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Economic analysis of fuel collection, storage, and transportation in straw power generation in China

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ABSTRACT

Biomass power generation projects involve green and renewable energy. This study regards Laifa Straw Recycling Company of Henan Sheqi as an example. Field survey and economic analysis are employed as the main research methods. The problems of straw collection, storage, and transportation are examined. According to the data obtained from the investigation and the mathematical model, when the straw recycling company uses the artificial model, the average price of each ton of straw is 385.4 yuan; when the straw recycling company uses the mechanical model, the average price of each ton of straw is 264.4 yuan. Comparison of the mechanical and artificial models reveals that the average price of each ton of straw differs by 121 yuan. Under the assumption that the annual purchase amount of straw is 2×10^5 tons, the cost of 2.42×10^7 yuan per year can be saved. Thus, Laifa Straw Recycling Company of Henan Sheqi should consider the mechanical model. Sensitivity analysis of the two models shows that the collection cost is the most sensitive factor when the straw recycling company utilizes the artificial model because most farmers go out to work, so a shortage in rural labor force occurs; this shortage results in increased cost of artificial collection. When the straw recycling company utilizes the mechanical model, the cost of storage is the most sensitive factor because of the large storage amount. High current land leasing and management costs lead to increased storage cost.

1. Introduction

China has abundant straw biomass resources, and it produces 8.17×10^8 tons of straw (equivalent to 3×10^8 tons of coal) per year [1,2]. The straw used for straw power generation is the base raw material [3]. Well-developed utilization methods for straw resources are lacking. Most of these resources are directly burned in fields. Straw burning causes serious environmental pollution and straw wastage. With the rapid development of the world's economy, the conflict between economic progress and environment protection has become increasingly severe. Converting the methods of energy output and consumption is thus necessary. Several modern scientific technologies to utilize renewable biomass energy, such as power generation from biomass, have been adopted. The rapid development of biomass power plants is essential to the construction of a sustainable energy system and improvement of the ecological environment.

The main method of power generation in China is biomass straw burning. This technology has broad development prospects, but it also involves several problems in the process of development. These problems include whether the biomass fuel economy can continue to supply biomass power plants, whether the safe and economic operation of biomass power plants can be ensured, and whether the supply of biomass resources will last; these problems affect the fundamental problem of whether biomass power plants will survive and thrive [4–7]. The fact that biomass straw has its own characteristics poses the main problem for its collection, transportation, and storage. However, collection, transportation, and storage of biomass straw are based on the household contract responsibility system in most regions, in which the cultivated land area is small. For a 2×10^{15} mw product of small and medium-sized biomass power plants, 2×10^5 tons of straw are consumed yearly. This scenario requires purchasing from nearly a thousand household farmers; thus, acquisition, transportation, or cost control is a challenge to biomass power plants [8]. When biomass power plants are in the planning stage, straw resources must be fully detailed in the local investigation because only through mastery of the straw resource can the capacity of power boilers be determined; therefore, complete straw resource investigation and evaluation

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provides important guidance in the construction of biomass power plants [9].

The large amounts and different varieties of crop stalk are fragmented. The traditional collection method is still utilized, and dependence on this method means that gathering straw quickly is difficult. Thus, the requirements of large-scale use are also difficult to meet. For example, when the straw collection radius is too small, the demand scale cannot be met. The straw collection radius should be expanded because of long-distance transportation or intermediate storage and management problems, such as increased collection cost [10,11]. Although straw is produced yearly, the time of collection is very short, and crop harvest lasts for a few days only. Shortage in straw biomass is mainly caused by useless disposal. Farmers do not spend time collecting straw, which has low density and is cheap. Straw is directly burned in fields as soon as it is produced to prepare the land and ensure production in the next crop season. This situation, which leads to serious wastage of straw biomass, is very common in China.

After straw is produced, it is immediately disposed so as not to delay production in the next crop season. At present, most straw resources are in the hands of farmers. The most convenient option is burning, As a result, straw recycling companies have no raw material.

The objective of this work is to conduct an economic analysis of fuel collection, storage, and transportation used in straw power generation in China.

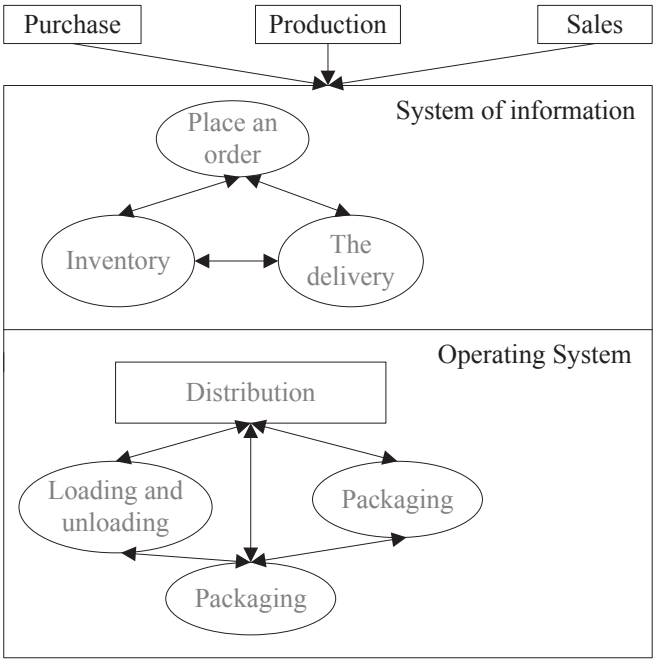

Fig. 1. Logistics system.

2. Logistics system of collection, storage, and transportation of Laifa Straw Recycling Company of Henan Sheqi

2.1. Description of the logistics system

A logistics system refers to two or more functional units that constitute complete logistics service for the purpose of organic combination [12]. Input refers to the procurement of a logistics system, circulation processing, transportation, storage, loading and unloading, handling, packaging, distribution, and logistics information processing. Logistics links include the required elements, such as labor, materials, equipment, resources, and process provided by the external environment to the system. The logistics system is shown in Fig. 1.

2.2. The research of logistics system of collection, storage, and transportation

Laifa Straw Recycling Company is a Pintle-level subsidiary of the enterprise group. It specializes in environmental protection, energy saving, new energy industry investment, development, research, and utilization of new energy [13]. The company was established in March 2006, and its headquarters is located in Zhengzhou, Henan. The overall layout of straw recycling exhibits gradual development investment in the business sector of biomass power generation, heat supply, straw feed, straw briquette curing, straw carbonization fuel, and energy distribution as well as in the Pintle-type biological energy power plant green energy sector. Gradually, biomass energy became the company's leading product.

After many years of research and exploration, through management mode innovation, resource integration and collectivization unified control, and other means, the company has made straw recycling undergo a large-scale modern transformation. The company is located in Henan Nanyang Sheqi and has the support of the local government and the masses. With their active participation, the straw recycling scale has gradually extended to the surrounding cities. The company is currently in collaboration with Nanyang Sheqi clubs and investment construction material plants. It has set up club banners for Straw Recycling Co., Ltd., in Zhumadian, Shangcai County, Pingdingshan, and Ye County, which have completed preliminary layout work.

Pintle energy will be realized in the next three years in 10 areas in Henan Province through straw recycling of 3 million tons. The company is expected to become a leader in the field of straw recycling in China.

The logistics system of collection, storage, and transportation of straw refers to crop straw from the field after harvest and after a series of linked activities, such as reaping, baling, transportation, loading and unloading, handling, and storage. Finally, the entire process is transferred to the power plant. The processes of each link are closely related. A straw logistics system includes a major logistics process and a supporting logistics process, which includes two sub-processes: (1) main logistics process, including transport operations, inventory operations, flow of information, and documentation and (2) supporting logistics process, including warehousing operations, material handling operations, purchasing activities, packing, handling, storage scheduling, and information maintenance work.

Straw as a by-product of crops has the following characteristics: low added value, low density, and seasonal. Low added value means straw supply should be prioritized over road transportation. Low density decides whether the straw stalk will be transported to rough machining to reduce the transportation cost. "Seasonal" involves having a perfect warehousing system; only through this can we check if the fuel supply is in shortage.

According to an actual survey, the purchase mode of Laifa Straw Recycling Company can be roughly divided into discrete artificial scattered stem purchase transport logistics mode and mechanical baling centralized purchasing and logistics mode.

The following illustration shows the straw collection and storage logistics system diagram. As shown by the figure in the center field around the power plant, this study assumes that the yard from the center to the power plant has no transportation. The dotted arrows in Figs. 2–4 indicate the two collection forms with two patterns, namely, artificial and mechanical baling collection. The