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E-Waste Recycling Systems and Sound Circulative Economies in East Asia: A Comparative Analysis of Systems in Japan, South Korea, China and Taiwan

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Abstract: The main purpose of this paper is to review and compare E-waste management systems operating in East Asian countries in efforts to identify future challenges facing the circulative economies in the region. The first topic of this paper is cost sharing (physical and financial) as applied to the various stakeholders, including producers, consumers, local governments and recyclers, in the E-waste management systems. The second topic is the environmental and economical impacts of these E-waste management systems on recycling technology, trans-boundary movement of E-wastes and Design for Environment (DfE). The final topic is the possibility for international cooperation in the region in terms of E-waste management systems. The authors' preliminary result is that the E-waste management systems operating in these East Asian countries have contributed to extended producer responsibility and DfE to some extent, but many challenges remain in their improvement through proper cost sharing among the stakeholders. It is also clear that the cross-border transfer of E-wastes cannot be resolved by one nation alone, and thus international cooperation will be indispensable in finding a suitable solution.

Keywords: E-waste recycling; extended producer responsibility; East Asia; circulative economy

List of Abbreviations

DfE: Design for Environment

DfR: Design for Recycling

EPR: Extended Producer Responsibility

EU: European Union

KAEE: Korean Association of Electronics Environment

KFEM: Korean Federation for Environmental Movement

OECD: Organization for Economic Cooperation and Development

REACH: Registration, Evaluation, Authorization and Restriction of Chemicals

RFMB: Recycling Fund Management Board

RoHS: Restriction of Hazardous Substances Directive

WEEE: Waste Electrical and Electronic Equipment

1. Introduction

This study addresses issues relating to the recycling of home electric and electronic appliances, a typical mainstay commodity of modern affluent societies. Here we define either waste or used home electric and electronic appliances as E-waste. By analyzing the recycling systems of E-waste in Japan, South Korea, China and Taiwan, in terms of the background to their adoption as well as their similarities and differences, we aim to evaluate the relevant policies and identify the future challenges facing the promotion of circulative economies in East Asia. Specifically, we will analyze the roles (separation, collection and recycling) and responsibilities (financial and physical) of each nation's E-waste disposal and recycling systems according to stakeholder (producer, consumer, central and local government) in order to clarify each system's characteristics and the extent of applying the Extended Producer Responsibility (EPR) [1].

The East Asia region, particularly Japan, South Korea, China and Taiwan, is a major consumer of home electric and electronic appliances, while also comprising a considerable global share of production and export. In addition, the increasing volume of trade in E-wastes in East Asian nations and the accompanying environmental impact have attracted attention in recent years [2,3]. The disposal of E-wastes is therefore not limited to a single nation in East Asia, but instead needs to be addressed as a regional issue. Some important studies analyzed East Asian nation's E-waste recycling systems with a focus on the responsibilities (physical and financial) of stakeholders [4-6]. In light of these previous studies, we have conducted our analysis with an emphasis on the content and stakeholder-based cost burden of recent new systems, the incentives to each stakeholder in terms of E-waste collection and recycling, and the possibility of cooperation on relevant policies among East Asian nations.

In the next section, we will consider the background of the reason that the EPR is applied to the policy design of E-waste recycling, not only from the perspective of domestic factors, but also from factors such as recycled resource trade in East Asia. In Section 3, we will outline and characterize policies relating to E-waste recycling in East Asia as well as undertake a comparative analysis. In Section 4, based on the results of the comparative analysis, we will outline the challenges facing the

promotion of circulative economies and the potential for cooperation to find solutions to these challenges in this region.

2. Background to Introduction of E-Waste Recycling Systems

In this section, we will describe the background to the adoption of systems for the proper disposal and recycling of E-waste in Japan, South Korea, China and Taiwan. Although we can observe differences in the timing, design and scope of each nation's E-waste recycling systems due to their respective stages of economic development, industrial structures and existing waste related policy schemes, we can also identify several common factors in the lead-up to their adoption.

The following four domestic factors can be identified in the lead-up to each nation's adoption of a E-waste recycling system: (1) recognition of the difficulty in disposal of E-waste compared to other kinds of waste; (2) the dire state of landfill shortages and environmental impact (including soil and groundwater contamination) arising from increased E-waste volume; (3) growing interest in the recovery and effective utilization of valuable resources contained in E-waste; (4) willingness to develop recycling companies as a "venous industry".

In addition, the process of formulating national policies on E-waste recycling was significantly affected, both directly and indirectly, not just by domestic factors but also by the policies of international organizations like OECD and the EU. Particular examples of factors having a major direct bearing on the formation of E-waste recycling policies include the following: the OECD's *Extended Producer Responsibility: A Guidance Manual for Governments*' (2001), and the EU's *WEEE Directive* (2002), *RoHS Directive* (2002), and *REACH Regulation* (2006).

Below, we will set aside the common background factors of increased E-waste volume and the accompanying shortage of landfill and environmental impact, and instead focus on examining those background factors in the policymaking process which were inherent to each nation.

In Japan, the *Law for Recycling of Specified Home Appliances* (Home Appliance Recycling Law) was enacted relatively early in 1991 and covered the recycling of four types of home electric and electronic appliances, namely, televisions, refrigerators, washing machines and air conditioners. Apart from the above-mentioned common factors, the sudden increase in illegal dumping of industrial waste was one of the factors behind the adoption of this law. This increase in dumping led to the amendment of all of Japan's waste policies and the enactment of the *Basic Act on Establishing a Sound Material-Cycle Society* in 2000, as well as the *Home Appliance Recycling Law*. In addition, Japan's *Home Appliance Recycling Law* stipulated a "manifest system", which is defined as a set of forms, reports, and procedures designed to seamlessly track waste from the time it leaves the generator facility where it was produced, until it reaches the off-site waste management facility, not seen in the corresponding laws of the other nations. This system was introduced with the aim of integrating the management of waste processes from waste generation to transport and final disposal, and to clarify the responsibilities of the relevant stakeholders. Despite positive evaluation of the system's contribution to the technological development of Japan's recycling industry, there have also been some negative assessments such as its effect in raising the social costs of disposing and recycling E-waste in Japan [7].

Background factors unique to South Korea include the oligopoly on the home electric and electronic appliance industry held by the nation's three major companies (Samsung, Daewoo and LG) and consumer criticism of improper disposal of E-waste led by environmental NGOs. As a result, companies concerned about their brand image entered into voluntary agreements with the government in which they conceded to greater producer responsibility. According to hearings involving South Korean E-waste recycling companies and citizens' groups, consumer criticism of corporations led by environmental NGOs had a substantial impact on the formation of the country's E-waste recycling system. This information is based on the hearings obtained by us upon visiting the KFEM and the KAEE from 26 February–2 March 2007.

The background factors endemic to China were that E-wastes, in most cases, have a market value and were improperly disposed of in the recycling process. Although China currently does not have any legislation pertaining to the recycling of E-wastes, a look at subjects presently under investigation reveals that measures to address the illegal distribution and disposal account for a significant portion. This situation has arisen due to the growing number of individuals who collect, repair and sell used home electric and electronic appliances in response to persistently high demand, particularly from farming villages. Residual substances from the disassembly and repair of these E-wastes are discarded as general waste without proper processing to prevent the release of chlorofluorocarbons (CFCs) and so forth, with the resultant environmental impact developing into a major problem [8]. However, the sharp rise in these used goods is occurring not only from within China, but also as a result of burgeoning illegal imports from Japan and South Korea, both recycling and disposal costs of China being very cheaper than those of these two countries. It is therefore essential that legislation within China be accompanied by cooperation with other East Asian nations.

In Taiwan, the management of contamination arising from the improper disposal and illegal dumping of E-wastes has been identified as a major factor [6]. This led to the design of a system which placed the financial burden of proper recycling on producers and provided subsidies to recyclers for proper disposal. As described above, the background to the introduction of proper disposal and recycling systems comprised some common factors as well as some inherent national factors, and was also strongly affected by international policies, particularly those of the OECD and EU already mentioned. Needless to say, factors not discussed in this chapter, such as the existing waste-related systems and industrial structures of each nation, also affected system design to a certain extent.

3. Comparative Analysis of E-Waste Recycling Systems

This section examines the content of Japanese, Korean, Chinese and Taiwanese E-waste recycling systems and compares them in terms of the timing of the introduction, targeted appliances, role of stakeholders, and their expenses and incentives for participation.

3.1. Timing of the Introduction of Recycling Systems and Targeted Appliances

There are major differences in the timing of the introduction, targeted appliances and stakeholder roles of the E-waste recycling systems in Japan, South Korea, China and Taiwan due to the respective stages of economic development, industrial structures and existing waste-related policy schemes.

Table 1 summarizes the transitions, targeted appliances and stakeholder-specific roles of each country's E-waste recycling systems.

Japan was the first country to enact a law specifically concerning E-waste, with the Home Appliance Recycling Law which came into force in 1998. South Korea introduced regulations on E-waste with the adoption of the Waste Deposit-Refund System in 1992 based on the Law for Promotion of Resource Saving and Reutilization (LRSR). Under this Deposit-Refund system, manufacturers of recyclable products, materials and containers are required to pay a deposit for the cost of waste recovery and processing, which is subsequently refunded once the waste has been properly collected and processed. However, this system did not distinguish E-wastes from other types of waste, such as containers and packaging. The system was reviewed in 2003, leading to the adoption of the EPR System which imposed mandatory recycling rates on 21 products including home electric and electronic appliances, containers/packaging, tires and batteries. However, this scheme also failed to distinguish E-wastes from other types of waste. From 2008, the mandatory recycling of E-wastes as well as waste vehicles was separated from the EPR System and stipulated under the Act for Resource Recycling of Home Electric Appliances and Vehicles (Figure 1).

In Taiwan, the Recycling Fund Management Board (RFMB) was initiated in 1998, and placed concern more on the securing of valuable resources in the selection of appliances to be recycled. In contrast, China is still in the process of introducing an E-waste recycling system and legislation is expected in the near future. China is presently considering the inclusion of home electric and electronic appliances and personal computers but, if it maintains its emphasis on resource procurement, then the scope of targeted products covered by law will more than likely be expanded.

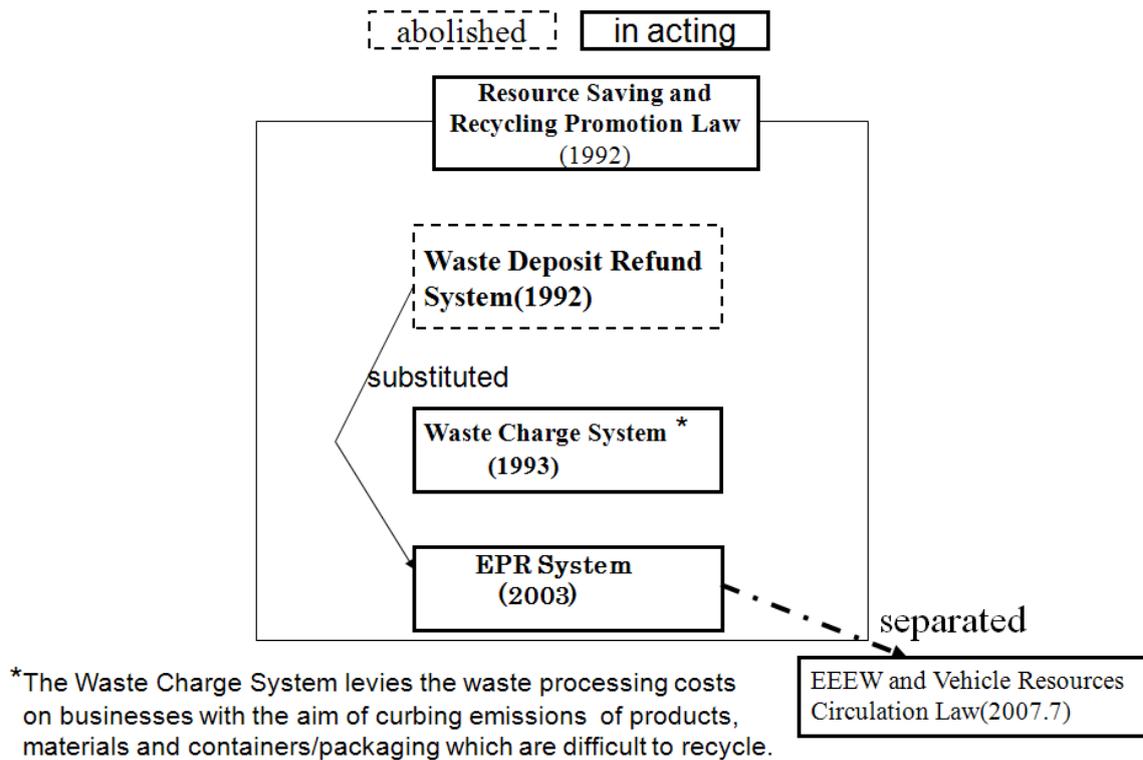
Since the adoption of E-waste recycling systems in Japan and Taiwan, there have been discussions of legal amendments but no major reforms have been undertaken to date. South Korea, on the other hand, has undertaken two extensive reforms of its system partly in response to the OECD's EPR Guidance Manual and EU policies, including the aforementioned enactment of a law targeting electric and electronic equipment and vehicles in 2008. In China, the bulk of E-wastes flowing from urban to rural areas are used goods with market value and are therefore rarely perceived as waste, while the valuable substances derived from the repair and disposal of these appliances are seldom recognized for their harmful impact on the environment and on humans. This is the reason why systems such as the "Law on the Quarantine, Inspection and Management of Imported Used Electrical and Mechanical Products" (2003) and China's version of RoHS (2007) have been implemented in advance of systems concerning the recycling of E-waste.

In terms of targeted appliances, Japan clearly specified a standard for selecting the target when enacting the Home Appliance Recycling Law. The product categories targeted by Japan's Home Appliance Recycling Law are required to meet the following conditions: (1) products which are difficult for local governments to recycle; (2) products containing significant quantities of recyclable resources such as metals which are inexpensive to recycle; (3) products capable of adopting readily recyclable components and materials in the design stage; and (4) products which can be transported by retailers upon replacement purchases. Ueta (1992) [9] also proposes the following four general criteria in order to realize recycling activities: (1) the existence of a substantial volume of waste, (2) the presence of valuable metals in the waste, (3) the availability of waste recycling technologies, and (4) the presence of demand for recycled products.

Table 1. Comparative evaluation of E-waste recycling systems in Japan, South Korea, China and Taiwan.

		Japan	South Korea	China*	Taiwan
Law		Home Appliance Recycling System (1998–)	Waste Deposit-Refund System (1992–2002); Producer Responsibility Recycling System (2003–2007); Act for Resource Recycling of E-waste and Vehicles (2008–)	Law on Waste Household Electrical Device Collection, Utilization and Management (under review)	Recycling Fund Management Board (RFMB; 1998–)
Targeted products		TVs, refrigerators, washing machines, air conditioners	Washing machines, TVs, air conditioners, refrigerators, PCs, audio, mobile phones, printers, copiers, faxes	TVs, refrigerators, washing machines, air conditioners, PCs	TVs, refrigerators, washing machines, air conditioners, laptop computers, motherboards, monitors printers
Role of Stakeholders	Consumers	Mandatory cooperation on collection ⇒ Retailers (upon replacement purchase), local government, collection companies	Cooperation on collection ⇒ Retailers (upon replacement purchase), local government, collection companies	Cooperation on collection via retailer, local government and collection contractor channels	In many cases, E-wastes are sold for profit
	Local governments	Collect E-wastes from consumer and transport to designated exchange; also collect illegally dumped appliances	Collect E-wastes from consumer and transport to designated exchange; also collect illegally dumped appliances	Collection and transport to storage yards	Management of waste collection centers and recycling consignment/sale to intermediate sellers; management of recyclers and used goods
	Producers	Mandatory collection via retailers; setup of designated exchange	Achievement of mandatory collection/recycling targets; construction of collection centers and recycling plants	No physical obligation	Active collection by major firms but other firms unknown
	Recyclers	Recycling by producer-designated contractors	Recycling via producer consignment	Voluntary collection from storage yards and recycling	Few contractors perform proper recycling
	Collection companies	Voluntary collection; distribution as used goods/parts (including exporting)	Voluntary collection; distribution (including exporting) as used goods (including parts); processing of remnants/residue unclear	Voluntary collection from storage yards and recycling	Private collection channels also exist; status of collection companies unclear

*The roles in China are summarized as they presently stand because the law is not yet enacted.

Figure 1. Transition of cycle related policy in Korea.

As described above, Japan's system stipulates various product selection criteria. However, examination of the product categories targeted by each country's system indicates that the Japanese system clearly recognizes the difficulty of processing E-wastes. Meanwhile, China and Taiwan's selection criteria place greater emphasis on the proper disposal of harmful waste and on obtaining valuable resources. As an example of Japan's approach, current discussions on reforming the E-waste Recycling Law suggest that flat-screen televisions and dryers are likely to be added to the list of targeted products, whereas appliances such as microwaves have been overlooked due to the potential difficulty of collecting them and recovering the associated costs from the consumer. As mentioned above, if China maintains its emphasis on securing resources, the scope of targeted products will probably be expanded.

3.2. Cost Sharing by Stakeholders and Their Incentives

This section compares the physical role and cost sharing for collecting and recycling for different stakeholders and analyzes their incentives for participation.

First, we will analyze the specific roles of each stakeholder in the collection, with an emphasis on physical responsibilities. The responsibilities of consumers, local governments and collection companies arise mainly within the collection process. In Japan and South Korea, the consumer's responsibility lies in cooperating with the other stakeholders (retailers, local governments) during collection whereas in Taiwan, the consumer's responsibility is not clearly stipulated but rather left to the market's discretion. In China, consumers typically sell their E-waste as used goods at present, and their responsibility in terms of collection for final disposal or recycling is expected to be limited.

In Japan and South Korea, the role of local governments is to collect E-waste (*i.e.*, those not subject to replacement purchase) from the consumer and transport them to collection centers operated by the producer. Local governments in Taiwan also collect some E-wastes and transport them to temporary storage yards, although they are not obligated to do so. In addition, local governments in Japan and South Korea are required to collect illegally dumped waste. Illegal dumping is on the decline and is not a major social issue in South Korea, where it is monitored by citizens groups commonly referred to as “*ssu-parazzi*” (a term coined from the Korean word “*ssu*” meaning “rubbish” and the Italian word “*paparazzi*”). South Korea has introduced a system which pays monetary rewards to citizens for reporting cases of illegal dumping to the authorities. However, the collection of illegally dumped waste is one of the main roles of local governments in Japan. Local governments in China are responsible for managing collection centers and overseeing the collection system, and also play a major role in managing used products.

In other words, Chinese local governments are obligated to manage and supervise the collection of E-wastes to a greater extent than the actual task of collection. In Japan, the role of the producer in the collection process is to set up and manage collection centers to temporarily store recovered appliances.

In South Korea, producers are also obligated to meet volume-based recycling targets (herein “mandatory recycling targets”) imposed by the government (revised annually). As a result, producers in this country use campaigns and collection contractors in order to meet their recycling targets. In Taiwan, producers have virtually no role in the collection process, and collection itself is not obligatory. As described below, Taiwanese producers only have a financial obligation to pay the cost of recycling to the RFMB. In China, some companies have assumed the task of collection on a voluntary basis, but the volume is very limited.

Next, the cost incurred in the recycling process can be broadly divided into collection cost and recycling cost. Table 2 summarizes the expense of different stakeholders in Japan, China, Korea and Taiwan.

Table 2. Cost Burdens of Stakeholders in Japan, South Korea, China, and Taiwan.

Stakeholder	Japan		South Korea		China		Taiwan	
	Collection cost	Recycling cost	Collection cost	Recycling cost	Collection cost	Recycling cost	Collection cost	Recycling cost
Consumer	Total cost	Partial cost	Almost not	Almost not	Almost not	Almost not	Almost not	Almost not
Local government	Illegal dumping collection cost	Almost not	Illegal dumping collection cost	Almost not	Unclear	Almost not	Illegal dumping collection cost	Almost not
Producer	Mainly physical obligation	Mainly physical obligation	Total cost (financial and physical obligation)	Total cost (financial and physical obligation)	Almost not	Almost not	Financial obligation	Financial obligation

In Japan, collection and recycling costs have changed since the E-waste recycling system was implemented, but the consumer cost burden has remained fixed, making it difficult to clearly distinguish which stakeholder is responsible for these costs. However, the cost-burden structure

arguably places the financial obligation of recycling on the consumer, and the physical obligation of establishing and operating recycling plants and collection centers on the producer. Japan's local governments are obligated to collect E-wastes at the consumer's request, but the cost of collection is levied on the consumer. The collection of illegally dumped waste, on the other hand, involves both physical and financial responsibilities, with the local government bearing the financial costs.

In South Korea, both the collection costs and recycling costs are generally borne by the producer. However, when local governments collect E-wastes, the consumers are required to pay the collection costs. In Taiwan, producers incur recycling and collection costs to the RFMB upon product shipping, thus producers are at least financially obligated for the volume of E-wastes collected via the RFMB. The fees paid by Taiwanese producers to the RFMB also include management costs and therefore in reality, the costs of both collection and recycling are both borne by the producer. E-wastes not collected through RFMB channels, however, are instead reclaimed voluntarily by collection companies according to market principles, with the collection costs also being borne by these companies.

For recycling costs, Japan's recycling fees are essentially calculated according to "primary transport" (*i.e.*, from consumer to retailer), "secondary transport" (from retailer to factory), and processing and recycling costs. As such, the cost of recycling is generally incurred by the consumer. In Japan, the recycling fee levied on consumers when disposing of Home electric appliances is 1,785 Japanese Yen per cathode-ray tube TV, 2,835 Japanese Yen per LCD and plasma TV, 3,780 Japanese Yen per small refrigerator, 4,830 Japanese Yen per large refrigerators, 2,025 Japanese Yen per washing machine and 2,625 Japanese Yen per air conditioner. Furthermore, collection and transport fees of 1,000 Japanese Yen or more per lot are also levied in some areas. However, fees may be borne by distributors or retailers from the perspective of system operation [10].

By contrast, South Korea's consumers do not have to pay any costs whatsoever for discarding home electric appliances when purchasing a replacement product. In South Korea, both the physical and financial obligations for recycling are borne by the producer, thus, all expenses relating to recycling are incurred by the producer. Taiwan, on the other hand, does not impose the physical obligation for recycling on the producer. Instead, the RFMB on the behalf of producers pays the cost of recycling to a contractor which satisfies the RFMB-designated standard recycling rate, which means that the costs of recycling not conducted through the RFMB are not borne by the producer.

In the preceding paragraphs, we have examined the collection and recycling cost structures in Japan, South Korea and Taiwan. Now, we will examine the incentives that these cost structures provide to each stakeholder in terms of collection volume, illegal dumping and development of recycling technologies. In South Korea where producers incur collection costs, there is an incentive for producers to reduce their collection volume as much as possible. For example, the incentive for negative behavior exists for collecting E-wastes, other than those generated by replacement purchases, so collection volume is largely dependent on sales resulting from replacement demand. For these reasons, South Korea sets recycling targets for producers by stipulating the above-mentioned annual mandatory recycling targets for each product (Table 3). This approach arguably facilitates the steady growth of E-waste collection volumes in South Korea. The annual collection volume of discarded home appliances in South Korea rose sharply between 2004 (the year after adoption of the EPR system) and 2007: from 67,433 tons to 106,376 tons [11,12]. The system also provides producers with the incentive to collect E-wastes, with producers conducting collection campaigns and reclaiming

appliances flowing from consumers to the used goods market in order to meet their mandatory collection targets.

Meanwhile, Japan's E-waste collection volume has also grown but the concurrent major increase in invisible flows (*i.e.*, E-waste arising from the used good market and illegal dumping channels) has become problematic. This issue has arisen because Japan's Home Appliance Recycling Law has compelled consumers to bear the cost of collection, thus creating an incentive for consumers either to have their appliances reclaimed by collection companies or dispose of them illegally. In addition, the lack of a physical collection obligation on the part of producers means that there is no incentive for them to increase their collection volume beyond those appliances collected in response to replacement demand or by local governments. Put simply, Japan's recycling law arguably does not provide any incentives for producers to increase collection volumes of their own accord. There is, however, an incentive for producers to increase their collection volumes in order to boost the operating rates of their E-waste recycling plants. If the used goods or export markets were to become active, the law could conceivably have the unintended effect of encouraging the invisible flow of some appliances collected by retailers.

Table 3. Recycling Obligation Rate * of E-waste by Korean Government.

	2003	2004	2005	2006	2008	2012 (target)
TV	11.6	9.2	11.8	12.6	14.5	21.0
Refrigerator	9.0	10.8	14.1	16.9	18.9	25.0
Washing Machine	25.3	21.8	21.2	23.4	25.3	30.0
Air Conditioner	0.7	0.7	3.6	1.7	2.1	2.6
Personal computer	-	-	8.5	9.4	10.3	14.0
Mobile Phone	-	-	11.9	15.4	18	25.0
Printer, Facsimile	-	-	-	8.4	11.2, 11.4	15.0
Copier	-	-	-	9.0	12.7	15.0

* Recycling Obligation Rate (%) = Recycling Obligation Amount/Shipping Amount.

In Taiwan, collection is largely dependent on collection contractors rather than producers or local governments. The higher the subsidies these contractors receive from the RFMB, the greater the incentive to boost their E-waste collection volumes. In contrast, setting the subsidy low will encourage contractors to increase their supply of E-wastes to used goods and export markets instead of dealing with the RFMB. The critical factor in determining collection volumes in Taiwan is therefore subsidies.

Finally, we will examine the incentives that the stakeholder cost burdens provide in terms of developing recycling technologies. In Japan and South Korea, the physical responsibility of recycling is, at the very least, borne by producers. We can therefore reasonably assume that there is an incentive for producers to develop recycling technologies as a way of reducing their recycling costs. Accordingly, the development and streamlining of recycling technologies are advancing in the case of producers operating their own recycling plants. In fact, recycling plants constructed by producers in Japan and South Korea have undergone technological developments (insulation materials, CFC recovery, *etc.*) and improvements in efficiency. On the other hand, where producers

outsource recycling operations, there is a need to provide incentives to contractors to develop recycling technologies.

The recycling systems of Japan, South Korea and Taiwan all stipulate standard recycling rates (recycling rates for individual products), although to differing degrees. For example, the recycling rates for televisions, refrigerators, washing machines and air conditioners are 55%, 50%, 50% and 50% in Japan, and 65%, 70%, 80% and 80% in South Korea, respectively. These recycling rates constitute an incentive for producers to provide information and transfer technology to recycling contractors, which in turn enables contractors to develop recycling technologies. In fact, the majority of recycling contractors in South Korea are small to medium-sized operators, thus producers are engaged in providing them with information and support. Meanwhile, recycling contractors in Taiwan are required to possess a certain level of technology in order to participate in the RFMB recycling scheme, and are therefore generally well equipped in terms of technology. In other words, although Taiwan's producers are the ones responsible for recycling costs, the RFMB's incentives for the development of recycling technologies are directed more towards contractors than producers.

In summary, the role of consumers and local governments in Japan and South Korea is emphasized in the collection process, while producers play an important role in the recycling process. However, South Korean producers are also required to fulfill a certain role in the collection process due to the imposition of volume-based recycling targets. From the perspective of EPR, South Korean producers therefore have a considerable physical and financial obligation in both the collection and recycling processes, whereas other stakeholders are only required to assume a limited "cooperative" role. In Japan's case, while responsibility is largely held by local governments, it is now being spread to the producers and in some aspects to consumers who have financial responsibility for the collection and recycling of E-waste.

4. Conclusions: Challenges toward the Sound Circulative Economies in East Asia

In this paper, we have undertaken a comparative analysis of the backgrounds, targeted products, stakeholder-specific roles and cost burden structures of legal systems relating to E-waste recycling in Japan, South Korea, China and Taiwan, touching upon the details and current status of these systems. While the E-waste recycling systems adopted in each country vary to a certain extent, we have demonstrated that they are all moving towards enhancing the onus on producers, largely due to the influence of the EPR principle. A brief outline of each nation's cooperative feasibility is provided below together with a summary of their unresolved issues.

One of the most important issues for Japan is the increasing volume of E-wastes arising from invisible flows. The producers entrust the retailer with the E-waste recycle law, which levies a recycling fee on consumers when disposing of home electric appliances. Retailers have an incentive to cheat the recycling fees by treating the E-wastes to the invisible flow instead of the legal flow. In addition to the export of used goods, the improper disposal and illegal dumping of E-wastes by scrap traders not covered by the Home Appliance Recycling Law have been highlighted as challenges. The underlying causes of these problems include the fact that products subject to recycling in Japan are determined not on the basis of shipped volume but on the actual collected volume, and the fact that collection costs are borne by the consumer.

Despite various arguments regarding the method for calculating South Korea's mandatory recycling targets, the system appears to have caught on among producers in light of the fact that actual recycling levels constantly surpass mandatory collection targets. The actual rate of achievement of the mandatory reutilization rate (2006) was 106% for TVs, 117% for refrigerators, 127% for washing machines and 182% for air conditioners, thus surpassing the mandatory recycling rate in each category. On the other hand, the increasing social costs of imposing the mandatory recycling rates and the setting of the recycling rates themselves have been underscored as major problems in South Korea's system. South Korea's recycling rate differs from that of Japan in that products are counted in the recycled weight provided that they are used as a resource of some kind. It will therefore be necessary to make the recycling rate stricter in the future to encourage producers to develop recycling technologies.

In Taiwan, the collection and recycling of E-wastes under the RFMB system has produced some positive outcomes, but the sheer volume of E-wastes processed outside of this system is a major cause for concern. The only solution for this, under the current system, is to increase substantially the subsidy to collection traders and recycling manufactures, but this would be difficult as it would force producers to bear more of the cost. Therefore, it would be important to revise the system to obligate producers to take physical responsibility while maintaining the current RFMB system.

One problem shared by the systems of Japan, South Korea and Taiwan is that they do not really leverage the benefits of the DfE or DfR approach, one of the key objectives of EPR. In other words, the E-waste recycling systems of these countries do not provide producers with enough incentives to adopt DfE. The reason is that although producers would derive better cost benefits by cooperating in their E-waste collection and recycling costs, disclosing information on component materials, assembly methods and product design poses a dilemma as these are important elements in determining a company's product value. The construction of a framework which incorporates data obtained from the collection and recycling of waste household products into the product design stage is therefore a major challenge towards the creation of better circulative economies [13].

China has yet to establish a system for recycling E-wastes, and thus we have limited our remarks in this study to a summary of the present situation. However, we will now examine the feasibility of China's cooperation in recycling based on its relationship to the other three countries. Japan, South Korea and Taiwan currently do not have substantial domestic used home electric and electronic appliance markets, partly due to the rising income levels in all three nations. However, none of these three countries has any regulations governing the export of used home electric and electronic appliances, thus the export of these goods to China is growing exponentially. This problem is being exacerbated by the rising number of illegal exports in an attempt to dispose of E-wastes. It is clear that this cross-border transfer of E-wastes cannot be resolved by the exporting or importing nation alone, and international cooperation is indispensable to finding a solution.

Japanese, South Korean and Taiwanese home appliance manufacturers have made inroads in China, thus any E-waste recycling system to be enacted in China will inevitably include products from these three countries. This suggests that the likelihood of China cooperating is relatively high. Therefore, in order to resolve the cross-border transfer of E-wastes it will be necessary to conclude a regional producer agreement involving the major producers in the region, and to actively undertake the creation of a system to monitor and track the cross-border transfer of E-wastes as well as the international

division of recycling operations, while also examining systematic reforms to enable each country's system to deal with this issue.

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