A REVIEW OF SUPPLY CHAIN OPERATION MODE OF AGRICULTURAL STRAW BIOMASS AND BIOMASS INDUSTRY IN HEILONGJIANG PROVINCE, CHINA

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Abstract

A stable supply system of straw biomass is critically important to the successful operation of a biomass-based power plant. However, it is noted that the current collection, storage and transportation of crop straws in China have not come to the stage of industrialization, not to mention the establishment of a complete and scientific straw collection system. Therefore, it is critically important to solve these problems that restrict the large-scale development and utilization of biomass energy. In this paper, the basic operation links of agricultural straw biomass supply chain including collection, pre-treatment, transportation and storage, and the current operation modes in China are briefly reviewed. The existing problems that restricted the development of biomass supply industry in Heilongjiang Province, China, are analyzed and some reasonable suggestions are put forward in order to promote the development of bioenergy industry in this province.

Keywords: biomass, storage, collection, operation mode, countermeasures

1. Introduction

Due to the concerns on the limited fuel sources, energy security, pressure in reduction of greenhouse gas emissions and other factors, adjusting the energy structure and promoting low-carbon development have become the inevitable choice for China. Bioenergy is considered to be one of the most potential alternative sources [1]. In the National Medium- and Long-term Technology Development Plan of China (2006-2020), the "Agriculture and Forestry-based Biomass Project" is listed as a major project and considered as an important part of the national energy strategy. Heilongjiang Province is a one of the largest provinces in China, rich in agricultural and forestry products. With 9.9 million hectares of arable land, the province can supply abundant soybean, wheat, corn, rice and other food crops to the national market [2]. Its forest area, total forest stock volume and timber output rank far above the national level in China [2]. According to relevant statistics, the potential biomass quantity for utilization in this province is approximately 22 million tonnes in agriculture and 9.6 million tonnes in forestry [3]. If these biomass resources can be effectively developed and utilized, we can not only save resources and improve the environment, but also greatly improve the energy supply in rural areas and create more job opportunities. However, it is noted that the current collection, storage and transportation of crop straws in China have not come to the stage of industrialization, not to mention the establishment of a complete and scientific straw collection system. The technologies related to the utilization of crop straw resources are just in a starting stage. The underdeveloped mechanical equipment and technology make the investment from the crop straw enterprises and its expenses in fuel costly in the early stage. Therefore, it is critically important to solve these problems that restrict the large-scale development and utilization of biomass energy.

In this paper, the basic operation links of agricultural straw biomass supply chain including collection, pre-treatment, transportation and storage, and the current operation modes in China are briefly reviewed. In consideration of the practical situation in Heilongjiang Province, the existing problems that restricted the development of biomass supply industry in Heilongjiang Province, China, are analyzed and some reasonable suggestions are put forward in order to promote the development of bioenergy industry in this area

2. The Nodes of Crop Straw Supply Chain

2.1 Collection of crop straws

Crop straw harvest is a seasonal work, which should be completed within a certain time. However, the straw biomass-based industries require the crop straws around the year. Therefore, it is very important to collect sufficient quantity of crop straw in the harvest season and meet the requirement of continuous production [4]. During straw collection, the following issues should be considered: Firstly, the collection radius of biomass shall be reasonably

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determined to meet the scale and requirement of the utilization plant; Secondly, the transport distance and storage space of fuel should be considered and correct packaging ways such as bulk material packaging should be used; Finally, the dehydration degree of fuel under natural conditions should be controlled in consideration of the technical requirements. It should also be avoided to include foreign matters such as dirt and others in the collection process so as to prevent slag formation during its combustion [5]. In China, the Land Contract Responsibility System is widely exercised in rural regions, which gives local farmers the right of cultivating and operating the rural lands and responsibility for the profits and losses of land management. The collection and harvest of crop straw relies mainly on manual work, supplemented by mechanical operation. Compared with large-scale mechanized and centralized operation in developed countries, there is a big gap in technology and working efficiency. The practice in China for harvesting rice straw or wheat straw manually is to carry both the crop grains and straw to the drying and threshing yard first, and then stack them in piles after manual or mechanical threshing. In corn harvest, the corn cobs are collected from the field first and then the corn stalk is collected and delivered for proper treatment.

2.2 Pretreatment of crop straw

In China, generally, the crop straw will not be delivered from the field directly to the biomass-based power plant and most of the crop straw shall undergo necessary pretreatment in the purchasing stations. Such practice can not only reduce the subsequent transportation costs, but also improve the density, hardness, particle size and other properties of fuel. The main pretreatments include compression and drying. Compression can improve the efficiency of transportation and combustion heat value of crop straw. The drying process can improve the performance of storage and combustion of crop straw through reasonably control on the moisture content of crop straw [6].

2.2.1 Compression

Straw can be compressed in many forms, among which baling is the most common compression method. In some developed countries, the crop straw residue and other biomass can be baled directly by straw balers simultaneously when the crop is being harvested (Fig. 1a). However, in many developing countries, the biomass fuel has to be delivered to the transfer stations for baling (Fig. 1b). The density of the biomass fuel can be improved after baling, from the initial density of 0.16 t/m^3 to 0.29 t/m^3 after the treatment, compressed by nearly 1.8 times [7]. Biomass fuel bales can be divided into round bales, rectangular bales and compact bales. The round bales are simple in baling technique, but their density is low, not convenient for transport and storage. The rectangular bales have a relatively higher density and are more convenient for transport and storage. With this form, the load space of trucks can be efficiently used. Therefore, the rectangular bales are the most popular form in practice in China.

(a) Baling in the field (b) Baling in the purchasing station

Figure 1. Baling of crop straw

2.2.2 Drying

Biomass fuel can be dried either under normal condition or by artificial drying. In the natural drying, the crop straw is placed in a cool, well-ventilated place for dehydration with natural wind and sunlight exposure. Under this way, the moisture content of crop straw can be maintained from 10% to 15%. The advantages of natural drying lie in the fact that it does not require any special equipment and its cost of processing is very low. The disadvantages are its liability to natural climate condition, high labor intensity and low efficiency. Also, it is hard to control the moisture content of crop straw after drying. In the process of artificial drying, the crop straw is heated by heat source and the moisture of crop straw is vaporized [8].

2.3 Transportation of crop straw

After the initial pretreatment, the power plants and other facilities can use large duty trucks for long-distance transport of the baled crop straw (Fig. 2a). Farmers can also use the flatbed cart or three-wheel cart for short distance transport (Fig. 2b). To economically complete the transportation, the following factors such as the type of transportation vehicles, transport distance, investment cost, vehicle operation and maintenance costs and many other factors should be considered. If the transportation cost is too high, it will inevitably push the final fuel cost to a high level, which will be disadvantageous to the development the power generation enterprises.

(a) Large duty truck (b) Three-wheel cart

Figure 2. Transportation of crop straw in China

2.4 Straw storage

Straw collection is characterized by large quantity, scattered distribution and high moisture content, which leads to a time span between production and the supply of fuel. Therefore, it is important to effectively manage biomass storage in a long term. The common storage way is to stack the fuel directly in the field or transfer stations and cover the fuel with tarpaulin to prevent rain (Fig. 3a). However, subject to the restrictive conditions such as fuel demand and size of the yard, the most popular way of straw storage is open-air storage by various biomass power plants during their operation (Fig. 3b) [9]. Though open-air storage is of low cost, the biomass fuel without any processing is extremely liable to decaying and deterioration, significantly damaging the fuel quality. In biomass transfer stations, the main form of straw fuel storage is stored as bales. It can not only save the storage space, but also provide convenience for transport and access. Sanderson et al. found that the losses of dry matter during baling ranged from 1% to 5% depending on moisture concentration in the biomass at baling [10].

(a) Storage of crop straw (b) Loading crop straw

Figure 3. Storage and loading of crop straw

3. The Supply Chain Operation Modes of Crop Straws in China

The operation modes of crop straw supply chain in China can be divided into two categories: decentralized mode and centralized mode [11]. The principals in the former mode refer to individual farmers, specialized households, or crop straw brokers. They collect crop straw from scattered villages and supply it to the enterprises directly. While, the principals in the latter mode mainly refer to the companies specializing in collection, storage and transportation of crop straw and farms that are responsible for a series of work such as collection, drying, storage, maintenance, and transportation of crop straw biomass and are also responsible for checking the quality of crop straw delivered and sold by individual households or crop straw brokers.

3.1 Decentralized mode of collection, storage and transportation

3.1.1 "Company + Individual Farmers" mode

Under this mode, the farmers usually collect crop straw from their own farmland in consideration of the next season of sowing and sell the straw directly to the power plant. Usually, the farmers who live around the power plant (e.g., 5 km away from the plant) collect their own crop straw and carry it to the plant using three-wheel cart or flatbed cart. This mode is suitable for the energy-related enterprises with low consumption of crop straw, such as crop straw gasification or solidification. However, it is hard to manage and control the supply of crop straw [12].

3.1.2 "Company + Brokers" mode

Under this mode, the companies that use biomass as fuel shall organize a procurement team that is composed of specialized fuel purchasing households or crop straw brokers. They are specialized in collection, drying, storage, maintaining, and transportation of the crop straw fuel and other tasks. A long-term supply agreement shall be signed between the straw brokers and the company. The straw fuel shall be collected by the specialized households from the farmers and then sent to the company in lots. This mode is suitable for the energy-related enterprises with high consumption of crop straw, such as straw biomass-based power plants, or large-scale solid briquette enterprises. If there are no large forestry bureaus or farms around the company, it is a relative better operation mode compared to the company plus individual farmers mode. In addition, both operation modes can help the biomass-based company save the storage and drying space, which can greatly reduce the investment, management and maintenance costs of straw biomass materials.

3.2 Centralized mode of collection, storage and transportation

3.2.1 "Company + Bases" mode

Under this mode, a fuel supply agreement is signed between the company and the nearby farms, forest farms, timber processing factories or other units that own large quantity of agricultural and forestry residues. According to the practical situation, the fuel in the fuel bases can be processed to meet the demand of the company for fuel (Fig. 4). This operation mode is characterized by long-distance and large quantity of supply, stable supply of raw materials, long-period cooperation and easy control on the material flows, which is suitable for the energy-related enterprises with low consumption of crop straw, such as crop straw gasification or solidification.

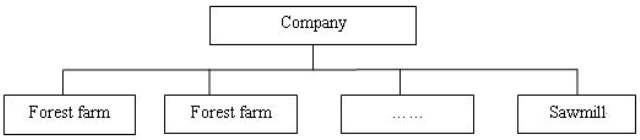

Figure 4. "Company + base" mode

3.2.2 "Company + Biomass Company" mode

The principal in this mode refers to the companies specializing in crop straw collection, storage and transportation. The biomass company shall establish one or more crop straw collection and storage stations at suitable locations around the townships to meet the local quantity of reserves and limit of regional division and further form a collection and storage network. When the plant demands crop straw as fuel, it is possible to regulate the quantity of purchase and reserves of crop straw and provide the crop straw in good quality and in sufficient quantity to the plant (Fig. 5). This operation mode is mainly suitable for biopower plant and the specialized company is also developed from the power plant. For example, the Wangkui Biopower Plant in Heilongjiang province, which belongs to the National Bio Energy Co., Ltd, has set up a specialized biomass company and established 12 purchasing stations around the plant to provide straw biomass efficiently.

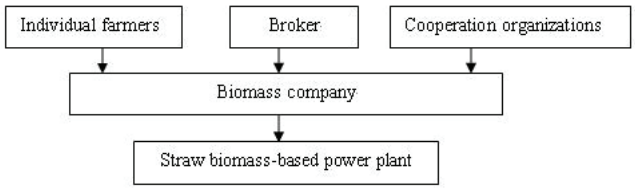

Figure 5. "Company + Biomass Company" mode

4. Analysis on Straw Biomass Industry in Heilongjiang Province and the Problems and Countermeasures for Development

4.1 Current situation

As a major agricultural province in China, Heilongjiang Province owns vast arable land and rich crop straw resources. The available quantity of crop straw resources for bioenergy is approximately 27.42 million tonnes in Heilongjiang Province in 2010 (Table 1) [13]. Several straw biomass-based power plants have been established to reduce the dependence on conventional fuels and greenhouse gas emissions (Fig. 6). The surrounding cities can provide an approximate of 17.85 million tones of straw biomass to the plants (Table 2). However, the influence of the basic national conditions of small-scale farmer-based economy leads to a wide range of restrictions in collection and utilization of crop straw resources [14]. For a long time, crop straw has been the main fuel for cooking and heating for the residents in the rural area. Direct combustion of biomass is a primitive and backward way of energy utilization with energy utilization rate of less than 10%, which has lower economic benefit, social benefit and ecological benefit [15]. The farmers do not have full understanding towards utilization of crop straw resources. Some people mistakenly believe that burning the crop straw in the fields directly means to apply fertilizer to the field. However, such practice not only burns out the original organic matter, but also causes serious environmental pollution. Long-term burning of crop straw will change the structure of the surface soil, leading to the evaporation of surface moisture and damages of soil's ability to resist drought and keep moisture.

Crop straw resources have the inherent features of low calorific value, large volume and loose structure, which make the insufficient collection of crop straw. Compared with developed countries, the machinery and technologies we applied during the processes of collection, pretreatment, transport and storage are still backward and most are in exploration stage. Most of the survey reports and references focus only on the policies related to the prospect of utilization of crop straw. Little work has been done by specific research on the possible problems and solutions in practice. With the rapid development of biomass-based enterprises, it is very difficult to achieve fast collection of crop straw resources merely by traditional method, and it is more difficult to meet the requirements for large-scale, standard and sustainable utilization of crop straw resources [16]. To solve these problems efficiently, Heilongjiang Province called for vigorously strengthening utilization of crop straw resources, turning crop straw into treasure and bringing practical benefits to farmers in the "11th Five-Year Plan for Development of Agriculture and Rural Economy in Heilongjiang Province" and "Outline (2007-2010) of Development of Cyclic

Economy of Heilongjiang Province". Several biomass-based companies such as Wangkui power plant have established a mature supply chain for the crop straw biomass, which provides references for the other biomass-based facilities.

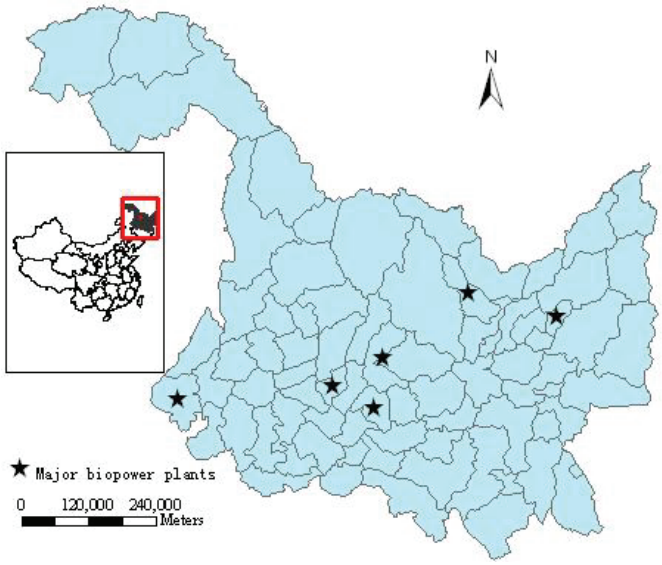

Figure 6. Major biopower plants in Heilongjiang Province, China

Table 1. Usable straw biomass output in Heilongjiang Province, 2010

	Rice	Wheat	Corn	Foxtail millet	Sorghum	Beans	Potatoes	Oil crops	Bast fiber crops
Agricultural output	1843.9	92.5	2324.4	4.1	17.8	601.9	126.2	27.5	2.2
Usable straw biomass (10,000 tonnes)	590	26.4	1673.6	3.8	17.1	360.2	40.4	29.1	1.3

Data source: The Statistical Yearbook of Heilongjiang Province, 2011

Table 2. Available quantities of straw biomass around major biopower plants in Heilongjiang

City	Harbin	Suihua	Qiqihar	Jiamusi	Daqing	Shuangyashan
Straw quantities (tonnes)	5,034,173	4,732,622	3,498,348	1,977,015	1,799,309	806,078

4.2 Problems and countermeasures

Under the guidance and support of national policies, Heilongjiang province has planned to rationally and rigorously develop biomass energy industry relying on her own advantages in resources and has achieved progress in the field of biomass energy industry, such as biomass power generation, biomass solid fuel, biomass gas, biomass liquid, etc [17]. However, some problems still exist during the utilization of biomass resources in Heilongjiang Provinces.

4.2.1 Backward of core technology

Since biomass utilization technology started relatively late in China, the utilization technology lags behind the world advanced level whether in technical level or in the utilization ways. At present, such technology leads to industrial production and in some cases to commercial production in developed countries, such as large-scale and medium-scale biogas project and garbage landfill power generation technology. In China, biomass utilization for bioenergy mainly focused on power generation such as biopower generation by direct combustion. Even though large scale biogas power generation from industries or livestock breeding industry is also commercialized, profitability is not so good if electricity is the only product. Many other technologies are still in the early stage of commercialization or even in demonstration. This is a widespread and urgent problem for the whole country, which restricts large-scale utilization of the resources for bioenergy production. In order to achieve large-scale utilization and production of bioenergy, some related production technology and mechanical equipment must be vigorously developed to get rid of the dependence on foreign technology and equipment, and the production technology and industrial organization should be improved. Only in this way, can we achieve long-term, sustainable and stable development in utilization of biomass energy.

4.2.2 Small-scale utilization

Mountainous regions cover a large area of Heilongjiang province and agricultural production is decentralized. Crop straws are scattered in the field after harvest. Some biomass resources are distributed in mountain regions where transport is difficult and the transportation cost is extremely high. Currently, manual collection is the main form of collection for agricultural residues and the mechanization degree is low, which increased the difficulty of the collection and result in a larger radius of collection and a higher transportation cost. The availability of straw biomass is dependent on the choice of the farmers. They will choose the most beneficial way of utilization. Therefore, the quantity of crop straw and other resources for bioenergy production can hardly be guaranteed. Such problems have led to a complicated relation between utilization and supply of biomass energy and short supply of fuel. It is hard for the enterprises to fulfill large-scale energy utilization in the real sense.

4.2.3 High cost of bioenergy

The widespread distribution and relatively difficult collection of biomass resources make the additional cost of biomass resources continue to increase. Therefore, the high collection cost is one of the major factors that restrict the development of the enterprises that

use biomass. When a biomass-based enterprise starts production, if the supporting mechanical equipment has not reached the scale of industrialized utilization, the one-time investment for the biomass energy enterprise will be too high and the fixed cost such as machinery depreciation expenses and financial expenses will be relatively increased, leading to a higher total cost of production and the enterprise will be unable to gain profit. Such problems can also lead to lower market competitiveness of bioproducts. Investors can not get return in a short period, and they will loose confidence in the use of biomass energy and tend to cut investment in the enterprise, which hinder the normal development of biomass energy utilization.

4.2.4 Policy guidance to be strengthened

In recent years, more and more attention has been moved to the development and utilization of biomass energy. The promulgation of the Law of the People's Republic of China on Renewable Energy and other relevant laws and regulations has vigorously stimulated and promoted the enthusiasm for regional development of bioindustry since 2006, resulting in rapid improvement of the overall utilization level. At present, Heilongjiang province has achieved some success and experience in management and comprehensive utilization of crop straw and other biomass resources. But there are still some problems such as the technical standards have not been well regulated, the service management has not been scientifically established and a set of reasonable and effective modes of operation is absent and required. The potential for comprehensive utilization of crop straw and other biomass resources has not been in full play. To solve these problems, joint efforts are needed from the enterprises concerned and the broad masses of farmers. Only by this way, can Heilongjiang province achieve sustainable utilization and development of biomass energy.

5. Conclusion

According to the National Medium- and Long-term Technology Development Plan of China (2005-2020), the key development areas of bioenergy in China in the future 10 years are biopower generation, biogas engineering, biofuels and solid fuels. In 2020, the total utilization of bioenergy per year will account for 4% of the total energy consumption in China. Due to the characteristics of agricultural biomass utilization such as wide distribution, seasonal work, and different types of ownership, the collection, storage and transportation of agricultural biomass become the major bottlenecks of large-scale utilization of agricultural biomass. Therefore, it is necessary to establish a reasonable and efficient agricultural biomass supply chain management system in order to support the sustainable development of bioenergy industry. In this paper, the collection, pre-treatment, transportation and storage of crop straw resources in China and the current operation modes of crop straws supply chain are reviewed. Heilongjiang province is rich in agricultural and forestry biomass, which can ensure the important position in the national sustainable energy development. In consideration of the practical situation in Heilongjiang province, the existing problems that restricted the development of biomass industry in Heilongjiang Province, China, are analyzed and some reasonable suggestions are put forward in order to promote the development of bioenergy industry in this province. Future research can consider the assessment of the economics of straw biomass supply chain as well as the economic feasibility of biomass-based facilities in Heilongjiang province.

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