

RECYCLING AND WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT MANAGEMENT IN TAIWAN: A CASE STUDY



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LIST OF ACRONYMS

ACG	Auditing and Certification Group
CRT	Cathode Ray Tube
EEE	Electrical and Electronic Equipment
EPAT	Environmental Protection Administration of Taiwan
EPB	Environmental Protection Bureau
IT	Information Technology
LCD	Liquid Crystal Display
MSW	Municipal solid waste
NTD	New Taiwan Dollar
PE	Polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
RFMB	Recycling Fund Management Board
RRRC	Recycling Rate Review Committee
RRW	Regulated Recyclable Waste
WEEE	Waste Electrical and Electronic Equipment

Executive Summary

In the 1970s and 1980s, Taiwan struggled with municipal solid waste management. Dumping in rivers and on streets was common, and informal recyclers dismantled used equipment without environmental or health protections. In 1997, Taiwan established its “4-in-1 Recycling Program”, which aimed to reduce municipal solid waste, increase recycling, and improve the efficiency and safety of the recycling industry. Under the 4-in-1 Program, manufacturers and importers of new goods pay fees that are used to subsidize the recycling of those goods when they are discarded. As a result of this program, waste quantities in Taiwan have decreased from 1.14 kg/day/person in 1997 to 0.4 kg/day/person in 2011. This program also led to the establishment of Taiwan’s formal recycling sector. In particular, the waste electrical and electronic appliance (WEEE) recycling industry in Taiwan grew significantly, from zero formal recyclers in 1997 to 19 facilities at the end of 2011. Taiwan’s collection rates of 50% or more for recycling of several WEEE items are on par with or higher than the takeback rates of developed countries such as Japan and Korea, and twice as high as the estimated 25% WEEE recycling rate in the United States. This report documents the development and implementation of Taiwan’s 4-in-1 Recycling Program, with particular focus on WEEE recycling, and is intended to serve as an information resource for policymakers around the world.

1. Introduction

Since 1980, municipal solid waste (MSW) in Taiwan has increased from 0.63kg to 1.15kg per person a day. Over time, landfill space in Taiwan has become scarce, people's environmental awareness has grown, demonstrations and protests about MSW have become common, and waste reduction and recycling have become topics of widespread interest. In addition, Taiwan is a small island with limited natural resources; most raw materials in Taiwan are imported. To solve the increasingly serious waste problem and encourage a closed-loop economy that minimizes resource loss, the Environmental Protection Administration of Taiwan (EPAT) actively promotes resource recovery and has developed standards for collection, waste treatment and recycling of MSW. Among the wastes targeted by EPAT's recycling and resource recovery program, waste electrical and electronic equipment (WEEE) are increasing the most rapidly.

The various materials contained in WEEE are complicated. They may include hazardous substances such as lead, cadmium, mercury, and chlorofluorocarbons. If WEEE is not collected, stored and recycled in an environmentally sound manner, these substances can cause harm to human health and the environment. At the same time, WEEE also contain valuable resources, including gold, silver, copper, and palladium, whose recovery can support a closed-loop economy. For these reasons, it has been important to EPAT to define standards for WEEE treatment and incentivize WEEE recycling as part of its broader recycling and resource recovery program.

EPAT's recycling efforts began when the Waste Disposal Act of 1979 was amended in March 1997 to require recycling and resource recovery for selected MSW, or regulated recyclable wastes (RRW)¹. In response to this requirement, EPAT established the 4-in-1 Recycling Program. This program integrates manufacturers and importers of new RRW products into a complete system that also includes recyclers, municipal collection teams, and community residents. The 4-in-1 Recycling Program created a fee-and-subsidy system, operated by EPAT's Recycling Fund Management Board (RFMB), which is used to incentivize recycling of RRW, including WEEE. To develop the 4-in-1 Recycling Program, EPAT looked at the policies of countries such as Japan, South Korea, New Zealand, Australia and Germany, and adapted components of these systems to local culture.

Prior to 1997, citizens recycled on a voluntary basis, usually to earn extra money by selling their waste materials. Individual citizens worked as informal waste collectors, paying citizens for their waste and re-selling the waste to recyclers. Recycling was not regulated and was negatively impacting the environment and human health. The 4-in-1 Recycling Program aimed to formalize MSW recycling channels and reduce the environmental impacts of recycling. Under the program, residents may send their RRW to municipal collection teams, private collectors licensed by EPAT, or to the second-hand market. However, all RRW,

¹ A complete list of RRW is given on Page 6.

including WEEE, must be recycled in accordance with EPAT standards upon reaching their end-of-life.

This document provides an introduction to the 4-in-1 Recycling Program, its history, management, impacts, and future path. It begins with an overview of the 4-in-1 Recycling Program and the organizational structure behind it, introduces the program’s environmental and safety standards and financial management system, describes the current status of WEEE collection and recycling under the 4-in-1 Recycling Program, and identifies areas where the program could be improved in the future. The purpose of this case study is to serve as a resource for policymakers working to improve MSW and WEEE management by providing an example of a policy system that has supported the growth of the formal recycling industry that meets environmental and safety standards.

2. Overview of the 4-in-1 Recycling Program

(1) The System

EPAT began carrying out the 4-in-1 Recycling Program in January 1997. Figure 1 illustrates how community residents, private collectors and recyclers, municipal collection teams, and a recycling fund (which is based on fees charged to manufacturers and importers of new RRW products) are integrated in the 4-in-1 Recycling Program.

Four-in-one Recycling Program

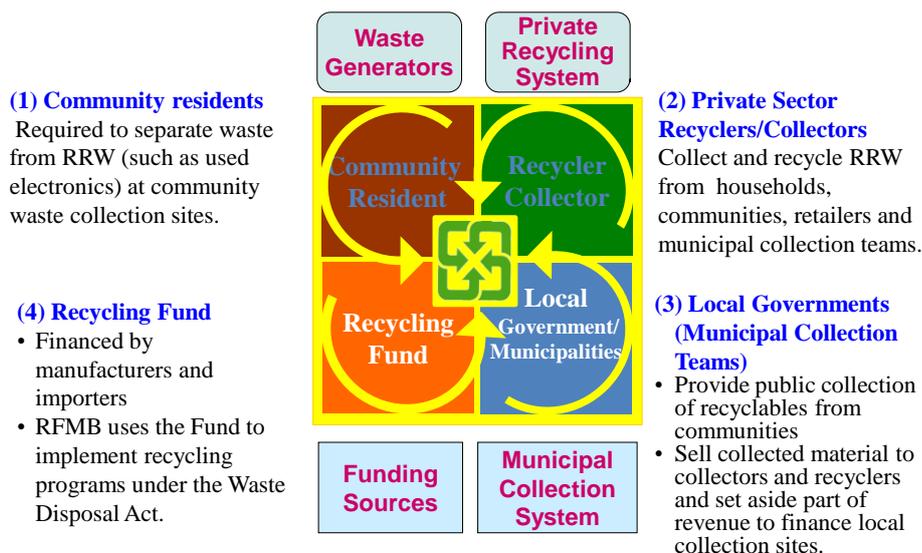


Figure 1: 4-in-1 Recycling Program

The role of each party in the 4-in-1 Recycling Program is as follows:

1. Community residents: Community residents make up the foundation of the 4-in-1 Recycling Program. Residents who deposit their waste at municipal collection points must separate their recyclable, non-recyclable, and organic wastes.
2. Recyclers and Collectors: Private recyclers and collectors buy regulated recyclable waste (RRW), including waste electrical and electronic equipment (WEEE), from residents, community organizations, retailers, businesses and others in order to recover resources from these wastes and generate revenue in the process.
3. Local Governments: Municipalities and local governments organize collection teams to collect RRW and other wastes from community collection sites. They sell RRW and other MSW of value to private recyclers and give a portion of the income back to the local government in order to fund grants for community waste collection sites.
4. Recycling Fund: The Recycling Fund is the most important aspect of the 4-in-1 Recycling Program because it subsidizes municipal RRW collection as well as private collectors and recyclers who meet EPAT's environmental and safety standards. Under the 4-in-1 Recycling Program, manufacturers and importers of new RRW products, including EEE, are required to pay fees to EPAT depending on the quantity of items they put on the market. These fees feed into the Recycling Fund, which is managed by the Recycling Fund Management Board (RFMB).

(2) Regulated Recyclable Wastes under the 4-in-1 Recycling Program

Since 1997, EPAT has announced several types of wastes that must be recycled in accordance with EPAT regulations under the 4-in-1 Recycling Program. To date, this list includes 33 items divided into 13 categories, listed in Chart 1. Categories 11, 12 and 13 define WEEE in Taiwan.

RRW collectors with facilities over 1000 square meters and RRW recyclers of all size are required under the Waste Disposal Act to register with local Environmental Protection Bureaus (EPBs) and meet EPAT's environmental and safety standards in order to be eligible for subsidies under the 4-in-1 Recycling Program. RRW collectors with facilities under 1000 square meters, collectors of non-RRW and recyclers of non-RRW are not required to register with local EPBs but must meet separate environmental and safety standards set by EPAT. Enterprises that are registered with local EPBs are considered to be "licensed", while enterprises that meet the additional standards required by the 4-in-1 Program are considered to be "eligible for subsidy".

Under the 4-in-1 Recycling Program, different RRW items have different subsidies associated with them. For regulated WEEE items, recycling is subsidized but collection is not. Collection and recycling of non-RRW items, including electric or electronic products

that are not listed in Table 1, are not eligible for subsidy.

Table 1: Regulated Recyclable Wastes under the 4-in-1 Recycling Program

Containers	1.	waste metal containers(1998)		
	2.	waste aluminum containers(1998)		
	3.	waste glass containers(1998)		
	4.	(1) waste Tetra Pak ² brand containers, paper containers(1998)	(2) waste paper tableware(1998)	
	5.	waste plastic containers		
		(1)PET (1998)	(2)PVC (1998)	
		(3)PE (1998)	(4)PP (1998)	
		(5)PS foam(1998)	(6)PS non-foam(1998)	
		(7)other plastics(1998)	(8)bio-plastics(2010)	
	6.	waste containers of pesticides(1998)		
Materials	7.	waste batteries(1998)		
	8.	waste automobiles/motorcycles(1998)		
	9.	waste tires(1998)		
	10.	waste lead-acid batteries(1998)		
	11.	Waste IT Equipment		
		(1)waste laptops(1998)	(2)waste shells(1998)	
		(3)waste motherboards (1998)	(4)waste monitors(1998)	
		(5)waste hard-disks (1998)	(6)waste printers(2001)	
		(7)waste power packs (1998)	(8)waste keyboards (2007)	
	12.	Waste Electrical Appliances		
		(1)waste televisions (1998)	(2)waste washing machines(1998)	
		(3)waste refrigerators (1998)	(4)waste air-conditioners (1998)	
		(5)waste fans(2007)		
13.	Waste Light Bulbs/Tubes(2002)			

The first year of regulation is indicated in parentheses for each waste item.

Retailer takeback is not mandatory for all RRW, but it is required for waste home appliances. EPAT's regulations on waste home appliance takeback were issued July 1, 2010 and require that retailers provide free collection of waste televisions, washing machines, refrigerators, and air-conditioners for consumers who purchase new appliances. Retailers must make sure the waste appliances are sent to licensed collectors or recyclers within three (3) months of collection. This regulation marks the first time that a takeback system for RRW was established in Taiwan and is intended to increase the waste home appliance recycling rate by making recycling more convenient for citizens.

(3) Management of the 4-in-1 Recycling Program

² Tetra Pak containers are packaging for non-refrigerated beverages.

Following the 1997 amendment to the Waste Disposal Act, EPAT created specific administrative bodies to manage the 4-in-1 Recycling Program. The Recycling Fund Management Board (RFMB) was created to manage the Recycling Fund that is used to subsidize the recycling and collection of RRW. For each RRW item, RFMB calculates a recycling fee rate based on the cost of recycling and collecting that item. The current formula for calculating the recycling fee rate is: [total cost of collection, transportation, and recycling + cost of auditing and verification – total revenue generated by recyclers from processing RRW – prorated trust fund surplus] / quantities of new RRW products. More information on the rate calculation is given in Appendix 2. Based on this rate and the quantities of new RRW products placed on the market, manufactureres and importers must pay recycling fees to EPAT. RFMB also determines the appropriate collection and recycling subsidy rates for each type of RRW.

RFMB regularly reports the status of the Recycling Fund to a Recycling Rate Review Committee (RRRC) and makes recommendations on whether the fee rate or the subsidy rate needs to be modified, and if so, how. The RRRC is responsible for final decisions on the fee and subsidy rates based on RRW component materials, the per unit weight or volume of RRW, the annual cost of municipal RRW collection, the value of recycled or reused RRW products (based on a market survey), the cost of private collection, recycling and disposal (of non-recyclable components), collection and recycling rates (verified through auditing), auditing costs, the financial condition of the Recycling Fund, and other relevant factors. The concept of green design also figures into fee rates, serving as the basis for differential fees charged to manufacturers and importers of RRW products that meet labeling standards for energy conservation and other environmental measures. This serves as an incentive for manufacturers and importers to design products that can enhance resource reuse and reduce the production of waste.

The recycling fee and subsidy rates have a direct impact on collectors' and recyclers' costs and competitiveness, so the RRRC is made up of representatives from multiple sectors. Specifically, the RRRC is composed of 21 members appointed by the Minister of EPAT from representatives of governments, industry and trade associations, environmental protection NGOs, consumer protection NGOs, and academia. Representatives from governments may not exceed one-third of the membership. The RRRC has three (3) working groups which focus on recycling fee and subsidy rates for RRW containers, vehicles, and EEE, respectively. Each stakeholder group is represented within each working division; one (1) additional member is a convener, who has no decision-making authority and is elected by the other members. Working division decisions on recycling fee and subsidy rates are reviewed in the RRRC Assembly and sent to the Minister of EPAT for approval. Figure 2 illustrates the working divisions of the RRRC.

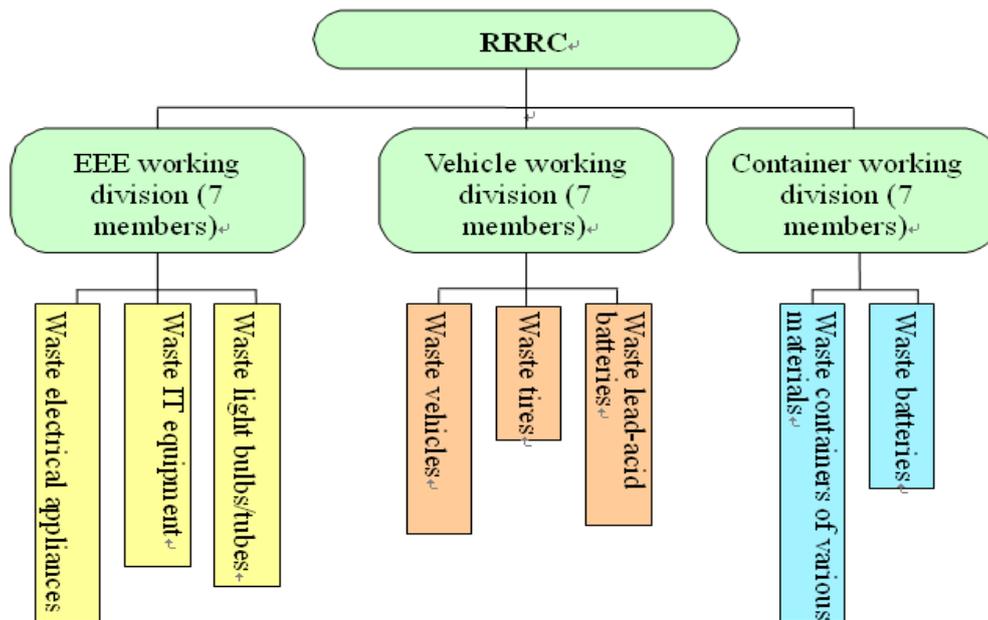


Figure 2: RRRC Working Divisions.

In addition to the RFMB and RRRC, EPAT established the Auditing and Certification Group (ACG) to verify the volumes of RRW that are collected and recycled by companies under the 4-in-1 Recycling Program. These verified volumes determine the amount of subsidy received by collectors and recyclers. The ACG is also responsible for auditing collectors and recyclers to ensure their compliance with EPAT’s environmental and safety standards. To ensure that the ACG itself is meeting its regulatory requirements, EPAT created an Auditing Supervisory Committee to oversee it.

It should be noted that the ACGs do not confer any “certification” to subsidized recyclers as the R2 and E-Stewards programs do in the United States. Instead, the ACGs verify that subsidized enterprises are in compliance with their regulatory requirements and that they receive subsidy amounts corresponding to the amount of material recycled according to EPAT’s standards. These enterprises’ abilities to remain subsidized under the 4-in-1 Recycling Program depend on their successful audit results. Eligibility for subsidy is the desired outcome in Taiwan just as R2 or E-Stewards certification (and subsequent eligibility to receive Federal electronics) may be the desired outcome of recyclers in the United States.

environmental protection bureaus. Further registration requirements, including mandatory environmental and safety management plans for recyclers and size thresholds for collector registration, were introduced in 2002 and 2004, respectively. In 2002, environmental and safety standards specific to each RRW item became mandatory for recyclers and collectors seeking registration and subsidy eligibility. Standards for WEEE management are described in the next section.

Subsidized recyclers under the 4-in-1 Program can be independently operated or may be owned by electronics manufacturers and importers (who benefit by recovering the fees they paid into the Recycling Fund), retailers, and others. Following the establishment of the new eligibility requirements, several private WEEE recycling plants were established. By the end of 2002, there were three (3) waste IT equipment recycling plants and six (6) waste home appliance recycling plants in the 4-in-1 Program. At the end of 2011, there were 12 plants recycling all types of WEEE, six (6) IT equipment recycling plants, and one (1) waste home appliance recycling plant qualifying for the subsidy, totaling 19 subsidized recycling facilities. Of these, two (2) enterprises have precious metal refinery techniques and equipment. Currently, there are no non-subsidized WEEE recycling enterprises operating in Taiwan.

The geographic distribution of subsidized WEEE recyclers in Taiwan is shown in Figures 4 and 5 (for further details, please refer to Appendix 1). Formal recycling facilities in Taiwan are all located on the western side of the island due to the highest levels of economic development being concentrated there. The areas on the east coast do not have a high market penetration of electric and electronic goods, but WEEE materials collected there are sent to recycling facilities on the west coast. While it is likely that some informal recycling, which is now illegal, still occurs, the market share of this industry has been greatly reduced through subsidy and regulation under the 4-in-1 Recycling Program.

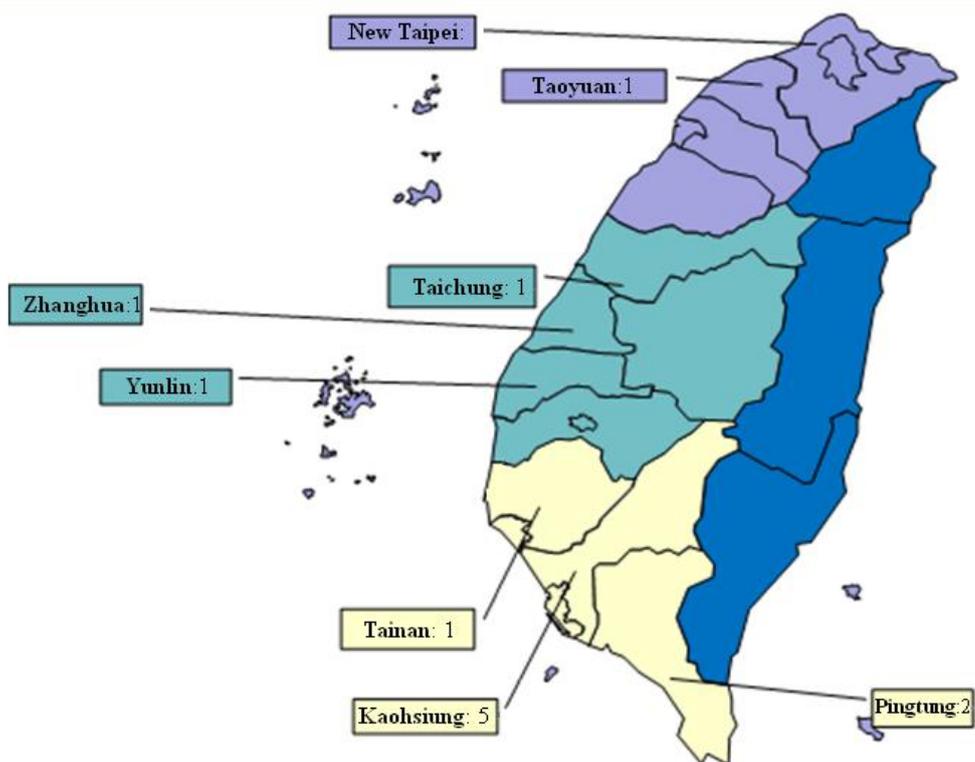


Figure 4: Geographic distribution of subsidized waste home appliances recyclers (number of enterprises per province)

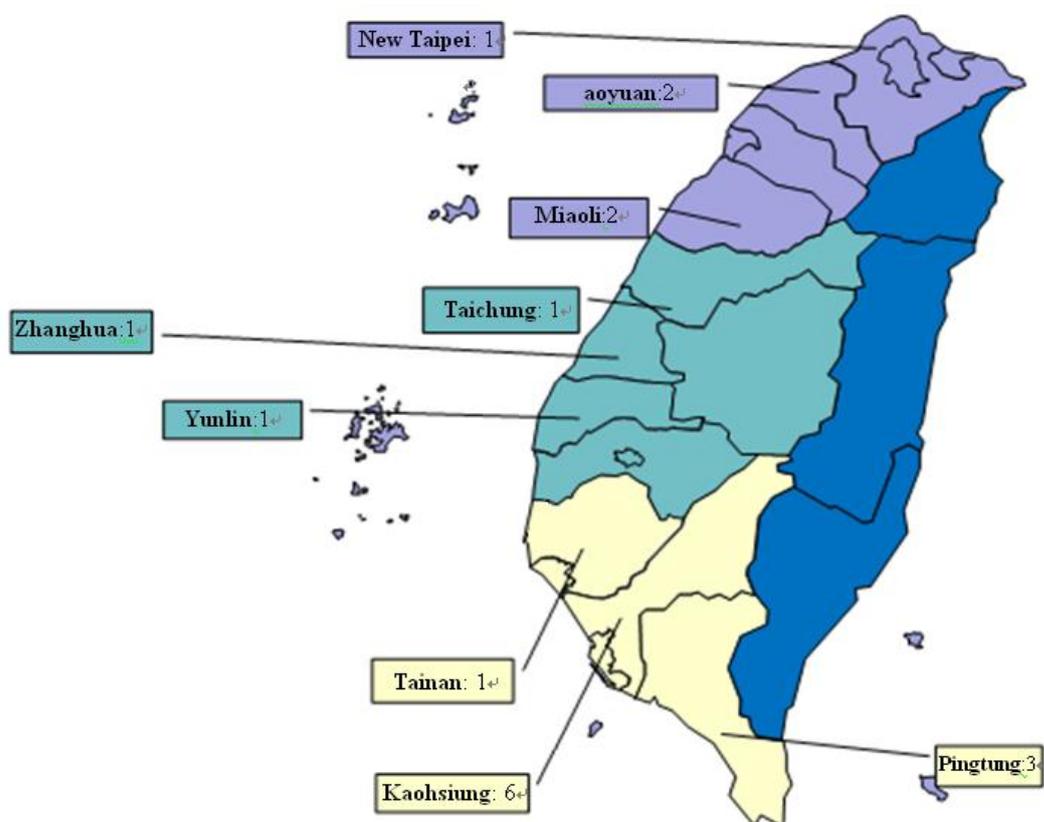


Figure 5: Geographic distribution of subsidized waste IT equipment recyclers (number of enterprises per province)

(2) Standards for WEEE Collection, Storage, and Facility Management

According to Article 18 of the Waste Disposal Act, WEEE collection, storage and recycling must follow EPAT's environmental and safety standards. These standards were issued in 2002 and revised in 2007. Some standards were developed using prior experiences from some countries such as Japan and Germany.

Enterprises that collect, store and transport waste home appliances and IT equipment must meet the following requirements:

- (1) No disassembly of E-waste is allowed during the process of collection, storage and transportation.
- (2) The vehicles or carriers used for transportation must be equipped with rain covers.
- (3) The location, containers, and facilities of E-waste storage must be clean and dry. No emissions, odors, or leaks of refrigerant, fluorescent powder, and liquid crystals are allowed.
- (4) Stored WEEE must be categorized and labeled clearly according to RRW categories.
- (5) Maximum stacking height is three meters. The height difference between adjacent stacks of WEEE must not exceed 1.5 meters. The aisles between categorized areas must be at least one meter in width.
- (6) The waste items must be stored appropriately in designated areas enclosed by fences. Stacks of WEEE must be secured by ropes, nets, or by other means to prevent collapsing.
- (7) Drainage and waste-intercepting systems must be installed in storage plants/yards to prevent pollution, and the floor must be laid with water-impermeable surfaces.

Recyclers of waste home appliances and IT equipment must meet the following standards in their facilities:

- (1) The plant must be installed with equipment for wastes liquid, odor, pollutant and contaminants controls. Install essential facilities against discharging waste odors and other pollutant.
- (2) The recycling process must be carried out in enclosed buildings with roofs and firm walls and foundations.
- (3) The floor must be paved or laid with water-impermeable surfaces to prevent contamination of soil or groundwater.
- (4) Equipment for liquid interception, collection and oil-water separation must be installed.
- (5) For facilities that have shredding operations, soundproof and dust collection systems must be installed.
- (6) Ambient light or illumination must be sufficient in the recycling plant.
- (7) The plant must be installed with pollution control facilities and alternative set-ups for emergency response.

In addition, the following specific standards must be met when recycling waste home appliances and waste IT equipment:

- (1) All dismantling must be carried out in Taiwan, and WEEE must not be sent to incinerators or landfill.
- (2) Electric wires and motors must be removed first.
- (3) Mercury-containing parts must be collected separately without physical damage to prevent mercury vapor leakage, and must be stored in closed containers.

(4) For WEEE that contain Cathode-Ray Tubes, funnel and panel glasses must be separated, and fluorescent powder must be stored in closed containers according to the following rules:

- i. The operation must be conducted in a separate and confined space.
- ii. Collection of fluorescent powder must be conducted in hoods, and the exhaust port of the hood must be equipped with filters and dust collection system.

(5) Refrigerant or lubricant in E-wastes must be recovered before shredding. The pressure of the refrigeration system must be released to lower than 102 mmHg before the compressor can be removed and subsequent process continued.

(6) Refrigerant in foam insulating material and equipment must be recovered.

(7) The panel glass of LCD contained in waste appliances and IT equipment must be separated without physical damages. The operators must wear protective gloves, and the liquid crystal must not leak during disassembly. Cold Cathode Fluorescent Lamps must be stored in a designated area separately.

(8) Integrated circuit boards from waste IT equipment must be shredded before further processing.

(9) Regulations for waste refrigerator recycling:

- i. Shredding of the cabinet must be carried out in a closed and negatively pressured facility.
- ii. Refrigerant liquefaction systems must be installed to collect foaming agents in foam insulating materials.
- iii. Soundproof and dust collection systems must be installed.
- iv. Explosion-proof measures must be installed.

(10) Derivative wastes and materials from recycling waste appliances and IT equipment must be categorized, clearly labeled, and stored separately.

(11) Derivative wastes and materials that are liquid or gaseous must be stored in leak-proof containers with pressure meters or liquid level monitors.

(12) Recovered refrigerant can be transmitted to retailers or plants, which are certified by administrators, for sale or destruction.

Additional standards for collectors and recyclers of waste light bulbs are given in Appendix 3.

4. Financial Management under the 4-in-1 Recycling Program

(1) Funds managed by RFMB

Under the 4-in-1 Program, EPAT operates a Recycling Fund made up of recycling fees from manufacturers and importers of new RRW products. Detailed information on the recycling fee rates is given in Appendix 2. Twenty percent (20%) of the income from the fees go to a “special income fund”, while 80% are distributed among eight (8) trust funds, which are organized by waste category (home appliances/lighting equipment and IT equipment account for two (2) of the trust funds). The trust funds subsidize private collectors and recyclers; this subsidy is the main economic incentive in the 4-in-1 Recycling Program. The special income fund supports outreach, research and development on recycling processes, auditing and certification, grants for municipal collection teams and community recycling projects, and EPAT’s administration of the 4-in-1 Recycling Program. All fees and funds are managed by RFMB. The flow of finances to and from the Recycling Fund is shown in Figure 6.

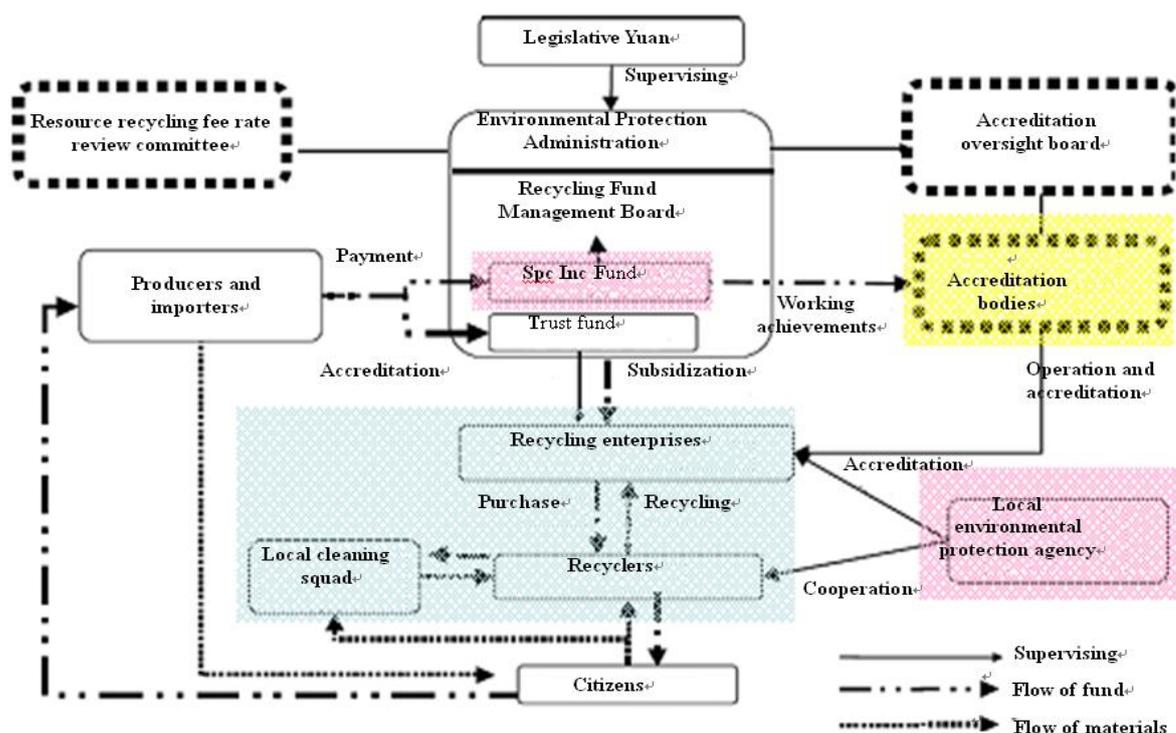


Figure 6: The Flow of Finances in the 4-in-1 Recycling Program

Figure 7: The Flow of Finances in the 4-in-1 Recycling Program

(2) WEEE Recycling Fee and Subsidy Rates

Subsidy rates for each RRW item are calculated based on the difference between the cost of collecting and recycling that type of product and the revenue generated by selling the collected units to recyclers or selling the recovered resources, respectively. In order to ensure accuracy of the data used in calculating fees and subsidies, RFMB surveys registered recyclers

and collectors on their cost and revenue data on an annual basis. The volumes of RRW handled by these enterprises, also influences the subsidy rate; these volumes are verified by the ACG to ensure accuracy.

Examples of current recycling fee rates and subsidy rates for WEEE are given in Tables 2, 3 and 4 below.

Table 2: Current recycling fee rates and subsidy rates for waste home appliances

Item Fee rate	Waste Air conditioner	Waste television				Waste refrigerator		Waste washing machine	Waste fan	
		CRT<25 inches	CRT>25 inches	LCD<25 inches	LCD>25 inches	<250 liters	>250 liters		<12 inches	>12 inches
Fee	248	247	371	127	233	404	606	317	20	35
Subsidy	500	635.5		379.5		303		346.5	20	

Unit: NTD/item

Table 3: Current recycling fee rates and subsidy rates for waste IT equipment

Item Fee rate	Waste mainframe	Waste monitor			Waste printer			Waste notebook	Waste keyboard
		CRT	LCD<25 inches	LCD>25 inches	Inkjet	Laser	Dot Matrix		
Fee	114.8	127	127	233	81	137	151	39	15
Subsidy	182	215	303		150			303	12

Unit: NTD/item

Table 4: Current recycling fee rates and subsidy rates for waste light bulbs/tubes

Item	Waste light bulbs/tubes			
Fee rate	31			
Subsidy rate	Long Fluorescent Tubes	Recycling rate (R _T %)	Recycling rate of Mercury (R _{Hg} %)	Subsidy rate
		R _T % ≥ 90%	R _{Hg} % ≥ 50%	29
			40% ≤ R _{Hg} % < 50%	20
			R _{Hg} % < 40%	0
		R _T % < 90%	-	0
	Incandescent, Compact Fluorescent, HID, and other Bulbs	Recycling rate (R _T %)	Recycling rate of Mercury (R _{Hg} %)	Subsidy rate
		R _T % ≥ 60%	R _{Hg} % ≥ 35%	40
			20% ≤ R _{Hg} % < 35%	20
			R _{Hg} % < 20%	0
		R _T % < 60%	-	0
	Broken light bulbs / tubes	15		

Unit: NTD/Kg

5. Current Practices for WEEE Collection, Recycling and Refining in Taiwan

(i) Collection channels

Under the 4-in-1 Recycling Program, consumers can send WEEE for recycling through retailers, municipal collection, private collection, or donations to charities who sell WEEE to licensed recyclers. Most WEEE are sent to subsidized recyclers; other WEEE are sent to the second-hand market, and some WEEE may go to informal recyclers. The recyclers in the 4-in-1 Program do not play a role in the reuse market in Taiwan.

(ii) Recycling technologies for WEEE

WEEE recycling systems in Taiwan were developed using techniques from developed countries. The methods and equipment used by most subsidized recyclers to recycle WEEE are similar across most facilities and are based on the requirements of EPAT's regulations. WEEE recyclers in Taiwan focus on dismantling; their primary techniques include manual product disassembly, mechanized CRT separation, manual phosphor powder removal, mechanized refrigerator shredding and separation, mechanized coolant removal from refrigerators and air conditioners, and mechanized circuit board shredding.

(iii) Refining techniques for recycling precious metals

Refining techniques in Taiwan were developed based on the experience of many countries, especially those in Europe. Two (2) enterprises in Taiwan are capable of recovering gold, silver, and palladium from WEEE components, particularly motherboards. While EPAT does not regulate the type of equipment used for the refining process, it does regulate the environmental protections associated with refining under Article 36 of the Waste Disposal Act.

Since refining capacity is limited, some materials that result from WEEE recycling are exported for further processing, although the export of whole WEEE units is prohibited by EPAT. Shredded integrated circuit board scrap is sent to Japan, Korea, and Mainland China, but these exports are classified as mixed metal waste and are therefore considered hazardous waste exports by Taiwan, so shipments must be registered with the local EPB. Cleaned CRT funnel glass is exported to India as a commodity, although this market is rapidly diminishing. Steel, aluminum and copper can be refined in Taiwan, and plastics and glass can also be processed locally.

6. WEEE Collection and Recycling Rates Under the 4-in-1 Recycling Program

(1) WEEE Collection Rates

The collection rate is a performance index for the 4-in-1 Recycling Program. This measure uses the total amount of each WEEE item certified by the ACG as having been sent to registered recyclers in a given year and compares it with the amount of that product expected to be reaching its end-of-life that year. The life span calculations vary by WEEE item and are derived from EPAT consumer studies. Sales volumes are calculated based on the quantities of new goods put on the market by manufacturers and importers under the 4-in-1 Recycling Program. These enterprises are required to report their sales data to EPAT. The quantity of secondhand goods sold is not included in the sales volume calculation because it is assumed that those goods were already accounted for when they were originally sold as new or imported goods. When comparing the recycling volume and sales volume, home appliance and keyboard sales are assumed to be stable from year to year, but sales of other IT equipment can vary depending on marketing and the release of new models. The formulae for calculating the collection rates of WEEE items are shown in Table 5.

Table 5: WEEE Collection Rate Formulae

Category	Item	Collection Rate Formula
Home Appliances	television	Certified recycling volume in year x / Reported sales volume for the same year
	refrigerator	
	washing machine	
	air-conditioner	
	fan	
IT equipment	monitor	Certified recycling volume in year x / Reported sales volume from year $x-5$
	mainframe	
	printer	
	notebook	Certified recycling volume in year x / Reported sales volume from year $x-7$
	keyboard	Certified recycling volume in year x / Reported sales volume for the same year
	lighting equipment	Certified recycling volume in year x / Reported sales volume for the same year

The annual collection rates for waste home appliances and IT equipment from 2006-2010 are given in Table 6, Table 7, Figure 7, and Figure 8.

The collection rates for several WEEE items are consistently higher than 50%. These rates are on par with or higher than the takeback rates of developed countries such as Japan

and Korea, and are twice as high as the estimated 25% WEEE recycling rate in the United States.

Several items experienced a drop in collection rates in the year 2009. This drop was the result of the global recession, which led consumers to continue using existing products instead of replacing them with new goods.

Table 6: Annual waste home appliance collection rates

Year	Waste television	Waste washing machine	Waste refrigerator	Waste air-conditioner	Waste fan
2006	87.9	46.0	63.7	23.5	-
2007	107.9	51.6	50.2	27.8	27.4
2008	120.5	51.1	53.7	30.9	0.9
2009	139.5	51.0	51.2	31.4	0.5
2010	139.5	62.3	56.6	37.3	0.4

Unit : %.

Table 7: Annual waste IT equipment collection rate

Year	Waste PC	Waste monitor	Waste printer	Waste notebook	Waste keyboard
2006	54.1	19.8	84.0	4.8	-
2007	43.4	45.2	65.8 ³	12.5	-
2008	44.8	42.0	60.6	14.2	-
2009	34.3	41.2	53.4	12.0	13.0
2010	49.3	54.5	64.4	11.4	16.6

Unit : %.

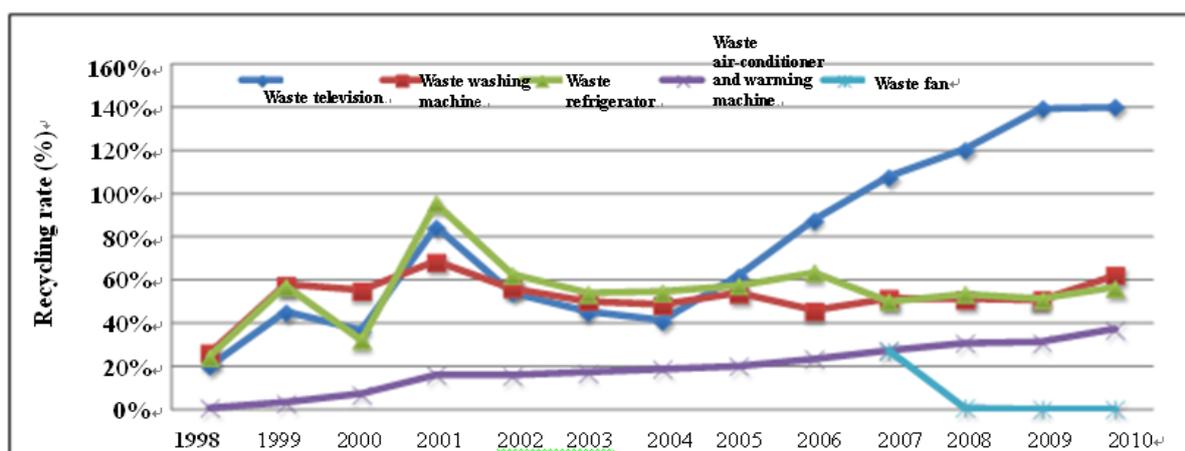


Figure 7: Annual waste home appliance collection rates

³ The drop in Waste Printer collection rates in 2007 was due to a subsidy rate adjustment that went into effect that year.

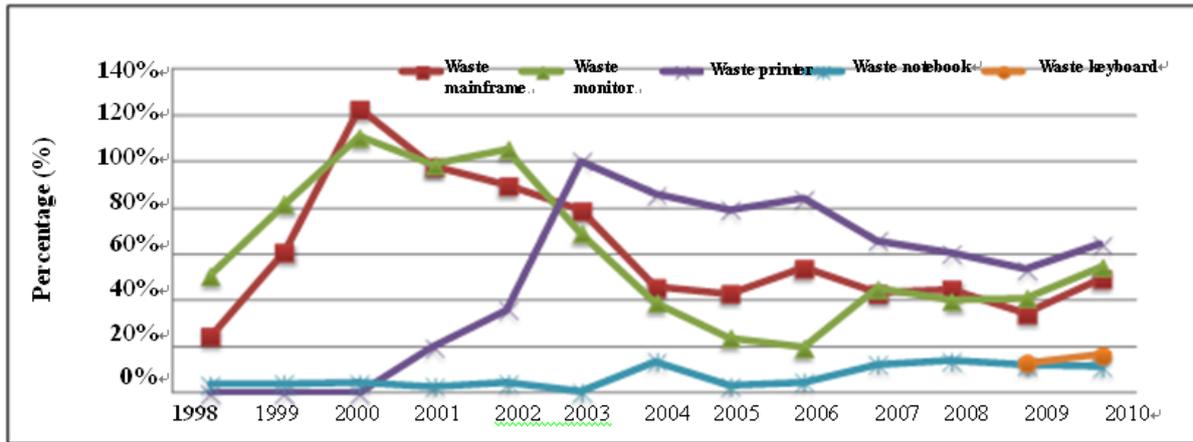


Figure 8: Annual waste IT equipment collection rates

(ii) WEEE Recycling Volumes

Table 8, Table 9, Figure 9, and Figure 10 show the volumes of WEEE certified by the ACG as having been recycled under the 4-in-1 Program between 2006 and 2010. These metrics indicate an overall increase in certified quantities of recycled WEEE over time.

Table 8: Annual certified waste home appliance recycling quantities (in thousands of items)

Year	Waste television	Waste washing machine	Waste refrigerator	Waste air-conditioner	Waste fan	Total
2006	547	272	360	287	-	1466
2007	603	311	332	377	14	1637
2008	484	294	319	360	17	1474
2009	505	292	294	326	9	1426
2010	602	370	333	469	12	1786

Table 9: Annual certified waste IT equipment recycling quantities (in thousands of items)

Year	Waste PC	Waste monitor	Waste printer	Waste notebook	Waste keyboard	Total
2006	1,112	260	760	9	-	2141
2007	934	635	687	31	7	2294
2008	988	691	690	38	372	2779
2009	839	822	583	45	281	2570
2010	1,178	1,202	698	53	423	3554

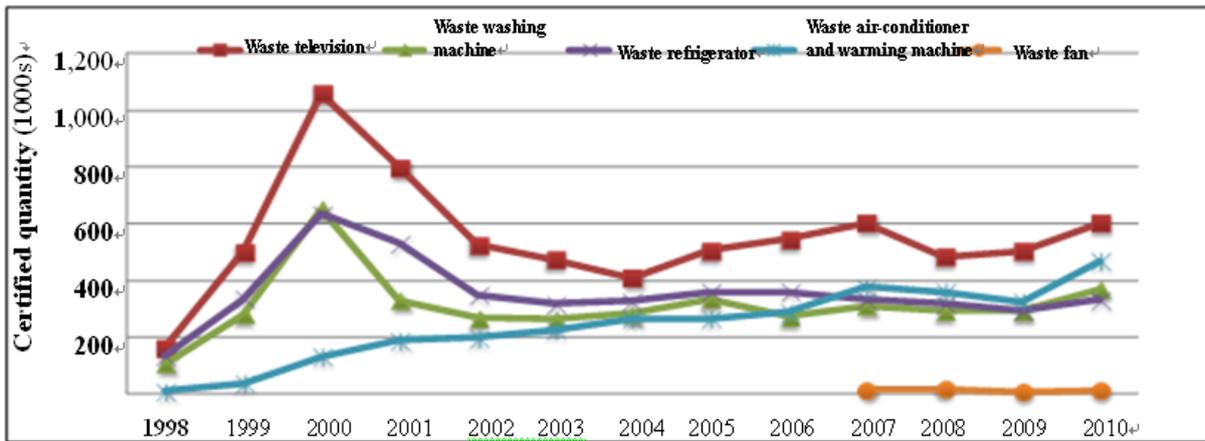


Figure 9: Annual certified waste home appliance recycling quantities (in thousands)

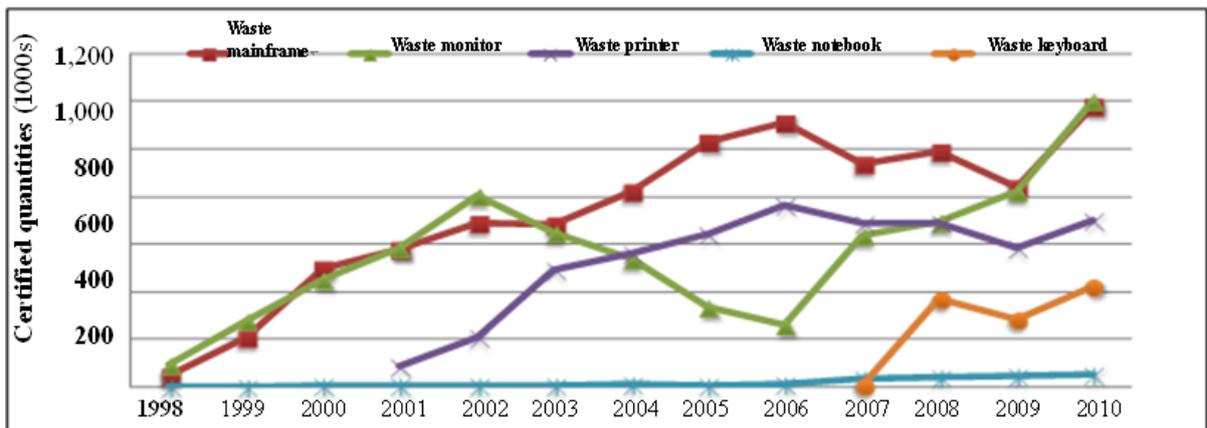


Figure 10: Annual certified waste IT equipment recycling quantities (in thousands)

7. Goals for Improving WEEE Management under the 4-in-1 Recycling Program

1. Increase collection rates

While the 4-in-1 Program achieves a collection rate greater than 50% for several types of WEEE, there is still room for improvement for many items that have low collection rates, such as waste fans and waste keyboards. Through the 4-in-1 Program, EPAT aims to increase the number of WEEE recyclers in Taiwan and to increase the amount of WEEE that is sent to these recyclers.

2. Increase the number of regulated recyclable WEEE items under the 4-in-1 Program

The administration plans to add new regulated recyclable WEEE items to the 4-in-1 Recycling Program. In evaluating future items for inclusion in the 4-in-1 Program, EPAT uses the European Union WEEE Directive and other sources as references and selects categories of wastes which are reaching their end-of-life in high quantities and which have high household usage in Taiwan. According to research commissioned by EPAT in 2011, the tape recorder, radio, cell phone, dehumidifier, microwave and fax machine may be appropriate for regulation under the 4-in-1 Program. However, additional factors must be evaluated before these waste items can be regulated.

One obstacle to adding new items to the list of RRW is the related resource burden for EPAT. Staff time must be available for calculating fees and auditing the quantities of goods sold, imported, collected and recycled for each new item. It is a challenge to identify which products, if added to the list of RRW, would present the greatest environmental gain and least resource burden.

3. Increase resource recovery from WEEE recycling

To continue reducing waste in Taiwan, EPAT hopes to improve the quality of resources recovered by recyclers under the 4-in-1 Recycling Program. In 2007, EPAT introduced regulation requiring WEEE recyclers to recover iron, copper, aluminum, glass, and plastics for recycling. WEEE recyclers are prohibited from disposing of these materials. However, enforcement of this regulation has not been consistent, and EPAT hopes to strengthen compliance in the future in order to minimize solid waste generation and move closer to a closed-loop economy.

4. Revise environmental and safety standards

Although WEEE collectors and recyclers are required to meet environmental and safety standards under the 4-in-1 Recycling Program, pollution can still result from the recycling process. Damage to the ozone layer from coolant emissions is a particular concern for EPAT; environmental and safety standards for pumping coolant out from waste home appliances already exist but could be improved. Disposal of LCD and CRT funnel glass also continues to be a major environmental challenge. In the future, EPAT hopes to strengthen the

environmental and safety requirements of the 4-in-1 Program to mitigate these and other pollution and health concerns.

5. Enforce registration requirements for informal collectors

Although informal recyclers have been incorporated into formal operations under the 4-in-1 Recycling Program, informal collection is still an issue. Many of these collectors operate collection facilities which are over 1000 square meters, which means they are required to register with EPAT and meet EPAT's environmental and safety standards. In the future, EPAT hopes to strengthen enforcement of its registration requirements for these enterprises.

8. Conclusion

EPAT's 4-in-1 Recycling Program was initiated in 1997 as a way to incentivize environmentally sound recycling and resource recovery. Since then, the program requirements, including its environmental standards, have been revised and strengthened. The overall number of formal WEEE recyclers has increased over the course of the program's implementation, and the percentage of units processed annually by registered recyclers is over 50% for several types of WEEE.

Through its experience developing and implementing the 4-in-1 Recycling Program, EPAT has learned lessons that may be useful to other policymakers who are trying to manage WEEE. One key lesson relates to the development of the recycling industry; despite the incentive of the 4-in-1 program's subsidies for recycling of RRW, recycling facilities did not develop as rapidly as hoped due to overly complex registration requirements. By simplifying requirements for recyclers to become licensed to join the 4-in-1 Program, EPAT encouraged the industry to grow, and consequently stimulated recycling of RRW.

In the future, EPAT hopes to continue strengthening the collection and recycling rates for WEEE and other RRW, as well as to improve the environmental and safety standards associated with the 4-in-1 Program. It is hoped that this case study will be a useful tool for policymakers seeking to improve the environmentally sound management of WEEE.

Appendix 1: Companies subsidized for waste electrical appliances and waste computer appliances

Name of subsidized companies	Disposal items		Location	Year of inauguration	
	Waste electrical appliances	Waste computer appliances		Waste electrical appliances	Waste computer appliances
Super Dragon Technology Co., Ltd.		⊙	Taoyuan County		1999
Citiraya Technology Co., Ltd.		⊙	Miaoli County		2003
Hong Chin Recycling Enterprise Corp.	⊙	⊙	Pingtung City	2000	2003
Perfect Recycling Company	⊙	⊙	Kaohsiung City	2000	2003
Taipei Factory, E&E Recycling, Inc.	⊙	⊙	New Taipei City	2000	2004
Yangmei Factory, E&E Recycling, Inc.	⊙	⊙	Taoyuan County	2000	2004
FGD Industrial Co.	⊙	⊙	Taichung City	2000	2004
Liuh-Jian Co., Ltd.	⊙	⊙	Kaohsiung City	2002	2005
Second Factory, Jiu Fa Environmental Engineering Company	⊙	⊙	Kaohsiung City	2003	2004
Household Appliance Factory, Da Chi Environmental Technologies Co., Ltd.	⊙		Kaohsiung City	2005	
Cheng Gong Resource Company		⊙	Miaoli County		2005
Big South Resource Recycling Company	⊙	⊙	Tainan City	2006	2007
Hung Kuang Environmental Protection Company	⊙	⊙	Pingtung County	2010	2006
Computer Factory, Da Chi Environmental Technologies Co., Ltd.		⊙	Kaohsiung City		2007
Rui Yuan Environmental Protection Company	⊙	⊙	Yunlin County	2008	2008
Ke Bai Sheng Environmental Technologies Co., Ltd.	⊙	⊙	Zhanghua County	2009	2009
West Environmental Technologies Co., Ltd.		⊙	Pingtung County		2010
Han Lin Environmental Technologies Co., Ltd.	⊙	⊙	Kaohsiung City	2011	2011
He Wei Co., Ltd.		⊙	Kaohsiung City		2011

Note: the statistics cover till the end of 2011.

Appendix 2: Recycling Fee Formula and Rates

The following formula is used to calculate the recycling fee rate for each RRW item:

Recycling fee rate = [total cost of collection, transportation, and recycling (H) + cost of auditing and verification (L) – total revenue generated by recyclers⁴ and collectors from processing RRW (V) – prorated trust fund surplus (F)] / quantities of new RRW products put on the market in Taiwan (S)

The subsidy rate, auditing and other administrative costs that are supported by the Recycling Fund must equal the recycling fees brought in from manufacturers and importers. Table 10 gives an example of the factors that go into the calculation of the fee rate for manufacturers and importers of EEE.

Table 10: Recycling Fee Rate Calculation Formula

Recycling Fee Rate Calculation Formula
<p>H : Total Cost of collection, transportation, and recycling (NTD)=D+T+E D (Cost of collection, transportation, and recycling)(NTD)=(C1+C2)×g T (Additional Municipal Collection Costs) (NTD) = 0 E⁵ (Environmental External Cost, including cost of environmental effects) (dollar) C1 : Unit cost of collection (NTD/unit) C2 : Unit cost of recycling (NTD/unit) g : Certified quantities from processing RRW (number of units)</p>
<p>L : Cost of auditing and certification (NTD)</p>
<p>V : Revenue generated by recyclers from processing RRW (NTD) = r× g : r : Average unit profit for recyclers and collectors (NTD/unit) g : Certified quantities of materials recovered from processing RRW (unit)</p>
<p>F : Prorated trust fund surplus (NTD) = (f– q)/ y : f : Accumulated trust fund surplus (NTD) q : Amount set aside from surplus for future fund management (NTD) y : RRW life span (years)</p>
<p>S : Quantities of new RRW products put on the market in Taiwan (total units)</p>

⁴ In the case of WEEE, recyclers are subsidized under the 4-in-1 Recycling Program but collectors aren't, so only recyclers' revenues are considered in the rate formula.

⁵ The variable "E" represents the cost of the environmental impacts of improper disposal. Currently, this cost is estimated by the amount of subsidies given to local governments' municipal collection teams, which come from grants financed by the special income fund.

Recycling Fee Rates:

IT equipment

Recycling Fee (NT/unit)								Subsidy (NT/unit)					
PC	Monitor		Notebook	Printer			Key Board	PC	Monitor		Notebook	Printer	Key Board
				Laser type	Ink-jet type	Dot-Matrix			CRT	LCD			
114.8	CRT & LCD ≤ 25"	>25" LCD	39	137	81	151	15	182	CRT	LCD	303	150	12
	127	233							215	303			

Home Appliance

		Recycling Fee (NT/unit)	Subsidy Fee (NT/unit)
Television	CRT	> 25" : 371	379.5
		≤ 25" : 247	
	LCD	> 25" : 233	303
		≤ 25" : 127	
Refrigerators		> 250 kg : 606	635.5
		≤ 250 kg : 404	
Washing machines		317	346.5
Air conditioners		248	500
Fans		> 12" : 35	20
		≤ 12" : 20	

Appendix 3: Regulations and Standards for Waste Light Bulb Collection, Transportation, Recycling and Facility Management

1. Regulations for collection, storage, and transportation
 - (1) The waste lamps must be stored in solid containers.
 - (2) The quantity of waste storage must not exceed monthly average of the previous quarter.
 - (3) The location, containers, and facilities of waste lamps must be clean and dry. No emissions, odors, leaks or leaching are allowed.
 - (4) Collection and storage plants/yards must be installed with equipment preventing water leakage, and the floor must be laid with water-impermeable surfaces.
 - (5) Storage areas must be categorized and labeled clearly. Maximum stacking height is six meters. The height difference between adjacent stacks must not exceed 1.5 meters. The length and width of categorized areas must not exceed 20 meters. The aisles between categorized areas must be at least one meter in width.
 - (6) The waste items must be stored appropriately in designated areas enclosed by fences. The stacks must be secured by ropes, nets, or by other means to prevent collapsing.
 - (7) The vehicles or carriers used for transportation of waste lamps must be installed with clearly labeled solid containers.
 - (8) During transportation, rain covers and protective equipment are required to prevent waste lamps from cracking and hazardous content from spreading.
 - (9) Recycling, fluorescent powder and activated carbon storage (prior to mercury recycling), and storage of mercuric compound derived from recycling waste lamps must take place in isolated areas.

2. Regulations for waste light bulb recycling plants
 - (1) Drainage and wastewater interceptors must be installed in the recycling plants.
 - (2) Recycling plants must be enclosed, with roofs and concrete walls and foundations. The floor must be paved or laid with water-impermeable surfaces to prevent contaminating soil or groundwater.
 - (3) The plant must be installed with mercury recycling facilities and equipment for wastes liquid, odor, pollutant and contaminant control.
 - (4) Minimum total area of the plant (included temporary storage area) is 1983.48m²; the designated area for waste light bulb recycling must be larger than 991.74m².
 - (5) The plant must be installed with pollution control facilities and alternative set-ups for emergency response.

3. Regulations for the waste lamp recycling process
 - (1) The processes of dismantling, mercury collection, shredding and sorting must be carried out in Taiwan, and sending non-processed waste lamps to incinerators or landfill is prohibited.
 - (2) The waste RRW light bulbs must not be mixed with non-regulated waste light bulbs during recycling.

- (3) Mercury contained in waste lamps must not leak during collection, storage, transportation and recycling.
 - (4) Mercury-containing components, lead-containing glass, and other derivative wastes must be disposed of appropriately. Fluorescent powder must be collected and stored properly during recycling process.
 - (5) Recycling plants must have mercury detectors. Discharge of waste gas, wastewater, and the ambient air quality in operation area must be compliant with relevant regulations.
 - (6) Mercury-containing fluorescent powder must be disposed in according to regulations of industrial waste.
 - (7) Mercury, lead-containing glass, other glass, and metals derived from recycling lamps, when handled by recovery processes, must be treated in accordance with EPAT's industrial waste regulations.
4. In addition to the environmental and safety standards listed in the previous sections, waste light bulb recyclers that intend to apply for recycling subsidies must meet the following standards:
- (1) The recycler must install weigh stations to measure the mass of incoming waste equipment, CCTV surveillance systems, independent electric meters and other facilities that facilitate auditing and certification.
 - (2) The resource recovery rate must meet the standards by EPAT. The total recovery rate for waste lamps⁶ must exceed 90%; mercury recycling rate⁷ must exceed 40%.

$$R_T\% = \frac{\text{Weight of products and recovery material (kg)}}{\text{Certified weight of recycling (kg)}} \times 100\%$$

$$R_{Hg}\% = \frac{\text{Certified weight of mercury recycling (kg)} \times \text{mercury content ratio(\%)}}{\text{Certified weight of recycling (kg)} \times \text{mercury content in unit weight} \times 10^{-5}(*)} \times 100\%$$

* Mercury content in unit weight for Waste fluorescent tube is 5.52mg/100g.