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EXPLORING INCENTIVE MECHANISM IN SMART E-WASTE MANAGEMENT SYSTEM IN CHINA

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With the vast increase in global e-waste, e-waste management is becoming increasingly critical. China produces a large amount of e-waste every year, but the recycling rate is minimal. To avoid causing severe environmental pollution and affecting human health, the Chinese government has focused on recycling e-wastes. E-waste contains precious metals and critical minerals, which are misplaced resources and have recycling value. We combined the incentive system with the smart e-waste collecting system and constructed a set of incentive measures suitable for China's smart e-waste collection system, which is conducive to enhancing the e-waste recovery rate and is applicable. The existing smart e-waste collection system adopts a single economic incentive method. It faces fierce competition from unauthorized informal recyclers, resulting in a small number of users and a failure to fully utilize its advantages. In the reverse logistics of e-waste recycling, consumers are the starting point of product recycling. By analyzing the characteristics and determinants of Chinese users' recycling behavior, this study selected appropriate incentives for a smart e-waste collection system to satisfy Chinese consumers' perceptions of end-of-life electrical and electronic equipment. The incentive system is based on economic incentives, including currency, reward points, and tax incentives, and combines negative incentives, mainly fines. Rewards and punishments are employed simultaneously to achieve long-term and sustainable incentive effects. The incentive system is based on the convenient infrastructure of the smart e-waste collection system, and its financial model must be shared by multiple stakeholders from the government, smart e-waste systems, and manufacturers.

Key words: *e-waste, smart e-waste collection, incentive system, consumer behavior, circular economy, electrical and electronic equipment.*

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Introduction/ To reduce the effect of economic activities on the natural environment, we must adapt the traditional economic growth paradigm of mass production, mass consumption, and mass abandonment. No actual waste exists in the circular economy – simply misallocated resources. The circular economy mandates that socio-economic activities must be founded on the principles of "reduce, reuse, and recycle," with low energy consumption, low emissions, and high efficiency as the primary characteristics; it also follows the sustainable development economic growth model [1]. The circular economy is an approach used to alleviate resource limits on economic development in China, which is currently suffering from resource shortages but massive consumption.

The amount of waste electrical and electronic equipment (WEEE) has expanded rapidly worldwide due to the swift growth of information and communication technology, making it the fastest-growing waste stream [2]. In 2015, the total amount of WEEE produced globally was 43.8 million tons, and in 2019, it reached 57 million tons. The management of e-wastes has become a global challenge due to its severe influence on the environment and human health [3]. China's WEEE volume has risen each year, reaching 10.129 million tons in 2019, making it the world's largest producer of e-waste. Given the rapid development of the Internet, the Internet of Things (IoT), cloud computing, big data, and other technologies [4], smart e-waste collection, which overcomes the shortcomings of traditional methods regarding collection scope, flexibility, convenience, and accessibility of services, has become a mainstream innovation of formal e-waste collection and demonstrates a strong development trend [5].

Even though the volume of e-waste is rapidly increasing, the rate at which it is recycled in a formal and reasonable manner is relatively low, and e-waste recycling rates vary by country [6]. According to Baldé et al. [6], Asia generates 40.7% of global e-waste, but only 15% is collected. Given the lack of legislation and technologies, as well as the availability of informal recycling techniques, China's formal e-waste recycling rate is quite meager. We defined an

incentive system that encourages consumers to recycle their end-of-life electrical and electronic equipment (EoL EEE) through the smart e-waste collection system, increases formal recycling rates, and promotes the long-term and healthy development of legal recycling businesses.

E-waste management in China

On the one hand, e-waste contains dangerous compounds, such as lead, cadmium, mercury, brominated flame retardants, polychlorinated biphenyls, and so on. These compounds can cause major air, soil, and groundwater contamination if processed in an informal manner, such as open-burning or acid leaching [7; 8]. On the other hand, e-waste also contains valuable materials, such as gold, platinum, palladium, silver, polymers, and other rare resources. It can alleviate the shortage of rare resources in the electronics industry if properly recycled [9]. Given that extracting metal from e-waste emits less CO2 than mining metal-rich ores, proper recycling of e-waste can have good environmental, resource, and economic consequences.

The legal and informal sectors of China's e-waste recycling management system comprise two independent yet interrelated portions. Due to a lack of monitoring and related norms and regulations, informal e-waste recycling has become a business in some parts of China, such as Guiyu Town in Guangdong Province and Taizhou City in Zhejiang Province, posing substantial environmental and public health risks. According to reports, the average concentration of lead in the blood of local children in Guiyu Town is 15.3 lg/dl, and children whose lead content exceeds 10 lg/dl are advised to seek treatment [10]. Approximately 60% of China's recyclable e-waste went into the informal recycling process, resulting in a supply shortage in the legal recycling sector [11]. The management of e-waste recycling in China is remarkably impeded. According to Yang et al., existing informal collectors and recyclers must be transformed or integrated into the formal recycling sector, and the informal sector must be regularized through regulations and standards to increase the collection rate and to completely utilize the resources in e-waste [12].

Residents in developed countries, such as Germany, Spain, and other countries in the European Union, are required to deliver e-waste to collection stations, and producers are responsible for the cost of recycling [13]. Consumers in Japan pay for the recycling of e-waste because the selling price of new electronic devices includes recycling charges [14]. In most locations in the United States, the expense of e-waste recycling is shared by producers, citizens, and the government [15]. Since the environmental awareness and economic levels of developing countries are relatively low compared with those of developed countries, incentive programs to persuade residents to recycle their e-waste must be implemented. In China, e-waste is regarded as a valuable commodity that may be refurbished and remanufactured before being sold in the secondary market. Wang et al. [11] considered collection price as one of the determinants of Beijing residents' willingness and behavior to recycle e-waste. Chi et al. [16] found that collection price is one of the critical factors for Chinese residents to choose recyclers, accounting for 23.8%. The introduction of economic incentives into formal recycling systems is conducive to increasing recovery rates.

To cope with the increasing amount of WEEE and its potential environmental impact, the Chinese government has promulgated a series of regulations to promote the development of the e-waste recycling industry. In 2002, China banned the importation of dangerous waste from electrical and electronic products. In 2006, China promulgated the Ordinance on Management of Prevention and Control of Pollution from Electronic and Information Products, which was regarded as the China RoHS Directive. In 2009, China launched a pilot project on old-for-new replacements for household appliances. In 2011, the regulation on the Management of Recycling and Disposal of Waste Electrical and Electronic Products, known as the China WEEE Directive, went into effect. The regulation pushed for extended producer responsibility (EPR), which states that EEE manufacturers are responsible for the entire life cycle of electronic items and must recycle EoL EEE. Large EEE producers are willing to recycle their EoL EEE because the product design is recyclable rather than linear [17]. They have created standard processing facilities for e-wastes, such as Haier and Huaxing, which aim to remanufacture and transform e-wastes to utilize EoL EEE effectively. However, they are currently unable to gather enough e-waste to sustain their typical manufacturing capacity, resulting in the production line's closure or only infrequent operation [18].

Consumers are unaware of the impact of informal WEEE recycling on the environment and human health due to a lack of environmental knowledge and social responsibility. EoL EEE holders prefer informal collection channels due to their comparatively high currency income, and they are unwilling to bear the cost of e-waste recovery. Due to the features of e-waste flow, China's economic development level, cheap labor, and current recycling models, China must construct a personal collection system consistent with the current conditions, rather than copying the WEEE collection models of other countries.

In 2015, China's National Development and Reform Commission issued a circular economy promotion plan. This plan aims to provide policy support for the development of new recycling methods, such as intelligent recycling and automatic recycling, and to actively promote an Internet-based e-waste collection strategy. The Internet-based e-waste collection platform, which combines online transactions and offline logistics via websites and mobile phone applications, is rapidly expanding. Manufacturers, Internet corporations, and recycling enterprises have expressed interest in intelligent e-waste recycling. China released the "Internet +" Green Ecological Action Implementation Plan in 2016 to promote dynamic environmental monitoring, develop innovative environmental protection technologies, and improve recycling and online resource trade. Innovative e-waste collection and recycling technology help increase recycling rates; however, the ultimate effect is determined by e-waste owners and encouraging customers to actively participate in a formal e-waste collecting platform based on intelligent technologies.

The Internet-based e-waste collection platform allows participants to make online appointments for on-site e-waste collection [19]. The network platform can track the information, material, and capital flow for consumers, e-commerce platforms, registered recycling plants, third-party logistics firms, cooperative collection companies, and secondhand product buyers [20; 21]. Internet-based e-waste collection makes online transactions increasingly convenient for consumers [18] and provides them with quick access to the official e-waste management system by utilizing information technologies, such as the Internet, IoT, and smartphone apps. By contrast, the Internet-based e-waste collecting system is still in its infancy, and its implementation is plagued with obstacles. The government, the platform, and the users are the platform's three stakeholders. Determining how to entice consumers to use the smart e-waste collection platform is crucial. E-waste is plentiful in China, but only a minute percentage of it is recycled using an environmentally friendly method. According to studies, e-waste recycling in China has been significantly hampered by user participation [22].

Smart e-waste collection, as an innovative solution, may be able to successfully address the issues of e-waste collection and dismantling. Online tracking, processing, and tracing of recycled products are all possible with this new technology. System functions include data statistics, order collection, warehouse storage, and dismantle quality. Residents' inclination to recycle may be influenced by the economic rewards of smart recycling. Collectors' bids maximize the income of consumers who participate in e-waste recycling. This article explores ways to encourage consumers to participate in smart e-waste recycling through incentives.

Materials and methods. Several scholars have studied the influencing variables of waste recycling behavior, and the theory of planned behavior is widely acknowledged and implemented as a psychological theory. Azjen [23] proposed the concept of planned behavior, which states that human behavior is a type of planned behavior. Furthermore, behavioral intention is the most crucial aspect in defining recycling behavior. Individuals' behavioral intentions are determined by their attitudes, subjective norms, and perceived behavioral control and are influenced by these three elements, as shown in Figure 1. People's behaviors are influenced by intention and perceived behavioral control. According to this theory, the perceived behavioral control that occurs in e-waste recycling represents the individual's ease or difficulty in completing this activity [24]. According to Boldero [25], recycling convenience, storage space, and the simplicity of use of recycling facilities are all factors that influence consumers' recycling behavior. Consumer behavior is one of the most essential factors in e-waste management [26]. Consumers play two critical roles in the life cycle of e-waste: users and owners. The e-waste management system is ineffective if users do not actively participate.

Expectation theory, also known as valence-means-expectation theory, was proposed by Victor Froome. He believes that incentives depend on the value evaluation (valency) of the action result and its corresponding expectation, and the formula expressed is as $M = V \times E$. Therefore, the expectations of individuals must be considered to obtain optimal incentives; that is, individuals can achieve certain benefits through their efforts, and beneficial results should be rewarded. Furthermore, this reward must be determined in accordance with the demands of the individual. We analyzed how to formulate incentive mechanisms for consumers to increase the recycling rate of waste electrical appliances based on the characteristics of the benefits generated by recycling waste electrical appliances using the incentive mechanism of expectation theory.

To solve the problem of e-waste collection and recycling, we must first resolve obstacles, such as service inconvenience, and introduce changes in services or infrastructure. Innovative recycling platforms based on the Internet and IoT technologies make recycling highly convenient for consumers. Under the premise of ensuring that the infrastructure is established, incentives enable consumers to engage in rational behavior [27]. Incentives are considered as means to maximize the efficiency of waste management infrastructure. If no infrastructure is available to facilitate recycling, even if consumers have a high awareness of recycling, this will lead to frustration in recycling behavior. By contrast, even with a complete recycling delivery system, but the willingness and motivation of consumers to recycle is low – ndicating that consumer participation is low – the recycling system cannot be promoted well, as shown in Figure 2.

Consumers' willingness to recycle e-waste is affected by several factors, including policies, regulations, socio-economic factors, convenience, environmental awareness, attitudes, motivations, and traditional habits [28; 29; 30]. Colesca et al. [31] considered that the characteristics of

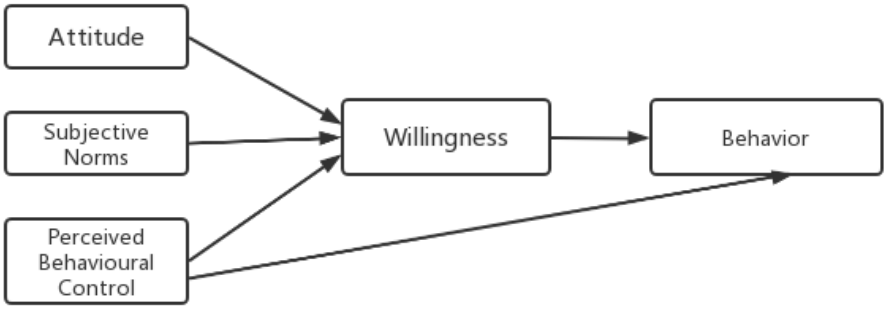

Figure 1. Theory of Planned Behavior, TPB (Wang et al. [24])

different countries affect the collection and recycling behavior of e-waste. Different countries have different methods to collect and dispose of e-waste [32]. Understanding the efficiency of existing collection channels and residents' recycling preferences is a prerequisite for the successful design of the e-waste collection system in China [16].

The recycling rate of e-waste in European countries is at the top level globally, and the level of awareness and knowledge of e-waste recycling are vital factors that affect the behavior of European consumers [33; 34]. However, American consumers are highly concerned about the convenience of e-waste recycling [28; 35]. In developing countries, such as India, and in Africa with relatively backward economic development, e-waste recycling depends on the informal sector to varying degrees [32; 36]. Although the formal sector has been expanding with the support of pilot projects and recycling projects initiated by the Chinese government, especially in highly developed regions of China, the informal sector still dominates the e-waste management industry. In China's e-waste management system, consumers have no specific responsibilities, and the role of consumers is limited to passive interactions with the e-waste department. E-waste is a tradable commodity with a high reuse rate in China [37]. Despite the poor technical and environmental performance of the informal e-waste disposal department, it is still accepted by Chinese consumers. The development of smart e-waste recycling technology has reduced the time and economic costs of consumers for e-waste collection and recycling. However, establishing e-waste recycling habits still takes several years [38]. Under the premise of China's current social economy and people's environmental awareness, some measures must be considered to change the dominant position of informal recycling methods and increase the recycling rate.

Through an analysis of papers related to China's e-waste recycling in recent years, the main determinants of China's consumer e-waste recycling behavior are sorted out, as shown in Table 1. According to Chi et al. [16], economic benefits, convenient recycling, and environmental awareness are vital determinants for residents in selecting disposal channels. The lack of economic incentives is why a large amount of e-waste does not enter the formal recycling sector. Li et al. [39] emphasized that monetary incentives and raising environmental awareness are effective ways to improve the effective recycling of mobile phones by researching consumer mobile phone recycling behavior. Yin et al. [40] studied mobile phone recycling behavior and willingness to pay for e-waste recycling (WTP) among Chinese consumers. Considering traditional Chinese consumers and low WTP, manufacturers and the government should jointly undertake the cost of recycling used mobile phones. Consumers are encouraged to participate in the recycling of used mobile phones through financial incentives and regulatory requirements and to integrate informal sellers and recycling workshops into the formal recycling system. Orlins et al. [41] found that consumers and public institutions are more willing to sell e-waste to informal collectors because of higher economic benefits. Because traditional customs are aware of the

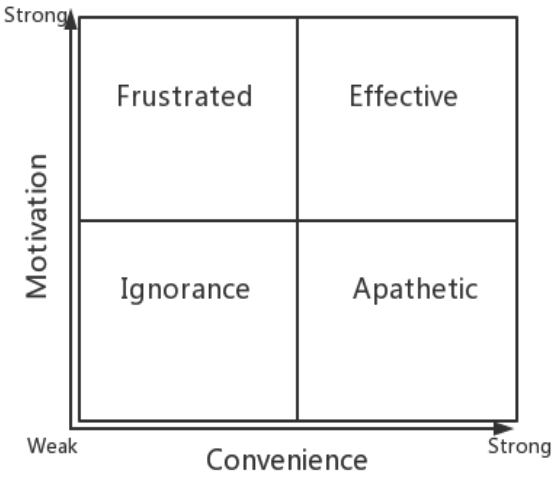

Figure 2. Interaction between motivation and convenience (AEAT Evaluation of the Household Waste Incentives Pilot Scheme [27])

residual worth of e-waste, over 90% of Chinese individuals are unwilling to pay for recycling [37].

Scholars conducted case studies based on the e-waste recycling situation in different regions of China to analyze the behavior of home e-waste recycling in China. Due to Beijing's limited living space, residents are eager to recycle e-waste rather than store it at home or discard it as municipal solid waste [11; 37]. Veenstra et al. [42] utilized the findings of Xi'an as an example to study the flow of e-waste in China. By contrast, Streicher-Porte and Geering [43] reviewed specific types of e-wastes in Taizhou, and they all deemed that most consumers choose informal hawkers. China's e-waste management faces a huge problem – but also an opportunity – in regulating and controlling the informal e-waste collecting and recycling sector and integrating it into the formal recycling system [41]. From the analysis of the determinants of China's consumer electronic waste recycling behavior, economic incentives are one of the primary motivations for Chinese consumers to recycle e-waste. Therefore, the introduction of financial incentives will encourage e-wastes to enter the formal recycling system.

Figure 3 shows the recycling weight and number of e-wastes from 2014 to 2019 in China. The overall amount of e-waste recycled and dismantled in 2019 remained steady, with only a minor increase. The amount of waste recycled via businesses' recycling channels is minimal, and novel recycling means, such as Internet+ and reverse logistics recycling, should be encouraged further. Given the poor collection and delayed distribution of subsidy payments in 2020, e-waste dismantling and processing businesses' capacities were underutilized, resulting in a reduced volume of business.

In China, six primary types of recycling channels are as follows: sold to peddlers, given as donations, sold to the secondhand market, directly discarded, exchanged at retailers or manufacturers, and stored. The proportion of each recycling method in Taizhou City, China, in 2007 is shown in Figure 4 [43]. Only 12.1% of household appliance waste is recycled in the formal sector [16]. Among the

Table 1 – Determinants of Chinese consumers' recycling behavior

Consumer's Recycling Behavior Determinants in China	Economic incentives	Convenience	Habits	Attitude, Mentality	Environmental awareness	Income	Education level	Privacy security
Chi et al., 2014 [16]	√	√			√			
Orlins and Guan, 2016 [41]	√	√		√	√			
Li et al., 2012 [39]	√				√			
Yin et al., 2014 [40]	√					√	√	
Liu et al., 2006 [37]	√	√						
Wang et al., 2011 [11]	√	√	√			√		
Wang et al., 2019 [24]	√	√		√	√			
Wang et al., 2019 [44]				√	√			
Qu et al., 2019 [45]	√	√						√
Ignatuschtschenko, 2017 [46]	√		√	√	√			

current disposal methods of household e-wastes in China, storage at home, selling to hawkers, and directly discarding household wastes are the three methods with the most considerable proportion, posing a significant obstacle to official e-waste recycling.

Consumers are more likely to keep EoL EEE at home rather than properly dispose of it. According to Yin et al. [40], up to 47.1% of EoL mobile phones are kept at home in China. Three reasons contribute to this action: first, most consumers (45.9%) are unsure where to recycle their cellphones; second, they are concerned about personal information disclosure (17.7%); and third, they repurpose obsolete cellphones as data storage devices (8.1%). According to the report, consumers are willing to trade their mobile phones with manufacturers or standard retailers for old-for-new activities or bonuses. Given the toxic compounds and precious materials in e-wastes, direct disposal of household waste (14%) will result in substantial environmental damage and resource waste. The percentage of people who use these three unreasonable disposal methods can be significantly reduced, and the official recovery rate can be enhanced owing to incentives.

Many academics have focused on economic motivation and employed incentives to promote adequate waste management to motivate customers to participate in sustainable waste management [27,47]. Monetary and non-monetary incentives are two types of incentives. Dixit and Vaish [48] classified incentives into three categories: financial incentives, environmental incentives, and social incentives. Defra [27] used a "carrot or stick" technique to distribute currency and volunteer incentives. The four forms of financial carrots are as follows: prize draw, currency reward incentives, currency rewards, and currency discounts. Individuals or communities that participate in the recycling program will be rewarded financially. Fee-based plans and required participation, which refer to the penalty or taxation of not participating in the recycling program, are examples of financial penalties. Community rewards, charitable donations, school rewards, and personal non-monetary rewards are the four forms of voluntary carrots. They appeal to people's generosity and willingness to help the community and the environment. Ylae-Mella et al. [49] suggested that a currency deposit refund system must be implemented to promote the return of e-wastes in Finland because 70% of respondents stated that a deposit of 20 euros would encourage them to return their old mobile phones. The Thai government proposed charging fees for the sale of certain electronic items and using the collected

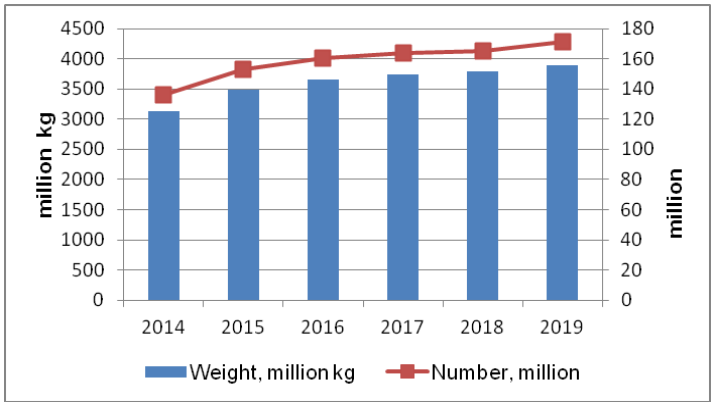

Figure 3. Formal e-waste recycling in China, 2014–2019 (The Ministry of Commerce's Report on the Development of China's Renewable Resources Recycling Industry)

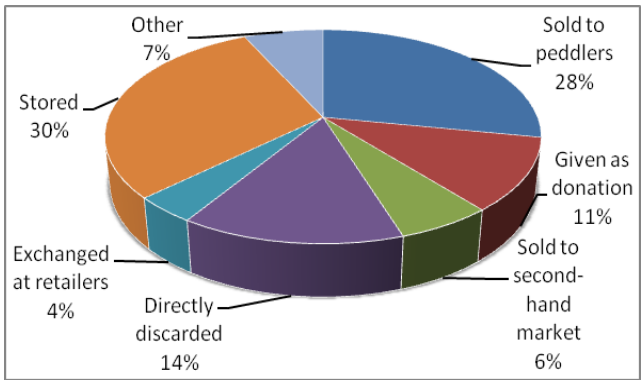

Figure 4. Rates of different e-waste disposal channels in Taizhou in 2007 (Streicher-Porte and Geering [43])

money to buy back WEEE from homes to reduce the negative impact of the informal recycling industry on the community and the environment [14]. Fullerton and Wolverton [50] considered this strategy a deposit-refund system (DRS) update that incorporates the front-end product cost and the back-end repurchase method. The back-end repurchase is different because it is motivated by financial incentives. The wide-scale use of DRS to EEE recycling is a difficult task [49]. The residual value after use varies due to the uniqueness of EEE, different types and models, and service life, making it impossible to calculate how much deposit to collect in advance [37]. More than 60% of respondents in Beijing, China, sold their outdated household appliances to hawkers, and acceptance of using DRS to dispose of e-waste is low [11].

China has established a special subsidy fund for electronic device manufacturers and importers, which gives proportional subsidies to e-waste dismantling and treatment enterprises, depending on the actual amount of e-waste deconstructed. Monetary incentives must be given to recycling businesses through the deployment of fund subsidies. The list of e-waste disposal fund-subsidized enterprises must be dynamically changed, the subsidy mechanism must be optimized, and the policy orientation of eliminating the backward enterprises must be developed. However, significant flaws exist, primarily in fund auditing and environmental oversight, as well as insufficient subsidy collection and delays.

Results. We investigated the incentive mechanism of a smart e-waste recycling system and suggested a comprehensive reward system that primarily consists of three components. The first component is monetary compensation. The electronic payment will be made to the account of the e-waste generator based on the e-waste recycling price. Second, the smart recycling platform must work with major e-commerce platforms and hypermarkets that sell electrical appliances. If consumers need to buy new appliances, outmoded appliances can be recycled for cash through a smart recycling system, similar to the old-for-new program. Humanely, the types of electrical appliances purchased and recycled can differ. Furthermore, the smart recycling system's reverse logistics can be flexible and diversified. For example, small household appliances can be delivered, with the delivery fee covered by the Internet recycling site. A smart recycling system may form a cooperative agreement with the courier firm to reduce delivery costs. For large and heavy household appliances, the smart recycling platform's employees will schedule a pick-up appointment with the e-waste holder. These above-mentioned options are monetary incentives. The third component combines non-monetary rewards. Consumers who participate in recycling on the smart e-waste recycling system can earn reward points in exchange for social benefits in their local areas. Points can be redeemed for tickets to local attractions, public activities, and small appliances.

China has three primary sources of e-waste: households, institutional sources, and equipment manufacturers [51]. How to persuade consumers to deal with EoL EEE through appropriate channels, rather than selling them to household workshops, must be determined. Relevant laws and regulations can be developed, and the implementation process can be tracked to control the two latter forms of e-waste. In this process, the incentive mechanism is also crucial. Enterprises that return e-wastes to a formal recycler may be eligible for tax concessions, exemptions, or preferential treatment from the government. By contrast, enterprises that give e-wastes to unlicensed recyclers should be severely penalized. Specific fine standards can be formulated. Companies that violate relevant legislation will lose a lot of money. Due to governmental restrictions, few businesses will risk selling generated e-wastes to illegal collectors and recyclers.

Figure 5 shows the incentive mechanism of a smart e-waste system. Consumers participating in the smart e-waste recycling system receive monetary incentives and accumulated reward points. Furthermore, administrative laws govern e-waste institutional sources, such as colleges and businesses, and tax reductions are employed as incentives. In addition, fines are given as negative incentives. This incentive scheme has obvious advantages compared with the current single-currency incentive with low recycling prices in the smart e-waste collection system.

Currency incentives have been integrated into China's smart e-waste recycling system. Smart recycling systems based on the Internet, such as Taolv and Aihuishou, estimate the quotation of waste based on the user's basic

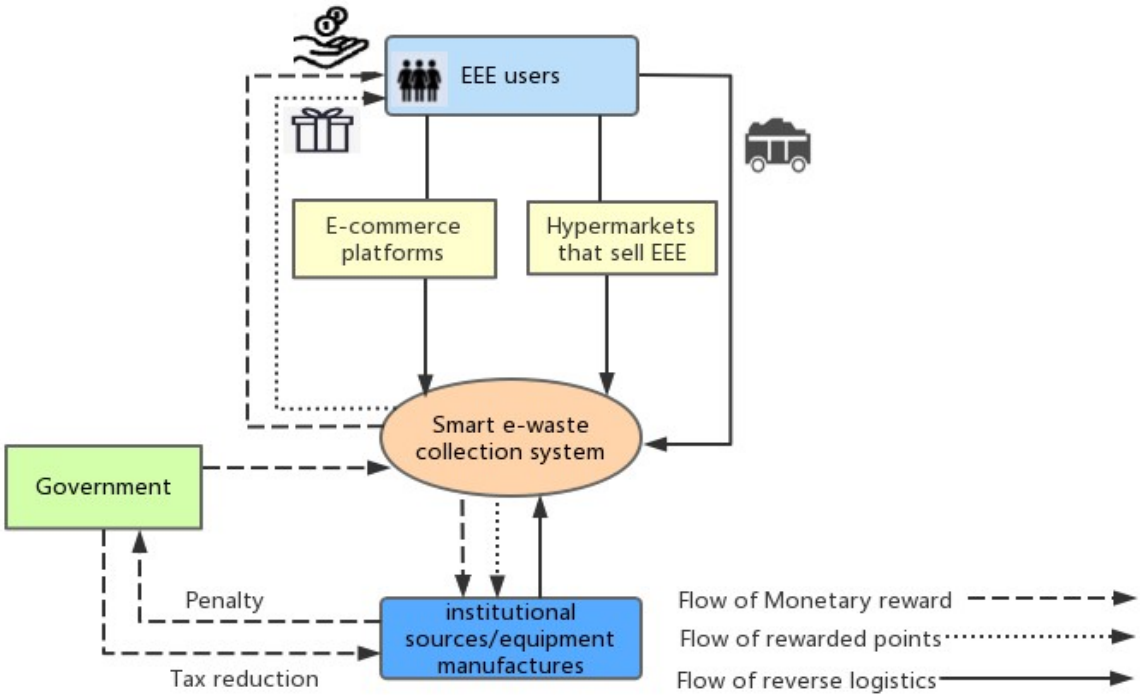

Figure 5. Incentive mechanism of a smart e-waste system

information and photos of obsolete household equipment and then analyze it professionally. Finally, the user's account will receive cash. Informal collectors compete with smart recycling platforms, and the only way to acquire a competitive advantage is to increase recycling prices. As a result, smart recycling platforms require government financial incentives to raise recycling prices and attract price-sensitive users.

To tackle the problem of the insufficient supply of e-waste by formal recycling firms, the smart recycling system collaborates with e-commerce platforms that offer discount links to the smart e-waste recycling system. In this manner, the smart recycling system can be pushed, and consumers who buy new home appliances can be directed to it so that they can appreciate the ease of the new recycling process and increase the amount of e-waste recycled. This new trade-in incentive will remind consumers who are used to storing them at home to discard their EoL EEE responsibly. Similarly, smart recycling solutions can work with hypermarkets that sell electrical products. Log in to the smart recycling system via a mobile phone or computer terminal application while purchasing new home appliances in the store to recycle old home appliances. The selling price of new appliances can directly reduce the corresponding recycling price of recycled old appliances. Every time a user engages in a recycling behavior through the smart recycling system, the behavior is logged and awarded points. Different points are given depending on how difficult the type of household appliance is to recycle. Old appliances that easily flow into informal recycling, store at home, and throw as ordinary garbage can be assigned a high-point value, and we can accumulate the points. When points reach a certain value, they can be traded for various rewards.

The Chinese government's introduction of the old-for-new policy in 2009 demonstrated that monetary incentives could overcome e-waste collection barriers in China. Twenty-six million obsolete appliances were collected during the initiative's 18-month implementation [52]. However, the plan's implementation will necessitate significant government funding. The incentive mechanism suggested in this study does not require any extra infrastructure and uses the current intelligent recycling system's staff and warehouses. The incentive fund is shared by the government, the smart e-waste recycling system, and the manufacturers. The Chinese government provides subsidies to a special fund based on the number of recyclers dismantled. Special funds are collected from manufacturers or importers through the EPR system. Economic incentives can enhance the reverse recovery rate of e-waste by promoting collaboration and active participation among stakeholders.

Fiscal expenditures as incentives in the early stages are necessary to use; however, as social and economic development, environmental awareness, and the establishment of proper e-waste disposal habits progress, the degree of economic motivation is reduced, eventually evolving into consumers' free voluntary recycling behavior. By contrast, after informal individual collectors are incorporated into the formal recycling organization, environmentally friendly disposal and dismantling methods are used. Individual collectors will not recycle at unreasonably high prices, and no profitable space will be available for informal recycling. The smart way of recycling will become the first choice for people. The smart recycling system not only makes recycling easier, but also ensures that abandoned electronic products are correctly recycled and that personal information is kept private. Therefore, it has a unique advantage compared with the recycling of individual hawkers. However, for smart recycling platforms to gain traction, an incentive mechanism is required.

Discussion. Given that e-waste is profitable in China, individuals usually sell these wastes, and the WTP is very low. Due to the influence of time and capital expenses, even though some people have developed an environmental consciousness and a willingness to recycle e-waste, they have not considered e-waste recycling actions. As a new technology, the smart recycling solution has evident advantages over traditional recycling systems. The smart collection and recycling system assures not only the ease of collection and recycling but also the protection of personal privacy, as well as open and transparent transaction pricing. Incorporating an incentive mechanism into the smart recycling system aims to increase awareness and promote the smart e-waste collection and recycling system, increase the recovery rate of discarded electronic goods through monetary and non-monetary incentives, solve the problem of an insufficient supply of formal recycling enterprises, and encourage the effective implementation of the circular economy. Municipalities, smart recycling platforms, and manufacturers should share the currency source of financial incentives. In developing countries, providing financial incentives to recycling enterprises during the early stages of e-waste recycling is a widespread and necessary practice. The smart waste recycling system requires financial assistance, and the incentive mechanism's purpose is to raise the average price above that of informal individual hawkers' recycling prices.

Many fields employ coupons, rebates, gifts, and prizes as economic incentives to boost the recycling rate of recyclable materials [53]. The smart recycling collection system collaborates with online e-commerce platforms and offline electrical appliance stores to recycle old appliances from the sale of new appliances and to expand the smart recycling system's user base. This incentive program benefits not only distributors but also the entire smart recycling system. This program is feasible and a win-win situation. Reward points have been incorporated into the smart e-waste collection system. To generate excellent incentive effects, communities, businesses, and other social groups must cooperate to ensure that numerous benefits can be obtained by accumulating points in consumers' accounts.

Negative incentives are also crucial for improving the incentive mechanism. Developing countries have a widespread lack of legislation and regulations for the recycling and disposal of e-wastes. Relevant laws and regulations are created to supervise and penalize forbidden recycling methods and ecologically detrimental dismantling methods to ensure that rewards and penalties are coordinated. Schools, institutions, and businesses, as independent legal entities, are frequently faced with batch processing of e-wastes. Their e-waste typically has identifiable signs that are easy to track and trace. They are required by legal policies to participate in official recycling. If the entity performs an excellent job of implementing the regulations, the government may give favorable taxation; otherwise, administrative fines may be applied.

Individual hawker recycling dominates the traditional recycling method; the recycling market is chaotic, and the recycling channels are hidden, making supervision challenging. Statistics on the amount of e-waste recycled, the type of recycling, and the resources available for disassembly are difficult to obtain. E-waste is lured into the smart recycling system through an incentive mechanism. The data flow is clear, and you may collect a lot of important information on e-waste recycling. Smart technologies, such as big data analysis, can help stakeholders keep abreast of e-waste recycling. Manufacturers should also be forced to consider disassembly and environmental factors during recycling, as well as incorporate circular economy principles into new product design.

Conclusion. As technology progresses, the likelihood of replacing obsolete electronic equipment after a set amount of time increases. EEE is highly likely to be discarded before its useful life expires as technology advances. As a result, the global volume of e-waste continues to rise. For a long time, informal recycling has dominated China's e-waste recycling. Many e-waste items end up in household workshops for rudimentary recycling, producing major environmental issues. In recent years, the Chinese government and corporations have made significant efforts to improve e-waste recycling and processing.

The growth of the Internet, the IoT, cloud computing, big data, artificial intelligence, and other developing technologies has provided new avenues for China's e-waste recovery and treatment. Recycling through the Internet has become a trend in China. Intelligent e-waste recycling bins based on the IoT and artificial intelligence have the potential to be widely used in communities and other public areas. In China, smart e-waste management is regarded as a powerful and creative novel method for addressing the e-waste crisis. However, its promotion and implementation confront significant obstacles. This article provides a comprehensive set of incentive mechanisms to increase consumer participation in smart e-waste recycling.

According to the literature, economic factors are the most critical determinants of Chinese consumers' e-waste recycling behavior. As a result, the incentive mechanism is initially centered on monetary incentives, with consumers receiving currency rewards on the smart e-waste recycling platform. An increasing number of consumers have been attracted to recycling outdated appliances stored at home or intended to be discarded as household waste on the smart recycling platform by offering a financial reward through a partnership between the smart recycling platform and online and offline appliance sales. To strengthen the efficiency of the incentive mechanism, consumers on the smart recycling platform are awarded incentive points for each recycling activity, allowing them to fully utilize social resources. Finally, using negative incentives, the entire e-waste recycling process in companies and organizations is monitored; rules, and regulations are improved; and rewards and penalties are synchronized through enforcement.

In the incentives proposed in the article, the government, smart recycling systems, manufacturers, retailers, collectors, recyclers, consumers, enterprises, and institutions are all participants, and the financial costs are shared by the government, smart recycling systems, and manufacturers. In actuality, considerations, such as the sharing ratio and cost-effectiveness, necessitate additional investigation.

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МЕХАНІЗМ СТИМУЛЮВАННЯ SMART СИСТЕМИ УПРАВЛІННЯ ЕЛЕКТРОННИМИ ВІДХОДАМИ У КИТАЇ

У статті обґрунтовано інструменти стимулювання для існуючої у Китаї smart системи роздільного збирання відпрацьованих електричних та електронних виробів для підвищення ступеня їх утилізації авторизованими переробниками. Для формування мотиваційної складової smart системи збирання електронних відходів, набула наукового обґрунтування система стимулів на основі аналізу детермінант поведінки китайських користувачів щодо належного поводження з відпрацьованими виробами.

***Ключові слова:** циркулярна економіка, зелений кампус, сталий розвиток, поводження з відходами.*

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