

Characteristics of E-waste Recycling Systems in Japan and China

Bi Bo, and Kayoko Yamamoto

Abstract—This study aims to identify processes, current situations, and issues of recycling systems for four home appliances, namely, air conditioners, television receivers, refrigerators, and washing machines, among e-wastes in China and Japan for understanding and comparison of their characteristics. In accordance with results of a literature search, review of information disclosed online, and questionnaire survey conducted, conclusions of the study boil down to:

- (1)The results show that in Japan most of the home appliances mentioned above have been collected through home appliance recycling tickets, resulting in an issue of “requiring some effort” in treatment and recycling stages, and most plants have contracted out their e-waste recycling.
- (2)It is found out that advantages of the recycling system in Japan include easiness to monitor concrete data and thorough environmental friendliness ensured while its disadvantages include illegal dumping and export. It becomes apparent that advantages of the recycling system in China include a high reuse rate, low treatment cost, and fewer illegal dumping while its disadvantages include less safe reused products, environmental pollution caused by e-waste treatment, illegal import, and difficulty in obtaining data.

Keywords—E-waste, Recycling Systems, Home Appliances, Japan and China.

I. INTRODUCTION

A. Viewpoint and Objective of the Study

IN China huge volumes of e-wastes (electrical and electronic wastes) have been discarded in recent years as people purchase new home appliances for replacement more often than before. In addition to those generated in the country, China actually imports some 70% of e-wastes in the whole world¹⁾, in spite of the fact that China’s Maritime Customs Service banned import of eleven types of waste electrical appliances in April 2000²⁾. Since the environmental pollution caused by illegal dumping and improper treatment of those e-wastes become a serious problem, establishment of a proper e-waste treatment system is now receiving attention as a large issue to be solved. In Japan, on the other hand, implementation of the Home Appliance Recycling Law in 2001 has ensured the proper treatment of waste home appliances. However, the illegal dumping in the country remains a serious problem, and some of e-wastes are exported overseas as a product.

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Consequently, the study aims to identify and compare characteristics of recycling systems for four home appliances, namely, air conditioners, television receivers, refrigerators, and washing machines, among e-wastes in Japan and China. To that end, at first a literature search and review of information disclosed online were conducted. Chapter II identifies the current situations surrounding e-wastes in China and Japan, then Chapter III makes clear a whole process from production to sale, disposal, collection, dismantling and finally recycling of their recycling system for the four home appliances. Next, Chapter IV identifies current situations and issues of the recycling systems based on results of a questionnaire survey conducted among home appliance recycling plants and manufacturers.

B. Earlier Studies in Relevant Field and Position of this Study

Earlier studies on e-wastes include: the one on generation and flow of e-wastes among Asian countries by Terazono [1]; the one on the realities of e-waste recycling in China by Du, et al. [2]; the ones identifying the current generation and treatment of e-wastes in India and Thailand by Jain [3], Shrihari [4], and Hengrasmee [5], respectively; and the one on responsible e-waste management in the US by Wagner [6]. They, however, just present specific instances, with a little reference to problems of an e-waste recycling system and to what it should be. A few studies have been conducted on a recycling system for the four home appliances, although there is a study on the current personal computer recycling in Japan and China by Yoshikawa et al. [7] and an analysis of a cellular phone recycling flow by Nakajima et al. [8].

Therefore, the study, going one step further from the earlier studies listed above, identifies processes, current situations, and issues of recycling systems for the four home appliances among e-wastes, so as to understand and compare their characteristics.

II. CURRENT SITUATIONS SURROUNDING E-WASTES

A. Definition of E-wastes

EU’s Waste Electrical and Electronic Equipment (WEEE) Directive defines e-wastes as abbreviation for electrical and electronic wastes, meaning waste personal computers and other electrical and electronic products that include electrical/electronic wastes and waste electrical/electronic equipment. The directive applies to the following ten categories of wastes: large home appliances; small home appliances; IT and telecommunications equipment; consumer equipment;

lighting equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; and automatic dispensers [9].

Furthermore, Terazono [9] identifies the following two problems in using a term of “e-waste(s)”. The first problem is whether a term of waste(s) include(s) used products and/or valuable items is not clear. Those that are globally distributed and may cause the environmental pollution include used products, often presenting a great issue to be solved. The second is how to deal with wastes whose hazardousness receives mixed judgments. Taking those into consideration, for the purpose of the study the e-wastes cover used electrical and electronic products, in addition to the ten categories stated above.

B. Classification of Wastes and Position of E-wastes

In Japan wastes are broadly divided into industrial and non-industrial wastes. E-wastes are recognized as “bulky trash” among non-industrial wastes. Classification of wastes in China is clarified here in an organized manner, after the examination of laws related to wastes in China and based on the information disclosed on the website of China’s Ministry of Environmental Protection ³⁾. Wastes are roughly classified under three categories; non-industrial, industrial, and hazardous wastes, with e-wastes being recognized as “electrical and electronic wastes” among non-industrial wastes.

C. E-waste Laws

In Japan the Law for Promotion of Effective Utilization of Resources (revision of the Law for the Promotion of Utilization of Recycled Resources) came into effect in 2001. The law aims at establishment of a recycling-based economic system (1)by strengthening measures such as collection and reuse of products by businesses, as well as (2)by introducing new measures to reduce wastes through saving materials used in products and extending product lifetime and (3)to reuse components of products collected. The Law for Recycling Specified Kinds of Home Appliances (Home Appliance Recycling Law) ⁴⁾ also became effective in 2001. The law applies to household air conditioners, CRT television receivers, refrigerators and washing machines, and set out a clear role that manufacturers, importers, retailers, consumers, and municipal and national governments have to play.

In China the Environmental Protection Law of People’s Republic of China went into effect in December 1989, followed by ten laws concerning pollution caused by solid wastes that include the Laws on the Prevention and Control of Environmental Pollution by Solid Waste and on the Promotion of Clean Production. However, they contained a few legal systems related to e-wastes, and no legal system to address trans-boundary import of e-wastes. Therefore, the following two legal systems were introduced in and after 2006 in order to reduce, recycle and detoxify e-wastes. A policy for technology to prevent and control environmental pollution by waste home appliances and electronic equipment ⁵⁾ implemented since 2006 applies to all electrical and electronic products, requires

polluters (manufacturers and importers) to collect and recycle relevant wastes, and sets out that the polluters should bear costs of collection, transportation and recycling. In addition, a procedure to manage the control of environmental pollution by electrical and electronic equipment ⁶⁾ adopted in 2007 has restricted or prohibited the use of hazardous or harmful materials in products by manufacturers. Manufacturers that have no other choice but to use hazardous or harmful materials are required to clearly label on the relevant product the specific hazardous or harmful materials used. A law called Regulation for the Management of the Recycling and Disposal of Waste Electronic Products, counterpart of Japan’s Home Appliance Recycling Law, is expected to come into effect in 2008, but has yet to become effective.

III. PROCESS OF E-WASTE RECYCLING SYSTEM

A. Recycling System in Japan

Japan has employed a home appliance recycling ticket system, which was developed by Association for Electric Home Appliances to ensure that relevant parties, such as consumers, retailers and manufacturers, would push forward smoother home appliance recycling activities under the Home Appliance Recycling Law. The system comes in two types: the one requiring consumers to pay recycling and transportation fees to a retailer, and another requiring them to pay recycling fees through postal transfer.

Fig. 1 below presents a concrete flow of the waste home appliance recycling system in Japan, based on information disclosed on a website of home appliance manufacturers as to their home appliance recycling activities. Since almost all e-wastes in Japan are generated in the country, the treatment flow under the Home Appliance Recycling Law mainly contains only one route as Fig. 1 shows: (1)A consumer pays collection, transportation and recycling fees of a specific home appliance of air conditioner, television receiver, refrigerator, or washing machines to be disposed of to a home appliances store that will take it back; (2)A retailer takes responsibility for taking back any of the appliances it sold and for delivering it to its manufacturer; and (3)A manufacturer (importer) properly treats and recycles any of the appliances it manufactured or imported.

“Home appliances manufacturers” and “designated collection sites” are divided into Groups A and B for home appliance recycling activities. Group A is composed of companies including Matsushita and Toshiba, while Group B consists of Hitachi, Sharp, Mitsubishi, Sanyo, Sony and other businesses. The manufacturers have a lot of “designated collection sites” specifically for Groups A and B around the country to take back their products. Consumers purchase a home appliance recycling ticket for their appliance to be disposed of, and deliver it, either directly or through a retailer or store from which it purchases, to one of designated collection sites. Group B employs a system where waste home appliances are transported to one of designated recycling plants that is the nearest, and are ultimately dismantled, treated and

recycled in recycling plants. Group A ensures that waste home appliances are delivered to a recycling plant within the premises of manufactures or recycling plant designated by manufacturers for treatment and recycling. Thus, Group A greatly differs from Group B in that some of its manufacturers treat and recycle wastes internally. The Home Appliance Recycling Law provides for a recycling rate of the four home appliances in a recycling plant: 60% or higher for air conditioners, 55% or higher for television receivers, 50% or higher for refrigerators, and 50% or higher for washing machines.

B. Recycling System in China

Fig. 2 below provides a summary of information disclosed on a website for China's electrical and electronic wastes⁷⁾ as to current e-waste recycling in the country. The figure shows that a strong e-waste recycling system for proper treatment has not been fully developed yet in China. Both e-wastes generated in the country and imported from other countries are collected and treated primarily in two different ways as shown in Fig. 2.

The first way is "collection by individual collectors". The individual collectors "purchase" e-wastes from consumers and treat them in another two different ways: (1) Some repair and/or refurbishment of usable "used home appliances" for selling to a second-hand store or at a rural area; and (2) Selling "waste home appliances" without any value in use and function to "individual dismantlers". Especially treatment facilities for "individual dismantlers" mentioned in (2) above concentrate at rural areas in Guangdong and Zhejiang. The individual dismantlers, who do not have any equipment designed specifically for e-wastes treatment, manually dismantle them with a simple instrument to extract heavy metals out of substrates and other components made of rare metals. They abandon or bury in the ground the remaining, unnecessary portions of e-wastes for treatment. In China a large number of treatment facilities for the individual dismantlers and improper e-wastes treatment lead to aggravating environmental problems such as air, water and soil pollution.

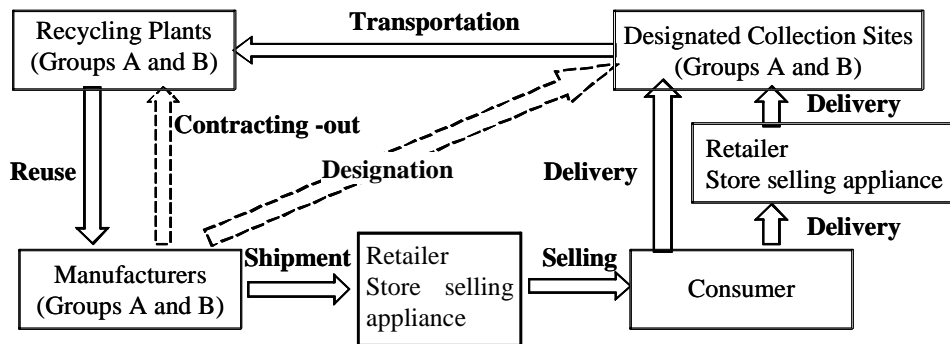


Fig. 1 E-waste Recycling System in Japan

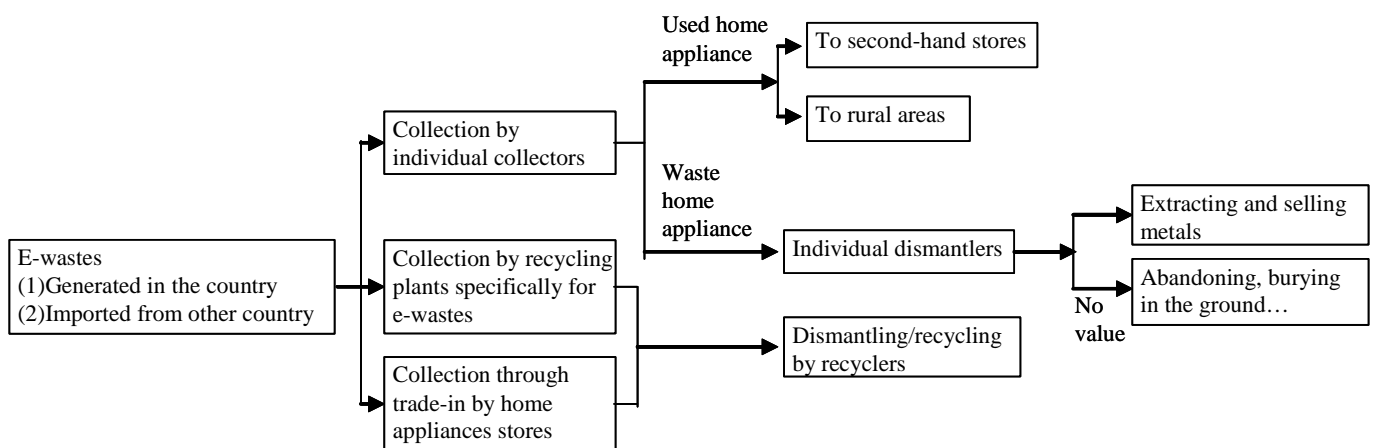


Fig. 2 E-waste Recycling System in China

Another way of collection is “collection by recycling plants specifically for e-wastes” and “collection through trade-in by home appliances stores”. In fact, only a few e-wastes are collected in these two ways. Firstly, collection by recycling plants specifically for e-wastes requires consumers not only to expend some effort, but also to pay a transportation fee, resulting in a low collection rate. Secondly, collection through trade-in by home appliances stores grows in recent years, and enables consumers to obtain a certain discount when purchasing a new home appliance if they deliver their unnecessary home appliance to the stores. For example, large home appliances stores of SUNING and GOME introduced the “collection through trade-in” as a way to collect e-wastes in January 2007⁷⁾. However, mainly because this way of collection takes more effort and time than individual collection and treatment, the collection rate remains low.

IV. CURRENT SITUATIONS AND ISSUES OF E-WASTE RECYCLING SYSTEM

A. Outline and Results of Surveys

1) Preliminary Survey

To begin with, one representative plant was selected from among home appliance recycling plants in Japan that belong to Groups A and B, respectively, for a hearing survey conducted in July 2008 for Group B and in September 2008 for Group A. Results of the surveys show:

- Waste home appliances are separated into the four categories and treated on four treatment lines accordingly.
- A recycling process in a plant contains three stages of pre-treatment (collection), during treatment (treatment), and post-treatment (recycling).
- The treatment stage is further divided into dismantling (manual work) and final (crushing and screening) sub-stages. Manual dismantling is followed by mechanical crushing and recovery of materials.
- Although recycling is done by component almost internally, components difficult to recycle are sometimes contracted out.



Fig. 3 Air Conditioners



Fig. 4 Television Receivers



Fig. 5 Classification of Freon



Fig. 6 Compressors Divided from Waste Home Appliances



Fig. 7 Takeoff of Boards and Coils



Fig. 8 Waste Oil Divided from Waste Home Appliances

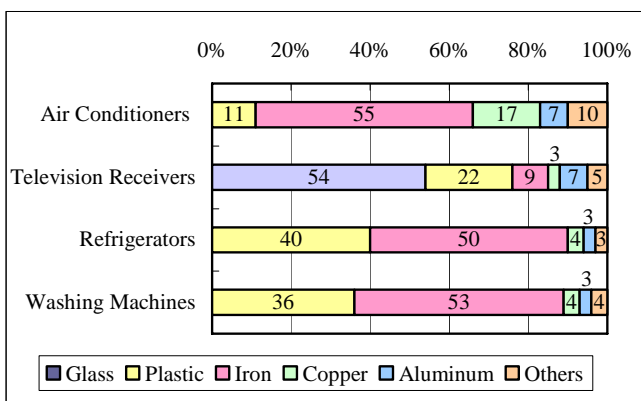


Fig. 9 Each Material Constitution of Four Home Appliances

Fig. 3, 4, 5, 6, 7 and 8 show the inside of the above-mentioned plant that belongs to Group A. Furthermore, based on the findings of the hearing survey of the plant, Fig 9 indicates each material constitution of four household appliances.

2) Questionnaire Survey

Japan has 48 recycling plants around the country; 30 for Group A, 16 for Group B, and two shared by Groups A and B. Out of them, surveyed were 38 plants that conducted recycling activities for all or any of the four home appliances. On the other hand, China, as mentioned in Chapter II above, does not have a strong legal system for e-wastes. In recent years, recycling plants have been under construction mainly in Beijing and Tianjin. Therefore, a survey of 19 Japanese home appliance manufacturers expanding into China was conducted to know if they have introduced or applied Japan's recycling system to their plants in China. The questionnaire was designed on the basis of results of the preliminary survey. It contains three sections of collection, treatment and recycling of the four home appliances for the survey in Japan, and four sections of collection, treatment and recycling of the four home appliances as well as business in China for the survey in China. The sections include detailed questions designed by stage, namely, collection, treatment and recycling, for each of four home appliances.

The number of home appliance recycling plants in Japan that

were actually surveyed was 11 among the 38 plants, with 27 not responding by reason of "confidentiality obligations to home appliance manufacturers". Valid responses were obtained from eight plants (one for Group A, and seven for Group B), resulting in the valid response rate of 72.7%. Eight (one for Group A, and seven for Group B) out of the 19 home appliance manufacturers expanding into China offered valid responses, with the valid response rate of 42.1%.

B. Recycling System in Japan

Results of the questionnaire survey of home appliance recycling plants in Japan show that all of the eight plants collect wastes through recycling tickets, while only one plant does so also from a household. In the treatment stage, all of the eight plants separate the wastes into the four categories to treat them on four different treatment lines accordingly. Several kinds of discharges are provided to recyclers for selling as second-hand goods after treatment. Although most of the plants contract out the recycling, television receivers are a little more likely to be disposed of by landfill or incineration than the other three appliances, implying that some discharges are not recycled.

Next, let us discuss issues of the recycling system in Japan. As an issue for the treatment and recycling stages, the most common answer is "requiring some effort" for all of the four home appliances. On top of this, one of the plants answers "shortage of hands" for each of four home appliances. Except for these two, the answers differ among the four home appliances. They include: "unable to equalize the number of staff due to wide business fluctuations, and fluorocarbon refrigerants requiring management with care" for air conditioners; "safe work in separating panel from funnel glass" for television receivers; "a wide variety of chlorofluorocarbons and thermal insulators requiring batch processing, and poor transport efficiency (requiring storage space)" for refrigerators; and "treatment would require more time if the number of drum-type washing machines increases in the future" for washing machines. The largest number of the plants, namely, four plants, mention "strengthening legal penalties to control illegal dumping" as an issue of the overall recycling system. Two plants insist that "a method to pay recycling fees should be changed from the recycling ticket to pre-payment", while three argue that "the Recycling Law should be revised to extend to additional home appliances". The other answers include "controlling outflow of e-wastes overseas" and "controlling improper treatment with an invisible flow".

C. Recycling System in China

Results of the questionnaire survey of Japanese home appliance manufacturers expanding into China show that their expansion into China is mainly for enlargement of their outlet and cost reduction, and that all of them have not conducted home appliance recycling activities in China. As a reason for not conducting the activities, seven out of the eight manufacturers give "no appropriate law in China", with one mentioning that "being engaged only in production in China". The other answers include "no legal obligations", "not subject

to legal restrictions since preparations are currently underway to enact WEEE in China”, and “inadequate legal system for home appliance recycling”. This implies that Japanese home appliance manufacturers have not introduced or applied Japan’s recycling system to their plants in China.

Then, in order to clarify the present situations of home appliances collection, treatment and recycling, current operations of two recycling plants in China are summarized below, based on a document entitled “Report of Findings from Inspection Tour to China in FY 2007 (edited by Association for Electric Home Appliances)” [10], obtained from one of the Japanese home appliance manufacturers. The document does not contain data on recycling rates.

- a) Sino Star Group’s Environmental Protection Industry Development Co., Ltd. , the largest facility in Beijing, started treatment operations in 2006. It mainly collects e-wastes from home appliances retail stores, residential estates, governmental agencies and manufacturing businesses, and has four treatment lines for (1)air conditioners/refrigerators, (2)CRTs, (3)substrates, and (4)personal computers (to be determined). Its recycling capacity is now 200 units per day for the (2)CRTs line only.
- b) Tianjin Hechang Environmental Protection Technology Co., Ltd. is a recycling plant, of which construction started in 2006, has not been in full operation yet. It will employ three treatment lines for (1)personal computers, (2)television receivers, and (3)air conditioners, with recycling capacity (planned) of 330,000 units a year.

V. CHARACTERISTICS OF RECYCLING SYSTEMS IN JAPAN AND CHINA

This chapter identifies and compares characteristics of e-waste recycling systems in Japan and China for each of the three stages.

A. Collection Stage

Results of the questionnaire survey show that “collection through recycling tickets” predominates in Japan as a way to collect e-wastes. As stated in Chapter III, issuance of recycling tickets enables to know the volume of home appliances collected, and a system to maintain the recycling tickets for three years ensures specification of a route from collection to treatment and recycling of home appliances discharged by consumers. The system, however, requires consumers to pay transportation and treatment fees for their waste home appliances, bringing about problems such as illegal dumping that is more likely to occur and illegal export.

In China, on the other hand, e-wastes are primarily collected by individual collectors (collection by individual collectors). The individual collectors visit a residence of consumers to “purchase” e-wastes. This is convenient for consumers, and would be its advantage. In China where e-wastes are “valuable items”, rather than “trashies”, illegal dumping has not become a very large problem. However, remaining issues are difficulty in

acquiring data on collection and unclear route of from collection to treatment and recycling due to wider spread and liberalization of the “individual collectors”.

B. Treatment Stage

In Japan e-wastes are collected through a “recycling ticket system” to completely dismantle for treatment at 48 recycling plants specifically for e-wastes around the country. Results of both the preliminary and questionnaire surveys show that they can monitor what is happening at field sites, operations of treatment lines, and data on discharges and recycling rates in each stage. The recycling plants are committed to maximizing recycling rates not only for compliance with regulations provided for in a relevant legal system, but also with taking into consideration their business conditions as well as environmental impacts. Additionally, treatment of home appliances by almost fully dismantling has pushed forward designing of new environmentally friendly products. It is because, firstly, consumers now purchase new home appliances for replacement more often than before due to low reuse rates. Secondly, feedback given to manufacturing factories by recycling plants, which face various problems associated with the treatment of home appliances including difficulty in treating specific components and in recycling specific materials, enables designing of products easier to recycle. Results of the questionnaire survey, however, reveal an issue of “requiring some effort” in the treatment stage while results of the preliminary survey reveal an issue that pursuit of materials with higher purity brings about generation of additional wastes.

In China, most e-wastes are collected by individual collectors and sold as products at rural areas. It is considered that this controls generation of wastes through dismantling, with high reuse rates. Non-reusable e-wastes are treated by individual dismantlers manually. Therefore, the treatment cost would be low. However, individual dismantlers dispose of non-treatable e-wastes by abandoning or burying in the ground, causing very serious pollution problems such as soil and water pollution. If a large majority of reused e-wastes have passed their useful life span, safety in reuse becomes a problem. Another issue is illegal import of e-wastes from foreign countries, because of the low-cost collection and treatment systems in the country.

C. Recycling Stage

Like the treatment stage described in Section V-A above, in Japan e-wastes are recycled mainly at recycling plants specifically for e-wastes with the commitment to maximization of recycling rates partly for environmental friendliness. Easiness to monitor data on recycling would be an advantage. However, results of the questionnaire survey highlight an issue of “requiring some effort”.

In China around 80 percent of e-wastes are collected and treated by individual collectors and dismantlers. The wider spread and liberalization of them make it very difficult to acquire quantitative data on e-waste recycling. Even results of the questionnaire survey and the document on the two e-waste

recycling plants in Chapter IV do not provide data on recycling such as recycling rates. Hence, it is still impossible to adequately identify current situations of e-waste recycling in China, which is an issue to be solved.

VI. CONCLUSION AND TASK FOR FUTURE STUDY

Conclusions of the study are boiled down to:

- (1) The e-waste recycling system in Japan ensures collection through recycling tickets to recycle after full dismantlement at recycling plants specifically for e-wastes. In China e-wastes are collected by individual collectors, with high reuse rates of useful e-wastes. It is found out, however, that improper treatment of e-wastes causes a wide range of environmental problems.
- (2) Results of the preliminary survey identify a recycling process and concrete treatment method of e-wastes in Japan. Specifically, the e-waste recycling process consists of three stages: pre-treatment (collection), during treatment (treatment), and post-treatment (recycling), and all of the four home appliances are dismantled manually before mechanical crushing and materials recovery.
- (3) Findings from the questionnaire survey include collection, treatment and recycling of the four home appliances in Japan as well as the fact that all of the Japanese home appliance manufacturers expanding into China have not conducted home appliance recycling activities in China. Results of the survey also show that in Japan most of the four home appliances are collected through recycling tickets, with an issue of “requiring some effort” in treatment and recycling stages, and that most plants contract out the recycling.
- (4) Identification and comparison of characteristics of recycling systems in Japan and China highlight their advantages and disadvantages. Advantages of the recycling system in Japan include easiness to monitor concrete data and thorough environmental friendliness ensured while its disadvantages include illegal dumping and export. Advantages of the recycling system in China include a high reuse rate, low treatment cost, and fewer illegal dumping while disadvantages include less safe reused products, environmental pollution caused by e-waste treatment, illegal import, and difficulty in obtaining data.

The study fails to acquire detailed data in the three stages of collection, treatment and recycling, because of the insufficient recycling system in China. Consequently, tasks for a future study will include development of a well-thought-out method of survey to acquire more detailed data on China's recycling system in each stages for evaluation of the system, based on findings from the study.

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