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PET Bottle System in Sweden and Japan:

an Integrated Analysis from a Life-Cycle Perspective

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Abstract

In the course of economic activities based on mass-production/consumption/disposal, total amount of solid waste has increased rapidly. Among them container and packaging wastes provide a significant share. PET (Polyethylene terephthalate) bottle is recently invested packaging; however the market share of it has expanded dramatically. Each country is seeking a sustainable PET bottle system. The idea of sustainability must consider the interplay of social, economic and environmental aspects with integrated and long-term perspectives. This study will analyze in an integrated manner, the best alternative system to improve the product system better through comparing the PET bottle life-cycle system in Sweden and Japan.

In Sweden two types of PET bottles (refillable and one-way bottle) are distributed. Industry managed the PET bottle cycle system based on a deposit refund system. Consumers take back consumed PET bottle to retailers and beverage companies collect them and transport to the recycling plant. Meanwhile, in Japan, only a one-way PET bottle is distributed without a deposit system. The Japanese PET bottle cycle system is based on three actors – consumer, municipality and industry. Industry is able to achieve their recycling responsibility to pay the recycling fee. The municipality has responsibility for sorted collection and transport from consumers to recycling plant.

The analysis shows each country has different material and financial flow, and outcome is also different. As an environmental aspect, Swedish refilling system contributes to source reduction; the recycling rate is one of the highest rates in the world. In Japan, the recycling rate has rapidly increased, but the waste PET bottle treated in landfill or incineration is still significant due to the expanding total consumption of PET bottles. Furthermore, the miss match of recovered PET bottle and recycling capacity cause scramble for waste PET bottle. As for economic aspects, increasing PET bottle consumption and recycling raise the cost of industry in Swedish system. Meanwhile in the Japanese system, increasing PET bottle consumption and recycling drives increasing the cost of municipality and reduces the costs for industry. As for social aspects, it could be said that Swedish system is more consumers-friendly rather than the Japanese system. Referring examples of advantage and disadvantage from each system would be effective to develop a sustainable product system.

Key words:

PET Bottle, Sustainability, Integrated Assessment, Material Flow, Financial Flow, Life-cycle Perspective, Product System Development

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Chapter 1: Introduction

1.1 Introduction

There has been a strong movement to change the socioeconomic system is based on mass production, mass consumption and mass disposal. This product system has led to a spiraling demand for scarce resources and a shortage of landfill space due to enormous amount of solid waste. "Preventing the generation of solid waste is a critical task if we are to create a truly sustainable society" (Saphire, 1997). Furthermore, the impact of a product would also bring problems through its life cycle stages.

Containers and packaging make a significant contribution to the household solid waste stream. They become useless after products are consumed or taken out from them. The packaging that is produced, consumed and discarded regardless of its quality. This research focused on PET (the abbreviation of Polyethylene Terephtalate) bottle system as one of the rapidly developed product systems. PET bottle is a newly invented container and has expanded market share among the beverage containers attracting with its advantages. For example, glass like transparency, ability to retain carbonation, toughness, lightweight, large capacity, unbreakable and resealable aspects are considered (Yasui, 2003). The introduction of PET bottles contributes to an expansion in choice of beverage containers, but at the same time, it increases extraction of raw materials and produces large amount of solid waste. It has become an urgent task to establish a sustainable product system.

The notion of sustainability is a complex and contested concept. According to Carter (2001), the definition of sustainability is concerned environmental protection, economic and social development. It would be impossible to continue production activities in a sustainable and progressive manner without dealing with these three aspects appropriately. The analysis of this research is taken by an integrated perspectives and methods. Uniting the separate aspects of the PET bottle system is necessary to complete understanding of the dynamics of the system and it would helpful to identify the strategies to improve the product system better. In order to find the better alternative, a case of the Swedish and Japanese PET bottle system is reviewed.

1.2 Objectives and Scope

The objective of the research is to analyze in an integrated manner from a life-cycle perspective, the best alternative system to improve the system better through comparing the Swedish and Japanese system.

In order to understand the dynamics of the system, the research is taken by integrated perspectives and methods. Uniting the separate aspects of the PET bottle system would be helpful to identify the

strategies to improve the product system better. Analyzing one perspective of the system is not enough to see the real impacts of it. For example, environmentally effective but economically inefficient system is not a sustainable system. Even if it an economically beneficial system, it is not sustainable system when it has an environmentally or socially significant impact. It would be impossible to continue production activities in a sustainable and progressive manner without dealing with these three aspects appropriately.

◈The main research question is:

- What would be the best alternative to improve the PET product system better?

◈This will be accomplished by:

- How PET system works in each country?
- What is the advantage and disadvantage of the PET system of each country from three aspects?
- What measures has a possibility to be implemented?
- What could be the impediments to promote the better system?

In order to cover the objective, the thesis is written in the following manner: In chapter two, the Swedish PET bottle system is described as basic understanding of how the systems work. Chapter three explains the Japanese PET bottle system as the same order as chapter two. Chapter four shows the present situation in the Swedish and Japanese PET bottle systems, and an analysis from the three perspectives (environment, economic, and social). Chapter five is a discussion about the outcome of the two systems and suggestions minimizing impacts. In the end, chapter five summarizes the conclusion of this thesis.

1.3 System Boundaries

The system boundaries make clear the contents of this thesis. In order to focus on one products of the system, this analysis focused only on the PET bottles. Other containers and packaging such as glass and cans are out of system boundaries. Other plastic products are out also of the boundaries as well.

The impact of a product through its life cycle stages could be considered from extraction and processing raw materials to manufacturing, transportation, and distribution and finally reuse, maintenance, recycling and final disposal. In this research, material flow starts from oil exploitation and ends with landfill or manufacturing reclaimed products. The ways of landfilling or after manufacturing of reclaimed products are out of the material flows. Additionally, as input and output

of the material flow, this research is focused on solid waste only, other input and output such as emission, energy consumption, and transport is outside of the analysis.

1.4 Methods

In order to answer the research questions put forward, the research investigated from a variety of sources, both literature review and informal interviews. Basically, the information of the legal framework, market, and financial flows are collected by literature review. There is limited literature available about the Swedish system, so the mass of the information was collected through interviews via e-mail or telephone. The analysis of this research is carried out by material flow charts, scenario analysis and Causal Loop Diagram (CLD).

Chapter 2: The Swedish PET Bottle System

This chapter provides a basic understanding of Swedish PET bottle system covering the legal framework, market conditions, material flows and financial flows.

2.1 Legal Framework for PET Bottle in Sweden

In Sweden, the first one-way PET bottle was introduced in the early 1970s, and there was no regulation of the system for the consumed PET bottle at that time. Due to rapid increase in consumption of the PET bottles, the Swedish government and industries have cooperated together and established new legislation (Deponet, 2002).

2.1.1. The Waste Hierarchy

In Sweden, the basic policy of waste management is set by the waste hierarchy: 1) prevention, 2) reuse, 3) recycling/recovery (material/energy), and 4) safe of disposal (landfill). In the more detailed version of waste hierarchy, reuse has priority over recycling, which has priority over energy recovery, which is in turn has priority over landfill. The most important thing is to decrease the generation of waste, and the overall objective is to minimize the environmental impact of waste management (Mattsson, 2003).

2.1.2 the Act on Certain Beverage Containers

In 1991, the Act on Certain Beverage Containers (PET) *(SFS 1991: 336)*[1] was introduced. The Act defined the following requirements; 1) Fillers must participate in an approved reuse and recycle system; 2) PET bottles must be marked with a symbol indicating participation in such system (Hagengut, 1998). The Act permitted a distribution of a refillable PET bottle; however, it brought considerable protest from small producers, because refilling system gave a competitive advantage to the large breweries (Robinson, 1996). Due to their opposition, in 1993, the Swedish parliament passed resolution *(SFS 1993: 418)*[2] on the recycling of PET bottles. This resolution admitted a one-way PET bottle; if it has suitable return and recycle system (Vanthournout, 1996). At the same time, a deposit system was introduced to induce people to return all bottles. A deposit paid on purchase must be refunded to the consumer when a waste PET bottle is returned (Ministry of the environment, 1996).

Returpack-PET AB was formed to manage one-way PET bottle recycling system. It is an independent cooperation owned by a packaging industry REXAM, the Swedish Breweries

[1] A more detailed legal framework is given in: Ministry of the Environment (1996)
[2] A more detailed information is given in: Ministry of the Environment (1996)

Association, and trade organizations. Swedish Breweries Association is responsible for the refillable PET bottle cycle system (Returpack-PET, 2004). Consequently, the Act on Certain Beverage Containers introduced two kinds of PET bottle distribution with a deposit system in Sweden.

2.1.3 The Ordinance on Producer's Responsibility for Packaging

In 1994, The Ordinance on Producers' Responsibility for Packaging *(1994:1235)* was introduced and in 1997 entered into full effect *(SFS 1997:185)*[3] The Ordinance prescribes requirements on certain recovery rates. The requirement for PET bottle is at least 90% will be recycled (Swedish Environmental Protection Agency, 2003).

2.2 Products

2.2.1 Sales

The total recorded consumption of soft drink and bottled water has increased year-by-year in Sweden. In 1993, 591.9 million liters of domestic and imported beverage ware consumed. In 2003, the amount increased to 947.4 million liters (Swedish Breweries Association, 2004). Figure 1 shows the changes in market share of classified packages in volume (Returpack-PET, 2004). Among them, the PET bottle is a quarter of total market share. Reusable PET bottles have been steadily losing market share, with one-way bottle increasing in popularity (Swedish Breweries Association, 2004).

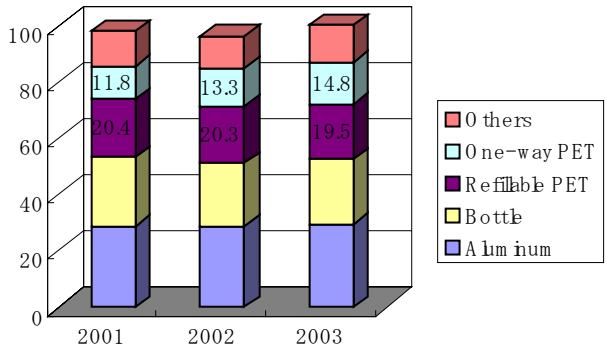

Figure 1 Shares of Classified Packages in Sweden

2.2.2 Facts about PET bottle

Table 1 shows the information about both refillable and recyclable PET bottles in Sweden. The refillable PET return system started in 1991 and recycling rate is 98%. The size is 1.5 liter only and the weight is about twice as much as one-way bottle (Rexam, 2004). The one-way PET bottle recycling system started in 1994, and the recycling rate is 79%. There are varieties of sizes and colored one-way PET bottles distributed (Swedish Breweries Association, 2004).

[3] A more detailed information is given in: Swedish Environmental Agency http://www.internat.naturvardsverket.se/index.html

Table 1 Comparison between Refillable and One-way PET bottle

	Refillable PET bottle	One-way PET bottle
System Start	1991	1994
Managed by	Returpack-PET	Swedish Breweries Association
Sales (per year)	160 million bottle	200 million bottle
Appearance *1	6 container	Variety of designs and colors
Volume	1.5 liter only	0.25 liter to 3 liter
Weight *2	107g	0.5L: 20-28g, 1.0L: 36-44g, 1.5L: 42-50g
Recycling Rate	98%	79%

Source: *1 Coca Cola Sverige, *2 REXAM, other information is from Swedish Breweries Association

2.3 Material Flows

Figure 2 explains the life-cycle flow of PET bottles in Sweden. The arrow shows the flow of materials. The words written in black capital letters show the main actors of the system. The words written in gray small letters refer to the substances of each process. The orange colored arrow shows the flow of refillable PET bottle and green colored arrow shows the flow of one-way PET bottle. The PET bottle material flow could be divided into three groups: bottle production process, consumption system, and take-back system.

2.3.1 Bottle Production Process

PET resin manufacturing company initiates the flow. Manufacturing PET bottle[4] starts from the raw materials –ethylene and para-xylene. Ethylene is usually produced by cracking either natural gas or the naphtha fraction of crude oil. In PET resin manufacturing plant, they produce PET resin from these raw materials (Eco-Profile, 2002). Bottle manufacturing company produce both refillable and recyclable PET bottle from PET resin, and sell them to beverage companies (REXAM, 2004).

2.3.2 Consumption System

Beverage manufactures fill their beverage into the PET bottle. They transport these beverages (beverage 1 in figure 2) to retailers who sell them to consumers. There are approximately 50 beverage companies and 500 plants inside Sweden. Beverages are imported from other countries as well (Swedish Breweries Association, 2004).

Consumers buy beverages from retailers, and eventually consume them. After consumption,

[4] A more detailed manufacturing process of PET bottle may be found in: Eco-Profiles (2002)

consumers have two choices. One choice is throwing the waste bottle away with other household waste. In this case, waste PET (discarded PET 1 in figure 2) bottle mixed with other garbage and collected by municipality. In this case, the waste PET bottles are collected with other household waste by municipality and transported to incineration or landfill (Returpack-PET, 2004).

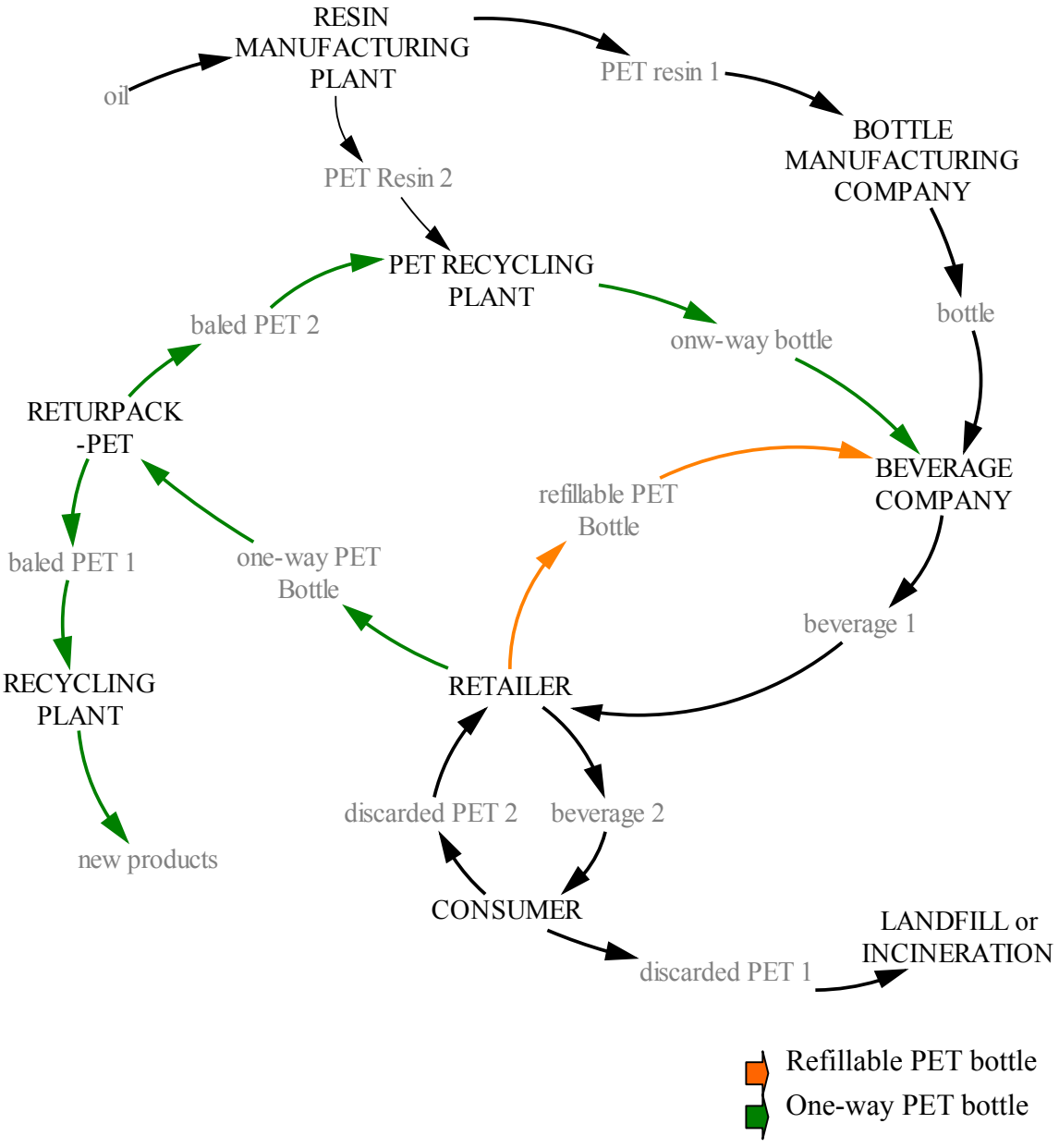

Figure 2 PET Bottle Flow Chart in Sweden

The other choice is that consumers take back empty PET bottles (discarded PET 2 in figure 2) to the retailers. Most of retailers and supermarket have the Reverse Vending Machine (RVM) inside the

store. Approved PET bottle are recognized by a bar code or "EAN code", which all importers and breweries registered their bar code to Returpack-PET (Returpack-PET, 2004). Recyclable PET bottle are compressed to one-tenth inside the machine and refillable PET bottle are uncompressed (TOMRA, 2004). There is no RVM in small stores and kiosks, bottles can take back manually and be collected in a big bag (Vanthournout, 1996). Special collection containers are also set up at sports centers, tourist facilities, open-air venues, and camping site for "on-the-road" consumption (Returpack-PET, 2004).

2.3.3 Take Back System

After consumers take back waste PET bottle to retailers, there are two different flows depending on the refillable or one-way PET bottle.

◈*Refillable PET bottle*

Beverage companies bring refillable bottles, which are temporally stored at retailers, back to their plants, they deliver new products to retail store (Returpack-PET, 2004). In the refilling plant, caps and labels are taken away, and washed inside and outside for 15 minutes. These bottles pass a sniffer and a X-ray check, which can make sure that the bottles are clean and intact. If bottles are scuffed too much or too damaged, they are then sorted out of the process. Finally beverage are refilled and capped and transport to retailers again (Interview from Coca Cola Sverige, 2004). Usually the refillable PET bottle is refilled approximately 20-times (average rate of reuse 3.3times in year) (Swedish Breweries Association, 2002).

◈*One-way PET bottle*

Beverage companies transport waste one-way PET bottle to Handelo factory in Norrkoping, which is owned by Returpack-PET (Returpack-PET, 2004). All waste one-way PET bottles deposited in Sweden are stored, counted and baled for further transported to various recycling companies. From this stage, there are two different flows. Half of recyclable PET bottles are used for new PET bottles, and the other half are used for other products (Swedish Breweries association, 2004).

The baled PET bottle (baled PET 1 in Figure 2-2) used for manufacture new PET bottles are melted down to make another PET bottle by the three-layers technology; new plastic material (PET resin 2 in Figure 2) put on the inside and outside and recycled material put in the middle layer. Now 25 % of total weight of new bottles is recycled material (Swedish Breweries Association, 2004). The baled PET not used for PET bottles (baled PET 2 in Figure 2) is delivered to fiber factories, which spin a fiber from waste PET, and used to produce other products as fleece-wear, sweaters, car upholstery, fiberfill. There is no recycling plant inside Sweden, so bottles then go to recycling plant in Holland or Germany (Returpack-PET, 2004).

2.4 Financial Flows

The financial flow of PET bottle recycle system is managed by Returpack-PET through a deposit system. All breweries, which manufacture beverage bottled in a PET bottle, should be a part of the system. The system mainly operates with a handling fee, administration fee, deposit, and scrap income from recycled material. Initially it requires a special handling permit (SEK10, 000 per year) that Returpack-PET applies from Swedish Broad of Agriculture. Administration fee is 0.27 SEK for a litter or less one-way PET, 0.77 SEK for over a litter one-way PET, and 0.60 SEK for refillable PET bottle. Extra sorting fee 0.15 SEK added for colored PET bottle. Deposit levels are different between size and type; 1 SEK for a litter or less size PET, and 2 SEK for over a litter and 4 SEK for refillable bottle (Returpack PET, 2003).

Overall financial flow is described in figure 3. The orange colored arrow shows administration fee and the green colored arrow shows deposit refund. The gray arrow shows handling fee. The blue arrow means the scrap value. First, bottle manufactures pay the deposit, which is based on production volume, and administration costs to Returpack-PET. When beverage manufactures buy necessary containers from bottle manufactures, beverage manufactures pay bottle price itself, administration fee and deposit to bottle manufacture. Importers pay the deposit and administration fee to Returpack-PET. Retailers pay the deposits to the filler at delivery of products. Consumers pay deposit to retailers when they purchase the filled beverage. When consumers return empty bottles in retailers, they receive deposit. Returpack-PET pay handling fee and deposit to retailers, based on collected empty bottle. After beverage manufacture collect and baled after-used PET bottle from consumer, they receive handling fee as reimbursement from Returpack-PET. The sales from baled PET material are the revenue source of Returpack-PET (Returpack-PET, 2004).

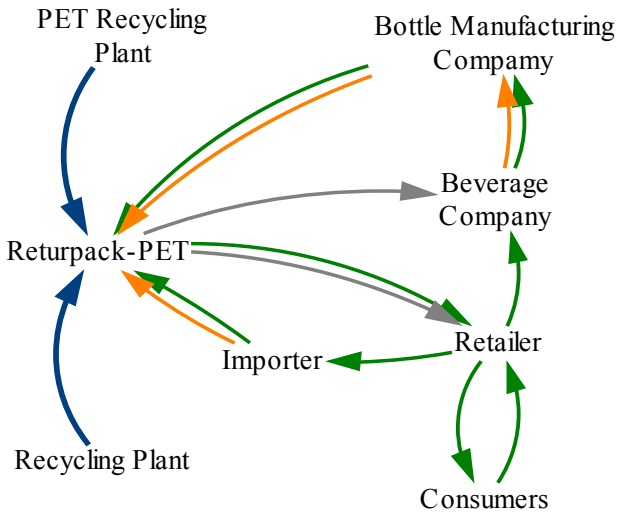

Figure 3 Financial Flow of Swedish System

The payment of the retailers' deposit and handling remunerations are made through an automatic process, so-called Direct Credit. It enables quick payment to retailers from Returpack-PET. Once a week, Returpack-PET contacts all RVM in Sweden and checks the PET flow in the system. The machine supplier of RVM deliver weekly payment file to Returpack-PET (Returpack-PET, 2004).

Chapter 3: The Japanese PET Bottle System

This chapter likewise explains the Japanese PET bottle system covering the legal framework, market conditions, material flows and financial flows.

3.1 Legal framework for PET Bottle in Japan

In Japan, the PET bottles were firstly introduced in 1977, and in 1982 admitted for beverage container. Municipality traditionally collected PET waste with other waste and almost all of waste PET bottle directly went to the incineration without any care. There was no consistent sorted collection system about PET bottle at that time (Plastic Recycle Kenkyu-kai, 2000).

3.1.1.the Waste Hierarchy

Government set waste hierarchy as a waste management policy in Japan. The waste hierarchy has been turned into the more easily to use "3R concept" - Reduction of waste generation, Reuse of parts, and the Recycling of used products as raw materials. Japanese government has been working on smooth promotion of the 3Rs aiming to decrease the amount of natural resources utilized and migrating environmental burden (METI, 2002).

3.1.2 the Waste Management Law

In 1970, the waste management law was settled. The law is the first law to define waste and general scheme of proper waste management. Under the law, municipalities have responsibility for household waste management. They use their own discretion in choosing measure or policy depending on their budget size, residents' characteristics. For example, incineration, selection and direct landfill are chosen regarding standards (Morishita, 1997).

3.1.3 Containers and Packaging Recycling Law

Law for Promotion of Sorted Collection and Recycling of Containers and Packaging (Containers and Packaging Recycling Law) put into force in 1995 and enacted in June 1997. PET bottle is added under the force of the law in 1997. The law defines PET bottles in the market should be either reused or recycled (Yoda, 1999). Under the container and packaging recycling law, Japanese PET bottle recycling system started in 1997. The Council for PET bottle Recycling was organized as one of the designated organizations founded by Japanese government and specified business parties. The council administers the PET bottle recycling system following the law (Plastic Recycle Kenkyu-kai, 2000).

- ***Responsibility of Actors***

The law clearly designates responsibility among consumers, municipalities, manufacturers, bottlers, and importers. First, municipalities take the responsibility of sorting, collecting, intermediately

processing (washing and compressing), and temporarily storing of bottles. The law defines that municipalities bring PET bottles to recycling plants in a compressed and reduced state without mixing them with other substances (METI, 2003b). Second, consumers have responsibility for sorted waste PET according to municipal criteria. It is a common rule for consumers that take off cap and label from PET bottles, wash the inside of the bottle, and compress the bottle (The Council for PET Bottle Recycling, 2004). Third, industries have responsibility to recycle sorted waste. They have to recycle materials of their obliged amount of waste. When they do not treat the waste PET, it is admitted to pay recycling fee to the designated organization instead of manage recycling themselves (Ishiwatari, 2002). If industry fails to fulfill its obligations, they will be subject to penalties. When these penalties are not complied with, a fine not exceeding 500,000 JPY will be imposed (METI, 2003b).

◈ ***Three Recycling Routes***

There are three recycling routes admitted by government. Industry is able to choose "Designated Organization Route" or "Self Collection Route". "Designated Organization Route" is that industry pay recycling fee to Designated Organization who manage recycling system instead of industry. Designated organization handle waste PET collected by municipality to recyclers who have contract with designated organization. "Self Collection Route" is that industry themselves collect the waste PET and bring them directly to recycling plant. Municipality is able to choose "Designated Organization Route" or "Own Recycling Route". "Own Recycling Route" is that municipality themselves have contract with recycler and manage recycling system without designated organization (METI, 2003b).

3.2 Products

3.2.1 Sales

Figure 4 shows the share of classified beverage. The share of beverage bottled in PET bottle is increasing rapidly, every year it has 10 % growth rate in volume from 1997 to 2001 (The Council for PET Bottle Recycling, 2004). The share of beverage in PET bottle reached 57% in 2003 (Japan Soft Drink Association, 2004). Accompanying the expanding market share, the total production volume also

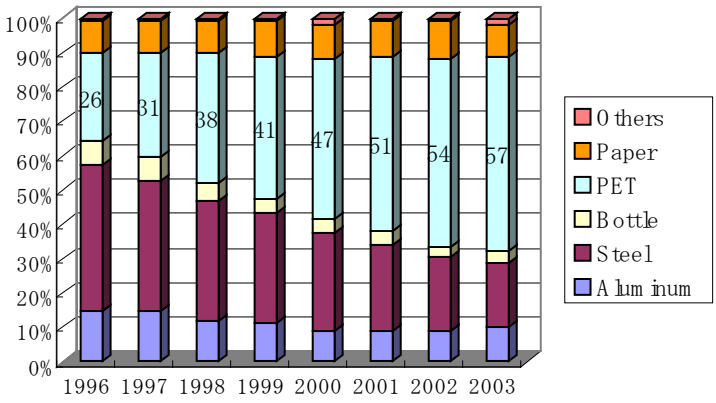

Figure 4 Shares of Classified Packages in Japan

has been increasing. In 2003, 471,000 tons of PET bottles were manufactured and 8,872 million PET bottles consumed. Tea has the biggest share among them, sports drink and mineral water followed (METI, 2004).

3.2.2 Small Sized PET Bottles

Before the Container and Packaging Recycling Law was enacted, beverage manufactures voluntarily restrained from using small sized (less than 500 ml) PET bottles for beverages. Only imported water is sold in small sizes PET bottles. Since there is no concrete system to take back PET waste, the majority of PET bottles are directly go to the municipality's incineration. Around that time, dioxin from plastic waste was a big problem, and high possibility to damage incineration due to its burning temperature. Municipalities considered new types of plastic containers would bring not only growth of waste, but also bring dioxin and damage of incineration (Plastic Recycle Kenkyu-kai, 2000).

Due to the PET bottle recycling system becoming consistent under the Containers and Packaging Recycling Law, industries discontinued their self-restriction in 1997. After that, small PET bottle consumption dramatically expanded, and now small size PET share is 75% of total PET bottle market (Nishimura, 2002). Now there are a variety of PET bottles in the market, 2L, 1.5L, 1L, 750ml, 500ml, 350ml, 250ml, and 200 ml and PET bottles for hot drinks (the Council for PET Bottle Recycling, 2004).

Every year, the weight of bottle becomes lighter; for example, in 1997, the 500 ml of one-way bottle weighted 32 grams, and the weight was cut down to about 23 grams (weight saving rate; 28.1%) by 2003. The weight of 2 liters PET bottle became 42gram from 63 gram (weight saving rate; 33.3%). In Addition, industry has introduced a self-control for colored PET bottle since 2001. (The Council for PET Bottle Recycling, 2004).

3.2.3 Recycling Rate

Figure 5 shows the transition in the amount of PET resin consumption and PET waste going to landfill or incineration. As explained the previous chapter, the amount of PET resin consumption increased dramatically with increasing use of small PET bottle. Furthermore, the recycling rate has also been increasing rapidly with the increasing number of municipalities, with a sorted collection. When the law was introduced, 80% of municipalities were uneasy to execute sorted collection due

to the high transportation cost, the long distance between municipalities and recycling and processing facilities, and therefore they kept themselves from sorted collection system (JETRO, 2001). In 2003, 92 % of municipalities have sorted collection system. At the same time, the recycling rate is also increased from less than 10% to 61%. The Council for PET Bottle Recycling mentioned this recycling rate is one of the highest recycling rates without deposit system in the world.

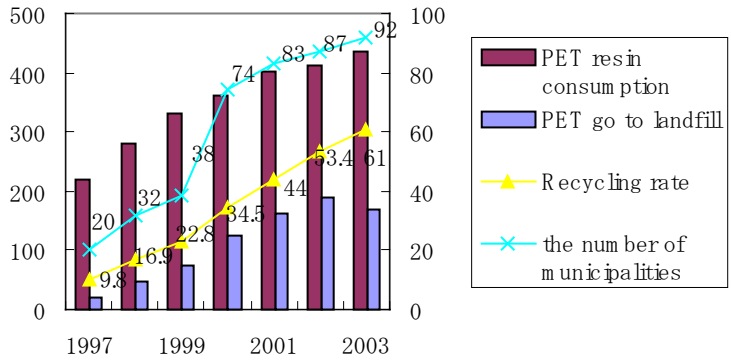

Figure 5 PET Consumption and Recycling Rate

3.3 Material Flow

Figure 6 explains life-cycle flow of Japanese PET bottle system. As mentioned in the previous chapter, the Containers and Packaging Recycling Law admit three recycling routes in Japan. Thick black line explain common route of material flow, the orange colored line means “Self Collection Route”, and Green colored line means “Own Recycling Route”. Blue colored line means “Designated Organization Route”.

3.3.1 Bottle Production Process

The same as in Sweden, manufacturing PET bottle initiates the flow of PET cycle system. First, resin-manufacturing plants produce PET resin from crude oil. Then, bottle-manufacturing plants buy PET resins and manufacture PET bottle.

3.3.2 Consumption system

Beverage companies buy PET bottles from bottle manufacturing company in order to refill their beverage. About 2 % of the bottles and beverages made in outside Japan are imported to beverage companies. After beverage companies fill their beverage into the bottles, they transport them to retailers who sell them to consumers (The Council for PET bottle Recycling, 2004).

One of the market characteristics in Japan, convenience stores have big sales among retailers (Ministry of the Environment, 2003). There are over 40,000 convenience stores – that is one for every 3,000 residents (Japan Chain Store Association, 2003). These ubiquitous 24hours retailers have become a part of daily life and have great impact for the beverage marketing. Additionally, vending machine has the big beverage market share as well. More than 50% of beverages are sold

from vending machine. As of 2003, there are 2.6 million beverage vending machines on the street, park, office, and everywhere in Japan. The number of vending machine is the second-largest following on U.S, and its market share in Japan is bigger than in U.S. (Japan Vending Machine Manufacture's Association, 2003).

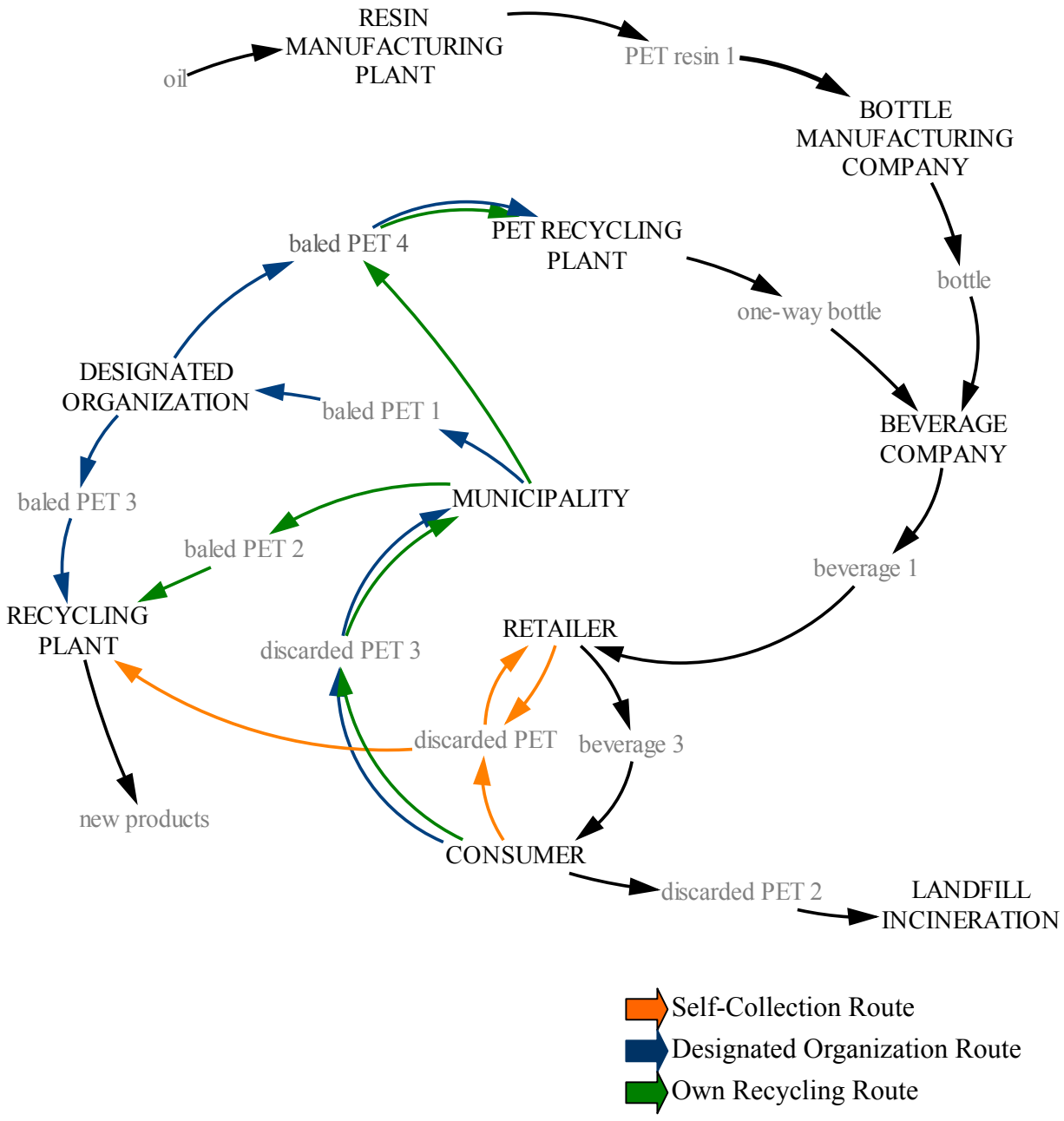

Figure 6 PET Bottle Flow Chart in Japan

After consumption, consumers have three choices; 1) throw waste PET bottles in recycling box on

the street; 2) throw them with other household waste; 3) throw them separated from other household waste. First choice follows the flow of "Self Collection Route". After consumers throw the waste PET (discarded PET in figure 6) in the recycling box next to vending machine on the street, beverage companies collect them when they bring new beverage (Monthly Waste, 2004). They directly bring waste PET to recycling plant. Second choice is that the municipality collect waste PET (discarded PET 2 in figure6) with other household waste. They are treated by incineration or landfill. Third choice is that consumer separately discharged waste PET (discarded PET 3 in figure6) following with the discarding household waste rule of each municipality (The Council for PET Bottle Recycling, 2004).

3.3.3 Recycling System

After municipalities collect waste PET bottles from consumers. They sort, wash and baled these bottles. In addition, they should store them in appropriate storage facilities for the further recycling. Municipality has two choices for the next step. One is "the Designated Organization Route" and the other is "Own Recycling Route".

◈*Designated Organization Route*

The Council for PET Bottle Recycling, which is a designated organization for PET bottles, manages the "Designated Organization Route". The council does not have recycling plant like Swedish Returpack-PET. They do not collect waste PET (baled PET 2 in figure 6) physically; just handle the contract between recycler and municipality by bidding system. In 2003, 60 company and 73 recycling plant are involved in the system (The Council for PET Bottle Recycling, 2004).

◈*Own Recycling Route*

Own Recycling Route" is the route, which the designated organization dose not intervened in the system. The municipalities have a direct contract with recycling plant. Among them, estimated 10,000 ton of waste PET bottles are exported to China for recycle to stuffed doll or fleece wears (Nikkei Ecology, 2004).

In recycling plant, PET bottles and their caps (made of polyethylene or polypropylene) were shredded and separated completely in order to improve the grade of the raw input used in PET bottle recycling (Japan PET bottle Association, 2000). X-ray separation, electrostatic separation and floatation are used for plastic separation methods (Dodbiba et al, 2001). Reprocessed PET is called recycled PET (here in after called R-PET). Japanese government has not admitted to recycle from R-PET to food container because of hygiene problem, so that whole R-PET has been used for other products and never recycled to PET bottle. This is called "cascade recycle" - the reclaimed material is used for degrade quality products (Yasui, 2003). For example, R-PET is used for variety kinds of

products such as fiber, plastic sheet, container of detergent, fleece wear, carpet, plastic bag and so on[6] (Kawanura et al, 2001).

◈ ***"Bottle to Bottle" Recycling***

Since 2004 April, newly invented "bottle to bottle" system[7] has introduced in Japan. This system is a highly advanced chemical recycling system, which enables the recycling of recovered PET bottles into PET bottle resin. After DMT is derived from recovered bottles, it is hydrolyzed to yield highly pure terephthalic acid (TPA). The quality of TPA, which is a raw material of production of PET, is equivalent to that produced from petroleum. "A complete polyester recycling system with minimal independence on petroleum will thus come into operation " (Teijin, 2004). In 2004, 10 % of R-PET bottle recycled to new PET bottle by "bottle to bottle" technology. Japanese government is expected this recycling technique will become a dominant recycling way (The Council for PET Bottle Recycling, 2004).

3.4 Financial Flows

As above mentioned in previous paragraph, industries are able to achieve their recycling obligation by practicing the "Self Collection Route", which industry collect and transport the waste PET to the recycling plant. However, in fact, 80% of industries chose the "Designated Organization Route", which industry can fulfill their responsibility by paying a "recycling fee" (Appendix 1) to the designated organization. Basically recycling fee is calculated by the "amount of recycling obligation" (Appendix 2) multiply "recycling unit cost" (METI, 2003b).

The recycling obligation is that the amount of waste PET bottles, which industry has to recycle (METIb, 2003). In Japan, automatic recording system such as Swedish EAN code has not introduced. Additionally, labels on the PET bottles are taken off when consumers discard them (Deponet, 2002). In order to identify each industry's recycling obligation clear, calculating formula (Appendix 1) is set. The formula is calculated by not only the amount used or manufactured PET bottles but also the amount of estimated sorted collection and recycling capacity. The government announces these figures in the five-year plans. The recycling unit cost is calculated from the estimated recycling costs. This values changes each year and announced from the government and the Council for PET bottle Recycling (METI, 2003b)

[6] More detailed information is "Catalogue of reclaimed products from PET bottle 2003"
[7] More detailed information is given in Teijin Home Page
http://www.teijin-eco.com/english/ecoproducts/tec_06.html

Figure 7 shows the financial flows of the recycling system Japan. The gray colored arrow shows the material flow. Blue colored arrow shows the financial flow of the "Designated Organization Route". First, bottle manufacturing companies and beverage companies pay the "recycling fee", based on the calculation formula, to the designated organization. When municipalities collect the waste PET bottles, the designated organization manages the contracts between municipalities and recycling plants by competitive bidding system (METI, 2003b). In this route, municipalities do not need to pay the recycling cost to the recycling plants. Instead of them, the designated organization pays the cost to recycling companies using the "recycling fee" from industry (Ishiwatari, 2004).

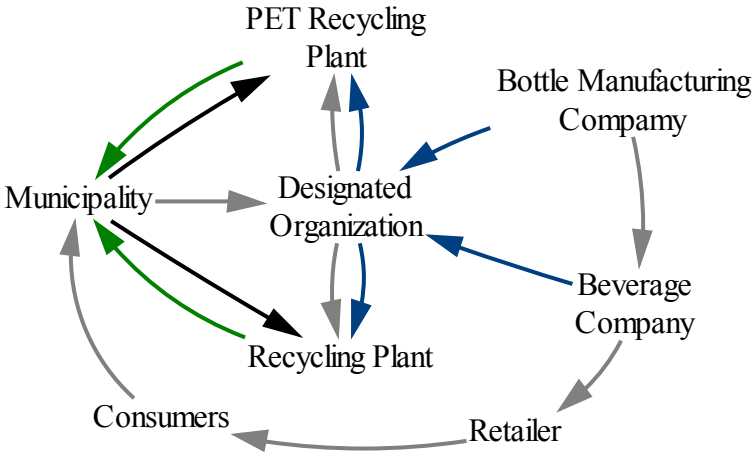

Figure 7 Financial Flow of Japanese System

The green colored arrow identifies the financial flow of the "Own Recycling Route". In this route, the municipalities originally make contract with recycling plant without the intervention of the designated organization (METI, 2004). In this route, municipality sells their collected waste PET (the black colored arrow in figure 7) to the recycling plants. Municipalities have to pay the recycling cost themselves; however, more recently the waste PET started to sell by this route. Now this flow is the only way to earn income of baled PET for municipalities (Ishiwatari, 2004). The financial flow of the "Self-Collection Route" is not included in the figure 7. Beverage companies manage this system physically and financially. They pay whole PET waste management cost such as collection, storage and transportation of the waste PET bottle (METI, 2003b).

Chapter 4: Systems Analysis

With the presentations of both PET bottle systems in chapters two and three, chapter four is intended to identify the advantages and disadvantages of each system and examining where the possible improvement can be made. The analysis is performed in an integrated manner by including environmental, economical, and social aspects of each system.

4.1 Environmental Aspects

In this section, the analysis is focused on the environmental effects of each system. The analysis is based on the material flow chart of the systems. Furthermore, A scenario analysis is performed of the system to determine future potential problems under the rapidly changing situation like the Japanese system.

The environmental effect of the PET bottle recycling system could be analyzed from a solid waste, energy use, pollution emissions, water pollution, hygiene, public health impacts and urban traffic congestion perspective (Boustead and Lidgren, 1984). Saphire (1994) mentioned the most environmentally effective strategy is one using less materials and processes with the least energy. Both in Sweden and in Japan, the PET bottle recycling system has been devised because of the increasing raw material exploitation and expansion of PET waste with rapid PET bottle consumption. Under the circumstance, my analyses have focused on solid waste. Especially how the system has functioned to reduce the resource input and waste PET treated by incineration.

4.1.1 Swedish Environmental System for PET bottles

This section analyzes the outcome of environmental impacts of Swedish system. The environmental impact of the Swedish system is analyzed via two aspects: one is the effect of Swedish source reduction measure, and the other is the amount of PET waste that is recovered.

◈*Source Reduction*

Source reduction is the most important area in Sweden, putting the priority in material use hierarchy. It enables to reduce the waste at the source before it is generated. Introducing the refillable PET bottle is the main waste prevention measure in Sweden. Refilling system also contributes to prolong the life cycle of the bottle.

Refillable PET needs more energy and raw material in the manufacturing process, and it weighs about twice as much as the one-way PET bottle (REXAM, 2004). However, the refillable bottle is designed to be filled a maximum 25-times, so it needs less material to deliver the same amount of beverage in the end. The more trips the bottles make through the cycle, the fewer the number of

new bottles that are needed (Saphire, 1994). The average refilling trips in Sweden is 20-times, so it eliminates the need for 19 more new bottles of a similar size to be produced (Swedish Breweries Association, 2004).

Moreover, high recovery rate drives to circulate the bottle loop many times. Even if there is significant damage, they recycled to manufacture new PET bottle. The Swedish refilling system contributes significant reduction of input resource, and output as well. Additionally, in Sweden, the recycling system of one-way PET bottle also functions well. Recovered one-way bottles are used as resources again and recycled to new PET bottle with the three-layer technology. Twenty-five percent of PET resin can be saved by this approach (REXAM, 2004). Swedish resource reduction measures are functioned well, and contribute to reducing input material.

◈***High Recycling Rate***

Figure 8 shows the change of the one-way PET bottle recycling rate after recycling system introduced in Sweden. When the recycling system was firstly introduced in 1994, the recycling rate is 51%. A year later, the recycling rate achieved became 78%. In 2003, the recycling rate was 79% (Returpack-PET, 2004). The Swedish system of deposit on PET bottles achieved a high recovery rate (RVF, 2003). It contributes to reduce the waste PET treated by incineration or landfills and expand product life as new bottles or other materials.

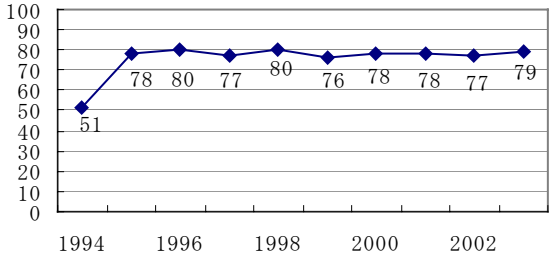

Figure 8 One-way PET Bottle Recycling

The Swedish system appear to work well because of an effective source reduction and high-recycling rate, but there is a problem that the recycling rate has stayed constant, not exceeding 80%. According to the Swedish Environmental Office, the reuse and recovery target of large PET (90%) was achieved, but the small PET bottle did not. Nowadays the share of one-way small PET bottles has increased among the PET bottles, so improving recycling rate, especially small PET bottle, would be the biggest issue of the Swedish PET bottle system.

4.1.2 Japanese Environmental System for PET bottles

This chapter analyzes the environmental impacts of Japanese system. As with the Swedish system, the environmental impacts of the system are analyzed by source reduction and amount of recovered PET bottle.

◈***Source Reduction***

The source reduction is the first measure on the Japanese waste hierarchy. Both the Japanese government and industry have promoted the lightweight PET bottle as a source reduction measure instead of a refilling system. From 1999, the two-liter bottle weight was reduced 33% and now the lightest bottle-weighting 42 grams (Kirin Beverage, 2004). This weight is the same as Swedish lightest bottle of 1.5-liter. According to the Council for PET Bottle Recycling, 108,000 tons of PET resin has been saved since 1999, because of the lightweight invention. Additionally, the "bottle to bottle" recycling contributes source reduction. Newly invented the technology enables to manufacture new PET bottle from waste PET bottle without any new PET resin input (Teijin, 2004). Compared to the Swedish three-layers recycling technology, the "bottle to bottle" recycling can save much more PET resin.

Analyzing the effect of source reduction measures in Japan, it is assumed that the measure is not enough for source reduction. First, the lightweight bottle reduces the amount of materials to make a single container. Nevertheless, it is impossible to continue the invention of lighter and lighter weight bottle since there is a limit. Furthermore, refilling system contributes to prolong the life cycle of the products, but lightweight bottle do not have that function. Second, the "bottle to bottle" recycling dose not have the mechanism to reduce the total consumption of PET bottles. On the contrary, it could be said that it contributes to producing much more PET bottles because they can be recycled. Considering these problems, the Japanese system needs more efforts to reduce the waste PET generation on the first stage of the product.

◈***Increasing Recycling Rate***

Increasing recycling rate shows that it is increasing the amount of waste PET, which is recovered. Figure 5 in chapter three shows the changes of recycling rate. As the figure shows, the recycling rate of PET bottle in Japan has been increasing rapidly. At first glance, the waste of PET bottles treated by incineration or landfills have also decreased due to the improving the recycling rate; however, the total amount of waste PET bottle treated is still large in the Japanese system. This is because consumption of PET bottles has increased dramatically. Furthermore, development of lightweight bottle and increasing consumption of small PET bottle contribute to increase the total number of waste PET treated in incineration or landfill (Monthly Waste, 2004).

Comparing with Swedish system, the Japanese recycling rate is low, but the recycling rate has increased without deposit refund system. Moreover, it is said that the quality of waste PET is also improved a lot (The Council for PET Bottle Recycling, 2004). Increasing the recycling rate is achieved by the cooperation of municipalities and their citizens. Figure 5 in Chapter 3 shows recycling rate is in proportion to the number of municipalities, which started sorted collection. In

2003, the number of municipalities, which has sorted collection system, was 92% (The Council for PET Bottle Recycling, 2004). Almost all of municipalities have already started sorted a collection system. It means now on that possibility of improvement of recycling rate is achieved only by cooperation of consumers.

◈***Miss Match of Recovered Amount and Recycling Capacity***

There is other problem in the Japanese PET bottle system. The rapidly increasing the amount of recovered waste PET bottle has exceeded the recycling capacity. Figure 9 shows the relationship between collected PET and the overall the capacity of recycling system (The Council for PET Bottle Recycling, 2004). When the recycling system started, there were not enough manufacturing plants in Japan. But due to the preferential government tax treatment for recycling companies, the numbers of waste PET recycling plants have been increasing (Monthly Waste, 2004).

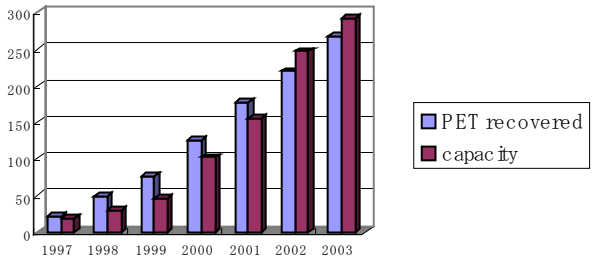

Figure 9 The Amount of PET Recovered and Recycling Capacity

In 2004, the "bottle to bottle" technology was introduced with the recycling capacity of 310,000 ton (Asahi Shinbun, 2004). Additionally, more than 100,000 tons of waste PET is estimated to exporting to China these days (Nikkei Business, 2004). These two amounts of recycling capacity are not included in the figure 9, so in fact the recycling capacity is siginificant. According to the Negoro Sangyo Co., Ltd (the recycling company), the biggest problem for them is that, it became difficult to supply the enough baled PET bottles for running the recycling plants. The shortage of waste PET drives increasing the cost of products and the exportation of waste abroad. The ministry of the Environment and METI agreed the recycling system in Japan should be in domestic recycling. This will cause scramble for waste PET and destroy the compact recycling system inside Japan (Ishiwatari, 2004).

◈***Scenario in 5 years***

In order to identify the critical uncertainty of the future situation, a scenario analysis is performed defining scenario can show uncertain possibilities by characterizing the systematic framing (Swert R. J, e*t al*, 2004). Especially in the Japanese system, drawing future scenario is important, since not only expanding PET consumption, but also increasing recycling rate causes problems.

Figure 10 is the estimated scenario for 5 years ahead in Japan. It shows the case when the recycling

rate will continue increasing every year at 5 % and the PET bottle consumption increasing 5% each year. PET bottle recycling capacity assumed to increase 1.1% every year. As graph shows, the amount of recovered PET bottle will increase, while the waste PET going to landfill will slightly decrease, but still remain large. It means that if the effective source reduction measures are not taken, the consumption of PET will continue to increase, and amount of waste PET treated by incineration or landfills will still be significant.

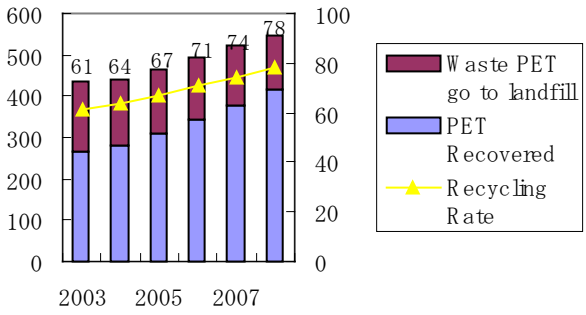

Figure 10 Scenario in 5 years in Japan

This scenario is based on the assumption of increasing the recycling rate every year. If the recycling rate continues constantly, the rate achieves as same as the Swedish recycling rate in 5 years. However, as mentioned in "increasing recycling rate" section, now the possibility of improvement of the recycling rate is achieved only by cooperation of consumers. If the recycling rate becomes stabilize like Swedish system and the expansion of PET consumption continues, then the waste PET treated by landfill or incineration would be expanded. Additionally, the scramble of waste PET bottle could become more severe, and then the Japanese recycling system would be collapse.

4.1.3 Environmental System Analysis Results

In the Swedish system, refilling system contributes to source reduction. The refilling system is also effective in prolonging the product life cycle and closing the product loop the bottle loop. Recycling of one-way bottles also contributes to reduce input of virgin resources. Considering the amount of waste treated by incineration or landfills, high recovery rates help to circulate the bottle loop many times. The problem of the Swedish system is stabilizing recycling rate.

Meanwhile, in the Japanese system, the source reduction measure is not enough to reduce the PET consumption even if the lightweight bottle introduced. The newly introduced "bottle to bottle" recycling system contributes to reduce the input of resources. Nevertheless, as figure 11 shows, the amount of waste PET treated by incineration or landfill is still too significant. The focus of the Japanese PET bottle system is based on how to recycle the waste PET, not in source reduction or reusing, even if Japanese government has the policy of waste hierarchy. There is still a system of mass production, mass consumption, and mass discharge (Ishiwatari, 2004).

4.2 Economic Aspects

In this chapter, the analysis is focused on comparison of economic parameters of both systems. It will be impossible to establish sustainable product system without dealing with not only environmental aspects but also economic impact appropriately. In order to look where economical problem occur and where improvements can be made, a Causal Loop Diagram (CLD) is used as a method for understanding the system.

According to Haraldsson, (2004), a CLD is a way to show the structure and feedback of the system by mapping out its mechanisms Arrows convey the effects in the indicated direction. Plus and minus sign means the balance of the two factors connected by an arrow. For example, when arrow goes from A and B with the sign plus, it means if A increases, B also increases. When the sign is minus, it means if A increases, B decreases.

4.2.1 Swedish Economical System for PET bottles

In figure 11, the CLD shows the mechanism of financial flows of the Swedish system. The system begins from PET bottle consumption. When the bottle consumption is increased, waste PET bottles are automatically increased as well. If waste PET is increased, then they drive to increase the amount of waste PET going to the landfill. The expansion of solid waste that is treated in incineration or landfill enhances the cost of waste management for the municipalities. This was the situation before recycling system introduced. After the recycling system introduced, consumers take back waste bottles to the retailer. As the number of sorted waste PET collection increased on, one hand, waste PET bottles to landfill or incineration decrease. Decreasing waste PET to landfill also reduces the municipality's cost of waste management. On the other hand, increasing sorted waste PET collection enhances the transport from retailer to recycling plant. Increasing waste PET transportation promote increasing cost of industry since beverage companies have responsibility for transportation of waste PET under the producer responsibility. Furthermore, PET bottle consumption affects the cost of industry. Industries'

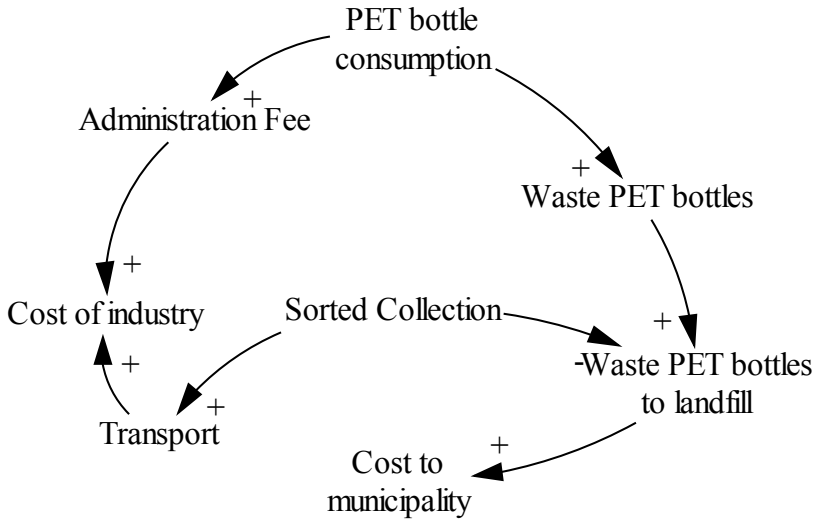

Figure 11 CLD of Swedish Financial Flow

administration fee for Returpack-PET is based on the number of PET bottle production or usage. It means that increasing PET bottle consumption enhanced the administration fee. Increasing administration fee promote increasing cost of each industry.

The recycling system in Sweden has the mechanism increasing PET consumption enhances the cost to industry. Additionally, increasing the sorted collection also affects the cost to industry by increasing the transportation. On the other hand, the system decreases the cost to the municipality.

◈ ***The Swedish Deposit System***

There would be a problem about the Swedish deposit system. According to SCA report (2003), the Swedish deposit system is difficult for small industries and non-Swedish industries to enter the Swedish market. Returpack-PET forms some kind of legal monopoly in the Swedish recycling system. They manage the only systems operating on a nation wide basis. It means it would be impossible for others to create alternative recycling system (Vanthournout, 1998). Additionally, the requirement of management permits is the economic burden for small industries. As mentioned in financial flows in chapter 2, each industry initially has to pay the handling permit to Returpack-PET. It is not volume-related cost, so it could be an impediment to market entry for small industry (SCA, 2003).

4.2.2 Japanese Economical System for PET bottles

Figure 12 is the CLD of the mechanism of financial flows in the Japanese system. Increasing the PET consumption initiates the system. As with the Swedish system, increasing PET bottle consumption enhances the amount of waste PET bottle and solid waste in landfill or incineration. In the end, increasing solid waste enhances the municipality's cost of waste management. After the Containers and Packaging Recycling Law enacted, municipalities started sorted collection. On one hand, if sorted collection increased, then waste PET go to landfill or incineration decreases. When solid waste treated incineration or landfill decrease, then the cost of municipality's waste management also decrease. On the other hand, the cost to the municipality is affected by transport of waste PET. Introduce sorted collection means that

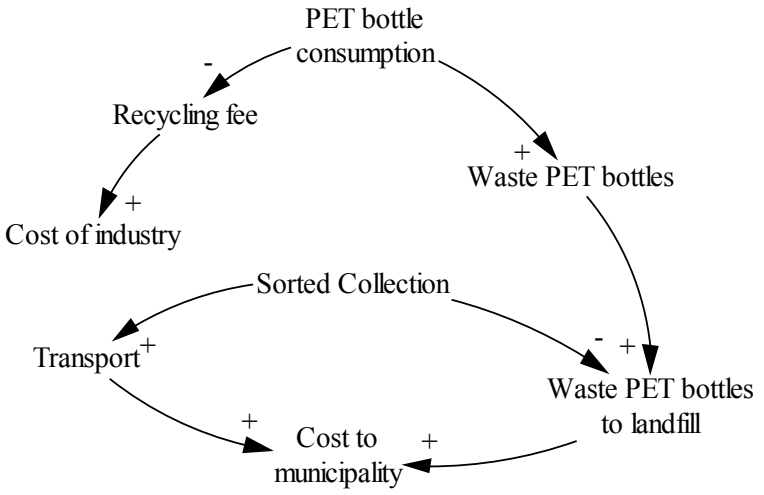

Figure 12 CLD of Japanese Financial Flow

municipality have to manage the transportation and storage of waste PET. When the quantity of waste PET increases by consumer's sorted discharge, transport for the waste PET also increases. Increasing transportation bring increasing cost to the municipality. As a result, the cost to the municipality increases, even if the amount of waste treated in landfill or incineration decreases.

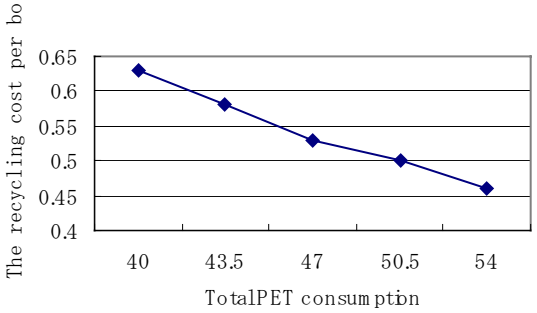

Figure 13 Industry Cost Per Bottle

Meanwhile, when PET bottle consumption increases, the recycling fee decreased. Decreasing the recycling fee reduces the cost to the industry. This is because the recycling fee is calculated based on the each company's PET consumption per total amount of PET consumption. Increasing in denominator reduces the each company's distribution. Figure 13 shows the relationship between total PET consumption and the recycling cost per bottle (7token haikibutu mondai kentoiinkai, 1998).

◈***The Cost to the Industry and the Municipality***

In the Japanese system, industries theoretically pay the recycling cost through designated organization. However transportation cost, which is the largest hidden cost for recycling is not included in the fee; so that increasing PET consumption and recycling rate enhance the transportation cost of municipality, and reduces the cost of industry. Now the difference is escalated. The transportation and storage cost of municipality account 153 JPY per 1 kg. Recycling fee paid by industry is 75 JPY (Kankyo Keizai Shinbun, 2004). The municipality pays more than two-times as much as cost to PET bottle recycling.

Originally, recycling fee is defined for reduce the municipal financial burden of recycling. Municipality entrust Designated Organization, and the organization collect the recycling fee from industry and manage the contract between municipality and recycling plant, instead of municipality. That time, waste PET was low value, so it cost money to manage the recycling. Municipality has received the benefit of removing the cost of management. Nevertheless, the situation is changing. Due to the waste PET scrambling, the waste PET becomes a valuable resource. Nowadays it becomes possible to sell them (Mainichi Sinbun, 2004). Under the situation, municipality start to choose "Own Recycling Route", which municipality originally makes contract with recycling plant (see figure 6 in chapter 3) (Ishiwatari, 2004). In this route, municipality is able to sell their collected waste PET to recycling plant. If they choose "Designated Organization Route" they do not earn any

income from them; however if they use "Own Recycling Route", they earn maximum 20 JPY per 1kg. Scramble situation for PET waste is pushing up the price for the products (Kankyo Keizai Shinbun, 2004). If more municipalities start to choose "Own Recycling Route", the "Designated Organization Route" would corrupt. The corruption of "Designated Organization Route" means the recycling fee from the industry could be useless, and Japanese financial system could not function.

Furthermore, the Japanese system has one more route, the "Self-Recycling Route", that is similar to the Swedish system. In this route, the industries themselves collect the waste PET bottle, and transport them to recycling plant. If more industries chose this route instead of paying recycling fee, the burden of municipalities would decrease and system would be simplified (Deponet, 2002). However choosing "Designated Organization Route" or "Self-Collection Route" show a considerable disparity in the cost. Figure 14 shows the difference between each of the actor's costs. The cost to industry shares 90% of the "Self-Collection Route", but with the "Designated Organization Route", the share is only 5% of total cost (7token haikibutu mondai kentoiinkai, 1998). Under the mechanism, industry prefers to choose "Designated Organization Route" instead of "Self-Collection Route" which is the refilling system route. It could be argued that one of the reasons that refilling system has not been introduced in Japan is that sorted collection cost must be bared by industry.

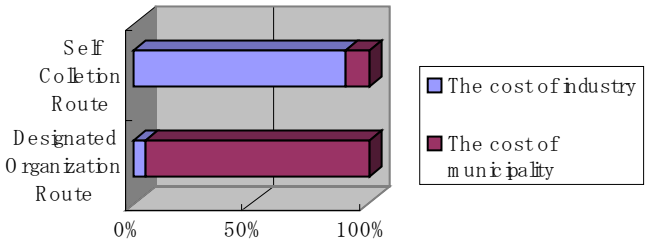

Figure 14 The Difference of the Cost

4.2.3 Economic Systems Analysis

According to the CLD, expanding the PET bottle consumption impacts the cost to industry in the Swedish system. The administration fee is based on the amount of bottle production, so that increasing bottle consumption enhances the cost to industry, which provides an incentive to reduce production. Meanwhile, the cost to the municipality has decreased due to the decreased the amount of waste PET bottle treated by incineration or landfills. This system is designed by industry themselves, so that high degree of compliance is to be expected. It could be said producers accomplished their responsibility physically and financially in Swedish system.

In Japanese system, the biggest problem is that the municipality pays the cost of sorted collection. Increasing consumption and recycling rate produces much more transport for recovered PET bottles. One hand, it could cost more for municipality. On the other hand, cost to industry decreased. As the result, municipalities start to choose their own route of recycling. These movements could

breakdown the basic financial system, which collecting recycling fee from industry and use them for recycling. Meanwhile, industries prefer paying less expensive "recycling fee" instead of collect and transport the waste PET themselves. It could say comparing to the Swedish system, the producer's responsibility is partly fulfilled in the Japanese system. They do not completely perform the financial responsibility of the recycling system.

Municipality's financial burden is too hard to continue the system. Furthermore, this cost to the municipality impacts social costs. All their revenues are from taxes, which are paid by each taxpayer. In this mechanism, consumers pay equally the same amount whether they consume a lot of PET bottle beverages or not.

4.3 Social Aspects

There are some aspects that can be considered social aspects; however, the social aspect of this study focused on convenience of consumers disposal activity. They are central members of closing the cycle loop. Without public contributions, recycling system would not function in both countries. The waste PET bottle are discharged with other waste and treated in incineration or landfill without their conscious and cooperation (McDonald and Ball, 1997).

4.3.1 Swedish Social System for PET bottles

In the Swedish system, consumers take back empty PET bottles to retailers. The RVM in the retail shop automatically recognizes the bottle and one-way bottles are compressed inside the machine. Retail stores open from morning to evening, so that consumer takes back waste PET whenever they are open. According to Roseveare (2001), there is a significant cost to households and firms in sorting, cleaning and transporting packaging waste to the collection point. It is estimated that each household spends an extra half an hour per week for these work. These costs could add up to 1,660 SEK per household over a year, bringing total costs to society of recycled packaging to an estimated 34,000 SEK per ton.

4.3.2 Japanese social systems for PET Bottles

Meanwhile, consumers are not required to take-back after consumed PET bottles to retailers in the Japanese system. It is said that the recycling carried out, as part of municipality collection system requires relatively little effort by household rather than take-back system (Roseveare, 2001). However Japanese PET bottle recycling system lays significant responsibility on consumers. As mentioned in Chapter 3, under the Container and Packaging Recycling Law, consumers have responsibility for sorted discharge of waste PET following by municipal criteria. There are more than 3,000 municipalities in Japan, and each of them has their own rules. There is curbside

collection, station collection, group collection and so on: additionally for curbside collection, the day and time of discarding waste PET is also different between each municipality. For example, in Osaka, PET bottles are to be collected in a special type of bags and must be brought by consumer to the nearest recycling station. The collection time at these stations is before eight a.m. every 2nd and 4th Monday. It is not admitted to discharge the waste the day before the discharging day, since the recycling station is placed temporally on the edge of the load, and additionally, stray dogs and cats scatter them. As the result, we should store the waste PET bottle for two weeks in the house and discard the waste PET within the limited time and place. Furthermore, consumers have to spare the time and energy to treat the waste PET before discharging, such as take caps and label off from PET bottle, wash inside, and compress the bottles (The Council for PET Bottle Recycling, 2004).

Due to the consumers inconvenience, beverage industry is looking for a small way to reduce consumers burden. They have introduced the easily squashable bottle and simple peel-off label, which has a perforated line (Suntory, 2004). This container aimed to at reducing consumer burden, even if only slightly. It could contribute somehow, but still it would be an inconvenience for consumer the time and place for discharging regulated. If they move to other city or town, they should check that municipality's discharging rule all over again. According to the questionnaire to the Japanese consumers taken by Aoki (2002), what they dislike about recycling the most is "recycling need a lot of work". "Recycling needs time" is second biggest answer. I could not find the data exactly how much time and effort Japanese consumer spend for sorted discharging, however it would be clear they need much more energy for discharging. It could say Swedish system is more consumer-friendly rather than Japanese system.

Chapter 5 Discussion and Recommendations

As analyzed in chapter four, both Swedish and Japanese PET cycle system has advantages and disadvantages from three aspects. In this chapter, discussing the examples of advantages and disadvantage from each system, recommendations are given in order to help develop an effective sustainable product system effective from environmental, economical and social perspective.

5.1 The Swedish System

The two PET bottle related law guide the Swedish system. Compare to the Japanese system, the Swedish system looks simpler. The Swedish government only defined the target-recycling rate, so that industries themselves create and manage the system under the producer responsibility. The system works well and has strong advantages over the Japanese system. Firstly, distribution of refillable bottle is effective to reduce the input of resource and prolong the product life cycle. Secondly, the Swedish system allows for the bottle circulation many times. The system regulates accumulate the waste by a high recycling rate. Finally, the Swedish industry fulfills their responsibility physically and financially.

However, the PET recycling rate in Sweden has stabilized, and the recovery of small one-way PET bottle is decreasing. It would be important to motivate consumer take back waste PET bottle. Consumer based education or raise deposit would be considered as a measure. Furthermore as a source reduction measure, a lightweight bottle invention would bring more effects for input of the resource.

5.1.1 Educational Improvements

The PET bottle system is managed by many actors. However, among them, a key actor to cycle the system would be consumers. As figure 2 in chapter two shows the flow of the material, they have two choices. One is take-back empty bottle to retailers, and the other choice is that throw them away mixed with other household waste. When waste PET bottles thrown away by consumers, then the material cycle loop ends in the incineration or landfills. On the other hand, when they are taken-back to retailers, then the waste PET bottle is refilled or recycled. Extending the bottle loop or not is depending on consumer's decision.

The recycling rate of Swedish system has stabilized. In order to improve the bottle circulation, further recovery of waste PET is necessary. Considering the importance of consumer's role in the system, motivate consumers to return-back empty bottles to retailers would be a key policy. Returpack-PET is trying to improve the collection of waste PET bottles by on-going special information campaigns by advertisement and TV commercial (Returpack-PET, 2004). Consumer based environmental education would be key point in order to improve the Swedish system better.

5.1.2 Deposit System

The Swedish PET bottle system is managed by deposit refund system. Figure 8 in chapter 4 shows the effect of the deposit system. Due to the introduction of the deposit system, a high recycling rate has been achieved. Although deposit refund drives significant impact on the first year, the recycling rate has stabilized after that. Nowadays, small PET bottle consumption is increasing and their recycling rate is lower than larger bottles, so measures to improve the recycling rate of small PET bottle is critical.

Increasing the deposit fund would be one effective incentive. Now deposit of small size one-way PET bottle is 1 SEK. Comparing with returnable PET bottle (deposit 4 SEK), the fee is small. Referring the returnable PET bottle, it achieved 98% of recycling rate with high deposit fund. It is assumed that this low deposit fund of small PET bottle could be a negative incentive for consumers not to return them back to retailers. If the deposit raised to 2 SEK or more, the recycling rate might be improved.

5.1.3 Lightweight Bottles

The main source reduction measure of the Swedish system is based on refillable bottle distribution. Refillable bottle enable to reduce the input of raw materials and prolong the lifecycle of the product. However, introducing other source reduction measures together with refilling system could prevent more materials from becoming a part of the waste stream. Introducing a lightweight bottle like Japanese system would be effective for source reduction. It could reduce the amount of materials to make a single container. The lightweight bottle also reduce consumer's burden during their transportation.

Besides, colored bottle regulation, which Japanese beverage industry voluntarily regulated, would be considered. Colored resin is difficult to remove its color in the recycling process, so that this regulation is effective for simplifies the process of recycling (Yasui, 2003). In Sweden, Returpack-PET set extra sorting fee for colored PET bottle. However, regulation for colored bottle would be more effective for further recycling process.

5.2 The Japanese System

Compared to the Swedish system, the Japanese PET bottle system is more complex; therefore, it is difficult to grasp the whole picture of the system. This is because the Containers and Packaging Recycling Law structured the system, and industry and municipality have two choice of route each, and both of them choose financially beneficial route. As the result, the Japanese system has

problems environmentally, economically, and socially.

First, Other measure such as refillable bottle introduction would be considered. Second, the Japanese PET bottle economical system imposes the biggest financial burden to municipality, not industry. Furthermore, the expansions of PET consumption reduce the cost to industry, and increase the cost to municipality under the financial mechanism. In order to meet real financial producer responsibility, the transport cost and storage cost should be paid by industry. Finally, the Japanese system imposes much work for consumers. Establishing the new system to reduce their burden would be important.

5.2.1 Refillable PET bottle

As environmental aspects, source reduction measure is not enough in the Japanese system, comparing to Swedish system. Only introducing the lightweight PET bottle do not have significant impact. In order to reduce the input resources, introducing a refillable PET bottle would be useful measure; however, there are some impediments for implementation of refillable bottles in Japan. First, consumers' awareness is one of the biggest concerns (Universal Reuse Kenkyukai, 2003). According to the questionnaire taken by Bin Reuse Network (2002), retailers and bottlers are estimated that refillable bottle will not accepted by Japanese consumers, because of a scratch and hygiene problem. They believe consumer consider physical appearance even if it is a beverage container. Furthermore, referring the situation decreasing the share of reusable bottle, it is clear that distribution of refillable PET bottle would be difficult. Second, the Japanese financial mechanism plays an impediment to promote refilling system, even if there is already established the PET bottle route, which is similar to Swedish refilling system. As mentioned in chapter five in Japanese financial system, financial mechanism motivate industry to choose "Designated Organization Route" instead of "Self-Collection Route" which is the refilling system route.

Meanwhile, there would be a possibility to introducing refilling system. According to the questionnaire taken by Tezuka (2002), Consumers answered that they will choose refillable bottle rather than one-way bottle if it is less impact to environment or cheaper price. Furthermore, even if transportation and storage cost start to include in the recycling fee, more industries will choose the "Self-Collection Route" and it could bring the incentive for them to establish the refilling system.

5.2.2 Recycling Fees

Japanese system imposes financial burden for municipality instead of industry. There is no incentive for industry to reduce the input resource, and drives more production and consumption. These problems are come from the function of "recycling fee".

Theoretically, recycling fee is the fee of recycling paid by industry. It is looks like administration fee in Sweden; however the function is totally different. Swedish administration fee is the cost to industry, which calculated by the quantity of PET bottle consumption. Japanese "recycling fee" is the cost to industry, which calculated by the share of each company's PET consumption among the whole consumption. It assumed that if the total consumption of PET bottle increase, the each company's share will decrease, and it drives to reduce recycling fee (See figure 14 in chapter four). If the Japanese recycling fee were calculated by based on exact production and consumption like Swedish system, it would also be an incentive for industry to reduce the input resource.

Furthermore, municipality have the biggest financial burden is the problem of the Japanese PET bottle system. This is because they have a responsibility for sorted collection under the Containers and Packaging Recycling Law. The cost to municipality is based on the transportation and storage of waste PET bottle. These costs are the largest hidden cost for recycling, and affect the social cost as well. All consumers pay equally the same cost whether they consume a lot of PET bottle beverages or not. If transportation and storage cost of municipality included in the recycling fee, their burden would decrease. It might increase the beverage bottled in PET bottle; however, in this case, consumer fairly affected the impact. The more people consume the PET beverage, the more they need to pay the recycling fee for PET bottle.

5.2.3 Take-back System

Swedish take-back waste bottle system would be more consumers friendly rather than Japanese system. However there are estimated impediment such as space and logistic problems. First, there is not enough space in retail store. As mentioned in chapter three, convenience store and vending machine has large market among retailers in Japan. In order to establish take-back system like Sweden, the RVM would reduce retailers and consumers extra effort. However even in Sweden, the RVM are established only in supermarket or big shopping center, and small shop such as convenience store or kiosk use big bag for collection. According to Family Mart Japan (convenience store chain), the biggest problem to introduce take-back system is "the storage space". Second, Logistic problem is considered. As already mentioned in 5.2.1, even if there is already established the PET bottle route, which is industry itself collect the waste PET and transport them to recycling plant. Nevertheless, financial mechanism could be an impediment to promote the route.

Meanwhile, there is a possibility to introduce the take-back system in Japan. Concerning the space problem, it would be difficult to keep the space for waste bottle in the convenience store or vending machine, since they are managed in a limited space. However, other supermarket and shopping center could have possibility to settle the RVM. Now the government and RVM Company, TOMRA Japan, cooperated together, and has started to settle the RVM in downtown and shopping center in

metropolitan area since this October (TOMRA Japan, 2004). The model system has planned for three month, so still the result has not show up, however this approach will be a main stream from now on. Furthermore, if the industry financially has to perform the responsibility of transport and storage by including these fee to the "recycling fee), it could move industry to establish the take-back system. As the result, it would reduce consumer's burden.

As explained previous part, there are more problems in Japanese recycling system comparing to Swedish system. However, there are some distinctive advantages of Japanese system. First, recycling rate has increased rapidly. It is said this rate is the highest recycling rate without deposit system in the world (Yasui, 2003). In order to continue increasing the recycling rate, consumers cooperation is necessary. Second, lightweight bottle is effective as source reduction measures. Regulation of colored bottle prevents extra work of removing color in further recycling process. In order to achieve further source reduction, introducing refilling system together would be effective. Third, "Bottle to Bottle" technology invented, which enables to remanufacture waste PET bottle to new PET bottle without any raw PET resin input (Figure 5 in chapter 3). This is the first invented technology to chemically recycle the waste PET to new PET bottle completely. Consumers could not recognize which bottle is made from waste PET with "bottle to bottle" technology. The bottle looks like totally "new" bottle at glance. In order to close the bottle loop in the Japanese system, promote this recycling system would be important.

Chapter 6 Conclusion

This study has analyzed in an integrated manner from a life-cycle perspective, the best alternative system to improve the system better through comparing the Swedish and Japanese system. The analysis is revealed by the three aspects of sustainability.

In the Swedish system, refilling system is effective to reduce the input of resource and prolong the product life cycle. High recycling rate allows for bottle circulation many times. Additionally, the industry fulfills their producer responsibility physically and financially, but the system was difficult for small industries and non-Swedish industries to enter the Swedish market. Furthermore, the recycling rate has stabilized. In the Japanese system, the bottle consumption and recycling rate increased rapidly, and expanding recycling capacity drives scrambling waste PET bottle. The problem is the biggest financial burden is imposed to municipality, not industry. Japanese sorted collection system is unfriendly for consumers.

This study recommends the following the measures to be taken improve the PET bottle system in Sweden:

- Educational improvements to consumers
- Raising the deposit cost of small-sized PET bottle
- Introduce lightweight PET bottle and regulate the colored PET bottle

The same recommendation is given for the Japanese system.

- Introduce refillable PET bottle
- Include the waste PET bottle transport cost to the industry
- Establish take-back collection system

References

Aoki Michiyo, 2002 “Marketing and Environment – In order to Promote Recycling” (in Japanese)

Bin Reuse Network, 2000 “Returnable bin ni tuite no jigyousya anke-to zenkoku issei tyousa houkokusyo”

Boustead, I. and Lidgren, K. 1984 “Problems in Packaging – the Environmental Issue”

Carter Neil, 2001 “The Politics of the Environment” Cambridge University Press, 2001

Deposit hou seitei zenkoku network (Deponet) 2002, “Daredemo dekiru Deposit – Nakusou poisute! Sigen recycle no susume” (in Japanese)

Eco-Profiles of the European Plastics Industry, 2002 “ Polyethylene Terephthalate”

G. Dodbiba, N. Haruki, A. Shibayama, T. Miyazaki, T. Fujita, 2001 “Combination of sink-float separation and floatation technique for purification of shredded PET-bottle from PE or PP flakes”

Hagengut, M. A. Christina, 1998 “Packaging Recovery and Recycling in Europe – Implementation of the European Directive on Packaging Waste” INTEC Consulting GmbH

Haraldsson, V. Hordur, 2004 “Introduction to System Thinking and Causal Loop Diagram”

Ishiwatari Masayoshi, 2002 “Sanpai Connection – Sanpai G men ga kokuhatu Huhoutouki Business no sinsou” (in Japanese)

Ishiwatari Masayoshi, 2004 “Recycle Under World” (in Japanese)

Japan Chain Store Association, 2003 “Sales Statistics 2003 (in Japanese)”

Japan PET bottle Association, 2000. “Guideline 2000 (in Japanese)”

Japan Soft Drink Association 2003 “Soft Drink Statistics 2004”

Japan Vending Machine Manufacture’s Association, 2003 “Jihanki Hukkyuu daisuu oyobi nenkan jihan kingaku (in Japanese)”

JETRO (Japan External Trade Organization), 2001 “Environment Japan 2001”

Kankyo Keizai Shinbun 2004/3/22 “Jichitai ga baikyaku 1kg 20 yen de”(in Japanese)

Kawamura Chikara, Kei Ito, Reijinro Nishida, Ichiro Yoshihara, Nobushige Numa, 2001 “Coating resins synthesized from recycled PET”

Kirin Beverage “Environmental Report 2004” (in Japanese)

Mainichi Shinbun, 2004/7/21”Jichitai hutan Maker no bai” (in Japanese)

Mattsson Cecilia, 2003 “Waste Management and Producer Responsibility in Sweden”

Ministry of Economy, Trade and Industry, 2002 “Legislative System and Policies to Establish a Recycling Oriented Society”

Ministry of Economy, Trade and Industry, (METI), 2003a “Law for Promotion of Sorted Collection and Recycling of Containers and Packaging”

Ministry of Economy, Trade and Industry, (METI), 2003b “the Containers and Packaging Recycling Law”

Ministry of Economy, Trade and Industry, (METI) 2004 “Inryoukyouki no doukou” (in Japanese)

Ministry of the Environment, department of waste management and recycling, 2003 “Youki housou haikibutsu no siyou haisyutsu jittai tyousa oyobi kouka kennsyou ni kannsuru jigyou Report in 2003” (in Japanese)

Ministry of the Environment “Swedish Environmental Legislation - booklet 3 Waste Disposal” Stockholm, 1996

McDonald Seonaidh and Ball Rob, 1998 “Public Participation in Plastics Recycling Schemes”

Monthly Waste, 2004 April, “Plastic Gomi no Yukue (in Japanese)

Morishita Ken, 1997 “Gomi mondai wo dousuruka – haiki, shori, and recycle” (in Japanese)

Niikkei Business, (2004), June “Thugoku danomino saisei ni matta” (in Japanese)

Nikkei Ecology, 2004 August “Report- Recycle” (in Japanese)

Nishimura Hisashi, 2001 “History of Manufacture methods and used materials for beverage container”

Robinson, L. David, 1996 “Beverage Container Deposit Return Systems: the case of Sweden and California” IIIEE

Roseveare Deborah, 2001 “Encouraging Environmentally Sustaonable Growth in Sweden” Economic Department Working Paper No.289 OECD

Plastic Recycle Kenkyu-kai, 2000 “Saishin Plastic no Recycle 100 no Chishiki” (in Japanese)

Returpack-PET, 2003 “Deposit, Handling Fee, Administration Fee and VAT”

RVF 2003 “Swedish Waste management”

Swedish Competition Authority (SCA), 2003 “Deposit Systems for Aluminum Cans and PET Bottles”

Saphire David, 1994 “Case Reopened – Reassessing Refillable Bottles” Inform Inc, NY

Suntory (2004) “Suntory Ecoship Report 2004” (in Japanese)

Swert, R. J, Raskin, P, Robinson, J. (2004) “The Problem of the Future: Sustainability science and scenario analysis”

Teijin (2004),“Environmental Report 2004” (in Japanese)

Tezuka Yuko, (2002) “Returnable bottle wo hukkyu saseru kotoga dekirunoka” (in Japanese)

The Council for PET bottle recycling, 2004 “PET bottle recycle annual report 2004” (in Japanese)

The Council for PET bottle recycling, 2003 “PET bottle recycled Products Catalogue 2003” (in Japanese)

Universal Kenkyukai, 2003 “Returnable Bottle – recycle suru mae ni returnable bottle wo tukaitai” (in Japanese)

Vanthournout Helga, 1998 “Beverage Container Recycling System in Germany, Sweden and Switzerland” IIIEE

Yasui Itaru, 2003 “Recycle – Mawaru karakuri tomaru wake” (in Japanese)

Yoda Naoya, 1999 ”Corpotate management in the age of global environmental awareness : a case study of PET-bottle recycling issues in Japan” Polymer International 48:944-951

7 token haikibutu mondai kentoiinkai, 1998 “Research of PET Bottle Recycling” (in Japanese)

Internet Source

Coca Cola Sverige
http://www.coca-cola.se/index.jsp [Accessed on November 16]

Returpack-PET
http://www.returpack.se/ [Accessed on November 20]

REXAM
http://www.rexam.com/ [Accessed on November 16]

Swedish Breweries Association
http://www.sverigesbryggerier.se/eng/index.htm [Accessed on November 20]

Swedish Environmental Protection Agency
http://www.internat.naturvardsverket.se/index.html [Accessed on November 20]

The Council for PET Bottle Recycling
http://www.petbottle-rec.gr.jp/english/index.html [Accessed on November 20]

TOMRA
http://www.tomra.no/ [Accessed on November 16]

Interviews

Sweden

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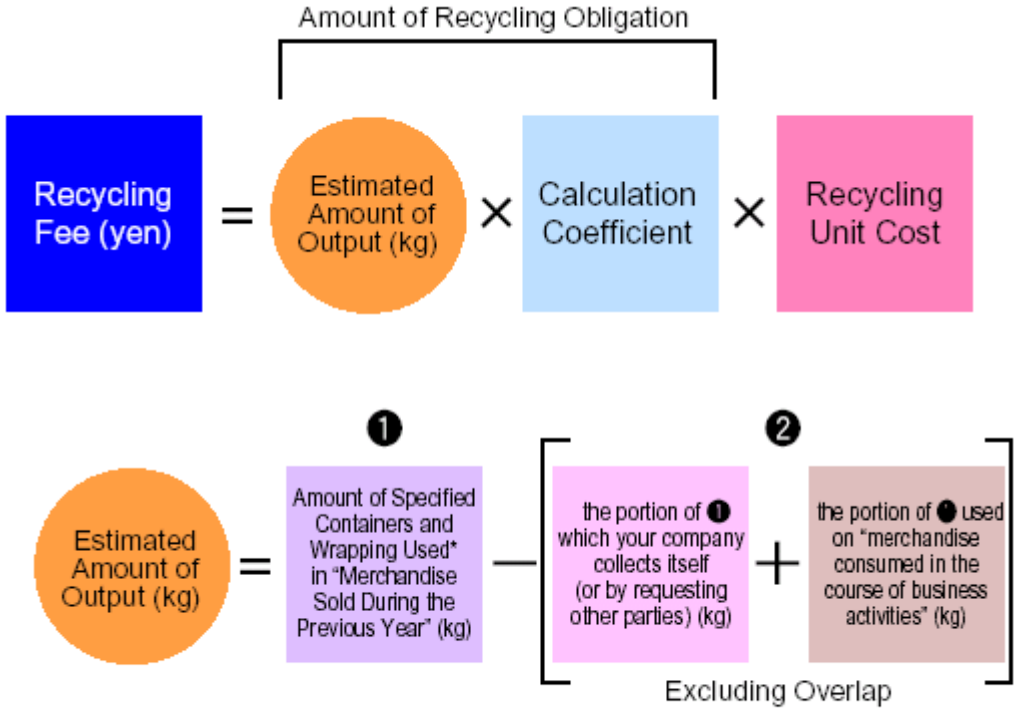
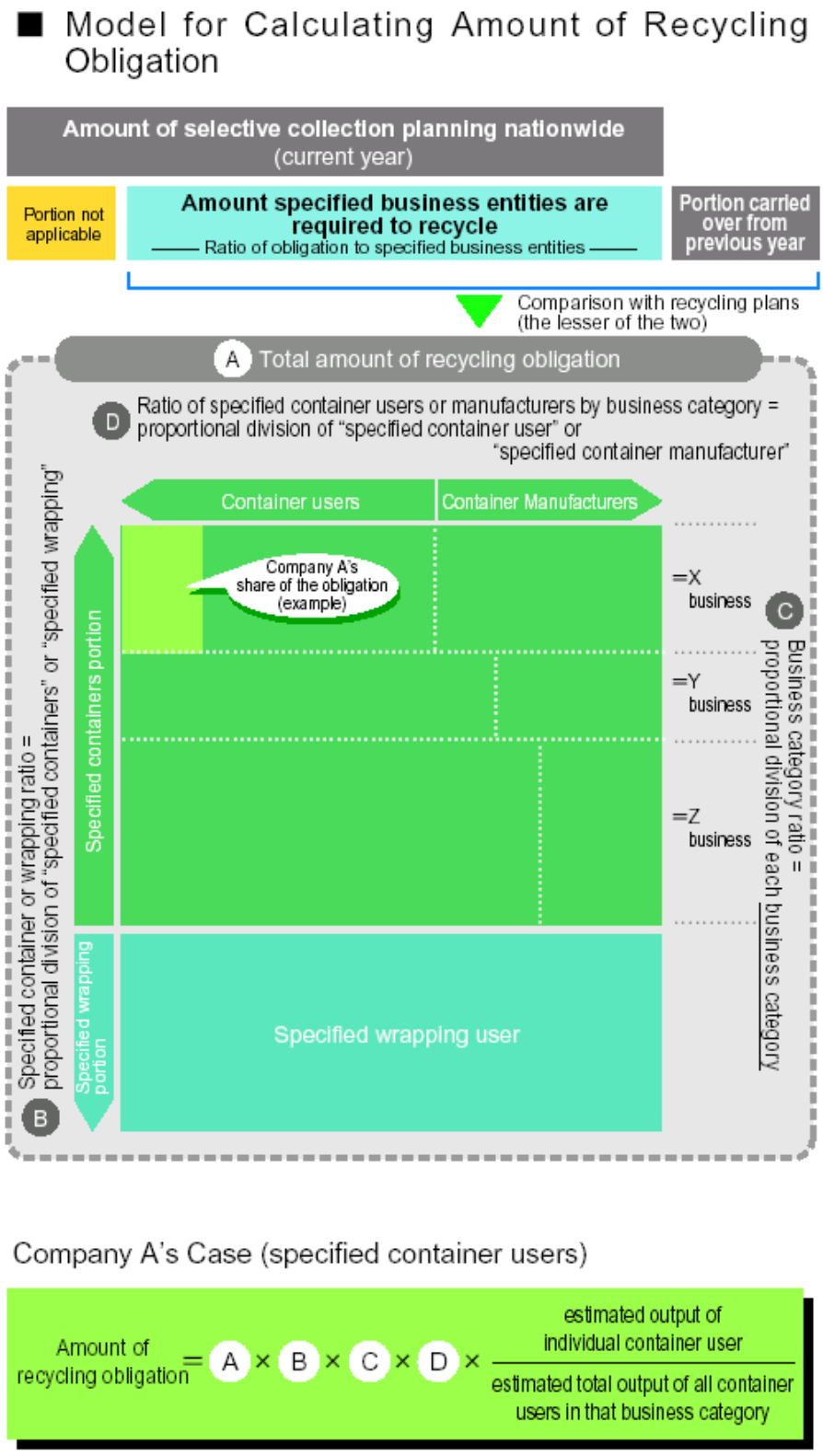
Appendix 1



*For "specified container manufacturers," please substitute "manufactured" in place of "used."

Source: METI (2003a), "Law for Promotion of Sorted Collection and Recycling of Containers and Packaging"

Appendix 2



Source: METI (2003a), "Law for Promotion of Sorted Collection and Recycling of Containers and Packaging"