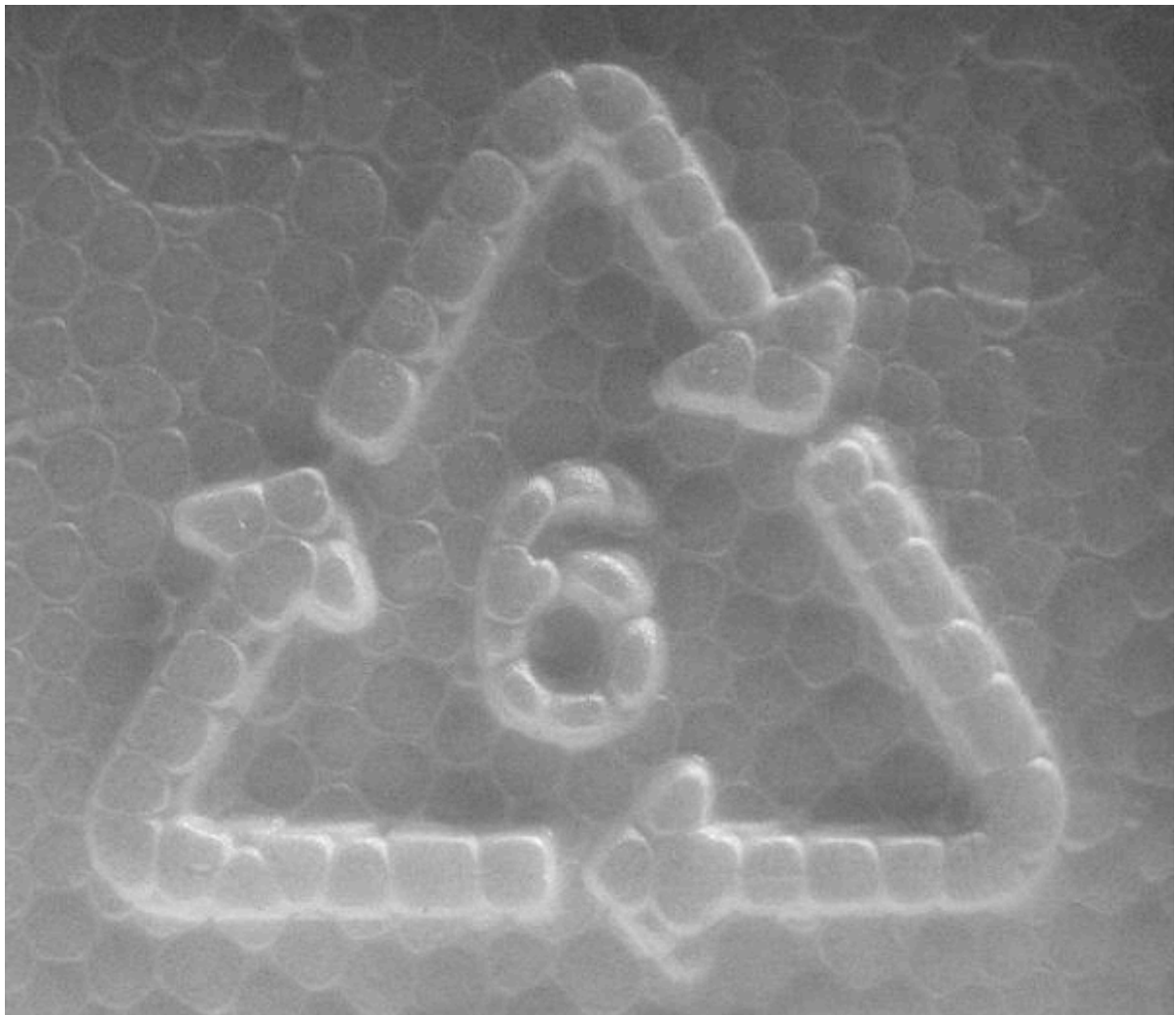

Examining the Potential for Expanded Polystyrene Diversion in Nova Scotia

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Abbreviations

ACGIH - American Council of Governmental Industrial Hygienists

CAP – Canada-wide Action Plan

CCME - Canadian Council of Ministers for the Environment

CNS – Central Nervous System

CO₂ – Carbon Dioxide

CPIA – Canadian Plastics Industry Association

EPR – Extended Producer Responsibility

EPS – Expanded Polystyrene

GHGs – Greenhouse Gases

IARC - International Agency for Research on Cancer

LCA – Life Cycle Analysis

MCDCA – Multi-Criteria Decision Analysis

MRF - Materials Recovery Facility

NO_x – Nitrogen Oxide

NTP – National Toxicology Program

OEL – Occupational Exposure Limits

OECD – Organization for Economic Cooperation and Development

SO₂ – Sulphur Dioxide

SO_x – Sulphur Oxide

STEL – Short Term Exposure Limits

UBC – University of British Columbia

USEPA - United States Environmental Protection Agency

UW – University of Wisconsin

WHO - World Health Organization

XPS – Extruded Polystyrene

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Purpose

Expanded polystyrene (EPS) is the most commonly used form of foamed polystyrene, and is manufactured from beads made of styrene monomer into a polymeric material that can be shaped and used in many ways. The purpose of this report is to determine effective management methods for EPS waste, both at Dalhousie University and throughout the province of Nova Scotia.

Executive Summary

Three steps were utilized to determine effective management methods for EPS waste. First, the costs and benefits of EPS are identified. Second, the costs and benefits of recycling EPS by municipal curbside pickup compared to those associated with landfill disposal are highlighted. Finally, EPS reduction and recycling strategies for Dalhousie campuses are outlined. Peer reviewed and grey literature were examined, interviews were conducted with waste management and EPS experts both within and outside of Nova Scotia, online surveys were completed, and a pilot project at Dalhousie University was undertaken and audited. From this data, key findings were outlined (Figure 1) and recommendations created (Figure 2).

Figure 1. Summary of key report findings from the literature, surveys, and interviews.

- EPS is used for a variety of purposes in Nova Scotia.
- EPS has been linked to environmental and health risks in manufacturing and as litter.
- EPS recycling is reported as having low health risks.
- Recycling EPS was highlighted as a key strategy for reducing the quantity of EPS in the waste stream.
- Research into more environmentally-friendly, cost effective replacements for EPS is recommended.
- Recycling EPS would increase available space in landfills and create jobs throughout the province.

- The high volume to weight ratio was seen as the largest barrier to EPS recycling; contamination of EPS and upfront costs to implement a recycling program were also raised as barriers.
- Local experience suggested that approximately 450kg of EPS would fit on a pallet for shipping to facilities that make use of recycled EPS.
- The selling price of recycled EPS is inconsistent. Prices have been as high as \$600/tonne, but are currently closer to \$300/tonne. Coloured foam, such as Styrofoam™, can sell for below \$100/tonne.
- Determining the weight and volume of EPS in Nova Scotia landfills was a challenge. Data from a 2008/2009 waste characterization survey by Halifax Regional Municipality suggests that EPS is between 1% and 2% of all waste by weight.
- The Dalhousie pilot study found that one cubic metre of (uncompacted) EPS can weigh approximately 10 kg.
- Approximately 198 kilograms of EPS was produced from the Tupper Building during the four-month pilot study, which was measured at approximately 26 cubic metres in volume.
- It was found that lids and other packaging materials had lower weight to density ratio when compared to laboratory boxes.
- EPS contamination, due to stickers and labels, was highest for laboratory boxes (17.4%), followed by laboratory box lids (13.6%). Contamination of other packaging was by far the lowest (4.1%).

Figure 2. Summary of key recommendations.

- This research provides evidence that the recycling of EPS in Nova Scotia could be beneficial.
- On the basis of the research, support for a Nova Scotia EPS recycling program should be considered, provided that certain conditions are met.
- Further research regarding EPS volumes in landfills should be undertaken.
- Efforts should be taken to ensure sustainable end-markets for recycled EPS. This includes exploring local EPS recycling markets.
- It is recommended that funding for infrastructure (e.g. buildings, storage space) and, if required, new recycling trucks is provided in addition to funding for machinery.
- While conclusive evidence regarding harmfulness of EPS is not available, it is recommended that adequate ventilation systems be placed in MRFs if EPS recycling is implemented in Nova Scotia
- Education is important to both increase diversion rates and reduce contamination rates. It is recommended that a public education campaign be instituted is EPS recycling is enacted.
- Regarding EPS recycling at Dalhousie University in particular, increased storage space for EPS at the warehouse is required to maximize the success of EPS recycling on a wider scale at Dalhousie. During the pilot study, storage space was limited, meaning trips to Truefoam were required before trucks were filled to capacity. Greater storage space will mean fewer trips to Truefoam, decreased labour costs, and decreased GHG emissions.

1.0 Introduction

Polystyrene is a widely used plastic made from styrene, a chemical compound produced by combining ethylene and benzene. The final product is comprised of 95 to 98% air (Tan & Khoo, 2005). Polystyrene can be manufactured and used in numerous forms. These include expanded polystyrene (EPS; used, for example, in take away containers and transport packaging), moulded, or sheet polystyrene, (commonly used for hard plastics such as CD cases and cutlery), spray foam polystyrene (used for insulation purposes), and extruded polystyrene (XPS), often used for crafts and model making (Myint, Zakaria & Ahmed, 2010). While polystyrene is commonly referred to as Styrofoam™, this is actually a trademarked form of XPS made by Dow Chemical (The Dow Chemical Company, 2015).

As polystyrene is often used to store and protect other objects, it quickly becomes a waste product. It has been suggested that globally, polystyrene accounts for more than hundreds of thousands of metric tonnes of waste in landfills (Myint, Zakaria & Ahmed, 2010). This is important, as EPS compacts at much lower rates than other types of waste. In recent studies conducted by the Canadian Plastics Industry Association (CPIA, undated), EPS in the landfill compacted to between 20kg and 30kg per m³. This contrasts with typical compaction of mixed materials from a range between 350kg and 900kg per m³ depending on the size, and machinery used at a landfill site. The bulky nature of EPS has contributed to decisions by recycling programs to not accept it, as it takes up space in curbside recycling containers that could be filled by other recyclable products (Resnikoff, 2014). However, polystyrene can be recycled and landfill diversion of polystyrene may hold economic, environmental and social benefits.

Under the *Environment Act 1994-95*, the Nova Scotia government set solid waste diversion targets of 50%, which was first achieved in 2000 (RRFB Nova Scotia, 2002), and continue to be surpassed. While the goal of 50% diversion has been successful, the province has not yet achieved its targeted 300kg disposal per person per year (Government of Nova Scotia, 2014). As outlined in the *Environmental Goals and Sustainable Prosperity Act 2007*, the solid waste disposal rate target of 300kg per person per year is to be achieved by initiatives such as developing new programs and product stewardship regulations. Nova Scotia's solid waste

generation has only dropped slightly in recent years, from 378 kg per capita in 2008 to 373 kg per capita in 2013 (Province of Nova Scotia, 2014). Finding new avenues for solid waste diversion is a priority to reduce solid waste generation and disposal. Given the bulky nature of EPS, diverting from the landfill could be a priority for the solid waste management industry. This review will explore the issues related to EPS recycling in greater detail, and consider the potential limitations and benefits of implementing a polystyrene recycling program in Nova Scotia and at Dalhousie University.

2.0 Background

2.1 Uses of EPS

EPS is commonly used in a variety of applications because of its characteristics. EPS has shock absorbing properties, making it beneficial for storing and transporting fragile items such as wines, chemicals, electronic equipment, and pharmaceutical products (Truefoam, 2012). Its thermal insulation and moisture resistant properties lend it to the packaging of cooked food as well as perishable items such as seafood, meat, fruit, vegetables, and eggs.

EPS is light and can support many times its own weight in water, leading to its use in flotation devices. It can be used in the manufacture of sliders, model planes and surfboards because of its positive strength to weight ratio. The strength of EPS along with its shock absorbing properties make it effective for use in children's seats and cycling helmets. EPS is also compression resistant, meaning that EPS is ideal for stacking packaging goods. EPS has applications in horticulture in seedling trays to promote aeration of soil.

2.2 EPS in Nova Scotia

The versatility of EPS means that it is used in many ways in Nova Scotia. The major uses of EPS in Nova Scotia include building insulation, food packaging (namely trays, clamshells, and cups); fish boxes; laboratory boxes; and packaging of delicate goods, such as electronics.

EPS is produced in Nova Scotia at Truefoam Limited's manufacturing plant in Burnside Industrial Park. The largest market demand for their EPS is seafood packaging (fish boxes) and building insulation for the construction industry.

2.3 EPS vs XPS

EPS and XPS, while different products used for different purposes, also have some similarities. While both products come from an expanded bead, the processes used to get to the final product are different.

2.3.1 EPS and the manufacturing process

The major chemical component of EPS is styrene (C_8H_8), which is derived from petroleum or natural gas and formed by a reaction between ethylene (C_2H_4) and benzene (C_6H_6); benzene is produced from coal or synthesized from petroleum (Uihlein, Ehrenberger, & Schebek, 2008). Styrene is usually polymerized with heat or by an initiator such as benzoyl peroxide, which begins the process of polymerization (ACH Foam Technologies, 2015). The styrene droplets combine to form chains, which in turn combine into beads. These beads are the raw material of EPS, and are approximately 0.5mm to 1.3mm in diameter (Figure 3).

Figure 3. Raw EPS beads



To create a styrene monomer, the beads are heated with steam, and the softened plastic expands to approximately 40 times their original size as the pentane gas trapped in the plastic beads expands (Figure 4). The beads are then cured, using heat to do so (Truefoam, 2012). Once cured, the beads are then placed in a block-moulding machine, where steam is used to soften and expand the beads, which causes polymerization, fusing the beads together. The block moulding can take from five to 20 minutes, depending on the level of densification required. The moulded foam can be shaped in large rectangular blocks that are further processed by cutting with hot copper and nickel wires, melting the EPS on impact to produce standard sized sheets or custom-sized pieces.

Figure 4. EPS beads after expansion due to pentane gas.



2.3.2 XPS manufacturing process

Extruded polystyrene foam begins with solid polystyrene crystals (Diversifoam, undated). The crystals, along with special additives and a blowing agent, are fed into an extruder. Within the extruder the mixture is combined and melted, under controlled conditions of high temperature and pressure, into a viscous plastic fluid. The hot, thick liquid is then forced in a continuous process through a die. As it emerges from the die it expands to foam, is shaped, cooled, and trimmed to dimension. XPS is subject to higher compression than EPS during the manufacturing process, which makes XPS stronger and more rigid than EPS when first produced. Its process also allows XPS to maintain its thermal properties more uniformly than EPS.

2.4 Impacts of Polystyrene

2.4.1 Exposure to Polystyrene

Styrene is a clear, colourless liquid that is derived from petroleum and natural gas by-products, which also occurs naturally. Once airborne, styrene is quickly broken down, usually within one to two days (Canadian Council of Ministers for the Environment [CCME], 1999). Styrene monomer is widely used in the production of a range of products. Approximately five billion tonnes of styrene is produced in North America annually (Cohen et al., 2002). While the majority of styrene production in North America occurs in the United States (U.S.), Canadian domestic production exceeded 800 kilotonnes in 2006. The most common use of styrene monomer is the production of polystyrene, with approximately half of all Styrene production used for this purpose in the U.S. (Luderer et al., 2005).

Occupational exposure to styrene could occur during manufacture of the monomer, production of polystyrene or other styrene-based polymers, processing of styrene-based polymers, and manufacture of glass-reinforced plastics. Inhalation is the primary route of exposure, as styrene and styrene-based polymers or copolymers are generally manufactured using closed processes that limit potential exposure to the monomer (Miller, Newhook, & Poole, 1994).

According to the Canada Labour Code, as well as most provincial legislation, including Nova Scotia, the acceptable Occupational Exposure Limits (OEL) for styrene are 20 ppm (Carex Canada, 2015). Short Term Exposure Limits (STEL), for a maximum exposure period of 15 minutes, are 40 ppm. These limits are consistent with those stipulated by the ACGIH. The exposure limits are based upon the neurotoxicity, irritation, and central nervous system (CNS) effects of styrene (National Toxicology Program [NTP], 2006).

A number of studies have examined levels of exposure to styrene in the manufacturing industry (Miller, Newhook & Poole, 1994; Cohen et al., 2002; IARC, 2002; Pinchin Environmental, 2008). Researchers at Harvard University and the International Agency for Research on Cancer (IARC) independently reviewed a total of 10 exposure studies conducted between the 1960s through 1990s that reported air levels of styrene in styrene monomer, polymer, and copolymer manufacturing plants, many in the U.S. (Cohen et al., 2002; IARC, 2002). Mean air levels of styrene were reported at ≤ 35 ppm, with most values below 10 ppm. This was similar to results of studies by Miller and colleagues (1994) that found the styrene manufacturing industry having time-weighted average atmospheric concentrations less than 5 ppm, and Pinchin Environmental (2008) that found styrene in the air did not exceed the OEL. Cohen and colleagues (2001) and the IARC (2002) found that higher values were usually associated with older studies. Levels occasionally peaked at up to 50 ppm. Peaks were reported to occur during filling of drums or during occasional bursts or leakage from equipment. IARC reviewed three studies measuring air styrene levels in industries processing polystyrene, acrylonitrile butadiene styrene, and styrene-butadiene rubber polymers in the 1970s and 1980s; measurements were obtained in at least one US plant. With the exception of styrene levels of $17 - 285 \text{ mg/m}^3$ ($3.9 - 65.6$ ppm) measured in one US plant in the late 1970s, all other measurements were well below 1 ppm.

2.4.2 Health Risks

Styrene is considered to be carcinogenic to those working in the manufacturing of reinforced plastics and styrene-butadiene rubber (Kolstad, Juel, Olsen & Lynge, 1995; National Toxicology Program, 2014). Assessing the health impacts of exposure to styrene in the EPS manufacturing industry is a more complex process. Apart from occupational exposures, non-occupational exposure to styrene occurs in many ways, including through cigarette smoke, indoor and outdoor air, and food – both as an additive and contaminant (NTP, 2006). For example, cigarette smokers are exposed to approximately ten times more styrene than non-smokers on a daily basis. Studies of worker carcinogenicity in the styrene monomer and polystyrene manufacturing industries are also limited because of the low incidence of cancer cases among exposed workers. Co-exposure to benzene confounds this problem (NTP, 2014), as it has been identified as a human carcinogen (Duarte-Davidson, Courage, Rushton & Levy, 2001).

Despite these challenges, various studies have been conducted in recent decades to determine the toxicity and carcinogenicity of styrene (Cohen et al., 2002). Many studies have exposed rats and mice to levels exceeding OEL via inhalation. This method was used as humans are most exposed to styrene in this way. Research studies suggest sufficient evidence of carcinogenicity in animals (NTP, 2014). Cruzan et al. (2001) found that mice exposed to various levels of styrene developed malignant and benign lung tumours. Styrene is also toxic to the respiratory tracts of rodents, but these effects have not been discovered in humans (Cohen et al., 2002). A report by the WHO (2000) reported on a number of studies that had found higher than expected deaths from lymphomas and leukaemia in workers exposed to the polymerization of styrene. However, the NTP reported in 2014 that, given limited numbers of cancer cases in individuals working in the styrene monomer and polymer industries, conclusions could not be drawn about the impact of exposure to styrene on health in these industries.

Additionally, a number of neurotoxic, non-cancerous health risks of styrene exposure have been found in research (Kolstad, Juel, Olsen & Lynge, 1995). These include CNS and peripheral nervous system function impacts. High levels of occupational exposure (exceeding 100 ppm) can lead to CNS depression, the symptoms of which include

drowsiness, dizziness, headache, and balance disturbances. Colour vision problems have been observed where workers are exposed to styrene that exceeds the threshold limit value of 50 ppm (Cohen et al., 2002).

2.4.3 Drinking Water

The major sources of styrene in drinking water are discharged from rubber and plastic factories, and leached from landfills (USEPA, 2014). Exposure to styrene in drinking water at concentrations of 20 mg/L for 1 day or 2 mg/L for 10 days is not expected to cause any adverse effects in a child. Lifetime exposure to 0.1 mg/L styrene in drinking water is not expected to cause any adverse effects (CCME, 1999). Consumption of water containing styrene well in excess of the maximum contaminant level for many years produces a risk for liver, kidney, or circulatory system problems (USEPA, 2014).

2.4.4 Effects of Polystyrene on Food and Drink

Styrene is known to be present in packaged foods as it migrates from polystyrene food containers and packaging materials (United States Department of Health and Human Services, 2010). When EPS food containers are refrigerated or heated, there are higher risks of styrene contamination in food (Tawfik & Huyghebaert, 1998; Choi, Jitsunari, Asakawa & Lee, 2005). Research has found that styrene migration is more prevalent when liquid is heated than refrigerated (Tawfik & Huyghebaert, 1998). Foods with higher fat contents have also been found to absorb higher amounts of styrene, which will enter the muscle tissues and bloodstream.

2.4.5 Environmental Risks

Studies have revealed numerous counts of marine life interactions with discarded polystyrene. Polystyrene is a form of microplastic contributing to the pollution of marine habitats. The colour of polystyrene has been linked to the likelihood of ingestion by marine species (Wright, Thompson & Galloway, 2013). Studies have found that plastic debris, including polystyrene, that is either landfilled or not diverted from the landfill, is found in the marine environment (Carpenter, Anderson, Harvey, Miklas & Peck, 1972; Kartar, Abou-Seedo & Sainsbury, 1976; Derraik, 2002). As long ago as the 1970's, over 20% of certain fish species in the Bristol Channel, UK, were found to contain polystyrene beads (Kartar, Abou-Seedo & Sainsbury, 1976). Closer to home, 8 of 14 fish species in the New England coast

were found to contain polystyrene beads, and over 30% of certain species contained the beads (Carpenter et al., 1972). Microbeads in personal care products are a common current source of polystyrene in the marine environment (Environment Canada, 2015). Research by Obbard and colleagues (2014) suggests that polar sea ice is becoming a sink for microplastics, which may be released back into the environment as sea ice melts. While many studies have found evidence of adverse effects of microplastic ingestion (primarily from physical impacts such as blockages; Environment Canada, 2015), some studies have found no adverse effects of microplastics on marine species (e.g. Kaposi, Mos, Kelaher & Dworjanyn, 2014). There is ambiguity in unequivocally linking the ingesting of EPS beads by marine species to their mortality (Moore, 2008).

It is important to consider the life-cycle environmental impacts of EPS in comparison to similar products made of different materials. For example, corrugated cardboard and EPS are often used for similar purposes, such as food and drink containers and protective packaging. Comparing the environmental impacts of EPS and corrugated cardboard has not always been straightforward (Hocking, 1991). The generation, use, and subsequent disposal of EPS products inevitably contribute more to greenhouse gas emissions, water course acidification, and produce smog in comparison to the use of paper or cardboard for similar products (Zabaniotou & Kassidi, 2003). Polystyrene products emit higher levels of NO_x and SO_x than recycled paper products. However, this is somewhat offset by recycled paper producing more heavy metal and carcinogenic pollutants. These LCA impacts change as new technologies and processes are used.

2.5 EPS Landfill Diversion

2.5.1 Current Uses and Material Flow

EPS is currently being recycled into a broad assortment of products, including picture frames, coat hangers, seedling trays, cornices and mouldings, base boards, office supplies and fire-retardant materials. The major opportunities for selling blocks of recycled compressed EPS are in export markets, in particular in China and South Korea. Many products are made from recycled EPS in China, including decorative moulding, compact disc cases and photo frames (Cirko, 2008). Other methods of recycling EPS continue to emerge. For example, Waste-To-Waves collects EPS material to make new surfboard blanks. With 18

collection sites in California, special events and corporate partnerships with companies such as Patagonia and Rip Curl, this initiative provides a new product for recycled EPS (Waste-To-Waves, 2015). Nine Lives Products have a recycled glue product, Glu6, which is made from a blend of recycled EPS collected in the San Francisco Bay area and plant-based ingredients (EPS Industry Alliance, 2013).

2.5.2 Product Stewardship/Extended Producer Responsibility (EPR)

Product stewardship, in the case of solid waste management, is the process of managing the end-of-life process of a product. This is often the responsibility of the municipality or waste management facility, but can also be made the responsibility of manufacturers and retailers. There is evidence that the introduction of an environment recovery fee associated with the recycling of EPS would help improve landfill diversion rates. Financial incentives have been found to improve recycling rates, and therefore, increase the rate of landfill diversion (Yepsen, 2007).

The OECD defines EPR as the producer's responsibility beyond a product's life cycle, to the post-consumer stage (OECD, 2015). The two distinguishing features of EPR policies are the shifting of responsibility upstream away from the waste managers to the producer, and the provision of incentives for producers to include environmental considerations in the design of their products.

The Canada-wide Action Plan (CAP) for EPR reflects the 4R waste management hierarchy (discussed below; CCME, 2009). The CAP suggests that designated producers should be individually responsible for financing and operating a stewardship program for the end-of-life of products they produce or put on the market for sale. Further, the CAP states that Canadian jurisdictions agreed to implement operational EPR programs for products and materials, including packaging from the Industrial, Commercial, and Institutional (ICI) sector by 2015. Packaging materials make up a significant percentage of the polystyrene waste stream.

Nova Scotia is one of the few Canadian provinces without substantial EPR regulations in place, with programs already existing in Ontario, Manitoba, Quebec, British Columbia, and

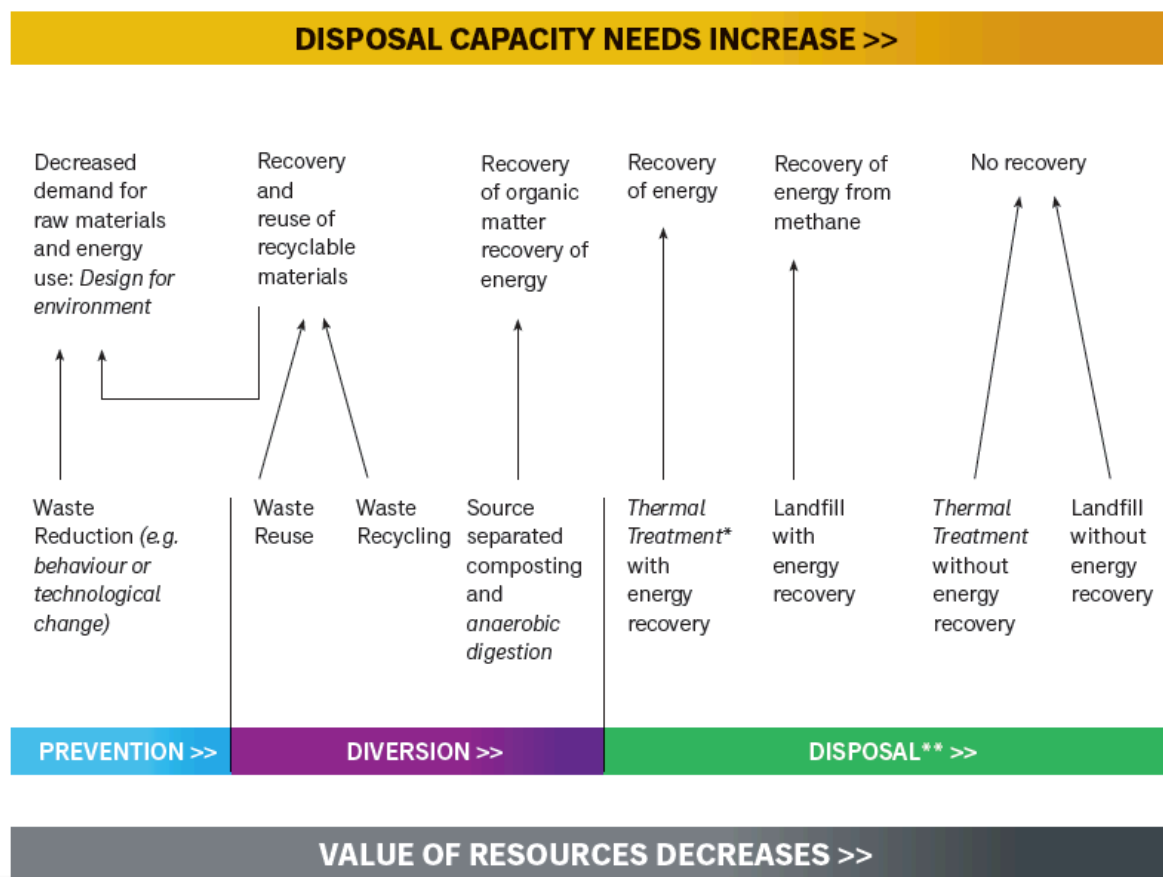
Saskatchewan (Government of Nova Scotia, 2015). This presents an opportunity for Nova Scotia to increase its solid waste diversion rate.

The Resource Recovery Fund Board (RRFB) has a mandate to ‘promote the development of value-added manufacturing’ (RRFB Nova Scotia, 2014). The recycling of EPS has the potential for economic benefits in the form of revenue creation from the processing of recycled EPS.

2.5.3 Waste Management Hierarchy

The current waste management hierarchy in Canada is known as the 4Rs - Reduce, Reuse, Recycle, and Recover (Figure 5). Reduce and Reuse are collectively also known as waste prevention. Recycle refers to waste diversion, and recover relates to the recovery of energy from a waste product.

Figure 5. Waste management hierarchy.



There are many examples of EPS waste management programs taking place in North America that align with different segments of the waste management hierarchy. A few examples are detailed below.

2.5.4 EPS Reduction

Laboratory-based EPS pilots have occurred at a number of universities in North America. The University of British Columbia (UBC) Vancouver and Okanagan campuses have both implemented an EPS reduction and recycling regime. The pilot at UBC, undertaken at the Vancouver campus, focused on the core research laboratories. The pilot recycled EPS on campus, and also collaborated with suppliers to find alternative packaging sources to EPS (University of British Columbia, undated). UBC waste management staff collect EPS from nine locations around the Vancouver campus every two weeks. A private recycling company transports the EPS off campus. The expanded polystyrene reduction and recycling pilot program at UBC aims to reduce EPS packaging through collaboration with suppliers to find alternatives. A similar EPS reduction and recycling pilot is taking place at Dalhousie University, and will be discussed in greater detail later in this report.

The use of EPS for disposable food and drink containers has been banned in many cities, towns, and counties across North America. This is more common in the U.S., particularly in California, where EPS is widely banned. One recent high profile EPS ban was announced in New York City (NYC) (City of New York, 2015), and commenced on 1 July 2015. The ban in NYC has since been overturned in a judgement handed down by the New York State Supreme Court in September 2015 (Mueller, 2015). Other major cities to have banned EPS include Washington D.C., Portland, Oregon, and Seattle, Washington.

2.5.5 EPS Diversion

As of October 2014, 45 Canadian municipal regions offered curbside EPS recycling. Additionally, there are approximately 40 depot programs around Canada (Magder, 2014). In most municipalities across Nova Scotia, all plastic containers and bags are accepted as recyclable material, aside from EPS (Davidson, 2011). However, in a survey conducted at Dalhousie University in 2010, the majority of students were unaware that EPS was not a recyclable product (Heathcote et al., 2010). The recyclability of EPS is increasing in Nova Scotia. In November 2014, Nova Scotia introduced its first municipal EPS curbside collection

program in the Annapolis Valley (Fairclough, 2014). The Valley Waste Resource Management waste management facility, based in Kentville, invested in EPS densification equipment to process the material onsite. In conjunction with Scotia Recycling, the machine is used to compress the material into dense plastic blocks (Fairclough, 2014). Colchester County has recently announced that it will be investing in an EPS densification machine, and commence recycling EPS in 2016 (Sullivan, 2015). Colchester County plans to collect EPS from the residential and ICI streams, including Dalhousie University's Agricultural Campus.

Some members of industry have taken a lead in the recycling of EPS. In 2007, London Drugs introduced a program to accept recycled EPS in their stores for recycling. In the first four years of the program's operation, London Drugs diverted more than 40 tonnes of EPS in western Canada (London Drugs, 2011). Similarly, Pacific Seafood has invested in a machine that breaks down the polystyrene to be made into other consumer products (Business Wire, 2009). In 2008, Pacific Seafood diverted approximately 275 tonnes of EPS program from landfill.

In Langley, BC, an EPS curbside collection pilot was conducted in 2012 (Entec Consulting Ltd, 2012). Langley has a single-stream collection of recyclables, and it was discovered that no extra garbage trucks were required for collection of EPS. The success of the pilot was converted into a regular 'blue-box' curbside collection program, currently operated by Emterra Environmental.

A depot dropoff program for EPS recycling was recently established in Montreal. An initial three-month trial was conducted in 2011, followed by another 12-month pilot 2013-14. Following the completion of the pilot, it was decided that the program would continue for at least five years. All material delivered to the depot is sent to a recycling facility for processing. The operators of the program are currently considering introducing a curbside collection program (Magder, 2014).

At the University of Wisconsin (UW), an EPS recycling program is in place across campus (University of Wisconsin, 2012a). Having established the UW-Boxable Team in 2012, they

have been successful in receiving grants of over \$100,000 to assist with their program. UW have 24 designated areas to drop-off EPS on campus, and most of the EPS is sent to Uniek, a local company who repurpose the foam into picture frames. UW have partnered with other universities, including Washington University in St. Louis, Missouri, to assist with their EPS recycling programs. In addition to EPS, UW also collects reusable freezer gel packs and packing peanuts. The freezer gel packs are taken to UW's Surplus With A Purpose, where they are sold to the public (University of Wisconsin, 2012b). UW have also found solutions for re-use of post-consumer EPS, and are working with local bio-technology companies to develop a reuse program for EPS shipping containers, wherein the boxes are reintroduced into the shipping marketplace.

2.5.6 EPS (Energy) Recovery

The fourth 'R', recovery, represents the waste-to-energy recovery possibilities for waste plastics that are destined for landfill (International Institute for Sustainable Development, 2013). A recent study by Gibson, Pegg and Asamany (2014) investigated the burning of plastics in high-temperature kilns to produce a fuel source. The use of the kilns in this study has been found to produce minimal air pollution. The study deduced that to supply the same amount of energy, a 30% lower mass of plastic is required in comparison to a coke-coal mixture. Pollutants, such as NO_x, CO₂ and SO₂, were also found to be lower from plastics burned in a kiln than the coke-coal mixture. Water vapour was found to be higher due to the burning of plastic. A recent German study suggests burning EPS at 900 to 1000 degrees Celsius for energy purposes creates combustion of toxic chemicals and pollutants (Mark et al., 2015).

Covanta Energy is a leader in the waste-to-energy industry in North America. With more than 40 facilities across the continent, there are two in Canada: one in British Columbia (BC) and another in Ontario (Covanta Energy, 2015a; Covanta Energy, 2015b). The plant in Burnaby, BC provides enough power for 20,000 homes, with 285,000 tonnes of waste (including plastic) providing 17,000 MWh of power (Covanta Energy, 2015c). EPS is one of the many plastic materials burned at the Covanta Energy plants.

2.5.7 Challenges to EPS recycling

Contamination of EPS is a major challenge preventing the recycling of EPS. Most processors of recycled EPS require that the product be clean. Contamination from other plastic products is a risk if EPS is recycled in a 'blue bag' program. In the case where EPS is recycled for food packaging, recycling bodies communicate with users that the EPS must be cleaned before it is included in the waste stream. In recent years, China has introduced stricter standards around the quality of recyclable products the country is importing. By building a "Green Fence", China has stemmed the importation of dirty bales of recycled material. This has created a major challenge in the recycling of EPS, and has also increased the costs of recycling (Earley, 2013).

2.6 Summary

EPS is a product with a wide range of uses. However, given its most common uses, it quickly becomes a waste product. There have been challenges associated with the implementation of programs to reduce the quantity of EPS in the waste stream across North America. Despite these challenges, diverting EPS is considered to be an option for reducing the amount of solid waste to landfill in Nova Scotia. This project will explore whether introducing EPS diversion may be an appropriate decision for Nova Scotia and Dalhousie University. The costs and benefits of recycling EPS by municipal curbside pickup compared to those associated with landfill disposal will be identified by analyzing data obtained from interviews and surveys conducted with EPS and solid waste experts. EPS reduction and recycling strategies for Dalhousie campuses will be highlighted by reflecting on the outcomes of an EPS diversion pilot project.

3.0 Methods

This study aims to provide decision makers, in the province of Nova Scotia and at Dalhousie University, with information related to the costs and benefits of EPS waste diversion options. The limited data relating to landfill and recycling costs for EPS in Nova Scotia has highlighted the need for further original research. Data from a broad literature scan has been used in conjunction with original data collection from interviews and a survey. Interviews were conducted with participants who work in the plastics industry, as well as people who work in municipal waste management facilities, and Dalhousie staff who are

involved in the EPS pilot (see Appendix A). An online survey was used to collect data from municipal recycling and landfill operators (see Appendix B). Onsite audits and EPS pilot information at Dalhousie were used to assess the costs and benefits of targeted EPS diversion on campus.

3.1 Provincial EPS recycling versus landfill comparison

3.1.1 Interview and Survey Recruitment

A total of six individuals (experts in EPS and solid waste management from across Canada) formed an Advisory Group for the project. Advisory Group members were individuals who possessed a high level of knowledge in solid waste management, including the recycling of plastics. A total of 13 individuals took part in an interview, while five individuals completed an online survey. It is important to note that there was overlap between Advisory Group members and those who completed interviews or surveys. Four members of the Advisory Group were participants in the research. Two interview participants also completed an online survey. Ethics approval to conduct interviews was obtained from the Research Ethics Officer of Faculty of Management at Dalhousie University (Appendix C).

Recruitment emails were sent to a pre-determined list of individuals for participation in either an interview or an online survey. Participants were chosen on the basis of their level of knowledge regarding solid waste management. Dates and locations were organized for interviewees, while online survey participants were emailed a link to the survey.

Participants were interviewed in person (at Dalhousie University or at the work site of the interviewee) or over Skype using questions specifically designed for the constructed AHP (Appendix A). Interviews lasted between 15 and 60 minutes. Participants in the online survey were sent regular reminders via email to complete the survey leading up to the closing date.

3.1.2 Data Analysis

A number of factors (e.g., cost, job creation) were considered to be important in deciding whether EPS diversion was appropriate for the province of Nova Scotia. Multi-criteria decision analysis (MCDA) tools assist in structuring and solving problems that involve multiple criterion important to the decision making process. A number of MCDA tools were

considered for the purpose of the project including Elimination and Choice Expressing Reality (ELECTRE), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Simple Multi-Attribute Rating Technique (SMART), and Multi-attribute utility theory (MAUT). Analytic Hierarchy Process (AHP) was ultimately chosen for use for this study, as it allows for the use of both qualitative and quantitative data. AHP is a relatively straightforward tool in comparison to many other decision-making analysis tools that rely heavily on the use of statistics and formulae.

AHP can be used to aid decision-making involving a finite number of alternatives (Brunelli, 2015). The evaluation of each alternative is conducted with respect to an overall goal. The AHP decision-making process is graphically represented in a hierarchical structure, consisting of the goal, the criteria (and, if relevant, sub-criteria) considered important in meeting the goal, and the alternatives (Saaty, 2008). A weighted arithmetic mean (also called an eigenvalue) based on the relative importance of each criterion and subcriterion is incorporated into the AHP. AHP has been previously used in studies relating to municipal solid waste management where multiple stakeholders have been involved (Soltani et al., 2015), and in cases in which both qualitative and quantitative data were collected.

A number of steps are required to complete data analysis utilizing AHP (Table 1). After deciding on a research question (in this instance, what is the preferred method of EPS waste management – Table 1, step 1), criteria were selected with which to answer this question (Table 1, step 2). In this instance, the criteria were chosen based on literature review, review of existing EPS recycling programs, and consultation with the Advisory Group. Subcriteria were then created (Table 1, step 3).

The next stage in AHP involves assigning weights to each criterion and subcriterion (Table 1, step 4). Pairwise comparisons of the relative importance of each criterion were undertaken. The lead researcher made decisions regarding relative importance of each criterion based on information obtained from the Advisory Group, the literature review and the RRFB mandate. Each criterion was compared to each other and it was determined whether each criterion was equally important, slightly, moderately or strongly more important using the fundamental scale of absolute numbers described by Saaty (Table 2). Detailed information

regarding the decision making process for assigning weights to each criterion and subcriterion in this project can be found in Appendix D.

Table 1
The steps in the AHP method.

Step Number	Step Name	Data and Process
1	Create Alternatives	The Research Team selected the alternatives, namely the recycling of EPS or landfilling of EPS.
2	Create Criteria	Criteria was chosen by the Research Team . The criteria chosen were discussed with the Advisory Group , as well as compared to the Literature Review findings .
3	Create Sub-criteria	Sub-criteria was chosen by the Research Team and reviewed with the Advisory Group . The sub-criteria was chosen based on these being the largest stages in the solid waste recycling process.
4	Assign Weights	Pairwise comparisons are undertaken, so that each criterion is independently compared with each other criterion in turn to determine the relative importance of each criterion. Decisions were made based on information from the Advisory Group and Literature Review . This process resulted in the assignation of weights to each criteria. The same process is completed for each subcriterion.
5	Analyze Data	Using Interview and Online Survey data , as well as information obtained from the Literature Review , pairwise comparisons between the recycling of EPS and landfilling of EPS were undertaken at each subcriterion.
6	Compare Results	The eigenvalue related to each comparison for both recycling and landfilling EPS was summed. The alternative with the highest summed value is considered to be the more appropriate solution.

Table 2

The fundamental scale of absolute numbers. Adapted from Saaty (2008).

Intensity of Importance	Definition
1	Equal importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong importance
8	Very, very strong
9	Extreme importance
Inverse of above (x)	In the corresponding cell of the pairwise comparison, a fraction is recorded i.e. 1/x

Microsoft Excel software was programmed with formulae to produce a weighting for each criterion. The formula programmed into Excel involved several steps. First, the number of fundamental importance for each criteria was divided by the sum of the fundamental importance for that column (that is, the rating for cost vs cost was divided by the sum of cost vs cost, cost vs diversion rate, cost vs social/health, cost vs GHG emissions, and cost vs job creation; Table 4). Once this process was completed for the criteria, the same procedure was undertaken for the subcriteria below each criterion.

The same pairwise comparison process was undertaken to analyse the data (Table 1, step 5). Using the information obtained from the interviews and the online survey, as well as information obtained from the literature review, comparisons between the recycling of EPS and landfilling of EPS were undertaken at each subcriterion. Once again, the fundamental scale of absolute numbers (see Table 2) was used to measure the degree to which either alternative was preferable for that subcriterion. The same process outlined above was undertaken to create eigenvalues for the alternatives at each subcriterion. The eigenvalue related to each comparison for both recycling and landfilling EPS was summed (Table 1, step 6). The alternative with the largest sum of eigenvalues is considered to be the outcome most in line with the priorities of the decision makers.

Table 3
Table depicting the creation of weights for each criterion.

	Cost	Diversion Rates	Social/ Health	GHG Emissions	Job Creation	Total	Weight
Cost	0.28	0.29	0.23	0.29	0.28	1.37	0.27
Diversion Rates	0.28	0.29	0.27	0.29	0.28	1.42	0.28
Social/ Health	0.06	0.05	0.05	0.02	0.06	0.23	0.05
GHG Emissions	0.09	0.10	0.23	0.10	0.09	0.61	0.12
Job Creation	0.28	0.29	0.23	0.29	0.28	1.37	0.27

3.2 EPS Diversion at Dalhousie University

For the Dalhousie pilot, a number of data collection methods were used including auditing the material brought back from the pilot building (Tupper Building) for volume, weight and contamination and meeting with staff to understand limitations and opportunities.

At Dalhousie University, the use of EPS for food service offerings has been eliminated on campus for a number of years. The University is aiming to extend their current level of EPS reduction and recycling. From 1 June 2015 until 30 September 2015, Dalhousie University engaged in an EPS recycling pilot. This pilot involved the cooperation and coordination of many stakeholders across campus. To build on the work of the Green Labs study (Miller, 2014), all EPS from the laboratories in the Tupper Medical Building were recycled for the period of the pilot. Bins were placed on 15 of the 17 floors in the building (the foyer and 2nd floor were excluded). Each of the bins was positioned next to the freight elevator. Lab staff and managers were responsible for taking the EPS from the lab to the bins. Before the EPS was taken to the bins, it was expected that lab staff and managers remove all stickers and labeling from the EPS. Compliance to the removal of stickers and labeling (contamination) was monitored in the pilot. Members of the custodial staff were responsible for taking the

EPS from each of the bins down to the basement, where the EPS was put in clear bags in the recycling room. Once the recycling room was full, staff from Tupper Receiving connected with Grounds staff. Bags were transferred to the warehouse, which was located approximately 1.6 km away, as the reusable bags provided by Truefoam (EPS manufacturer) were too large for the small recycling room that holds other streams of recyclables, including paper and compost. Up to six bags were be stored in the warehouse depending on adequate storage space, and remained until they were ready to be delivered to the EPS recycling facility. This recycling took place at Truefoam, which is based in the Burnside Industrial Park, approximately 11km from the warehouse. Truefoam have an EPS densification machine at their warehouse, and the EPS sent from Dalhousie University is placed in this machine. The material is transformed into condensed blocks of the original product, and these blocks are sent in a shipping container to China.

3.2.1 EPS Diversion Audit

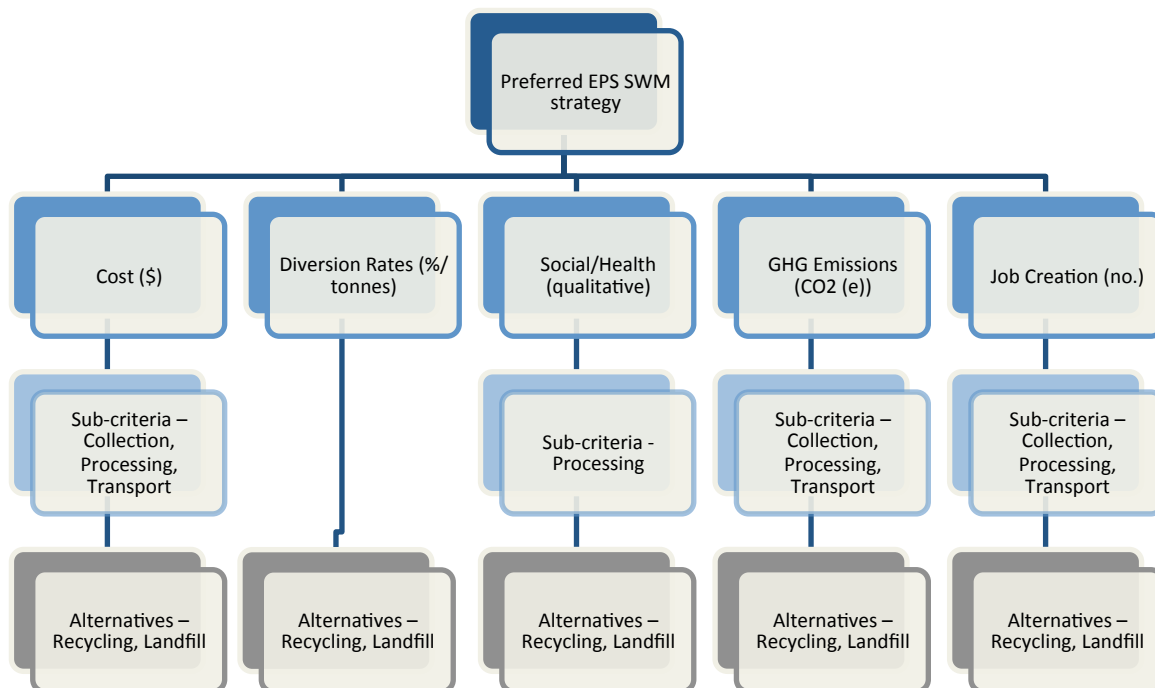
During the period of the pilot, five audits were conducted to measure the adherence to procedures by laboratory employees, Custodial staff, and Facilities Management staff. EPS was tested to measure its weight, volume and levels of contamination. Contamination of EPS was defined as EPS that had objects attached to the material, and therefore could not be recycled. The most common forms of contamination were stickers and packing tape. The time taken to audit all of the material and decontaminate EPS were also recorded. EPS was separated in three different groups: laboratory boxes without lids, laboratory box lids, and all other EPS. These categories were chosen because the most common form of EPS coming from the Tupper Building were laboratory boxes, and the separation of lids and boxes was made to determine which had a higher incidence of contamination. All other EPS included larger pieces of EPS used for packaging materials, and smaller pieces used for storing biomedical goods.

4.0 Results

4.1 Provincial EPS Recycling Versus Landfill Comparison

The decision making criteria selected included cost (in Canadian dollars), waste diversion rates (either in tonnes or as a percentage), social and health impacts (qualitative data), greenhouse gas (GHG) emissions (CO₂e) and job creation (in number of jobs). Subcriteria in this study included consideration of cost, GHG emissions, and job creation at the collection, processing and transportation stages. The final detailed structure of the AHP is presented in Figure 6.

Figure 6. AHP structure used for provincial analysis of recycling versus landfilling EPS



The values resulting from the comparisons between each criteria were inputted into a matrix in Microsoft Excel software (Table 4). Computations as described above in Methods were undertaken to create an eigenvalue, also known as a weight, for each criteria. Table 3 depicts the creation of weights for each criterion. As noted in Methods, similar computations were undertaken for each subcriterion. Tables 5, 6 and 7 depict the creation of weights for each subcriterion.

Table 4

Matrix comparing importance of criteria for this project; comparisons are from left to right.

	Cost	Diversion Rates	Social/Health	GHG Emissions	Job Creation
Cost	1.00	1.00	5.00	3.00	1.00
Diversion Rates	1.00	1.00	6.00	3.00	1.00
Social/Health	0.20	0.17	1.00	0.20	0.20
GHG Emissions	0.33	0.33	5.00	1.00	0.33
Job Creation	1.00	1.00	5.00	3.00	1.00

After comparing each alternative (landfilling vs recycling EPS) at each subcriterion, the resulting eigenvalues were summed. For detailed information regarding the decision making process for assigning weights to the alternatives at each subcriterion, see Appendix E. The summed eigenvalue for landfilling EPS was 0.4045, while the summed eigenvalue for recycling EPS was 0.5954, suggesting that recycling EPS is the preferred waste management strategy based on the selected criterion and subcriterion and the data obtained (Table 8).

Table 5

Table depicting the creation of weights for Cost subcriterion.

	Collection	Processing	Transport	Total	Weight	Weight as proportion of Cost weight
Collection	0.63	0.75	0.43	1.81	0.60	0.17
Processing	0.16	0.19	0.43	0.77	0.26	0.07
Transport	0.21	0.06	0.14	0.23	0.14	0.04

Table 6

Table depicting the creation of weights for GHG Emissions subcriterion.

	Collection	Processing	Transport	Total	Weight	Weight as proportion of GHG Emissions weight
Collection	0.43	0.43	0.43	1.29	0.43	0.05
Processing	0.43	0.43	0.43	1.29	0.43	0.05
Transport	0.14	0.14	0.14	0.43	0.14	0.02

Table 7

Table depicting the creation of weights for Job Creation subcriterion.

	Collection	Processing	Transport	Total	Weight	Weight as proportion of Job Creation weight
Collection	0.16	0.15	0.47	0.79	0.26	0.07
Processing	0.82	0.76	0.47	2.05	0.68	0.19
Transport	0.02	0.08	0.05	0.16	0.05	0.01

Table 8

Table depicting the eigenvalues for each alternative at each subcriterion.

	Landfill	Recycling
Cost / Collection	0.1243	0.0414
Cost / Processing	0.0260	0.0089
Cost / Transport	0.0286	0.0095
Diversion Rate / -	0.0284	0.2553
Social and Health Cost / Processing	0.0113	0.0339
GHG Emissions / Collection	0.0435	0.0087
GHG Emissions / Processing	0.0457	0.0065
GHG Emissions / Transport	0.0145	0.0029
Job Creation / Collection	0.0181	0.0542
Job Creation / Processing	0.0235	0.1646
Job Creation / Transport	0.0047	0.0095
Summed total of eigenvalues	0.4045	0.5954

4.1.1 Themes of Interviews and Surveys

4.1.1.1 EPS Reduction

A number of common themes emerged from the interviews and surveys. Given that EPS is used widely, recycling of EPS was most commonly described as one of the methods to reduce EPS in the waste stream. Reduction in the use of EPS was also provided as a solution. Dalhousie University staff stated that it was important to be, “Reducing how much (EPS) comes on to campus to begin with. Part of the purchasing process should include a procurement deal with suppliers who agree to take away packaging once delivering a product” (M. Wilkinson, personal communication, July 29, 2015). A local solid waste consultant, highlighted that, “There should be a reduction in how much EPS is used in the first place. But industry almost always goes for the cheapest option, and EPS is a cheap form of protective packaging” (D. Hickman, personal communication, July 31, 2015). Innovations from industry through research, or the use of alternate products to EPS were also suggested as ways in which reduction could be achieved.

4.1.1.2 Landfill Diversion

The most common responses given as benefits for recycling EPS were landfill diversion and reducing landfill costs, and the conservation of resources and raw materials. One solid waste facility employee claimed that recycling EPS “saves space in the landfill,” which a municipal employee highlighted as important, as, “Any landfill survives on its airspace” (B. Forest, personal communication, August 12, 2015).

4.1.1.3 Job Creation

A local solid waste consultant highlighted job creation as a benefit of recycling EPS, noting, “Jobs are created and resources are conserved by recycling strategies” (D. Hickman, personal communication, July 31, 2015).

4.1.1.4 Environmental Benefits

Interviewees in the EPS and plastics industries highlighted further benefits of recycling EPS, in that it, “Reduc[ed the] use of virgin materials and GHG [emissions]” (K. Friesen, personal communication, August 13, 2015) as recycling made it possible to “Reuse the materials within the product” (B. Rowlings, personal communication, July 30, 2015).

4.1.1.5 Health Risks

Questions regarding the health risks during the manufacture of EPS brought about no particular themes. An individual from the EPS recycling industry stated, “I think it’s a low-risk industrial activity or process. It’s loud, but hearing protection is worn” (B. Rowlings, personal communication, July 30, 2015). Other possible health risk considerations mentioned by interviewees were dust, off-gases, particles, and fire risk. One interviewee was aware of the research linking styrene to cancer.

4.1.1.6 Other Themes

In addition to the above themes, interviewees highlighted the importance of education, policies such as EPR, the location of end markets, and the positive aspects of EPS.

Education was mentioned both in terms of recycling and preventing EPS from entering the waste stream. Members of the plastics industry were united on this front, stating, “EPS is not a bad product as many people believe...” (K. Jensen, personal communication, August 6, 2015) and that, “Education by informing the public that EPS is recyclable is needed” (K. Friesen, personal communication, August 13, 2015).

Government intervention in the form of policy and regulation, such as EPR legislation was another common suggestion, as evidenced in this statement from a municipal interviewee: “I would like to see there be some policy mechanism from the provincial authorities that would encourage the manufacturers and distributors of this packaging move into those areas of reduction away from polystyrene” (L. Lewis, personal communication, August 6, 2015). EPR was discussed as a policy mechanism by which EPS could be much more widely recycled. One municipal employee stated, “EPR for packaging and paper would change the discussion regarding the densifying of EPS onsite in Guysborough... If EPR for printing and packaging exists in a full-model, the cost of transporting it from Guysborough to Colchester would be paid by the industry body” (N. Haverkort, personal communication, August 14, 2015). A government member noted that, “Until EPR is introduced in NS, I’m unsure if Halifax will add EPS to their recyclables” (B. Kenney, personal communication, August 13, 2015).

The major location of end markets has been determined to exist in China. The largest company in the recycled EPS market, Intco, is known to guarantee a market for recycled EPS. In return, Intco provide an EPS densification machine, which has occurred in one region in Nova Scotia (A. Garrett, personal communication, July 31, 2015).

In addition to the qualitative themes of this report, there were also some consistencies in quantitative data provided, such as the weight of shipments. One interviewee stated that 450kg of EPS would fit on a pallet (A. Garrett, personal communication, July 31, 2015), while another supported this by saying that a shipped pallet of EPS would carry 1,000 pounds of the material (B. Rowlings, personal communication, July 30, 2015).

4.1.1.7 Barriers to Recycling EPS

Barriers to recycling EPS were raised on a number of fronts. One Nova Scotia government employee highlighted a barrier issue, stating that one “barrier has always been high volume and low weight” (B. Kenney, personal communication, August 13, 2015). This was echoed by another interviewee, who noted, “EPS is very light and very voluminous, it has a huge volume to weight ratio” (D. Hickman, personal communication, July 31, 2015). The market demand for high quality EPS that is clean was also discussed in interviews. Individuals involved in EPS recycling noted that, “Contamination, such as food, is a barrier,” (B. Rowlings, personal communication, July 30, 2015) and that, “Meat trays are the biggest problem for contamination” (A. Garrett, personal communication, July 31, 2015).

The profitability of recycling EPS, including the cost of implementation was raised as a barrier of concern by some interviewees. A local municipal employee observed that, “Halifax would expect to need to invest in extra trucks for the recycling of EPS. Who is going to pay for this implementation?” (L. Lewis, personal communication, August 6, 2015). Further to the point of implementation costs, storage space is an initial investment that is required for EPS recycling to be implemented to its optimal capacity. Valley Waste Resource Management were unable to receive funding for storage of EPS post-densification, as it is not within RRFB’s mandate to cover a storage facility. “Any MRF (Materials Recovery Facility) or municipality that sets up an EPS recycling program needs ample storage. This

should be covered through funding programs from RRFB, and the recycling programs they provide funding to” (A. Garrett, personal communication, July 31, 2015).

The question of sustainable end markets for recyclables was also raised as a barrier in the interviews. One interviewee noted that, “We don’t want to see EPS end up in landfill at end markets because the recyclable end market is not sustainable” (L. Lewis, personal communication, August 6, 2015). The possibility of EPS being designated for depot collection was observed as a potential barrier, with one municipal employee noting that “Collecting curbside is better than depots, as the public in our area is becoming tired of taking recyclables to depots” (N. Haverkort, personal communication, August 14, 2015).

Despite these barriers, there was acknowledgement that recycling EPS was important, with one municipal employee stating, “Recycling EPS will probably cost us money, but it is the right thing to do” (B. Avery, personal communication, August 14, 2015).

The selling price of recycled EPS is also a challenge. Since the rapid growth market commenced in recent years, there have large variances in sales prices. There is no simple reasoning for price fluctuations, but there have been possible reasons put forth, such as supply and demand, and economic downturn in the buyer market. Foreign exchange rates could also be a factor. Sales prices are highest for clean, white EPS. These prices have been as high as \$600/tonne, but are currently closer to \$300/tonne. Coloured foam, such as Styrofoam™, can sell for below \$100/tonne.

4.1.1.8 Overcoming Barriers

Interviewees were asked how the contamination of EPS could be prevented. The most common suggestion was the introduction of regulations and guidelines from government and industry that improve the labelling of EPS. The solid waste consultant stated, “A policy could be developed across Canada for protective packaging, which could be led by Canadian Council of Ministers of the Environment. This can help with the prevention of contamination” (D. Hickman, personal communication, July 31, 2015). A similar solution was provided by another interviewee, who noted, “A national policy or legislation would help with the issue of contamination. The Food & Consumer Products of Canada and Retail

Council of Canada should be engaged in this process” (B. Kenney, personal communication, August 13, 2015). One industry member hypothesized that education regarding contamination as a barrier to recycling could be beneficial, stating, “If users know it needs to be pristine and will be recycled, then this could prevent contamination” (B. Rowlings, personal communication, July 30, 2015).

When discussing suggestions for decreasing EPS volumes, densification was by far the most common response. One interviewee noted that, “Densification of EPS and reduction of its volume should take place as early in the process as possible, as it is such a low weight product for its volume.” (A. Garrett, personal communication, July 31, 2015).

4.2 EPS Diversion at Dalhousie

The pilot study and audits have found that one cubic metre of EPS can weigh approximately 10 kilograms. It is important to note that the measurement of cubic metres has not been determined in a compacted form. However, there is a relatively high variance in the weight of a cubic metre of EPS dependent on the type of EPS being audited. Approximately 198 kilograms of EPS was produced from the Tupper Building during the four-month pilot study, which was measured at approximately 26 cubic metres in volume. It was found that lids and other packaging materials had lower weight to density ratio when compared to laboratory boxes. This is why the overall weight of audited EPS is well below 10 kilograms per cubic metre (approximately 7.5kg/m³). EPS contamination was highest for laboratory boxes (17.4%), followed by laboratory box lids (13.6%). Contamination of other packaging was by far the lowest (4.1%).

5.0 Limitations

There are some limitations to this study. The interviewees represented people involved in plastics manufacturing, industry associations, and municipal, provincial, non-profit and university staff involved in solid waste. There were no health experts interviewed, and while health risks have been highlighted from the literature, new information may have been identified if health experts had been consulted.

This study focuses on the Nova Scotia context. Results could vary if a similar study were conducted in another province of Canada, or in another country. Considerations in implementing a solid waste management program may differ based on a number of factors relevant to a geographical location.

It has been challenging to ascertain current levels of EPS in the waste stream in Nova Scotia. Current levels of academic and grey literature on the subject of EPS in the waste stream are limited.

Limitations of this study also centred around financial aspects of EPS recycling. The cost of implementing an EPS recycling program, including the purchase of machinery and other infrastructure, can vary. Cheaper machines can be purchased for \$30,000, while some larger machines can cost well in excess of \$100,000. The infrastructure within a MRF can influence the cost of implementation. In addition to machinery, infrastructure such as access to connect to an electricity network can potentially add to the cost of implementation. The volume of EPS in Nova Scotia will influence the type of EPS densification machinery required. With a greater knowledge of EPS volumes in Nova Scotia, more informed decisions about the costs of implementation could be made.

This study also had difficulty determining the cost of shipping EPS. One source provided an estimated cost of \$5,000 to ship a 40,000-pound container. The cost of shipping EPS requires further research so that the costs of operating an EPS recycling program are more fully understood.

Determining the weight and volume of EPS in Nova Scotia landfills was a challenge. In response to the survey by Halifax Regional Municipality, a 2008/2009 waste characterization study conducted by the municipality revealed that 1.3% of residential waste and 1.6% of ICI material waste comprised of polystyrene material. This percentage is measured by weight, and is consistent with other data, which suggests that EPS is between 1% and 2% of all waste by weight.

Finally, sale prices of EPS are known to vary, depending on the quality of the material. Sale prices for EPS are not readily available, and the reasons for these fluctuations are not easily identifiable. Obtaining a definitive market price for post-consumer EPS needs extensive research for there to be a guarantee of financial benefits from selling recycled EPS.

6.0 Recommendations

6.1 Provincial EPS Recycling Versus Landfill Comparison

This research provides evidence that the recycling of EPS in Nova Scotia could be beneficial. On the basis of the research, we recommend the implementation of an EPS recycling program throughout Nova Scotia, provided that certain conditions are met. The following recommendations would assist with the success of an EPS recycling program in Nova Scotia.

There were concerns raised about the existence of long-term sustainable end-markets by some interviewees. Other interviewees explained that the major market for recyclable EPS (China) has a major supplier (Intco) that guarantees a market for any MRF who decides to purchase a densification machine from them. It is recommended that, should Nova Scotia decide to implement an EPS diversion program, options for local EPS recycling markets be explored in greater detail.

A number of interviewees observed that funding for machinery and storage space were significant barriers to implementing an EPS recycling program. If Nova Scotia is to implement an EPS recycling program, it is recommended that funding for infrastructure (e.g. buildings, storage space) and if required, new recycling trucks is provided, in addition to funding for machinery.

While conclusive evidence regarding the harmfulness (or lack thereof) of recycling EPS does not currently exist, it is recommended that adequate ventilation systems be placed in MRFs if EPS recycling is implemented in Nova Scotia.

Finally, the importance of education regarding the recyclability of EPS and the costs of contamination of this material was highlighted. If Nova Scotia implements an EPS recycling

program, it will be important for the general public to be provided with information about examples of products made of EPS and the requirements for EPS to be accepted for recyclable product (e.g. cleanliness).

6.2 Dalhousie University EPS Diversion Pilot Recommendations

Education is important to reduce contamination rates. Regular communication with Tupper Building laboratory staff that are not adhering with the procedure is necessary to effect change in reducing contamination rates.

Storage space for EPS at the warehouse is important to the success of EPS recycling on a wider scale at Dalhousie. During the pilot study, storage space was limited, meaning trips to Truefoam were required before trucks were filled to capacity. A truck has the ability to hold up to 10 full mesh bags of EPS, compared to six that were transported during the study. Having greater storage space at the warehouse will allow for a truck to be filled to capacity when transporting EPS to Truefoam. This will cut down on the time spent by Facilities Management staff travelling to Truefoam, as well as the frequency of trips required. In turn, this will save on labour costs for the transporting of EPS, as well as the fuel and vehicle costs incurred by Dalhousie. Greater storage space will also limit the emission of GHGs by Dalhousie from the transporting of EPS to Truefoam.

7.0 Conclusion

The Nova Scotia government has set a number of solid waste diversion targets, and have yet to meet their target of 300kg disposal per person per year. As solid waste diversion has stagnated in recent years, finding new avenues for solid waste diversion is a priority. This project explored the potential costs and benefits of an EPS diversion program, both in the province of Nova Scotia and at Dalhousie University.

The results of this project demonstrated that diverting EPS from the solid waste stream could be beneficial. Almost 200kg of EPS was diverted from the Tupper Building during the four-month pilot project at Dalhousie University. Information obtained from literature review, experts and stakeholders suggest that the benefits of commencing an EPS recycling program in Nova Scotia outweigh the costs.

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9.0 Appendices

Appendix A. Interview script and questions

Interview Script – AHP stakeholders

Good morning/afternoon, my name is Dirk Xanthos and I am completing a Master of Resource and Environmental Management at Dalhousie University. With funding from the Resource Recovery Fund Board and support from the Office of Sustainability, I am completing a study titled *Examining the Potential for Expanded Polystyrene Diversion in Nova Scotia*.

The Nova Scotia government is committed to reducing annual solid waste disposal to a rate of 300 kg per capita; the rate of solid waste generation has reduced from 378 kg per capita in 2008, to 373 kg per capita in 2013. Progress toward this goal is a major challenge for the Nova Scotia government, but there are many opportunities available to work towards this goal. One such opportunity is to divert expanded polystyrene from the landfill. This research has been designed to outline costs and benefits of reduction and recycling versus landfilling expanded polystyrene waste for Nova Scotia.

The objective of this interview is to provide insight into the quantitative and qualitative factors that are to be considered when determining the preferred method of managing expanded polystyrene waste.

With your permission, I will record the session and the recording will only be accessible to my research supervisor and I. Notes and recordings from this session will be stored in a secure location at Dalhousie until December 2015, at which point all documents will be destroyed. If any question makes you feel uncomfortable, please let me know and we can move on to the next topic.

Interview Questions (see below)

Closing

That brings us to the end of our interview. Thank you so much for your time and contributions to this study. The recording from this meeting will be analyzed and will contribute to the preparation of a final report and presentation.

I would just like to reiterate that all information shared today is confidential. As noted in the consent form, if a direct quote is to be included in any report or presentation, you will first be contacted for consent and will have until October 1st, 2015 to review the inclusion. If you wish to remain anonymous, or do not provide written consent, the information will be paraphrased and not directly cited, or a pseudonym will be used in place of your name. If you have any questions please do not hesitate to contact me directly; my contact details are included in the consent form. Alternatively, please feel free to reach out to the Dalhousie Research Ethics Office.

Interview Script – EPS Pilot Dalhousie staff

Good morning/afternoon, my name is Dirk Xanthos and I am completing a Master of Resource and Environmental Management at Dalhousie University. With funding from the Resource Recovery Fund Board and support from the Office of Sustainability, I am completing a study titled *Examining the Potential for Expanded Polystyrene Diversion in Nova Scotia*.

The Nova Scotia government is committed to reducing annual solid waste disposal to a rate of 300 kg per capita; the rate of solid waste generation has reduced from 378 kg per capita in 2008, to 373 kg per capita in 2013. Progress toward this goal is a major challenge for the Nova Scotia government, but there are many opportunities available to work towards this goal. One such opportunity is to divert expanded polystyrene from the landfill. This research has been designed to outline costs and benefits of reduction and recycling versus landfilling expanded polystyrene waste for Nova Scotia.

The objective of this interview is to provide insight into the quantitative and qualitative factors that are to be considered when determining the preferred method of managing expanded polystyrene waste.

With your permission, I will record the session and the recording will only be accessible to my research supervisor and I. Notes and recordings from this session will be stored in a secure location at Dalhousie until December 2015, at which point all documents will be destroyed. If any question makes you feel uncomfortable, please let me know and we can move on to the next topic.

Interview Questions (see below)

Closing

That brings us to the end of our interview. Thank you so much for your time and contributions to this study. The recording from this meeting will be analyzed and will contribute to the preparation of a final report and presentation.

I would just like to reiterate that all information shared today is confidential. If a direct quote is to be included in any report or presentation, you will first be contacted for consent and will have until October 1st, 2015 to review the inclusion. If you wish to remain anonymous, or do not provide written consent, the information will be paraphrased and not directly cited, or a pseudonym will be used in place of your name. If you have any questions please do not hesitate to contact me directly; my contact details are included at the top of the consent form. Alternatively, please feel free to reach out to the Dalhousie Research Ethics Office.

Interview Questions

EPS is a lightweight, high-volume and low-density form of foamed polystyrene used to produce a variety of products. Some of the major EPS products used in Nova Scotia include fish boxes, food packaging, protective packaging (ex. electronics), building insulation, and laboratory boxes.

General questions (to be asked of all participants)

1. Do you have ideas on how to reduce EPS in the waste stream? If so, what are some strategy examples?
2. Do you think there are the benefits of recycling EPS versus landfilling? If so, please provide examples.
3. What do you think are the barriers to EPS curbside recycling?
4. Contaminated EPS is not able to be recycled and can cause damage to EPS densification machines. Contaminated EPS is defined as that which has other objects attached to it, such as tape, stickers, plastic, paper and dirt. Do you have any suggestions as to how contaminated EPS can be prevented, or how packaging labels can be improved?
5. Do you anticipate health risks associated with compacting EPS in recycling facility? If so, what might be some of the risks?
6. EPS is light in weight, yet bulky in size and volume. This causes it to take up a lot of space for storage and transportation. Would you have any suggestions for how to decrease the volume of EPS?
7. Do you have additional comments (concerns/support) regarding the implementation of EPS curbside recycling in Nova Scotia?

Dalhousie Facilities Management interview questions

From 1st June to 30th September 2015, an EPS recycling pilot project has been established in the Tupper Medical Building. All boxes coming from the laboratories in the building are being transported to the warehouse on campus, and then to the nearest EPS recycling facility at Truefoam, in the Burnside Industrial Park. The pilot is measuring the volume and weight of EPS coming from the building, and the time taken to handle and transport EPS at Dalhousie is also being monitored. The carrying capacity of the transport truck is being tracked, as well as the greenhouse gas emissions to transport EPS.

1. What costs are incurred from the recycling of EPS at Dalhousie through the Tupper pilot project?
2. If EPS was recycled more broadly at Dalhousie, what strategies would you recommend to maximize recycling diversion across all four campuses?
3. In your opinion, do you think the university receives enough EPS to make investment in onsite machinery useful (ex. chipper to reduce volume)? If so, what onsite machinery or equipment would you like to see explored in more detail?
4. Do you think having an option to have EPS be incorporated into the blue bag recyclables is more effective than a drop-off system to a depot?
5. Do you have additional comments (concern/support) for EPS recycling on campus?

Industry specific questions.

1. What are the approximate costs of purchasing and installing a densifier?
2. What is the average selling price per tonne of recycled EPS?
3. Is most densified EPS shipped on a pallet, loose or in other ways?
4. Do you know the approximate weight of each pallet?
5. Are there major price fluctuations in this market? To what degree? What are the influences?
6. Can you predict for a municipality of 40,000 people on average annual profit from selling compressed blocks of EPS?
7. Can you predict for a municipality of 400,000 people on average annual profit from selling compressed blocks of EPS?
8. Where are the most common markets located for purchasing recycled EPS?
9. What are the estimated transport costs associated with transporting per tonne of EPS?
10. Other comments?

Appendix B. Consent text and questions for online survey

Interview Background with consent box for Online Survey

This survey is being conducted by Dirk Xanthos, a Master of Resource and Environmental Management student at Dalhousie University. It will contribute to a study titled *Examining the Potential for Expanded Polystyrene Diversion in Nova Scotia*, which is funded by the Resource Recovery Fund Board and supported by the Office of Sustainability.

The Nova Scotia Solid Waste Strategy is committed to reducing annual solid waste disposal to a rate 300 kg per capita; the rate of solid waste generation has only reduced from 378 kg per capita in 2008, to 373 kg per capita in 2013. Progress toward this goal is a major challenge for the Nova Scotia government, but there are many opportunities available to work towards this goal. One of the opportunities is to divert expanded polystyrene from the landfill. This research has been designed to find a preferred method for management of expanded polystyrene waste for Nova Scotia.

The objective of this survey is to gain insight into the current methods of recycling expanded polystyrene on campus, and how these methods can be improved.

Notes from this survey will be stored in a secure location at Dalhousie until December 2015, at which point all documents will be destroyed.

Online Survey questions - Municipal operators

1. Do you operate a Transfer Station or Landfill?
2. (If you operate a Transfer Station) Which Municipalities do you receive waste from?
3. (If you operate a Landfill) Which Waste Transfer Stations/Municipalities deliver waste to your landfill?
4. Do you currently recycle EPS? If yes, what type of densifier is used, when was it installed and what was the cost?
5. Do you think there are the benefits of recycling EPS versus landfilling? If so, please provide examples.
6. What do you think are the barriers to provincial EPS curbside recycling?
7. Approximately, how much EPS by tonnage or % currently goes into your municipal landfill each year? (Or if they don't have an approximation is there an average that could be multiplied by their total tonnes landfilled?)
8. Which Waste Transfer Stations deliver waste to your landfill?
9. Most recycling facilities and depots that recycle EPS require it to be clean and not contaminated. Contaminated EPS is material that has other objects attached to it, such as tape, stickers, plastic paper and dirt. Have any waste audits been conducted to estimate the amount of contaminated EPS that comes to your MRF?
10. Do the garbage trucks serving your municipality compact? If so, what is the compression ratio?
11. Do the recycling trucks serving your municipality compact? If so, what is the compression ratio?

12. It is estimated that, on average, EPS takes up 1-5% in blue bag recycling by volume. Would this require extra investment in recycling trucks, or alternatively, extra trips by the recycling truck?
13. What is the compaction rate at your landfill per cubic metre?
14. What is the cost of landfilling EPS in your landfill?
15. In other jurisdictions, the square footage required for an EPS compressing machine, or densifier, would be up to 300 square feet. Would your MRF be able to accommodate an EPS densifier in your facility?
16. Do you know the approximate costs of purchasing and installing a densifier?
17. Would you be able to incorporate EPS sorting on your line? If not, will another employee be required to sort and process recyclable EPS?
18. Do you know what the selling price per tonne for blocks of recycled EPS is from your facility including all transportation costs? If so, what would be approximate costs?
19. Do you know if there major price fluctuations in this market?
20. Can you predict on average annual net costs from selling compressed blocks of EPS?
21. Where is the market located in which you are selling recycled EPS? What are the estimated transport costs associated with this?
22. Other comments?

Appendix C. Ethics approval from the Research Ethics Officer of the Faculty of Management at Dalhousie University



Faculty of Management Graduate Student Ethics Approval for a Course-based Project

July 24, 2015

Mr. Dirk Xanthos,

I am pleased to inform you that I have reviewed your project "**Examining the Potential for Expanded Polystyrene Diversion in Nova Scotia**" (file no. 071515), for the course ENVI 5501 (The MREM Internship) under the supervision of Rochelle Owen and Kate Sherren, and have found the proposed research involving human participants to be in accordance with the *Faculty of Management Ethics Review Policy for Course-based Projects* and the *Tri- Council Policy Statement on Ethical Conduct for Research Involving Humans (TCPS2)*. This project has received ethics approval.

This approval will be in effect until and not exceeding August 31st, 2015. It is your responsibility to immediately report any adverse events involving participants to both your instructor and to the Research Ethics Officer. Please note that any significant changes to the research methodology, consent form or recruitment materials must be resubmitted to Research Ethics Officer for review and approval prior to their use.

Congratulations on your successful Faculty of Management Graduate Student Ethics Approval for your Course-based Project. I wish you all the best as you begin this next phase of your research. Should you have any questions regarding ethical issues at any point during your project, please do not hesitate to contact me.

Sincerely,

A handwritten signature in black ink that reads "Ashley Doyle". The signature is written in a cursive style.

Ashley Doyle
Faculty of Management Research Ethics Officer
Rowe 2029
Dalhousie University
PO Box 15000, Halifax, NS B3H 4R2
a.doyle@dal.ca

Appendix D. Pairwise comparison decisions for criterion and subcriterion

Criteria:

Cost (1.00) vs Diversion Rates (1.00)

Based on the information and interests expressed by the EPS Advisory Group, the cost to implement a recycling program for EPS/the cost of landfilling EPS is of equal importance to the improvement of solid waste diversion rates. Without the necessary money to implement the recycling of EPS, a program cannot be implemented. The mandate of the RRFB is to reduce solid waste by increasing its diversion from landfills. Given these facts, they are considered to be of equal importance.

Cost (5.00) vs Social/health (0.20)

The cost of implementing an EPS recycling program is seen as strongly more important to decision making in comparison to health risks of recycling EPS. While there is a body of literature that contains evidence to suggest that the manufacture of EPS is a health risk and is possibly carcinogenic, it seems to be low risk in the recycling process. Health risks were not emphasised by the EPS Advisory Group to be as important as factors such as the cost of implementation.

Cost (3.00) vs GHG emissions (0.33)

The cost of implementation of an EPS recycling program/the cost of landfilling EPS is judged to be moderately more important than GHG emissions associated with recycling or landfilling EPS. While GHG emissions are important, an emphasis in the research is to look at the financial costs, as cost of an EPS program can determine its viability.

Cost (1.00) vs Job creation (1.00)

The cost of implementation of an EPS recycling program/the cost of landfilling EPS is equally important to the creation of jobs. As expressed in the Nova Scotia Solid Waste Management Strategy, a key objective of reducing waste through recycling programs is to create employment opportunities.

Diversion Rates (6.00) vs Social/health (0.17)

Diversion rates of solid waste are seen to be of strong to very strong importance to the decision making process in comparison to the social/health implications of recycling EPS. As mentioned above, health risks from recycling EPS are not seen as a major priority for the interested parties of this study.

Diversion Rates (3.00) vs GHG emissions (0.33)

Diversion rates are moderately more important to the decision than GHG emissions. Improving diversion rates for solid waste is one of the major priorities for many of those on the Advisory Group and for the RRFB. Less emphasis was placed on the consideration of GHG emissions from the recycling or landfilling of EPS.

Diversion Rates (1.00) vs Job creation (1.00)

Diversion rates of solid waste are considered equally important to the decision making process as the creation of jobs. As expressed in the Nova Scotia Solid Waste Management

Strategy, a key objective of reducing waste through recycling programs is to create employment opportunities.

Social/health (0.20) vs GHG emissions (5.00)

GHG emissions relating to the recycling of EPS is strongly more important than social/health costs relating to the densification of EPS. Health impacts from the recycling of EPS are seen to be a low risk.

Social health (0.20) vs Job creation (5.00)

Job creation is strongly more important than social/health costs of recycled EPS manufacturing. Members of the Advisory Group see job creation as a priority of the Nova Scotia government.

GHG emissions (0.33) vs Job creation (3.00)

Job creation from EPS recycling is moderately more important than GHG emissions. Job creation is a priority of increasing recycling programs in Nova Scotia.

Subcriteria:

Cost

The cost associated with landfilling EPS has not been explicitly considered within the AHP is. The cost of landfilling EPS is significant, given the material's lightweight and bulky characteristics.

Collection (4.00) vs Processing (0.25)

The cost of collecting EPS for recycling is of moderate to strong importance in the decision making process in comparison to processing. While there is a large initial investment for EPS densification machinery and storage, the ongoing costs of delivering the material to location where EPS densification takes place, such as Colchester County and Valley Waste, is a long-term cost that could determine the viability of the project. Municipalities, in particular Halifax, are most concerned about who is going to pay for the EPS recycling program.

Collection (3.00) vs Transport (0.33)

The cost of collection is moderately more important than the cost of transport. The cost of collection will be high for municipalities, given the lightweight nature of EPS. Cost will be particularly high for the rural municipalities who have to drive their material from transfer station to a facility with EPS densification equipment. Transport costs are low in comparison, given the amount of material that can be sent in one shipment (in the vicinity of 450kg? for the cost of \$500).

Processing (3.00) vs Transport (0.33)

The cost of processing recycled EPS is moderately more important than the cost of transport. As processing is a large initial cost to the operations of an EPS recycling program, the necessary funding is required to enable the investment in the cost of the processing. The cost of storage is also an important consideration in the recycling of EPS, given its bulky in nature. Transport costs are likely to be higher than processing costs over time, but they

are not significant costs. Transport costs would also be more than offset by revenue earned from the sale of EPS.

GHG emissions

Collection (1.00) vs Processing (1.00)

The GHG emissions from collection of recycled EPS are equally important compared to GHG emissions from processing. Obtaining data on GHG emissions from EPS recycling has been a limitation of this study. However, the use of heat and melting procedures in the densification of EPS is likely to produce a significant level of GHG emissions. Densification machines are not anticipated to be operating for long periods of time, maybe as little as one hour per day. GHG emissions from collection will vary throughout municipalities, and will be dependent on their proximity to EPS densification facilities.

Collection (3.00) vs Transport (0.33)

The GHG emissions from collection are moderately more important than GHG emissions from transport. Costs of collection are higher due to these costs being incurred prior to densification of EPS. EPS is transported after the material has been densified by up to 40 times its manufactured size, making it a much more cost-effective delivery.

Processing (3.00) vs Transport (0.33)

The GHG emissions from processing recycled EPS are moderately more important than those from transporting densified EPS. Due to the heating or melting procedures used to densify EPS, GHG emissions from processing can be intense. The Advisory Group places more emphasis in the operational aspects of EPS recycling, as opposed to the delivery of the final product to end-markets.

Job creation

Collection (0.20) vs Processing (5.00)

Job creation from processing EPS is strongly more important than job creation from collection. Based on the information gained from the literature review and the Advisory Group, more jobs are likely to be created in the processing of recycled EPS than in the collection of EPS.

Collection (9.00) vs Transport (0.11)

Job creation from the collection of EPS is extremely more important than transporting recycled EPS. Information provided by the Advisory Group indicates that the job of shipping and delivering EPS out of the EPS recycling facility is largely conducted by organizations external to the recycling organizations and municipalities. Transporting EPS is not going to cause significant growth in employment. The collection of EPS is much more likely to create higher demand for employment in the solid waste management industry.

Processing (9.00) vs Transport (0.11)

Job creation from the processing of EPS is extremely more important than transporting recycled EPS. The processing of EPS is likely to create the highest demand for employment growth in the solid waste management industry. Transporting EPS is not going to cause

significant growth in employment in solid waste management, as this work is largely external to the industry.

Appendix E. Pairwise comparison decisions for alternatives

Cost – Collection

Landfill (3.00) vs Recycled (0.33)

The cost of collection is moderately favourable for the landfill when compared to recycling EPS. EPS is currently sent directly to landfills in most municipalities in Nova Scotia. The cost of delivering EPS from recycling transfer stations to EPS recycling facilities is expected to be higher than the cost of sending EPS from solid waste transfer stations to landfills. This is due to there being fewer EPS recycling stations than landfills in Nova Scotia.

Cost – Processing

Landfill (7.00) vs Recycled (0.14)

The cost of processing is very strongly favourable for the landfilling of EPS in comparison to recycling EPS. The cost of processing landfilled EPS is minimal – it is placed in the landfill. The cost of processing is not the highest operating cost of recycling EPS, but the initial investment in machinery, storage and equipment is much more significant.

Cost – Transport

Landfill (3.00) vs Recycled (0.33)

The cost of transportation is moderately favourable for landfilling compared to the cost of transport for recycling EPS. Given that the cost of shipping a container of densified EPS to China is relatively low (approximately \$500 for 450kgs), the cost of transporting EPS will not prevent an EPS recycling program from going ahead. Transport costs for landfilling EPS are minimal, or zero.

Diversions Rates

Landfill (0.11) vs Recycled (9.00)

Diversions Rates are extremely better by recycling EPS in comparison to landfilling EPS. Landfilling of EPS will not change diversion rates, but recycling EPS will improve them.

Social/health

Landfill (0.33) vs Recycled (3.00)

In terms of social and health impacts, recycling EPS is moderately better than landfilling. While EPS is an inert and inorganic material, it takes up valuable space in the landfill. There are those who believe that EPS does not break down in a landfill and cause leachate or methane that pollute the environment and contribute to climate change. However, the relative short-term existence of EPS means there is some doubt about this claim. Recycling EPS is beneficial for maximising the use of resources, while placing EPS in a landfill is a waste of resources. While there are known health risks in the production of EPS, there is to date no evidence regarding the health risks for recycling EPS. Therefore, recycling is considered to be less harmful than landfilling EPS.

GHG emissions – Collection

Landfill (5.00) vs Recycled (0.20)

The GHG emissions in relation to the collection of EPS are strongly better for landfilling in comparison to recycling EPS. This is due to the longer distances recycled EPS has to travel to recycling facilities compared to landfills. Why talking about processing here?

GHG emissions – Processing

Landfill (7.00) vs Recycled (0.14)

The GHG emissions for the processing of EPS are very strongly preferable for landfilling when compared to recycling EPS. No processing takes place in the landfilling of EPS, whereas there is energy-intensive machinery used in the processing of recycled EPS.

GHG emissions – Transport

Landfill (5.00) vs Recycled (0.20)

The GHG emissions related to transporting EPS are strongly better for landfilling compared to recycling. There are minimal GHG emissions with transporting landfilled EPS, but the transportation of recycled EPS constitutes significant GHG emissions.

Job creation – Collection

Landfill (0.33) vs Recycled (3.00)

Job creation in the collection of EPS is moderately better in EPS recycling compared to EPS landfilling. There is a potential for new jobs in recycling, as a greater volume of recycling will take place. This could be offset by jobs lost as a result of reduced solid waste; however, new job creation is more likely with the collection of EPS recycling.

Job creation – Processing

Landfill (0.14) vs Recycled (7.00)

The creation of jobs in relation to processing EPS is very strongly better in the recycling of EPS than the landfilling of EPS. Processing recycled EPS is the largest source of new jobs in the solid waste management industry. Processing does not exist in landfilling EPS.

Job creation – Transport

Landfill (0.50) vs Recycled (2.00)

The creation of jobs for the transportation of EPS is deemed to be slightly better in recycling EPS than landfilling the material. While there may not be any new jobs created that can be directly attributed to recycling EPS, no new jobs would be created by landfilling EPS.