LAPPEENRANTA–LAHTI UNIVERSITY OF TECHNOLOGY LUT
School of Energy Systems
Department of Environmental Technology
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Master's thesis 2019

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Possibilities of Utilizing Polyethene Terephthalate (PET) Bottle Deposit-refund System in China

Examiners: Professor Mika Horttanainen
Associate Professor Jouni Havukainen

ABSTRACT

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Keywords: Plastic waste, deposit-refund system, PET bottle, extended producer responsibility, China.

To shed light on the potentials and possibilities of domestic Polyethene terephthalate (PET) bottle waste recycling and collection in China, this paper studied the DRS used in developed countries and explored the status quo of the challenges and needs in China. The pros and cons of utilizing a DRS have been analysed. The results show that the success factors to increase the PET bottle recycling rate lies on the following aspects: the strict legislation concerning tax regulations on beverage producer's responsibilities; the awareness of consumers to return the deposit packages and also well-educated to form habits on return; the correct deposit values and broad coverage of deposit packages to promote the citizens to join the recycling process; and the well-functioning reverse vending machines, convenient collection points and wide collection network. The dual-flow scenario of DRS shows the strong advantages of the social benefits especially concerning the scavengers, and the collection and the rate of return can be increased by the formal recycling system. The main conclusion is that DRS is an urgent need in China to formally recycle PET bottles and increase the recycling rate. The adaptation needs to be further considered, such as utilize the unique resource of scavengers and assign a governmental organization of DRS administrator and operator. From the case study in Beijing, we can see many potentials and grounds to utilize DRS in future market. This study provides a good understanding of the sustainable chain for PET bottle recycling in China, which can reduce the environmental impacts, and improve the social well-being of health and safety.

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Wei Kou

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Abbreviations

DRS Deposit-refund System

EEA European Economic Area

EPR Extended Producer Responsibility

PET Polyethene Terephthalate

1. INTRODUCTION

1.1 Background

Plastics as emblematic materials have been transforming our lives for more than 60 years with unprecedented and versatile functionalities in a broad range of applications. Plastics production which is primarily from fossil oil has risen sharply in the past decades accordingly. The plastics produced in the past three decades corresponds to the total amount during the last ten years worldwide. Polyethene terephthalate (PET) is the most useful and essential plastic material for beverage packaging globally today, and it is utilized as the containers of beverages, such as water, soft drinks and alcohol. It features lower weight and tougher than glass due to polyethene terephthalate's chemical characteristics. The usage of PET bottles has been growing fast all over the world. PET used in packaging beverages drives the Global consumption of PET resin and accounts for 79% of the world total beverage containers in 2017 (Information Handling Services 2018). In 2016, about 485 billion PET bottles were produced, and the annual growth rate was about 5.1% between 2004 and 2016 (Statista 2018). This number has been forecasted to reach 583.3 billion in 2021 (Statista 2018).

With the increasing demand for PET bottles, it has brought huge impacts on the environment and resource use. Firstly, the raw material of PET is mostly extracted from crude oil, energy-saving gas and coal. As we know, during the 1970s, the world met the energy crisis and the oil crisis because of the shortage of petroleum in the industrial countries. The crisis has warned the globe on the urgency of energy-saving and sustainable use of fossil resources for the future. However, with the growing demand for human consumptions, the use of natural resources have been tripled in the past 40 years (Ecowatch 2016). It has been reported that every minute a million plastic bottles are consumed around the world (The Guardian 2017), and in the U.S., the petroleum used to produce PET bottles to supply national need can

approximately run more than 1 million vehicles for a year (Water well 2016). Secondly, during the production process of PET bottles, fossil resource is burned, and the toxic chemicals are released into the air, e.g., toluene, acetone, trichloroethane, which are the main components of greenhouse gas emissions. It is reported that PET bottles generate 100 times toxic gases to the environment than the same size of glass bottles (Ecology Center 2018). Greenhouse gas emissions will seriously cause a toxic environment and affect social well-being. Obviously, the production and use of PET bottles have become one of the hot topics as global warming and climate change (The Conversation 2019).

After the PET bottles consumed, they become household solid waste, so-called post-consumer PET bottles. In 2016 worldwide, less than half of the bottles were recycled in which only 7% were ideally turned into new bottles. The other remained post-consumer bottles had to go to landfill or ocean (The Guardian 2017). As reported by Plastics Europe, in 2017, 31.1% of the collected plastic wastes were recycled, 41.6% were used for energy recovery, and 27.3% went to landfill (Plastics Europe 2017). In the U.S., the recycling rate of post-consumer PET bottles was 30.1% in 2015 and 28.4% in 2016 (APR 2016). Recycling of PET bottles can reduce the consumption of fossil resource and energy per unit of product, hence can lower the impact on the environment and is recognized to be eco-efficiency (Lehni and WBCSD 2000). The life cycle case study showed that among the three methods, recycling could reduce environmental impacts by 30 times than landfill and three times than incineration (Xie et al. 2011). To achieve a higher recycling rate of PET bottles, deposit-refund system (DRS) (Walls 2013) has been introduced to the market by collecting the post-consumer PET bottles from the consumers with granting a surcharge. In Europe, the member states of the European Economic Area (EEA) have introduced systems of separating the collection of packaging waste. For example, Sweden, Denmark, Norway, Iceland, Estonia and Germany have implemented mandatory DRS schemes on beverage package. Finland uses a voluntary system that is close to a mandatory DRS because of tax regulation. After one year with the utilization of the DRS, the recycling rate of drink containers has been

increased by 15% in Finland. A DRS was utilized in Germany in 2003 and now it achieves 99% recycling rate of plastic bottles (Hassi & Pietkainen 2011). Currently, DRS is gaining ground and actions across the globe. Besides the 38 countries which have DRS running, other countries are also intensively developing or testing their own DRS that can adapt to the local market and social culture. For example, a forthcoming deposit-return scheme is announced and will be utilized in England, and a plan is also going on to introduce DRS in Wales (The Guardian 2018; Defra 2019).

From a global perspective, during the past decades, we have seen the fast-growing of consumed PET bottles and a pretended interest on the DRS. However, it is of significance to know how the PET bottle recycling in the largest consumer market in the world, China. In 2010, China had 3.2 million tonnes of a consumed PET bottle, and in 2016 it took account of 24% of global demand. China has become the world's number 1 leading country on PET bottle consumption and demand. Furthermore, the growing trend is still expanding in China. Before 2018, China was also the leading importing country for waste plastics as 56% of the worldwide waste were received by China (ISWA 2014). China is the key player in the global stage for the production, consumption and trade of PET bottles. Nonetheless, in 2018, China announced a plastic waste ban and refused to accept West's plastics anymore. It gives an urgent sign to the western countries but also brings a serious question to himself as that a safe system for the plastic product returning and recycling cannot wait especially concerning the legislation, resource use, and social aspect. Until 2017, the Incom Recycle, a company working on the DRS of recyclable PET bottles, has installed 5000 waste-buying depots in Beijing and almost 55,000,000 PET bottles have been successfully collected and recycled (People's Daily 2017). The recycling rate is as high as 70%. Currently, PET bottles have a high collection rate and it involves an informal army of recyclers working with the waste. However, there is no systematic regulations and laws to standardize the industry and residents on how to recycle and dispose of the PET bottles.

To shed light on the potentials and possibilities of domestic PET bottle waste recycling and collection in China, the DRS used in developed countries will be studied and the current situation of the challenges and needs in China will be explored. The pros and cons of utilizing a DRS will be analysed. Through this study, a good understanding of the DRS and a discussion of its adaptation will help to develop a sustainable chain for PET bottle recycling in China, which could further lower the environmental impacts, and improve the social well-being of health and safety.

1.2 Objective and scope

The study aims to introduce the deposit-refund system to China's PET bottle recycling collection by revealing the existing problems and needs, learning from the successful DRS schemes in developed countries, and comparing the pros and cons when adapting a DRS in a case study of China. The results can provide an insight to the policymakers to develop the idea and make the plan of a returning scheme for plastic waste, and as well push the relevant stakeholders and end-users to participate in the sustainable chain of PET bottle recycling. Ultimately, the DRS will help to meet the domestic demand for PET bottle production, efficient collection and environmental collection, and to achieve a healthy and safe social environment for the public.

The study focuses on post-consumer PET bottle's recycling collection. Herein, the PET bottle is used to contain the beverages of water, soft drinks and alcohol. The stakeholders involve end-user, retailer, informal recycler, producer or importer, recycling industry, and also the key players of government or organization.

1.3 Research Questions

Three main research questions are to be addressed in this study:

- Status quo of PET bottle in China: how the post-consumer PET bottles are collected for recycling, and what are the existing problems, needs and challenges for the future?
- DRS schemes: what is a DRS and how it works? What are the success factors of the DRS in Sweden and Finland?
- The possibilities of implementing DRS in China: what are the potential benefits and challenges of implementing DRS in China? What might be the success factors to implement a DRS in China?

1.4 Methods

A literature review was used to search the relevant standards, articles, papers and news. The searching engine and database involved Mendeley, Science Direct, and Google Scholar. The keywords being searched include PET bottle, deposit-refund system, environmental impact, plastic waste, and sustainable waste recycling.

This study compared the DRS in Finland and Sweden. These two countries are represented in Northern Europe and are leading the research of sustainable development regarding waste treatment and recycling, and the advanced strategies on environmental protection and low carbon society.

A case study was conducted in the city of Beijing, China. Beijing is one of the domestic leading consumers of PET bottles. Aiming to implement the DRS in the future, two scenarios were designed concerning the involvement of recyclers and the responsibilities which include sole-flow from consumer to DRS and dual-flow from either consumer to DRS or consumer to the private recycler and thence to DRS.

In the Beijing case study, the SWOT analysis was utilized to systematically explore the pros and cons of using DRS in China. The features of the DRS used in Finland and Sweden were further analysed, and the success factors and the limitations were figured out when adapting DRS to China's society.

The following figure 1 presents the approach structure of this study, involving the workflow with a research subject, research questions, methods and targets.

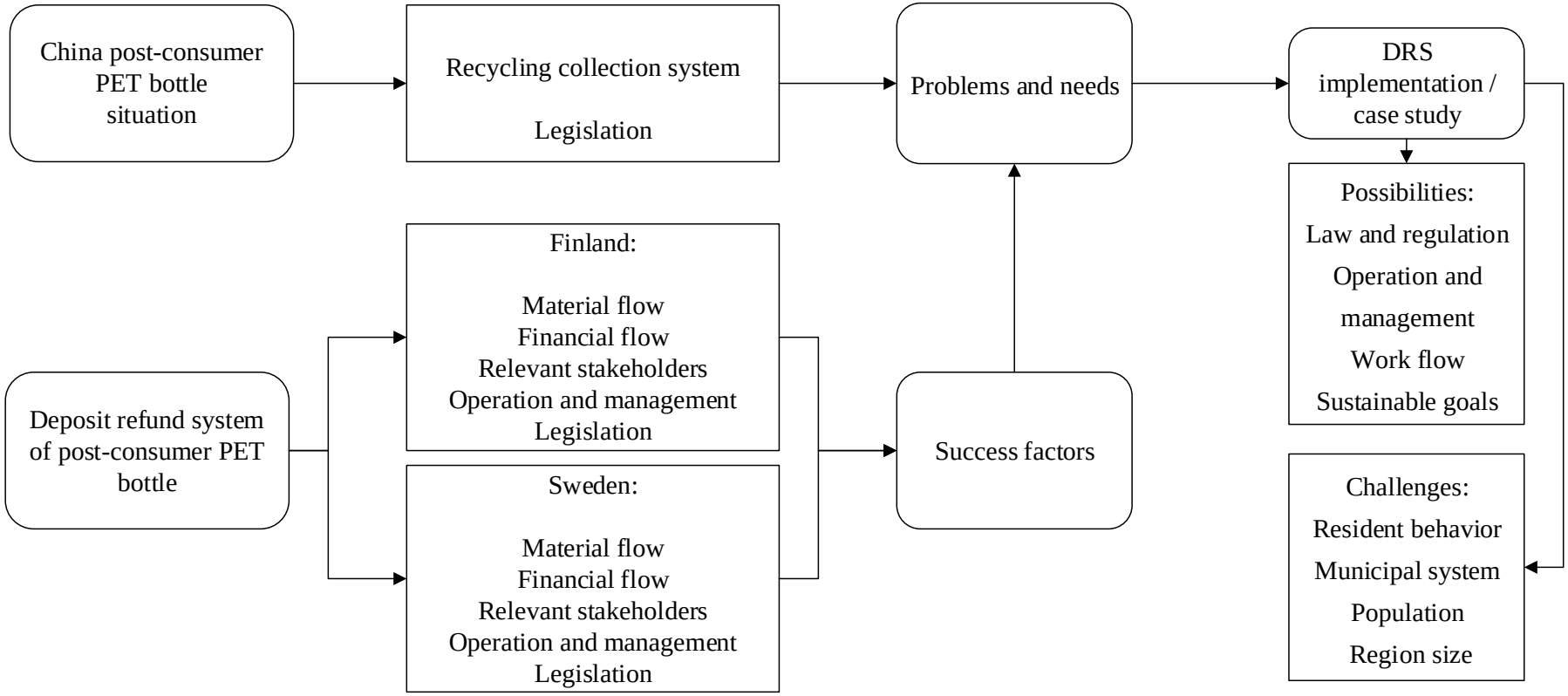

Figure 1. Approach frame structure

2. STATUS QUO OF POST-CONSUMER PET BOTTLES IN CHINA

2.1 The Recollection and Recycling of Post-consumer PET Bottles

When the recycling rate of PET bottles was expected to be 50% in Europe and 27% in the US, in 2010 the recollection rate of PET bottles in China especially in the urban cities has been studied to be nearly 100% (Frank Welle 2011; Hu, 2012; Chinabzp 2011; Li et al. 2010). It indicates that the total amount of the consumed PET bottles is approximately equal to the recollected PET bottles after the consumption. The possible destinations for the post-consumer PET bottles can be to garbage cans, waste-buying depots, recycling stations, landfill places, and waste incineration plants. However, the special situation in China is that all the PET bottles thrown to the garbage or on the ground will be hugely collected by the scavengers who are the so-called informal army of recyclers. They have been playing a key role to help with the high rate of PET bottle collection in the society nowadays.

Nonetheless, the nearly 100% recollection rate in urban China does not take the losses and rejections during the transfer and recycling process into account. The real recycling rate can be lower than the ideal collection rate. Currently, the post-consumer plastic bottles account for more than one-third of the total municipal solid waste in China. It has been reported by Beijing Daily that in Beijing there still exist tons of recyclable waste abandoned in the landfill places and PET bottle accounts for more than 90% (Ma 2017). If we focus on one regional waste transfer station in Beijing, on average every day at least 2.7 tons of PET bottles which are recyclable are mixed with the other non-recyclable waste. Another study addressing the recycling rate was conducted during the eleventh five-year plan. In some pilot cities, the recycling rate of plastic wastes was studied to be 40%. After applying the new system of neighbourhood collection points, the recycling rate has been increased to be 70% (Costas Velis 2014).

The above information illustrates the imbalance between the recycling rate and recollection rate. So far, we still lack the representative and statistical data on PET bottle's recycling rate in China as well as the detailed material flow of post-consumer PET bottles. Nonetheless, some case has been conducted based on evidence-based data collection regarding PET bottle's consumption, recollection, recycling and disposal. Zhang and Wen (Zhang and Wen 2014) conducted holistic questionnaire studies in Beijing to study the consumption and recycling collection of PET bottles. Based on the collected 580 surveys, it found that 90% of the post-PET bottles were recollected by informal recyclers including scavengers and itinerant waste buyers, and nearly all the PET bottles were reprocessed in private recycling factories. This case study is a good example to show the material flow of the PET bottle in Beijing, China.

An interesting question of PET bottle in China is where the post-consumer PET bottles have gone after the high-rate of recollection. Based on the data information from the case study in Beijing (Zhang and Wen 2014), we further illustrate the recycling rate of PET bottles and the material flow in the following figure 2. Given the quantity of the total flow of consumed PET bottles is 1, 0.6 is thrown into the garbage bin, and 0.4 is still saved by the consumer. Nearly all the PET bottles in the garbage bin are recollected by the scavenger as the informal recyclers. They further sell the bottles to the recycling dealers containing both formal dealer of recycling company and informal dealer of redemption depots. A difference can be that the formal recycling company needs to fulfil the requirements on land use and environmental pollution control. In this case study, all the scavengers sell PET bottles to the redemption depots. Finally, the recyclable dealers sell the PET bottles to the recycling factory for further treatment of raw and processed materials, e.g. fibre for clothing, blankets, as well as the sheet, strapping and re-use PET bottle. In figure 2, we also see the other path of a post-consumer PET bottle is through the trade between consumer and buyer which accounts for 0.4. Regarding the buyers, they are also partly informal depots at the community level. In 2006, China implemented the formal collector system of "small community waste-buying

depots" which get officially governmental permission to collect the recyclables and also make the separations accordingly. Apart from the formal buying depots, there still exist itinerant buyers who are informal but play a key role in the recycling system. We can see that 0.3 PET bottles have been delivered to the community small buying-depots than 0.1 to the formal depots. After the recollection at the personal and community levels, the collected PET bottles are sold to the recyclable dealers which is the same as shown in the other path. However, in this case, a difference is a small part of PET bottles are delivered to the recycling company although the formal depots still send a big part of PET bottles to the informal redemption depots. Lastly, all the PET bottles go to the recycling factory for further treatment. In figure 2, it assumes the total flow of PET bottles is 1, and nearly all the post-consumed PET bottles which have been thrown away are collected by the scavengers. However, we should be aware that there would be some PET bottles in the trash cabin or outdoor have not been finally collected and recycled but ended up into landfill or waste incineration.

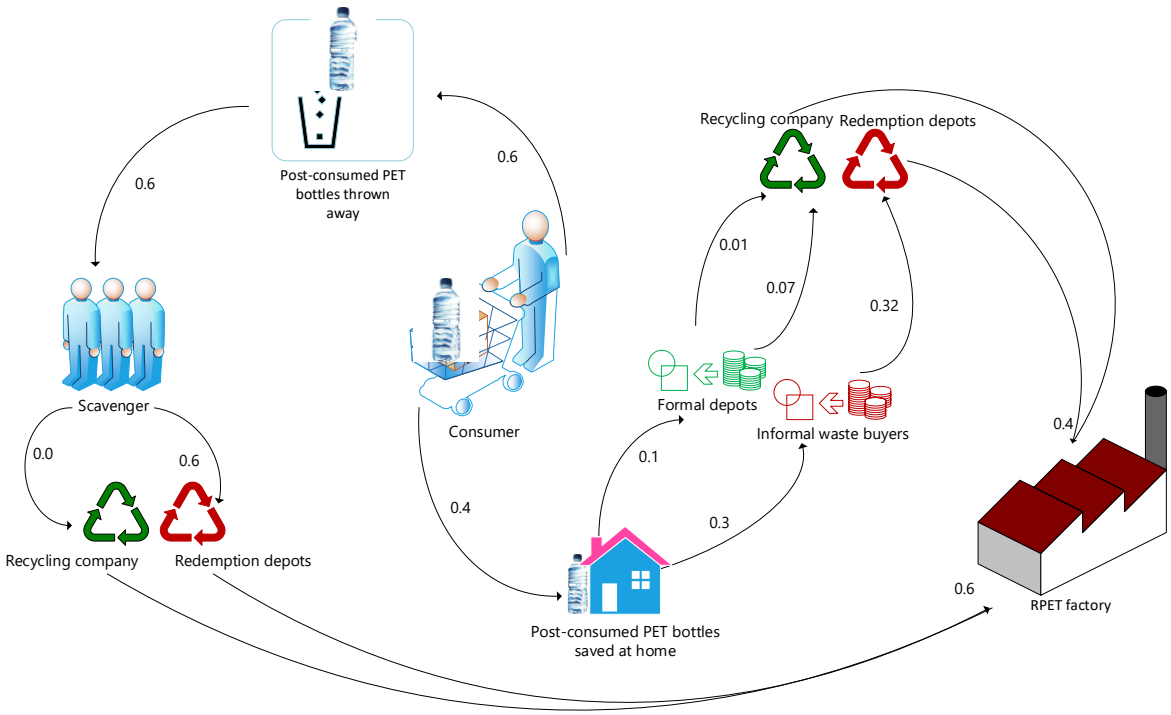

Figure 2. An illustration of the material flow of PET bottles and recycling rate in Beijing (data source: Zhang and Wen 2014)

In the material flow, we should notice that currently, many RPET factories are still not qualified from the legislation and pollution control perspectives. Moreover, in the above case study, almost no recycling dealers sell PET bottles to the RPET factories which fully qualify for the treatment process.

In parallel, we see that most of PET bottles are sold to informal redemption depots other than recycling companies. One reason is the selling price. Zhang (Zhang and Wen 2014) has provided the price information which is 5600 Yuan/ton when selling to the recycling company. However, it is a 200 Yuan/ton lower than selling to the redemption. It is reasonable that a recycling company needs a higher investment in land use and environmental protection. Obviously, it brings the disadvantage to the collectors concerning the economic perspective.

2.2. Laws and regulations

Currently, there are no incentives have been established to formally and safely collect post-consumer PET bottles. However, in the past decade, China has been increasingly putting efforts on environmental protection and resource conservation. The regulations, norms and plans have been comprehensively collected and summarized in table 1. Renewable resource recycling and waste management are the key areas to develop further. In 2006, the Ministry of Commerce had worked on a plan for the construction of Recyclables' Collection System. After that, many local governments started to build a formal recycling system by banning some private and small community waste-buying depots (Zhang and Wen 2012). After the follow-up "management for recyclables" launched by the Ministry of Commerce, Beijing demonstrated the work plan of structuring a formal recyclable collection system. In the same year, great progress going forward a formal recycling system is the "Extended Producer Responsibility (EPR)" implementation plan launched in the area of a handful of industries – electronics, automobiles, lead-acid batteries and packaging products such as paper-based composite beverage cups (The State Council 2017). Although it does not relate to plastic

waste and PET bottles, it indeed provides an exemplar to formalise the responsibility of the stakeholders in the entire process of PET bottle's lifecycle. The high motivation of the government has been also reflected in the past two "Five-Year" plans during 2011-2015 and 2016-2020, which promoting the industrialisation of the utilization of recyclable resources, the use of recyclable resources in a large scale, and building the networks of waste recycling and renewable resource reuse. In 2014, Environmental Protection Law, the state council further pointed out that the local governments should take actions to promote the separation, recycling and reuse of household waste. Just a few years later in 2017, breaking news on prohibiting the entry of foreign garbage to China was reported (The State Council 2017). Moreover, PET bottle is listed in the prohibitive category. No doubt that China intends to make the nation sustainable and friendly from a long-term development perspective. Under this law, we are also under the pressure to urgently increase the recycling rate of PET bottles and make an efficient circular system and qualified treatment for the reuse and reprocessing. In 2019, Shanghai Municipal People's Congress official announced the classification of domestic garbage as "recyclables waste", "hazardous waste", "household food waste" and "residual waste" (China Daily 2019). More cities in China are preparing to publish the local regulations of classifying household waste. It has been being great efforts to push the efficient collections of PET bottles in the near future.

Table 1. Relevant laws and regulations on waste recycling collection and extended producer responsibility in China

Year	Title	Issuing authority	Relevant objectives
2006	Work Plan for the Construction of Recyclables' Collection System	The Ministry of Commerce	The central government declared the plan of building small community waste-buying depots (i.e., depots that supply recyclables collection services to the household in the community) for recyclable collection, and chose 24 cities (including Beijing) for starting a pilot program. This pilot program continues to present, including 88 cities and 11 terminal markets.
2007	Management for Recyclables in 2007.	The Ministry of Commerce	Start the pilot program work plan for the construction of formal recyclable collection system.
2011	Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products	State Council	The state shall establish a fund for the disposal of waste electrical and electronic products to provide subsidies for the expenses for recovering and disposing of waste electrical and electronic products.
2011-2015	The "Twelfth Five-Year" Plan of China	National Development and Reform Commission	Promoting industrialization of the utilization of recyclable resources: to promote the use of recyclable resources in a large scale, to build up a batch of "urban mining" demonstration bases which have advanced technology, high environmental protection level and standard management, large-scale and strong demonstration effect. Promoting municipal solid waste sorting collection and household kitchen waste separation and recycling: to implement the municipal waste classification step by step to

			improve the collecting system gradually, and to establish and develop the close, environmentally sound and highly efficient municipal solid waste collection, transfer and transportation system; to speed up the construction of facilities by the investment being mainly made by the local government while the central government will provide appropriate support and the social capitals being encouraged to participate.
2014	2014 Environmental Protection Law. Art. 37	The National People's Congress of the People's Republic of China	The local governments should take actions to promote the separation, recycling and reuse of household waste.
2017	Extended Producer Responsibility (EPR) implementation plan	The State Council	Require manufacturers to be responsible for the entire lifecycle of a product. As for 2019 and onwards, the government will seek to build a credit information collection system. By 2020, a framework for the EPR policy will be taking shape, and relevant laws and regulations should be finalized by 2025.
2017	Notice of the General Office of the State Council on Issuing the Implementation Plan for Prohibiting the Entry of Foreign Garbage and Advancing the Reform of the Solid Waste Import Administration System	General Office of the State Council	The import of solid waste shall be strictly administered, and by the end of 2017, the import of solid waste posing a grave danger to the environment and triggering strong response from the people will have been fully banned; and by the end of 2019, the import of solid waste which can be replaced by domestic resource will have been gradually ceased.

2016-2020	The “Thirteenth Five-Year” Plan of China	National Development and Reform Commission	Promoting the network of recycling and reuse of renewable resources, enhancing the connection between household waste’s separation and recycling and renewable sources’ recycling.
2019	Shanghai Household Waste Management Regulation	Shanghai Municipal People’s Congress	Establishing new rules for sorting household waste and limiting the use of disposable items in the hospitality sector. Domestic garbage is classified according to the classification of “recyclables waste”, “hazardous waste”, “household food waste” and “residual waste”.

2.3. Problems and Needs

PET bottle was invented in 1976 and fast applied to the market as containers of, i.e. food, beverage. On the one hand, because the material cannot be degraded in nature it induces serious problems in the environment of air pollution. On the other hand, the production of PET bottle consumes fossil oil which aggravates the greenhouse emission and resource use. If the PET bottle cannot be collected and recycled toward the maximum rate, the risk to the climate and earth is an unimaginable disaster. However, in China separate the waste is still a problem so that a high percentage of recyclable PET bottles are still mixed and treated with the municipal solid waste which is eventually ended in either landfill or incineration. It will reduce the materials to reprocess new product or reuse the PET bottles. One possible reason is we still lack knowledge of the waste category. Even though in most urban areas, there are clear regulations on waste separation and advanced facility of waste recycling bins, in suburb areas, such as the small villages, the collection and recycling system is still insufficient and mature.

Figure 3. PET bottle transportation by informal waste buyers (Image source: The guardian 2017)

Concerning the material flow of PET bottles shown in the above figure 2, we are already aware that nowadays collectors can easily sell the PET bottles to informal waste buyers and redemption depots and even non-qualified recycling factories. It increases the risks to the air pollution emitted during the separation and reprocessing. Apartment from these PET bottles with the known flow direction, there are even many PET bottles which are unknown for the directions. Thus, it is very possible for these PET bottles being sent to the non-qualified small studio which may use improper chemicals to clean and reprocess. Because of the unsafe process, the air can be polluted, and unsafe PET bottles can be produced.

Since there is no national formal PET bottle collection system in China yet, it is not clear and controllable that where the post-consumer PET bottles go ultimately. Moreover, the informal sector recycling spreads widely all over the country which comprises scavengers, private recycling stores and so-called three non-enterprises that stand for no operation rules, standards and no supervision (Costas 2014). Hence, the risk exists that they are used by informal sector recycling which is not qualified or lacking technology or knowledge to

conduct a hygeian reprocess. It can directly affect the health and safety of the stakeholders who are involved in the collecting and reprocessing the PET bottles as well as the consumers of the recycled products.

So far, the collection of PET bottles is still initiated by individual behaviour. The major group of collectors and recyclers is informal and volunteer who are mainly driven by financial benefits. They are scavengers and the so-called informal army of China's waste. Consequently, it causes many social and environmental problems (Wang 2008). A common problem can be the sanitary condition of the circumstances where they collect PET bottles such as street, garbage bin, and the storage places where they save and keep the PET bottles, i.e. the tricycle, the yard. As we know, if a post-consumer PET bottle is not saved properly, it may be polluted by chemicals, bacteria, and other waste. It not only makes environmental pollution to the public but also deteriorates the health and safety of those people.

Figure 4. PET bottle collection out of landfill by the informal army (Image source: The guardian 2017)

The demanding PET bottle consumption has been expanding in China because of the industrialisation and urbanisation. However, in the past decades, the major collector is still the informal army and volunteers. The financial benefit is a driver for these groups of people to collect the post-consumer PET bottles from the individual end-users, the distributed waste container or station, and from other consumers such as shopping mall, and restaurant. After they collect the PET bottle waste, they further sell them to the salvage station by the weight, quantity or category. For example, a 600 ml post-consumer PET water bottle could be sold for 0.05 Yuan RMB. Then the collected PET bottles are further sold to the factory, processing plant, etc. and can be reprocessed to be new bottles or chemical fibre materials. Because of this social and economic context, when planning formal systems of PET bottle collection recycling in China, a follow-up problem will be how to consider the participation and role of informal sectors including scavenger and private recycler in the formal system. A prohibitive idea can influence the direct income for these people and may cause a social problem accordingly. However, an integration idea may increase the complexity of the formal system to some extent. See the following figure 3 which shows the regulations issued by local governments for and against the integration of informal WM Activities (Steuer 2017). It is indicated that the number of prohibitive regulations is higher than the integrative regulations in general between 1990 and 2016 except one year in 2011.

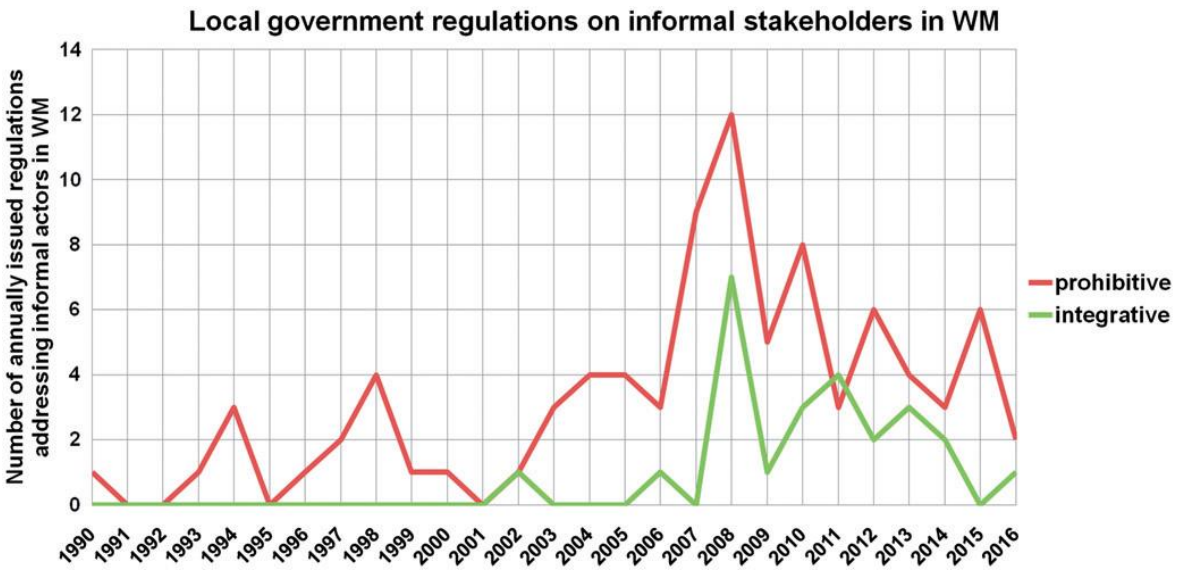

Figure 5. Regulations issued by local governments for and against the integration of informal WM Activities (Image source: Steuer 2017)

Based on the environmental and social problems shown in the above, a formal and robust recycling collection system of post-consumer PET bottles is indeed needed. Regarding the municipal policy and population size in China, the management and operation of such a collection system is also a question of concern. Until now, there are no regulated laws or associations to be responsible for collecting the PET bottle waste (Zhang and Wen 2012), and not sufficient incentives to encourage the residents and recyclers to join in the recycling. Hence, a recycling collection system which can be adapted to China's market and concerning different levels of legislation, stakeholders and participants are on demand.

3. DRS – DEPOSIT-REFUND SYSTEM

3.1 Deposit-refund System Introduction

Deposit-refund system (DRS) is basically a recovery system composed of a subsidy and a tax. It is defined Glossary of Environment Statistics Terms as *"A deposit-refund system is the surcharge on the price of potentially polluting products. When pollution is avoided by returning the products or their residuals, a refund of the surcharge is granted."* (UNSD 1997). The consumers need to pay an extra monetary deposit on the product at the point of purchasing. When they put the waste back to the official take-back point, the charged deposit will be refunded to the purchasers again (Turner & Opschoor 1994). A beverage container, e.g. PET bottles, aluminium cans and glass bottles, is the prevailing goal of deposit-refund system. Also, the deposit-refund system is applied to non-beverage packaging waste, e.g. motor oil, consumer electronics, batteries, tyres, hazardous materials and so on (Walls 2011).

Broadly speaking, the deposit-refund system is used as the financial instrument and policy to protect the environment (OCED 2011). Deposit-refund system aims at specific types of waste without collecting other potentially contaminated waste. Therefore, it has its advantages over other recycling collection systems (Turner and Opschoor 1994). It can help with the increase of reuse and recycle rate of the waste and materials, and contribute to the reduction of littering and uncontrolled disposal by a monetary incentive to encourage empty packaging return. Beyond that, it can prevent hazardous waste or materials from entering the residual waste stream as well. Ultimately, DRS helps to reduce the total amount of disposed waste (EC 2009; Dominic et al. 2010).

The deposit-refund system is one of the most common instruments which is used to implement the Extended Producer Responsibility (EPR) principle (Kaffine and O'Reilly 2015). There have been various interpretations of EPR, but defined by OCED, it is an

approach of environmental policy that extends the responsibility of producers for their products to the post-consumer stage in the life cycle of the products. The responsibility either could be a physical one, or a financial one, in which the producers bear the cost of end-of-life waste management (OECD 2001). EPR was brought in the legislative framework in the early 1990s to solve the products' life cycle issues with a goal-oriented method, substituting the traditional command-and-control regulations (Watkins et al. 2017).

The development of EPR is facilitated by the legislative framework which incorporates waste management general legislation and specific directives on recycling and recovery of specific waste in the European Union. The general framework for waste management is set by the Waste Framework Directive (2008/98/EC), which requests each member of the European countries to establish its own efficient separate waste collection system to promote the products reuse. Moreover, the Packaging and Packaging Waste Directive (94/62/EC) sets the collection, reuse, recycling and recovery targets on packaging waste, aiming at preventing the packaging waste production. In order to meet the requirements of the Waste Framework Directive (2008/98/EC) and the target of the Packaging and Packaging Waste Directive (94/62/EC), some EEA member states have adopted the deposit-refund system for beverage packaging in their countries (Watkins et al. 2017).

Deposit-refund system can exist as mandatory systems initiated by the government and imposed by legislation or voluntary systems generated by the market (Turner & Opschoor, 1994). It has been implemented in many countries and adopted different versions of the deposit-refund (Walls 2011). Worldwide, 38 countries have similar deposit-refund schemes for beverage packaging in place (The Guardian 2018). Moreover, in Europe 21 countries have implemented the DRS for drinking containers of plastic, metal and glass (European Parliament 2011). In Sweden, Finland, Denmark, Netherlands, Germany and Norway, deposit-refund system for PET bottles are in operation (Zero Waste Europe 2010). Among Nordic countries, the PET bottles are mostly collected and recycled via different deposit-

refund systems, and the recycling rates of the beverage containers are extremely high (Stenmarck et al. 2017)

In this thesis, the deposit-refund system on beverage containers including PET bottles in Finland and Sweden are chosen as examples for presenting how the DRS is utilised and works in practice. Because Finland dominates the global record-high return rates of beverage containers (PALPA 2018) and Sweden was the first European country that introduced the deposit-refund system, and additionally, the author has studied the waste management courses in Finland and is familiar with the practical conditions in both countries.

3.2 DRS in Finland

Finland is the most diligent country in recycling beverage containers with the best return rate of more than 90% worldwide. According to the statistics in 2018, the return rates for the can, PET-bottle and glass bottle are 96%, 92%, 88% respectively (Reloop and CM consulting 2018). Finns returned approximate 1.7 billion beverage containers through the deposit-refund system. Namely, 17600 metric tons of aluminium, 12700 metric tons of PET bottle bales and 51000 metric tons of glass were recycled in 2016. Finland leads the way in the deposit-refund system in the matter of recycling rate (PALPA 2018). See the following figures 6 and 7 for the returned rates and packages of the can, PET and OWG during 1996-2016.

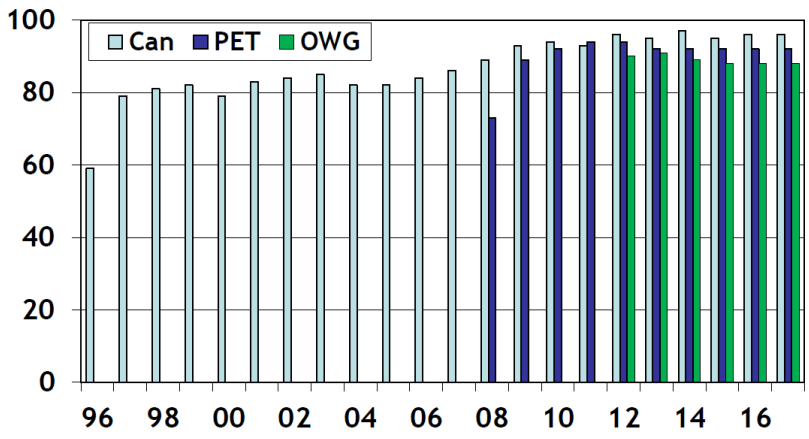

Figure 6. Return rates of can, PET and one-way glass bottles in Finland
(Image source: Nurminen 2017 and SlideShare 2017)

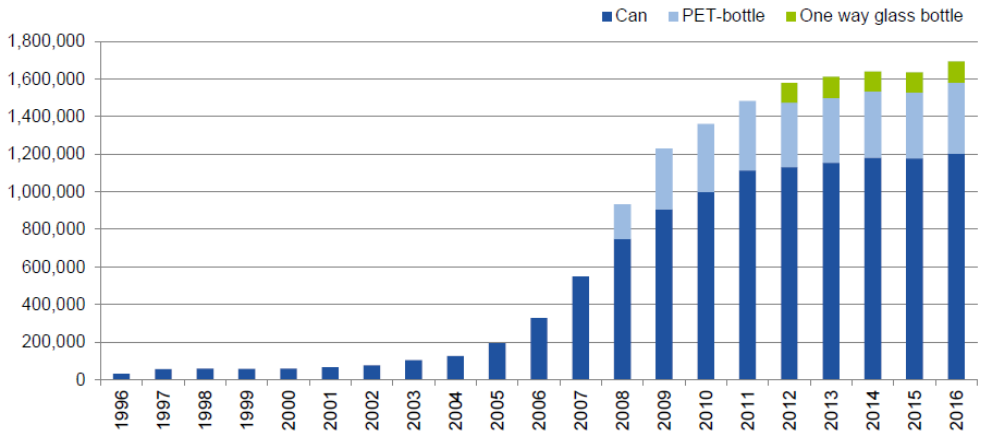

Figure 7. Returned deposit packages 1996-2006 (1000 units)
((Image source: Nurminen 2017 and SlideShare 2017)

The Finnish breweries industry utilizes the deposit-refund system voluntarily to avoid paying a packaging tax on alcoholic and soft drinks packaging. Currently, several beverage package deposit-refund systems are in operation in Finland and administered by different administrators which are shown in Table 2 below.

Table 2. The Finnish beverage package deposit-refund systems (European Parliament 2011)

Name	Scope	Remark
PALPA	Cans, PET and glass bottles	the largest in Finland
Ekopullo	Reusable glass and PET bottles	-
Alko	Reusable glass bottles	-
A-Pullo	Reusable glass bottles	-

In addition to the systems listed in the above table, another 7 closed systems, to which no additional importers and producers could join, are used in Finland as well. Lidl, a German global supermarket chain brand, holds the largest volume among these closed systems in Finland (European Parliament 2011).

The Suome Palautuspakkaus Oy, PALPA, was established in 1996 and is a non-profit organization. PALPA is an administrative company of managing and developing the largest beverage packaging return systems in Finland. It administers three different deposit-refund systems on different package types, aluminium cans, PET plastic bottles and glass bottles. The PALPA's responsibilities cover from the collection, recycle, to the reuse of the beverage containers, and as well as managing the administration of the deposits, systems development and communication in its deposit-refund systems (PALPA 2018).

In this chapter, the PALPA is used as an example for describing DRS in details due to its largest volume in Finland and sophisticated information.

3.2.1 Legislation Basis

Finnish legislation on packages recycling stems from the EU directives, the Waste Framework Directive (2008/98/EC) and the Packaging and Packaging Waste Directive (94/62/EC).

Finnish waste law and act on excise duty on beverage containers:

- Waste law 17.6.2011/646
- Act on excise duty on beverage containers 27.6.2013/526

The Waste Act 17.6.2011/646, in chapter 7, encourages the beverage containers producers to establish a deposit-based return system or join such a system that is open to the

membership. The producers who do not participate in deposit-refund systems need to pay tax according to the Act on Excise Duty on Certain Beverage Containers (1037/2004). The tax levied on beverage container in customs tariff group CN 22 is 0.51 euros per litre of the produced alcoholic or soft drink. The act on excise duty on beverage containers 27.6.2013/526 stipulates the minimum deposits on beverage containers and reuse and recycling obligation goals.

In Finland, joining the deposit-refund system is not mandatory. However, to voluntarily take part in a deposit-refund system which is approved and controlled by the Finnish environmental authority can obtain the exemption from the tax. For the beverage companies obviously the latter choice is more appealing and beneficial. Practically most of the beverage companies including producers and importers are involved in the deposit-refund systems by either establishing or joining one (PALPA 2018). For instance, many companies entered the PALPA, while Lidl chose to build up its own one.

3.2.2 Stakeholders

Many parties like producers and importers, consumers, PALPA, retailers, hotels, restaurants, caterings and other organizations and groups are involved in the beverage packages deposit-refund system in Finland. Producers and importers bring the beverage packages to the market and fund the return system by different kinds of fees. PALPA takes care of the management and development of the system. Consumers take the deposit packages back to the shops and kiosks, while hotels, restaurants, caterings, offices, schools and other organizers return the packages via their suppliers. The retailers sell the beverage and receive the deposit packages back. Figure 8 shows all the involved stakeholders in Finnish deposit-refund systems.

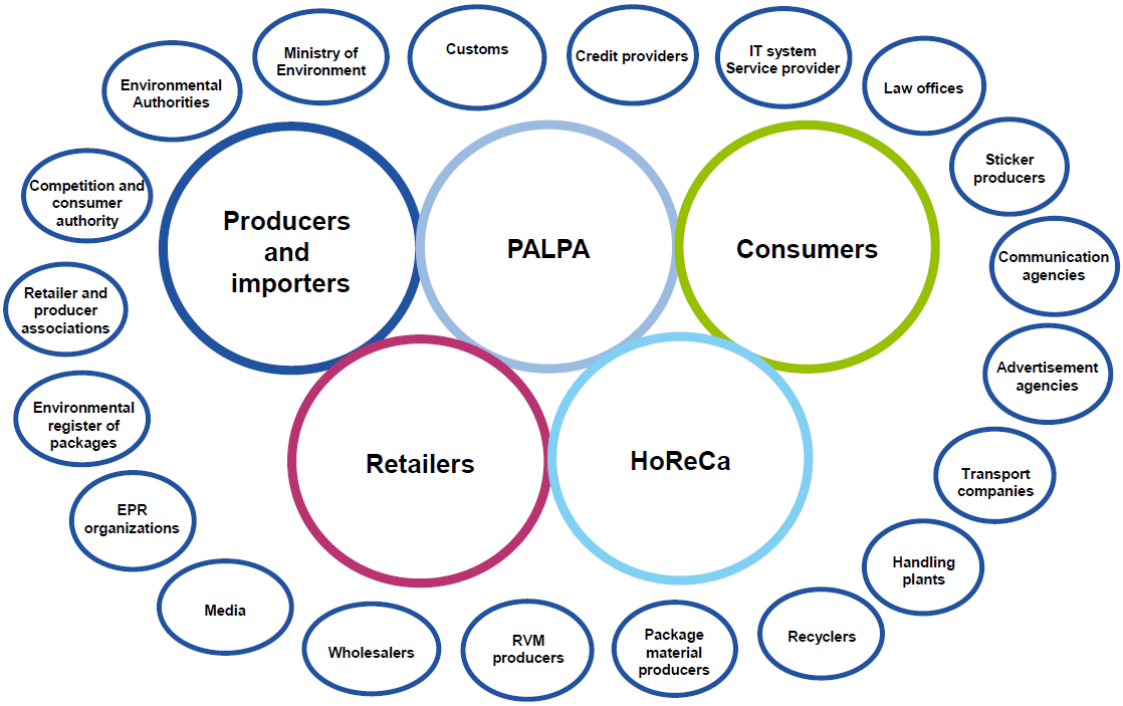

Figure 8. Stakeholders of the deposit system in Finland (Image source: Nurminen 2017 and SlideShare 2017)

3.2.3 Beverage Container Types and Deposit Values

In PALPA deposit-refund system, there are three types of beverage containers, aluminium cans, PET bottles and glass bottles. See figure 9**Error! Reference source not found.** in the below.

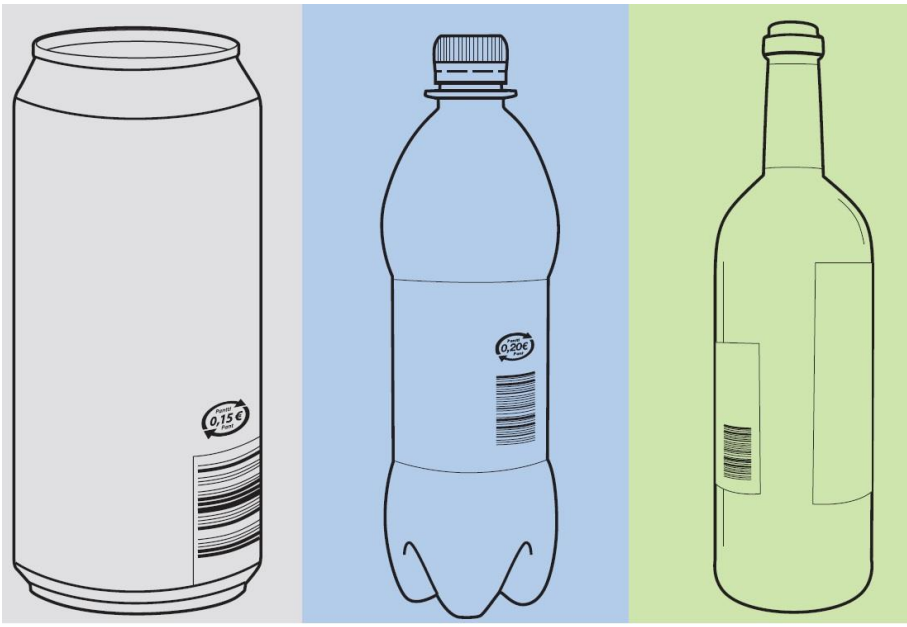

Figure 9. Three types of beverage containers in PALPA (PALPA 2018)

Table 3. PALPA Beverage container return key figures (PALPA 2018)

Type	Annual amount	Return rate 2017	Deposit value per unit
Aluminium cans	1.22 billion cans	94%	0.15 euro
PET bottles	400 million bottles	91%	0.1 euro, 0.2 euro, 0.4 euro
Glass bottles	122 million bottles	87%	0.1 euro

Table 3 gives the key figures of each beverage container type in PALPA. Aluminium cans dominate the total annual amount, 1.22 billion cans, and the return rate of 94% in 2017. The deposit values are determined by the Finnish beverage package legislation. The value of aluminium can and the glass bottle is 0.15 euro and 0.10 euro respectively regardless of the volume of the containers. However, the PET bottles have three deposit values, 0.10 euro, 0.20 euro, and 0.40 euro, depending on the different beverage container volume. See Table 4 below.

Table 4. Deposit values on PET bottles (PALPA 2018.)

Deposit value per unit	Beverage container volume
0.10 euro	0.35 L or less
0.20 euro	more than 0.35 L and less than 1 L
0.40 euro	1.0 L or more

3.2.4 Financial Flow

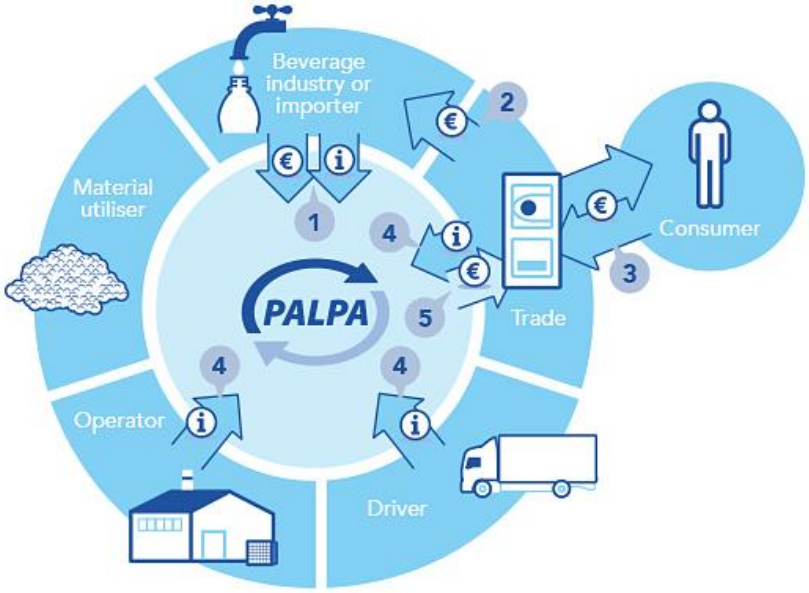

Figure 10. The financial flow of PALPA (Image source: PALPA 2018)

Figure 10 illustrates the financial flow in the PALPA deposit-refund system. Firstly the deposit of a beverage container is charged by PALPA from either the beverage industry or the importer when the beverage product is produced and ready for sale. Secondly, when the beverage product is delivered to a supermarket or shop for trade by its manufacturer or importer, the deposit is paid by the retail outlet to the manufacturer or importer in the product sales price. Thirdly, the customer pays the deposit while purchasing the beverage product, and get it back after returning the beverage container to a collecting point. Lastly, PALPA pays the deposits to the collecting point as to the total number of returned beverage containers which is reported by the collecting point and processing plant to PALPA (PALPA 2018).

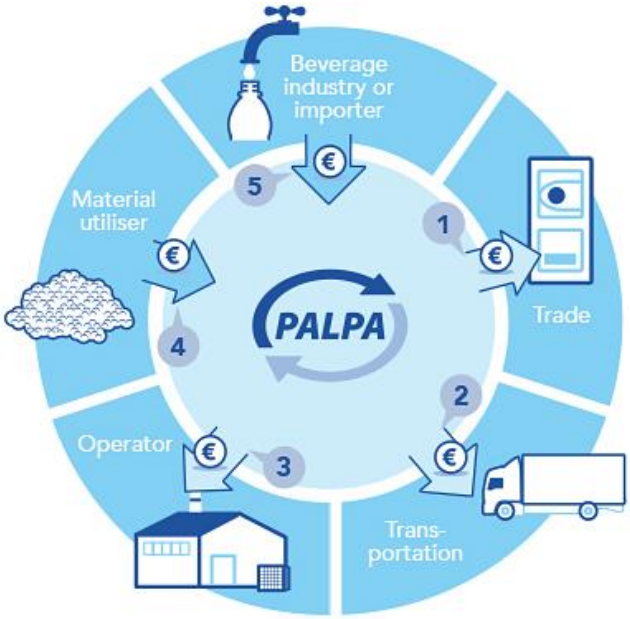

Figure 11. Other cost flow of PALPA (Image source: PALPA 2018)

Figure 11 shows other cost flow in PALPA. The administrator of the deposit-refund system PALPA is a non-profit company, and the system operating expenses are covered by membership and container processing fees from its members as well as the earnings from material selling. For income of the deposit-refund system, PALPA collects the costs of the deposit-refund system from its members, e.g. beverage manufacturer or importer, in the form of membership fees and container processing fees, and the material utilizer pays the material price to PALPA. As to the expenses of the deposit-refund system, the collecting point which takes beverage containers back from consumers receives processing fees from PALPA, and other compensations on transportation and material processing to the drivers and the processing plants are also paid by PALPA (PALPA 2018).

3.2.5 Material Flow

Figure 12. The material flow of PALPA (Image source: PALPA 2018)

The material flow in the PALPA deposit-refund system shown above in Figure 12 goes as follows. The beverage product is delivered to a retail outlet by the beverage industry or importer. Then the customer purchases the beverage product and takes the empty container back to the collection point after consumption. The collected empty container is transported to the processing plant by the driver. After processing, the empty beverage container turns into the material and is sent to material utilizer for reprocessing. Practically the majority of the recycled materials from returned beverage containers is used as new beverage containers and some other products (PALPA 2018).

3.3 DRS in Sweden

Sweden was the first European country that introduced the deposit-refund system. In 1984, the legislated deposit-refund system on aluminium beverage containers was introduced in Sweden (The Local 2018). In general, there are two types of beverage containers return

system in Sweden. One system is for refillable glass bottles which are handled by the breweries, and another is for metal cans and PET bottles (European Parliament 2011). The current system of metal cans and PET bottles was established in the year 2006 under the regulation SFS 2005: 220 on return systems for plastic bottles and metal cans (Bottle Bil 2019). With 2169 million beverage containers sold and 1850 million packages recycled in 2017, the recycling rates of metal cans and PET bottles in Sweden are 85.7% and 84.1% respectively. The total recycled materials were 16740 metric tons of aluminium and 20282 metric tons PET (PANTAMERA 2018).

Swedish beverage container deposit-refund system is obligatory and regulated by law. All the beverage packaging sold in Sweden must be collected by its producer or importer and disposed of in an environmentally responsible way. The beverage containers such as aluminium cans and PET bottles should be covered by a return and recycling system (Bottle Bill 2019). At the moment, three private return companies operate the return systems for plastic bottles and metal cans in Sweden as shown in table 5 below.

Table 5. The Swedish return systems for PET bottles and metal cans (European Parliament 2011)

Name	Scope	Revenue	Remarks
Returpack Svenska AB	One way cans and PET bottles	2.7×10^6 Tkr	Largest
Dela AB	One way cans and PET bottles	8.4×10^3 Tkr	-
PET-System AB	One way cans and PET bottles	8.3×10^3 Tkr	-

Returpack Svenska AB is a private company which specializes in one-way metal cans and PET bottles recycling in Sweden. It is jointly owned by Sweden's breweries, container producers and retailers and under the supervisory of the Swedish Board of Agriculture. In 1984, Returpack Svenska AB started its aluminium cans deposit return system, and then began its PET bottles collection in 1994. The name “PANTAMERA” was introduced in 2004 and is used by Returpack as a brand for cans and PET bottles recycling (PANTAMERA 2018).

The PANTAMERA is taken as an example for describing DRS in details in this chapter as it is the largest system in Sweden.

3.3.1 Legislation Basis

The latest Swedish regulations on one-way PET bottles and metal cans deposit return systems were implemented in 2006 and 2007, and stipulated that all beverages introduced to Sweden in plastic bottles and metal cans must be covered by proper recycling and return system.

- SFS 2005:220 Ordinance on the return system for plastic bottles and metal cans
- SFS 2006:1273 Regulation on producer responsibility for packaging

The SFS 2005:220 defines the scope of the mandatory one-way plastic bottles and metal cans deposit system, and stipulates an economic incentive to encourage recycling and returning beverage containers but does not specify the deposit amount. The amount deposit is decided by the system operator with the Swedish Board of Agriculture's approval. The SFS 2006:1273 requires all the consumer packaging in Sweden to be collected by its producer or importer and disposed of in an environmentally responsible way, and as well as setting recycling rate targets 90 %.

In the Swedish market, the importer and the manufacturer who sell a beverage in either plastic bottles or metal cans have to include the bottles or cans in a return system approved by the Swedish Board of Agriculture.

3.3.2 Beverage Container Types and Deposit Values

In PANTAMERA deposit-refund system, there are two types of beverage containers,

aluminium cans, and PET bottles. See figure 13 in the below.

Figure 13. Two types of beverage containers in PANTAMERA ((PANTAMERA 2018)

Table 6. PANTAMERA beverage container return key figures (PANTAMERA 2018)

Type	Annual amount	Return rate 2017	Deposit value per unit
Aluminium cans	16,740 tonnes	85.7%	1 SEK (0.11 euro)
PET bottles	20,282 tonnes	84.1%	1 SEK (0.11 euro) 2 SEK (0.22 euro)

Table 6 shows the key figures of PANTAMERA beverage containers. In 2017, PANTAMERA recycled 16740 metric tons of aluminium cans and 20282 metric tons of PET bottles. The return rates are 85.7% for cans and 84.1% for PET bottles. The deposit values are decided by PANTAMERA's company, Returpack Svenska AB, with the approval of Swedish authority. The value of aluminium cans is 1 SEK (0.11 euro) regardless of the volume. However, the PET bottles have two deposit values, 1 SEK (0.11 euro) and 2 SEK (0.22 euro), depending on the different beverage container volume. See Table 7 below.

Table 7. PANTAMERA deposit values on PET bottles (PANTAMERA 2018)

Deposit value per unit	Beverage container volume
1 SEK (0.11 euro)	PET bottles up to 1L
2 SEK (0.22 euro)	PET bottles over 1L

3.3.3 Financial Flow and Material Flow

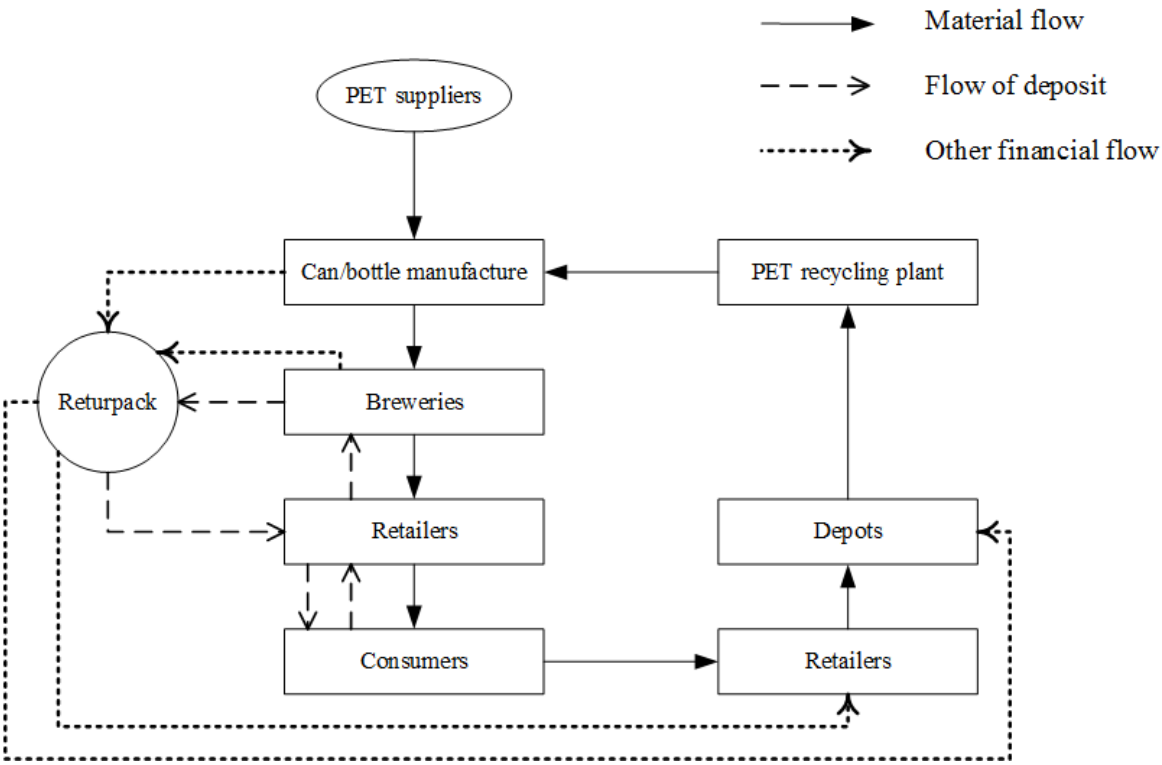

Figure 14. Deposit, financial and material flows of PANTAMERA
(Image adapted from PANTAMERA 2018)

The deposit flow goes as followings in PANTAMERA. The breweries pay the deposit to Returpack before they deliver beverage product to retailers. Retailers pay the deposit to breweries at the time of delivery. Then consumers buy the beverage from retailers and pay for the deposit. When consumers return the beverage containers to the collecting point at retailers, they get the deposit back from the retailers. Finally, Returpack pays the deposit to retailers based on the returned packaging (Tojo 2011).

The other financial flows in PANTAMERA system incorporate administration fee, handling fee and income from selling recycled material. The fees and income support the operation of the system. The manufacturer and importer pay administration fees to PANTAMERA system. PANTAMERA gives the handling fees to retailers and depot stations when they handle the beverage containers. Returpack gets paid by aluminium and PET recycling plant when it sells the recycled material to them. (Tojo 2011).

The materials of aluminium cans and PET bottles flow from the container manufacturer to the breweries. The breweries fill the containers with their products and deliver them to retailers. The consumers buy the products from retailers and return the empty packaging back. The returned beverage containers are handled by retailers and depot stations, and then transported to aluminium and PET recycling plant (Tojo, 2011).

3.4 Reverse vending machine

In the deposit-refund systems of Finland and Sweden, consumers return the empty beverage containers and get the deposit reimbursed at retailers through reverse vending machines. The reverse vending machine as the centrepiece of deposit-refund system is one device that provides an automated way of collecting and handling the used beverage containers for recycling (TOMRA 2018).

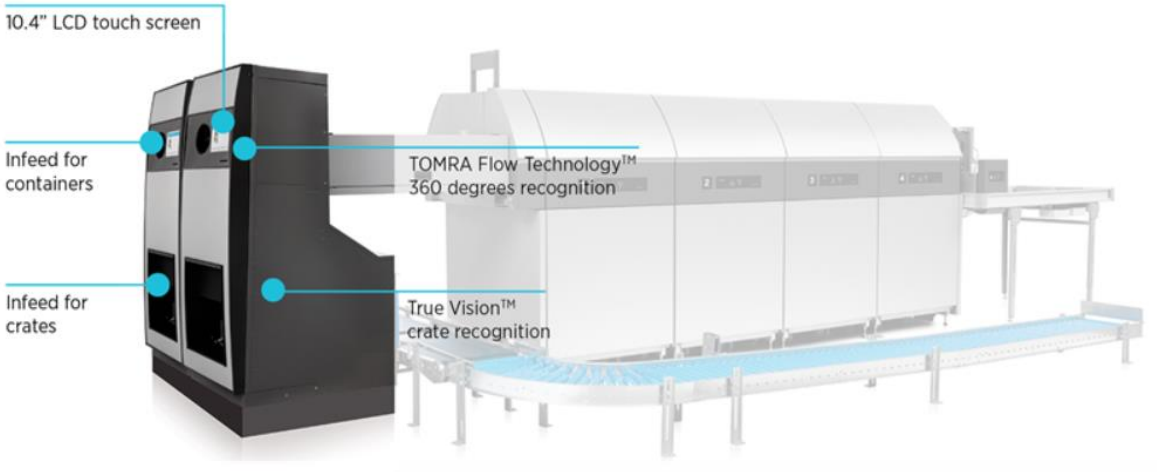

Figure 15. Front-end part of TOMRA reverse vending machine (TOMRA 2018)

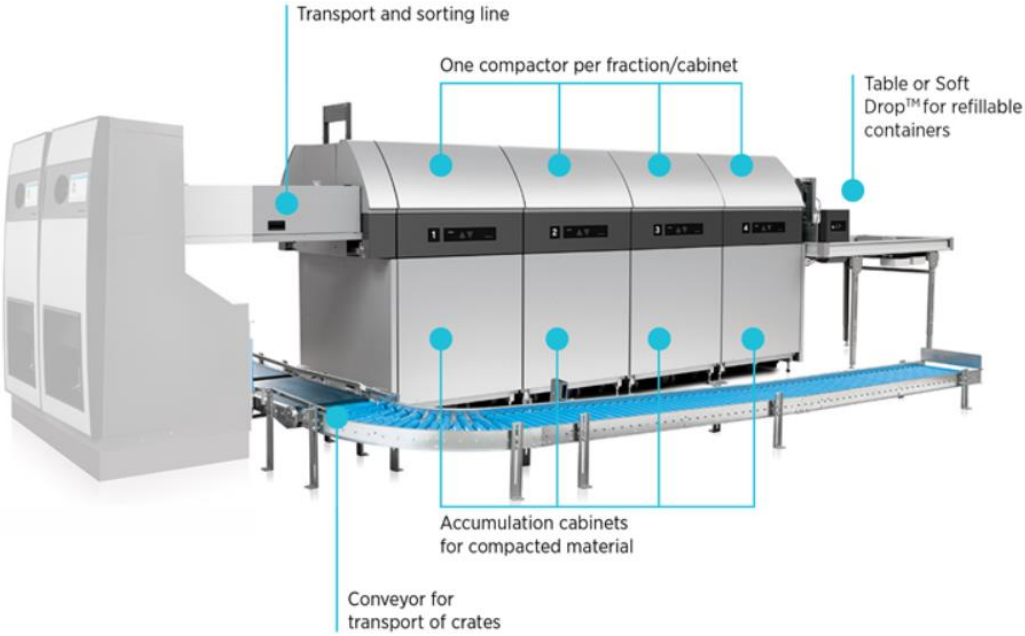

Figure 16. Backroom part of TOMRA reverse vending machine (TOMRA 2018)

The RVM, reverse vending machine, usually is installed through a wall facing the consumer who puts the containers into the RVM, and used along with a handling system behind that wall. Figure 15 and Figure 15 above show the typical Front-end and backroom of TOMRA's RVM.

Consumers put the aluminium cans and PET bottles into the RVM, and then RVM automatically calculates the returned deposits by scanning the barcode on the packaging and handles the returned containers. After collecting the containers, consumers receive a deposit certificate from RVM which can be used for deposit reimbursement at the retailers (TOMRA 2018).

3.5 Success factors of DRS in Finland and Sweden

The deposit-refund system in Finland and Sweden have been successfully operating for

Figure 17. Consumer returns PET bottle via RVM in Finland

many years. Finland achieved the best return rate of more than 90% in the world in 2016, and Sweden in 2017 recycled 1850 million packages, i.e. 16740 metric tons aluminium and 20282 metric tons PET.

From the Finnish PALPA system and Swedish PANTAMERA system, the success factors of the high return rates and a large number of recycled materials can be derived as follows.

1. Strict legislations tax regulations on beverage producer's responsibilities;
2. Correct deposit values and broad coverage of deposit packages prompt consumers to return the empty containers;
3. Environmental awareness of citizens, and good habits on return;
4. Well-functioning reverse vending machines, convenient collection points and wide collection network.

3.6 Comparing to the DRS in Lithuania

To seek more evidence and applicability of DRS in the Chinese market, the latest example of implementing DRS in Lithuania is reviewed. We aim at the results and find the problems in the system and further compared with the situation in China.

On the website of 'Recycling today global', it is reported that in 2016 February, a deposit-refund system for recycling plastic beverage bottles and aluminium beverage containers were launched in Lithuania (Taylor 2018). By the end of the year 2016, the government achieved 74.3% recycling rate of beverage containers and it has raised to be 91.9% by 2017 which has exceeded the DRS scheme plan. Before equipping the vending machines, there was about 30% of the beverage bottles been collected. The numbers have quantified the good performance of DRS in Lithuania. The feedback from the stakeholders and public opinions are also very positive. For example, the director of the Lithuanian retailers association said he is confident on the DRS as it is the right thing to do. In practice, 89% of the population in Lithuanian public have used the system at least once. It shows that DRS has been implemented successfully and increased the recycling rate for society.

Concerning the possible success factors, we can find some clues. Firstly, before implementing DRS, the government Ministry of Environment organized non-profit organization USAD as the operator of DRS. It was built by three associations in Lithuania, representing brewers, trade enterprises and manufactures. Thus, the extended producer responsibility EPR has been efficiently addressed and applied in the DRS. Secondly, the government also made efforts to increase public awareness. In the year of the DRS implementation, 99.8% of the Lithuanian public was aware of the new recycling system, and as mentioned in the above, 89% of the population has used at least once. Thirdly, concerning the price, the deposit is set to be 0.1 euro, and the returnable size is from 0.1 to 0.3 litres.

From the latest example of DRS implementation in Lithuania, we can see there are similarities to the DRS used in Finland or Sweden. For example, EPR has been addressed and DRS operator or administrator has involved multi-stakeholders in the beverage producing field. It provides one more solid evidence for DRS's applicability in other countries. By learning the success factors in the Lithuania example, we can confirm that the deposit system of PET bottles is promising and the government needs to assign a right organization to efficiently manage the DRS system and address the extended producer responsibility matters. Moreover, it is of significance to involve the public in the recycling system and increase their awareness and interests. The above experience is valuable inputs for China to plan own DRS system in the coming future. It is also a strong motivation for making the relevant law or regulation concerning EPR for PET bottles recycling.

4. PET BOTTLES DRS IMPLEMENTATION POSSIBILITIES IN CHINA – A CASE STUDY IN BEIJING

4.1 Case study description

Beijing is the capital of the People's Republic of China, with a metro population of 24,000,000 and covering 16,808 km^2 area. It has significant status both domestic and worldwide. It is one of the world's leading centres for politics, economy and business, and the nation's political, cultural and educational centre. Beijing is also the second populous city in China, and therein 38% of the population are immigrants from other provinces who seek a career and life there. With the urbanization, more and more people move to the city which induces social problems of resource use and waste generation. It is reported that in 2016, Beijing headed the list of municipal solid waste production in China and the future generation has been predicted to be 28,000 tons per day in 2020. Moreover, more than one-third of the municipal solid waste is PET bottles because Beijing is one of the domestic leading consumers of PET. Hence, it has raised a serious problem of refuse disposal and is also facing the challenge of waste recycling especially for the growing generations of PET bottles.

A similar situation of informal collection and recycling system of PET bottles exists for the whole of China, including Beijing. Since the 1990s, informal sectors have been taking the key role in the recycling process. Furthermore, in 2006, Beijing started the pilot program to develop its formal recyclable collection system. Until 2017, the Incom Recycle, a company working on the DRS of recyclable PET bottles, have installed 5000 waste-buying depots in Beijing and almost 55,000,000 PET bottles have been successfully collected and recycled. The recycling rate is as high as 70% (People's Daily 2017).

Figure 18. Students experience pilot RVM in Beijing (TENCENT 2018)

Nowadays, more and more experts support DRS of PET bottles in China. The positive side is that from some pilot projects we see the promising future for the recycling system. However, so many details need to be studied and discussed further to successfully implement DRS in a large scale and in the long term perspective, for example, legislation development, responsibility improvement, and social and economic sustainability.

Based on the above background information and challenges, the case study will design the deposit-refund system by proposing potential scenarios for Beijing PET bottles' recycling to provide further suggestions for establishing formal recycling system and developing the legislation. The scenarios will illustrate what the designated DRS is and how it works. They, furthermore, address the involvement of stakeholders, the responsibilities from different players, and the social and environmental concerns. After proposing different scenarios of DRS, SWOT method will be applied to analyze the pros and cons of different scenarios and holistically compare the results. Consequently, a potential DRS solution will be introduced

when multiple disciplinary and primary factors are concerned.

4.2 The method of SWOT

A SWOT analysis is an acronym for strength, weakness, opportunities and threats. It is a strategic planning method used to help a person or organization to identify the internal and external factors related to business, competition or project planning (Morrison 2016). Strength and weakness are internal factors, and opportunities and threats are external factors. Figuring out the SWOT can find the correct solutions to achieve the final objectives. It is an important step for the decision-maker to determine the strategy for future planning. A well-known use of SWOT in modern life is the Ads of Coca-Cola to effectively attract customers.

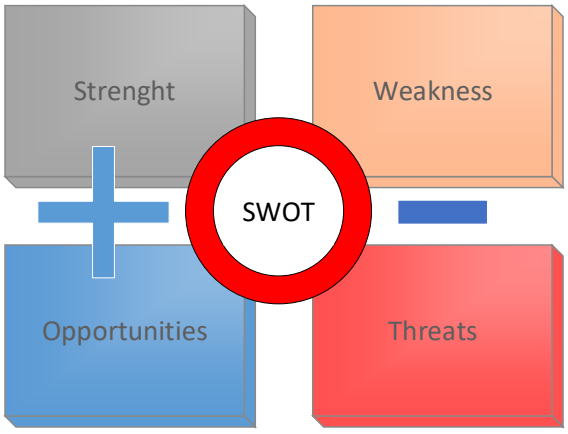

Figure 19. Strength, weakness, opportunities and threats SWOT method

4.3 DRS scenario designs

In the following, two scenarios are developed. Scenario 1 is sole-flows from consumer to return and collection point. Scenario 2 is dual-flow from the consumer to return and collection point, or from the consumer to the waste buyers including the former scavengers and itinerant buyers and thence to return and collection point. The money flow for the two scenarios is also briefly explained and compared in the following figures.

4.3.1 Scenario 1: Sole-flow

Scenario 1 is a sole-flow for post-consumer PET bottles which are consumed by consumers and then sent to the return and collection points of DRS directly. The collected PET bottles are further sent to the operation factory for cleaning, separation, and processing, etc. After the preliminary process, the PET bottles are sold to the material utilizer. The basic materials and re-used PET bottles are received by PET bottle producers to produce new PET bottles. In the end, they are utilized by the beverage industry and recycled in the market. See the following Figure 20.

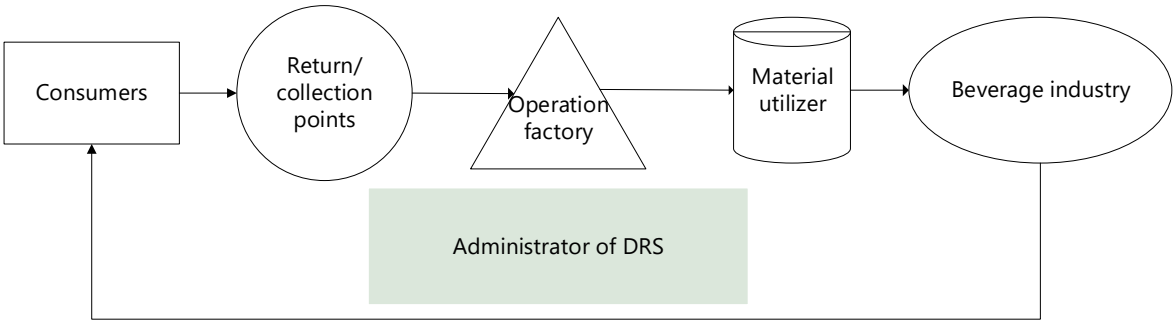

Figure 20. The sole-flow of DRS between consumers and PET bottles' collection

In this scenario, all the stakeholders are involved in the formal recycling process, including consumers, beverage industry and importers, processing plant, and manufactory of PET bottle production. When the consumer purchases the beverage, they also pay the deposit of the beverage container. In designated return and collection points, they can get back the deposit when returning the PET bottles. In the entire recycling process of DRS, a key part is the administrator of DRS, who is responsible for the management and operation of PET bottles' recycling. DRS administrator pays the bottle deposit to the consumers which have been firstly paid by the beverage industry. DRS administrator also collects money from membership fee and selling the PET bottles to the material utilizers.

In this sole-flow scenario, the responsibility to PET bottles is largely extended among

producers via consumers and DRS administrator. Under the formal management and operation of DRS administrator, the PET bottles can be efficiently collected, and safely processed in the factory. The material utilizer can also guarantee the hygiene standard to process the collected PET bottles.

4.3.2 Scenario 2: Dual-flow

Comparing to scenario 1, scenario 2 takes the formerly informal recyclers including the scavengers and itinerant waste buyers into account and involves them as part of the formal recycling process, so-called waste buyers. See the following Figure 21. The post-consumer PET bottles can be collected and returned by either the consumers or the waste buyers. Only when the PET bottles are sent to the formally collected points, the deposit can be returned to the waste buyers. The consumer can decide if they want to take care of the return of post-consumer PET bottles to DRS by themselves or they want to be easy with the aid of waste buyers. Scavengers are previously considered as an informal army in PET bottles' recycling. It is estimated to be 150,000 scavengers in Beijing (China Youth Daily 2016) which is worthy of the "army". Even though they can be volunteers to do the collection, they are now legally assigned to enter the loop of DRS and contribute to the safe and efficient PET bottle recycling process.

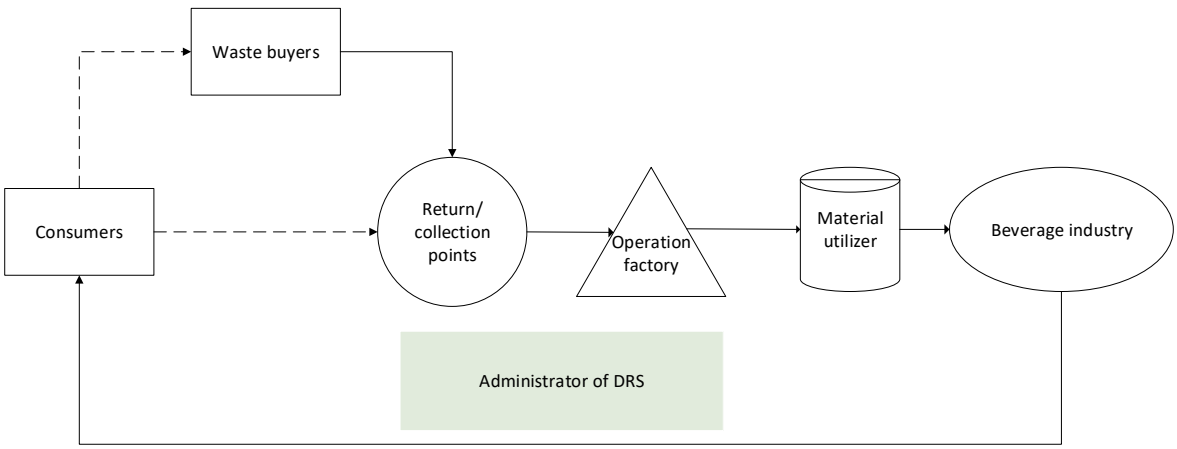

Figure 21. The dual-flow of DRS between consumers, waste buyers and PET bottles' collection

The involvement of scavengers takes many advantages. They help to share the responsibility of PET bottle recycling in the society, improve the recycling rate, and furthermore, can earn the living income for the scavengers. Regarding the large population of scavengers in Beijing, more than 150,000 people, the economic problem is a serious concern for society and government. If the income on collecting PET bottles disappeared, it could induce serious problems in the current society. Moreover, considering the consumers' interest in returning PET bottles and the convenience to find return and collection points, scavengers can provide more convenience and assistance to them. Thus, taking the scavengers to the formal recycling process is a good solution according to the current status in Beijing, and also in China.

4.3.3 Money flows

The price of the PET bottle deposit should consider multiple aspects and stakeholders. For example, the operation fee and staff cost of DRS administrator, the profit of waste buyers, the economic ability of the consumers, and the investment of producers. According to the current situation of the common collection price of a beverage container in Beijing shown in the study (Zhang and Wen 2014), the scavengers sell the PET bottle for 0.135 Yuan RMB to the redemption depots. The door-to-door waste buyers sell the PET bottle for 0.145 Yuan RMB but firstly collect them from the consumers for 0.1 Yuan RMB which means the profit is about 0.05 Yuan RMB. Furthermore, according to the news of Beijing Daily, it is reported that the price of recycling the PET bottles has been being cracked down the motivation of scavengers because of the selling price of such as 0.05 Yuan RMB or even lower. Thus, the higher the deposit price, the higher the possibility to return the PET bottles and the higher recycling rate. Apparently, the deposit price should also be based on more accurate financing calculation concerning different stakeholders' profits involved in the DRS.

Referring to the aforementioned price information, herein, we simply estimate the deposit price and take one example to explain the money flow among the stakeholders in the process.

Thus, in the sole-flow scenario of DRS, as shown in Figure 22, we assume the deposit of the PET bottle is designed to be 0.2 Yuan RMB. The consumers when buying the beverage, they pay the deposit of the PET bottles to the retailer, e.g. supermarket for 0.2 Yuan RMB. The retailer has paid the deposit 0.2 Yuan RMB to the beverage company. And the beverage company also gives the deposit of the PET bottles to the recycler DRS administrator for 0.2 Yuan RMB. When the consumers return the PET bottles, they get 0.2 Yuan RMB deposit back from DRS collection point. In the sole-flow, the deposit of the PET bottle is circulated among different stakeholders. There also exist other money flows. For example, beverage companies pay the service fee to the DRS administrator and recycling factories also buy the PET bottles from DRS administrator. The money earned by DRS administrator is used to keep the running cost and staff cost in the operation phase. It needs to be noted that the DRS administrator sets the collection points to return the deposit to the consumer. Thus, the retailers are not responsible for the consumer concerning the deposit. The concern is to lower the complexity of a large number of private retailers existing in China.

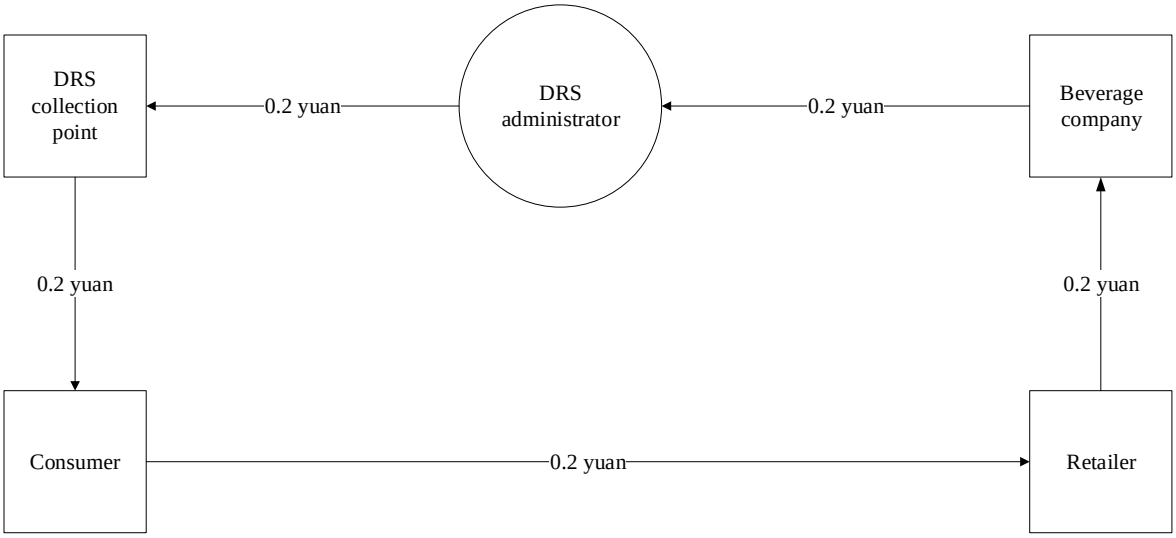

Figure 22. Example of deposit money flow of sole-flow scenario of DRS

In the dual-flow scenario of DRS, as shown in Figure 23, we assume the deposit of the PET bottle is set to be the same as 0.2 yuan. The consumers have two alternatives: alternative 1 in red line and alternative 2 in blue line. They can either return the PET bottles to the

collection point, and get the deposit back from the DRS administrator or they can sell the PET bottles to the waste buyers including the formal scavengers and itinerant buyers with a lower price. The waste buyers return the PET bottles to the recycling depot and then get the deposit 0.2 Yuan RMB back from the DRS administrator as shown in the red line. When the consumer sells it to the waste buyer, the price can be 0.1 Yuan RMB. Then the waste buyer can sell the collected PET bottle to the recycling depot for 0.2 Yuan RMB. Thus, the waste buyer can earn a profit of 0.1 Yuan RMB per PET bottle. To keep the DRS administrator's running cost, the beverage company pays for the service fee and DRS administrator also sells the PET bottles to the recycling factory to earn the money. The same as the sole-flow that the beverage company adds the cost on the final price of the beverage for the consumer. The deposit is circulated among the stakeholders. However, the main difference comparing to the sole-flow scenario is the duel-flow scenario provides two options for the consumers when returning the PET bottles so that the recycling rate could be increased. Furthermore, the DRS system can turn the scavengers into part of the waste buyers in the formal system. Scavengers can make a profit from collecting and returning the PET bottles in a formal way. Both the consumers and waste buyers can get the deposit from the collection point which is operated by DRS administrator. In China, there are a huge number of private retailers in a different scale. If they are supposed to be involved in the process of returning the deposit, it needs a lot of efforts to organize and standardize the way for the retailers. By implementing the collection point, the complexity of the retailers is reduced. The collection point is independent of the retailers and is operated by the DRS administrator. It is responsible for the consumers regarding the deposit.

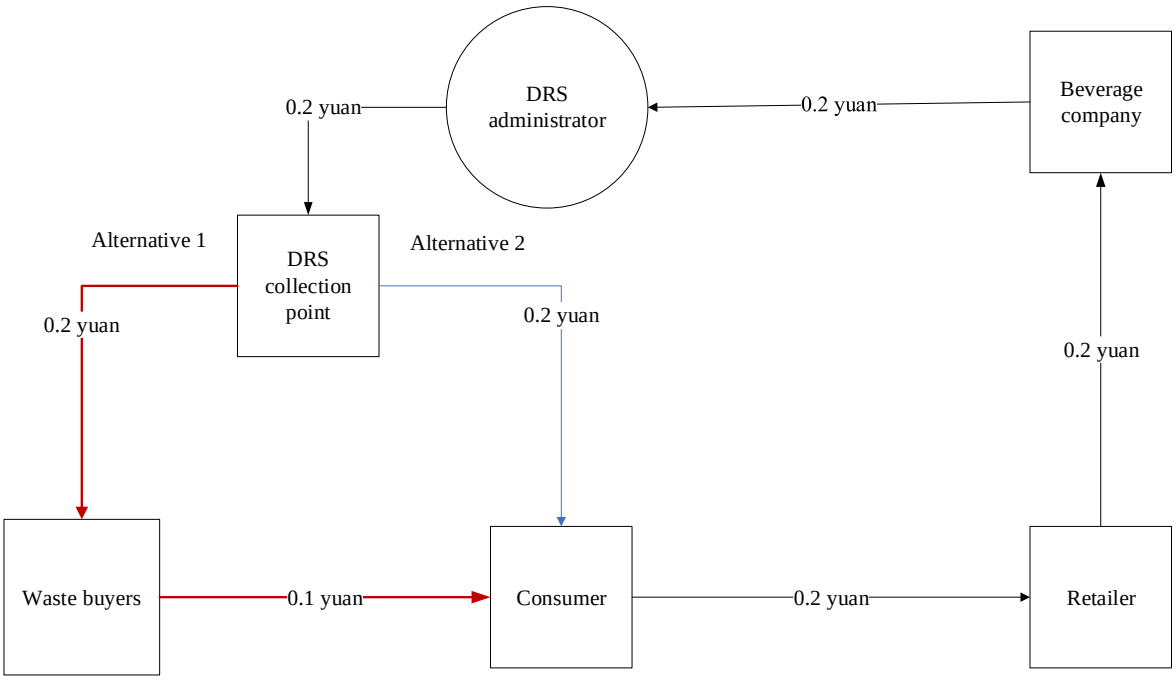

Figure 23. Example of deposit money flow of dual-flow scenario of DRS

4.4 Results of a SWOT analysis

Using the SWOT method, the strength, weakness, opportunities and threats can be analyzed. The results of scenario 1 and scenario 2 are summarized in Table 8 and Table 9 respectively. In the SWOT analysis, the following aspects are concerned: sustainabilities of economy, environment and social well-being as well as management and operation in practice.

Table 8. The SWOT analysis of scenarios 1: Sole-flow DRS

Strength	Weakness
- Easy management and control of the recycling process; - Simple recycling process; - Lower impact on environmental pollution during the collection of PET bottles; - Fossil resource conservation; - Improving people's resource recycling consciousness.	- Consumers are the solely responsible part to collect and return the PET bottles; - The price of the beverage on sale is increased; - The purchasing interest from the consumers might be decreased in the beginning phase.
Opportunities	**Threats**
- Promoting the application of installing	- PET bottle return rate is low;

return and collection points of DRS in the suburb; - Extending the EPR to PET bottle category in the legislation.	- The sales are decreased; - Scavengers become jobless; - Social problems of proper living for the scavengers.

Table 9. The SWOT analysis of scenarios 2: Dual-flow DRS

Strength	Weakness
- Involving consumers and scavengers in the formal recycling process of PET bottles; - Promoting the living and working environment for scavengers; - Possible to achieve a higher recycling rate; - Lower impact on environmental pollution during the collection of PET bottles; - Fossil resource conservation; - Improving resource recycling consciousness in the whole society.	- More complex on the management and operation from DRS administrator; - The trade price between consumers and scavengers is not fixed by legislation; - The recycling consciousness of consumers is improved slowly; - The price of the beverage is increased; - Decrease the purchasing interest and ability of consumers.
Opportunities	**Threats**
- Achieve a higher recycling rate; - Help to turn the scavengers into formal waste buyers; - High scalability in other cities; - Promote the income for low-income families.	- The safe storage of PET bottles by scavengers; - Fewer consumers take care of the collection and return of PET bottles; - The competence of price occurs among the waste buyers; - A risk of the free market emerging among private waste buyers or private companies.

Based on the details of the strength, weakness, opportunities, and threats from the SWOT analysis for scenario 1 and 2, we find that the weakness and threats in sole-flow are almost the strength and opportunities in the dual-flow. For example, if the collection rate of PET bottle is low in the sole-flow scenario, involving the scavengers as the waste buyers in the dual-flow scenario can increase the possibilities of returning the PET bottles. Similarly, the management and operation section in the dual-flow scenario is more complex in terms of organizing the scavenger group is to be easy and simple for DRS administration in the sole-

flow scenario. Therefore, depending on the main concern and focus of the current government, both of the two DRS scenarios can be considered. To make a smooth transition to the new DRS from the present status, scenario 2 with the dual-flow can be expected more by the authorities in the policy planning.

5 DISCUSSION

This study refers to the advanced DRS of PET bottles in Finland and Sweden to seek the possibilities of implementing DRS in China. Theoretical design of two DRS scenarios has been considered, which are the sole-flow and dual-flow. The main difference between the two scenario lies in the involvement of the scavengers and itinerant waste buyers. Even though there are many similarities to the Finnish or Swedish DRS systems, it is of significance to consider the different conditions among different countries and how to utilize the local resource to make the DRS more efficient and successful.

5.1 Adaptations of DRS in China

There exist urgent needs of collecting post-consumer PET bottles in China especially concerning the environmental and social impact of sustainability. During the past decades, the 'volunteer army' forming by scavengers have been the major party collecting the post-consumer PET bottles and earn the income for the living. Thus, when implementing DRS in China, especially during the transitional phase, in the beginning, the scavengers could be a unique resource to help with implementing the new recycling system in practice. However, their role and responsibility should be legally clarified so that an efficient work loop can be organized together with other participants, e.g. the consumers, recycling companies. For example, from the national level, the involvement of scavengers in the PET bottle recycling process should be mentioned in the regulation or law. Also, the requirement to join in the recycling process for the scavengers needs to be clarified from the perspectives of hygiene condition, personal safety, standardized returning process, etc. In parallel, the local government can also establish the relevant office to organize the scavengers and itinerant waste buyers and provide sufficient training for them. The knowledge and education can ultimately help them to transit from the "volunteer army" to the real practitioner in the field.

In DRS, multi-stakeholders are involved which makes the process complex concerning practical management. The financial flow should be seriously controlled and monitored to avoid any 'free market' in the system for the future. For example, the selling price and collecting price should be fixed in terms of legislation, as well as the official registration of the private collector and recycling company is needed. For the private waste buyers, the collecting price is difficult to control in practice, so it is not necessary to be fixed price but needs to be adjusted in the market. In the Finnish system, the DRS administrator is a governmental organization who is responsible for the management and control of the stakeholders in the system. It is easy to monitor the responsibilities of each stakeholder and the financial flow. In the future Chinese DRS, it will be a much larger market and more participants would be involved at provincial and municipal levels. Therefore, it needs such a dedicated organization to manage the entire process and keep the PET bottle recycling business growing steadily. By meaning this, a governmental organization would be optimal to take the role of DRS administrator and control the financing flow and material flow. It can assign government-owned sub-companies in different province to manage the local business and make the deposit price flexible in different regions according to the economic development level.

DRSs in Finland and Sweden have been implemented for the past decades. However, to China, it will be a revolution in PET recycling area. Public awareness is not yet mature for the new concept and human behaviour has not solidly formulated. Thus, to improve the efficiency of DRS in China, a big challenge is how to increase consumers' awareness of collecting and returning post-consumer PET bottles and collaborating with waste buyers to increase the recycling rate. New guidelines and regulations on waste management and recycling are efficient ways to grow public consciousness. For example, the new household waste management regulation has been newly announced in Shanghai in 2019. By implementing the new regulation, the government has made first efforts to introduce the citizens how to categorize the domestic garbage according to the classification of

“recyclables waste”, “hazardous waste”, “household food waste” and “residual waste”. People will also gain deep understandings on PET bottle management and recycling. Public media, educations in the school and popular science dissemination are useful ways to extend the knowledge into practice. In parallel, the sufficient financial motivation of returning the PET bottle is crucial to drive the users and grow the habit of being used to the DRS. Young and adults are the major part of the consumers of PET bottles. The broad dissemination in the schools and company should be acknowledged. Encouraging or bonus actions can be considered to stimulate their involvement and interests. Increasing the public awareness is a long-term task and plays a key role of achieving a successful DRS in China, so the government needs to invest and consider sufficiently to conquer the gap between the policy and the human behaviour.

5.2 Limitations

This study has extensively learned from literature and status quo of DRS implementation in the globe. However, real data are lacking, for example, the actual recycling rate with the years, the detailed financing flow and material flow among various stakeholders and national statistical information on PET recycling in China. The survey of public awareness is limited from the previous studies as well. Therefore, more data collection are expected in the coming future to identify the challenges and needs existing in society.

6 CONCLUSIONS

In this study, DRS was introduced including the concept, structure and principle, advantages of the environmental and social aspects, and the significant needs to be implemented concerning both international and national scopes. Two scenarios of DRS, sole-flow and dual-flow were designed aiming to involve the potential extended producer responsibility for PET bottles and involve the consumers, scavengers and itinerant waste buyers for achieving a higher recycling rate of PET bottles. DRS in Finland and Sweden were reviewed and the implementation of DRS in Lithuania was compared with China. A case study in Beijing was conducted to implement the suitable DRS with proposing return and collection points, setting DRS administrator, clarifying the relevant stakeholders and responsibilities, and showing the environmental and social benefits. SWOT method was used to analyze the pros and cons of DRS scenarios as well as identify the internal and external factors to determine the proper scenario.

- By reviewing the experience of DRS implemented in Finland and Sweden which are the most advanced in the world, we found that the success factors to increase the PET bottle recycling rate lie on the following aspects. The first aspect is the strict legislation concerning tax regulations on beverage producer's responsibilities that enable the establishment, participation and compliance of DRS. The second aspect is the awareness of consumers who are willing to return the deposit packages and also well-educated to form habits on return, and have been developing environmental awareness since childhood. The third aspect is the correct deposit values and broad coverage of deposit packages to promote the citizens to join the recycling process. The last aspect is the well-functioning reverse vending machines, convenient collection points and wide collection network making the DRS viable.

- DRS is an urgent need in China to formally recycle PET bottles and increase the

recycling rate. China is a leading country on beverage consumption and PET bottle demand. China has been greatly encouraging the waste recycling rate by both legislation incentives and social efforts. The success factors of DRS in Finland and Sweden could be taken as lessons when implementing the adapted DRS in China. However, the challenges exist, such as public awareness, the formal involvement of scavengers and the legislation of extended producer responsibility for PET bottles. The adaptation of DRS in China needs to be further considered, such as utilize the unique resource of scavengers and assign a governmental organization of DRS administrator and operator. From the pilots which have been demonstrated in Beijing, we can see many potentials and grounds to utilize DRS in the future market.

- In the case study of Beijing, a dual-flow scenario of DRS was compared with the sole-flow scenario when concerning the alternatives for the consumers and involvement of scavengers and itinerant waste buyers. From the SWOT analysis, we can clearly see the weakness and threats in the sole-flow DRS are actually the strengths and opportunities in the dual-flow DRS. The main advantages of the dual-flow scenario are the social benefits to the scavengers and can also increase the collection and return rates in the formal recycling system. However, their role and responsibility should be legally clarified so that an efficient work loop can be organized together with other participants, e.g. the consumers, recycling companies.

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