UBC Social Ecological Economic Development Studies (SEEDS) Student Report

A Life Cycle Analysis and Impact Assessment on Styrofoam collected through the Reduction and Recycling Pilot Program

Ida (Yunbai) Li

University of British Columbia

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What happens next?

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Ida (Yunbai) Li

Project Supervisor: Brent Skura
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Project Committee:
Paula Goldspink; Keely Johnston; Noga Levit; Liska Richer

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I. Executive Summary

Focusing on the User and Disposal Phases, this report assessed the life cycle impact of Styrofoam waste collected through the UBC Vancouver Styrofoam Reduction and Recycling Pilot Program. In the User Phase, participating buildings had different experiences with various vendors, including seeing the companies' improvements in package reduction and positive reactions to campaigning efforts. In the Disposal Phase, three current cases of waste management for Styrofoam are assessed and compared in terms of the economics, environment, and social impacts. Recycling is a three-staged process: collected Styrofoam materials from UBC are first shipped to WCS Recycling to be made into #6 pellets, which are then sent to Merlin Plastics for purification and further processing. The resultant Polystyrene #6 pellets will be shipped to an injection-molding company which produces virgin-blended recycled plastic products that are sold internationally. Re-use is the case for UBC Okanagan, as a partnership with Turtle Tanks was developed to incorporate Styrofoam waste into household septic systems. Landfill is a last and most inefficient option. Three alternatives are discussed in this report: 1. Expansion of the current recycling program; 2. Reduction from the source by working with vendors; 3. Explore partnership for re-using Styrofoam boxes; 4. Incineration. Each of these alternatives is evaluated upon four criteria of feasibility, environmental impact, cost, and sustainability of initiative. The alternatives are not exclusive from each other and could be implemented in an integrative fashion. The report concludes with several suggested areas for further research.

II. Background, Goal, and Scope

The industrial term used for Styrofoam is "expandable polystyrene (EPS)", which is produced when blowing agents are added to polystyrene[1]. As a type of plastic, polystyrene is classified as the number six category ("PS #6"), according to the US Federal Trade Commission[2]. Polystyrene #6 composites around 0.90% of the total waste stream in the Greater Vancouver Regional District, which means 9559.06 tonnes per year and 4.49 kg per person per year[3]. It is the fifth-ranked most consumed type of plastic in the Greater Vancouver region.

The UBC Styrofoam Reduction and Recycling Pilot Project aims at reducing the amount of Styrofoam, or Polystyrene #6 (PS #6), packaging consumed on campus by recycling instead of landfill. With the goals of examining the actual recycling process and exploring alternatives for managing Styrofoam waste, this SEEDS project takes a life-cycle-analysis approach to evaluate the complete life cycle of Styrofoam recycled from the pilot program. Using those results, this project also compares the two main streams of Styrofoam waste disposal -- recycling and landfill – according to their environmental, economic, and social impacts. Lastly, this report will discuss possibilities of expanding this pilot program as well as alternatives to better achieve the goal of reducing Styrofoam consumption on campus.

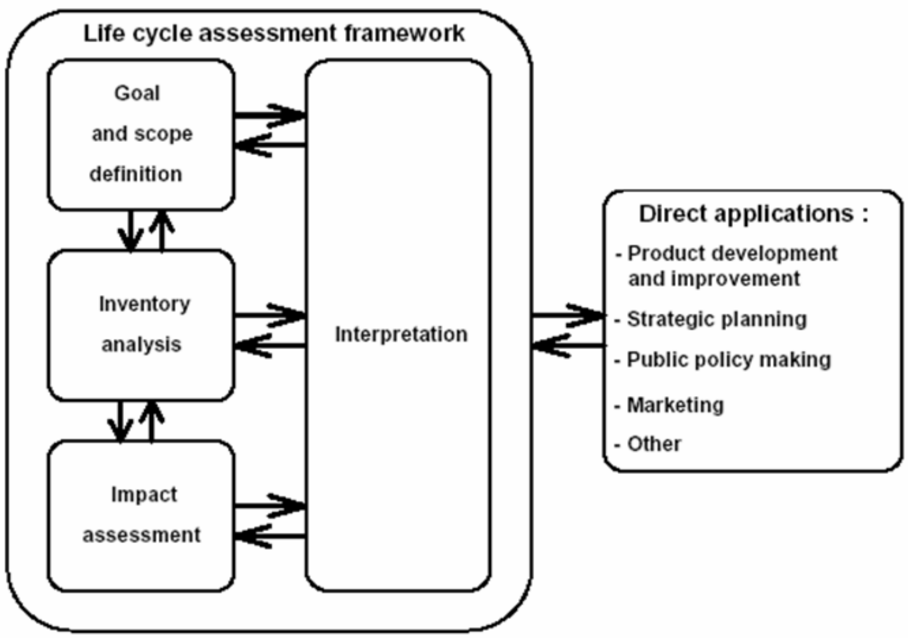

Figure 1

Although this project was first proposed to be a life-cycle analysis, the scope of this project mainly focused on the recycling and post-recycling process of Styrofoam plastic instead of a complete life cycle. A typical life cycle analysis will include both inventory analysis and impact assessment, together with interpretations of the results, as shown in Figure 1[4].

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[1] (Kremer, 2003)
[2] (Plastics Industry Trade Association (SPI), 2008)
[3] (BC Ministry of Environment, 2009)
[4] (European Commission (Commissioned), 2004)

Given the limited time frame, however, it is impossible to complete a life-cycle inventory analysis, which requires longer period of observation and data collection, as well as more specific measurements. In that case, the final project report will only cover a partial life cycle for Styrofoam packaging brought to UBC. Because we are more interested in the qualitative effects of this pilot project and because inventory analysis would need more site-specific evaluations as well as measurements, this project is better defined to be a general life-cycle impact assessment.

Major goals of this SEEDS project will include:

- Understand the recycling process of Styrofoam collected on-campus, from WCS to its downstream company, Merlin Plastics;
- Ensure that the processes above are responsibly managed and transformed into useful resources;
- Assess the potential environmental impacts of those recycling process (and the market that the recycling companies serve), so as to compare with landfill;
- Compare and evaluate on the economic and social impacts for recycling vs. landfill;
- Provide recommendation on possibilities of expanding the pilot program in UBC;
- Discuss and recommend alternative ways of reducing Styrofoam consumption, e.g. re-usage, alternative packaging, etc.

III. Methodology

Research for this project is conducted mainly through primary research on the major companies and participants in the Styrofoam recycling life cycle together with some other people with expertise in the field. Those primary research results then guide further research from secondary sources on relevant topics.

Primary research in this project is largely interviewing people for general overview of the issue and follow-up for specific questions. The interviews are conducted generally through email, phone calls, and sometimes in-person communications. Major companies involved in the Styrofoam recycling project include WCS Recycling located in North Vancouver and Merlin Plastics located in Delta. The mode of communication is mainly through e-mail. Phone calls are also arranged when the issue is better explained via phone. After retrieving first-hand information from the recycling companies, I then consult with professors in chemical engineering and chemistry departments to evaluate the potential impacts of the recycling processes and determine what further information is needed. The cycle of interviewing, evaluation and discussion, follow-up interviews, and re-evaluation is formed following the described research method. A table of interviewees, the purpose of interview(s), and the findings are outlined in Appendix I.

In addition, research on secondary sources, such as Environment Canada, Environment Policy Agency in the United States, American Chemistry Association, and academic journals in chemical engineering and environmental science, is conducted to collect supporting information on this project.

Certain limitations apply to this project. First of all, this is a case study focusing specifically on the UBC Styrofoam Reduction and Recycling Pilot Program. Thus, the information presented in this report is contingent with the specific conditions and environment at UBC, indicating limited applicability or transferability of the knowledge. Secondly, since most of the information is collected by email and telephone interviews, it is possible for ambiguity or misinterpretation when processing the interview data. This may be mitigated by confirming and developing information received with follow-up questions, sourcing from multiple interviewees, and referencing secondary sources. Lastly, due to the lead time between interview requests and the actual realization of an interview, not all of the contacts were successfully reached by the end of this project, leading to some unanswered or un-clarified questions. These will be addressed in the last section, where areas for further research are suggested.

IV. Life-Cycle Impact Assessment

This section summarizes the findings of this SEEDS project in two phases of the Styrofoam life cycle: Use Phase and Disposal Phase. In the Use Phase, Styrofoam is consumed on UBC campus in different forms for a variety of purposes. Some existing efforts of vendors to reduce Styrofoam packaging will also be highlighted. In the Disposal Phase, Styrofoam could follow four major streams: recycling, re-usage, landfill, and incineration. Each of these streams will be explained with facts and details found through research and interviews. For the purpose of this project, recycling, re-usage, and landfill are examined.

In particular, for the Disposal Phase, impact assessment will follow the description of current situations. This includes evaluation of impacts on the economics, environment, and social aspects. Detailed criteria are illustrated in Figure 2. These criteria will also correspond to the evaluations in alternatives and recommendations, so as to better compare the different options.

Figure 2

4.1. Use Phase: Current Perspectives

Styrofoam collected from research buildings at UBC are mostly used for packaging and insulation, especially for temperature-sensitive bio-medical materials. Each building puts in their own orders from different vendors. Some major vendors mentioned by two or more buildings include: Abcam, Fisher Scientific, Sigma-Aldrich, Millipore, VWR, Bio-Rad, and Cedarlane. Shipments are quite frequent among these research labs, ranging from 2-5 times a week to at least 5 boxes daily. Many of the labs stated that there is a rather steady demand for those products and that packaging like Styrofoam that fulfills insulation purposes is necessary.[5]

According to email correspondences with the research labs, several companies have already made efforts to change. For example, Abcam has "significantly reduced their box sizes", while Fisher and Santa Cruz were already doing sustainability self-evaluations to re-assess their box sizes and shipment packaging. VWR and Fisher now "rarely uses" Styrofoam. In particular, NEB (New England Biological) ships in boxes with prepaid Canada Post so that boxes could be returned for re-use. This would involve arranging additional loads with campus mail. A local company supplying bio-medical materials, Applied Biological Materials (ABM) Inc., also collects used Styrofoam boxes from campus, the details of which would be discussed in the "Alternatives and Recommendations" section.

Concerns for the vendors concentrate on two aspects. Firstly, some excessive packaging could not be avoided. A comment was made on international shipment standards, which requires vendors to package extensively for safety reasons[6]. This makes it difficult for vendors to slim down packaging, while some research labs chose not to order from those vendors as a result.[7] Secondly, variable forms of packaging – such as Styrofoam chips, peanuts, blocks, virgin Polystyrene (PS) #6, and mixed PS – make it hard for lab administrators to sort the recyclable, which also makes it hard for recycling companies to process, as impure polystyrene is useless for recycling[8].

One effective way of persuading companies to turn to more sustainable packaging is through letter campaign. One lab administrator suggested that companies tend to be more responsive when being persistent and when concrete examples of excessive packaging are presented.

It is notable that the recent amendment in the Recycling Regulation of British Columbia has specified some responsibilities of packaging producers (or distributors when applicable) in terms of product stewardship. Producers will be required to submit a stewardship plan detailing the financing and methods of recycling packaging of their products[9]. The submission and approval of this stewardship plan are required to have been completed by May 2014 for all producers. Although the scope of this SEEDS project starts only from the Use Phase, this piece of regulation will provide useful reference when selecting vendors and producers in the future.

4.2. Disposal Phase

We consider three ways to dispose Styrofoam here: recycling, reuse, and landfill. The life cycle impact assessments for recycling and re-usage are evaluated according to the current practice of UBC Vancouver (for recycling) and UBC Okanagan (for re-usage, since UBC Vancouver does not yet have a comprehensive re-use program). Contrastingly, impact assessment for landfill is only a hypothetic case with qualitative explanations according to secondary sources. These

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[5] (Administrators, 2012)
[6] (University of North Carolina-Chapel Hill)
[7] (Administrators, 2012)
[8] (Jasper, 2012)
[9] (Province of British Columbia, 2011)

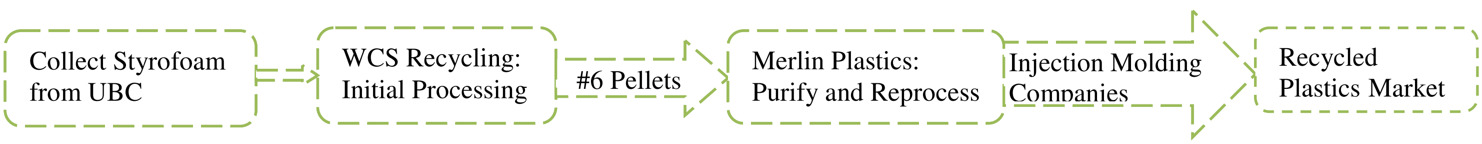
impact assessments will provide reference to the comparisons made in the "Alternatives and Recommendations" section.

4.2.1. Recycling

The Overall Process

The overall recycling process of Styrofoam collected from UBC goes through three main stages:

1. Extruded and processed into #6 pellets at WCS Recycling located in North Vancouver.
2. Purified and prepared for mold injection at Merlin Plastics located in Delta.
3. Molded at injection mold companies in North America.
4. The end product produced from the injection mold companies could enter two possible paths:
   a. If the company is a part of a plastic product company, then the end products may directly enter the consumer market. For example, if the company is owned by Rubbermaid to produce plastic containers, then the end product will be directly sold to retail stores.
   b. If the company is just a contracted manufacturer, then the end product may go through yet another phase of production involving labeling or other additional processes, before the products circulate back to the market. For example, if the molding companies makes computer components with the recycled plastics, then the end product will be shipped to another company or factory to enter an additional step of computer assembly manufacturing before reaching the consumer market.



A few main questions were asked when communicating with these two companies:

1. What criteria do you impose on the Styrofoam collected?
2. What process does the Styrofoam go through and what would the end product be? (If possible, we would appreciate some details, such as processing temperature, chemicals added, etc)
3. Does the process generate any waste or by-product?
4. Where would the end products be shipped to, or what market do they mainly supply for?

Some follow-up questions on certain details were also asked.

WCS Recycling

WCS Recycling is a recycling company that collects a comprehensive range of recyclables in the Greater Vancouver area. Their services reach locations at Whistler, Squamish, North Shore, Vancouver, Burnaby, New Westminster, Port Moody and Coquitlam.[10] WCS's partnership with UBC involves picking up Styrofoam from a centralized point at the Environmental Services Facility on South campus and processing the Styrofoam for shipment to their down-stream company to further be recycled and re-produced into useful products.

[10] (WCS Recycling, 2009)

Process Description

1. Pick-up and Transportation:

Styrofoam packaging is bagged for pick-up at each research building. Because of the low density of Styrofoam, George at WCS mentioned that it was quite inefficient to transport a large volume of Styrofoam with very little weight. Currently, the Styrofoam is collected bi-weekly from the central pick-up location and the volume could vary from month to month, ranging from 3,500 L to 17,000 L per month. These volumes are possibly correlated with the seasonality of demand during the school year cycle – more in the fall and the spring, less over winter break[11]. The cost of picking up is a flat one-year rate plus the cost for plastics bags used to pack the Styrofoam.

The type of Styrofoam collected should strictly be Polystyrene #6, instead of starch-based foam peanuts made from 50% #6 Polystyrene and 50% #7 Cornstarch-mixed Styrofoam. It is easy to distinguish between PS#6 peanuts and the starch-based – the latter does not inflate when squished. According to both George and Dr. Ed Grant at the UBC Chemistry Department, purity is extremely important for Styrofoam recycling[12].

Located at 1493 dominion Street, North Vancouver, BC, WCS Recycling is around 22.8 kilometers away from UBC Environmental Services Facility (6025 Nurseries Road, Vancouver, BC V6T 1W5) by the shortest route for cars, according to the driving calculations from Google Map[13]. Assuming a 25 miles-per-gallon (MPG) car, it will require around 0.57 gallons of gasoline to complete a one-way trip for this distance[14].

2. Processing at the Facility

The Styrofoam first goes through a selection process, as some "impure" Styrofoam will be sorted out before being shredded. Then, all polystyrene #6 foams are broken into small pieces to go through a compression process. This process could also be called "extrusion", as its purpose is to physically compress the polystyrene pieces and then solidify them in a cool environment, resulting in "extruded polystyrene (XPS) foams". Though both are formed with polystyrene polymers, XPS is different from expanded polystyrene (EPS) foam, because the latter is produced through an "expanding" process with blowing agents, while the former is produced by extrusion. Since the compression process adds pressure to Styrofoam, the air inside the foamed cells may be released during compression.

The compression process could be heated or cooled. The former tend to be more energy-consuming. The end product will be more compact but hence, more gas will be released as air comes out of the foams when compressed. The heat developed during extrusion is both due to the machine's own operating temperature and the work that the machine does to the foam itself during extrusion. The cooled compression process, however, is messier and the end product is less compact, hence it is less cost-efficient for WCS with lower revenue per truckload.

[11] (Risk Management Services, 2012)
[12] (Jasper, 2012) (Grant, 2012)
[13] (Google Map, 2012)
[14] (Fuel Economy, 2012)

Considering the cost and benefits, as well as the convenience for operation, WCS uses the heated compression process.

WCS Recycling uses the machine type NEPCO ne45. The operating range for the EPS compression is 120F to 160F, which translates to about 49-71˚C. As a patented product of The Dow Chemical Company, Styrofoam's Material Safety Data Sheet (MSDS) could be found on the Dow website. A variety of products in the Styrofoam line could be found, not all of which has a melting point. For example, Styrofoam™ 10.0 X 20 Inch Buoyancy Billet Extruded Foam has a melting point estimated at 90 – 130˚C[15], while Styrofoam SIS ™ 1.00 Inch Structural Insulated Sheathing no indicated melting point, with a note that exposure to temperatures above 150˚C can cause the product to decompose[16]. In either case, the stated operating temperature of the compression machine seems to be in the safety range.

However, potential environmental impact of this process could be complex and questionable. According to Dr. Grant, the quality of re-produced plastic and the temperature for processing depends on the thermal history of the Styrofoam used. In this case, it is hard to trace the Styrofoam from different vendors and sources, especially when some vendors also re-use their packaging.

3. Shipping to the Downstream Company

The resultant No.6 pellets will then be shipped to a downstream company, Merlin Plastics, located at 109 - 917 Cliveden Ave, Delta. According to calculations on Google Map, WCS Recycling is around 23 kilometers from Merlin Plastics[17], which translates to around 14.3 miles and 0.57 gallons of gasoline for a car with 25 MPG. The pellets are transported in a cube truck which runs on bio-diesel (5~20 % ethanol blend depending on season)[18]. Nevertheless, it is important to note that the efficiency for this shipment will be much larger than the initial transportation from UBC to WCS, as the density of pellets will higher for the same truckload.

Merlin Plastics

Located in Delta, Merlin Plastics is a company that recycles plastics to produce products such as HDPE (#2 plastic) pellets, PET (#1 plastic) flakes, and others. The company receives #6 pellets from WCS Recycling and prepares them into more purified #6 pellets for injection molding companies to further blend and mold into recycled plastic products to channel into the market.

Process Description[19]

1). Polystyrene is shredded by color into flakes: white will be made into white "repro pellets", while colored flakes will be turned into black "repro pellets".
2). Wash and dry the shredded flakes to remove dust and other contamination

[15] (The Dow Chemical Company, 2007)
[16] (The Dow Chemical Company, 2008)
[17] (Google Map, 2012)
[18] (Jasper, 2012)
[19] (Jasper, 2012)

3). Process the shredded flakes into oval shaped pellets used by injection mold companies to manufacture non-food related products

The resultant PS pellets are sold to companies throughout North America, where the pellets are then blended with virgin plastics up to about 20 to 25 percent, so that the integrity of the product structure is not damaged. Some examples of the end products include Polystyrene nursery trays for plants and seedlings, picture frames, protective product packaging.

Impact Assessment for the Recycling Process

1. Economics

Direct costs of recycling for UBC include a flat rate of about $4000 for pick-up each year, and the cost of plastics bags used to hold the Styrofoam waste for around $500 per year[20]. Indirect costs of recycling include the cost of time and human resources among the participating buildings. In addition, WCS Recycling, Merlin Plastics, and the injection molding company will also need to bear the cost of transportation, power, equipments, chemical additives, etc, which will be reflected on the value added of the end products.

Transforming Styrofoam packaging into pellets is a value-adding process. Recycled polystyrene price is around 15 cents (or 40-50%) higher per pellet than Polystyrene crumbs[21][22]. Transforming pellets into virgin-blended recycled plastic products is a second and higher value-added process.

2. Environment

At WCS and Merlin Plastics, there are two main sources of emission: transportation and extrusion. The shipment of Styrofoam waste from different locations on UBC campus to WCS and shipment of No. 6 pellets from WCS to Merlin Plastics consumes around 1.3 gallons of gasoline per truckload one-way. Moreover, shipment from Merlin Plastics to the molding companies will add to the transportation emissions during the process. Extrusion, on the other hand, does not have significant emission in addition to the electricity used to operate the extruding machine.

It is not obvious whether there is any hazardous by-product in the WCS process. The purification process at Merlin Plastics is still under investigation.

Lastly, the end product of the recycling process will probably enter the production or consumption phase of another life cycle of the recycled product, in which the recycling process could be seen as part of the production phase. For the processes described in this section, the end product at Merlin plastics is mainly #6 PS pellets, shipped to molding companies for further production. Unlike landfill, the end product of recycling does not enter or directly interact with the natural environment. Nevertheless, how people discard the recycled plastic products could hardly be monitored, so it is still possible that the recycled products will also end up in the

[20] (Levit, 2012)
[21] (Plastics Technology, 2000)
[22] (Plastics News, 2012)

landfill stream. In that case, the same amount of plastics avoided entering landfill at least for an additional cycle of usage, which may also count as positive impact.

3. Social

Recycling through WCS and Merlin Plastics needs a fair amount of coordination at each research building. A coordinating person is needed to organize the collection of Styrofoam waste and correctly sort out the Polystyrene #6 foams.

On a side note, the fact that Styrofoam could be made into recycled plastics and be marketed as a different product imposes the social impact that encourages recycling. In fact, Merlin Plastics seems to be a large plastic recycler with a fair amount of social presence, as they are also the recycler for the BC Capital Regional District recycling program[23]. Considering the current shortage of fossil fuel supplies and that plastics are originally made from oil and natural gas[24], encouraging recycling will loop the amount of fossil fuel used to produce plastics back to plastic production, reducing the amount of "new" raw materials used to produce virgin plastics.

4.2.2. Reuse: The Turtle Tank Case

UBC Okanagan (UBCO) has a Styrofoam reuse program in which about 150 cubic yards of Styrofoam is reused per year. According to David Adel at UBCO Supply Management, all departments are on board with this project and the reuse rate of Styrofoam on-campus is very high, being at least 90%[25].

The partner company that reuses the Styrofoam from UBCO is Turtle Tanks, a company that produces a variety of containment applications located in Kelowna, BC. UBCO launches the program and distributes recycling bags for each department to collect waste Styrofoam. The bags of collected Styrofoam are then put in a dedicated blue bin for recycling, just as other recycling materials. According to David, Turtle Tank comes to pick up every second or third month in a 2-ton cube van.

Styrofoam collected from UBCO is mainly used for septic tanks for household water treatment systems. The Styrofoam is first shredded into 3 X 3 inch chips[26] and then formed into a leaching bed in the septic system. The purpose of this leaching bed is to drain the treated waste water from household into the soil[27]. Usually, layers of bacteria called "bio-mat" are formed on the side and bottom of the trench for treatments to occur. There are specific sewerage system regulations regarding the construction of such treatment systems[28].

Impact Assessment

1. Economics

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[23] (BC Capital Regional Dsitrict (CRD), 2011)
[24] (American Chemistry Association, 2012)
[25] (Adel, 2012)
[26] (Adel, 2012)
[27] (Canada Housing and Mortgage Corporation, 2012)
[28] (BC Ministry of Health, 2004)

There is no monetary transaction between UBCO and Turtle Tank. UBCO exchanges the Styrofoam waste for Turtle Tank's transportation, pick up, and re-usage of those waste. As the Styrofoam will re-enter the production phase of septic tanks, there would be much value added to the re-usage process.

2. Environment

Styrofoam seems not to be reactive even in long-time exposure of water. Normally, leaching bed of a conventional septic system should last at least 20 years, but the actual system lifetime may be shorter because of clogging with bio-mat, in which case the bed will have to be repaired or replaced[29].

3. Social

Re-usage of Styrofoam seems to require a similar level of commitment and coordination as recycling. The end product of re-usage in this case is household water treatment system, which also creates social value for improving sewerage system.

4.2.3. Landfill: description and assessment

Same as all landfill procedures, Styrofoam that goes into garbage will be sent to landfill for natural decomposition in the soil. However, this is hardly a solution for Styrofoam waste management. Because of the inert properties of Polystyrene, it is extremely hard for Styrofoam products to degrade in the soil. Although very few studies have done complete evaluation on the exact time for Styrofoam to decompose, several sources indicate that it takes at least 500 years[30][31].

1. Economics

Landfill costs the least but also creates the least value. On the other hand, preventing Styrofoam from going into landfill – by recycling programs, collection facilities, and social coordination – could be costly. Hence, for both individuals and collective groups, it probably makes the most sense to simply discard Styrofoam waste to the "garbage" stream. Once overcoming that barrier of setting up a well-designed waste management program, though, it is reasonable to believe that recycling and re-use programs will benefit the society more in the long run.

2. Environment

Landfill does not generate much emission aside from transportation, because plastic itself is of fossil origin[32]. Rigid plastic PS #6 is classified as relatively inert in BC's landfill gas assessment guideline[33], generating around 20m³/tone of methane each year. Given this inert quality, Styrofoam takes up a lot of space underground and could affect the normal decomposition and

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[29] (Canada Housing and Mortgage Corporation, 2012)
[30] (CBC News, 2011)
[31] (EPA, 2011)
[32] (EPA, 2012)
[33] (BC Ministry of Environment, 2009)

ecological activities in the soil, such as blocking water and air. Moreover, since the Styrofoam packaging evaluated in this specific project are often packaging for bio-medical materials, it would be inappropriate to allow those packaging go directly into the soil without de-contamination for bacteria and other residuals[34].

3. Social

Styrofoam goes into the landfill stream usually from the "garbage" category of waste collections. There is no convenient venue for students and residents of UBC to recycling or reuse Styrofoam like the research buildings. Resources for recycling or reusing Styrofoam in communities are very limited, which could be a reason why there is still a large amount of Styrofoam entering the landfill.

V. Alternatives and Evaluation

Following the findings from the life cycle impact assessments and considering the current situation at UBC, three main alternatives were generated: first is to focus on the current recycling program and explore possibilities of expansion, second is to reduce packaging from the source by convincing vendors; third is to encourage re-usage of Styrofoam packaging. Lastly, the alternative of incineration of Styrofoam for energy generation is briefly discussed.

To better assess these three alternatives, several contacts at different departments of UBC and related companies were interviewed via email. While many other alternatives could be generated to achieve the same goal of better implementing waste reduction at UBC, recycling, re-using, and reducing source of packaging are existing efforts that could be leveraged to a larger extent and are easier to implement.

Where applicable, alternatives are each assessed according to four criteria: 1) Feasibility (including the social aspect involved); 2) Environmental Impact; 3) Cost; and 4) Sustainability of Initiative.

5.1. Current Recycling Program and Possibility of Expansion

This alternative seeks the possibility of expanding the current pilot program to a larger extent on UBC campus. In addition to partnering with more research labs, other Styrofoam "consumer groups" at UBC can also get involved. For example, collaborating with UBC Housing to set up Styrofoam collection boxes in residences, involving UBC IT (from communications with Randy Goldenberg at IT Services, this seem to be already undergoing), or working with the Alma Mater Society (AMS) to implement more powerful marketing campaigns and incorporate this program in the new student union building plans.[35] Nevertheless, these possibilities will need more detailed feasibility study and implementation plans. The assessment here is only a very rough, qualitative estimate.

1. Feasibility

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[34] (Giratalla, 2012)
[35] (Goldenberg, 2012)

There are many ways to realize the expansion of this pilot program. On the recycler's side, WCS has recently purchased a new machine with enhanced operating performance for compression. George at WCS has expressed the willingness to accept more Styrofoam to the facility for processing. WCS is also considering accepting Styrofoam containers with food residuals, although achieving that would involve an additional process of decontamination.

On the UBC community's side, there are several ways to involve more participants in this program, although careful planning of how to coordinate a larger pool of participants is needed. Currently, many UBC recycling programs have their own recycling venue and they directly work with waste management without a middle person[36]. In that sense, this recycling pilot could be regarded simply as a platform that provides Styrofoam recycling alternative for the UBC community. Buildings, departments, or even households on-campus could choose to participate as long as there is a centralized and easily accessible collection site. Then, even with expanded scope of collection, the processes beyond collection of Styrofoam waste would remain the same. Corresponding to WCS's expanded processing capabilities, expansion of the pilot is a realistic proposal.

2. Environmental Impact

As discussed in the Life Cycle Impact Assessment section on recycling, the environmental impact of recycling Styrofoam is insignificant compared to the damage to the soil environment in landfill and the potential pollutants emitted through incineration. Recycling enables the Styrofoam to enter another product's life cycle, bypassing the negative environmental impacts during production phase of the raw material, polystyrene.

Furthermore, expanding the project could potentially create economies of scale, where the more influence this pilot project has on the UBC community, the more people are aware and willing to recycle the appropriate type of Styrofoam, hence more environmental benefit is achieved.

3. Cost

Looking solely at the monetary cost, recycling may be the second most costly among the four streams of reuse, recycle, landfill, and incineration, incineration being the most costly because of the large fixed cost of establishing a facility. Compared to landfill, the recycling process costs more human efforts and transportation, but creates more economic value. Compared to re-usage, recycling may cost more processing and transactions, but the end product is a different type of market good that could also be re-used. Hence, the different methods here are not necessarily comparable financially.

4. Sustainability of Initiative

If partnerships with different departments were adequately discussed and carefully communicated, it is very likely that the expansion of Styrofoam recycling programs will sustain. This is mainly because of the constant consumption of Styrofoam-packaged products, as well as the capacity on the recycler's side. Certainly, it would be a difficult process to educate the communities to correctly sort the Styrofoam and closely monitor the collected Styrofoam waste

[36] (Levit, 2012)

(e.g. whether there is food residual, whether it is not #7 peanuts). Those processes may impede development of the program.

5.2. Reduction at the Source

Instead of handling excessive Styrofoam waste, a better solution, perhaps, would be reducing wasteful Styrofoam packaging directly from the source – the vendors.

1. Feasibility

Convincing the vendors to switch their packaging methods and standards would require sincere and long-term efforts in communication and collaboration. This involves heavily campaigning for slimmer packaging, actively looking for alternative packaging materials for temperature-sensitive products, and developing viable, standardized, and mutually-beneficial guidelines for future orders.

As three lab administrators mentioned in their emails, the companies are already taking actions to re-evaluate their packaging and reduce the size of boxes, but certain shipment standards may have prevented them from shipping in slimmer packaging[37]. While international shipment standards could not be avoided, the labs may consider more orders through local companies. In addition, persistent emailing campaigns and collective campaigns would be more effective than simply a one-off request (Administrators, 2012).

Another way to reduce Styrofoam use is to look for alternatives, which is a path taken by VWR. At a meeting with VWR in February, two alternative forms of re-usable packaging were introduced that could potential replace Styrofoam for insulation. A Credo cube is box with a liquid-filled Thermal Isolation Chamber (TIC) that provides thermal solution for different temperatures. The life span of the TIC is 5 years, while the vacuum cover has a life span of 3 years. The box is made from #2 Plastic, HDPE. Despite the fact that information on end-of-life disposal for Credo cubes is yet to be provided, the clean-up for the TIC solutions "is like any non-toxic aqueous solution", according to VWR sales representative[38]. A second alternative introduced was the ThermoSafe green boxes with a bar-coding system for tracking and re-use, although there is currently no Canadian logistics solution for that type of packaging[39].

It is not difficult to start the initiative of campaigning vendors, but the extent of influence could be limited. On the other hand, being more selective of vendors and looking for alternative forms of packaging could be more feasible and easier to do.

2. Environment Impact

Reducing from the source reduces environment impact from the very beginning and thus is ideal for minimizing environmental impact throughout the life cycle. Neither form of the two introduced alternative packaging is made from organic material that could easily degrade in the soil; nevertheless, they allow a more streamlined process to channel those materials and dispose

[37] (Administrators, 2012)
[38] (Bisnaire, 2012)
[39] (VWR, 2012)

them at the end of their life cycle. Also, being able to re-use those boxes with the same vendor companies means less transportation, as boxes from earlier deliveries are picked up at later deliveries.

3. Cost

Campaigning for less Styrofoam packaging involves more human efforts instead of monetary cost. As for alternative packaging such as Credo cubes and ThermoSafe products, an additional cost for renting or buying the boxes may incur, while the cost of recycling would be saved. However, since the cost of recycling with WCS is a flat rate, partially replacing Styrofoam packaging will not generate cost savings, unless Styrofoam waste is entirely eliminated. This would be something to be considered, if the project budget is limited.

4. Sustainability of Initiative

Sustainability of this initiative would be dependent on the companies' choices of packaging materials and standards. There is reason to believe that, once actions are taken to reduce packaging, companies are likely to stay with their decisions and improve.

5.3. Re-use: analysis and assessment

Based on the Turtle Tank case at UBC Okanagan (UBCO) and ABM's current efforts to re-use their own Styrofoam boxes after delivery, re-using Styrofoam was brought to attention in this project. As mentioned and compared in the life cycle impact assessment, this is also a convenient and sustainable choice.

1. Feasibility

ABM has expressed willingness to take in more Styrofoam boxes from research labs, even if they did not originate from ABM shipments. Generally, they collect Styrofoam boxes around 12" x 12" x 14" or smaller, but larger boxes are occasionally accepted, too. The frequency of pick-up so far has been once every three weeks in a minivan; this frequency could be increased if supply were to increase. The current estimated numbers are about 100 boxes/month and a garbage bag of chips/month.

Picking up from different locations will be possible. What has worked for ABM was an on-site location for Styrofoam boxes to be stored or picked up, as well as a contact person at each building, so that the ABM personnel could collect the boxes while making deliveries.

Currently, ABM delivers the most at three locations: the UBC hospital, Life Science Centre, and the Museum for Biodiversity. One way to start this Styrofoam box re-use program is to first focus on buildings where labs are more concentrated and Styrofoam boxes are consumed more; then, involve the other buildings and laboratories. It was mentioned by Earnest that Life Science Centre would be an appropriate place to start, as many labs using biomedical materials that require insulated packaging are concentrated in that one building. If this re-use program were to be implemented, a dedicated coordinating person and a given storage space for collecting discard Styrofoam boxes will suffice.

2. Environmental Impact

As ABM is a biological materials company, they have expertise in handling contamination and thus have no specific requirements on the condition of the boxes. As written in the email correspondence with ABM's house manager, Earnest, "universal precautions and a bleach/peroxide soak/wash usually suffices for dealing with the contaminated". However, ABM has decided not to collect from chemistry labs, because they "do not have the facility or expertise to test powders, residue, etc from those labs for proper decontamination".[40]

According to EPA's emissions factor estimations for plastics, re-use and recycling are the only two disposal alternatives that generate net emission reduction, and re-use reduces emissions the most[41]. This is mainly because of the reduced transportation for re-use (as opposed to the several "stages" of recycling process that takes place at different locations and companies), as well as the elimination of emissions from all the pre-consumption phases, such as raw material production, re-production, etc.

Exhibit 4: Net Emissions for Plastics under Each Materials Management Option ($MTCO_2E$/Short Ton)

Material	Net Source Reduction (Reuse) Emissions for Current Mix of Inputs	Net Recycling Emissions	Net Composting Emissions	Net Combustion Emissions	Net Landfilling Emissions
HDPE	-1.47	-0.86	NA	1.27	0.04
LDPE	-1.79	NA	NA	1.28	0.04
PET	-2.22	-1.11	NA	1.24	0.04
LLDPE	-1.57	NA	NA	1.27	0.04
PP	-1.55	NA	NA	1.27	0.04
PS	-2.50	NA	NA	1.64	0.04
PVC	-1.98	NA	NA	0.67	0.04
Mixed Plastics	NA	-0.98	NA	1.25	0.04

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
NA = Not applicable.

Figure 3

A few downsides to re-use include the decontamination phase and the ultimate end-life of re-used Styrofoam boxes. First, the decontamination process may involve a certain amount of harmful chemicals such as bleach, which contains chlorine that may contaminate the water stream if disposed improperly. Secondly, instead of a complete solution, re-use could be regarded as just a means to repeat and pro-long the User Phase of the life cycle. This results in elimination of other phases and thus increasing efficiency (more "output" to the same amount of input) and saving energy, but does not avoid or resolve the issue with Styrofoam waste management. Hence, it is equally important to monitor the end life of those re-used boxes and make sure that they enter into a responsible Disposal Phase. As ABM also supplies UBC with biological materials, the re-used boxes should supposedly cycle back to the UBC waste stream and probably be recycled or land filled.

3. Cost

[40] (Leung, 2012)
[41] (EPA, 2012)

Like Turtle Tank's case with UBCO, there would be no direct cost for ABM to pick up extra Styrofoam boxes from UBC. The indirect costs incurred may include designating a place for box storage and collection, and a coordinating and contact person at each building. This does generate cost reduction on both sides, though. UBC will save the cost of recycling as well as the risk of reputation if excessive Styrofoam waste is discarded into the landfill. For a small cost of decontaminating the boxes, ABM will be able to save the hassle and financial burden of purchasing Styrofoam boxes. There is a level of riskiness, though, for incomplete decontamination that may lead to serious consequences. Hence quality control is extremely important for re-using the boxes from laboratories.

4. Sustainability of Initiative

ABM is in constant demand of Styrofoam boxes for packaging and would be able to take Styrofoam boxes from any labs that are willing to participate. In fact, ABM's house manager Earnest says that the company is now beginning another phase of operation and distribution expansion, so this seem to be a good time to discuss plans for more box pick-ups [42]. If this initiative is supported and runs well, there is also the possibility of convincing other biomedical material vendors or producers to re-use their own boxes. Then the model may become similar to the Credo cube and ThermalSafe solutions suggested by VWR in the previous alternative.

4.2.4. Incineration: a brief discussion

Incineration of Styrofoam could be made possible through very high temperatures of burning and processing. As Polystyrene's structure contains chlorine, benzene, and other harmful chemicals that may be released during burning, incineration is not a recommended alternative for Styrofoam disposal. CO is another major component of synthetic gas produced during incineration[43]. However, it is necessary to briefly discuss the possibility and its implication for future reference. Though different from an incineration system, UBC already has its own bio-energy facility to burn clean, urban waste wood for energy generation, which is a biomass gasification system designed by Nexterra company[44]. After communicating with Jeff, the Alternative Energy Manager at UBC Building Operations, it seemed obvious that incineration would not be possible at that gasification facility, since the system only takes in clean wood. Styrofoam products, especially biochemical-contaminated materials, would not be ideal for incineration, because extremely toxic chemicals such as dioxins and furans could be released[45]. Jeff also had a strong opposition to Styrofoam packaging, thinking that it should be banned because of the disposal problems caused by chlorine or fluorine contents.

VI. Summary and Conclusion

The four alternatives listed are not exclusive of each other and could be implemented in an integrative way. For example, extending the re-use program to Styrofoam-heavy labs would still allow recycling of damaged or repeatedly-used Styrofoam boxes. A comparison of the four alternatives is shown in Table 1.

[42] (Leung, 2012)
[43] (Lau, 2012)
[44] (Nexterra, 2012)
[45] (Czuczwa & Hites, 1984)

Table 1. Comparison of Alternatives

	Feasibility	Environmental Impact	Cost	Sustainability of Initiative
• Expanding the Pilot	Feasible, requiring more coordination	Improve through redirecting into the User Phase of Life cycle	Flat rate per year	Long-term impact in the community once scale is established
• Reduction at Source	Feasible, requiring more campaigning and being selective of vendors	Improve through less consumption and less to dispose	Indirect	Contingent with companies' decisions
• Re-use	Feasible and welcomed, requiring coordination/Management	Improve through repeated User Phase and less recycling efforts per input	Indirect	Constant (and growing) demand
• Incineration	Unfeasible. Otherwise need big investment in plant	Energy-intensive and releases hazardous gas	Large fixed cost	Could be used for multiple wastes

To obtain the goal of reducing Styrofoam consumption and waste on campus, actions to monitor and improve both the source and the end-life of Styrofoam are needed. Looking at the current situation of Styrofoam consumption at UBC, there is necessity for demand of insulated packaging and alternative forms of packaging materials are not yet available, so it is an inevitable problem of waste management. While re-use increases the efficiency of Styrofoam consumption during User Phase, recycling ensures responsible and effective end-of-life treatment during Disposal Phase. There is certainly potential for developing a re-use program with multiple labs and the pilot program may be able to grow through wider range of initiatives. Aside from those means, many new technologies are stemming to provide better solutions to package and transport temperature-sensitive products.

Despite the outlook above, UBC is just a small agent in the macro-environment of the Styrofoam life cycle and the industry supply chain. It takes much more than the programs on-campus to fully develop sustainable solutions to problems such as reducing Styrofoam packaging for temperature-sensitive products. This will involve initiatives from not only the vendors, the buyers, and the waste management industry, but also governments who regulate the transportation safety standards and the shipment requirements, as well as organizations that develop guidelines for production and recycling. The scope of this project is limited to its applicability for the UBC pilot program and the specific companies or agents involved in the lie cycle. Nevertheless, it is important to acknowledge the other factors that may have played a role in the situations we are in today.

VII. Suggested Areas for Further Research

1. Detailed and Complete Information for the Recycling Cycle

Given the long time frame used to connect to the right person and the lead time in interview responses, some information and details were not obtained during the term of this project. This includes confirming the recycling and purification or washing process with Merlin Plastics and information on its downstream companies in North America. Also, according to Dr. Grant, the thermal history of Polystyrene also affects the stability of the material as well as the temperature range that it is sensitive to. Hence, a more careful examination of how recycled plastics "cycle" back to the plastics market would be interesting to do. Nevertheless, the cycle will become more and more complicated, and will perhaps surpass the scope of this pilot.

2. Site Visit and Audit

Due to facility problems and time constraint, we were not able to make a site visit to Merlin Plastics or WCS Recycling. A site visit will be helpful if an audit were to be done to observe, record, and calculate the exact emissions or energy indexes. This will contribute to a more quantitative analysis of the life cycle.

3. Feasibility Study or Planning for the Expansion of Pilot Program

As mentioned in the section for alternatives, expansion of pilot program with UBC Housing Services or IT Services may need more detailed planning and coordination to establish a feasible plan for Styrofoam collection and dealing with food residuals from the residence wastes. Moreover, certain guidelines and programs to educate the UBC community about how to correctly sort and recycle Styrofoam products would be needed.

4. Further Investigation into Alternative Packaging

Following up with VWR's push on alternative insulated packaging, further research on related innovations, industrial products and technologies could be conducted. When a few options are available, a plan for incorporating those materials into the UBC supply chain would be needed. For example, UBC may develop a special partnership with its vendors by using its own Credo cubes to ship lab materials, as opposed to receiving standard Styrofoam packaging.

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Appendix I. Table of Contacts (categorized by function; in no significant order)

Interviewee	Form of Interview	Purpose of Interview
George Jasper Operating Manager, WCS Recycling george@wcsrecycling.com	• E-mail • Phone call	Understand the initial recycling process and the downstream company
[redacted]	[redacted]	[redacted]
Kevin Andrews Merlin Plastics	• E-mail	Request site visit
Earnest Leung ABM Goods	• E-mail	Understand current re-use initiative Explore possibility for expanding re-use program
Research Buildings Pilot project participants[46]	• E-mail	Understand the User Phase of Styrofoam, demand or concerns for Styrofoam recycling, and effect of pilot project
Randy Goldberg UBC IT Services	• E-mail	Explore possibility of Styrofoam recycling at UBC IT department
Dr. Ed Grant Professor at the Chemistry Dept	• E-mail	Inquire the chemistry of Styrofoam recycling and its impacts
Dr. Tony Bi Professor at Dept of Chemical and Biological Engineering	• In-Person	Understand Life Cycle Analysis and related topics
Dr. Anthony Lau Professor at Dept of Chemical and Biological Engineering	• E-mail	Understand the chemistry mechanism and environmental indications of the recycling process
Waleed Giratalla Water and Waste Management Engineer	• Phone call	Understand impact of incineration and connect to other waste management contacts
Jeff Giffin Alternative Energy Manager	• E-mail	Understand impact of incineration for Styrofoam and the current UBC biomass energy system for clean wood

[46]See complete list and contact information at http://www.riskmanagement.ubc.ca/environment/styrofoam. In this report, all communications with the lab administrators are cited as "Administrators" to avoid mentioning individual names and/or labs when commenting on certain vendors.

Appendix II. Bag Volume Calculation

Determining the volume of Styrofoam collected: Bags are 35 in x 50 in (88.90 cm x 127 cm)
To calculate the product volume for a pillow bag with a given bag width and cutoff length the following formula applies:

$$V = \frac{C^2}{4\pi} \times H \times 0.35$$

C = Circumference of bag = 2 x bag width = (2)(88.90) = 177.80 cm
H = Cutoff length (Height) of bag = 127 cm
0.35 = 35% usable bag volume
V = Product Volume = 111878.44 cm^3 = 111.88 L ≈ 110 L

Volume of one bag/160 bags:
0.11 m^3 x 160 bags = 17.60 m^3
3.97 ft^3 x 160 bags = 635 ft^3
110 L x 160 = 17600 L

Notes:
(1)Determining the usable volume of a pillow bag starts by calculating the cylinder of film as it is formed by the forming tube. The diameter of the forming tube gives us the circumference of the cylinder. The bag length is the height of the cylinder. Because the cylinder is flattened on both ends when the cross seals are applied, the volume of the cylinder is reduced to approx. 35% usable volume. The 35% usable bag volume includes the possible filling degree of a pillow bag and the reduced space caused by the cross seals.
(2) Equation taken from www.technikpackaging.com/**Bag**_Sizing.doc

Appendix III. EPS vs. XPS

EPS – Physical Properties of Common Types Used in Building Envelopes				
Classification:	*Type I*	*Type II*	*Type VIII*	*Type IX*
Density (pcf)	1.0	1.5	1.25	2.0
Comp. Res. (psi)	10	15	13	25
R-value (@ 75 degrees F.)	3.85	4.17	3.92	4.35

XPS – Physical Properties of Common Types Used in Building Envelopes					
Classification:	*Type IV*	*Type V*	*Type VI*	*Type VII*	*Type X*
Density (pcf)	1.6	3.0	1.8	2.2	1.3
Comp. Res. (psi)	25	100	40	60	15
R-value (@ 75 degrees F.)	5.0	5.0	5.0	5.0	5.0