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Logistics Mode and Network Planning for Recycle of Crop Straw Resources

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Abstract To realize the straw biomass industrialized development, it should speed up building crop straw resource recycle logistics network, increasing straw recycle efficiency, and reducing straw utilization cost. On the basis of studying straw recycle process, this paper presents innovative concept and property of straw recycle logistics network, analyses design thinking of straw recycle logistics network, and works out straw recycle logistics mode and network topological structure. Finally, it comes up with construction and operation strategies of the straw logistics network from infrastructure, organization network, and information platform.

Key words Straw resources, Recycle logistics, Logistics network, Topological structure, Planning

1 Introduction

Compared with conventional energy resources, new energy resources feature little pollution and large reserve. Thus, it is of great significance to solving the deteriorating environmental pollution problem and exhaustion of resources. In this situation, the demand for new energy becomes a global focus and receives wider and wider attention. For example, biomass energy, as a type of environment-friendly and economic renewable energy, has been widely applied in western developed countries. As a large agricultural country, China is rich in biomass energy. Crop straws are major agricultural byproducts and main sources of China's biomass energy^[1]. Crop straws contain abundant N, P, K and trace elements. In combustion, the average S content is only 3.8‰ (1/3 of the coat), and the calorific value is about 1/2 of standard coat, showing a bright application prospect. In 2005, the State Council issued the *Circular on Carrying out Key Works for Establishing Resources-saving Society*, which includes comprehensive use of crop straws into key works and calls for implementing comprehensive use of crop straws and conserves agricultural means of production. With scientific and technologic progress and social development, straw has lost its leading position of fuels in rural areas, and it has developed to certain scale in generating power, gas, feed, and building materials^[2–4]. At present, the straw energy industry in China develops rapidly, but the industrialization degree of the entire industry is low and resource utilization ratio is low, and surplus straws have become Non-point Source Pollution (NPS) in agricultural ecological environment. Thus, it is a significant program and new practice to study how to build high efficient straw recycle logistics network, promote development and utilization of straws,

foster development of straw energy industry, accelerate building straw recycle logistics network, increase recycle logistics efficiency and reduce recycle cost.

2 Straw recycle mode at current stage

Abundant crop straws of China are mainly distributed in main producing areas of grain, including Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Henan, Shandong, Hubei, Hunan, Jiangxi, Anhui, Sichuan and Yunnan^[5,6]. In 2008, output of crop straws reached 700 million tons. Calculated at the development speed in the Eleventh Five-Year Plan period, the figure will reach 900 million tons, half of which can be used as raw materials of agricultural biomass energy. In China, agricultural production is mainly household contract management, so the planting area per household is small, crop straws are widely distributed, and rural traffic is backward. Besides, due to low density, large volume, and seasonal harvesting of straws, the collection, storage and transportation costs become main bottleneck restricting development of biomass energy industry^[7]. With increase in rural commercial energy, more and more straws are combusted directly in fields. In many areas, the more than 60% straws are discarded, which not only squanders energy, but also pollutes environment, and exerts certain degree of negative influence on social life and economic development.

In this study, we surveyed straw collection, storage and transportation system of Jiangsu Guoxin Huaian Biomass Generation Electricity Company, and Suqian Straw Combustion Power Generation Project of China Energy Conservation Investment Corporation. There are two representative straw collection, storage and transportation modes: extensive mode and intensive mode, the former takes straw dealers as subject and the latter takes straw collection and storage companies as subject. Because it lacks support of specialized recycle logistics network, following problems occur.

(1) Separate storage of straws results in failure to achieve scale

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merit; (2) Lack of specialized circulation facilities hinders reuse of straws; (3) Unsmooth straw recycle logistics channel increases costs^[7]; (4) Low application level of transportation and warehousing logistics technologies causes low efficiency of straw recycle logistics; (5) Lack of specialized straw recycle logistics operators leads to disorderly management; (6) Unsmooth and asymmetric straw recycle logistics information obstructs the whole-process monitor.

3 Design of straw recycle logistics network

3.1 Analysis of straw recycle logistics network property

From straw recycle logistics process and characteristics, it can be found that the straw recycle logistics network is similar to open-loop network in reverse logistics network. The open-loop network mainly means recycled articles fail to flow back to original producers but are used by other enterprises (the third party manufacturers). In this situation, it needs building an independent recycle logistics network. Since straws have low added value, the recycle, storage and transportation of straws must reach certain scale, then it may realize scale merit. This will be reflected in relative concentration of logistics network structure. It imposes strict requirements on planning of logistics nodes and facilities. Thus, it must take into full consideration storage, transportation and circulation treatment capacity of all nodes. Requirements for straw quality and types are different, so it needs advanced treating technologies and special equipment. This increases investment cost. As a result, it needs relatively centralized recycle treating facilities, so the network belongs to multiple-level complex type.

3.2 Design ideas of straw recycle logistics network

3.2.1 Build specialized straw stockyard to recycle straws nearby. Straws are numerous, their source is separate and their production is seasonal, so straw stacking needs much land. Consequently, it will increase land rental and other taxes. In this situation, it is recommended to build straw stock yard with village as unit in waste vacant lot in villages. This not only realizes recycle nearby, but also saves land rental. The setup of this primary logistics node ensures recycle rate and realizes overall decentralization of stock at low cost.

3.2.2 Implement separate collection and centralized storage and transportation management. Straw generation is numerous in harvesting season, while in most times of one year, straws used by enterprises are stock straws. Enterprises are not able to undertake such huge stock. Therefore, stock must be decentralized, and it is required to maintain quantity and quality of stock at relatively low cost. The newly built straw recycle logistics network shall be arranged with several logistics nodes in certain regional range, to form a specialized recycle network, regulate straw collection and stock, and deliver straws to processing enterprises timely at the request of production enterprises, to realize decentralized collection and centralized storage and transportation management.

3.2.3 Concentrate regional resources to realize scale merit of storage and transportation. One of the unique characteristics of

straw recycle logistics is that its entire network coverage region is rural area, and most logistics activities take place in rural areas. Then, the traffic capacity of rural roads poses an obstacle to efficient recycle of straws. In addition, straw transportation itself is a thorny problem, because straws are large in volume, small in density, and light in weight, and all of these easily lead to overweight and overload. In foreign countries, large scale farm planting, superior traffic, and advanced means of transport (such as high power platform trailer or open top container) are used to move straws directly out of the stock yard. Crushing and bundling of straws can be completed at the same time of reaping crops, but this is not feasible in rural areas because the common 5 – 10 tons trucks fail to drive to rural straw stock yard due to limitation of rural roads. To ensure prompt and sufficient supply of straws, it must set up adequate logistics nodes that can satisfy large truck transportation requirement and have certain stock. Therefore, setting straw recycle stations with towns as units can play the role of buffering the stock, and can consolidate resources as per demands. As a result it satisfies transportation conditions and increases transportation efficiency.

3.2.4 Conduct diverse utilization and development and build circulation and processing center. To achieve scale merit, recycle and pretreatment of straws must be in large volume. Through the large scale operation, it can effectively reduce logistics cost of the whole process. In future, the development of biomass industry is diverse, such as straw artificial board, ethanol fuel, and solid formation, *etc.* Since straws have large volume, small density and high water content, these enterprises must classify, crush, dry and compress straws. Such pretreatment and processing need advanced facilities, so the cost will be considerably high. If each enterprise builds pretreatment system, it may lead to repetitive investment and low system utilization rate. Once there is shortage of raw material supply, it will influence normal production of enterprises. In this situation, it should set up more circulation and processing centers responsible for pretreatment of straws and distributing pretreated straws the upper level production enterprise. Such arrangement can further reduce stock pressure and raw material pretreatment cost of production enterprises.

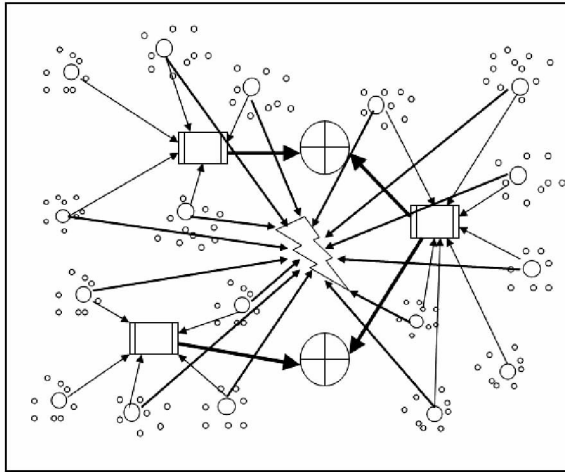
3.3 Design of straw recycle logistics network structure Logistics network structure is the structure composed by lines executing logistics movement command and nodes carrying out logistics stopping command. The flow direction of straws in the entire logistics system and layout of logistics nodes reflect, to some extent, the gathering flow of material from primary logistics node to the higher level node. Primary logistics nodes are numerous and widely distributed, so the entire logistics network takes on a shrinking form, which is also the basic characteristic of reverse logistics. On the basis of entire process from supply to demand of straws, following recycle logistics modes are designed.

Mode 1: farmer households → brokers → straw stock yards → recycle stations → circulation and processing centers → straw fine processing and utilization enterprises. With introduction of

specialized circulation and processing center, this mode can substantially increase efficiency of straw recycle and pretreatment, reduce processing and utilization cost. Thus, it is suitable for straw fine processing enterprises, such as papermaking, artificial boards and straw feed enterprises with straws as raw materials, and it conforms to the biomass energy industrial development plan.

Mode 2: farmer households → brokers → straw stock yards → recycle stations → straw rough processing and utilization enterprises. Some enterprises with lower quality requirement for straws, such as biomass power generation, straw thermal gasification, and straw marsh gas, can lessen intermediate operating sections, and directly deliver straws from recycle stations to their enterprises.

In the comprehensive operation of the above two modes, straw recycle logistics nodes and logistics channel are closely connected and divide work up for cooperation, forming the topological structure of straw recycle logistics network, as shown in Fig. 1.



Legends: ○ Straw stock yards with village as unit; ○ Straw recycle stations with town as unit; □ Straw circulation and processing centers; ⊕ Biomass utilization and fine processing enterprises; ⊖ Biomass utilization and rough processing enterprises; — Straws flowing from recycle stations to circulation and processing centers; — Straws flowing from recycle stations to rough processing enterprises;

Fig. 1 Design of topological structure of straw recycle logistics network

3.4 Construction of straw recycle logistics network The design of straw recycle logistics network should take into consideration geographical, traffic and climatic conditions, and make proper planning from entire overall level. In principle, logistics cost shall be minimized, and the layout should be favorable for straw purchase and supply. Besides, it is required to properly determine types, quantity and location of logistics nodes, as well as means of transport between logistics nodes. According to theory of logistics network, the construction of straw recycle logistics network should be carried out from following three aspects.

(1) Logistics infrastructure network. As the precondition for high efficient operation of logistics network^[8], the construction of this network includes the construction of logistics nodes and channels. The construction of logistics nodes mainly includes determi-

nation of location, quantity and scale of nodes in the network. Firstly, it should analyze distribution characteristics of straw supply and demand points and determine location and quantity of straw stock yards and recycle stations according to distribution of straws, location and quantity of existing straw processing enterprises. Secondly, it is required to determine the relationship between stock yards and recycle stations. Thirdly, it should determine location of circulation and processing center with the aid of network optimum theory. Finally, in the condition of market operation, it should introduce diversified investment, to ensure investment and construction of straw recycle logistics nodes. The construction of logistics channel is in the charge of traffic authority. Thus, its construction should focus on optimization and selection of logistics channel. Specifically, it is to determine proper traffic routes and select suitable means of transport and tools according to size of straw circulation between logistics nodes, regional road network structure and grade situations.

(2) Logistics organization network. This network is the organization guarantee for operation of logistics network and foundation and guarantee of effective performance of logistics activities^[9]. Excellent design of straw recycle logistics organization network can increase straw recycle logistics efficiency, reduce operational cost, and promote straw resource industrialization and comprehensive utilization. The design of this network mainly includes design of organization structure, innovation of logistics organization and management, formulation of logistics organization rules and regulations, and management of logistics business operation.

(3) Logistics information network. The construction of this network provides important technical support for straw recycle logistics network. Through collecting shared data, it provides basic support information for information system of enterprises in straw recycle logistics chain, satisfies information sharing demands of different enterprises, and promotes realization of functions of enterprises' information system. In addition, it can support enterprises' internal logistics management and establishment of enterprise cooperation working mechanism through shared information.

4 Management of straw recycle logistics network operation

4.1 Process of straw recycle logistics network operation

The straw recycle logistics network covers farmer households, brokers, straw stock yards, recycle stations, circulation and processing centers, third-party logistics enterprises, straw processing and utilization enterprises, and government sectors. Its operation process manifests coordinated operation of multiple subjects in the straw supply chain system. According to structure and features of the straw recycle logistics network, on the basis of flow process of straw resources, we designed the scheme for straw recycle logistics network operation, as shown in Fig. 2.

4.2 Management strategies of straw recycle logistics network operation

4.2.1 Accurately predicting and estimating amount of straws and

recycle rate. Straw production depends largely on natural and climatic conditions and reduction of ratio of grain to straw. It varies in years, so it is required to make prediction and estimation periodically. Investigation and research should adopt random sampling of many points in the region. When measuring the ratio of grain to

straw, the water content shall be indicated. Changes of straw utilization can be obtained through questionnaire and interview. In this way, it can determine the recycle utilization ratio, and release the relevant prediction information of straw amount on straw recycle logistics information platform.

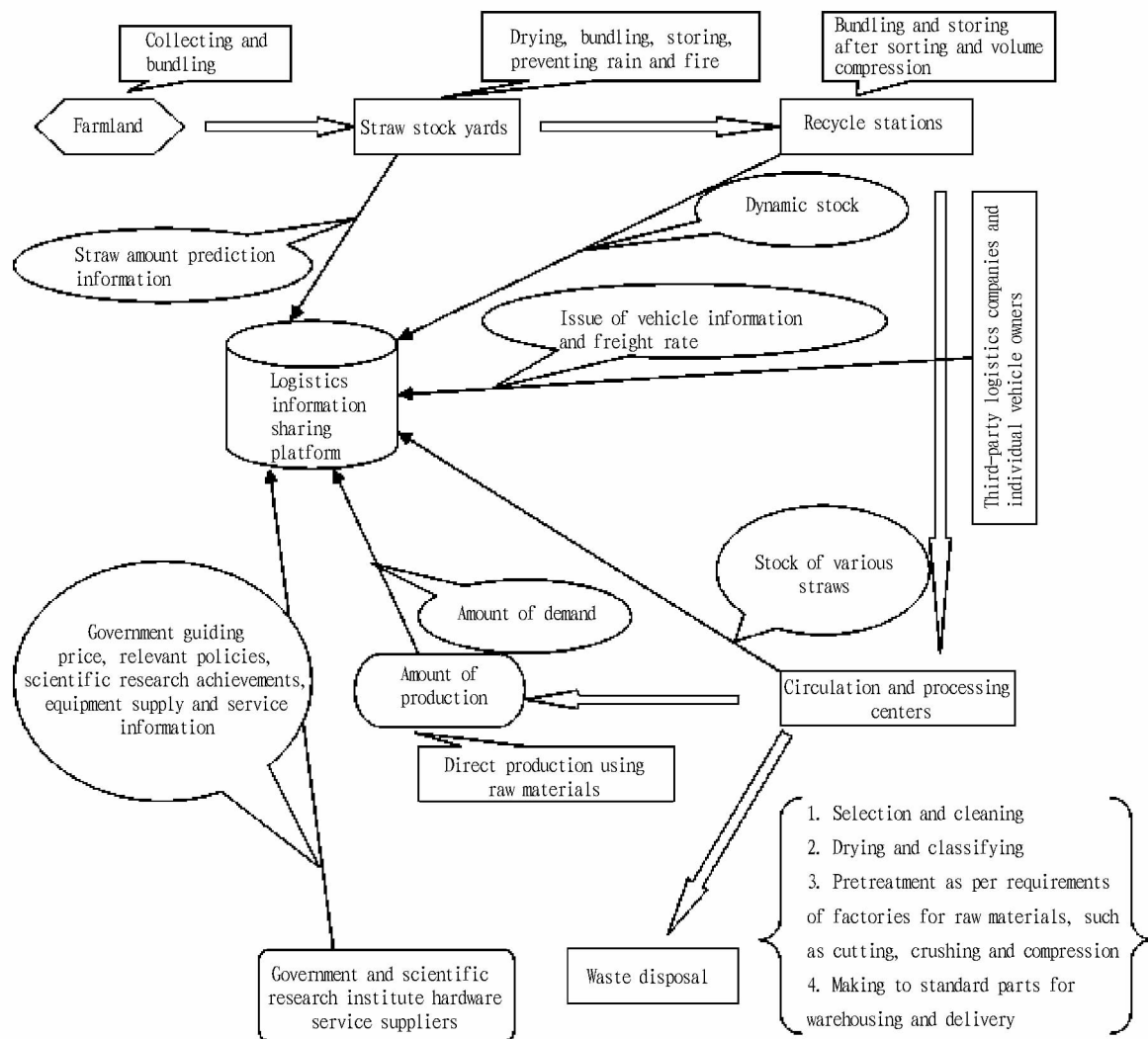


Fig.2 Process of straw recycle logistics network operation

4.2.2 Encouraging recycle of straws, to ensure adequate supply of straws. Government should extend propaganda of straw recycle utilization and raise awareness of the whole society, especially farmers, for importance of crop straws. In addition, government should assign reference index of straw recycle to each administrative village, and increase the amount of straw recycle in busy farming season, so as to guarantee supply of straw resources.

4.2.3 Making clear the investment mode and regulating process of logistics operation. Straw recycle stations can be built jointly by regional and township government and processing and utilization enterprises. It is required to make quality inspection, weighing, and payment, bundling, stacking, moisture and fire prevention and conservation of straws delivered from stock yards according to uniform standard specified by enterprises. Circulation and pro-

cessing centers should be built jointly by relevant straw processing and utilization enterprises, and managed by specialized logistics enterprises. Straws should be selected, cleaned, dried, and classified by advanced equipment and technology, and be pretreated at request of enterprises, such as cutting, crushing, compression, making to standard parts, warehousing and delivery, to guarantee straw quality and increase efficiency of straw pretreatment.

4.2.4 Properly selecting vehicles and carriers, to build strategic partnership. Vehicles for transporting straws from stock yards to recycle stations can be farmers' tractor, agricultural truck, or self-employed workers's vehicles. From the recycle station with towns as units to circulation and processing centers or biomass power generation plant, it can select third-party logistic company or big transport individual. Vehicles can be 5 – 10 ton trucks or platform

trailers with higher tonnage. Since processing and utilization enterprises have to keep certain level of stock, the supply and quality of pretreated straws are strict. It needs specialized transport and delivery management of the third-party logistics enterprises. Therefore, it is recommended that straw processing and utilization enterprises sign agreements with third-party logistics enterprises, to establish long-term cooperative partnership.

4.2.5 Improving logistics infrastructure and information platform, to realize information sharing. Government should speed up rural road construction, improve the every village coverage project, and promote the improvement of rural straw recycle channels. Besides, it should encourage straw recycle and processing and utilization enterprises to share information, so as to ensure balanced supply and demand of straws, and increase the operation efficiency of straw recycle logistics system.

4.2.6 Increasing research and development input, and improving policies for supporting straw recycle. Government sectors and scientific research institutions should accelerate special investment and technical research and development of integrated machinery, bundling machine, vehicle and pretreatment facilities for crops. Furthermore, government should issue and improve relevant management methods and financial preferential and subsidy policies, particularly for construction and operation of stock yard and purchase of straws.

5 Conclusions

The construction of straw recycle logistics system is not only the precondition and basis for industrialization and comprehensive use of straw resources, but also the requirement for implementing the Scientific Outlook on Development, developing the biomass energy resource, and realizing sustainable development of rural economy. However, the existing straw recycle logistics operation has problems of high logistics cost, low logistics efficiency and imperfect management system. Thus, it is required to consolidate social logistics resources, increase financial support, improve straw recycle

logistics network and promote circulation and utilization of straw resources. In this study, on the basis of straw recycle process, we explored the definition of straw recycle logistics network, analyzed open-loop feature of the network, and introduced the idea of construction of straw recycle network. From the perspective of rough and fine processing enterprises of straws, we designed two straw recycle logistics modes. Finally, from the levels of logistics infrastructure network, organization network and information network, we put forward strategies for construction, operation and management of straw recycle logistics network, in the hope of providing basis and reference for construction of straw recycle logistics system and policy-making of straw resource industry.

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change the dirty, disorderly and poor production and living environment in rural areas, and build new socialist countryside with "developed production, well-off living, civilized village culture, clean village environment, and democratic management". It is essential to improve urban image and promote integration of historical culture and modern civilization. Finally, it should rationally develop and utilize resources from environmental ecology, living comfort and living convenience, improve rural and urban living environment and ecological system, and build integrated urban and rural ecological protection system.

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