

The Construction of a Closed Loop for Recycling from the Perspective of Industrial Ecology

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Abstract. This paper provides a systematic summary of the construction of urban recycling resources in China from an industrial ecology perspective. Firstly, it analyzes the development history and trends of urban recycling resources in China and compares traditional recycling resource treatment paths to highlight problems such as resource loss and irregular construction. Additionally, the paper proposes a closed-loop path for the utilization of China's urban recycling resources, which can serve as a reference for addressing current recycling resource challenges. This closed-loop path of recycling resource utilization, characterized by the principles of reduction, reuse, and resourcefulness, involves the participation of various stakeholders such as government, enterprises, and producers, and offers valuable suggestions to further enhance the development of urban recycling resources in China.

Keywords: Industrial Ecology; Recycling; Two-way Recycling.

1. Introduction

At present, China's recycling of renewable resources has gradually developed towards standardization and centralization, and is also a recycling, processing and utilization of renewable resources industry chain, and under the leadership of the development concept of industrial ecology, the whole industry is showing good development. However, in view of the different characteristics of different recycled resources, and subject to the inconsistency of recycled resource treatment standards and the limitations of low treatment technology, the development of recycling of recycled resources still faces multiple difficulties, easily causing inefficient use of recycled resources, which in turn causes serious secondary pollution to the environment. According to the relevant statistics of the Ministry of Commerce, the theoretical injection volume of automobiles in 2013 was 5.721 million units, and only 1.35 million end-of-life motor vehicles were recovered by qualified enterprises recognized by the Ministry of Commerce, accounting for only 23.6% of the injection volume of automobiles in the same year[1]. With the deepening of the processing and use of renewable resources and the deepening of the concept of ecological civilization, the problem of secondary pollution caused by the processing and use of renewable resources and the problem of waste disposal after processing and use of renewable resources has been paid more and more attention to. In the context of the development of circular economy, the recycling of renewable resources is facing new problems, one is that the upstream recycling management is not standardized enough. The problem. According to statistics, individual scavengers and street vendors account for 90% of the upstream recycling industry[2]; secondly, problems arise in the process of linking up the upstream and downstream industries, which can easily lead to inefficient use of recycled resources and pollution of the environment, resulting in a waste of recycled resources and more safety hazards in the products formed by recycling resources.

Apart from finding more effective solutions, efficient resource management is the most obvious way to improve resource efficiency [3]. At present, the recycling industry in China's cities appears to be disorganized and scattered upstream and poorly connected upstream and downstream, thus leading to a low recycling rate of recycled resources is one of the key problems to be solved in the recycling process of recycled resources. Under the guidance of the concept of sustainable development, comprehensive material recovery is the basic concept of closed-loop circular economy[4], which therefore requires the joint participation of various stakeholders in the whole industry to improve the

efficiency of the use of renewable resources. Based on the theory of industrial ecology, this paper will study the operation mechanism of the closed-loop path of urban recycling in China and contribute to the realization of sustainable economic and social development.

2. Current Situation of Urban Recycling in China

2.1. The History of China's Urban Recycling Development

In the process of urban recycling, there are three main links: recycling, sorting, and renewable industries, which correspond to the recycling industry, sorting center, and renewable industry, respectively. The sorting center plays a crucial intermediate role between the recycling and renewable industries. Coordinated development of these industries can reduce waste of recycled resources, minimize secondary pollution in urban environments, and ultimately achieve the goals of reduction, reuse, and resourcefulness of recycled resources, promoting a new era of industrial ecology.

The recycling industry is mainly divided into three links according to the recycling process: collection link, transfer link, and transportation link. The collection link is mainly responsible for collecting recycled resources, and the supporting construction of the transfer link can be regarded as a secondary collection process[5], which is an intermediate link that exists to improve the transportation efficiency. The transportation link is the last link of the recycling process. The transportation link delivers the recycled resources to the corresponding sorting center through the urban area designated in advance. Recycling of renewable resources in China is still at an early stage of development, and the control of informal recycling enterprises is still in progress[6]. Recycling enterprises in China are undergoing a transformation from labor-intensive to technology-intensive. This shift is reflected in the reduction of manpower required for standardized management and technical equipment upgrades of formal enterprises, as indicated by the 2018 research data of the China Recycling Resources Recycling Association. As of the end of 2017, there were 110,000 recycling enterprises registered with the State Administration of Market Supervision and Administration, which represents a year-on-year decrease of about 8%. This shift to technology-intensive enterprises is an important step in improving the efficiency and quality of the recycling industry in China, and will contribute to the sustainable development of the industry.

2.2. Trends in the Development of Urban Recycling in China

With the rapid development of China's economy and society, the total amount of urban recycling resources in the country has continued to grow over the years, as depicted in Figure 1. From 2014 to 2019, the recycling rate of waste iron and steel, waste plastics, waste paper, and other recycled resources in China has significantly increased, except for a slight decrease in 2019. Overall, the total amount of recycling has increased from 245 million tonnes in 2014 to 354 million tonnes in 2019, representing a cumulative increase of 109 million tonnes. Moreover, the total value of recycled resources has also shown growth, as shown in Figure 2. Although there was negative growth in 2015 due to the continued low prices of major recycled resource species, the overall growth trend has been maintained, with the total value increasing from RMB 644.69 billion in 2014 to RMB 900.38 billion in 2019, representing a cumulative increase of 39.66%.

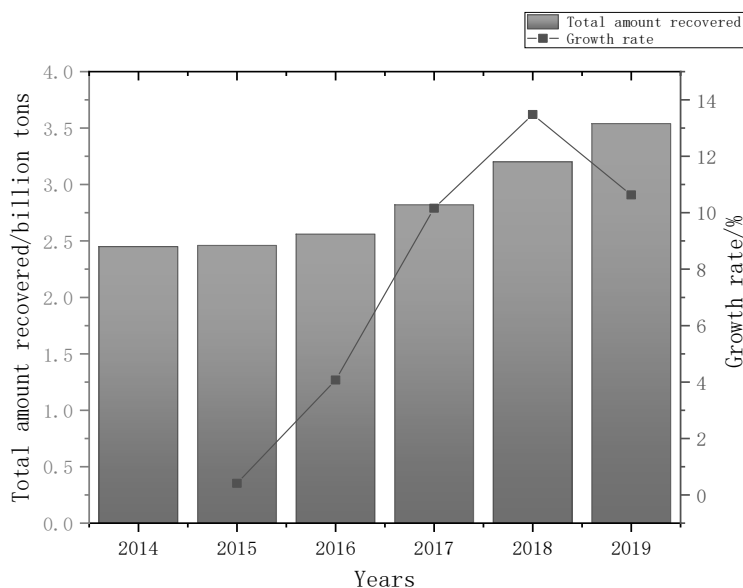


Figure. 1 Total urban recycling in China and its growth rate

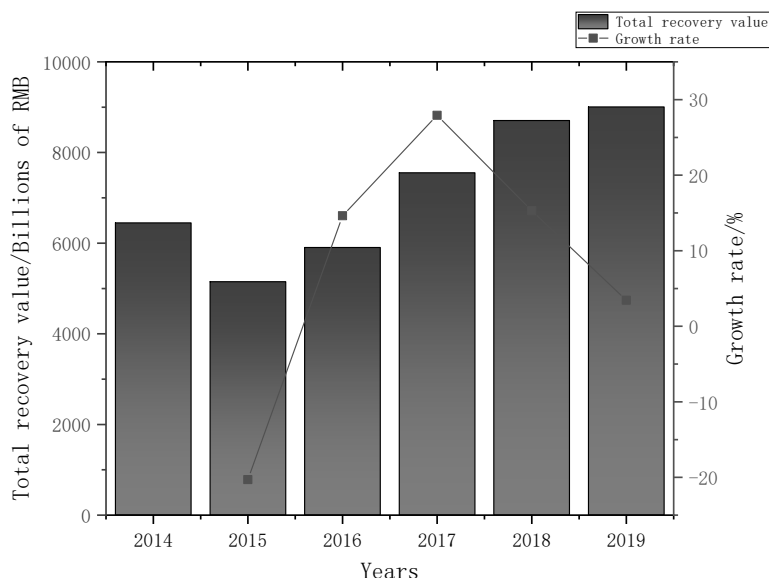


Figure. 2 The volume of urban recycling value and its growth rate in China

In an idealized perfectly competitive market, assume that a city is vigorously engaged in recycling initiatives. The existence of positive externalizations in the city, however, provides insufficient incentives for recycling activities in the city, as shown in Figure 3 for the relationship between the volume of recycling and price. The curve D is its marginal revenue curve, i.e. the demand curve for the amount of recycled resources recycled in the city. MC represents the marginal cost of recycling, i.e. the supply curve of the recycled industry, MEB is the marginal external revenue generated by recycling, and the MSB curve is the sum of the marginal revenue from recycling and the marginal external revenue, i.e. the marginal social revenue, with $MSB = D + MEB$. The area recycles its recycled resources according to their marginal cost, i.e. the point Q where the marginal cost curve MC intersects with the demand curve for recycling. However, looking at the city as a whole, the effective amount of recycling should be Q1 as determined by the intersection of the MSB curve and the MC curve. Clearly, the amount of recycling is far from adequate compared to the amount of recycling and the ecological need for conservation in the region, i.e. the positive externalizations of recycling in the city lead to a low level of recycling. Therefore, it is the involvement of the government, which has the main and leading role that fuels the motivation of enterprises to recycle and utilize recycling resources.

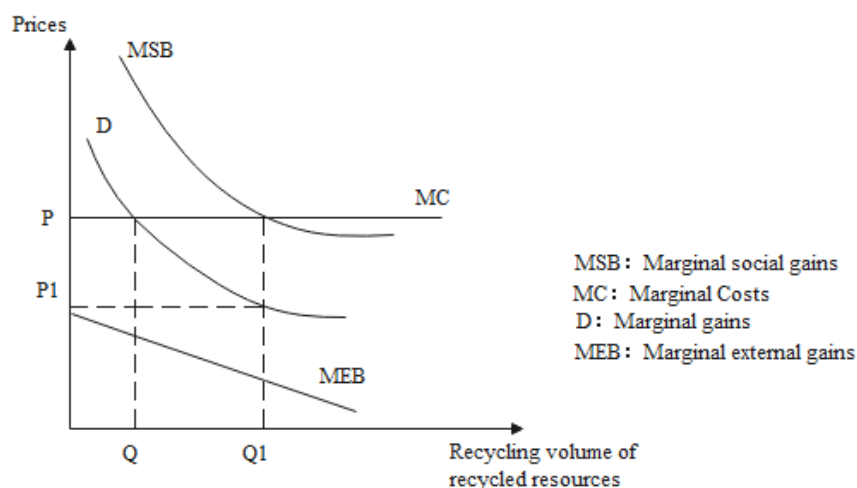


Figure. 3 Positive externalities of urban recycling in China

3. The Closed-loop Path of Urban Recycling in China

3.1. Traditional Recycling Treatment Path

The traditional treatment path for recycling resources in China follows a linear and inefficient process, as illustrated in Figure 4. The first step involves the collection of recycled resources by informal mobile vendors and individual recycling stations, which lack proper infrastructure and often operate without a business license, resulting in inadequate classification and loss of valuable resources. Furthermore, due to the absence of technical and financial support, these resources are often not utilized effectively, leading to environmental pollution and safety hazards. The next step involves the transportation of these resources to small-scale recycling enterprises, where they undergo simple disassembly, compression, and transportation to the renewable industry. However, due to the backward technology and small scale of operation of some of these enterprises, many valuable renewable resources flow to other cities, resulting in significant loss of resources. According to a survey conducted by the Shandong Province Renewable Resources Association, about 60% of the various types of recycled resources in the province are lost to other provinces for use.

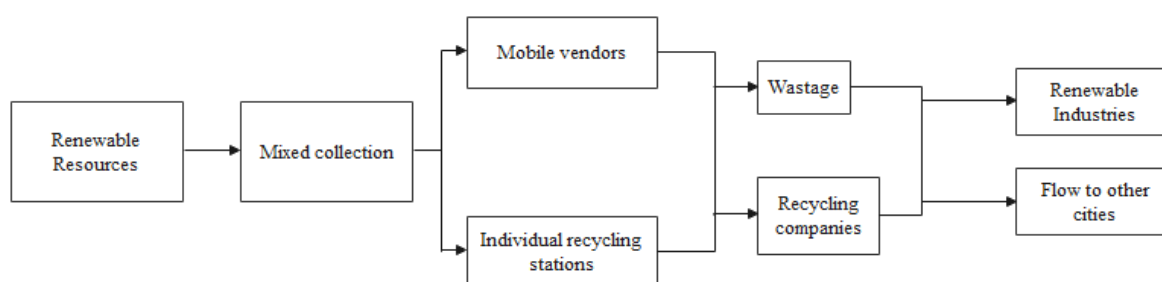


Figure. 4 Traditional recycling path

3.2. Recycled Resource Utilization Closed-loop Path

According to the U.S. Environmental Protection Agency [7], there are two types of recycling: closed-loop recycling and open-loop recycling. In the closed-loop process, materials are comprehensively recycled and materials with specific qualities are re-manufactured into the same product [8], i.e., one product is recycled into the same product or another product and its inherent material properties are not changed [9].

From an industrial ecology perspective, the development of urban industries should focus on improving the comprehensive recycling rate of recycled resources, integrating economic development into an ecological cycle, and promoting the in-depth reduction of recycled resources. At the input end, renewable resources should be classified and collected into categories such as scrap

metal, scrap batteries, electronics, etc., to reduce secondary pollution to the environment from the source. A standardized recycling mechanism should be established throughout the process to minimize waste generation through a two-way recycling network. At the output end, sorting and reproduction should be rationalized to realize the recycling and reuse of renewable resources. By doing so, we can achieve a more sustainable and efficient use of resources, while reducing environmental pollution and promoting the development of a circular economy.

Reuse is an important strategic choice to accelerate the development and utilization of renewable energy. In the two-way recycling channel between recycling enterprises and various types of upstream renewable resources, the recycled resources collected by classification enter their respective corresponding recycling enterprises for recycling and processing. Recycling enterprises not only carry out professional recycling work, but also test and process the corresponding resources. As shown in Figure 5, instead of the traditional one-way operation, various enterprises in China's cities establish cooperative relationships with their corresponding recycling enterprises. In the two-way recycling channel, the recycled resources generated by the upstream enterprises enter the recycling enterprises for recycling, while the recycling enterprises test and dispose of the recycled resources through standardized operations, and send the recycled resources to the corresponding enterprises after dismantling and processing for product re-manufacturing. Through the two-way recycling channel, we can achieve the purpose of maximizing the reuse of recycled resources and avoid environmental pollution and low utilization of resources caused by irregular operations.

Resourcefulness is a prerequisite for maximizing the utilization of recycled resources. The sorting center of renewable resources is the unified export of recyclables in a city, which provides sufficient guarantee for all kinds of raw materials needed by the processing and utilization base [10], and is also a key node to undertake the resourcefulness of renewable resources. After the recycled resources initially recycled by recycling enterprises enter the sorting center, waste paper, plastics, and waste metals are sorted again, and after secondary sorting, compression, and packing in the sorting center, the waste will be transported to the renewable industry for processing as primary materials, and the waste materials produced again in the production process of the renewable industry can be returned in the reverse direction, after repeated sorting and recycling. In this way, the upstream and downstream industries can not only do their own jobs, but also complement each other's advantages. Through the multiple recycling of various types of renewable resources in the closed-loop path, the output can be increased while maintaining good ecological and environmental benefits.

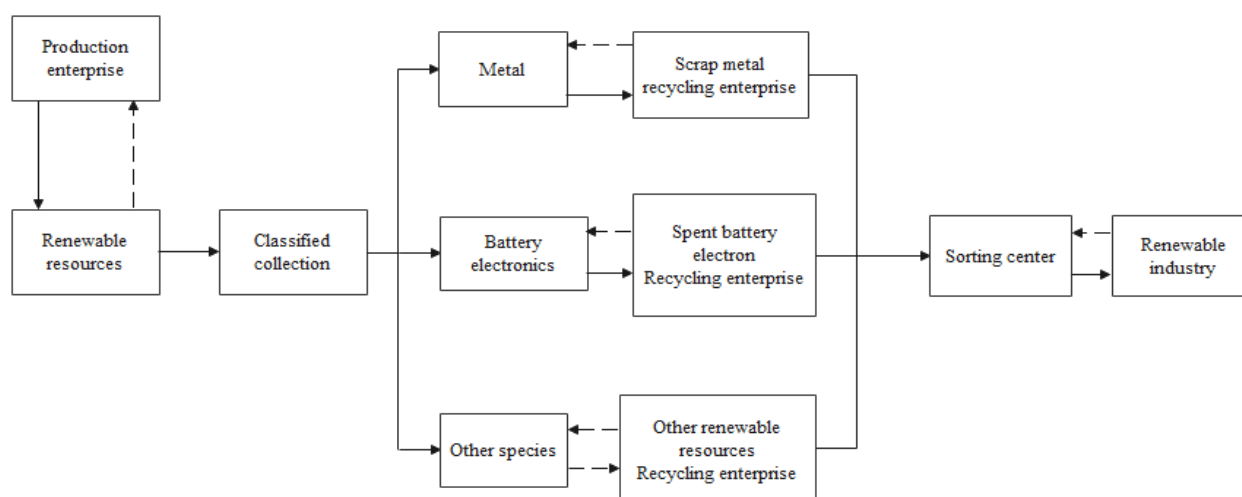


Figure. 5 Closed-loop paths for recycling resources utilization

4. Conclusion

To improve the recycling rate of renewable resources, it is necessary to address challenges and encourage the growth of the renewable industry. This can be achieved by establishing a closed-loop

system for renewable resource utilization that is characterized by industrial ecologization. The renewable industry is an ecologically sound model that prioritizes environmental protection and promotes natural restoration through resource regeneration and recycling within the closed-loop path.

In summary, the low recycling rate of renewable resources is a significant issue that must be addressed in the current recycling process. To address this problem and related issues, the government should lead the closed-loop path of recycling with transparency, emphasizing both technology and management. It is crucial to promote clean production practices across the industry, reduce waste and increase resourcefulness, and involve multiple stakeholders in the process. Effective support policies are necessary to ensure the development of the renewable industry.

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