

# Integration and Value-added Mode of WEEE Recycling Industrial Chain based on Eco-industrial Parks

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**Abstract.** WEEE is a typical stream of urban mines. It contains a large number of precious metals. Recycling and reusing WEEE can provide economic gains and mitigate environmental impacts. Firstly, based on the theory of industrial chain, it was analyzed of the necessity of WEEE recycling industrial chain (WRIC) established in China. The differences were compared between WRIC and general product's industrial chain (GPIC). The current structural status of Chinese WRIC was discussed. By applying field investigation methods, two types of industrial chain integration mode (ICIM) were put forward based on eco-industrial parks, including the type based on recycled raw materials enterprises and the other type based on recycled products enterprises as the core chain. The value-added mode of WRIC was emphatically discussed and the better WRIC structure was proposed. Finally related suggestions were put forward to upgrade the WRIC value.

## 1. Introduction

In recent decades, with the rapid development of science and technology, continuously enhanced views of people's personalization and innovative consumption, electrical and electronic equipments (EEE) flood into global market with unprecedented speed. The number of waste electrical and electronic equipments (WEEE) is also growing at an alarming rate. UNEP estimated that the world produced about 60 million tons of WEEE per year[1]. Historically, in EU the WEEE was observed to increase by 16-28% in every five years, which is three times faster than the generation of average annual municipal solid waste. China is a typical country in manufacturing, consuming and exporting a large number of EEE. In 2016 it was more than 1000 million units of the production of TV sets, refrigerators, electric water heaters, air conditioners, computers and other major home appliances in China. Meanwhile, China has also begun to enter end-of-life peak of EEE and there are more than 100 million units of EEE being scrapped every year according to theoretical calculation[2]. WEEE is becoming an emerging issue owing to adverse consequences on the natural environment and the human health. WEEE disposal may have commercial opportunities, because they contain precious metals, such as gold, aluminium, copper, silver, bronze, and other rare metals. WEEE Management has been one of the biggest challenges of current worldwide concern.

Nowadays, many countries have drafted some laws to dispose WEEE. The European Commission addressed the need for the legislation about the escalating problem of WEEE. This was later taken into the form of the WEEE Directive[3]. Lots of researches have discussed WEEE from different

aspects, particularly about the composition and value, influences on environment, recovery, disposal and recycling[4-5]. In most developed countries, it is a responsibility of producers and residents to recovery, reuse and recycle WEEE. The most important purpose is to avoid and reduce the pollution caused by WEEE. Therefore, WEEE is mostly exported to developing countries, such as China, India and Vietnam[6]. But in China, WEEE recycling and processing enterprises make more profit as the important purpose by excavating useful resources of WEEE. Under the premise of protecting natural environment, it becomes the emphasis to Chinese government how WEEE enterprises make WEEE recycling and maximize enterprise value. This article firstly introduced the theory of WRIC; secondly, it analyzed the structure about WRIC in China compared with the operation system of WEEE recycling in Germany; thirdly, it elaborated two integration modes of WEEE industrial chain based on eco-industrial parks; finally, it used the industrial chain value-added theory to rebuilt the structure of WRIC.

## 2. Theoretical analysis about WRIC

### 2.1. WEEE

WEEE mainly contains the waste of refrigerators, air conditionings, washing machines, TV sets, computers, mobile phones, etc. It is divided into ten categories according to WEEE Directive. The WEEE composition is quite complex and contains vast toxic chemicals, which can cause significant pollution to environment and be harmful to human if discarded discretionarily. Meanwhile, WEEE contains enormous and precious resources, such as gold, silver, copper, tin, chromium, platinum, palladium, etc. WEEE is main component of "urban mines". Its grade is dozens or even hundreds times of natural resources' grade.

As WEEE is rich in extremely high recycling value, in recent years the huge processing networks of WEEE have shaped spontaneously in Chinese southeastern coastal areas, especially Guiyu town, Qingyuan of Guangdong Province, Ningbo and Taizhou of Zhejiang Province. Before 2002, some WEEE processing enterprises only focused on their own economic benefits and paid little attention to environment pollution. In 2002 the government initiated the implementation of "circle area management" to WEEE processing enterprises and it has established dozens of demonstration industrial parks since then such as Zhangzhou of Fujian province, Taicang of Jiangsu province, Zhenhai District of Ningbo, Ziya-Tianjing recycling economic industrial zone. Enclosing these industrial parks, the WEEE disposal enterprises have formed certain industrial chains, but the chains operate at low level with less value-added of each segment, and the enterprises' profit margins are extremely low. Therefore the research on WRIC to increase its value has extremely vital significance to promote industrial development.

### 2.2. Industrial chain

Nowadays, with the development of economy and technology, the range of market competition has transferred from single enterprise to the whole industrial chain. As a type of new organization, industrial chain has become the main organization type of obtaining the advantages of market competitive. Industrial chain theory has been also widely concerned by scholars and industries. But there is not a unified definition on industrial chain. Generally, the definition about industrial chain is mainly from three aspects: (1) the process of industrial economic activities; (2) the process of value transferred and created; (3) industrial organization patterns[7]. We think that the first two definitions are rather similar to supply chain and value chain. Therefore we approve further of the third viewpoint; think that industrial chain is the organizational form of industrial activities, and the methodic linkage mode about related economic activities, processes, production phases or economic businesses in the process of producing goods and services. On the whole, industrial chain is the organization of the spatial aggregate of related enterprises based on the theory of the value chain; the

result of division and cooperation within some industries and belongs to the meso-level between microscopic and macroscopic view.

In general, an industry has only an industrial chain, but its structure is not immutable. In fact, the structure is changing constantly. The main factors of precipitating the change are technique, transaction cost, market structure and the development degree of its auxiliary industry.

2.3. WRIC

WRIC is defined as a mode of industrial organization by which related industrial activities are connected in the processes of WEEE recovery and optimal recycling based on the inherent technical association of WEEE industry. Through industrial division of labor and cooperation, WRIC can add the value of the enterprises of the industrial chain. Compared to GPIC, there are numerous differences such as structure, value-added linkages, as shown in Table 1. WRIC based on eco-industrial parks belongs to the type of cluster industrial chain (e.g., in Zhenhai District, and Ziya-Tianjing recycling economic industrial zone).

**Table 1.** The differences between WRIC and GPIC.

Item	GPIC	WRIC
Purpose	To provide consumers with products and services, in order to create value	To provide raw materials to related industries mainly, second-hand or remanufactured products, in order to recycle value and create value
Structure	Including complete processes and order of products' research and design, supply of raw materials, manufacturing, distribution, services, etc.	The lack of research and design, distribution services link flexibility
Value-added linkages	The linkages of value-added are mainly R & D and distribution; obey the spatial distribution of "smile curve"	The value-added distribution does not obey "smile curve", the range of value-added is narrow
Supply of raw materials	Determined by market demand; generally more stable	Influenced by the amount of WEEE recycling, with great uncertainty
Organizational type	Commercial form of market-oriented	Strong externality and more government regulations

**3. Integration modes of WRIC based on eco-industrial parks**

3.1. WEEE operation mode in some developed countries

Nowadays, the operation system of WEEE recycling is relatively well in some developed countries such as Germany and Japan. The government plays an important role in WEEE recycling; it requires manufacturers to recovery their EEE products in order to protect environment and alleviate the ecological pressure. The regulation of extended producer responsibility (EPR) has been established. EPR is defined as a policy approach in which producers bear significant responsibility, financial and/or physical, for the treatment or disposal of products[8]. In Germany the government plays an important role in WEEE recycling system, including establishing the management and coordination agency. The recycling system is still competition-oriented mode, shown Figure 1. In this system, EEE producers afford WEEE recovery and disposition fee by WEEE Directive, but producers are allowed to transfer the fee to consumers; commission disposition plants and third-party logistics companies perform transportation and disposition responsibility in the form of contracts. Disposition plants undertake the responsibility of placing dustbins in garbage collection points, arranging logistics and transport, sorting, dismantling and smashing WEEE. Under processing capacity permitted, those enterprises endeavor to obtain more WEEE to maximize their profit. Thus the market shapes mutual competition. The result of competition reduces the cost. The disposition cost of WEEE covers recovery, classification, dismantling, processing and other fields.

Figure 1 shows that all organizations are closely connected and constitute a more stable WRIC from collection to recycling stages through the EAR-WEEE management organization in Germany. The most important purpose of establishing WRIC is to facilitate government better managing WEEE, and make WEEE recover, reuse and recycle to avoid environment pollution in developed countries. On this basis, the purpose is to enhance the value of the whole process.

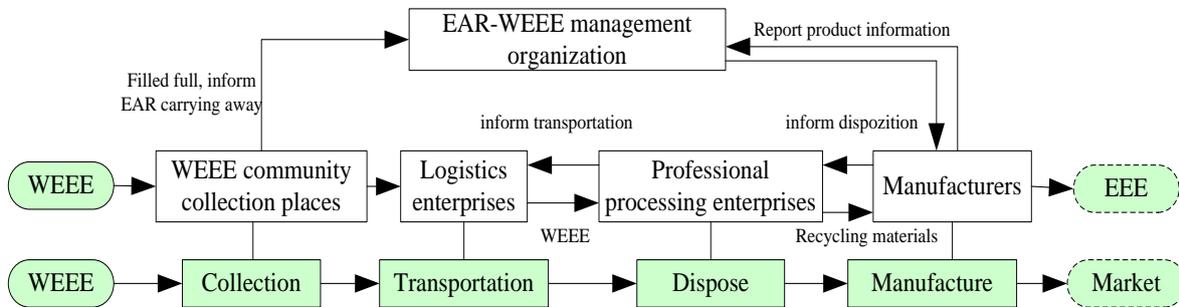


Figure 1. WEEE recycling system based on EPR in Germany.

3.2. The WEEE industrial chain modes based on eco-industrial parks

In China the WEEE recycling system is different from that in developed countries. The main purpose of WEEE collection and processing enterprises is to obtain profits by utilizing WEEE renewable resources, such as non-ferrous metals, ferrous metals, precious metals and scrap plastic. Consequently those processing enterprises not only utilize domestic WEEE, but also import a large number of foreign WEEE. According to certain statistical data, above 70% of WEEE was shipped to China which was imported from developed countries, such as United States, Japan and Germany. As numerous enterprises of WEEE processing appear and flock together, WRIC gradually shapes, shown in Figure 2.

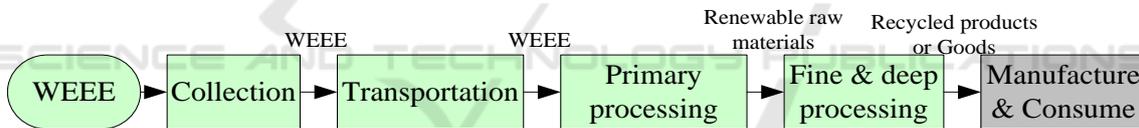


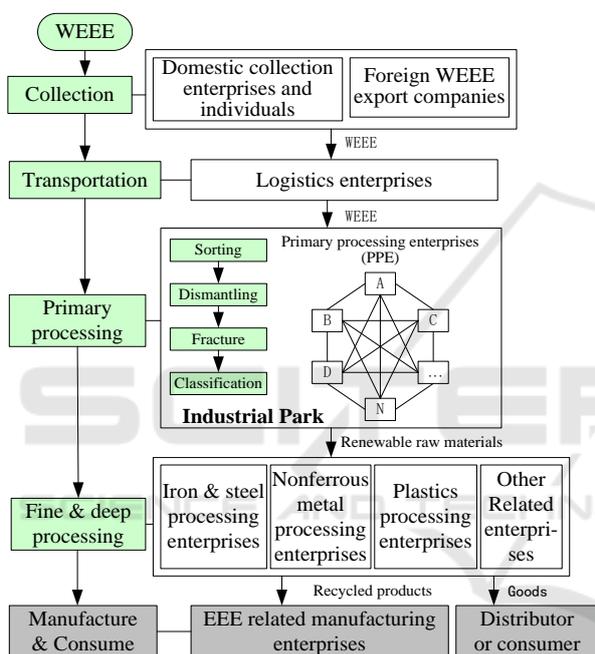
Figure 2. The current WRIC structure.

There are multiple modes in the integration process of industrial chain. Yang explained the diverse modes about the integration of industrial chain based on the effectiveness of scale economy and the economy of transaction cost[9]. In order to protect environment, the Chinese government has established dozens of eco-industrial demonstration parks of renewable resources and adopted centralized management to the enterprises in order to avoid environmental pollution caused by decentralized management. Based on eco-industrial parks two types of integration structure of WRIC have been shaped.

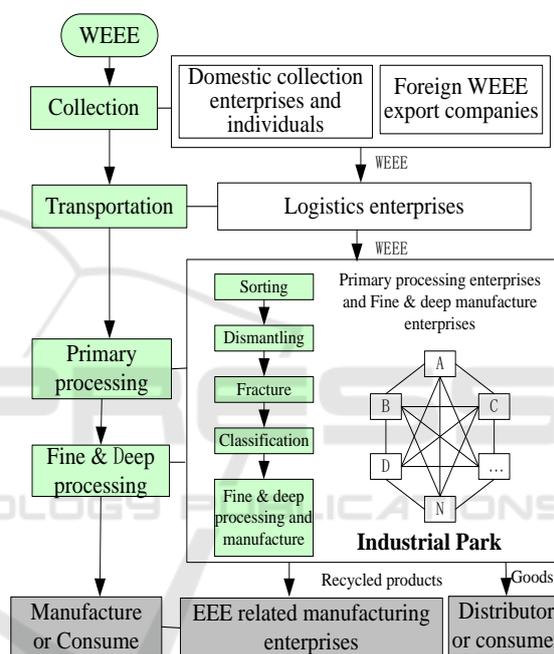
3.2.1. The industrial chain integration mode (ICIM) based on recycled raw materials enterprises as core chain. By applying field investigation methods, this ICIM is shown in Figure3. The mode is comprised of upstream collection and transportation enterprises, processing enterprises of parks and downstream fine-deep processing enterprises. On the basis of the mode, a large number of WEEE primary processing enterprises are gathered into eco-industrial parks of renewable resources. These enterprises mainly complete primary processing of WEEE and make WEEE be processed into primary semi-finished raw materials such as recycling scrap aluminum, scrap copper, scrap iron, waste plastics. Then these products are sold to the fine-deep processing enterprises outside industrial

parcs. The enterprises smelt and manufacture these raw materials, and transform them into various industrial material products such as ingots, aluminum ingots, stainless steel products, plastic particles.

Compared with foreign WEEE operation modes, domestic EEE manufacturers do not play an important role in the industrial chain and it is low of correlation with other enterprises because the EPR regulation has not been established so far in China. According to this mode, the enterprises form a mesh structure in some industrial park. It is quite short of the length of industrial chain in the park; the added-value of the products is rather low. There is not enough tight linkage degree between midstream processing enterprises of industries parks and downstream fine-deep processing enterprises. Undoubtedly this mode is a very good choice to gather numerous fine-deep processing enterprises around industrial parks. It belongs to this mode of the ICIM of Zhenhai-Ningbo renewable resource eco-industrial park. The industrial chain oriented by scrap steel, scrap non-ferrous metals processing enterprise has been shaped.



**Figure 3.** The ICIM based on recycled raw materials enterprises as core chain.



**Figure 4.** The ICIM based on recycled products enterprises as core chain.

3.2.2. *The ICIM based on recycled products enterprises as core chain.* The mode is taken shape according to the final products of WRIC, shown in Figure 4. In eco-industrial parks, WEEE is disposed primarily by midstream enterprises; then is manufactured into related intermediate or final consumable products such as aluminum ingots, copper rod, steel and stainless steel products, cable and plastic products. The ICIM constitutes the process of step-utilization resources. The key to improve the utilization efficiency of resources is reasonable resource allocation of each part of industrial chain. Ziya-Tianjing recycling economic industrial zone covers the enterprises of WEEE primary and fine-deep processing, and has formed this ICIM type in the region.

3.2.3. *ICIM analysis.* Figure 3 and Figure 4 show that the left side portion of the two modes is identical and the WRIC structure is current link status of WRIC in China. Based on different integration degree of enterprises in industrial parks, different ICIMs are formed. In Figure 3, midstream enterprises are loosely connected with downstream enterprises. However in Figure 4,

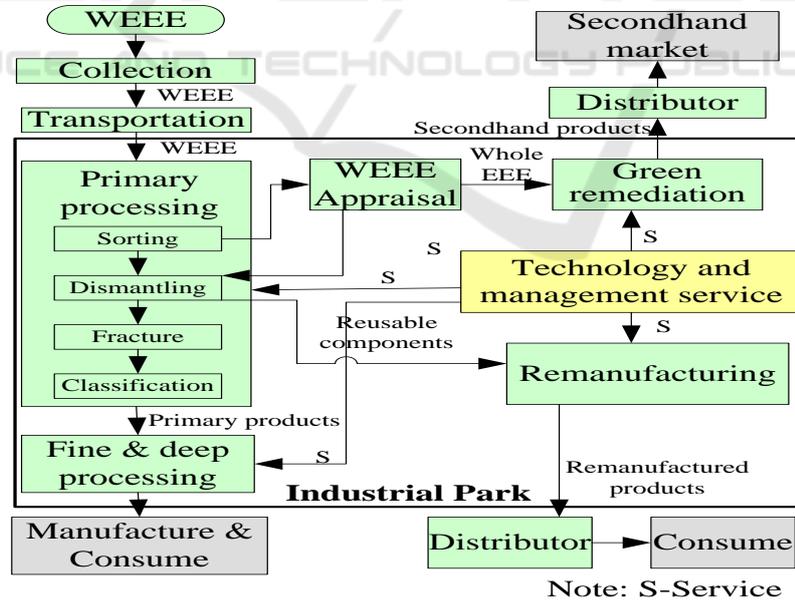
midstream and downstream enterprises are gathered in an industrial park; hence it can form a thorough cluster industrial chain and can also take advantage of achieving resource step-utilization, reducing costs, aggrandizing the stability and it enhance the value of the industrial chain.

**4. The value-added mode of WRIC based on eco-industrial parks**

*4.1. The value-added principle of industrial chain*

The formation mechanism of industrial chain is composed of four aspects, including promoting systematic value, economizing gross costs, boosting value innovation and improving innovation power. These constitute value-created mechanism and transform the operation impetus of industrial chain. The "smile curve", proposed by Stan Shih of Acer founder, expresses that the proportion of value-added distribution is asymmetrical in different links of product R&D, supply of raw materials, intermediate products processing, finished goods assembly, sales, service, etc. In general the value-added by the upstream R & D accounts for about 60% of the new created value; the value created by manufacturing sector is the lowest, no more than 15% of the value. In the era of knowledge economy, the value-added is decided mainly by creative knowledge, including "hard" technologies (e.g., patents, technology, etc.) and "soft" technologies (e.g., advanced management, organizational methods, technology standard system, etc.)[10]. Because WRIC lacks R&D phase and distribution services are under the control mainly by related industries manufacturers, the value-added of the main bodies of WRIC is rather little. This leads to low profit of WEEE collection and processing enterprises; the technology and equipment of enterprises are extremely backward and cause serious secondary pollution. So it is quite important of enterprise subsistence to advance the level of knowledge and technology about WRIC.

*4.2. The value-added mode of WRIC*



**Figure 5.** The value-added mode of WRIC based on eco-industrial parks.

To optimize obtaining and creating the value of WEEE, processing enterprises can't dispose WEEE by using almost the same way, namely dismantling, broken or molten WEEE to obtain the primary resources. These enterprises should adopt technical and economical assessments of WEEE firstly;

then make the EEE reused after a reasonable repair and remanufacture of the useful components of WEEE. These linkages demand higher technology and knowledge, so the corresponding technology and management consulting services are required to support these activities. According to the analysis, the value-added restructure of WRIC can be established based on eco-industrial parks, shown in Figure 5. The value-added linkages of the restructure are mainly the assessment, green repair, remanufacturing, technology and management consulting services about WEEE.

#### 4.3. Relevant suggestions

In order to achieve the value-added of WRIC, enterprises and government departments should do well relevant works, details as follow:

- Enterprises should develop and introduce advanced technology, equipment, management and organization methods. For example, according to statistics, transport costs accounted for 50% of the overall cost of WEEE disposition in Germany, so enterprises should strengthen cooperation with logistics enterprises to reduce transportation cost.
- Government departments should speed up the development of industrial technology and management services market. These services agencies can enhance technical level and increase industrial value by participating in various outsourcing businesses and providing R&D services, technical services and management consulting services etc.
- Government departments should establish corresponding technical standard system that make enterprises operation standardized, and enforce the enterprise qualification license of WEEE processing. These measures will compel enterprises to focus on one or several specific types of WEEE disposition and promote WRIC modularization operation.

### 5. Conclusions

The paper analyzed the differences between GPIC and WRIC from the aspects of industrial purpose, structure, value-added linkages, supply of raw materials and organizational type. The authors summarized the current structure of Chinese WRIC, compared with WEEE operation modes in developed countries based on the investigation of domestic eco-industrial parks; put forward two kinds of ICIM, including one based on recycled raw materials enterprises and the other based on recycled products enterprises as the core chain. The authors think that Chinese current WRIC is under low-level operation, lacks high value linkages and most of enterprises obtain extremely low profit. Because value-added is decided mainly by creative knowledge including “hard” technologies and “soft” technologies, the authors think that the value-added linkages of the restructure are mainly the assessment, green repair, remanufacturing, technology and management consulting services about WEEE. According to the principles, the authors proposed better WRIC structure. The research is vital significance to promote the development of WEEE recycling industry.

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