An investigation of the best practices for implementing a polyethylene terephthalate (PET) single-use non-alcoholic beverage container deposit-refund system in Ontario

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Abstract

Ontario contributes to the widespread and pervasive problem of plastic pollution as more than 50% of the single-use beverage containers sold in the province end up in the landfill or environment. This problem persists even with an extensive recycling program in place for household packaging waste. One plausible solution to increasing plastic bottle recycling rates, strengthening plastics' end-use value and alleviating the negative externalities associated with disposable products is for the province to implement a deposit-refund system (DRS) for polyethylene terephthalate (PET) single-use non-alcoholic beverage containers. This system charges a deposit to the consumer at the point of purchase and refunds the charge when the product is brought to a specified recovery collection point.

The purpose of my research is to examine what features or best practices of a DRS yield high recovery rates, of which can be applied in Ontario, if it decides to introduce this program. These practices have been determined by conducting a comparative case study of six jurisdictions with a DRS in place: California, Oregon, Nova Scotia, Alberta, Norway, and Sweden. An analysis and synthesis of similarities, differences and patterns across the cases is conducted. The results demonstrate the features of a DRS that yield high recovery rates which are intended to guide the potential implementation of this system in Ontario.

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Abbreviations

ABCRC: Alberta Beverage Container Recycling Corporation

AfH: away from home

BCRF: Beverage Container Recycling Fund

CRV: California Redemption Value

DRS: deposit refund system

EPR: extended producer responsibility

GHG: greenhouse gas

HDPE: high-density polyethylene

KEQ: key evaluation question

OBRC: Oregon Beverage Recycling Cooperative

PET: polyethylene terephthalate

PVC: polymerizing vinyl chloride

RVMs: reverse vending machines

rPET: recycled polyethylene terephthalate

1.0 Introduction

Plastics, the material of the modern economy, combines unrivalled functional properties such as light weight, corrosion-resistant and durable features, with relatively low costs. These favourable features have prompted the mass production and extensive use of plastics in a wide variety of applications, including plastic packaging. This ubiquitous application of plastics via packaging accounts for an estimated 26% of the world's total volume of plastic products. Most packaging is created for a single-use application, designed to be used once and then disposed of. After its short first-use, the value of the material can be significantly decreased if the material is indiscriminately disposed of or if erroneous sorting occurs at the waste management facility (WEF, et al., 2016). In addition to the value lost, improper disposal of plastics also results in numerous adverse environmental effects. Plastic pollution has the potential to cause injury or death to numerous species, inhibit important gas exchanges in benthic zones, as well as the possibility of damaging equipment associated with shipping, fishing and energy production. Furthermore, the plastic packaging can be continually fragmented into smaller pieces through physical processes, contributing to the ever-growing problem of micro plastics in the marine environment (Cole, et al., 2011). This phenomenon of plastic pollution is highlighted though the immensity of the Great Pacific Garbage Patch, a gyre of marine debris with high concentrations of plastic (Zalasiewicz, et al., 2016), and the fact that 80% of the litter in the Great Lakes region is plastic (Environmental Defence, 2016).

Ontario contributes to this endemic issue of plastic pollution as more than 50% of the single-use beverage containers sold in the province end up in the landfill or environment. This problem persists even with an extensive recycling program in place for household packaging waste. One plausible solution to increasing plastic bottle recycling rates, strengthening plastics' end-use value and alleviating the negative externalities associated with single-use disposable products is for the province to incentivize consumers to properly dispose of their beverage containers. Incentives can be established through the development of a deposit-return system (DRS) for polyethylene terephthalate (PET) single-use beverage containers, as proposed by the Canadian environmental action organization, *Environmental Defence* (Environmental Defence, 2016). This paper intends to explore this proposal by determining the best practices for implementing a DRS in Ontario, by comparing existing DRSs in Europe, Canada and the United States. In order to adequately outline the problem, fundamental explanations will be provided of Ontario's waste diversion services, PET beverage container recycling, and deposit-refund systems.

1.1 Ontario's Existing Waste Diversion Services

Curbside collections services are required for municipalities in Ontario with over 5,000 people (CM Consulting, 2012) and can operate as either a dual-stream system or a single-stream system. In a dual-stream system, recyclable materials must be separated into two different containers, the Blue Box and the Black Box. The Blue Box system allows Ontarians to place source separated materials, including glass, metal and plastic products at curbside for recycling. The Black Box accepts paper products such as newspapers, corrugated cardboard, and mixed fine paper (City of Ottawa, n.d.). Municipalities which have adopted a single-stream recycling system allow their citizens to commingle paper fibres and blue box materials, rather than separating them by material types. Proper sorting at recycling facilities for both dual and single-stream recycling methods is vital for reducing contamination. Single-stream collection often results in poor scrap quality as the materials require more rigorous sorting and contamination among material types is quite common (Taylor, 2015). Contamination arises as many plastic types appear to be similar. However due to the inherent immiscibility among different plastic types, a homogenous mixture cannot be formed when the polymers are melted. When different plastic types are mixed together, the resulting material's application for reuse becomes limited and the value is greatly reduced. For example, a small amount of polymerizing vinyl chloride (PVC) contaminant present in a PET recycle stream will degrade the resulting resin. In addition, processing requirements vary depending on the polymer type, package design and product. Therefore, a successful recycling process for mixed plastics requires high-performance sorting of these materials to ensure that they are separated to their highest levels of purity (Hopewell, et al., 2009).

Recycling facilities can undertake four different methods for recycling and recovering materials. The first is designated as primary, also known as closed-loop recycling, whereby mechanical processing converts the recycled product into one with equivalent properties. For example, PET bottles collected and recycled into new PET bottles or coffee cups being recycled into new coffee cups. Downgrading, or secondary recycling, involves mechanical reprocessing of the products into ones with lower properties. An example of downgrading would be processing PET from beverage containers into plastic lumber. The third category, known as tertiary, involves recovering the chemical constituents of the product for chemical or feedstock recycling. The last category is recovering energy from the product, also known as "energy-to-waste" (Hopewell, et al., 2009). While Ontario incorporates each of these methods for recycling and recovery, this paper will be focusing on increasing the efficiency of primary recycling specifically for PET non-alcoholic beverage containers. These recycling methods facilitate the creation of high and medium-quality secondary raw materials. If plastics are recycled into products that were previously made from other materials, like wood or concrete, the demand for polymer production will not be realized. The demand for this material can only be reduced by producing goods that would have otherwise been made from virgin polymer (Hopewell, et al., 2009).

1.2 PET Beverage Container Recycling

Polyethylene terephthalate (PET), identified by the resin identification code 1 (see figure 1), is a type of plastic that is used for numerous types of beverage containers due to its lightweight quality, durability and resistance to biological decay. The cost of recycling PET beverage containers is typically greater than the value of the recycled material produced. This difference in valuation is known as a material's scrap value. However, it is important to note that this value does not consider the benefits captured through the recycling process, such as a reduction in litter, decreased greenhouse gas (GHG) emissions and a preservation of resources (Taylor, 2015).

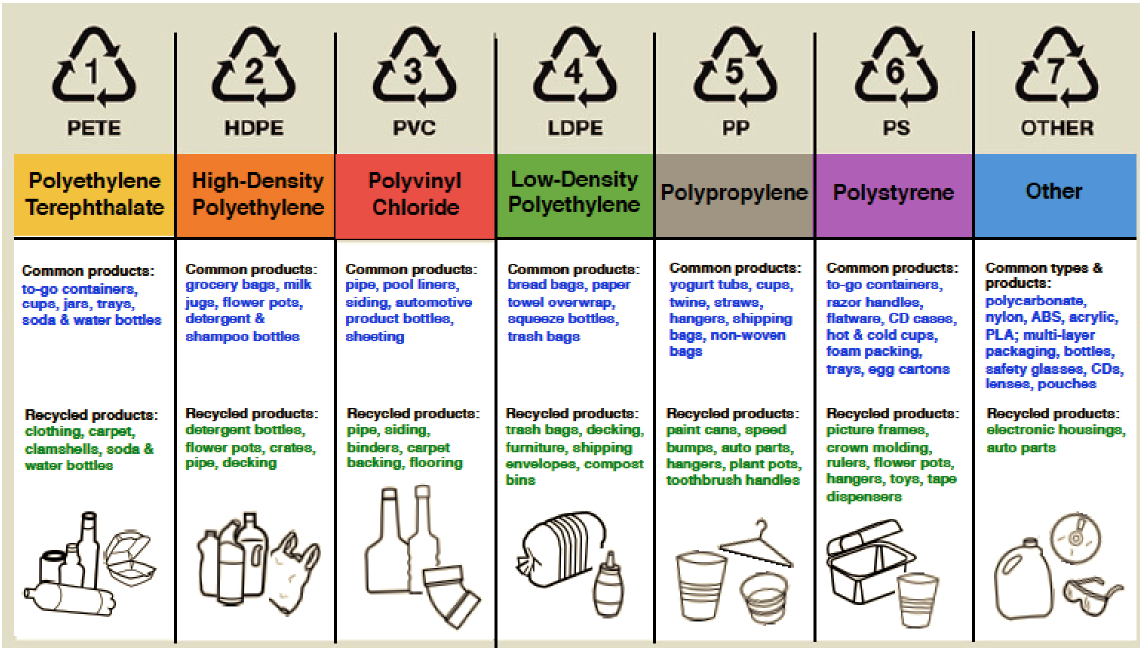

Figure 1: Plastic resin identification codes; developed by More Recycling (ARP, n.d.).

Petroleum is the principle feedstock for plastics, therefore the market value of PET is determined by the price of this fossil fuel, which is subject to price volatility. Higher prices generally make recycling more financially attractive as oil usage is directly reduced by producing recycled PET (rPET) instead of virgin polymer (Hopewell, et al., 2009). PET containers that are collected for recycling are typically baled, shredded and then flaked into rPET. This plastic flake can be down-cycled by turning it into a fibre that can be used for fleece clothing and carpet underlay. The National Association for PET Container Resources (NAPCOR) indicates the following North American consumption of rPET:

- 38% fiber
- 22% food and beverage bottles
- 19% sheet and film
- 13% strapping
- 6% non-food grade bottles

Recycled PET is made into new beverage containers via a closed-loop system (CM Consulting, 2012). This material is recognized as a nearly ideal material input for bottle-to-bottle recycling since a large amount of post-consumer bottles are available on the market and the rPET can operate comparably to virgin PET polymer (Welle, 2011). A narrow range of polymer grades makes it easier to replace virgin resin directly, as the material is more stabilized against degradation during the reprocessing stage and subsequent use. Plastic packaging or recycled material with a wide variety of polymers increases the difficulty of replacing the virgin resin and the final product may not be as durable (Hopewell, et al., 2009). Using rPET flake also provides additional environmental benefits beyond preserving resources. Studies have found that for every pound of rPET flake used, energy use is reduced by 84% and GHG emissions are reduced by 71%, compared to using virgin PET flakes (Zhang & Wen, 2014). Similarly, the net benefit in greenhouse gas emissions produced from PET bottle recycle is estimated to be 1.5 tonnes of CO_2-e per tonne of recycled PET. On the other hand, mixed plastic polymers provide a net benefit of approximately 0.5 tonnes of CO_2-e per tonne of recycled product. PET bottle recycling has a higher eco-efficiency compared to mixed plastic recycling due to greater efficiency in the recycling process and the particularly high emissions profile of virgin PET production (Hopewell, et al., 2009).

1.3 Overview of Deposit-Refund Systems

A deposit-refund system (DRS) charges a deposit to the consumer at the point of sale on a product that is potentially polluting and refunds the charge when the product is brought to a recovery collection point. If an individual improperly disposes of a product they forego their refund. This system exists as an incentive-based instrument under the framework of extended producer responsibility, commonly referred to as EPR. The general objectives of EPR schemes are to increase recycling rates of the products targeted and to shift the financial responsibility away from municipalities and to the producers themselves (OECD, 2014).

A DRS set specifically for beverage containers are commonly referred to as a "Bottle Bills" or "Container Deposit Laws". A focus is placed on beverage containers since they make up the majority of containers sold and are a large component of the litter stream. For example, over 80% of the containers sold in the U.S are used for beverages and 40 to 60% of the U.S litter stream is composed of these containers. Beverage containers are particular wasteful as the contents are often consumed in minutes, unlike products such as shampoo bottles or peanut butter jars which are consumed at a slower rate. In addition, these products are more likely to be consumed away from home, therefore a large portion are not captured by the curbside recycling system or any recycling system (CRI, n.d.-c). Away-from-home (AfH) consumption of PET beverage containers has seen an upsurge in recent years (CM Consulting, 2012), with an estimated 1/3 of all beverages consumed on-the-go, often where recycling is often inconvenient for the consumer or simply unavailable (CRI, n.d.- b). In areas with a DRS in place, beverage containers make up a small percentage of the AfH waste and recycling stream, while the opposite holds true for areas without a DRS in place (CM Consulting, 2012).

There are two common approaches for how returned containers and deposits are typically handled. The first is the return-to-retail method where retail stores accept empty beverage containers and provide consumers their refund, which can be seen in figure 2. The second is the use of redemption centers where consumers can redeem their refund in staffed centers established specifically for the collection of recyclables. In both these scenarios, the collected containers must be collected and transported to processing centers. Increasingly, collection is automated through the use of reverse-vending machines (RVMs), typically located at retail stores. Consumers place their containers in the machine which reads the modified EAN barcode on the container and receive the appropriate deposit. These machines can reduce the volume of the collected containers by compacting, shredding and crushing the materials on site. In addition, they often have ability to sort containers by type and colour. The initial costs of acquiring an RVM are quite high, however the cost of usage compared to manual sorting methods is more competitive, estimated in one study to be $0.0253 per container for the RVM method versus $0.0407 per container for manual sorting (Morris, et al., 2005).

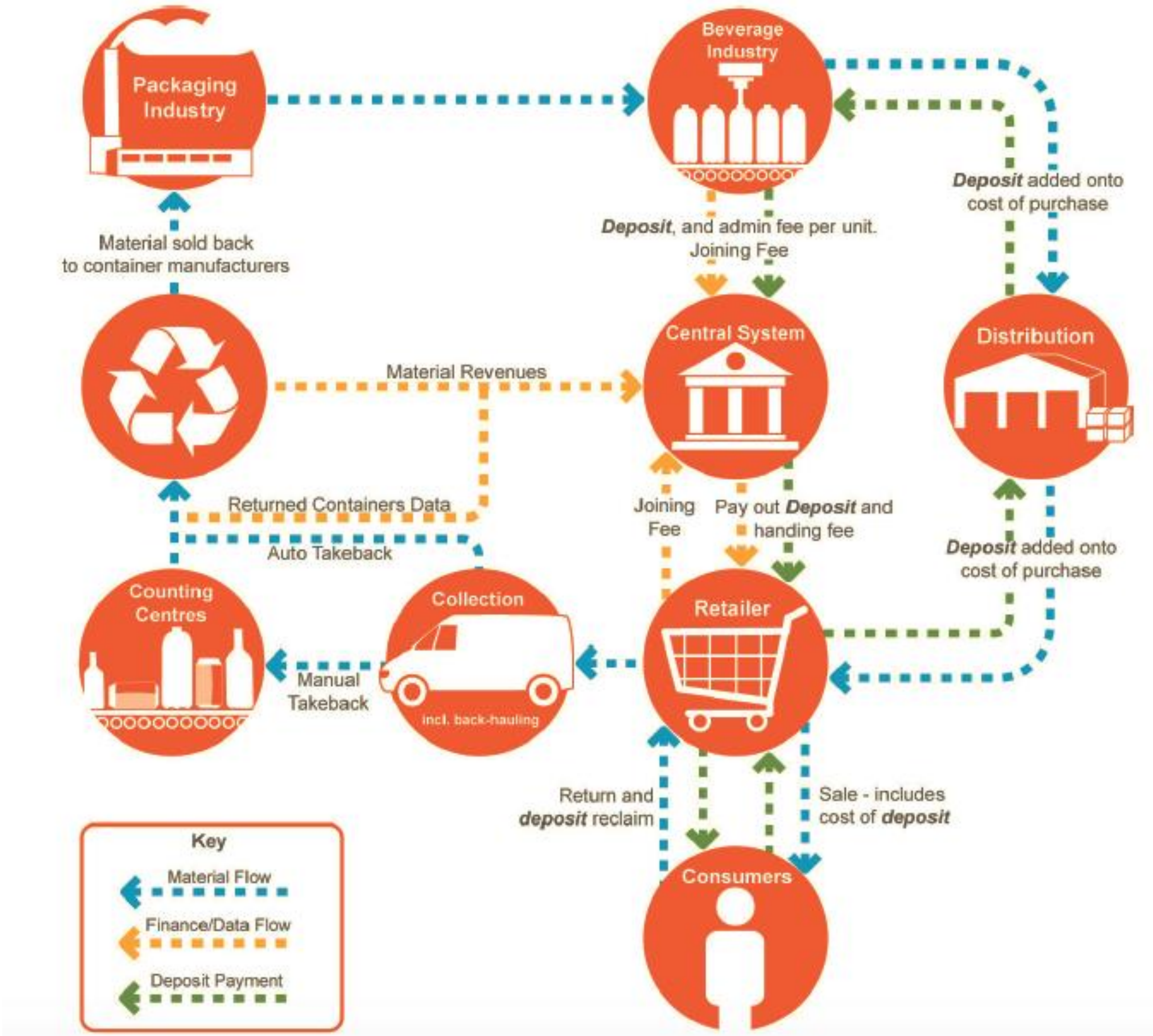

Figure 2: The general material and financial flows of a return-to-retail DRS, developed by Eunomia (Hogg, et al., 2017).

Most DRSs have the retailers playing the role of the middleman, where they pay distributors a deposit for each container they purchased for retail. When the container is purchased by a consumer, the retailer charges a deposit, and when it is returned the retailer refunds this deposit to the consumer. The retailer then recoups the funds from a central agency created to coordinate the DRS. Both the beverage industry and retailers often pay a fee to join the DRS to cover the central agency's service of coordinating the deposit and handling fees. A small handling fee is often paid to the retailer, which helps cover the costs of receiving, sorting, and storing redeemed beverage containers as well as paying out the refunds to consumers (Walls, 2011). The various role and responsibilities of the system actors are further outlined in table 1.

Table 1: Key players and their common responsibilities in a DRS for beverage containers.

Actor	Roles & Responsibilities
Beverage Industry	• Place the liquid matter into the containers • Pay a deposit to system operators • Pay admission fees to systems operators
Beverage Distributors	• Purchase products from the beverage industry; each container incurs a deposit • Sells products to retailers; adding a deposit to the cost of purchase
Wholesale & Retail	• Purchase products from distribution centres • Sells products to consumers • Charge consumers a deposit upon purchase • Reimburse deposits when containers are returned • Pay admission fees to system operators
Consumers	• Pay a deposit to the retail for each single-use beverage container purchased • Return containers to designated areas to have their deposit reimbursed

Central System Operators	• Manage and operate the deposit system • Pay out the deposit and handling fees to the retailer
Waste management companies	• Process containers from DRS • Sell material to container manufacturers
Packaging Industry	• Manufacture containers and sell them to the beverage industry

Operating system costs are typically covered either in full or partially through unredeemed deposits. However, with high return rates the amount of unredeemed deposits decreases, often causing the system to require additional funding to continue functioning (Albrecht, et al., 2011). This problem is avoided with the use of "half-back systems", whereby consumers are refunded half of the deposit they paid when they purchased the container. Program costs are then financed through the remaining half of the deposit (CM Consulting, 2012).

1.4 Effectiveness of Deposit-Refund Systems

DRSs for non-alcoholic beverage containers have been successfully adopted in numerous jurisdictions, including Norway, Denmark, Lithuania, and several U.S states. Most provinces and territories in Canada have also adopted this system, besides Nunavut, Manitoba, and Ontario. Provinces with a DRS in place have achieved high recycling rates for these products, recovering between 72 to 95% of all the plastic bottles sold in their province in 2012. Meanwhile, Ontario only achieved a 50% PET bottle recovery rate in the same year (Environmental Defence, 2016). The rationale behind the success of these program was identified in the study *Discontinuous Behavioral Responses to Recycling Laws and Plastic Water Bottle Deposits.* In this study, Viscusi, et al., examined individual recycling behavioural responses of a bottle deposit-refund system in the U.S. The study demonstrated that out of an average of 10 bottles, 2.73 additional bottles are recycled in states with a water bottle deposit law compared to those who only have effective recycling laws (defined in the study as either a mandatory recycling or opportunity to recycle law or a planning law). Furthermore, the percentage of non-recyclers in states with water bottle deposit laws was reported to be 12.8%, meanwhile in states only having effective recycling laws a total of 31.1% of the surveyed population was reported as non-recyclers. This difference can be explained through rational economic behaviour theory where individuals tend to gravitate towards extremes in their efforts to recycle, also known as a discontinuous effect. Due to the incentive provided by the refund in the DRS, individuals who were defined as reluctant recyclers are converted into diligent ones, leaving few intermediate recyclers in this system (Viscusi, et al., 2013).

Other known benefits from a DRS also include a significant reduction in littering. Prior to the introduction of the mandatory deposit-refund system in Germany, littering from single-use beverage containers was estimated to be about one-fifth of the total litter volume. It has been reported that littering of single-use beverage containers bearing deposits in the country is now negligible (Albrecht, et al., 2011). If a consumer decides to improperly dispose of a beverage container, a strong possibility exists that another individual will pick-up the container to redeem the deposit. Consequently, their removal from garbage or recycling bins allows for greater room for other waste, especially significant in municipalities with overflowing bins (Hogg, et al., 2010)

2.0 Purpose of Research

The purpose of my research is to examine what features or best practices of a DRS yield high recovery rates, of which can be applied in the potential implementation of this program, particularly in Ontario. These practices will be determined by examining cases of DRS in several areas and determining what features have made the system successful. Accordingly, the question I intend to answer through this research paper is:

What are the best practices for implementing a mandatory PET single-use non-alcoholic beverage container deposit-refund system in Ontario?

My report focuses solely on single-use PET containers because of its instrumental role in plastic pollution throughout the province and its widespread consumption, with an estimated 2.4 billion litres of bottled water purchased by Canadians annually (Environmental Defence, 2016). Aluminum cans were not focused on since this material's scrap value is greater than the cost to recycle it, meaning it already has an effective end market. Compared to both plastic and aluminum, recycling glass is very inefficient, with the cost of recycling to be roughly 30 times greater than its scrap value (Taylor, 2015). Therefore, PET is deemed to be the more sustainable material when compared to glass, when direct reuse is not considered. Additionally, my research concentrates on non-alcoholic beverage containers since Ontario already has a successful program for wine, spirits, coolers and beer containers. The success of this provincial program is highlighted by the 78.5% average recovery rate for all alcoholic beverage types and containers in 2015 (CRI, 2017). Lastly, mandatory DRSs, which are legislated and implemented by government agencies, were exclusively examined for this report. When there is no legal obligation to participate in this system, as seen in a voluntary scheme, market distortions may occur. For example, if one beverage producer assigns a deposit to their products and another producer sells deposit-free products, consumers will often purchase the lower priced product, which is often the product without a deposit. In other words, a mandatory government regulation creates a level playing field for all actors

3.0 Methodological Approach

My research was prompted after reading Environmental Defence's report, *Turning the Plastic Tide: How to Protect the Great Lakes and Fight Plastic Pollution.* In this report, the environmental organization outlines the immense problem of plastic pollution and proposes a DRS for single-use plastic bottles as a solution towards reducing this problem in Ontario. Once I obtained my research subject I conducted a comprehensive literature review regarding the concept of DRSs for beverage containers of all material types. I used several search terms to collect articles to analyze, including: "deposit refund system", "beverage containers", "extended producer responsibility", "bottle bill", and "container deposit laws". I used both Google Scholar and the University of Ottawa's Library search engine to obtain this preliminary research. The resulting literature was gathered from waste consultation reports, NGO reports, government reports, and peer-review articles, all dated from 2005 to 2017.

This initial review provided me with an extensive understanding of DRSs for beverage containers, including the various components and actors of the system, as well as the areas which have adopted this program. For each area with a DRS in place, I developed simple program summaries which typically included general descriptions, recovery rates, deposit rates, products covered, the redemption infrastructure, and unique characteristics. The extent of the summary was dependent on the amount of information provided in the initial literature review. These resulting summaries established the conditions to conduct a comparative case study, a methodology adapted from the UNICEF office of research. Comparative case studies involve both the analysis and synthesis of similarities, differences and patterns across two or more cases that share a common goal, in this case, achieving higher recycling rates for beverage containers (Goodrick, 2014). I chose this methodology since I want to both understand and explain how features within a specific program influence its success. Additionally, by examining real-world examples of DRS, I could distinguish between best practices developed in theoretical models and those found in existing programs. Distinguishing between theory and practice allows potential policymakers to see the system in a real-world setting, as a theory may not correspond to the real-world intricacies.

The rationale for selecting my case studies was directly linked to the key evaluation questions (KEQs), which are high-level evaluation questions about overall performance (Goodrick, 2014). These questions were inferred by my initial literature review which outlined the integral components for a successful system. The following KEQ's guided the selection of the case studies as well as the dimensions which would be studied:

1) How is the program being implemented?
2) How well does the program work; what is the recovery rate for PET?
3) What were the features of the program that made a difference?
4) Is the program sustainable in the long-term?

Due to the time constraint associated with this study, I could not conduct a comparison for all programs. Thus, I narrowed down my selection to six case studies: California, Oregon, Alberta, Nova Scotia, Norway and Sweden. These studies were chosen as they fall under the World Bank's high-income country classification. Ontario, like Alberta and Nova Scotia, is a province in Canada, thus falling within the category of high-income. Since urbanization and economic development are inextricably linked to solid waste generation, it was of value to compare areas with a similar consumption of goods and a high amount of waste generation. Notably, plastics are one of the materials which make up the highest proportion of municipal solid waste in high-income countries (Hoornweg & Bhada-Tata, 2012).

These six systems were also chosen because of the unique attributes associated with the program's features or policy approaches, including half-back refunds, regulations regarding depot locations and varying methods of returns. The reason why I focused on distinctive features was to evaluate a variety of programs, as opposed to focusing on programs with similar features. For example, evaluating both Alberta and British Columbia's DRSs would likely not advance my analysis since the programs operate almost identically. Another factor influencing my choice in case studies was the date of the system's implementation. Dates of implementation for each chosen program ranged from 1971 to 1999, averaging a duration of 33 years. Programs implemented at an early date were more likely to be well-documented and are likely to have undergone various amendments for the betterment of the program, elements which are valuable for the purposes of my report.

Once the case studies were chosen, I conducted another literature review to gather more information on the specific components of each case study. Additional research was gathered from waste consultation reports, NGO reports, government reports, peer-review articles, as well as websites established by DRS operators. As a result of the KEQs and the additional research on the chosen case studies, the following elements were described:

1) Program description
2) Redemption rate
3) Funding mechanism
4) Deposit rate
5) Redemption infrastructure and access (ease of use)
6) Program Amendments

3.1 Limitations

A multitude of DRSs exist in the world, however given the time constraints related to the production of this report, only six case studies could be examined sufficiently. The selection of these case studies can become a limitation to the research. The cases I chose were intended to provide a range of examples, covering different regions, different sized countries and different system operations. Ontario, the area which my research intends to determine the best practices for implementing a DRS, has a different population (13.6 billion) and density (14.1 p/km^2) than each of the case studies examined. As a result, the findings are not guaranteed to effectively function when applied to Ontario. In addition, other explanatory factors may have determined the success of a program such as historic, cultural and social contexts, of which are difficult to account for in this type of study. Therefore, this type of methodology can only provide applicable generalizations to inform sound decision making.

Another limitation was a lack of information on the chosen case studies. Notably, both Sweden and Norway were lacking, especially since most reports were in the Norwegian or Swedish language. California, on the other hand, had an ample amount of reports available and is considered to be one of the most studied bottle bills in the U.S. Similarly, some case studies had more recent data available compared to others. This becomes a problem when determining similarities and differences for the analysis because the dated information may be inconsistent with the current data, which is unavailable. As a result of both these limitations, some case studies were not able to adequately describe the elements of the system outlined in the methodology.

Lastly, across all the case studies there was a lack of data regarding the efficiency of the system in urban and rural areas. Information derived from my initial literature review determined that individuals in urban areas are more likely to use the system since they have greater access to depots or RVMs. Since the data was aggregated as an overall return rate, I was unable to get a strong sense of how this program works in rural areas. Further research may be done to examine specific best practices in rural areas with lower population densities. Despite these limitations this research is valuable in understanding what features of a DRS yield high recovery rates.

4.0 Findings

4.1 Case-study overview

Table 2 was produced to summarize the information collected across cases to facilitate the examination of similarities and differences of the case studies:

Table 2: Overview of chosen case studies.

Area	Population	Date of Implementation	PET Recovery Rate (non-alcoholic)	Deposit Values (CAN)	Handling Fee	Return Mechanism
California	39.5 million	1987	71.52% (2016)	≤710 ml = $0.06 >710 ml = $0.13	Yes	Recycling Centre
Oregon	4.1 million	1971	54.96% (2016)*	$0.13	No	Return-to-retail & Recycling Centre
Alberta	4.1 million	1972	78% (2014)	≤1L = $0.10 ≤1L = $0.25	Yes	Recycling Centre
Nova Scotia	0.94 million	1996	81% (2014)	$0.10	Yes	Recycling Centre
Norway	5.2 million	1999	90% (2010)	≤500 ml = $0.16 >500 ml = $0.41	No	Return-to-retail
Sweden	9.9 million	1984 (PET included in 1994)	82.7% (2014)	≤1 L = $0.15 ≤1 L = $0.30	Yes	Return-to-retail

Notes:

* This rate includes both alcoholic and non-alcoholic containers, as a separate rate was not found.

- All the chosen case studies include beverage containers produced from glass, aluminum and plastics, however due to the focus of my research paper recovery rates for PET bottles was examined.

- The deposit values have been converted from the country of currency (USD, NEK, or SOK) to Canadian currency (CAD) for comparison purposes via Google finance on April 21, 2018.

- The terms *recycling depot* and *recycling centre* are used interchangeably.

4.2 California

California's DRS, known as the Beverage Container Recycling Program (BCRP), was implemented in 1987. The deposit rate, referred as the California Redemption Value (CRV), is set at 5 cents ($0.065 CAD) for containers under 24 ounces (710 ml) and 10 cents ($0.13 CAD) for containers over 24 ounces (CalRecycle, 2014). The program expanded over the years to include more beverage types and also increased its CRV (R3 Consulting Group & Morawski, 2009). Since the implementation of the program recycling rates for CRV-eligible containers increased by 30%, from 52% in 1987 to 82% in 2015 (Taylor, 2015). Each period of rate increased coincided with an increase in redemption rates. Containers made from glass, plastic and aluminum are eligible for a deposit, however containers over 64 ounces (1.89 L) are not eligible (Taylor, 2015). In 2016, the program achieved a 71.5% recovery rate for PET bottles, and an average recover rate of 79.7% for all material types (CalRecycle, 2017).

The DRS is managed by the government, more specifically the Department of Resources, Recycling and Recovery, also known as CalRecycle (Taylor, 2015). Beverage producers are required to pay a deposit for each container they sell in the state, with the payments being deposited into the California Beverage Container Recycling Fund (BCRF) managed by CalRecycle. Payments are then made from this fund to the consumers when they return their empty beverage containers to the appropriate centre. Money from the fund is also drawn out to support the distribution of handling fees, processing fees, CRV payments, and grants intended to promote greater levels of recycling, public education and additional recycling programs. Notably, the state also awards annual funding toward the promotion of strong end-markets for the recycled materials and to improve the overall efficiency of the system (University of Maryland EFC, 2011).

Consumers can obtain their deposit by returning their empty beverage containers to convenience zone recycling centers, also known as CZ recycling centers, which are operated by independent businesses. State law requires that these facilities be located within a one-half mile radius of supermarkets with more than $2 million in gross annual sales. In 2014, approximately 2,000 of these centres were in operation. Handling fees are deployed to encourage recyclers to locate in the convenience zones, where property is often expensive, to make returns more convenient for consumers. These handling fees are paid on a per container basis. “Traditional” recycling facilities also exist outside these zones. These facilities are concentrated on large quantities of materials obtain from municipal or commercial waste collection services (Taylor, 2015).

In 2013, CZ recycling centers only redeemed about 32% of the total CRV-eligible containers. The majority of containers, more specifically 56%, are collected at “traditional” recycling centers (Taylor, 2015). These closures are partly due to the fact that handling fees in the state do not reflect contemporary costs of operations. Fees are determined by a statewide survey, which occurs periodically and by the time responses are reflected in the handling fee, the prices increase again (LAO, 2017). This particular situation is one of the contributing elements to the closure of over 300 CZ recycling centres as of early 2016. Declining scrap values, a lack of funding from the BCRP, and the strict state laws governing the location of the redemption centres also contributed to these closures. With fewer redemption centers remaining, consumer convenience is greatly reduced, forcing individuals to travel further to obtain a refund for their beverage containers. A majority of these closures occurred at rural, low-volume sites, which are more vulnerable to market changes due to their higher per-container recycling costs (LAO, 2016). As a direct result, fewer containers are recycled overall (LAO, 2017).

The system is beginning to run on a deficit due to high recycling rates and increased spending on supplemental programs (Taylor, 2015). With high return rates, there are less unredeemed deposits to support DRS operations. The market changes in the scrap value directly affects the state recyclers since they hold responsibility over the redeemed containers. Over the past years, processing payments have not been able to keep up with the declines in these values, which recyclers heavily rely on to remain profitable. In other systems, the manufacturers are financially responsible for the redeemed containers instead of the state. Manufacturers are better suited to absorb costs of the system and losses in scrap value since recycling costs are negligible compared to their beverage sales (LAO, 2017).

4.3 Oregon

Oregon's Deposit-Refund system for beverage containers was enacted in 1971. The collection of containers and the disbursement of deposits are operated independently by the Oregon Beverage Recycling Cooperative (OBRC), a cooperative of beverage producers. Unredeemed deposits from the program are returned to this cooperative (CRI, n.d.-c). Soft drinks and water are accepted in containers 3 L or less in size, and the remainder of non-alcoholic drinks are accepted in containers from 118 ml to 1.5 L (OLCC, n.d.). All containers hold the same refund value of $0.10 USD ($0.13 CAD), which was increased from $0.05 USD in April 2017, in an effort to increase redemption rates (CRI, 2018). In 2016, the return rate for single-use plastic beverage containers was 54.96% (OLCC, n.d.). It is assumed that this rate increased in correspondence to the increase in the deposit rate in April of 2017, as the overall redemption rate for all containers increased from 64.3% in 2016 to 82% in 2017 (CRI, 2018). However, redemption rates for specific container material types have not been released for 2017.

Oregon has numerous locations for consumers to obtain their refunds for empty beverage containers, which includes retail stores, BottleDrop Redemption Centres, and BottleDrop Express locations. Retail stores that are 5,000 square feet or more must accept and provide a refund for all deposit-eligible containers and they are also all required to have RVMs. Stores less than 5,000 square feet can refuse containers of which they don't sell the brand or size. Some retail stores are designated as a *PLUS* location by the OBRC, allowing customers to print a voucher from the store's kiosk that is worth 20% more at that particular store, thereby giving customers a 12-cent refund rather than 10. BottleDrop Redemption Centers, introduced in early 2010, are staffed facilities that are independently operated by the Oregon Beverage Recycling Cooperative (OBRC), with 21 centres across the state. These centers provide RVMs, manual counts, as well as a drop door for account holders. Individuals who hold an account with the redemption center can deliver green bags of empty beverage containers for the redemption center staff to count for refund. Individuals can access their account funds via kiosks located at these centers and at stores participating in the DRS. Account holders may also drop off their green bags at BottleDrop Express locations, which are located at retail stores. The OBRC collects these bags from the retailers, counts the containers and proceeds to credit the account holder's account (OLCC, n.d.). No handling fees exist in Oregon's DRS. Without handling fees, the retailers and redemption centres must absorb the costs of dealing with the containers, which includes dedicated space and paying employees. Without these fees to operate the program, concerns have been expressed regarding the sustainability of the system (University of Maryland EFC, 2011).

4.4 Alberta

In 2014, the return rate for PET bottles was 78% (ABCRC, 2016). The Beverage Container Management Board (BCMB) is a not-for-profit organization which oversees the program. The Alberta Beverage Container Recycling Corporation (ABCRC) was approved by the BCMB to be the agent for the collection of beverages in all non-refillable containers, which is primarily non-alcoholic beverages (ABCRC, n.d.-b). The program was amended in November of 2008 to increase deposit rates from $0.05 CAD to $0.10 for containers less than 1 L and from $0.20 CAD to $0.25 for containers greater than 1 L. This amendment increased single-use container collection rates by 7%, from 75% to 82% following the rate increase. Specifically, PET collection increased from 67% to 79%, three years following the deposit increase (CM Consulting, 2012). This supports the notion that higher deposit rates result in greater collection rates. In 2014, the return rate for PET bottles was 78% (ABCRC, 2016).

Consumers can return their empty PET containers and collect their refund via the 216 privately owned and operated "universal" bottle depots across the province. "Universal" signifies that both alcoholic and non-alcoholic beverage containers can be redeemed at these locations (CM Consulting, 2012). It is estimated that 51% of the province's population resides within a 10-minute drive of a depot, and 34% live within an 11 to 20-minute drive (CM Consulting, 2016-b). The ABCRC collects and then transports the containers to one of the two processing facilities in the province, where the materials are prepared for recycling end markets (CM Consulting, 2012). A survey conducted in 2016 reported that 89% of Albertans participate in the program with an overall 80% public satisfaction rate of the program. Satisfaction was considered on elements of convenience, refund amount, safety, depot hours, quality in service, depot wait times, and depot appearance (BCMB, 2016).

The program for non-alcoholic beverage containers "is funded through revenues generated from the sale of collected material, revenues from unredeemed deposits, and revenues collected through the application of a container recycling fee (CRF) paid at the point of purchase by consumers". The value of the material and the collection rate determines the value of the CRF, as the fee represents a portion of the net cost per unit. The CRF is comparable to a handling fee seen in other programs. Containers with high collection rates will generate less unredeemed deposit revenue, therefore a high CRF is warranted, and vice versa (CM Consulting, 2012). This fee varied from no fee to $0.10 CAD in 2010, depending on the material type. Currently, the CRF for PET containers less than 1 L is $0.02 CAD and for containers greater than 1 L the fee is $0.10 CAD (ABCRC, n.d.-a). The CRF is applied to fund system operations, such as collection, transportation, and marketing, that are not covered by material revenues (ABCRC, n.d.-b). As such, the costs of the program are paid for by the product consumers (CM Consulting, 2012).

4.5 Nova Scotia

Nova Scotia's DRS has been in place since April 1996, and operates as a half-back system. A half-back system ensures higher revenues than expenditures in the program (CM Consulting, 2012). A $0.10 CAD deposit is placed on all non-alcoholic containers less than or equal to 500 ml and a $0.20 CAD deposit is placed on containers greater than 500 ml. When consumers return the empty container to a depot they receive a $0.05 CAD or $0.10 CAD deposit, respectively. Non-alcoholic beverage containers that are 5 L or greater are not accepted in the program (CM Consulting, 2016-a). In 2014, the return rate for PET containers was 81%, with all single-use containers achieving a return rate of 84% (CM Consulting, 2016-b). A not-for-profit organization, Divert NS, act on behalf of beverage distributors to administer and operate the deposit-refund program. This organization also arranges collection of the collected containers from depots and transfers them to the nearest of three regional processing centres (CM Consulting, 2012).

There are 83 Enviro-Depot™ locations throughout the province, where consumers can obtain refunds for their empty redeemable containers. These depots are manually operated

(CM Consulting, 2012). Through the depots and regional processing centres, the province maintains 711 jobs each year, equivalent to 11,188 full-time jobs created over 20 years (Gardner Pinfold Consultants Inc., 2016). The program is funded through unredeemed deposits and the half of the deposit retained through the system's half-back feature. The retained portion of the deposit covers the handling fees for the containers and a portion is also distributed to municipalities to offset some of the costs associated with their waste diversion initiatives (CM Consulting, 2012).

4.6 Norway

Norway's system was implemented in 1999 (CM Consulting, 2016-a). The deposit value for containers less than or equal to 500 ml is NOK 1, which is equivalent to $0.16 CAD. Containers with a volume greater than 500 ml have a deposit value of NOK 2.5, equivalent to $0.41 CAD (CM Consulting, 2016-a). The program achieved a 90% return rate for non-alcoholic PET containers in 2010 (MS2, 2011). The operator of the system is Infinitum AS, which is a non-profit organization established for the sole purpose of operating the DRS. This corporation is owned by organizations in the beverage container business including the Grocery Manufactures' Service Office, Norwegian Association of Wholesale Grocers, and the Federation of Norwegian Food and Drink Industry (CM Consulting, 2016-a).

The system has 15,000 redemption locations through the return-to-retail model, with the majority of collection occurring through automation (CM Consulting, 2016-a), with approximately 3,700 RVMs existing across the country (Infinitum AS, n.d.-a). Other areas such as shops, kiosks, or gas stations can register as collection points, using manual collection or RVMs (Infinitum AS, n.d.-b). Funding for the program is generated from various fees, including joining fees, a fee for creating an EAN barcode, and an administration fee for each container. Unredeemed deposits and the sale of the recycled material also contribute to the operation of the system (MS2, 2011).

No handling fee exists in the Norway system (CM Consulting, 2016-a), however an environmental levy or material-specific administration fee is applied per bottle. This levy is dependent on the return rate; with a higher return rate, the environmental levy decreases

(Infinitum AS, n.d.-c). This fee ceases to exist when a 95% return rate is achieved (Infinitum AS, n.d.-d). In 2010, this levy was NOK 0.10 ($0.016 CAD) for beverages 500 ml or less and NOK 0.11 ($0.018 CAD) for beverages greater than 500 ml). PET beverage containers that are light blue, dark blue and ones that have a sleeve covering more than 75% of the surface carry additional charges of NOK 0.08 ($0.013 CAD), NOK 0.15 ($0.025 CAD), NOK 0.15 ($0.025 CAD), respectively (MS2, 2011). As a result, this system increases the incentive for producers to participate and for consumers to return their empty beverage containers beyond receiving their refund, since a higher overall return rate will result in a lower tax on the beverages (Infinitum AS, n.d.-d).

Infinitum AS collaborates with the Norwegian Red Cross to collect empty beverage containers in areas where there are no collection points. The Red Cross benefits from this as they collect the revenue from this collection and the country benefits as more empties are collected that could otherwise end up in the trash. In addition, Infinitum AS offers special arrangements to collect large quantities of empty beverage containers during major events, such as music festivals, school events, or humanitarian organizations (Infinitum AS, n.d.-b).

4.7 Sweden

Sweden's DRS was implemented in 1984, however PET beverage containers were only included 10 years after, in 1994 (CM Consulting, 2016-a). In 2014, the system achieved an 82.7% return rate for PET bottles (CM Consulting, 2016-a). Deposit values for plastic containers less than or equal to 1 L is 1 SEK ($0.15 CAD) and for containers greater than 1 L, the deposit value is 2 SEK ($0.30 CAD) (CM Consulting, 2016-a). Beverage producers with eligible containers must pay an annual registration fee of SEK 10,000 ($1513.30 CAD) as well as a fee for each EAN barcode they register (MS2, 2011). The system operates via a return-to-retail method, with 95% of the collection being automated and the remainder being manually collected (CM Consulting, 2016-a). Manual collection typically occurs in small retail outlets (MS2, 2011).

The system operator is *AB Svenska Returpack,* also known as *Returpack,* a privately-owned company owned by the retail sector, Swedish brewers and the grocers association (CM Consulting, 2016-a). Returpack pays handling fees to the retailers with RVMs and manual collection. RVM with compaction has the highest rate at 0.38 SEK ($0.058 CAD) for plastic containers less than 1 L or 0.42 SEK ($0.064 CAD) for plastic bottles greater than 1 L. RVM without compaction and manual collection are both 0.2 SEK ($0.030 CAD) (CM Consulting, 2016-a). The whole system is financed through material revenue, unredeemed deposit and the administration fees (CM Consulting, 2016-a).

5.0 Lessons Learned

Drawing from the case study comparison and the initial literature review, the best practices or lessons that can be extracted and applied toward implementing and effectively sustaining a DRS are as follows:

1) ***Handling fees need to be frequently adjusted.***

Handling fees are a critical factor of what makes DRS attractive for retailers and redemption centers. These fees should be adjusted over time to account for changes in managing the containers. In jurisdictions where handling fees have remained the same for decades, the compensation provided to the retailers and redemption centers is often not enough to adequately cover the operation costs, as seen in California. When costs are not adequately covered, redemption centres risk going out of business. Therefore, it is recommended that the fees are assessed on a bi-annual basis to coincide with potential rising operations costs.

2) ***Return-to-retail mechanisms outperform recycling centres in terms of achieving high return rates and minimizing GHG emissions.***

Return mechanisms in Sweden and Norway solely rely on the return-to-retail method, and in turn, they achieve the highest return rates among the chosen case studies. This mechanism facilitates the effect of a “one-stop shop”. Individuals can return their containers at the same time as conducting their weekly or bi-weekly grocery trip, reducing the costs associated with returning the containers. It is important that the negative effect of the opportunity costs associated with returning beverage containers are outweighed by the positive influence of the cash refunds. Hogg et al., study suggests a dense network of collection points for a possible DRS in the UK as this would reduce additional environmental impacts arising from making dedicated journeys to receive their refund (Hogg et al., 2010). Simon et al’s study on the life cycle impact assessment of beverage packaging systems illustrated that a DRS in a supermarket produces the least amount of kg CO_2-equivalent emissions in terms of waste collection for post-consumer PET beverage containers. Hence, this system outperforms curbside collection and recycling collection centers (Simon, et al., 2016). Maintaining a dense network of collection points for beverage containers is possible when the redemption mechanisms are situated in a grocery stores. A dense network exists in Norway's DRS for beverage containers, which is an instrumental element in the country's high return rate for PET bottles.

In addition, automated mechanisms via RVMs is more effective than manual sorting in the return-to-retail method. These machines can be installed in existing stores and can also reduce the volume of the collected containers by compacting, shredding and crushing the materials on site. This increases the overall efficiency of a DRS as trailers can carry more container per trip, thereby reducing GHG emissions. RVMs can process more containers at a time than manual sorting, making this method more cost-effective than manual sorting. The machine also addresses a potential problem of "fraudulent" returns via transboundary flows of materials. For example, if a neighbouring province has higher deposit values, individuals may bring containers purchased in Ontario to the neighbouring province to receive a higher refund. This activity is minimized through the use of RVMs as the scanned EAN barcodes can detect these "fraudulent" containers (Schneider, et al., 2011).

3) ***A DRS needs to be funded by a variety of sources to ensure its sustainability***

Higher revenues in relation to higher expenditures are needed to ensure the longevity and sustainability of the program. Simply relying on unredeemed deposits to fund the program places the whole operation in a volatile positon. This dependency is also counterproductive, as the main goal of a DRS is to achieve high recycling rates for the selected material and product. California's system is dependent on the unredeemed deposits and thus the program is beginning to operate on a deficit due to the relatively high recycling rates in the state. This has contributed to the closure of numerous recycling centres in the state. A half-back system should be examined for Ontario as this system ensures funds are always available for both the operation of the program and other initiatives which can help the environment.

4) ***Deposit rates must increase periodically to be in line with inflation.***

To maintain the incentive for consumers to retain their beverage containers, deposit rates must be increased periodically to be in line with inflation. If this does not occur, the value of the deposit relative to purchase price of the beverage decreases to a point where the incentive to return these containers is low. This is likely the reason why Oregon has the lowest redemption rate for single-use PET non-alcoholic containers among the chosen case studies. The state retained the original refund value of $0.05 USD from the commencement of the program in 1972 and only recently increased this rate to $0.10 USD in April 2017.

6.0 Discussion

6.1 Opportunities for Ontario

When recycling is no longer profitable or end-of-life materials have an unreliable market value, governments could address these situations by imposing regulations. This is the current situation for PET in Ontario as the material is fairly cheap to produce, while the costs associated with processing the material to be reused is more expensive. Thin and light plastics, as used for beverage containers, increase recycling costs since a large amount of containers are required to generate one tonne of rPET. For example, it used to take 35,000 plastic water bottles to recover 1 tonne of plastic and now it takes almost double to recover the same amount. This phenomenon is known as the “evolving tonne” and it has been the main force growing costs in the Blue Box system. Heavier materials are more cost efficient to collected on a revenue per tonne basis, since a higher density can be collected in the collection truck and these products are often less expensive to process (ECO, 2017). PET beverage containers have a low weight-to-volume ratio, a characteristic that makes them inefficient to collect at curbside (CRI, n.d.- a). By implementing a DRS using RVM compacting capabilities, Ontario can reduce the disproportionately high upstream effects of this material.

A DRS can address the low recycling rates with AfH consumption. In Ontario, bottles consumed at events or on-the-go only achieve an estimated 25% return rate (Environmental Defence, 2016). Implementing a DRS is proven to reduce the amount of beverage containers within the AfH waste and recycling stream (CM Consulting, 2012). The low rates of recycling associated with individuals living in multi-residential buildings can also be addressed through the implementation of this program. These individuals are less likely to participate in recycling activities due to the inconvenience of bringing materials to the common bins (Chung, 2018), however with the deposit as an incentive, individuals will likely be more inclined to participate.

A DRS also generates economic benefits, through the sale of beverage containers to processors and through the creation of jobs. Areas in remote and northern locations can especially benefit from the introduction of these depots, as seen in the 12 full-time jobs and 35 part-time jobs provided in the Northwest Territories from 2011 to 2012 at their DRS depots and processing centers (Giroux, 2014). This system is reported to have created significantly more jobs than curbside recycling, producing 11 to 38 times more (CM Consulting, 2016-b). In order to gain a better understanding of the plausible benefits of this system, I suggest conducting a cost-benefit analysis to compare the costs and benefits of implementing this program and determine if this program is a sound decision for Ontario.

6.2 Ontario's necessity for strong PET end-markets

The *2015 Post-Consumer Plastics Recycling in Canada* report states that 6% of the PET bottles material collected for recycling in Canada is exported overseas, primarily to China. In December 2017, China announced a ban on imports of foreign waste, including PET, which aims to reduce the amount of poor quality recovered material imported into China. This ban emerged as China continues its transition from a primarily manufacturing economy to a more consumer driven one. This transition requires the country to focus on formalizing their own recycling sector to deal with an influx of domestic plastic as more of its citizens enter the growing middle class (Moore Recycling Associates, 2017). Therefore, the once cheap and easy solution for Canada to export its waste has expired, prompting a struggle among municipalities to find suitable end-markets for these materials (Hounsell, 2018). This ban further encourages the creation of a DRS for PET beverage containers in Ontario. By implementing a DRS in Ontario for non-alcoholic PET containers along with provincial processing facilities focusing on closed-loop systems, the province has an opportunity to generate effective end-markets for this material.

Studies have shown that when producers are responsible for managing materials at their end-of-life, they have ensured market demand for the material (R3 Consulting Group & Morawski, 2009). For example, after the initial introduction of the mandatory deposit system for single-use beverage containers in Germany, the market for rPET strengthened. From January 2003 to early 2004, the price for rPET increased from approximately €60 per tonne to slightly below €200 per tonne (Albrecht, et al., 2011). In short, having a strong market for these secondary raw materials allows for greater independence from the primary raw materials and greater economical sourcing (Albrecht, et al., 2011).

6.3 Waste Free Ontario Act, 2016

The Waste Free Ontario Act was proclaimed in late 2016 (Bill-151, 2016), a piece of legislation which intends to address the problems associated with waste generation by increasing resource recovery. Accompanying this piece of legislation is a strategy, published in February 2017, outlining the province's formative actions which intend to achieve the objectives. One of the main ideas of this strategy is embracing the circular economy, whereby "products are never discarded, but reused, recycled and reintroduced into new products" (Government of Ontario, 2017). Resource efficiency is the main driver of the circular economy as resources are used repeatedly, with both commercially successful markets for diverted materials and closed-loop forms of production. It is ideal for resources to continually be used for their highest and best use to maximize their value (ECO, 2017).

The new Act is expected to increase the required share that printed paper and packaging companies contribute to the net cost of operating municipal curbside recycling programs. This rate is currently at 50%, however under the province's new waste diversion regime this can increase to 100%, becoming a full producer responsibility system (CM Consulting, 2016-b). However, by simply financing recycling facilities or the operation of the curbside collection system, consumers are not directly incentivized to utilize these systems, leading to the relatively low recycling rates we see in the province (Walls, 2011). Currently the Act is high level, so as time goes on the details of how the new system will operate will be determined through regulations. The Act does not explicitly recommend a DRS, however it is evident that this system will allow the province to embrace the circular economy, align with a subsequent beverage container disposal ban and address the province's poor blue box performance, actions aligning with the *Strategy for a Waste-Free Ontario: Building the Circular Economy.*

7.0 Conclusion

This research paper has demonstrated that a DRS presents a promising opportunity to enhance Ontario's poor recycling rates for PET single-use non-alcoholic beverage containers and addresses the pervasive problem of plastic pollution, notably in marine environments. The implementation of this system may quickly become a necessity for the province due to the ban on foreign waste to Chinese end-markets. Ontario can embrace this opportunity to create robust and sustainable domestic end-markets for these materials through closed-loop recycling, aligning with the concept of the circular economy.

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