjoy different biomass resources.

Part 3: Implementation Scheme Proposal of the "Competitive Grant-in-aid Project"

Present key problem of scale-up utilization for biomass power generation technology is that China is very weak in general manufacture and production ability of biomass power generation related equipment. In order to advance China's biomass power generation technology level and relevant energy equipment manufacturing ability, CRESP office particularly set up the Competitive Grant-in-aid Project according to GoC/ World Bank/ GEF. Relevant project implement scheme is proposed here.

1. Introduction

Renewable Energy Law has been legislated in February 2005 in China, in which the development and utilization of renewable energy ranks priority item among Chinese energy development. The establishment and development of renewable energy market will be improved through enacting general target of renewable energy development and utilization and taking responsive measures. Biomass resources in China are abundant with great utilization potential. Their development is in good agreement with national economic sustainable development, i.e. supplying energy for economic rapid development as well as reducing pollution to environment. But there is still a large distance between the present situation of biomass utilization and the requirement of the strategic target for diversified energy structure in China.

Electricity production from biomass is one of its primary utilization ways. Present key problem of scale-up utilization for biomass power generation technology is that China is very weak in general manufacture and production ability of biomass power generation related equipment, which has to be greatly developed to promote the industrialization of biomass power generation technology and reduce relevant investment.

China Renewable Energy Scale-up Program (hereinafter referred to as CRESP) cooperated between the State Development and Reform Commission of China and the World Bank aims at: expanding and developing China's renewable energy utilization to accelerate technological scale-up and industrialization process; improving China's energy structure, ensuring energy safety and abating environmental pollution through greatly developing renewable energy; solving residential electricity supply problem, especially in remote areas where power grid cannot cover, helping them shake off poverty and set out on road to prosperity, contributing to the goal of ensuring our people a relative comfortable life.

The content of the project is to discuss how to carry out the Competitive Grant-in-aid Project of CRESP to advance China's biomass power generation technology level and relevant energy equipment manufacturing ability. The project group systematically analyzed the present situations of technology R&D, industrialization and manufacturing of biomass power generation in China. The investigation emphases were the present situation of electricity power supply, the characteristics of biomass resources supply and the economic efficiency of various biomass power generation technologies and their existing problems. Based on the development situation and trend of biomass power generation in China, we proposed this report for the implementation of the “Competitive Grant-in-aid Project”.

2. Main Contents Proposed in the Report

- Biomass power generation technology categories funded by the project;
- Advancement items, ways and indices of the key technologies funded by the project;
- Admittance qualification for the corporation funded by the project;
- Project’s fund structure;
- Approval and objective evaluation mode for technology reconstruction project;
- Main documents for tendering and bidding.

3. Summary of the Implementation Ways Proposed

In order to improve the competitive ability of biomass power generation industry, the technology advancement project is to fund relevant enterprises and research institutes for technology development. They will be funded with grant-in-aid under the principle of cost allocation according to their project proposals. The technology advancement project aims to support those biomass energy industrial enterprises and research institutes who devote to reduce biomass power generation cost and improve power generation efficiency and its economic benefits, through competitive grant-in-aid.

Since biomass energy utilization is one of the important support fields in the Eleventh Five-year Plan of China and that of medium and long-term energy science & technology and industrialization development, we suggest that the support tendency of CRESP be agree with them, for the purpose of concentrating technological and economic resources to accelerate national biomass power generation technology level. The project will fund successful bidders, e.g. developer, equipment manufacturer and research institute, under the principle of cost allocation, to advance the general technology level and market competitive ability of biomass power generation and to promote the industrialization process.

During the project process, CRESP office is to extensively consult relevant experts and enterprisers, subsequently, determine the biomass power generation technologies to be funded by the World Bank. Those corporations specializing in this technology will be investigated about their development, in order to legislate industrial technological standards for competing for the grant-in-aid. Successful corporations will be determined through competitive bidding. CRESP office issues bidding invitation once a year, and a group of experts in charge of technology advancement will evaluate biddings according to participating corporations’ project propositions, with agreement of the World Bank.

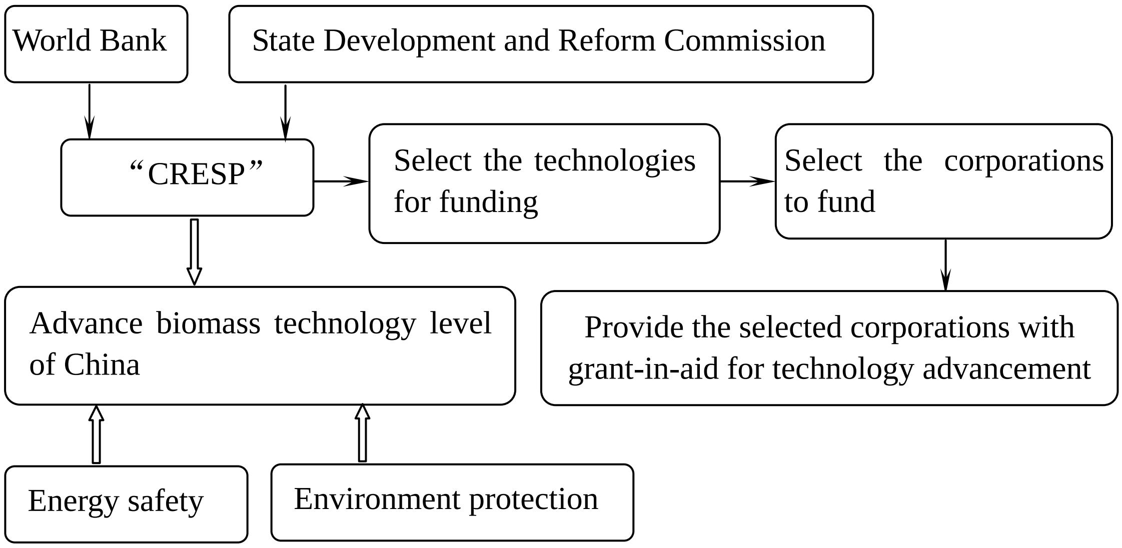


Fig. 1. Flow chart of implementation of "CRESP"

4. Technological Fields to Be Funded

The primary biomass resource of China is still crop residues at present, and this situation will continue for a fairly long time. Used as fuels for power generation, crop residues have the most obvious characteristic of dispersiveness, which results in difficult biomass collection and transportation. Additionally, biomass supply ability is greatly influenced by crops' planting scale, presenting obvious seasonality. Foreign biomass power generation technologies in developed countries have been industrialized maturely, but unsuitable to China's conditions due to their needs for large investment and scale. Therefore, practice of biomass power generation technologies in China has its special requirements in terms of local conditions and characteristics of biomass resources.

- Biomass power generation technologies must have good adaptability to most biomass;
- Biomass power generation technologies should offer flexible scales;
- Biomass power generation project has to match different capital status.

In principle, R&D activities in biomass field are covered by the technology advancement project. But in order to concentrate limited fund to obtain achievement as better as possible, the grant-in-aid will be used to support some important ones. Therefore, after comprehensive considering the characteristics of present biomass resources and biomass power generation technologies in China, comparing various technologies' generation efficiency, investment, generation cost, pay back time, etc. we propose the followings as funding emphases:

- Moderate biomass gasification power generation technology;
- Moderate biomass combustion power generation technology;
- Large biomass co-firing power generation technology, including two types — direct co-firing and gasification co-firing;

- Industrialized biomass molding technology suitable for various biomasses.

5. Analysis and Decision of the Target of Technology Advancement

5.1 Moderate biomass gasification power generation industrialization technology

The demonstration project of biomass integrated gasification combined cycling power generation system of 4MW has been achieved, proving the technological and economic feasibility of moderate biomass gasification power generation technology, and offering experiences for industrialization of 4-10MW systems. However, further expansion of the technology has to solve the four problems of small unit gas engine power (500kW), high wastewater treatment cost, low automation control level and lack of matched biomass collection and pretreatment system.

Research contents of this technology advancement include biomass gasification system, new gas cleaning system, treatment of tar wastewater, large power gas engine for low heating value gas, straw collection and pretreatment devices, computer supervision system, integrated key technology, optimal model, etc. details as follows.

Grasp the key of large biomass circulating fluidized bed gasification technology and the mechanism and technics of advancing biomass gasification efficiency, including the mechanism and mathematical model of biomass high temperature gasification, the mathematical model of biomass circulating fluidized bed gasification and its expansion theory.

New gas cleaning system: research the mechanism of thermal decomposition and catalytic decomposition of tar; reduce tar content in fuel gas; reduce tar wastewater production by over 50% and improve gasification efficiency.

Large power gas engine for low heating value gas: research the key of efficiency advancement and running characteristics and technics of 800kW gas engine for low heating value gas, and the feasibility of its combination with combined circulating power generation system.

Straw collection and pretreatment devices: develop 1-2 ton/h devices suitable for the characteristics of Chinese agricultural residues.

Computer supervision system: develop the system for biomass integrated gasification combined cycling power generation system to advance running security, reliability and automation level.

Objects of moderate biomass gasification power generation technology advancement: Develop large and highly efficient biomass gasifier adapted to various biomasses, and reduce uncombustible contents in fuel gas. Develop new gas cleaning system and 800kW and up new gas engine for low heating value gas. Advance gas heating value through high temperature gasification with air or oxygen rich air and steam, effectively reducing the tar content in fuel gas and tar wastewater treatment cost.

Develop straw collection and pretreatment devices suitable for the characteristics of Chinese agricultural residues and computer supervision system for biomass integrated gasification combined cycling power generation plant to advance running security, reliability and automation level.

5.2 Moderate biomass combustion power generation industrialization technology

China plans to develop utilization of biomass power generation more than 15,000 MW in 10 years. Presently, agricultural residues are the primary biomass resources in China, and have various categories. Additionally, different areas in China have different conditions. So, it is very difficult to realize scale-up utilization of biomass power generation if only depends on single technology route. Biomass combustion power generation technology is also one to be developed in the future.

Because various biomasses are different in physical and chemical characteristics such as shape, size, combustion behavior, ash content, etc. it is particularly exigent to research and develop biomass fluidized bed combustion boiler adapted to various biomass fuels, details as follows.

Design biomass circulating fluidized bed combustion boiler, according with the characteristics of biomass combustion through improving boiler’s interior structures. Different biomass combustion processes result in different ash features, which can be controlled through controlling the behavior of biomass fluidization and combustion.

Raise the melting point of ash according to the influence of biomass fuel and additive on ash formation. Research the mechanism, process and control of slagging and coking of low melting point ash in boiler hearth, and avoid this through controlling the behavior of biomass fluidization and combustion. Fly ash with high content of chlorine and alkali metals piles on heating surfaces. Ash erosion mechanism on them and erosion control method are to be researched. And present measures for clearing ash from heating surfaces will be selected and advanced.

Research the key technology of matched devices for biomass combustion and steam power generation, such as biomass material pretreatment, ash disposal and wastewater treatment. Advance whole set production ability of biomass combustion power generation system to improve technological commercialization.

Study on parameter matching and optimization of series design of biomass combustion and steam power generation system, and lay a foundation for developing various products of 6-20 MW for different users.

Expand the utilization of various kinds of products. Accelerate commercialization of biomass combustion and steam power generation technology through certain application projects, and advance standardization of equipment installation, commission and running during development and expansion process.

Objects of moderate biomass combustion power generation technology advancement:

Develop biomass fluidized bed combustion boiler adapted to various biomasses, with steam capacity of 35 ton/h, thermal efficiency of over 82%, installation capacity of 6 MW, generation efficiency of over 22%, investment cost of less than 6500Yuan RMB/kW decreasing by 40% of import.

5.3 Large biomass co-firing power generation industrialization technology

This technology only needs some additional investment on biomass part since original fossil fuel fired power plant has had good bases. It is a renewable energy utilization selection of low cost and low risk at present. China's biomass co-firing with coal technology just starts, so it is necessary to further perform relevant basic research and industrialization development.

Research contents of this technology advancement are as follows. According to mechanism research on slagging and erosion of ash from biomass co-firing with coal, put forward solutions. Experiment and research on co-firing reaction kinetics, and give out solutions for highly efficient and clean biomass combustion/co-firing technology, and research low NOx staged combustion technology and device. Design and construct biomass co-firing demonstration project, preparing and improving technological commercialization by industrial test.

Objects of large biomass co-firing power generation technology advancement: Through study on the characteristics of biomass fuel and the mechanism and reaction kinetics of biomass co-firing with coal, develop key co-firing technology. Biomass co-fired reaches 30MWt and up. Variation of boiler efficiency after reconstruction ranges within 2%. Emissions meet the requirements in national standard for the same coal boiler. Obtain independent intellectual rights of biomass co-firing with coal, and set up biomass co-firing demonstration project.

5.4 Biomass molding industrialization technology

Biomass molding technology was interesting in 1940s. Due to impact of global oil crisis and rise of environmental protection consciousness, many countries have realized the importance of development and conversion of biomass energy, and have invested in biomass molding and carbon conversion technology and devices. China started late in biomass collection and pretreatment technology and devices, and is weak in advanced biomass molding technology and devices.

Industrialization development of biomass molding technology will accelerate diversified utilization of biomass energy, simultaneously, satisfying rural family energy demand and changing the low efficiency style of biomass energy utilization of direct firewood combustion.

Research contents of this technology advancement are as follows. Research and develop biomass compact molding technology and devices for various biomasses. Study on biomass physical and chemical characteristics, biomass crush feature and mechanism of biomass cold compact molding. Research and develop biomass disintegrator, biomass compact molding machine and special stove for biomass molding fuel. Establish technological and operational standard for biomass collection, pretreatment, molding, selling and technology expansion.

Objects of biomass molding technology advancement: Research crush features of various biomasses and relevant influence factors, and decide suitable disintegrator type and optimal design. Develop general biomass disintegrator with high efficiency. Study on compact molding mechanism of crushed biomass, finding its influence factors. Develop cold biomass particles compact molding machine, with molding density of 900kg/m^3 and up, molding machine's electricity consumption of less than 70 kWh/ton, system electricity consumption of less than 100 kWh/ton.

6. Standards for Corporations to Be Funded

6.1 Basic conditions

Enterprises and institutions meeting the following conditions may participate in primary election of technology advancement project:

- Being producing biomass related equipment;
- Owning abundant strength.

Otherwise, the following conditions will also be possible:

- Interested in producing biomass related equipment;
- Owning abundant strength.

No matter national or private or joint venture corporations are welcome only if meet the above conditions.

Power production from agricultural residues is of strategic significance to improve energy structure, abate environmental pollution, ensure energy safety and accelerate economic development of mountain areas and rural areas. In key science and technology projects of the Eleventh Five-year Plan, there are some biomass power generation industrialization projects executed by strong and experienced enterprises and institutions. In order to concentrate fund to rapidly advance relevant technology level of China, it is proposed that this program first support those enterprises and institutions taking biomass energy development projects in the Eleventh Five-year Plan.

6.2 Conditions for project proposal

- Technology proposed in project must belong to the fields that the World Bank will fund;
- Project executive must have relevant specialty and capability;
- Project must be agreement with requirements of national and local sustainable development;
- Full and accurate project feasibility analysis is necessary;
- Strong partner;

- Project budget;
- Economic and social benefits of project proposed;
- Investment-output ratio

These specific conditions must be concluded only after investigation of participants.

7. Funded Items

Following technology advancement activities of successful bidders are to be funded by the World Bank:

- R&D personal pay
- Production costs of gas turbine, boiler and gasification equipment
- Site testing fee for gas turbine, boiler and gasification equipment
- Certification fee for technology and equipment
- Depreciation cost (or rent) for R&D during project period
- Power generation equipment or system operation related foster fee
- Purchase of necessary special software
- Market research expenses for new product or renovation product
- Research expenses for advancement of key technology and equipment performance
- Expenses of consultation and service about biomass power generation technology advancement
- Travel fee for project performance
- Certification fee for foreign and domestic potential partners specializing in biomass power generation subassembly or system production
- Feasibility study fee with foreign and domestic partner (joint venture company)

These activities can be funded by the World Bank with grant-in-aid under the principle of cost allocation, i.e. fund up to 50% of each activity's total cost.

However, following activities are not included in grant-in-aid:

- Equipment investment for commercialization
- Capital investment of joint venture company
- Purchase of production permits
- Overseas technology advancement project

8. Sustentation Scheme Proposal of the "Technology Advancement Project"

8.1 Moderate biomass gasification power generation technology

- Gasification system and equipment
- Gas engine power generation system (4500kW) and the manufacturing technology of gas engine
- Steam turbine power generation system (1500kW)

8.2 Moderate biomass combustion power generation technology

- Boiler improvement and development, including the hearth and afterbody heating surface
- R&D of equipment concerned e.g. biomass disintegrator and feedstock system
- Research on slagging, coking and fly ash erosion
- Technological standardization of pattern equipment
- Fluidized bed boiler
- Power generation unit

8.3 Large-scale biomass co-firing power generation technology

- Development of serial whole set of biomass circulating fluidized bed gasification
- Technological integration of biomass gasification and co-firing
- Reconstruction of boiler and feedstock system

8.4 Biomass molding technology

- Investigation of the key technology of biomass molding
- R&D of biomass molding machine

9. Expert Evaluation System and Checking Indices of Grant-in-aid Project

9.1 Evaluation system

CRESP office determines the scheme of grant-in-aid, and then openly recruits project proposals in society. After domestic experts' evaluation for the first time, some proposals will be selected as candidates from collected proposals.

To determine projects for grant-in-aid, CRESP office convenes the second evaluation meeting. Domestic and foreign experts evaluate the candidate proposals together and list them in order.

When the State Development and Reform Commission agrees with experts' evaluation results and the World Bank has no opposite opinions, CRESP office will issue the results, i.e. those project proposals can be funded according to their orders in the list.

During the second evaluation process, experts further examine and verify technology and cost contents of proposals and probably give some advices and requirements for improvement. Accordingly, CRESP office contacts those project applicants to talk about proposal improvement and grant-in-aid contract with them.

9.2 Technology advancement indices

9.2.1 Moderate biomass gasification power generation industrialization technology

Successfully develop new gas engine power generation unit for low heating value fuel gas with unit power of 800kW and up. Develop new gas cleaning system to realize obvious reduction of tar wastewater production compared with that in the Tenth Five-year Plan. Develop computer supervision system for biomass integrated gasification combined circulating power plant, with gasification efficiency of over 75% and system power generation efficiency of over 26%. Develop straw collection and pretreatment devices.

9.2.2 Moderate biomass combustion power generation industrialization technology

Develop biomass fluidized bed combustion boiler adapted to various biomasses, with steam capacity of 35 ton/h, thermal efficiency of over 82%, installation capacity of 6 MW, generation efficiency of over 22%, investment cost of less than 6500Yuan RMB/kW decreasing by 40% of import.

9.2.3 Large biomass co-firing power generation industrialization technology

Reconstruct large coal fired power generation unit to co-fire with biomass fuels. Variation of boiler efficiency after reconstruction ranges within 2%. Emissions meet the requirements in national standard for the same coal boiler.

9.2.4 Biomass molding industrialization technology

Develop biomass molding machine adapted to various biomasses, with molding density of 900kg/m^3 and up, molding machine’s electricity consumption of less than 70 kWh/ton, system electricity consumption of less than 100 kWh/ton.

Accomplishment of above technology advancements will promote the establishment of new biomass energy utilization system (biomass gasification power generation technology, demonstration project of biomass combustion and co-firing with coal, biomass molding technology) according with Chinese conditions, and lay a foundation for further expansion of biomass energy technologies in China.

Part 4: Implementation Scheme Proposal of the “Technology Improvement Project ”

In order to further construct necessary environment to support biomass power generation technology development, including financing channel, operable and supportive policies, economic promotion measures and fair market competition mechanism, CRESP office set up the Technology Improvement Project, which will work together with the Competitive Grant-in-aid Project to assure that CRESP of World Bank can promote the scale-up development of Chinese biomass power generation industry in deed.

1. Introduction

The development of biomass power generation technology is of great importance to the sustainable development of energy resources in China. There is abundant biomass resource in China, and great potential can be explored. From the long-term perspective, the development of biomass power generation technology can gradually improve current structure of electricity supply in which coal has large proportion, and ease the pressure in electricity supply, and protect the ecological environment. From the short-term perspective, according to the characteristics of biomass resources in China, the significance of the construction of distributed biomass power station lies in solving the problems of electricity supply to rural and remote areas in China, and accelerating the process of urbanization, and improving people’s living standard.

The three major factors that restrict the application of biomass power generation technology in China are of technology, economy and policy. The key problem of promoting biomass power generation technology in large scale is the great inadequacy of the manufacture and production ability of relevant power generation equipment. In the future development, it is important to strengthen the manufacture ability of the equipment, and improve the technology of biomass power generation, decrease the investment cost, and enhance the competitiveness of this technology in market. Hence, China Renewable Energy Scale-up Program (CRESP) set up the Competitive Grant-in-aid Project to support biomass power generation technology improvement.

The characteristics of biomass power generation projects in China are small in scale and high in cost. The investment sources are few except the subsidies provided by the government’s supportive economic policy. Thus, the difficulty in funding is another factor that restricts its development. Although Chinese government has formulated supportive policy for renewable energy, for the local governments and administrative departments, is hard to carry them out because of the lack of somewhat operableness. Therefore, these policies cannot be implemented in most regions. Furthermore, they are formulated on the basis of former planned economy system, which is of guidance without effective economic promotion measures and compulsory market policies. Such economic barriers impose great difficulty to the operation of biomass power generation. Hence, in order to smoothly implement the Technology Improvement Project and achieve its pre-set targets, we need to nurture corresponding supportive environment and deploy coordinated actions on preferential policies, financing channels and market mechanism that can promote the development of the biomass power generation in large scale.

2. Suggestion for the Design of the Project

The objectives of the Technology Improvement Project under CRESP are to improve biomass power generation technology, decrease cost, and further nurture favorable environment, including financing channel, operable and supportive policies, economic promotion measures and fair market competition mechanism. The ability construction of institutions should be supported in order to eliminate the barriers in market, promote the market-oriented operation of the technology, and raise the acceptance of biomass power generation in the government and society. The ability construction of the enterprises and terminal users and the construction of coordinated service system for industrialization should also be supported.

Biomass power generation Technology Improvement Project will work together with Competitive Grant-in-aid Project. The specific activities are suggested as following.

- Discussions on incentive mechanism, supportive policy and financing channel
- Establishment of inspection and certification institution of technical improvement
- Enacting technological standards
- Construction of basic database of biomass resources in terms of time and space
- Analysis of environmental benefit assessment and discussion on price system for biomass power generation
- Biomass power generation technology training and capability construction
- International communication, biomass publicizing and exhibition, establishing website

The frame of the Technology Improvement Project implementing is shown in Fig.1.

3. Funding Plan of Technology Improvement Project

3.1 Discussions on incentive mechanism, supportive policy and financing channel

3.1.1 Objectives

Complying with the National Renewable Energy Law, this activity is to propose suggestions on improving the policy environment that provides suitable policy support and an incentive mechanism for biomass power generation technology industry. It also aims to explore financing channels, which helps to bring sufficient and flexible money supply for biomass power generation industry and increase the competitive edge of the industry.

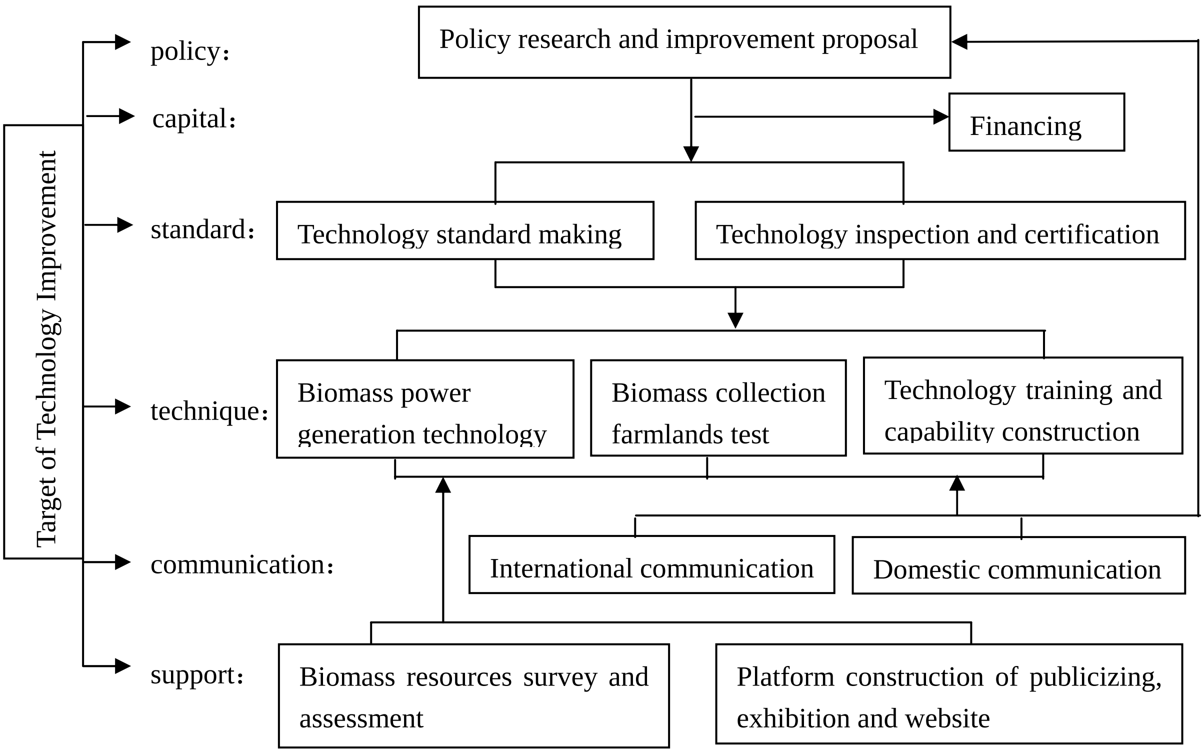


Fig. 1 Frame of the Technology Improvement Project

3.1.2 Activity plan

● To propose supportive policies for further improving the biomass power generation technology and developing the industry.

The present supportive policies on renewable energy development are vague in stipulation, unreliable in application and poor in implementation. Compared with the regular power generation technology, the biomass power generation technology, though mature, is still on the demonstration and promotion stage, lacking competitive edge. There is no particular supportive policy for the development of biomass power generation technology industry. It is not until the promulgation of *Renewable Energy Law* that the industry has got some legal support. However, economic incentive measures and mandatory market policies, such as the criteria on setting the power price, the sharing of the electricity price difference, loan, tax reduction or remission and green power quota shall be employed properly and creatively to promote the development of the industry. .

● To explore financing channels for the scale development of biomass power generation technology industry

The analysis of the application of biomass electricity generation technology in China shows that the biomass power generation technology industry demands a diversified technological development and that small and medium size biomass power generation projects are most suitable for China. However, the present project examination and approval procedure and loan funding system do not provide support for such development. Small as most biomass power generation projects are, they need to go through the fussy formalities. They also suffer from high cost and small investment scale, which means little attraction to large enterprises and high risk to investors like private enterprises and township enterprises. This activity will address the above-mentioned problems, focus on how to create a relaxed circumstance and explore multi investment channels for the biomass power generation technology industry. It also aims to put forward an applicable scheme in view of the Chinese conditions. China shall establish incentive policies on taxation, loan, investment, price and subsidy so as to ensure a fair competition in the market.

3.1.3 Kinds of organizations suggested to undertake the project

Academies and institutes of energy technology, energy economy, macro policy and technological economy; associations of energy industries; administrative authorities concerned.

3.1.4 Expected achievements

Report on the decision; draft of suggestions on the supporting policies and incentive measures.

3.2 Establishment of inspection and certification institution of technical improvement

3.2.1 Objective

Promote the normative and large-scale utilization of the biomass power generation technology by studying out the procedure, quantitative index and normative implementation of the improvement inspection and certification of the technology in question; provide policy support to the fair play in the market by setting up a normative procedure of certification and certification bodies with clear-cut functions.

3.2.2 Activity plan

- Set up a body to certify the approval and initiation of the CRESP project and a supervision institution of the project’s operation

China lacks the ability to take in the advanced exotic technology due to its weak industrial foundation and insufficient equipment processing and manufacturing capability. That results in the initiation of the project chiefly. In addition, the agricultural wastes account for the main proportion of the biomass resource in China, which differs greatly from the conditions of biomass power generation abroad. Different contents of the ingredients in the biomass resource will impose different influences and requirements on the equipments. When introducing the advanced exotic biomass power generation technology, China has to take into consideration the properties of its resources, capability of equipment management and of technical digestion and absorbency. The pure pursuit of large scale, high efficiency and high automatization must be prevented so that there will be no unnecessary waste.

● Ascertain the procedure and criteria of the inspection and certification of the technical improvement.

The evaluation criteria and system of different types of biomass power generation projects must be formulated under the help of domestic and overseas experts. The certification of the approval and initiation of the CRESP project, the early-stage preparation, the technical improvement will be evaluated and examined, which will promote the large scale and normative development of the industries related to the biomass power generation. The procedure, index and standard implementation of the inspection and certification concerning the technical improvement of the biomass power generation should be built.

3.2.3 Kinds of organizations suggested to undertake the project

Academies and institutes of energy technology, energy economy, macro policy and technological economy; associations of energy industries; administrative authorities concerned.

3.2.4 Expected achievements

The procedure, index, contents, criteria and implementation of the inspection and certification concerning the technical improvement of the biomass power generation should be drafted.

3.3 Enacting technological standards

3.3.1 Objective

Referring to other kinds of standards for power generation industry, enact biomass power generation related technological standards to standardize industrial development of the technology, which agree with the characteristics of biomass resources and the situation of biomass power generation technology development presently in China.

3.3.2 Activity plan

Survey and investigate biomass power generation related standards according to biomass production characteristics in China. Invite experts to put forward biomass power generation related technological standards to standardize industrial development of the technology referring to other kinds of standards for power generation industry. The standards will play an important role in instructing and standardizing the expansion and establishment of biomass power generation technology system.

In the technological standards, the flexibility of biomass power generation scale, i.e. the requirements and application conditions for different size systems, should be standardized to present diversified standards. So project investors have flexible selectivity as well as standards to comply.

Relevant industry associations and experts are preferred to enact the standards. In the near future, gasification and direct combustion are the primary technologies for biomass power generation to develop. When enacting the standards, it is necessary to communicate with the industry of manufacture and power generation and to consider the present industrial level in China and the practical significance of biomass power generation in improving energy manufacture and establishment of green power system.

The standards must include technological standard for construction and examination of biomass power project, design standard for various biomass boilers, grade standard for biomass material efficiency, environmental assessment standard for biomass power generation system, etc.

3.3.3 Kinds of organizations suggested to undertake the project

Academies and institutes of energy technology, energy economy, macro policy and technological economy; associations of energy industries; administrative authorities concerned.

3.3.4 Expected achievements

Accomplish the proposal draft of biomass power generation related technological standards and submit to administration.

3.4 Construction of basic database of biomass resources for energy utilization in terms of time and space in china

3.4.1 Objective

Obtain the survey and investigation results of biomass resources distributed regionally in China and a dynamic data system of the situation of biomass production, consumption, disuse, etc. Submit biomass resources investigation report to provide detailed resource information for government and investors and to service for the establishment of stable paths of obtaining biomass resources.

3.4.2 Activity plan

Take full coverage regional biomass resources survey in China, including current, future and potential available resources, biomass price trend.

With the software support of geographical information system, the database can provide biomasses distribution in terms of time and space besides their species and quantity. Moreover, regional energy and electricity requirement and price will also be recorded as auxiliary information. The database has the following functions:

- Provide data of spatial distribution of biomass resources. So that according to local biomass characteristics and requirement for energy and electricity, select reasonable utilization mode. And investigation of biomass material collection, transportation and storage can be further developed based on these data.

- Provide data of temporal distribution of biomass resources, including annual variation of biomass resource amount, which is important to assure stable supply, and variation estimation of biomass resource amount within 5 to 10 years due to energy crops production on afforestation lands and agricultural production reduction with available land reduction.

Based on this database system, it is possible to analyze and program dimensionally the information of biomass purchase price, the mode of purchase and storage, the scale and site layout of power plant and the distribution of equipment manufacture capability, to service for development planning of biomass power generation (including liquid fuel) operable and confirming with the national conditions.

3.4.3 Kinds of organizations suggested to undertake the project

Academies and institutes knowing well biomass power generation technology and requirement of biomass material and keeping contact with local development and reform commission and agricultural department.

3.4.4 Expected achievements

Submit authoritative information system of biomass energy resources and provide information for scientific decision making for near and long term planning of biomass power generation in China.

3.5 Analysis of environmental benefit assessment and discussion on price system for biomass power generation

3.5.1 Objective

Establish scientific accounting method concerning environmental cost internalization and provide scientific evidence of setting up fare market competition mechanism

3.5.2 Activity plan

Establish accounting method concerning environmental cost internalization corresponding to energy production and consumption process to promote development of biomass power generation technology.

For various biomass-fired and coal-fired power generation technologies, set up common and comparable environmental impact assessment model and platform, and research method for equivalent quantification or monetization of environmental impact. Propose a reasonable price making evidence.

It is advised to set up comparable environmental equivalent quantification indices and proceed with comparison analysis

3.5.3 Kinds of organizations suggested to undertake the project

Academies and institutes knowing well biomass power generation technology and requirement of biomass material.

3.5.4 Expected achievements

Submit accounting method and standards concerning environmental cost internalization in China, and demonstrate the accounting calculation of environmental cost internalization for coal-fired and biomass-fired power generation technology.

3.6 Biomass power generation technology training and capability construction

3.6.1 Objective

Provide specialized platform for technology training and capability construction of project approval, generating technology, equipment manufacture, power plant management and financing, etc. to promote industrial development.

3.6.2 Activity plan

Under the popularization and expansion of typical biomass power generation technology, training of construction and operation scheme and technology demonstration etc. will be provided for different technology requirements and different plant sections.

Detailed activities are proposed as following aspects:

- Regional popularization of biomass energy utilization: advance local administration’s recognition and public consciousness of renewable energy utilization.
- Introduction of commercial opportunity of biomass power generation to enterprises: attract enterprises to participate from introduction of energy development trend, new point for economic growth, innovation opportunity of independent energy technology, advancement of energy manufacture industry.
- Training of biomass power generation technology: includes project approval, assurance analysis of biomass resources, generation technology, equipment manufacture, power plant management, financing, technological standards, etc. The training may be many times with different subject for each time.

3.6.3 Kinds of organizations suggested to undertake the project

Presider of the training must be authoritative and with relatively high training level, e.g. CRESP office, and undertaker should be academies and institutes that are acquainted with national energy policy and strategy, have had outstanding achievements in biomass technology and have taken biomass power generation demonstration projects.

3.6.4 Expected achievements

Expand relevant technologies and capability construction for industrial development. Advance technology and management levels of much more professionals.

3.7 International communication, biomass publicizing and exhibition, establishing website

3.7.1 Objective

Study and draw lessons from relevant technology and operation experience of other enterprises. Establish a platform for communication and publicizing of biomass power generation technology, industrialization and policy to promote the formation of industry, communication among industry, administration and institute, and communication with foreign industry. Periodical and long term publicizing and consultation activities are appreciated.

3.7.2 Activity plan

Grasp foreign advanced industrial operation, study technological application level and management mode, and obtain relevant information of industrial development. Set up publicizing path for biomass power generation technology and relevant industry to provide communication space for professional and unprofessional consultation activities. Organize communication between domestic industrial institutions, and provide consultation platform and path with various mediums for technology transformation, equipment supply and demand, policy publicizing. Set up biomass website of CRESP office.

Periodically publicize and exhibit biomass power generation technology and relevant industry in various forms. Set up special website to provide search platform for technicians and managers and publicize biomass utilization to the public through website.

3.7.3 Kinds of organizations suggested to undertake the project

Presider of the publicizing and exhibition must be authoritative and with relatively high training level, e.g. CRESP office, and undertaker should be academies and institutes that are acquainted with national energy policy and strategy, have had outstanding achievements in biomass technology and have taken biomass power generation demonstration projects.

3.7.4 Expected achievements

Study and draw lessons from relevant experience of other enterprises, put forward improvement advices for domestic industry development, and form reference reports for convenience of technicians and managers. Establish publicizing platform for biomass power generation technology and relevant industry, and organizations in charge of various publicizing activities.

Closing Words

Each of the four parts of the report of Consultation on Biomass Power Generation Technology Improvement is a separate sub-report on own emphasis, but organically constitute the whole report on the industrialization development of biomass power generation.

From different aspects such as technology, economy, future development and application and so on, the sub-report of Analysis of the Application of Biomass Power Generation Technology in China describes and compares present biomass power generation technologies in detail, points out existing problems in biomass power generation and direction of technological research and political study, and concludes and proposes diversified development of technology and investment channel in terms of China conditions. In the report conference, exports and researchers exchanged many valuable opinions and proposals. It is a conference promoting China biomass energy utilization development and also enriching the report contents and depth. According to present situation and level biomass power generation technology in China and future industry development trend and target, the Competitive Grant-in-aid Project and the Technology Improvement Project provide fund support to excellent relevant enterprises on industrialization and necessary environmental construction, respectively, which will advance relevant technology level and energy equipment manufacture capability of China.

In general, on the occasion of China Renewable Energy Law legislation, the investigation and achievements of the project of Analysis of Potential in China for Improvement in Biomass Power Generation Technology are of strategic importance to promote the industrialization development in China.

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