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Analysis of and Measures to Improve the Recycling and Utilization of End-of-Life Vehicles in China

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Abstract: This study discusses the importance of improving the recycling and utilization of end-of-life vehicles from three perspectives: saving resources, environment protection, and transportation safety. It also analyzes the recycle rate of end-of-life vehicles, as well as related the dismantling capabilities, administrative regulations, and the supervisory system. Based on these analyses, this study proposes solutions to the problem and presents an ecological benefit evaluation model for the recycling and utilization of end-of-life vehicles.
Keywords: end-of-life vehicles; recycling; countermeasures; evaluation model

1 Introduction

To promote harmony between industrial and ecological civilizations, and to build a beautiful China, General Secretary Xi Jinping, at the 19th National Congress of the Communist Party of China, emphasized: "Building an ecological civilization is vital to sustain the Chinese nation's development. Promoting green development, we will step up efforts to establish a legal and policy framework that promotes green production and consumption, and promote a sound economic structure that facilitates green, low-carbon, and circular development." With the rapid development of China's automobile industry, car ownership is rising. According to the statistics of the Traffic Administration Bureau of the Ministry of Public Security, in 2016, the number of new car registrations in China was 27.52 million, leading to a net increase of 22.12 million vehicles and a total population of 194 million vehicles [1]. The fast growth in vehicle ownership has also resulted in dramatic increases in scrap quantities, and China is now entering the peak period of scrapping. It is expected that by 2020, vehicle population will exceed 260 million, and the number of scrapped vehicles will exceed 12 million [2]. Much attention has been paid to the safety, environmental protection, resource recycling, and reuse problems related to end-of-life vehicles (ELVs). The efficient recycling and utilization of ELVs, which is important for promoting an ecological civilization and building a strong automobile industry, has become the key to green, circular, and low-carbon development in the automobile industry.

2 Significance of improving the recycling and utilization of ELVs

2.1 Recycling and utilization of ELVs to promote resource conservation

The vehicle industry is a typical resource-intensive industry; vehicle production consumes massive resources, such as steel, non-ferrous metals, plastics, rubber, glass, and textiles. Steel used in automobile production accounts for more than 70% of the total raw materials used in automobile production. Accord-

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ing to statistics, it takes approximately 1200 kg of steel products to produce a vehicle. Practice shows that more than 90% of the steel and non-ferrous metal parts in old cars are recyclable, and the recovery and utilization rate of glass and plastics can be more than 50%. Nearly 1000 kg of scrap steel and 50 kg of non-ferrous metal can be recycled from a scrap car [3]. Meanwhile, recycling old automobiles can, effectively, save energy and reduce consumption, generating considerable economic benefits.

2.2 Recycling and utilization of ELVs to promote environmental protection

The following are the three main negative effects of ELVs on the environment. First, ELVs are stacked on vast areas of land. With the increasing number of ELVs, China will soon be the largest "car garbage dump" in the world if it does not recycle them. Second, gasoline and diesel vehicles that fail to meet the National No. 1 standard and National No. 3 standard, respectively, for exhaust emissions, and called "yellow label vehicles," have become sources of serious air pollution. According to the *Annual Report of China's Motor Vehicle Environmental Management* (2017) issued on June 3, 2017, the quantity of pollutants from motor vehicle emissions nationwide was calculated to be 4.472×10^7 tons, with automobiles being a major contributor; they contribute more than 80% of CO and HC emissions, and more than 90% of NO_x and PM emissions. According to the classification of the National standard for exhaust emissions, 12.8% of aging automobiles that will be scrapped fail to meet the National No. 2 standard for exhaust emissions; however, their contribution to CO, HC, NO_x, and PM emissions is 60.7%, 60.6%, 43.6%, and 67.1%, respectively [4]. Third, the improper disassembling and decomposition of ELVs results in environmental pollution, mainly through waste oil, liquid, and batteries, automobile broken residue (ASR), and toxic waste, such as lead, mercury, cadmium, chromium, etc.. Without strict recycling and disposal, this causes serious pollution to soil, water, and the atmosphere. Consequently, speeding up the elimination of "yellow label vehicles" and standardizing the recycling and dismantling of ELVs will be a significant contribution to controlling environmental pollution.

2.3 Recycling utilization of ELVs to promote traffic safety

There were 187 781 automobile traffic accidents in China in 2015, leaving 199 880 injured, 58 022 dead, and causing a direct property loss of 1036.917 million yuan [5]. Once the entire vehicle or some of its parts degrade to scrap, there is a drastic fall in reliability and safety coefficients; further, the operational safety technology fails to meet required standards. If allowed to ply on roads, such vehicles will pose a grave threat to the safety of others. According to the statistics released by the traffic department, nearly one-fifth of automobile traffic accidents are caused by the illegal reloading, assembling, and driving of automobiles that meet scrapping standards [6]. To eliminate the threat of ELVs to traffic safety, we should standardize their recycling management, prohibit discarding and assembling cars on the road, and use formal channels to scrap cars that meet scrapping standards.

3 Status quo on recycling and utilization of ELVs in China

3.1 Low recovery rate of normal channel recycling; phenomenon of "not enough to eat" in regular enterprises

In 2016, the vehicle population in China was 194 million, and the number of scrap vehicles was 5.4 million. The proportion of insured cars was 2.78%. Fig. 1 shows the number of scrapped vehicles and scrapped ratio in China in recent years. The data shows that the average scrap value of ELVs in China is only about 3% of the total, in comparison to 6%–8% in developed countries. In 2016, only 1.592 million vehicles were recovered through regular channels in China; the recovery rate (ratio of recovery to scrap) was only 29.48%. According to Fig. 1, in recent years, the recovery rate of ELVs has been low. The "black market" trade in scrap cars is flourishing; only 30% of ELVs are recovered through regular channels each year, and the remaining flow into the "black market." About half enter illegal dismantling channels, while the rest go to neighboring counties or rural areas for further use. This not only affects the regular recovery and disassembly enterprises, but also disrupts the normal order of recovery and disassembly. It is very important to eliminate serious hidden dangers to road traffic safety, environmental protection, and resource utilization.

Let us explore the reasons for the low recovery rate of ELVs in China. First, there is a significant lack of laws and regulations. At present, the public security department is responsible for cancelling the registration of ELVs and supervising vehicle dismantling. The Ministry of Commerce and the administration for industry and commerce are mainly responsible for supervising enterprises' scrap car recycling and dismantling. However, the departments concerned do not effectively monitor the loss of abandoned vehicles. Second, regular recycling enterprises have a single-profit approach, difficult operations, and low enthusiasm for recycling. At present, 90% of China's regular ELV-recycling enterprises rely on scrap iron and steel sales, which are mainly influenced by two factors. First, the policy that prohibits the sale of the "five main assemblies" (engine, transmission, front and rear axles, frame, and steering gear) of ELVs as spare parts. Second, the prices of scrap iron and steel have fallen in recent years. For recycling enterprises, the profits from recycling scrap cars and abandoned cars is relatively low, and the tax burden is heavy; this leads to difficulties in operation and low enthusiasm

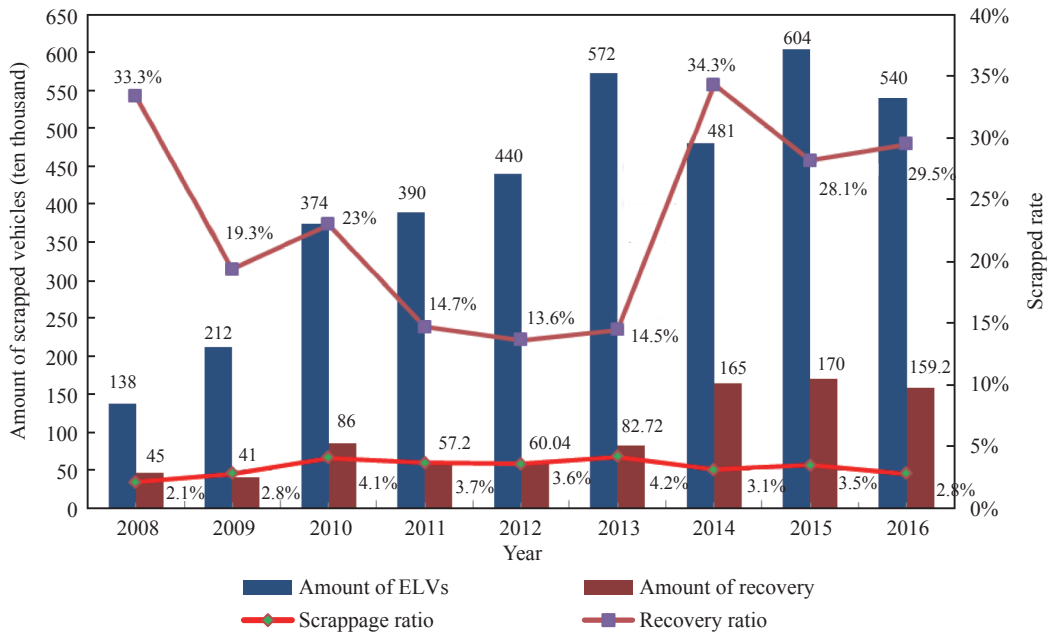

Fig. 1. ELV recycling in China.
Data source: National Bureau of Statistics, Ministry of Commerce Department of Market System Construction, and China Renewal Association.

for recycling. The recovery prices for regular recycling enterprises are far lower than those obtained by enterprises using illegal channels. Second-hand car dealers and illegal businesses are buying expensive vehicles at high prices. This is the fundamental reason why a large number of ELVs have entered the second-hand car market and the underground "black market."

3.2 Urgent improvements necessary in relevant laws and regulations on recycling management of ELVs

Recycling scrap automobiles is a management problem involving various aspects, including policies, technology, and coordination difficulties. For the healthy and sustainable development of the ELVs' recycling industry, it is necessary to establish a legal regulatory system. Developed countries, such as the United States, Germany, and Japan, have worked on the recycling management of ELVs in the past, and their policies and regulations are near perfect. These regulations usually consist of a legal system of management, systematization of recycling measures, and assigning responsibility for recycling.

China has promulgated some laws and regulations to develop the recycling and dismantling industry of ELVs, such as the *Measures for the Management of Recycling of ELVs* (2001). However, the management of ELVs in China began long after it did in developed countries; the relevant laws and regulations are imperfect, and there are loopholes in the legal system. Table 1 compares the laws and regulations for recycling management and the industrial characteristics of ELVs in China and developed countries [7–9].

3.3 Recycling industry for ELVs at a low level

After years of development, the recycling and dismantling industry for ELVs in China has achieved a certain scale of operations. According to the statistics of the China Renewal Association, the number of enterprises with dismantling qualifications in 2016 was 635; the total number of recycling outlets was 2465 and the industry had more than 30 000 employees. Only 40 ELVs recycling and dismantling enterprises had an annual dismantling capacity of over 10 000 vehicles. There were 324 units with annual dismantling capacity of less than 1000 vehicles, and although they accounted for 51 % of the total number of dismantling enterprises, they contributed only 7.8 % of the total recycling capacity. Thus, at present, scrap automobile recycling enterprises in China have scattered resources, a small scale of production, and low economic efficiency. The overall development of China's ELVs' recycling and dismantling industry is lagging that of developed countries. Most enterprises have inadequate investments, yet adopt extensive operation and management methods, use outdated techniques, and low-technology equipment. Most enterprises adopt manual dismantling classification, which has low efficiency.

Furthermore, the recycling reutilization rate of ELVs in China is around 75 % at present, which is far lower than the 95 % in developed countries. What remains for recycling after dismantling is essentially scrap iron, steel, and large, easy-to-sort non-ferrous metals, while other materials (such as plastics, rubber, and glass) are usually discarded without effective recycling.

Table 1. Comparison of laws and regulations for recycling management and industrial characteristics of end-of-life vehicles.

	USA	Germany	Japan	China
Major laws and regulations	*Resource conservation and recovery law, Clean Air Act*	*EU Directive on scrap cars, Circular economy and waste law, Old vehicle disposal regulations*	*Promoting effective use of resources, Specification for recycling of scrap automobiles, Recycling law of scrap cars*	*Recycling management of End-of-Life Vehicles, Recycling and utilization, Technology Policy of automobile products, Compulsory scrapping standard for motor vehicles*
Subject of recovery fee	As a valuable secondary resource transaction	Automobile manufacturers and importers	user	As a valuable secondary resource transaction
Index of recovery utilization rate	Recycling rate 95% in 2020	In 2015, the recycling rate was 95% and material reuse rate was 85%	In 2015, the airbag recovery rate was 85%, and the vehicle recycling rate was 95%	In 2017, the recycling rate was 95% and material reuse rate was 85%
Main characteristics of the industry	(1) The management mechanism is environmental protection-oriented and strictly enforced; (2) Advanced level of remanufacturing, and public recognition of remanufactured parts is high; (3) Clear producer responsibility extension system; (4) Sound social integrity mechanism	(1) The recycling rate of automotive materials and components must meet the required standard; (2) Clear producer responsibility extension system; (3) Systematic vehicle scrapping through market orientation; (4) Sound social integrity mechanism	(1) Consumers pay recycling fees when buying cars; (2) Manufacturer takes back three substances (Freon, airbag, and residue ASR) for recycling; (3) Separate management through the government and non-governmental organizations; (4) Sound social integrity mechanism	(1) Prohibition of "five main assemblies" in remanufacturing; (2) Imperfect information supervision system, ineffective supervision, abandoned automobiles drain regular enterprise profits; (3) Unclear extended producer responsibility; (4) Imperfect social integrity mechanism.

3.4 Serious loss of scrap steel after dismantling ELVs

Scrap steel is a type of energy saving and renewable resource that can be recycled indefinitely. Using 1 ton of scrap steel can save 1 ton of raw coal, reduce 1.7 tons of ore concentrates' consumption, 4.3 tons of raw ore mining, and 1.6 tons of CO_2 emissions [10]. Using less iron ore and more scrap steel in steel production is very beneficial for the sustainable development of the steel industry and improving the ecological environment. However, at present, the waste steel industry in China has not yet established a standard system for recycling, processing, distribution, utilization, supervision, etc. Coupled with the constraints of high costs of electric power and tax on the waste steel industry, the electric steelmaking that utilizes waste steel in China only accounts for about 10% of steel production; therefore, the waste steel ratio in China is relatively low. As shown in Fig. 2, during the 12th Five-Year Plan period, China's scrap ratio was only 11.5%, which is far lower than the global average of 37% [11].

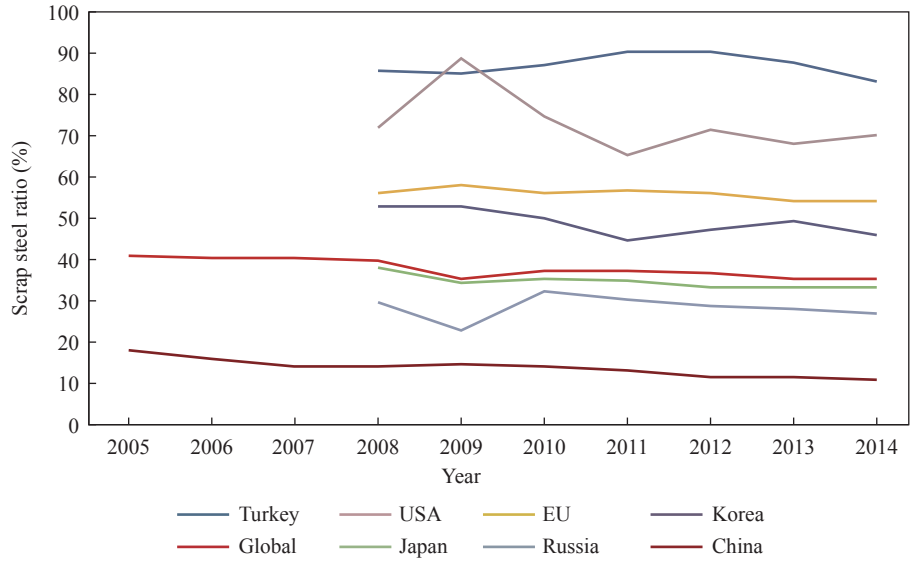

Fig. 2. Scrap steel ratio of major countries in the world.

4 Suggestions for improving the recycling level of ELVs in China

4.1 Enact better regulations and prevent ELVs from entering the black market

First, publish as soon as possible the state council's decision to amend the regulations for recycling ELVs. Further, allow recycling companies to purchase the "five main assemblies." This will enhance the circular use of resources, increase the profits of legal recycling companies, and, thus, their enthusiasm.

Second, re-establish the qualification recognition system for recycling and dismantling companies through legislations for operating ELVs recycling, and use administrative force to stop recycling companies that lack standardization, and are not environment friendly, to ensure the healthy and orderly development of the ELVs dismantling industry.

Third, to prevent the loss of scrap cars, establish the cash pledge system of recycling by borrowing ideas from developed countries.

Fourth, ensure that public agencies enforce legal regulations on car scrapping, registration cancellation, car recycling and disassembly; further, they should ban ELVs on the road. Furthermore, they should take strict precautions to prevent ELVs from entering the black market, thereby ensuring that scrap cars and re-assembled cars do not return to the roads.

4.2 Establishing a supervision system for recycling ELV information

The government should establish a public information platform, which is shared by car production companies, vehicle scrap management department, and ELV recycling enterprises, to collect basic information on automobile production, trade, maintenance, scrap, and recycling. In addition to a regulatory information platform, green assessment platform, and law enforcement platform, this would create a new supervision system for information on recycling ELV for the life cycle of car products (Fig. 3). Information on various stages of the life cycle of car products would be accessible, resulting in an accurate and transparent tracking program for ELVs.

4.3 Enforce green design in vehicle manufacturing

The recycling process for cars contributes only 10%–20% of the recycling profit and the rest is determined by the design stage [12]. Therefore, car manufacturers require a responsibility extension system to encourage them to implement green design in manufacturing, to enable disassembly, reproduction, recycling of materials and the recycling process itself, etc. Furthermore, green design can include the choice of non-toxic and non-polluting materials, which are recovery friendly, reusable, and degradable. This will create conditions for improving the recycling level of automobile products, maximize the utilization efficiency of ELVs, and reduce environmental pollution.

4.4 Promote re-manufacturing engineering for efficient use of ELV resources

Re-manufacturing is the development and extension of green manufacturing to the entire life cycle of a vehicle, which is conducive to the development of a circular economy and high efficiency in the utilization of resources [13]. The cost of producing a regular re-manufactured product is only 50% of that of a new product; the conservation of energy and materials is 60% and 70%, respectively, and there is almost no solid waste. This pro-

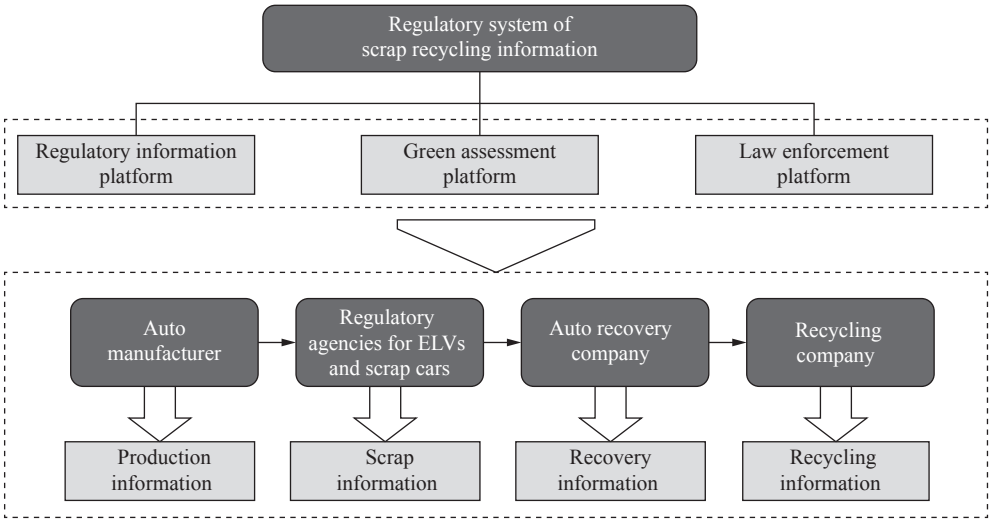

Fig. 3. Vehicle scrap recycling information regulatory platform.

cess can reduce air pollutant emissions by more than 80% [14]. Re-manufacturing helps in constituting a circular economy pattern of "resource–product–worn-out product–re-manufactured product," and, thus, allows one to take full advantage of the resources and protect the environment. Therefore, it is beneficial for the efficient cyclic utilization of ELVs to: set up a coordination mechanism between automobile manufacture companies, automobile recycling and dismantling industries, and resource recycling enterprise, smoothen the upstream and downstream relationship of the industry chain; establish standard specification of cyclic utilization of auto parts; and advance re-manufacturing engineering.

4.5 Increase the utilization rate of scrap steel

As the utilization rate of scrap steel in China is low, the government should enact a multilevel, extensive, and efficient regulatory system for scrap steel, which benefits the circulation of scrap steel, and promotes the use of advanced technologies in dealing with scrap steel. It is necessary to build a base to integrate the recycling, disassembling, processing, distribution, and utilization of scrap steel. Tax preferences and price subsidies should be given to companies that recycle, process, and distribute scrap steel; discounts on electricity price should be offered too. These polices will raise the enthusiasm of companies in utilizing scrap steel and encourage them to recycle more scrap steel. The scrap steel industry would develop organically, utilize more scrap steel, reduce the exploitation and consumption of iron ore, and maintain the export of low-priced parts from scrap cars parts within limits.

4.6 Objectively assessing the ecological benefits of recycling scrap cars

The government should establish a neutral appraisal agency for the life cycle assessment of cars and develop evaluation criterion. The assessment model of ecological benefits of recycling scrap cars (O-E-D model), shown in Fig. 4, works well in assessing the ore resources saved (ore resources, O), energy consumption (energy, E), and environmental discharge (discharge, D) in the recycling process of a scrap car in a specialized, standardized, and normalized manner. Consequently, it could provide a comprehensive perspective of the ecological benefits of recycling scrap cars. The basic O-E-D model can establish a creative management measure and provide innovative direction for recycling scrap cars. Developing an innovative method and process would promote greater recycling of scrap and the use of resources, while reducing the resource waste and waste discharge. The above measure can generally increase the ecological benefits of recycling scrap cars.

The O-E-D model aims to assess the ecological benefits of recycling scrap cars comprehensively and precisely, based on two principles: resource saving and environment friendliness. First, it analyzes the resource consumption and environmental discharge involved in car scrapping, dismantlement, cleaning, smashing, and transportation. Then, according to the 4R principles of cir-

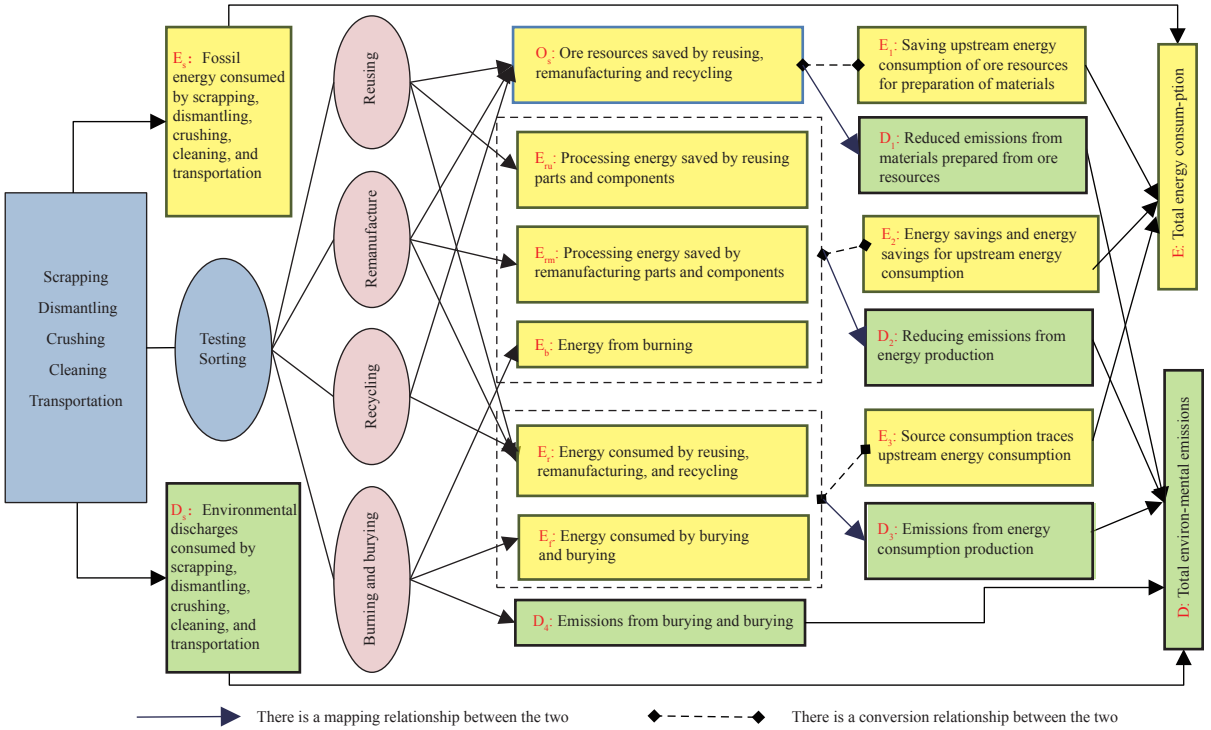

Fig. 4. Ecological benefit evaluation model from scrapping to recovery stages.

cular economy, it classifies the ways to handle the components of a scrap car as follows: reusing, reproducing, recycling, and burning or burying. The consumption of materials, energy, and emission is calculated individually in the following four ways. The "mineral resources and fossil fuels" are calculated as the total energy consumption (Antimony equivalent) using the specialized skill of characterizing technology. The "gas emissions and toxic and harmful substance" are calculated as the total environmental discharge using classified, specialized, and standardized skills. The ecological benefits of recycling a scrap car are represented by the total energy consumption and total environmental discharge.

5 Conclusions

The automobile industry is a pillar of the Chinese manufacturing sector and its sustainable development is the key factor in a progressive and healthy national economy. Scrap car recycling is an important part of the circular automobile economy. The recycling and utilization of scrap cars is beneficial for the economy, society, and the environment; it is also an important measure to ensure the recycling and utilization of resources for the sustainable development of a green automobile industry. In conclusion, the recycling and utilization of scrap cars is indispensable to China's auto power strategy and building an ecological civilization.

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