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Dilemma and Strategy of Biomass Power Generation Industry Development in China: A Perspective of Industry Chain

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Abstract

With the increasing scarcity of fossil fuel resources, the demand for greenhouse gas reduction and environmental protection all over the world, developing bioenergy becomes one of the most important energy strategies. This paper introduces the current development situation of biomass power industry, discusses the dilemmas of this industry's development in a perspective of industry chain and gives recommendations. Then it proposes the development strategy including development objectives, technology roadmap, and the related policy guarantee measures for the biomass power industry. Finally, we get the conclusion that in the future, with scientific and technological progress, China's biomass power industry will be rapidly developed with a bright prospect, and the cost will be further reduced.

Keywords: Biomass power industry; Industry chain; Dilemma; Strategy

Introduction

With the rapid development of economy and society, China has experienced a period of extremely high energy consumption which will likely continue for decades. China's aggregate primary energy consumption was 1455.31 million tons coal equivalent in 2000[1] and had grown up to 3250 million tons coal equivalent by 2010[2], with a 123.32% increase during the last decade, which has made China the largest energy consumer as well as the largest emitter of CO_2 in the world. And with the increasing scarcity of fossil fuel resources, the demand for greenhouse gas reduction and environmental protection all over the world, developing bioenergy becomes one of the most important energy strategies [1].

It is well known that China is a large agricultural country and has abundant biomass resources, China's theoretical biomass resource is 5 billion tons coal equivalent by estimate. But in practice, the available biomass resource is about 280 million tons coal equivalent. If it could be completely used, 680 million tons of CO_2 would be reduced, which accounts for about 11.28% in 2007. And as the only storable renewable energy, bioenergy is with the characteristics of wide distribution, large storage capacity and carbon neutral. Thus, enhancing the development and utilization of biomass energy will contribute to energy saving and emission reduction, and is also an important way to achieve a low carbon economy.

Currently, the total installed power generation capacity in China is 966.388 million kW, and for biomass power generation, it is only 5 million kW, which accounts for less than 0.52% of the whole capacity and is lower than that of the hydroelectric power and wind power. Therefore, it is promising to develop biomass power generation.

On the basis of a large number of literature review and fieldwork, the current situation of biomass power generation industry in China is analyzed from different perspective of raw material and equipment suppliers, fuel transportation, power generation sectors, electricity grids and consumer. The dilemmas of this industry's development are summarized and given some relevant policy recommendations. Finally, the development strategy of biomass power generation industry in China is suggested, and the appropriate conclusions might have great reference value for the scholars to study the biomass power industry development further.

[1]Source: Chinese Energy Statistic s Yearbook 2010

[2]Source: IEA website

Current Situation of Biomass Power Generation

Biomass power industry chain is relatively short, mainly composed of the fuel supply, electrical equipment, power production and grid. The initial investment of biomass power plants is relatively low, but once they have been built up, problems such as the increasing cost of raw materials and workers' wages are emerging. The profits of power generation sector are obviously squeezed and some plants even at severe loss. While in the expansion of biomass power generation industry, fuel and equipment suppliers have controlled the upstream resources and technologies so that they can obtain higher profits.

Generally speaking, China's current installed capacity of biomass power generation and its share of the whole installed capacity are both small, and biomass industry is still at a relatively high input, low output stage, not yet mature but has taken shape.

Suppliers

The upstream of the biomass power generation is electrical equipment manufacturer and fuel suppliers. In recent years, domestic power equipment market and the biomass fuel market have strong market power. Suppliers have strong bargaining power so that they can grasp the price and squeeze the profit margins of biomass power generation industry from expansion to the downstream.

Equipment: At present, China's biomass power generation equipment is still in its infancy, and the share of the power equipment market is relatively small. A number of large biomass power plants' tech-

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nology and equipment are from BWE Company in Denmark. As for major domestic manufacturers, such as the Dragon Power Co., Qingdao Dresdner Turbine Group, Wuhan Steam Turbine Plant, Jinan Shengjian Electrical Machinery Plant and Jinan Boiler Works, their technology and R & D are lagging, many based on the introduction of foreign technology and domestic manufacturing. Under this circumstance, equipment purchasing costs, as a major part of biomass power generation cost, usually account for 30% - 40% of the total investment of biomass power plants, due to the weak bargaining capacity of the biomass power plants.

Raw material supply: China has many kinds of crop straws which are wide geographical distributed and with obvious seasonal characteristics. The available biomass resources in China were equal to 350 million tons of standard coal by 2010, and will reach 460 million tons of standard coal by 2020, and reach 570 million tons of standard coal by 2030. As shown in Table 1, a large proportion of biomass resources are straw and animal manure at all the level years, which mainly provide the raw material for the biomass direct combustion and mixed combustion power generation and biogas utilization. Nowadays, the straw is still the main fuel for biomass power generation. Straw is produced from June to November in most area, and its supply will be very few from December to next May. In order to ensure continuous production, biomass power plants should store the fuel for six months' amount. In recent years, the increasing costs for production caused by the growth in demand for fuel and the lack of standard to guide the fuel market make the biomass power plants' profit decline and even completely loss, since the rising cost of fuel is out of the control for biomass power plants.

Fuel agency

It is crucial to establish an adequate raw materials' collection organization between farmers and plants, and two kinds of cooperation modes are followed [2]:

1. "Plants and Farms" mode

Power plant signs annual straw supply agreements directly with farmers, and purchases the raw materials according to the signed contracts. In this mode, the power plants need to manage a large number of contracts, requiring specific organizations to manage the collection, storage and transportation of the straws [3].

2. "Fuel Agency" mode

Power plant contracts with one or more fuel agencies, which purchase straws from farmers, and arrange for collection, storage and transportation of the straws. In this mode, the power plant can establish stable price mechanism with the broker, which brings certainties between the two sides [4].

Currently, the latter mode is more popular, and has been used in the supply of raw materials for biomass power generation. Since there is no open and transparent trading market for straws and most farmers are in vulnerable position relative to the power plant, local governments should pay attention to protecting the interests of farmers and also that of the plants. So it is necessary to establish a crop straw pricing advisory committee in order to guarantee the transparency of straw's price and protect farmers' interests in transactions with the large power plants under the absence of competition in market transact

Power generation

Total investment of biomass power generation in 2006 was 16.8 billion RMB and 58.6 billion RMB in 2010, with an average annual growth rate of more than 45% [5]. And the installed capacity rose from 1.4 million kW in 2006 to 5.5 million kW in 2010, with an average annual growth rate of 39%, a little lower than that of the investment Figure 1.

Structure of biomass power generation: China's biomass power generation technologies are mainly straw direct combustion power generation and waste incineration power generation. Up to 2009, China's total installed capacity of straw direct combustion power generation was 265 million kW, accounting for 62% of all biomass power generation [6]; the total installed capacity of waste incineration power generation was 125 million kW, accounting for 29%; other techniques, such as gasification power generation, gas generation and power generation fuel mix, shared a small proportion of less than 10% [7]. According to the plan from National Energy Commission (NEC), China's biomass power generation installed capacity will reach 13 million kW by 2015, 160% times more than that of 2009 [8]. Figure 2 shows the current structure of China's biomass power industry.

Power technology

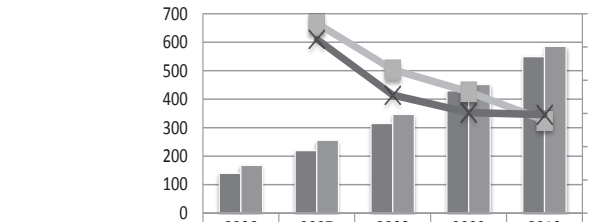
Power generation project: Development and application of biomass power technology in China started late. And the scale is small. But in recent years, inspired by the renewable energy Act and preferential pricing policies biomass power generation industry in China has developed rapidly. By the end of 2006, the total installed capacity of biomass power generation in China had reached 2GW approximately, mainly from bagasse power generation with a total installed capacity of about 1.7GW [9]. The remainder was gasification power generation from rice husk. In 2006, under the relevant regulations in China, new projects of

Classification	2008		2010		2020		2030	
	Physical quantity	Standard coal	Physical quantity	Standard coal	Physical quantity	Standard coal	Physical quantity	Standard coal
Crop straw	2.9	1.45	2.9	1.45	2.9	1.45	2.9	1.45
Wood residue	0.26	0.13	0.29	0.15	0.38	0.19	0.48	0.24
Animal manure	1.4	0.63	1.71	0.77	2.55	1.15	3.8	1.71
Industrial organic waste	500	0.39	566	0.44	724	0.57	927	0.73
Bio-organie municipal waste○11	1.5	0.2	1.91	0.25	3.12	0.42	4.19	0.56
Energy crop		0		0.02		0.09		0.14
Woody biomass energy	0.74	0.42		0.44		0.68		0.84
total		3.2		3.5		4.6		5.7
Unit: physical quantity (100 million tons), standard coal (100 million tons)								

Data source: National Energy Board Development Planning Division, 2010, 8, Research report of the renewable energy development strategy in China
○11The unit of the physical quantity is 100 million cubic meter of biogas

Table 1: Potential and available biomass energy resources in China.

biomass power generation could receive price subsidies of 0.25 Yuan/kWh in its first 15 years [10]. Inspired by this policy, the investment of biomass power generation in China has been rising rapidly, and the construction of various types of agricultural and forest residues power generation projects have been carried out. According to statistics, the government approved 39 biomass power generation projects in 2006 with total installed capacity of about 1.28 million-kilowatt [11]. New projects of biomass power generation are dominated by the straw direct combustion power generation project (for example, the straw direct combustion power generation project of Shanxian in Shandong province). Some other projects include power generation projects of co-firing of straw with coal (for example, Shiliquan power plant of Zaozhuang in Shandong province) and combined heat and power generation projects (for example, the forest biomass combined heat and power generation project of Tongliao in Inner Mongolia) [12]. The research on equipment of biomass power generation in China has also made significant progress. In 2006, in the stalk direct combustion power generation project of Suqian in Jiangsu province was put into operation that was the first project using domestic technology devices with independent property rights [13].



	2006	2007	2008	2009	2010
Total installed capacity (10 MW)	140	220	315	430	550
Total investment (hundred million RMB)	168	256	347	452	586
Growth rate (%)		57.14	43.18	36.51	27.91
Growth rate (%)		52.38	35.55	30.26	29.65

Figure 1: Scales of China's biomass power industry 2006-2010.

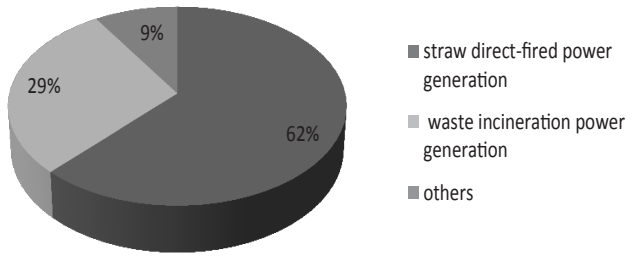


Figure 2: Biomass power structure in China 2009.

The cost and efficiency of power generation: The agricultural production in China is not intensive operation without large-scale processing activities of agricultural and forestry [14]. Therefore, the government should develop different kinds of biomass power projects according to local conditions and based on resource endowments and distribution of raw materials, in order to ensure the supply capacity of raw materials and the economics of projects. The costs of biomass power generation depend on the costs of biomass feedstock and the efficiency of power generation. Biomass feedstock costs rise as the project size increases. Usually biomass power generation projects using the technologies of direct-fired/co-fired power generation and combined heat and power generation could improve the efficiency of energy utilization. Statistical data shows that when the scale of biomass power generation project increase from 1MW to 20MW, the collection coverage of biomass feedstock will increase by more than 30 kilometers from 1-4 kilometers, and the integrated costs of collection and storage management of raw materials will increase by 1 time, as shown in Table 2. Experience has shown that with the constraints of the factors of biomass resources and costs, the collection radius of raw materials for biomass power generation projects should be controlled within the county. The scales of projects should be controlled below 15MW (except co-firing power generation) [15]. However, with the increase of the scale of biomass power generation projects and the introduction of large boilers and combined heat and power technology, the generating efficiency has improved significantly, proving the economies of scale are, as shown in Table 3. Therefore, considered the resources endowment and the technology economic features of bioenergy, in the areas which have abundant and concentrated resources such as energy shrubs forest, agricultural forestry processing plant, and large concentrated farm, large

Capacity of installed generator (MW)	1-2	5-10	10-20	>20	Remarks
Raw material supply(10000tons/year)	1-2	5-10	10-20	>20	Biomass calorific value of dry matter is 3250 kcal/kg
Average collection range (km)	<5	5-15	15-30	>50	
Basic costs of raw material (Yuan/ton)	100	100	100	100	The price is from farmers
Collecting and handling fees (Yuan/ton)	80	80	80	80	The labor cost of collection and handling
Transport costs(Yuan/ton)	10	20	40	70	It's available for the distance of more than 20 kilometers
Storage management costs(Yuan/ton)	10	15	30	50	The costs should consider the size and the storage time
Total cost(Yuan/ton)	200	215	250	300	

Data source: National Energy Board Development Planning Division, 2010, 8, Research report of the renewable energy development strategy in China

Table 2: Cost estimation of biomass feedstock (for example: crop straw).

Efficiency indicators	Gasification power generation			Direct combustion power generation		Mixed combustion power generation
Unit installed capacity	200kW	1MW-3MW	6MW	12MW	25MW	140MW
runtime (hours/year)	3500	6000	6500	7500	7500	4500
System power efficiency (%)	18	20	24	23	25	31
Station service power consumption rate (%)	10	12	12	13	13	11
Fuel dose (kg dry matter /kWh)	1.4	1.2	1.1	1.2	1.1	0.9

Data source: National Energy Board Development Planning Division, 2010, 8, Research report of the renewable energy development strategy in China

Table 3: Biomass power generation efficiency and technical and economic indicators.

and medium scale biomass direct combustion/co-firing power generation and heat and electricity cogeneration projects should be given top priority (above 10MW). In the areas which have scattered resources such as general agricultural district, small and medium scale biomass gasification power generation (below 10MW) and co-firing power generation with coal can be developed flexibly.

Technology evaluation: After decades of development, the biomass energy technologies become more and more diverse. But currently, the overall level of development and utilization of biomass energy in China is lower compared developed countries. The degree in maturity and commercialization of different technologies is very uneven. At present, some biomass energy utilization technologies have become more mature, with a certain economic competitiveness, having achieved the commercialization and large-scale applications, such as biogas technology. A number of biomass technologies have entered the early stages of commercialization. It is necessary to promote commercial development via subsidies and other economic incentives, especially toward the biomass power generation, forming dense biomass fuel and bio-liquid fuel made of raw materials such as food-sugar-oil crops. However, some emerging bio-energy technologies are in demonstration stage and are expected to be industrialization, commercialization gradually in the next 20 years, mainly toward the bio-liquid fuel from fiber material, such as the technologies of cellulose ethanol, biomass fuel synthesis fuel and pyrolysis oil, energy algae and microorganisms hydrogen. The mature degree, market competitiveness and development prospects of different biomass energy utilization technologies are shown in Figure 3.

Regional analysis of the biomass power industry: Straw is the main fuel for biomass power generation in China. The biggest characteristic of straw is that its distribution is both decentralized and centralized, especially in the food production areas which are the most affluent regions for producing straws. For example, in Hebei, Shandong and Henan province in Heilongjiang and Huang Huaihai area, Anhui province in southeast area, Sichuan, Yunnan, Guangxi, Guangdong and some other provinces in southwest area, the straw resources almost account for the half of national gross, as shown in Table 4 [16]. Therefore, some areas in China have good conditions to utilize agricultural straw in a large scale. However, in some other areas, low distribution density of straw resources leads to bigger levy radius, which is difficult to achieve large-scale production.

Because of the problems of resource distribution and transportation, biomass power generation industry in China has also developed in the regions disproportionally. China's biomass power generation is mainly concentrated in eastern China, up to the end of 2009, the region's installed capacity accounted for 49% of the country, followed by the south central China which accounted for 22%, and the third is Northeast China, accounting for 15% [16]. For the investment, up to the end of 2009, East China accounted 50% of the whole country, also followed by south central China which accounted for 21% (Figure 4).

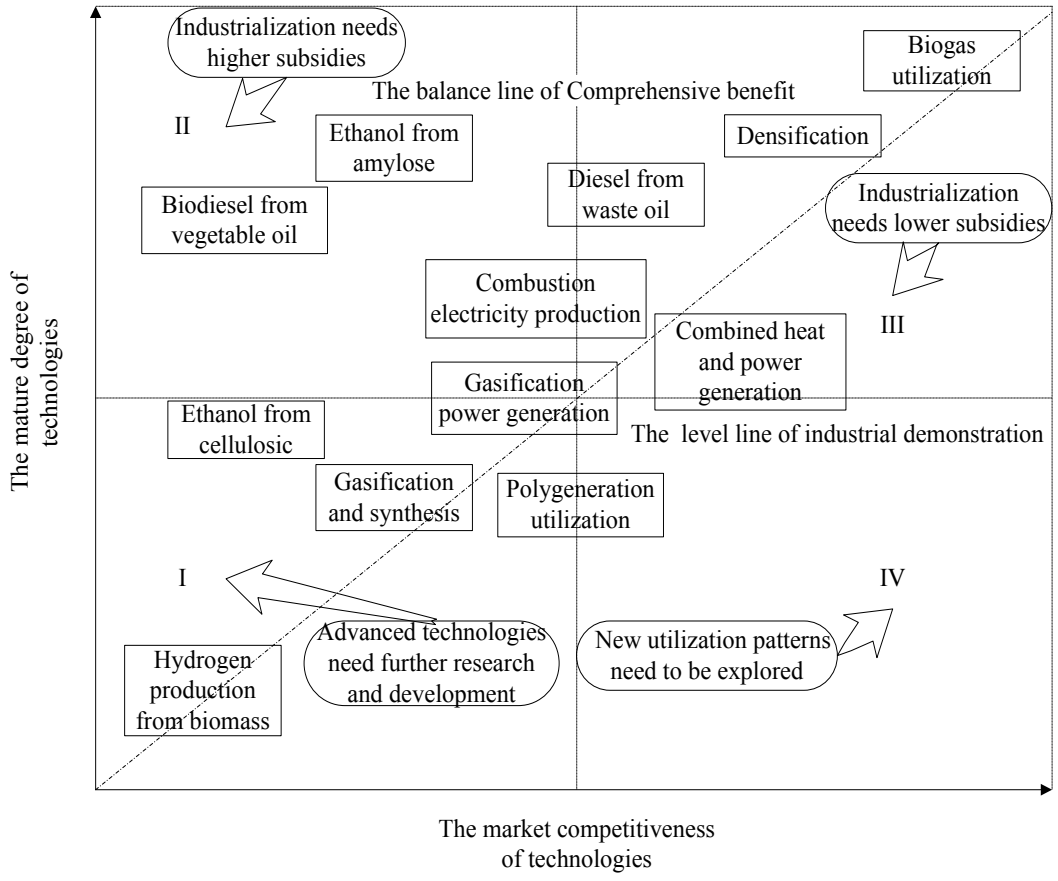


Figure 3: The mature degree, market competitiveness and development prospects of different biomass energy utilization technologies.

Region	Straw resources (10 thousand tons)	Proportion (%)
The whole country	54647.25	100
Northeast	9128.59	16.7
Huang Huaihai area	14059.72	25.7
Southeast	14933.29	27.3
Southwest	8631.52	15.8
The Loess Plateau	3642.67	6.7
Northwest Plain area	4081.78	7.5
The Qinghai-Tibet Plateau	169.78	0.3

Data source: National Energy Board Development Planning Division, 2010, 8, Research report of the renewable energy development strategy in China

Table 4: Available straw resources in various regions and its proportion of total nation.

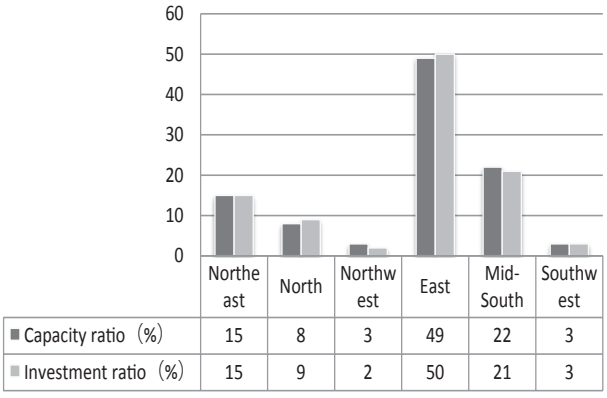


Figure 4: Regional distribution of installed capacity and investment for biomass power generation in 2009.

Industry concentration: Up to the end of 2009, the largest power generation group is National Bio Energy Group, whose installed capacity is 631 MW, accounting for 14.67% of the total bioenergy capacity. The second is Wuhan Kaidi Electric Power CO., LTD, whose installed capacity is 414 MW, accounting for 9.63%. Five Power Groups' total installed capacity of 397 MW, accounting for 9.23% Table 5 [18]. Other biomass power plants are mostly local and foreign SMEs.

From the Table 5, it is obvious that Five Power Groups, whose total installed capacity accounts for about 60% of all in China, invested little in biomass power industry, while joint ventures and private enterprises invested more such as National Bio Energy Group and Kaidi Co.

Grid and consumers

Grid industry is the downstream of all power generation industry, but also the upstream of electricity consumers, so it plays a special role in the national economy and maintains a high monopoly. The on-grid energy generated by biomass fuel is increasing dramatically from 104M kWh in 2006 to 6607.71M kWh in 2010, by more than 60 times [19]. And the amount of subsidy rose from 24.64 million RMB in 2006 to 1609 million RMB in 2010 Figure 5.

Since no green tariff system exists, the consumers of the biomass electricity are, namely, the consumers of all kinds of electricity. And the electricity price for consumers is the same as other kinds of electricity, fixed by the government. As for the higher cost of biomass power generation, government subsidizes it, fixing the feed-in price at 0.75RMB per kWh, but some plants are still under deficit (Figure 6)

Development Dilemmas

In recent years, with government's positive encouragement and vigorous support, biomass power industry developed rapidly in China and its industry scale enlarged gradually, which gave rise to the obvious social and economic profit. However, from the viewpoint of the theory of industries development life cycle, China's biomass power industry now stays at the transition stage from startup to growth stage. The development of each part of industry in this field lacks coordination, and some of them are falling into damping due to competition. Deficiency also exists in the aspects of feedstock supply, technology, policy and regulation, and follow-up services, etc.

Raw materials

Although China's theoretical biomass resource is 5 billion tons coal equivalent, the available biomass resource is about 280 million tons coal equivalent in practice [20]. Most agricultural wastes could not be effectively used for biomass industry development. And the existing biomass resources are used for paper making, compost and biological feed as well as power generation. So it is still short of feedstock resources.

Internal factors: The supply of the raw materials is highly seasonal dependent, more ample in summer and autumn than that in spring and winter. Raw materials are needed all through the year for the formal operation of power generation projects, while the busy farming season is just a short period of time, leading to the supply of raw materials for the project intermittently saturated and deficient. So it is necessary to build an exclusive station for fuel collection and storage, and to provide facility for collection, storage and transportation. This means high investment and fixed cost. Although the direct combustion of the straw pollutes the air and brings many negative effects, it makes the land fer-

Company name	Installed capacity(MW)	Market share (%)
National Bio Energy Group	631	14.67
Kaidi Co.	414	9.63
Huadian Co.	145	3.37
Datang Co.	105	2.44
China Power Investment Co.	63	1.47
Huaneng Co.	30	0.7
Jiangsu Guoxin Co.	115	2.67
China Energy Conservation and Environmental Protection Group	48	1.16

Table 5: Main biomass power generation groups' installed capacity and market proportion.

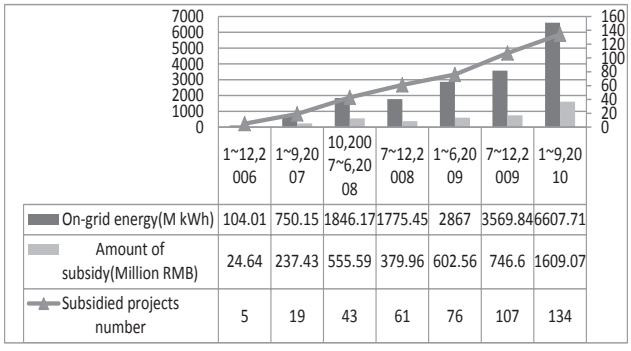


Figure 5: The amount of on-grid energy, subsidy and subsided projects.

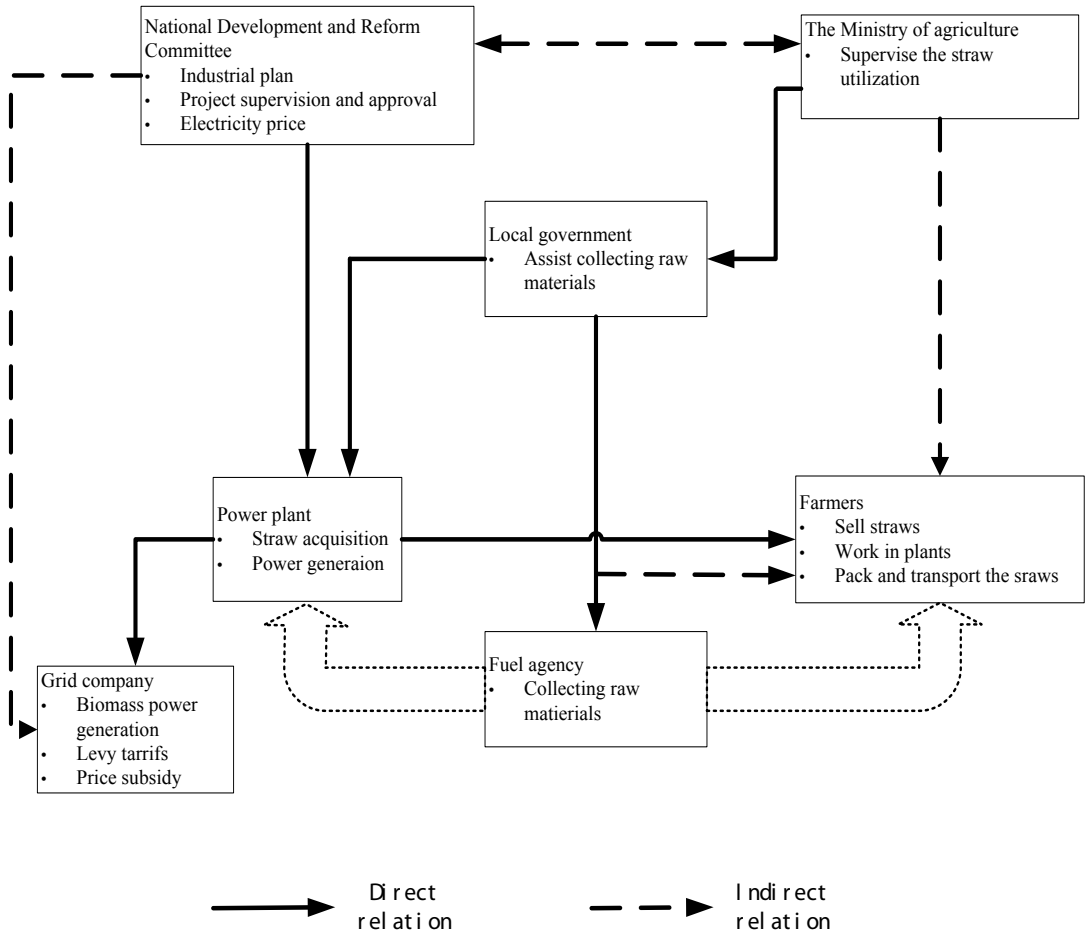


Figure 6: The operation framework of biomass power generation.

tile as well. If the demand stays unchanged or increases, decline in the supply of raw materials will increase acquisition costs.

External factors: And the more important thing is that the prices of raw materials are not fixed, mainly related to the season, type and quality, due to the lack of a market for farmers and biomass power plants to trade biomass materials, at reasonable and transparent price. Sparseness of professional operators for raw material purchasing and transportation, as well as lack of necessary quality assurance mechanisms for raw materials, also restricts the development.

- The power plants' raw materials are partly from the fixed place, and the other part is purchased from decentralized farmers [21]. Due to the decentralized source of the raw materials, and no professional operators of the straw purchase and transportation, there are no economies of scale for farmers and enterprises, and affect much on the cost.

- Due to the absence of quality standards, the quality of the raw materials such as straw can only be judged by the QC's experiences. Since there is no constrained mechanism for farmers, the raw materials are at various levels of quality.

Technology

At present, the sizes of most biomass power generation enterprises are comparable, but mainly differ in the equipment. A number of key power generation equipment relies on imports, but the cost of the imported equipment is too high for some enterprises to benefit from the generation, and so is the cost of the maintenance compared to the domestic equipment.

And also an important issue is that most biomass power plants are straw-direct combustion power plants, about 62% [22]. This kind of generation consumes a large number of raw materials and the heat of straw combustion is not stable. Co-combustion power generation needs much less straws, and it has good adaptabilities and economic benefits.

This technology has basically achieved the commercialization in Europe and got the validation of demonstration projects in many countries. However, there is no suitable straw burning methods for co-combustion (if straws are blended into the combustion furnace, the instable heat of the straw may make the boiler flame failure, which will cause a big loss and even cause the power grid failure), although this technique has several advantages, it is still not qualified to get appropriate support provided by PRC Law of Renewable Energy. This is the reason why most of the coal-fired power plants are unwilling to transfer to co-combustion power plants, even though co-combustion can to some extent achieve national subsidy to ease the current loss situation

of coal-fired power.

Electricity price

Although the National Development and Reform Commission raised bio-electricity price to 0.75 RMB per kWh in September 2010, many areas in China still do not meet the economic requirements, such as Hunan, Fujian, Zhejiang, Guangdong and other places, so do many power plants [23]. Here are two main dilemmas:

- On one hand, the same electricity price of feed-in cannot embody the different cost of the varying kinds of biomass energy. There are many kinds of biomass energy generation such as straw-direct combustion power generation, straw-gasified power generation, bagasse power generation, forest wood-direct combustion power generation, forest wood-gasified power generation, waste incineration generation, landfill-gasified power generation, biogas power generation and others. The cost of power generation varies due to the varying requirements of each power generation such as type of resources, technical route and environmental standard, for instance, the cost of waste incineration generation is 0.1 RMB higher per kWh than that of landfill gasified power generation.

- On the other hand, according to the rules, co-combustion power generation projects are not subsidized with fuel price if the proportion of conventional energy exceeds 20% of the whole energy consumption, which will not encourage the existing coal-fired units to transform into the units burned with biomass energy resource. With characteristics of dispersed production, seasonal dependence, short harvest period etc., the supply of biomass fuel does not meet the requirements such as centralized power generation, in scale and durative. Meanwhile, the value of biomass fuel is very low and its volume density is small as well as low output of per unit area, which leads to high storage cost. If coal-fired power plants burn with biomass energy without price subsidy, they will lose the transformation motivation [3].

The risk of CDM for biomass power generation development

China has the largest amount of registered CDM projects in the world, and up to the end of December 2010, 2,801 CDM projects were successfully registered in the United Nations, among which 1207 projects were from China, accounting for 42.8% [24]. It is well known that the direct benefits from CDM for owners are the carbon-selling earnings after the project gets CER, which can effectively alleviate the item financial pressure, as well as improving the project's rate of return on investments.

In reality, when CDM brings enormous benefits, it is also accompanied by high risks. Each link from initial project identification and negotiation to eventually income distribution may have risks as followed:

Approval risk: The biggest risk for CDM projects is the uncertainties of all levels in the approval process. The approval process of CDM project is very complex, while the CDM Executive Board of United Nations does not have rigorous and actionable CDM project approval criteria for a long time [25]. As for biomass project, the time for certification is at least half a year. The complex approval process brings uncertainty, whatever the outcomes are, thousands of dollars have been invested for preliminary design, packaging and registration costs, but EB will not provide any relief measures to the project. Since the emission reductions must be sold after the complication of the project, if it does not get the certification, the former investment for certification will be wasted, which will bring heavier burden on enterprises.

Policy risk: Sharp divisions had emerged within developed and developing countries over how to deal with Carbon emission reduction at the United Nations Climate Change Conference held in Copenhagen, December, 2009. The conference did produce consensus on some issues, but it failed to produce a major treaty that would bind nations to limits on their greenhouse gas emissions, which further increase the uncertainty of the CDM's future [26]. As a developing country, there is no obligation for China to reduce emission under the Kyoto Protocol. But uncertainties still exists whether China will belong to non-Annex I countries since China has become the largest emitter of CO_2 in the world. If China begins to implement the Kyoto Protocol emission reduction obligations, China will be carbon net importer instead of net exporter, making all enterprises facing significant emission reduction pressure. If the price of CERs is higher then, this means paying higher to buy what China has sold before, which will lead to additional loss.

Changing role of Carbon trading and the change between supply and demand of CDM market will bring increasing burden on China in the negotiation of international climate change regime, and will also have a huge impact on China's domestic carbon trading market.

Recommendations for the Development of Biomass Power Industry

Although biomass power industry developed rapidly in China with the increase of the investment by 41.8 billion RMB and the installed capacity by 410 million kW, there are still many dilemmas which constrain its development [27]. In light of the China's biomass power industry development status and problems mentioned above, based on sustainable development, the countermeasures to develop China's biomass power industry are proposed as follows:

Open fuel markets and promote market-oriented industry

Currently, most biomass power plants purchase biomass fuels from fuel agencies which obviously increases the cost of power generation since the fuel agencies get about 20 to 30 RMB per ton. In order to ensure this industry's fast and stable development, market mechanism should be introduced to raw material supply, which will function better. Open and transparent trade markets should be popularized to make buyers and sellers trade biomass fuels expediently. Under this circumstance, price's reasonability and the quality of the raw materials can be guaranteed, which will not only do farmers favor to sell their agricultural waste but also benefit the plants since the cost of the biomass fuel purchased directly from farmers will be lower than that from fuel agencies. And the trade market will bring many conveniences to both buyers and sellers of the biomass fuel. On one hand, although biomass fuel suppliers are eager to sell waste straws, most of them live far away from the power plants and their vehicles as well as the transportation in many villages are lagging, it is inconvenient for them to transport their agricultural waste to power plants. As a result, most farmers sell their agricultural waste to fuel agencies instead of directly to power plants. On the other hand, most power plants do not have the specific person to be in charge of the raw materials, they just purchase them from fuel agencies for convenience since it is not an easy thing to negotiate acquisition of raw materials with farmers in the surrounding areas within a radius of 100 km, although the acquisition cost directly from farmers is lower.

The trade market would better be set up by government, and the trading information can be searched on the Internet. This will ensure the fairness and transparency of price for biomass fuel. In one word, an open trade market will benefit both sides of the trade and will help the biomass power industry develop better.

Increase scientific research input and persist in independent technology innovation

It is well known that science and technology are primary productive forces for any industry's development. The fast and stable development of biomass power industry must be based on the advances in production technology. China's current situation is the vast majority of biomass power plants using technology imported overseas, namely the equipment such as the biomass boilers as well as operation and maintenance technology, since the domestic technology is lagging. This increases the cost of the biomass power plants to a large extent. So government should increase scientific research input, on one hand, this will not only reduce the power generation cost but is also conducive to promoting the development of the industry. On the other hand, technology advances are propitious for the profits transferring from upstream to the middle or downstream of the industry, since the import of most equipment results in the high profits of the upstream and some loss of the middle stream.

Also, government should increase the R&D input for mixed combustion of coal and straw technology. This will reduce the consumption of the coal as well as consume some agricultural wastes, and meanwhile reduces carbon dioxide emissions.

Short, medium and long term selection for price policy of biomass power generation

The entry or exit of any industry cannot be possible without the profit and policy support. The formation of mechanism for electricity price of renewable energy should be in conformity to the following four principles: facilitate the development, improve the efficiency, reduce the cost and encourage the competition. As for biomass power industry in China, government has implemented some effective policy to support its development, namely raise its feed-in tariff to 0.75 RMB per kWh and biomass power plants should be arranged in straw-rich areas, or within a radius of 100 km or each county should not repeatedly arrange biomass power plants. So policy choices on electricity price of biomass power should be as follows (Table 6).

Encourage grid enterprises to invest in biomass power industry

Currently, the most successful biomass power group is National Bio Energy Group who accounts for 14.67% of the market capacity. This group's registered capital is 2 billion RMB, of which Dragon Power Group invested 1.5 billion RMB, accounting for 75% and National Grid invested 500 million RMB, accounting for 25%. The grid company as one equity participant ensures that biomass electricity connects grid smoothly as well as the monthly sales revenues account successfully. Government should encourage grid companies to share in the investment of biomass power industry, and this will be win-win cooperation for both grid companies and biomass power plants. And based on the high feed-in tariff, preferential tax policies will introduces to grid companies in order to ensure the industry's stable development.

Selective application of CMD projects

Although application for CDM projects has many risks for biomass power plants, advantages still exist. The financing cost of CDM project is very low compared to the whole construction cost, the cash flow is steady, and the introduction of foreign capital can bring advanced technology from which we can learn to improve domestic lagging technology. So, CDM project is still a nice choice for the development of biomass energy as a financing model of low cost and stable cash flow. It is suggested that if the investor has abundant funds to turnover, the application for CDM project is beneficial, since the success of the application will bring profit and application cost will not affect the whole profitability. As for investors, they should be well prepared before submit their application materials in order to raise the probabilities of success.

Analysis of Development Strategy

Development goals

The development goals of biomass resource: Abundant biomass resources could not meet our future demand for biomass resources in China. Most of biomass resources are the cellulose waste. So the key to develop biomass energy in China is increasing the utilization rate of agricultural and forest residues such as straw, expanding the supply routes and supply capacity of the biomass resources. Development planning for the development and utilization of biomass energy in China, and development goals and principal tasks in the development and utilization stage of biomass energy in China are as shown in Table 7 and 8.

The technology goals of biomass power generation: Forestry and agricultural residues occupy a large proportion of biomass resource in China. And this structure does not significantly change in the short term. So the goal of the biomass power industry is to maximize utilization rate of biomass waste under the economic conditions. Based on this, for a long period, the main biomass electricity is from Forestry and agricultural residues such as straw which has been used in a large-scale. However, scattered agricultural waste and the high cost of centralized collection limit their supply, which make biomass power technology be applied in small and medium scale. Therefore, improving the efficiency of power generation and reducing the cost of power generation are the subjects of biomass power generation. Development goals of biomass power technology in China are as shown in Table 9.

Technology roadmap

Based on the above analysis, the goal of biomass power generation industry in China is to maximize the utilization rate of biomass waste under the economic conditions. Nowadays, biomass power technology can only applied in small and medium scale. However, resolving energy problems and helping local farmers increase income and improve their living conditions should be the principle and route guiding the biomass power generation industry. The development ways of biomass power generation in China is shown in Table 10.

Policy guarantee

Evaluate the biomass resource, and make an overall development plan: It's time to survey and evaluate the biomass power resources scientifically systematically, in order to clear the total amount of resources, uses and distribution. The government should make a development plan for the biomass power generation industry, clearing its direction and objectives. Meanwhile, integrated development of biomass power generation makes the land which is used to establish biomass power plants development planning and basic norms, promoting the coordinated development of energy, agro-forestry and ecology protection.

Develop the pilot demonstration actively, in order to promote the development of biomass power industry steadily: The whole country and each region should carry out pilot and demonstration of biomass power generation actively, according to the characteristics of resources, technology and energy demand, perfect management system and service system, accelerate the industrialization process of biomass power generation, promote various biomass power generation tech-

Short-term	The policy of fixed-price should be adopted due to the different price level of varying techniques, and also the mandatory policy of grid feed-in should be executed to ensure the investment of biomass energy. At the same time, we should consider the external value of power production and the related price situation between coal and raw material of biomass power generation so as to make the different electricity price of varying kind of biomass power generation.
Medium-term	Introduce the price policy of grid feed-in through bidding in some appropriate areas, and formulate the appropriate standard of price subsidies according to the external benefits.
Long-term	After 2020, we will decide whether to use subsidy or not according to the comparison result of the real cost and the utilization economy of biomass power generation and coal-fired power generation.

Table 6: Policy Choices on Electricity Price of Biomass Power.

	2010		2020		2030	
	Scale	**Standard coal**	**Scale**	**Standard coal**	**Scale**	**Standard coal**
Biomass power generation	6 million kW 36 billion kWh	18 million tons	30 million kW 180 billion kWh	90 million tons	50 million kW 300 billion kWh	150 million tons
Liquid fuel	2.2 million tons	2.2 million tons	15 million tons	15.8 million tons	50 million tons	52 million tons
Fuel ethanol	2 million tons	2 million tons	10 million tons	10 million tons	30 million tons	30 million tons
Bio-diesel	0.2 million tons	0.24 million tons	4 million tons	4.8 million tons	10 million tons	12 million tons
Synthetic fuel/cracked oil	—	—	1 million tons	1 million tons	10 million tons	10 million tons
Biogas and gasification	20 billion m^3	18 million tons	40 billion m^3	36 million tons	60 billion m^3	54 million tons
Briquette fuel	1 million tons	0.5 million tons	50 million tons	25 million tons	50 million tons	25 million tons
Total	—	41 million tons	—	183 million tons	—	333 million tons

Data source: National Energy Board Development Planning Division, 2010, 8, Research report of the renewable energy development strategy in China

Table 7: Development planning for the development and utilization of biomass energy in China.

Period/Target	Start-up Period(2006-2010)	Development period(2011-2020)	Mature stage(2021-2030)
Stage Target	Explore the utilization patterns of biomass energy. Use the agricultural and forest residues effectively to achieve the strategic objectives of environmental protection and energy saving.	Improve the proportion of biomass energy in the supply of clean energy effectively. Embody the role of biomass energy in CO2 emission reduction and supplying clean liquid fuels.	Improve the contribution of biomass liquid fuel. Play a role of biomass in rural modernization, and achieve the national strategy goal to reduce external dependence degree of liquid fuel.
Specific objectives	Utilization rate of agricultural and forest residues reach to 3%-5%. The power scale of bioenergy obtains 6 million-kilowatt. The biomass liquid fuel achieves 2 million tons.	Utilization rate of agricultural and forest residues reach to 15%-20%. The power scale of bioenergy obtains 30 million-kilowatt. The biomass liquid fuel achieves 12 million tons.	Utilization rate of agricultural and forest residues reach to 30%-40%. The power scale of bioenergy obtains 50 million-kilowatt. The biomass liquid fuel achieves 60 million tons.
The main task	Perfect the study platform on biomass energy technology. Develop advanced technologies to improve efficiency. Establish a biomass energy demonstration system. Put the interface in biomass energy and traditional industries. Make the related standards and supporting policies.	Raise the level of technology and large-scale utilization. Reduce costs and improve the market competitiveness. Develop different supply sources and channels of sustainable biomass resource.	Improve the production mode of energy agriculture and energy forestry. Establish the large-scale biomass liquid fuel supply pattern. Build a new model of decentralized use of biomass energy in rural areas.

Data source: National Energy Board Development Planning Division, 2010, 8, Research report of the renewable energy development strategy in China

Table 8: Development goals and principal tasks in the development and utilization stage of biomass energy in China.

Power generation technology	Total goals	Specific objectives
Mature and stable medium and large scale biomass power technology	Establish the centralized model of biomass power generation industry.	Towards 2030, form a biomass direct combustion power generation industry of 15 million-kilowatt
Biomass power generation technologies of combustion with coal	Achieve the goal of energy conservation and emission reduction in coal-fired power station.	Towards 2030, the power plant scale of co-firing of biomass with coal could run up to 15 million-kilowatt
Medium and small scale biomass gasification power generation technology	Establish the decentralised biomass power generation industry.	Towards 2030, the dispersed industrial scale of biomass power generation could reach 15 million-kilowatt
Off-grid independent biomass power technology	Seek for the effective way of using biomass electricity flexibly in the future.	Towards 2030, the capacity of biomass power generation in remote areas could attain 5 million-kilowatt

Data source: National Energy Board Development Planning Division, 2010, 8, Research report of the renewable energy development strategy in China

Table 9: Development goals of biomass power technology in China.

nologies, and form a complete industrial chain including the supply of raw materials, product processing, marketing and related services.

Establish and perfect the market system, promoting application of the biomass power technology: Grid enterprises should undertake the obligations to purchase renewable electricity, strengthen the construction of infrastructure, carry out the electricity sales, and encourage and support the development of small and medium scale biomass power projects according to the features such as decentralized biomass resources, strong regions, wide range of farmers' participation, in order to mobilize the positivity of enterprise and local resident, effectively increase the job opportunities and income.

Increase financial and technical support, promoting technological progress and industrial development: Currently, with high biomass power costs and weak market competitive, technology sector needs to increase investment in biomass power technology research and development. The financial sector should make fiscal and tax policies to promote the development of biomass power generation industry.

Strengthen comprehensive coordination and management among different sectors: Industrialization exploitation of biomass

Development content	2007-2010		2011-2020		2021-2030
	The main task	Key issues	The main task	Key issues	The main task
Biomass direct combustion power generation	Realize the equipment localization of biomass direct combustion power generation	Study on the adaptability of biomass boiler fuel. Research the manufacturing technology of biomass boiler core parts. Build the supply mode of raw materials in biomass power plants.	Establish a centralized biomass power generation industry	Develop the prevention technology of alkali corrosion in boiler. Develop new high efficiency biomass boilers. Manage and control the cost in large-scale biomass power generation	Fully realize the commercial applications
Biomass power generation of co-firing with coal	Develop biomass co-firing power generation technologies of small power stations	Research on the combustion technology in small-scale coal-fired boiler. According to the operation plan of small-scale coal-fired power plants, make the supportive policies and standards	Develop the co-firing technology of large coal-fired power plant	Study on co-firing technology with low rate for large-scale boiler. Set the running standard of co-firing in large-scale power stations	Fully realize the commercial applications
Biomass gasification power generation	Develop the low-cost biomass gasification power generation system	Study on the adaptability of efficient ordinary pressure gasifier system. Develop the low-cost equipment of gas-fired power generation. Develop the Low-cost fuel pretreatment technology	Develop the high efficient biomass IGCC power generation system	Develop the efficient high pressure gasification technology. Develop the technology of high-temperature dust removal in addition to Coke. Develop the special small-scale gas turbine	Fully realize the commercial applications
Off-grid biomass power generation	Develop the new-type gasification power generation model	Develop the micro-biomass gasification equipment. Study on the integration of gasification and Stirling power. Study on the integration of gasification and fuel cell	Develop the decentralized independent system of biomass gasification power generation	Apply and demonstrate the decentralized and independent biomass power system. Set the standard of technology and operation in small-scale biomass gasification power generation	Fully realize the commercial applications

Table 10: The development ways of biomass power generation in China

power generation involves some departments such as energy, forestry, taxation, science and technology, environmental protection, quality inspection and so on. The relevant departments need to strengthen collaboration and establish a comprehensive, coordinated and consistent management and policy support system of biomass power industry. Energy administration departments at all levels should incorporate bioenergy into management, evaluate the biomass resource, make the plans, construct the demonstration projects, formulate and perfect relevant policies. Agriculture and forestry departments at all levels should manage the resources of agricultural, forestry and bio-energy including the resource assessment, development, technical support and related administrative works.

Conclusion and Prospects

The above analysis indicates that the development of biomass power generation industry in China has made considerable progress in investment, installed capacity and on-grid energy, and also made enormous contributions to carbon reduction. Whereas, the industry is not market-oriented and the equipment technology is lagging, the upstream of this industry, namely the supply of the raw materials and production equipment, is still constraining its development. And the recommendations given above will provide policy support as well as development direction and method in order to ensure the stable and fast development. Finally, the development strategy of biomass power generation industry in China is suggested. It proposes development objectives, technology roadmap, and the related policy guarantee measures for the biomass power industry. The appropriate conclusions might have great reference value for the scholars to study the biomass power industry development further.

The installed capacity would reach 13 million kW in 2015 and 30 million kW in 2020 according to the goal of biomass power generation industry from the perspective of government planning. Under this situation, government will effectively support the development of biomass power generation industry, both in terms of promoting market mechanisms or the electricity price policy, as well as the research and development input. In the future, with scientific and technological progress, and economic and social development, China's biomass power industry will expand rapidly, and the cost will be further reduced. There is a bright prospect for the development of biomass power industry in China.

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