Examining the Waste from Electrical and Electronic Equipment Management Systems in Japan and Sweden

Kohei Sasaki

Lund, Sweden
LUMES, Lund University Master's Programme in Environmental Science

Thesis for the fulfilment of the Master of Science in Environmental Science
Lund University
Lund, Sweden, December 2004

Acknowledgement

I would like to thank everyone who assisted me intellectually, financially and mentally to complete this study. A special thanks to my supervisor, Deniz Koca at the Department of Physical Geography and Ecosystems Analysis, Lund University for valuable feedback and Miljövetenskapligt centrum, Lund University for financial support. I would also express my appreciation to Joyce and Katie who spent time to provide English support during their busy days. Lastly, my gratitude is forwarded to my friends in Lund and my parents for their warm support.

Lund, 22 November 2004
Kohei Sasaki

Abstract

The production of electrical and electronic equipment is one of the fastest growing industries. This trend ultimately increases the amount of waste from electrical and electronic equipment (WEEE) as well as environmental burdens throughout the life cycle of these products. Action on WEEE is an urgent need in the world, especially industrialised countries since these countries consume significant amount of electrical products. The WEEE management legislations has implemented since 2001 in both Japan and Sweden to treat WEEE in adequate manner. The legislations implement well in both countries, although there are some difficulties such as limited application of recycling. However, further measures ought to be taken in order to minimise the environmental burden caused by WEEE in accordance with the hierarchy of preferred waste management (See Section 4.2), which prevention and reuse are placed on the two highest positions. This paper provides technical and social context of WEEE to examine WEEE management systems in both Japan and Sweden with the focus on a selected product group, television. Both WEEE management systems are analysed by using systems thinking approach.

Key words: Waste from electrical and electronic equipment, Television, Sweden, Japan, Reuse, Recycle, Systems thinking, Causal loop diagram.

Table of Context

List of Figures

List of Tables

Abbreviations

CFC	Chlorofluorocarbons
CLD	Causal Loop Diagram
CRT	Cathode Ray Tube
EEE	Electrical and Electronic Equipment
EoL	End-of-Life
EPR	Extended Producer Responsibility
FPD	Flat Panel Display
NEG	Nippon Electronic Glass Co.,Ltd.
PBDEs	Polybrominated Diphenyl Ethers
PCB	Polychlorinated biphenyl
WEEE	Waste from Electrical and Electronic Equipment

Chapter 1: Introduction

1.1 Background

The production of electrical and electronic equipment[1] (EEE) is one of the fastest growing industries (Cui, 2003). For instance, 170 million units of televisions were produced worldwide in 2003, which was a 3.7% increase from 2002 and further growth is expected (Tahara, 2004). This trend ultimately increases the amount of waste from electrical and electronic equipment (WEEE) as well as environmental burdens such as the use of nonrenewable resource, energy consumption, and emissions to the environment throughout the life cycle of these products.

Action on WEEE is an urgent need in the industrialised countries, as growing sales of EEE has led to increasing volumes of electro-scrap (Bornand, 2002). In 2003, the amount of disposed brown goods were 16,000 tonnes in Sweden (Påhlman, 2004)[2] and 96,435 tonnes in Japan (METI, 2004a). These figures are not very significant compared to the total amount of waste[3] generated by households. However, treatment difficulties due to the high variety and complexity of products, and toxic chemicals in WEEE make this waste stream problematic. If WEEE is subjected to illegal dumping or inadequate treatment, toxic materials contained in them may adversely affect the environment and human health through several ways such as heavy metal leaching to ground water or dioxin emission to the environment.

Therefore, proper treatment of WEEE is important not only because of the reasons mentioned above, but it also enables valuable resources recovery and alleviates the landfill shortage problem, especially in Japan[4]. As a measure against such WEEE problems, some countries have implemented various regulations and legislations. Sweden and Japan having different industrial and societal structure, have implemented different WEEE treatment laws, which incorporate extended producers responsibly (EPR) since 2001. The WEEE treatment legislations work well in both countries (Tojo, 2004), although there are difficulties including the limited application of recycled materials and the lack of reliable statistics on the material flow of EEE to improve the WEEE management system. In order to have a fresh perspective on this complex issue and to investigate potential measures to improve the existing WEEE management systems in Japan and Sweden, these two systems are analysed and compared to each other with a focus on a selected product group; television.

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[1] Examples of electrical equipments are television, refrigerator, microwave etc., whereas PC, network server etc. are examples of electronic equipments

[2] This number includes television video recorder and so on. However, most of the weight shown is from television (Påhlman, 2004).

[3] WEEE consisted an estimated 4% of the total amount of household waste in 1998 in EU (Schultz, 2004). Designated four electrical wastes in Japan accounted for approx. 2% of total household waste (METI, 2001a).

[4] The landfill site remained for 4.3 years for industrial waste and 12.5 years for municipal waste in 2001 (MoE, 2004a and 2004b)

1.2 Objectives

The objectives of the study are;

- To analyse the existing WEEE management systems in both Sweden and Japan
- To compare these two systems for a selected product group –television, by using the systems thinking approach
- To suggest the potential measures to improve the efficiency of WEEE management systems in these countries

1.3 Terminology and Definition

Below is a list of terminology and definitions used in this paper:

- Consumer: "Consumer" is an owner of a product. Consumer includes household and business unless specified.
- End-of-Life: "End-of-life" is a state of which the owner does not want to possess it any longer. It does not matter whether the product works or not.
- Pre-treatment: "Pre-treatment" is to sort and dismantle disposed products for the following treatment, such as recycle or landfill.
- Recycle: "Recycle" is a process of treating waste including pre-treatment process so that they can be utilised again in an upstream material flow.
- Retailer: "Retailer" is a company or store that sells electrical and electronic equipments.
- Reuse: "Reuse" is to use products again for the same purpose. Reuse does not include a component reuse from WEEE in this paper unless specified.
- Television: A television only indicates a cathode ray tube television, but not a liquid crystal display or a plasma display panel television unless specified.
- Treatment: "Treatment" is processes including dismantling, recycling, and landfilling.

Chapter 2: Technological Context of Television Waste and its Recycling

2.1 Material Content of Television

Television mainly consists of cathode ray tube (CRT), casing, circuit board, speaker, coil (deflection yolk) and cable. Table 2.1 and Table 2.2 show the material and component composition of a television. Masuko (2000) reported that the weight of all television components except for CRT, have decreased from 1975 to 1995. As a result, the proportion of a CRT weight to the total television weight increased from 48% in 1975 to 67% in 1995 (ibid.). The weight of a 25-inch television also reduced by 80% from 1986 to 1994 (ibid.).

Table 2.1 Material composition of television

	Weight	Fe	Al	Cu	Plastics	Glass	Others
Television*	25kg	12%	1%	3%	26%	53%	5%

* Material composition of television manufactured in 1980s. (Source: METI, 2001b)[5]

Table 2.2 Component composition of television

	Weight	Housing	CRT	Circuit Board	Speaker	Coil	Cable	Other
Television*	15kg	21%	56%	12%	1%	3%	4%	3%

* Data indicate television composition manufactured 1980-1984. (Source: Masuko, 2000) [5]

2.1.1 Cathode Ray Tube

CRT is the heaviest and most problematic component in a television. A CRT consists of a panel glass containing barium and or strontium oxide, and a funnel glass and a neck glass both containing lead oxide. Frit –a soldering glass, also contains the high level of lead oxide (ICER, 2003). Fluorescent agents coated on a panel glass commonly contain yttrium, selenium, chromium and phosphors (ETC/WMF, 2003 and Toyo gosei, 2004). Metal oxide, some of which are hazardous, is stable when contained in glass; however, it can leach into ground water in a landfill site (Goforth, 1994). For this reason, a CRT glass has to be disposed in specially controlled hazardous landfill sites in Sweden and Japan.

2.1.2 Plastics

The television contains various kinds of plastics for casing, circuit board, etc. Among the plastics used in a television, the back casing has the biggest possibility of mechanical recycling because it is the biggest piece in a television and usually consists of one kind of polymer. An old television casing used to be composed of wood, polypropylene and acrylonitrile-butadiene-styrene, also known as ABS (Nagaya, 2003). These materials were replaced by high impact polystyrene around 1988 (ibid.). Television manufacturers started using brominated flame retardant such as poly-brominated diphenyl ethers (PBDE) from the 1970s to solve the ignition problem (Wired News, 2004). The use of such flame retardants reduced the risk to death or injury caused by fire by 45% (Crenson, 2002). Nevertheless, studies have found an unexpected consequence as the result of the use of

[5] The difference of data is due to the difference of research methodology.

PBDEs. PBDEs contaminate many parts of the world with evidence in Sweden, Netherlands, Japan, and U.S. (Manchester-Neesvig, 2001). Additional evidence suggest that these compounds bioaccumulate and induce undesirable biological outcomes (ibid.). Besides, PBDEs has potential not only to form brominated dioxin/furan[6] with the inadequate treatment because of their similar chemical structure, but also to contain brominated dioxin/furan unintentionally in a product as impurities (IPCS, 1998). As a respond to environmental problems, brominated flame retardants are being substituted to non-halogen flame retardant or tetrabrombisphenol A, which is less hazardous and has lower potential of dioxin/furan contamination or generation (ETC/WMF, 2003 and IPCS, 1998).

2.1.3 Metals

The hazardous potential of steel/iron, which is used as a reinforcing band and shadow mask is quite low. Non-ferrous metals, on the other hand, such as copper used for deflection yolk, cables, conductors, and pigment in plasticsmay leach from landfill site and cause environmental problems (ETC/WMF, 2003). Similarly, various metals used in televisions such as tin, lead (in soldering), barium, arsenic (in semi-conductor), and mercury (in hidden battery or switches on circuit boards) may constitute severe environmental problems (ibid.).

2.2 Recycling of Television

The actual recycling starts from dismantling the colleted television. The main purposes of dismantling are to remove component containing hazardous materials and to separate valuable components in accordance with the requirement of the following treatment. This is quite costly since this process is labour intensive. From the environmental point of view, this process may contaminate soil through improper storage of WEEE (ETC/WMF, 2003) or may emit brominated dioxin/furan (MoE, 2003).

2.2.1 Cathode Ray Tube

Although the cheapest treatment option for a CRT glass is landfilling (ICER, 2004), it is inevitable to recycle it to achieve the recycling target[7] set by the WEEE directive of the European Union (EU) and the Japanese legislation, since a CRT comprises more than 50% of television weight as mentioned in Table 2.1.

There are not many recycling applications for CRT glass from disposed televisions since it is likely to contain substances, such as toxic metal oxides or strong colouring metal oxides, which hinders the recycling process to produce new glass (ICER, 2004, and Tanimura, 2004). However, there are two ways to treat leaded CRT glass. One option is to use it in manufacturing of new CRTs (ibid.). The production process remains almost the same regardless if the raw material is virgin material or mixed with recycled CRT (Tanimura,

[6] Polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/DF)

[7] The recycling targets for a television are 65% in the WEEE directive and 55% in the Japanese legislation. Details are mentioned later.

2004). This would thus be the best option as it can close the material loop. The other option is to use it as silica flux in a non-ferrous metal smelter (Samuelsson, 2004). An unleaded CRT glass has several more options other than two options mentioned above, such as mixing to bricks or tiles, using as flux in a brick or ceramic kiln, and forming glass for insulation (ICER, 2004).

Currently, there are a few companies existing, where collected CRTs are used in manufacturing process (i.e. Nippon Electronic Glass Co., Ltd. (NEG) in Japan, Schott Glas AG in Germany and a few more in Europe). According to Tanimura (2004), such recycling process works well from the technological point of view. However, since most television production shifts to China, or South-East Asia, there will be no demand for recycled CRTs in Japan within a few years. It is technically possible to implement the recycling technology in foreign factories, at least owned by NEG, although it would be more expensive to buy recycled CRTs from Japan than virgin materials even if the government of Japan and other importing countries[8] allow the international trade of hazardous waste (ibid.). The same difficulty can be seen in Europe (ibid.).

2.2.2 Plastics

According to the Institute of Scrap Recycling Industries in U.S., an appropriate plastic recycling programme can save energy use as shown in Table 2.3; although, plastic recycling is challenging because it has the exceptionally wide variety of polymers, grades, additives and contaminations, such as stickers. The particular obstacle to recycle plastics in a disposed television is that PBDEs may form brominated dioxin/furan because of the similar chemical structure (Tange, 2004). Several studies demonstrate that the mechanical recycling of plastics containing such flame retardants can meet the strict dioxin/furan regulation of the German dioxin ordinance (ibid.). However, it must be noted that it is very difficult to run the technologies on the factory scale (Yamawaki, 2004). In addition, there is a risk that the hazardous flame retardants may spread again by the mechanical recycling, because of the uncertainty on where/how the recycled products are treated when it becomes waste (ibid.). It is also reasonable to break down such hazardous substance with the potential of brominated dioxin/furan generation by feedstock recycling, which runs on a factory scale or thermal recovery when the substance is collected.

2.2.3 Metals

Metals are the easiest component to recycle in a scrap television since metal recycling from various sources is widely operated. Parts, which consist of steel/iron, go to steel maker for recycling, while parts, which consist of non-ferrous metal, such as circuit board are treated in non-ferrous smelter. Boliden AB in Sweden and Dowa Mining Co., Ltd. in Japan run such recycling programmes. Table 2.3 shows the energy saving of using recycled materials over virgin materials including plastics as one of the benefits of metal recycling.

[8] CRT glass is under the "red list" of the Basel convention. However, it depends on the state CRT glass and countries.

The non-ferrous smelter can treat almost everything containing in a television. For instance, plastics are used as a heat source, CRT glass is used as silica flux, and steel/iron is used as a reducing agent. In some cases, these processes may not be counted as recycling (Mitsuya, 2004).

Table 2.3 Energy saving of using recycled material over virgin materials

Materials	Energy Savings [%]
Aluminium	95
Copper	85
Iron and Steel	74
Lead	65
Zinc	60
Plastics	>80

(Source: ISRI, 2001)

Chapter 3: WEEE Management System

3.1 WEEE Management in Sweden

3.1.1 Roles and Obligations of Main Stakeholders under the Legal Framework

Sweden implemented the WEEE management legislation[9] on July 2001 to ensure the appropriate treatment for WEEE for the human health and environment. Table 2.1 represents the main roles and obligations for the main stakeholders under the Swedish legislation.

Table 3.1 Main roles and obligations under the Swedish WEEE management legislation

Stakeholder	Roles and Obligations
Consumers	Ø Consumers can return old products to retailers when they buy a product with the similar new products (old-for-new rule). Ø Household consumers can leave their WEEE to municipal collection points. Ø Business consumers are responsible to cover the expense to treat their WEEE except for old-for-new rule.
Municipalities	Ø Municipalities manage collection points for household consumers.
Producers*	Ø Producers have an obligation to cover the collection and treatment cost of WEEE. Ø Retailers, who is one of the producers have to accept WEEE from consumers using old-for-new rule Ø Producers have to handle collected WEEE adequately from the health and environmental point of view. Ø Producers must provide information to households about the collection system.

* The definition of producers includes manufacturers, importers and retailers in Sweden.

3.1.2 Collection of WEEE in Sweden

El-Kretsen is a monopolistic company, owned by 23 trade/industry associations, in the field of WEEE management in Sweden. The company is in charge of the collection and treatment of WEEE in order to fulfil the EPR for its affiliated members, which cover approximately 90% of the total sales of EEE in Sweden (El-Kretsen, 2004). Producers pay according to the actual cost within each sector such as IT, or television, audio, and video sector in addition to the entry and the annual fee. For example, television producers pay between 140 and 240 SEK (16-27 EUR[10]) for each television disposed depending on the size.

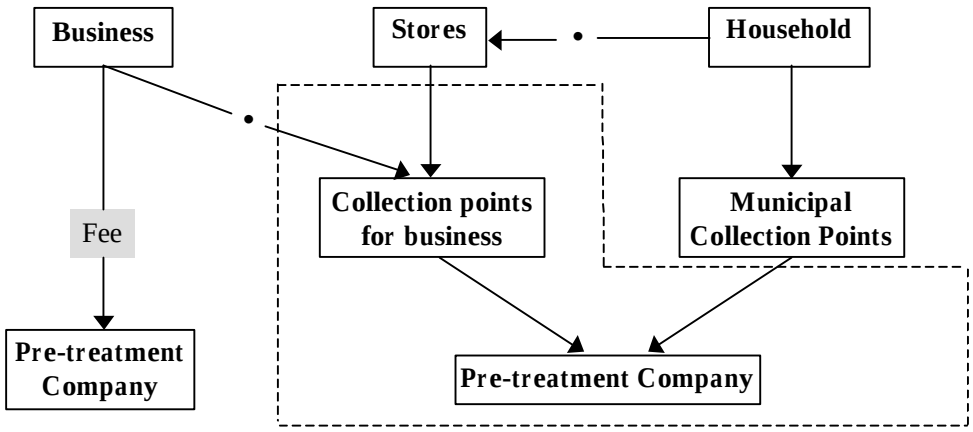
Their nation-wide collection and recycling system called "Elretur" is shown in Figure 3.1. Business consumers engage the services of a pre-treatment company to treat WEEE from their activities at their own expense or return such WEEE to EEE retailers when they buy

[9] Sections 21-25 of the Public Cleaning Ordinance (1998:902 amended 1 July 2001)

[10] With the exchange rate of 1EUR = 9.00 SEK (XE.com, 2004). The rest of paper employs the same exchange rate.

a new product with similar functions. The latter is known as the old-for-new rule. Household consumers either leave their WEEE to municipal collection points free of charge or they return it to electric stores using the old-for-new rule. Retailers have contracts with El-Kretsen to treat their collected WEEE as shown in Figure 3.1, while two retailers, OnOff and Siba, treat their collected WEEE at their own contracted pre-treatment company, which is not illustrated in the Figure 3.1.

El-Kretsen collects 90% of WEEE from municipal collection points, and 5% each from EEE retailers and the business consumers (Nyberg, 2004). Påhlman (2004) said roughly 23,000 tonnes of brown goods are sold annually in Sweden and El-Kretsen collected approximately 16,500 tonnes in 2002 and 2003. From this, it can be considered that small amount of second hand televisions are exported. Any estimation about export of second hand television in Sweden could not be obtained in this study.



• Old-for-new rule (Source: El-Kretsen, 2004)

* System within the broken line is organised and financed by El-Kretsen.

Figure 3.1 Swedish WEEE collection scheme -Elretur system-

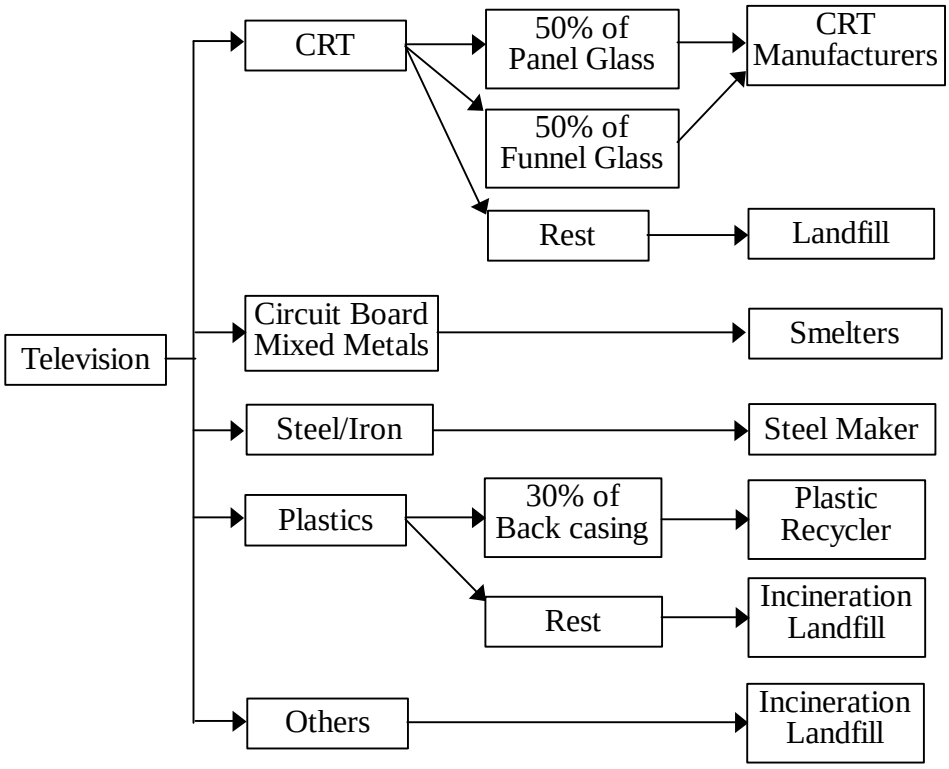
3.1.3 Current Television Waste Treatment in Sweden

Figure 3.2 shows the current television waste treatment in Sweden. Since there is no official recycling rate, estimated recycling rate based on the definition of the EU WEEE directive is calculated by the treatment method of El-Kretsen and the material composition data given in Table 2.1.

El-Kretsen recycles 50% of the panel and funnel CRT glass. A CRT, which covers 53% of total television weight. It is assumed that a CRT consists of 95% of funnel glass and panel glass and 5% of neck glass. Thus, the CRT recycling covers 25%[11] of total television weight. Almost all metals and circuit board, which consist 15% of television weight are recycled. Plastics comprise 26% of television weight. It is assumed that the rear casing covers 80% of total plastic weight. El-Kretsen recycles 30% of rear casing plastics. This is the proportion of 6%[11] to television weight. In total, Sweden recycles approximately

[11] These figures are from the calculations of: 53% * 95% * 50% = 25%, 26% * 80% * 30% = 6%, and 25%+15%+6%= 46%.

46%[11] of the collected television waste.



(Source: Nyberg, 2004)

Figure 3.2 Major television waste treatment in Sweden

3.2 WEEE Management in Japan

3.2.1 Roles and Obligations of Main Stakeholders under the Legal Framework

Japan implemented WEEE management legislation[12] on April 2001 to recycle and treat four major electrical equipment wastes namely air-conditioners, televisions, laundry machines, and refrigerators (including freezers). Table 3.2 represents the main roles and obligations of the main stakeholders under the Japanese legislation.

3.2.2 Collection of Television Waste in Japan

Producers in Japan formed two alliances to comply with the legislation. 19 producers, which are led by Matsushita/Panasonic, Toshiba formed the alliance known as A group[13], whereas the other 21 producers, which feature prominent companies such as Sony, Hitachi etc. enter into the alliance known as B group[13]. The A group has the tendency to utilise existing recycling factories and existing waste transport networks. On the other hand, the B group has set up many new pre-treatment plants and WEEE transport networks (Haneda, 2003). However, all the outstanding producers in both groups establish or manage at least one pre-treatment plant by themselves in order to collect data on recycling and other issues (ibid.).

[12] The Law for Recycling of Specified Kinds of Home Appliances (No.98 , 1998)
[13] A and B group are serviced by Ecology Net and Recycle Station, respectively.

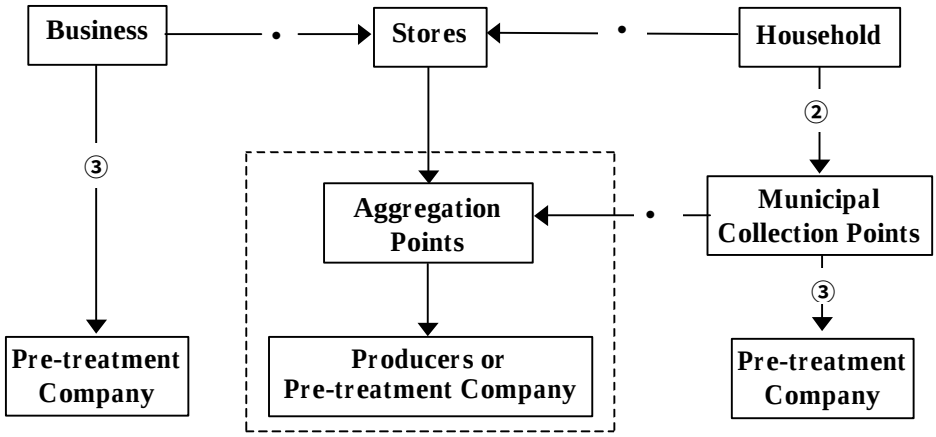
Table 3.2 Main roles and obligations under the Japanese WEEE management legislation

Stakeholder	Roles and Obligations
Consumers	Ø Consumers have to cooperate with the collection of their WEEE to retailers. Ø Consumers have to agree paying the pre-treatment fee, known as the "recycling fee"[14]. In addition, consumers are often charged transportation fee. This depends on retailers. Ø Business Consumers can either bring WEEE to retailers with the pre-treatment fee or treat WEEE as industrial waste at their own expense.
Retailers	Ø Retailers have an obligation to accept designated WEEE on the request of consumers. Ø Retailers have an obligation to transfer accepted WEEE to the producers' aggregation collection points. It depends on retailers whether they charge consumers for transportation cost.
Producers*[1]	Ø Producers can charge consumers the appropriate fee for efficient pre-treatment. Ø Producers are obliged to take back their products at their aggregation collection points from retailers. Ø Producers have to achieve the recycling target set under the legislation.
Municipalities	Ø Municipalities can transfer designated electrical waste to producers' aggregation collection points by paying the pre-treatment fee. They can charge their citizens for the treatment. Ø Municipalities can treat designated electrical equipment waste by themselves[*2].

*1 The definition of producers includes manufacturers, importers in Japan.
*2 Amount of WEEE collected by municipalities is very small comparing with producers' collection (METI, 2003). (Source: METI, 1999)

Figure 3.3 shows WEEE collection scheme in Japan. Business consumers either engage the services of a pre-treatment company to treat their WEEE at their own expense or return their WEEE to EEE retailers with the payment of the pre-treatment fee. Household consumers bring their WEEE to retailers with the payment of the pre-treatment fee. Then, retailers have the obligation to transport collected WEEE to the producers' aggregation collection points. Some municipalities, mostly in rural areas, take care of WEEE from households. In such cases, pre-treatment fee is dependent on municipalities, which either engage the services of pre-treatment company at their own expense or return them to aggregation points with the payment of the pre-treatment fee. It is the producers' responsibility to take care of the collected WEEE from their aggregation collection points

[14] This paper employs a term "pre-treatment fee" because the fee only covers collection and pre-treatment cost.



① Households, municipalities, and businesses pay the pre-treatment fee, 2,835 JPY (21 EUR[15]).
② It depends on municipalities whether it collect, how much it charges, and how to treat.
③ Fee is dependent on cases.
*, System within the broken line is organised and financed by producers. (Source: METI, 1999)

Figure 3.3 Japanese WEEE collection scheme

Table 3.3 Number of television put on the market and treaded in Japan [1,000 units]

	Before*	2001	2002	2003
Put on the Market	-	9,631	8,433	7,162
Treated	4,556	3,083	3,520	3,550

* Reference does not mention exact year, but only "before the legislation"
(Source: JEITA, 2004, and METI, 2001b, 2002a, 2003, and 2004)

Table 3.3 shows the number of televisions put on the market and the number of treaded television waste in Japan. Annual television sales in Japan were approximately 9 million (JEITA, 2004); however, the sales of CRT televisions have decreased since 2001 because flat panel display (FPD) televisions, such as liquid crystal display and plasma display panel televisions have arisen. FPD televisions took 17% of total television market in 2003 and it is estimated that FPD televisions will overtake CRT televisions by 2006 in Japan (Kyodo News, 2004). This implies that other television waste problems would occur in the near future.

Table 3.4 shows the estimated number of televisions that reached their end of life (EoL) and their fate. The difference between the numbers of televisions put on the market and of collected televisions is obvious. It is estimated that only 38% of total television reaching EoL was collected under the legislation, whereas the other televisions that reached to the EoL were illegally dumped, exported as second hand, or treated by pre-treatment companies, which are not designated by producers[16]. (This estimation excludes the domestic second hand market (Moriguchi, 2004)).

[15] With the exchange rate of 1EUR = 137 JPY (XE.com, 2004). The rest of paper employs the same exchange rate.
[16] This is legal as long as they comply with the waste treatment low (No.68, 1976, last amendment No.93 in 2003).

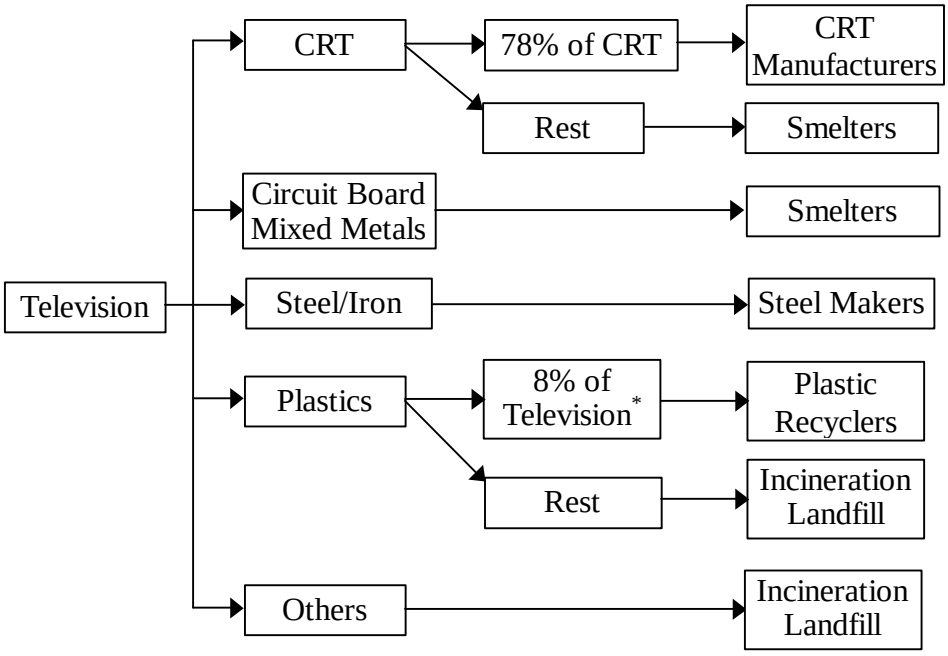
Table 3.4 Estimated number of television reached EoL and its fate on 2001 in Japan

EoL Television	8,020 thousand units
Collected under the legislation	38%
Exported as a second hand	53%
Reported illegal dumping	0.9%
Pretreatment companies*	0.7%
Municipal Treatment	0.5%
Unknown	6%

* "Pre-treatment companies" means the companies, which are not designated by producers.
(Source: Moriguchi, 2004)

3.2.3 Current Television Waste Treatment in Japan

Figure 3.4 represents the major manner of WEEE treatment in Japan (METI, 2004a). In 2003, Japan achieved a 78% recycling rate[17].



(Source: METI, 2002a and 2004)

* It is assumed that "other recycled material" on the document from METI is mostly plastics because it mentions other major material such as glass, iron, aluminium, copper, and mixed metals.

Figure 3.4 Current major television waste treatment in Japan

3.3 Main Differences of the Swedish and Japanese WEEE Legislation in Comparison with the WEEE Directive of the EU

After years of discussion, the WEEE directive (2002/96/EC) became effective on February 13, 2003. Member states have to bring into force the legislation to comply with the directive by 13 August 2004 although none of the member states except for Greece and Portugal managed to bring into force the new legislation at the time of writing (Waste

[17] By the definition of recycling under the Japanese legislation

Management World Magazine, 2004 and Raymond Communications, 2002). Although Sweden already has the legislation to treat WEEE, it still has to amend the ordinance to adapt the WEEE directive. The Japanese legislation, needless to say, has the differences from the Swedish legislation and the WEEE directive. This section is to explain the major differences of the Swedish and Japanese WEEE legislation with respect to the WEEE directive.

Recycling Rate and Target

Current Swedish legislation does not state any definition of recycling or the target; on the contrary, the WEEE directive and Japanese legislation stipulates both of them. In the WEEE directive, recycling means mechanical recycle to the original purpose or to other purposes, but excluding energy recovery. While recycling rate does not count feedstock and thermal recycling, "recovery rate" includes two of them. The directive classifies WEEE into 10 categories and puts the television under the "Consumer equipment" category. The category shall achieve the recycling target of 65% and recovery target of 75% by an average weight per appliance by 31 December 2006. In the Japanese legislation, recycling rate includes the mechanical recycling or reusing parts/materials removed from WEEE, which transaction has positive monetary flow[18]. Recycling target for television was set to 55% and Japan achieved a recycling rate of 78% on 2003 as mentioned section 3.2.3 (METI, 2004a).

Pre-treatment fee

It is allowed that producers charge consumers for their pre-treatment to recycle WEEE in Japan, whereas in both the current Swedish legislation and the WEEE directive, producers are required to take back WEEE from the consumer without any charge and they can implement their own incentives.

Product Categories

The WEEE directive and the Swedish legislation cover almost all of the EEE and incorporate almost the same product categories. However, the refrigerator and freezer is under the municipalities' responsibility under the current Swedish legislation[19] and the WEEE directive excludes the light bulb. On the other hand, the Japanese legislation, "the law for recycling of specified kinds of home appliances" only covers four major EEE such as the air-conditioner, television, laundry machine, and refrigerator (including freezer), as mentioned section 3.2. However, PC producers has set up voluntary collection and treatment scheme since October 2003, under "the law for promotion of effective utilization of resources", which is to promote recycling, the use of recycled materials, and the cleaner production. This law also requires voluntary collection and the recycling of secondary batteries as well as PCs.

[18] If pre-treatment facilities sells dismantled component, the weight of dismantled component is counted in recycling rate.

[19] Producers take the responsibility of other WEEE, which means they pay for the collection and pre-treatment.

Collection Target

There is no target for the collection of WEEE under neither the Swedish nor the Japanese legislation. However, EU WEEE directive sets the collection target of 4kg per inhabitant. For reference, Sweden collected 9 kg per inhabitant of WEEE in 2003 (El-Kretsen, 2004) and Japan collected 3kg per inhabitant of four designated home electric waste on 2003[20].

Definition of Producer

The definition of Producer under the WEEE directive and the Japanese legislation is the manufacturers and importers, while the current Swedish legislation include retailers as well as the two mentioned above.

[20] According to METI, Japan collected 372,821 tonnes of four designated home electric waste. 3 kg is calculated from collected waste divided by 127 million, the population of Japan at September 2004 (2004).

Chapter 4: Analysis

4.1 Introduction

This analysis employs the systems thinking approach. The building of causal loop diagrams (CLDs) is to understand the principle factors in the WEEE management systems both in Sweden and Japan. A CLD is a conceptual model to show how different factors and variables interrelate within a system. Due to its nature as a conceptual model, a CLD cannot represent the variables in quantifiable manner. To aid the comprehension of a model, a positive or negative relation between two factors connected by an arrow is denoted by either "+" or "-", respectively. An example of a positive "+" relation is that if sales increases/decreases, then revenues would also increase/decrease as shown below. In contrast, "-" next to the variable express the opposite relationship between the two such as that more product sales decreases product inventory[21].

(Source: Bellinger, 2004)

4.2 Causal Loop Diagram Analysis for the Present Situation

The CLD shown in Figure 4.1 illustrates the present WEEE management systems in Sweden and Japan. One can begin by viewing at the upper part of Figure 4.1 where the change in demand for televisions reflects the production of televisions. Conversely, more production leads to less demand. The amount produced equals to amount of television reaching EoL in long term. There are three different routes for televisions reaching their EoL. Thereafter, the television might be 1) pre-treated, 2) illegally dumped, or 3) reused (which indicates the amount being sold to second hand shops). As a consequence of these actions taken by consumers, the amount of television reaching EoL decreases. Parts generated by the pre-treatment of WEEE are then brought to landfill sites or recycling facilities and this would result in the reduction of the amount collected for pre-treatment. The recycling target represents mandate-recycling rate existing in Japan. The threat that the recycling target might increase in the near future encourages recycling. The arrow at the left side of "reuse" demonstrates the lifespan extending effect due to reuse of television reaching to EoL. Longer lifespan of televisions diminish the amount of televisions reaching EoL by restraining the demand for televisions. The pre-treatment fee located at the lower centre part of the model plays as an economic incentive to increase reuse, and illegal dumping because consumers may try to avoid paying the pre-treatment fee, but this reduce the amount of pre-treatment as a result of the increase in the two former options. The economic incentive also extends the lifespan of televisions since consumers hesitate to pay both the price of a new television and the pre-treatment fee.

These four consequences of the pre-treatment fee can be seen in reality in Japan. Firstly, the amount of WEEE collected decreased after the legislation, which introduced the pre-treatment fee as mentioned in section 3.2.2. Such decrease in the amount of WEEE

[21] Further explanation about systems thinking is available at http://www.systems-thinking.org.

collected lessens the efficiency of pre-treatment factories. According to Takegahara, a pre-treatment plant needs to run at 50-60% of its capacity in order to make profit (2001). The operation rate of pre-treatment plant is currently slightly higher than the break-even point (Mitsuya, 2004). For example, METEC[22] and NKK Trienekens[22] operated at 56%, and 50-60% of their capacity, respectively in 2001 (METEC, 2004 and G-west, 2001). Thus, there is a potential to be more profitable if more WEEE is colleted. Secondly, after the introduction of the pre-treatment fee, Japan has experienced the increase in the number of illegal WEEE dumping, especially televisions, as Table 4.1 shows. Since the social cost of such illegal dumping, which is to clean up and to investigate the dumper is considerably high, it is necessary to take measures against illegal dumping.

Table 4.1 Number of reported WEEE illegal dumping in Japan

	2000	2001	2002	2003
Illegally dumped TV	11,777	63,471	77,149	88,331
Per 100,000 residents	42.9	55.2	67.1	70.7
Investigating Municipalities	279 (22%)*	2,743 (90%)	2,743 (90%)	3,110 (99%)

* Number within brackets represents proportion to the total population in Japan. (Source: MoE, 2004c)

Thirdly, the second hand market for EEE has expanded especially after the implementation of the law (METI, 2002a). Due to the high pre-treatment fee, the number of EEE retailers with the second hand dealing license[23] has increased as well as second hand shops chain (ibid.). The export of second hand television additionally increased after the implementation of the law (Moriguchi, 2004). This might be a favourable trend caused by the Japanese legislation since this reuse would eventually cut the total amount of televisions reaching EoL as shown in the model. However, the treatment of WEEE including the export of second hand televisions from Japan can be very poor in importing countries. Several investigations (BAN, 2001 and Greenpeace China, 2004) revealed the poor recycling of imported WEEE and its dissembled component from developed countries in developing countries of Asia. This will be discussed later in section 4.4. Finally, it has been shown that the average lifespan of collected televisions has increased from 11.8 to 12.5 years from 1997 to 2003 as a consequence of pre-treatment fee (METI, 2004a).

On the contrary to Japan, there is no pre-treatment fee implemented in Sweden. The amount of television reused and illegally dumped could not be obtained in this study. However, it can be considered that the amount of illegal dumps is very small. The reason is that the collection rate is quite high as mentioned in section 3.1.2. Furthermore, there is no incentive for households to illegally dump their old television in Sweden, since it is free to dispose it at the municipal collection points, which are usually closer than areas suitable for illegal dumping. The pre-treatment fee being an economic incentive for illegal

[22] METEC in Hyogo, the west part of Japan is owned by Panasonic/Matsushita. NKK Trienekens in Kanagawa, the east part of Japan is owned by Mitsui, NKK, and Sanyo.
[23] The secondhand dealing licence is required to do the secondhand business in Japan.

dumping can be seen in case of WEEE from business in Sweden. Some companies dump their industrial machine waste such as a lathe, which they have to pay the pre-treatment fee, on municipal collection points[24] (Nyberg, 2004). This is illegal dumping, yet the social cost of this illicit dumping is quite low. If businesses dump televisions on municipal collection points, El-Kretsen does not know if a disposed television is from households or businesses unlike industrial machines (ibid.).

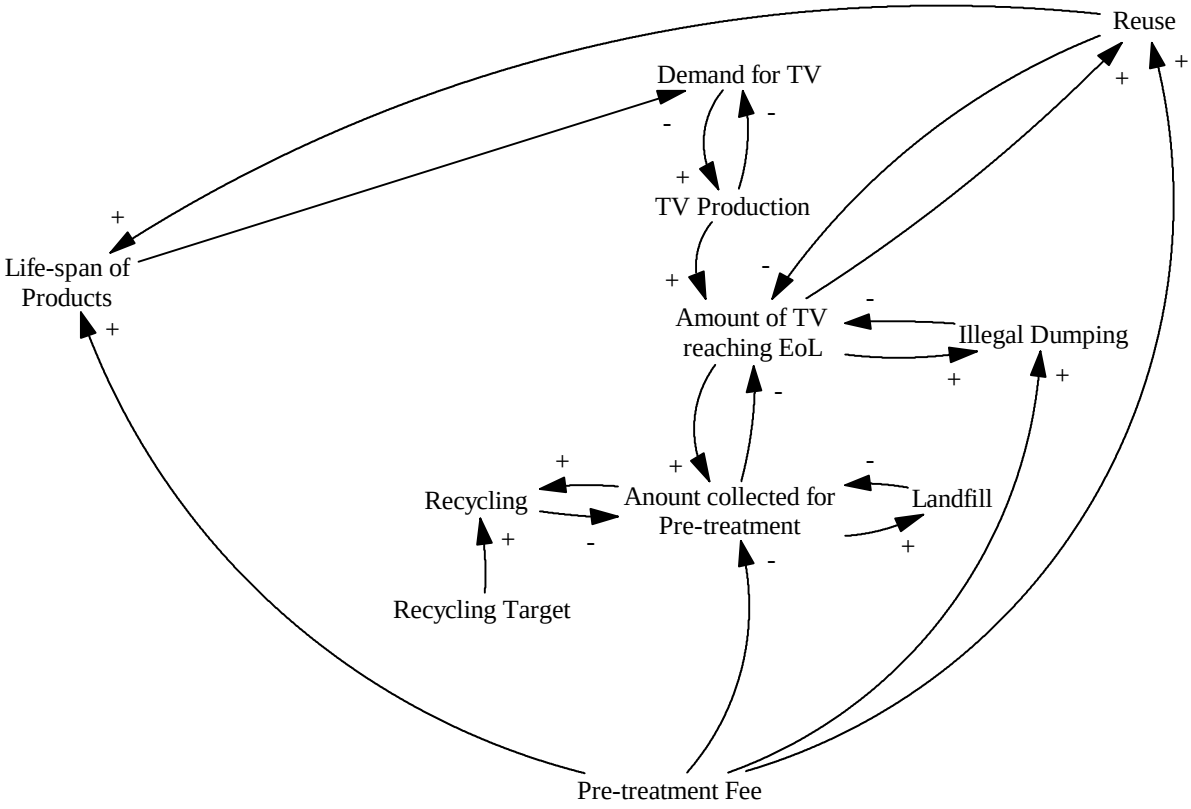


Figure 4.1 Causal loop diagram for the present situation of WEEE management

Another difference between the Swedish and Japanese WEEE management systems is the recycling targets. While the Japanese legislation encourages recycling by setting a recycling target, which is represented in Figure 4.1, Swedish one does not have any. As a result, Sweden has a lower recycling rate as mentioned in section 3.1.3. One important issue is that higher recycling rates are not always better. To give an example, a recycling process may consume more resource than conventional process from the life-cycle viewpoint. However, this recycling process might be driven if the unreasonable recycling is necessary to meet the recycling target. This paper does not discuss further in this issue and presumes recycling as better management than landfilling in accordance with a hierarchy of preferred waste management, which is set by European Commission (2001) and Ministry of Environment, Japan (1999) as shown below:

1. Prevention of Waste
2. Reuse
3. Recycle

[24] In such a case, El-Kretsen claims a bill to a municipality for the pre-treatment cost (Nyberg ,2004)

4. Energy Recovery
5. Optimum Final Disposal and Improved Monitoring

(Source: EC, 2001 and MoE, 1999)

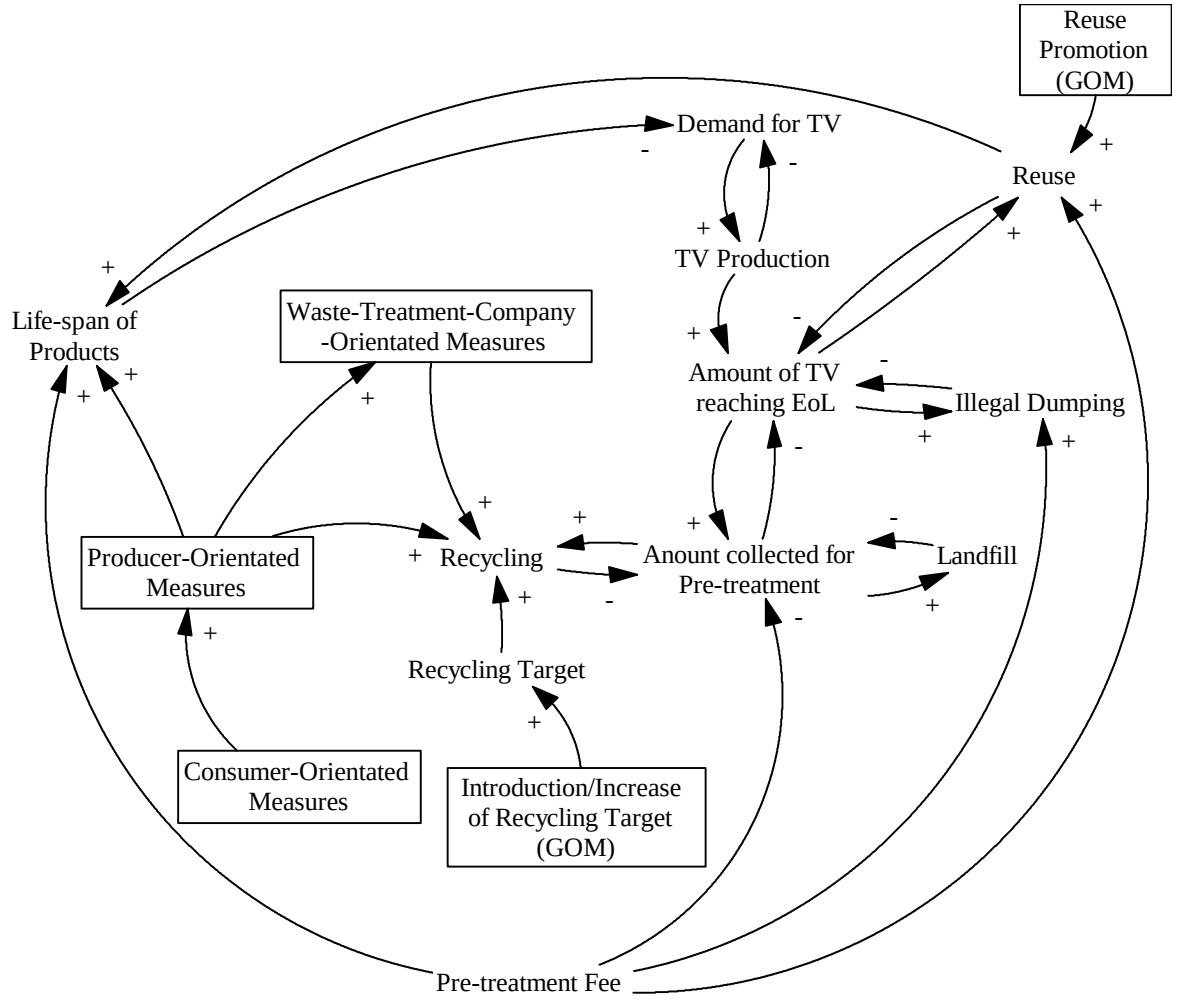
One of the problems in the WEEE management systems in both Sweden and Japan is that there are no measures to prevent the generation of television reaching to EoL except for pre-treatment fee, which encourages illegal dumping in Japan, as well as reuse. Nevertheless, both the EU and Japan has set the prevention of waste and reuse as the two highest position of the preferred hierarchy of waste management. Hence, the WEEE management systems in Sweden and Japan would improve through taking measures to diminish the amount of television reaching EoL, and measures to minimise illegal dumping in the case of Japan.

4.3 Causal Loop Diagram Analysis for the Measures to Improve WEEE Management

A CLD incorporating possible measures to improve the existing WEEE management systems in Sweden and Japan is shown in Figure 4.1. Furthermore, the diminution of the pre-treatment fee is discussed as a part of government-orientated measures. Measures in this section are mainly discussed for the television; however, most measures have the same effect on other types of WEEE.

4.3.1 Producer-Orientated Measures

Producer-orientated measures, which are represented in left-hand side of Figure 4.2, are the ultimate solution to minimise environmental problems of WEEE in the long term. Examples of the measures are to enhance the hazardous material substitution (not illustrated in the model), the durability (demonstrated by an arrow from "producer-orientated measures" to "lifespan of products") and the recyclability (represented by an arrow from "producer-orientated measures" to "recycling"). Prolonging the lifespan of the product would reduce the amount of television reaching EoL through the restraint of demand. However, it takes a long time to see the effectiveness of these measures, which is demonstrated as double crossed lines on the arrow from producer-orientated measures to recycling. Another producer-orientated measure is the cooperation of producers with WEEE treatment companies to increase the recycling. However, this driving force might be weak in Sweden. The reason is that it is not easy to influence the WEEE treatment method of El-Kretsen since the company monopolises the WEEE management market in the country (Wendschlag, 2004). The other concern on the measures is that the measures need to be driven by green consumer expectations, and current and future legislations related to WEEE problems, because if not, producers have little cause to implement measures. The followings are examples of producer-orientated measures such as the changing design and material substitution.



* A variable in a box and a dot line indicate the influence of measures
"(GOM)" stands for government-orientated measures.

Figure 4.2 Causal loop diagram for the measures to improve WEEE management

Design for Environment

It is important to enhance the recyclability, reusability as well as the durability since those would, in the long run, reduce environmental impacts caused by WEEE.

- Ø It increases the recyclability of plastics by using limited kind of plastics and marking used plastic/grade/flame retardant/pigment.
- Ø Anonymous EEE producer halved number of screw on the casing of a television (METI, 2002c). This makes the disassembling process of television easy and quick.
- Ø One of the prospective technologies helping dismantling is the active disassembly smart material (ADSM). The technology employs shape memory materials for the disassemble easiness (Warburg, 2001)[25]. ADSM technology is still on an experimental stage. Hence, further research is still necessary for the commercial application.

[25] A casing/fastener made of shape memory material change its form to disassembly when it reaches the transformation temperature (Warburg, 2001). Many articles are available (Chiodo, 2000, and Wiendahl, 2001)

Hazardous Material Substitution

Substitutions of polychlorinated biphenyl (PCB) and chlorofluorocarbons (CFC)[26] are good examples to show the possibility to replace hazardous materials by technological development. it is possible to replace hazardous materials used in EEE as well.

Some of the examples in this area are given below;

- Most of PBDEs, a brominated flame retardant, is replaced by tetrabrombisphenol A or non-halogen flame retardants.
- Lead alloy soldering can be replaced by other metal alloy. Panasonic is the first company, which implemented non-lead soldering for all of their products (Panasonic/Matsushita, 2003).
- Lead in a panel glass can be replaced by other metals.
- Chrome fluorescence agent can be substituted by the non-chrome one (Toyo gosei, 2004).

However, one of the obstacles with substituted materials is that the new material might cause other environmental problems. A good example is that the substitution of lead alloy soldering to bismuth alloy soldering resulted in difficulties in the recycling process on smelters, because bismuth is difficult to separate from copper, which is major metal in WEEE (Mitsuya, 2004).

4.3.2 Consumer-Orientated Measures

Consumer-orientated measures such as green consumer behaviour can be very strong driving forces to push producer-orientated measures through representing their eco-friendly demand. Producers would promote producer-orientated measures under the pressure of the green consumer. The arrow from "consumer-orientated measures" in Figure 4.2 demonstrates the driving forces to pressurise the producer to take action. However, Tojo (2004) pointed out that the pressure to take measures for WEEE problems is very low against EEE manufactures in Japan but not EEE manufacturers in Sweden. Thus, this pressure ought to be encouraged, especially in Japan. The followings are concrete examples of consumer-orientated measures:

Green Consumer Behaviour

Green consumer behaviour can be very strong engine to reduce the environmental impacts caused by EEE. Examples of green consumer behaviour are listed below:

- To buy long lifespan products
- To buy products with less harmful chemicals
- To buy products with the decent recycle system
- To buy products of eco-friendly company
- To utilise the leasing service

It is essential that consumers should be informed about the environmental issues related to what they buy and the fact they can change producers' attitude through their consumption pattern. Eco-labelling by the third organisation can help consumer's decision through

[26] Both PCB and CFC were widely used, but they are not totally substituted (Miller, 2004).

providing comparable performance information, such as the hazardous material substitution, the recyclability and the durability of products.

Choice of leasing system, which does not sell a product but a service, is one of the consumer-orientated measures. The system is very common on the copy machine market. Since the producer reserves the property right of the copy machine in use, it is in the interest of the producer to extend the lifespan of product and to reuse its parts. In the field of domestic electrics, Thorn in Sweden and Toshiba in Japan do the EEE leasing business, nevertheless leasing prices are quite expensive comparing with the prices of new same/similar products[27].

4.3.3 Waste-Treatment-Company-Orientated Measures

Even though both Sweden and Japan have established the decent management systems for WEEE (Tojo, 2004), the treatment stage has two major problems such as the plastic recycling difficulty due to flame retardants and other contaminations, and the lack of wasted CRT application as mentioned earlier in Chapter 2. Regarding dismantling, which is one of most costly process in the WEEE treatment, the research on the use of robots are examined to dismantle WEEE and applied in some cases (Kopacek, 2002). However, there are many difficulties to use a robot, as the variety of WEEE is significantly high. ADSM technology also helps the dismantling process if implemented as mentioned in section 4.3.1. Through the improvement of waste management, recycling would be facilitated as demonstrated at lower centre of the model.

4.3.4 Government-Orientated Measures

There are several ways for governments to be involved in WEEE management issues as well as other environmental problems. This section presents three government-orientated measures (only two of them are illustrated in Figure 4.2):

Reuse Promotion

An arrow from "Reuse promotion (GOM)" at upper right hand side of the model represents the force to boost the reuse option as a reuse promotion policy. With the promotion of the reuse option, the amount of televisions reaching EoL would be reduced through the restraint of demand as mentioned above. There are some examples of refurbish service for PCs in Japan and Sweden. Below is a list of policy options for the reuse promotion;

- Governments can organise a campaign to inform consumers about second hand market as means to sell and to buy.
- Governments can subsidise for refurbishment business/research.

[27] Thorn lease a 25-inch television for 279 SEK (31 EUR) per month, while the exactly same television costs 4790 SEK (530 EUR), which means 17-month rental cost is enough to buy new television (Prices are checked on http://www.thorn.se and www.siba.se at 10 November, 2004). In Japan, Basic leasing set, which consists of a 15-inch television, a microwave, a refrigerator, and a laundry machine, costs 4,725 JPY (35 EUR) per month, whereas, it costs around 70,000 JPY (510 EUR) to buy new similar products, which means 15-month rental cost is enough to pay the price of new products (Prices are checked on www,yodobashi.com at 29 October, 2004).

- Japan can facilitate reuse options through promoting second hand dealing license on EEE retailers, where consumers can leave their old EEE. Then, retailers can decide if the EoL products can be sold as second hand. This can prevent the pre-treatment of reusable EEE. Although retailers collect small amount of WEEE in Sweden, this policy would have the some effect. Reusable EEEs would lose their value if they are collected at municipal collection points in Sweden, because municipal collection points are similar to dumpsites.

Introduction/Increase of Recycling Target

This measure is represented as "Introduction/increase of recycling Target (GOM) in Figure 4.2. The increase of recycling rate can be achieved if it is mandatory. However, one should consider if it is reasonable from the economic and environmental aspects. Recycling targets accelerates the development of recycling technology and design for recycling. The threat of introduction/increase of recycling target alone also accelerates the developments of recycling technologies. In Sweden, the WEEE directive and the EU restriction of hazardous substance directive (2002/95/EC) plays the threatening role. The legislation revision planned in 2008 plays the same role in Japan.

Reduction of Pre-treatment Fee

This section is only to discuss in the context of Japan since the country has the pre-treatment fee. The reduction of pre-treatment fee would have a great impact in the EEE material flow in Japan as four arrows follows from "pre-treatment fee" as represented in Figure 4.1. The reduction of pre-treatment fee would decrease illegal dumping, reuse, and lifespan of products, but increase the amount WEEE collected for pre-treatment. Even though the diminution of pre-treatment fee might cause the cut in lifespan and the contraction in second hand market, consideration must be given to the adverse impacts of illegal dumping in terms of social costs and the environment damages, as there are significant advantages to diminish the pre-treatment fee in order to eliminate illegal dumping. The reduction of pre-treatment fee would result in higher efficiency in pre-treatment plants through the increase of WEEE collected. Considering the income cut for pre-treatment plants due to the reduction of pre-treatment fee, it might be necessary for producers to finance pre-treatment plant, which eventually puts the pre-treatment cost on the prices of new products. Putting the pre-treatment cost on the prices of new products would give rise to positive consequences in terms of the environment, such as the restrain of demand, the extension of lifespan, and the competition to minimise the pre-treatment cost as well as to maximise the profit from selling dissembled component from WEEE.

It is very controversial to fix adequate positive/negative economic incentive for waste treatment. In order to eliminate illegal dumping, some studies suggest deposit-refund system (Fullerton, 1996 and Sigman, 1998). The negative pre-treatment fee or refund would make the collection rate high; yet, it might not be suitable because Sweden can achieve the high collection rate without deposit-refund system. The cost-benefit analysis done by Turner (1994) suggests that a deposit-refund system does not create social benefit and is not economically efficient except for high hazardous materials such as car batteries

and engine oil. If there is no pre-treatment fee, the positive effects of pre-treatment fee are lost such as the promotion of reuse market as mentioned above. On the other hand, if the pre-treatment fee is low enough to make illegal dumping unattractive compared with actual cost of illegal dumping and the threat of enforcement, it could minimise illegal dumping while remaining the effectiveness as a reuse promotion. Therefore, it might be beneficial to reduce the pre-treatment fee to appropriate level.

According to the WEEE treatment legislation[28] in Japan, each producer fixes the appropriate pre-treatment fee. However, the government should require producer to reduce pre-treatment fee on grounds that the fee encourages illegal dumping.

4.4 Export of Second Hand EEE

As mentioned in section 4.2, estimated 53% of EEEs reaching their EoL in Japan are exported as second hand. According to the government of Japan, these second hand EEEs from Japan have quite a high value in importing countries (METI, 2002b). Such EEE are used for quite long time with repair (ibid.). However, Greenpeace China and Basel Action Network (2004) found various kinds of WEEE[29] including complete old products as well as new ones, with Japanese, South Korean, American, and European labels at "recycling" region in China. This indicates that some of export second hand ends their life cycle without reusing. In order to prevent recycling, especially in inadequate manner without reusing, the institutions in importing countries and Japan collaborate to control second hand trade. For instance, they can issue permission of international second hand trade only for a well-controlled and compliant company. They can also regulate the age of second hand products.

However, the main problem is inadequate recycling and treatment in developing countries rather than export of reuse. Greenpeace China (ibid.) and Basel Action Network (2001) revealed that there are many WEEE from the domestic as well as from developed countries. This implies that even if developed countries bans export of second hand EEE and WEEE[30], pollutions caused by improper recycling will not end. A similar case of this is that international trade of scrap of secondary lean battery has been reduced to very small amount since the implementation of the Basel convention, which require strict control on international trade of hazardous waste. Nevertheless, lead smelters, especially small-scale plants in developing countries continue causing pollution by using collected lead battery from the domestic and virgin materials (METI, 2004b). Hence, the solution for the problem of improper treatment of exported second hand EEE from Japan is not only a strict control on international trade, but also environmentally sound treatment technology transfer to developing countries.

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[28] The Law for Recycling of Specified Kinds of Home Appliances (No.98 , 1998)

[29] Imports of WEEE into China have been forbidden for several years and export of electronic waste without Chinese permission is also illegal in Japan[29](Hopkins, 2004). However, properly treated component of WEEE can be exported. This paper does not discuss the problems of such case.

[30] Export/import of WEEE is already forbidden by the Basel convention if the country ratifies.

Chapter 5: Conclusion

This paper examined the Swedish and Japanese WEEE management systems using the comparative analysis with the focus on the television and analysed those two systems by using the systems thinking approach. As described, the legislations in both countries have been implemented without big problems. However, further measures ought to be taken in order to minimise the environmental burden caused by WEEE. Several findings are listed below.

1. Pre-treatment fee in Japan plays an economic incentive to increase reuse and the lifespan of products but facilitate the illegal dumping and hinder WEEE collection for pre-treatment.
2. Swedish WEEE management system achieves a higher collection rate than the Japanese system due to the absence of pre-treatment fee and proper collection system.
3. Japanese WEEE management system achieves higher recycling rate than the Swedish system due to the mandatory recycling target.
4. Both the Swedish and Japanese WEEE management system do not have generation restrain measures such as reuse promotion, product levy except for pre-treatment fee, which encourage illegal dumping in Japan.

The followings are a summary of the recommendations:

1. Producer-orientated measures, such as the design for environment are the ultimate solution for WEEE problems; however, this measure needs inducements, such as to meet consumer demand or to comply current/future legislations related to WEEE problems.
2. Consumer-orientated measures such as green consumer behaviour are strong driving forces that can accelerate producer-orientated measures. Eco-labelling by a third organisation can help consumer decision through providing information about environmental performance of products.
3. Waste-treatment-company-orientated measures, such as pre-treatment/recycling technology development can increase recycling. The measures would be accelerated through the cooperation with producers.
4. Reuse promotion policy, as one of the government-orientated measures can diminish the amount EEE reaching EoL through the demand restraint.
5. Introduction/increase of recycling target encourage recycling; however, it should be within reasonable economic efficiency and environmental standards.
6. Reduction of pre-treatment fee in Japan is a very important measure to minimise illegal dumping and enhance the operation efficiency of pre-treatment facilities through the increase of collected WEEE; although the measure reduce the effects of reuse promotion and of lifespan expansion.
7. A strict control on international trade of second hand EEE and WEEE and a support to treatment plants ought to be taken in order to eliminate tragic pollution caused by WEEE in developed countries.

WEEE is notably heterogeneous and complex waste in terms of size, component and

materials. Furthermore, recent rapid technological development accelerates not only WEEE generation, but also types of WEEE. Thus, future research can focus on restraining WEEE generation and minimising the environmental impacts of WEEE with consideration to the aspects of society, technology and economy.

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