

UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

An Investigation into Biodegradable Utensils

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Abstract

This report presents a triple bottom line assessment of stainless steel and biodegradable plastic utensils. The purpose of this report is to recommend a utensil type for use in the new student union building that will have the least impact on society, the environment and the local economy at the University of British Columbia. The two material choices were assessed and compared on a use and disposal only level which led to a recommendation that biodegradable plastic utensils be used in the new student union building because they are disposable and require less facilities to support their use. Two suppliers of biodegradable plastic utensils were then compared using a life cycle assessment focussing on the energy requirements to manufacture and deliver the utensils to the University of British Columbia. The two suppliers were Biodegradable Food Services and Biodegradable Solutions International. Due to the lower energy requirements of utensils manufactured in Oregon by Biodegradable Food Services, it is recommended that these utensils be used in the new student union building.

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List of Abbreviations

SUB – Student union building

AMS – Alma mater society

UBC – University of British Columbia

PLA – Polylactic acid

BFS – Biodegradable Food Services

BSI – Biodegradable Solutions International

LCA – Life cycle analysis

1.0 Introduction

This report is a triple bottom line assessment of utensils made from two different materials: stainless steel and biodegradable/compostable plastics. These materials are assessed based on environmental, economical and social impacts. Both materials have this basic assessment presented in the following sections. The biodegradable plastics then have a more detailed life cycle analysis which compares utensils from two manufacturers based on the energy inputs that are required to produce and deliver the utensils to UBC. This assessment was carried out in order to make a recommendation as to which type of utensil is best to distribute at the new SUB.

2.0 Biodegradable plastic utensils

This section of the report assesses the use of biodegradable plastic utensils. Compostable and biodegradable materials have become more and more popular in making our household products. These products are affecting our lives significantly in the three different areas outlined in this section.

2.1 Environmental assessment

Biodegradable and compostable plastics provide both positive and negative impacts. These two different types of plastic are decomposed through different means. Biodegradable plastic is made of materials that undergo biological decomposition by micro-organisms such as algae,



Figure 2.1.1: Raw materials used for biodegradable plastic production. Source: Natur-Tec Sustainable Biobased Materials.

bacteria, or fungi. Figure 2.1.1 on the left shows some of the materials used to make biodegradable plastic products (Natur-Tec Sustainable Biobased Materials). On the other hand, compostable plastic is made of materials that undergo biological degradation during composting to produce water, CO₂ (carbon dioxide) gas and other chemical compounds and biomass. Utensils made from these materials are heat resistant up to 125 degree Celsius and are reusable (Compostable Plastics). These products can be decomposed by specific composting plants, wherein all

constitutive materials are decomposed fully or into useful by-products. In addition, the incineration of these products will create zero toxic emissions which will have no or negligible effect on the environment, unlike conventional landfills. However, to be decomposed in a short time, they must be composted properly at a composting plant. Landfills cannot efficiently break down compostable plastics because landfills are made to prevent moisture from forming to create toxic chemicals such as the methane gas. Furthermore, because of the world food shortages, massive deforestation is occurring in Brazil and, likewise, desertification in Africa. Land is being used and overused through agriculture to satisfy the large global demand for

food. This then also requires the use of fresh water for irrigation of crops. With the amount of fresh water left on Earth, farmers need to divert more rivers and fresh water resources to enable these crops to grow. Altering natural landscapes and changing natural weather patterns, which cause droughts in some regions and monsoons which cause major flooding in others, both of which render farmland unusable.

2.2 Economical assessment

Biodegradable and compostable utensils cost twice as much as the traditional petroleum-made plastic utensils. However, if the entire life cycle is evaluated, compostable and biodegradable cutlery will be cheaper. Figure 2.2.1 on the right shows the life cycle of compostable cutlery (Cereplast Compostables). Local shipping cost will not be a factor since both products are relatively available in the lower mainland and can be shipped for the same amount of money. The real difference lies in how the waste is processed and handled. With the in-house composting capabilities at UBC, our biodegradable utensils can be processed and recycled at the university instead of shipping them to landfills. This will result both cost savings for waste management and lower gas emissions into the environment.



Figure 2.2.1: Life cycle of compostable utensils. Source: Cereplast Compostables

2.3 Social assessment

Many problems arise from the use of biodegradable and compostable plastic. For one, food has become a scarce resource; the production of biodegradable and compostable plastics requires the diversion of edible parts of food crops that would otherwise be consumed by people. Food prices have increased approximately 83% to compensate for the increasing demand (Compostable Plastics). Food shortages have also become a major issue in different parts of the world where many people are struggling to get enough food to survive. Furthermore, genetically modified crops, which are used to make many of the bio-plastics, also raise the issue of gene manipulations. Both ethical and health issues still today are very debatable in

genetic engineering. Furthermore, since compostable utensils remain disposable, it also reduces labour costs, as there is no need to hire extra workers to wash the utensils.

3.0 Life cycle assessment of bio-plastics

This section analyses and compares the lifecycle of the biodegradable polylactic acid (PLA) plastic utensils from two different companies named Biodegradable Solutions International (BSI) and Biodegradable Food Service (BFS). The AMS currently purchases PLA food use products from BSI, a company that manufactures its wares overseas using corn based resin. BFS products are mostly manufactured from corn and potato-based products.

This life cycle analysis involves quantifying and comparing the amount of energy required to develop and transport each company's product to University of British Columbia (UBC). The three main areas of the life cycle were: agriculture, manufacturing/development and transportation.

3.1 PLA product background

PLA based plastic products are on the rise in recent years. These products are made from plant starches, hence making them renewable and biodegradable. These products are an excellent alternative to petroleum based plastic products and can potentially lead to tremendous reductions of plastic wastes. There are, however, still numerous environmental related issues associated to PLA plastic products. PLA plastic products can only be decomposed in an industrial controlled composter. In a landfill, it would take an extremely long time to decompose. One of the other concerns is that PLA plastic products cannot be recycled with petroleum based plastic products, and thus have to be separated out from the waste stream. Despite these issues, PLA plastic has the potential of becoming an environmentally friendlier alternative to petroleum plastic.

The agricultural process involves growing a crop (typically corn), harvesting, and then milling to separate out its starch. This starch is hydrolyzed into dextrose which is further processed into lactic acid. Further chemical treatment combines the lactic acid forms into long polymer chains. These polymer chains become PLA resin which can be used for variety of applications, such as: being extruded into sheets and formed into containers, plates, drinking cup lids and being moulded to form utensils.

3.2 Life cycle

A life cycle analysis (LCA) is a tool for investigating the environmental impact of a product over its entire "lifespan." The LCA of the above mentioned products is defined as beginning with initial farming to produce starch, and ending with the finished product arriving at UBC. This

LCA uses the quantity of energy required to make and deliver the final product as its means of assessing environmental impact.

For the BSI product, corn is grown in China, and then trucked to a manufacturing site elsewhere in the country. The product leaves China in its final form i.e. as a lid or a utensil. Upon reaching Canada it is stored in a warehouse and then shipped to a distributor and finally arrives at UBC. The lifespan of PLA plastic utensils by BSI is shown in Figure 3.2.1.

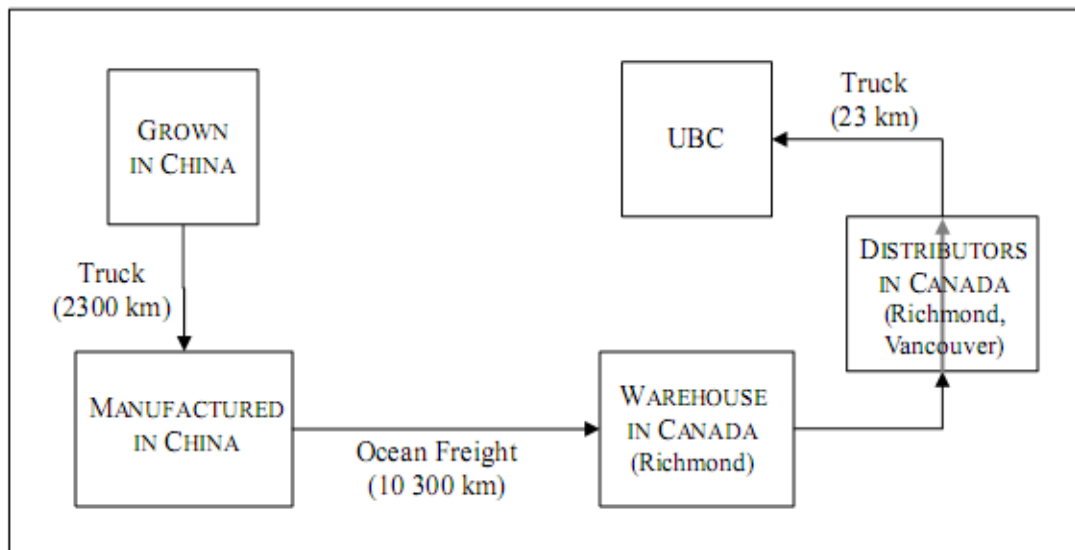


Figure 3.2.1: BSI Process location and Transport diagram (Chinese crop). Source: Lee.

For the BFS product, potato wash is first purchased in Oregon. Twenty-five percent of this wash is sent to Gresham, Oregon for manufacturing; the remaining 75% is sent to China. The finished products are then returned to the US and stored in a warehouse. Finally they are shipped to a distributor and the product arrives at UBC. The lifecycle of the BFS product is shown in Figure 3.2.2

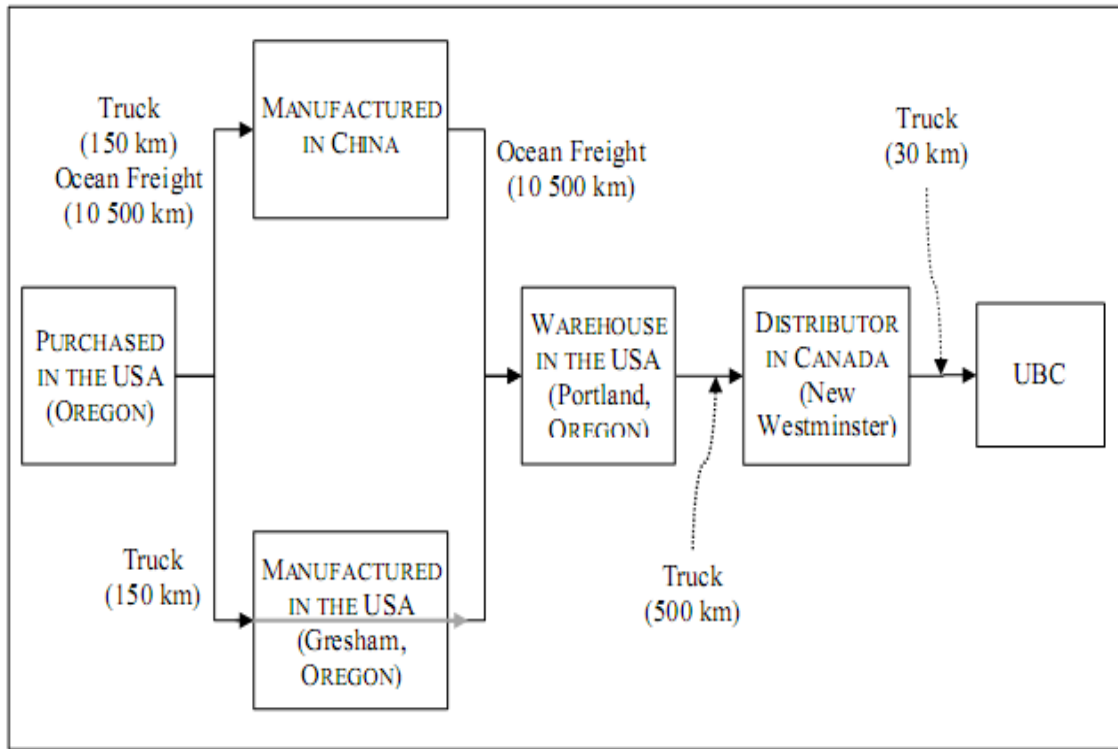


Figure 3.2.2: BSI Process location and Transport diagram (US crop). Source: Lee.

3.3 Agricultural costs

BSI and BFS have different ways for obtaining the PLA for the development of their utensils. BSI purchases PLA resin that is made from corn, whereas BFS purchases potato starch that needs to be further processed into resin. For the purposes of this LCA, both corn and potato based starches are considered equivalent and agricultural energy inputs are defined as those up to and including the production of starch.

3.3.1 BSI corn starch production

Table 3.3.1 below summarizes the energy inputs required for the production of corn starch.

Farming		
Energy Input ^{ix}	73033211	kJ/ha
Crop Yield ^x	5014	kg/ha
Input per kg Corn	14567	kJ/kg
Input per kg PLA	25874	kJ/kg
Milling		
Input per kg Corn ^{xi}	2315	kJ/kg
Input per kg PLA	4112	kJ/kg
Total		
Input per kg Corn	16882	kJ/kg
Input per kg PLA	29986	kJ/kg

Table 3.3.1: Energy Inputs for the Production of Corn Starch. Source: Lee.

The farming energy input and crop yield values found in Table 3.3.1 above are based on agricultural practices in the Liaoning province in China in the 1980's. This data might be somewhat outdated as a result of farming practices becoming more mechanised (and thus more energy intensive) within the last thirty years.

Once the corn is harvested, it undergoes a wet milling operation. The milling operation involves slow cooking the corn in water for thirty or forty hours at approximately 50° C. This causes the corn to soften and release its starch. The corn is then ground, allowing for the starch to be separated out. The milling process was calculated to require about 2300 kJ/kg of corn.

The total energy input per kilogram of corn was calculated to be 16 882 kJ/kg; this was then converted to 29 986 kJ/kg of PLA. Accounting for a water content of 15%, corn is approximately 63% starch. In addition, perhaps 10% of the starch is not converted into PLA (this assumes that the starch can be completely broken down into dextrose). Thus, only about 56% of the corn harvested and milled is converted into the desired end product. For consistency, this LCA normalizes all energy flows against a unit mass of PLA.

3.3.2 BFS potato wash

BFS purchases potato wash and converts this into PLA resin. Potato wash is essentially starch and water. When potatoes are cleaned before processing, they are subjected to high pressure water which not only removes their skin, but a portion of starch as well. Because potato wash is considered a waste product, the energy required for growing and processing potatoes will not be considered in this

analysis. However, as was with the corn, it is assumed that only about 90% of the potato starch is converted into PLA resin. Thus, one kilogram of potato based PLA requires 1.1 kg of potato starch to produce.

3.4 Manufacturing

The manufacturing portion of this LCA is bounded by the conversion of starch into resin and the production of the final utensil or food container product.

3.4.1 Energy used in manufacture

While BFS produces its own resin, and BSI purchases it, both companies either directly or indirectly follow a very similar sequence of steps: converting starch to resin, plastic compounding, and some method of shape formation, such as injection moulding in the case of utensils. While energy usage will certainly vary due to equipment or process differences, given the scope of this analysis and a lack of specific machine details, it is assumed that both companies use the same amount of energy for manufacture. A rough estimate of 4000 kJ/kg of PLA was obtained to encompass the manufacturing process.

3.4.2 Energy sources

BSI manufactures its products in China. In 2004, China produced 82% of its electricity from conventional thermal sources (predominately coal), 16% from hydroelectricity, and 2% from nuclear sources. The Figure 4.4.1 shows the breakdown of electric production in China for the year 2004.

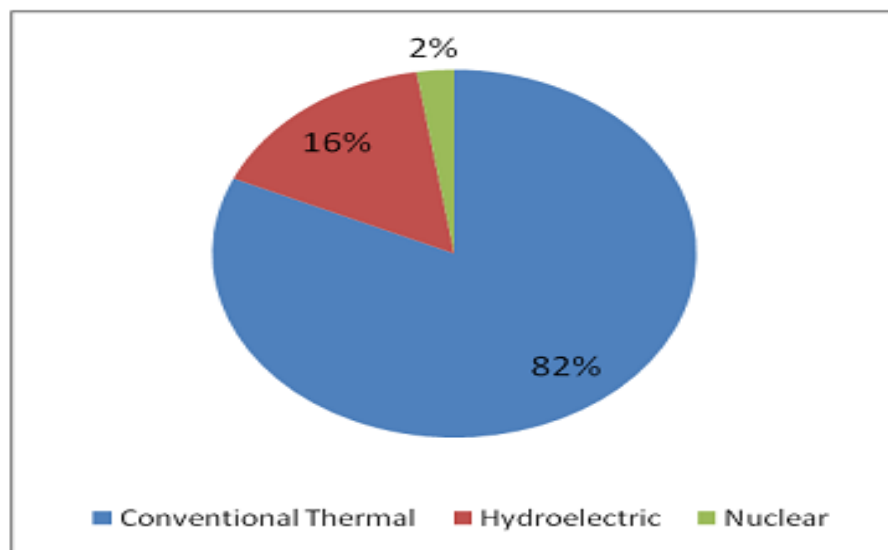


Figure 3.4.1 Electric power generation in China, 2004. Source: Lee.

BFS also manufactures most of its products in China. However, 25% of its manufacturing is done in Oregon, USA. As seen in Figure 3.4.2 below, 72% of its electricity is generated using renewable sources (mainly hydroelectric).

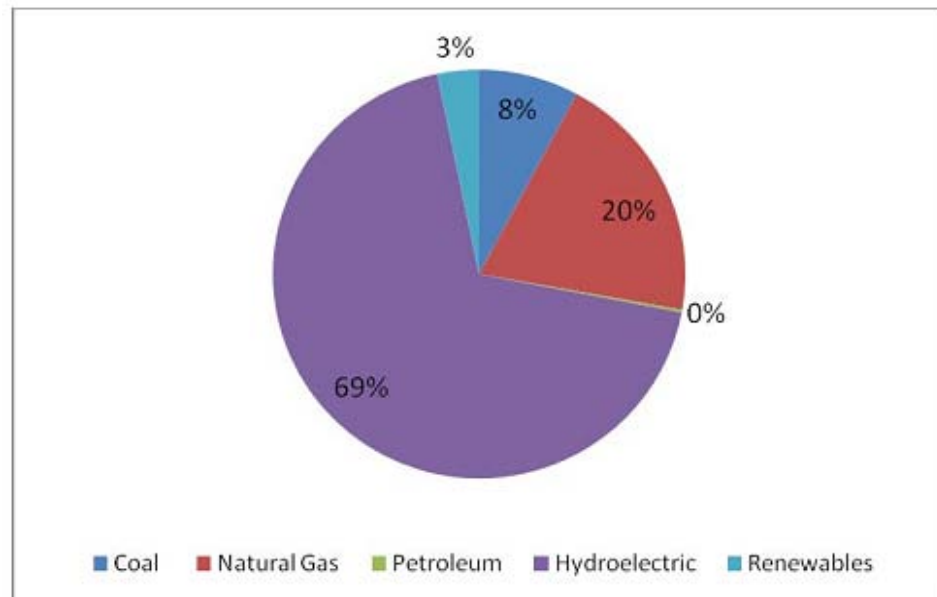


Figure 3.4.2: Electric Power Generation in Oregon, 2005. Source: Lee.

BFS’s Oregon option uses the least amount of conventional thermal sources, only 28%. When weighted (25% Oregon, 75% China), BFS uses 13.4% less non-renewable energy than BSI for its manufacturing process. The manufacture of BFS products will also likely produce fewer air pollutant emissions, as it uses less coal, which is notoriously dirty. These values are summarized below in Table 3.4.1.

Supplier	Conventional Thermal	Hydroelectric and Renewable	Nuclear
	<i>Percentages</i>		
BSI	81.7	15.8	2.5
BFS (Taterware)			
Oregon Option	28.0	72.0	0.0
China Option	81.7	15.8	2.5
Weighted Average	68.3	29.9	1.9

Table 3.4.1: Electric Power Generation sources. Source: Lee.

3.5 Transport

Both BSI and BFS products travel between China and North America through trucks and ocean freights. One complete trip includes a starting point from the corn farm or a potato wash site and ending at UBC.

3.5.1 BSI shipping

The corn is grown in China's Liaoning Province. It is assumed that it departs from a port near Hong Kong. The site of manufacturing is noted to be very close to the port (about 10 km). The distance from Liaoning Province to the port is approximately 2300km. The distance from the Hong Kong port to the BSI warehouse in Richmond is about 10,300 km by ocean freight. Finally the distance from the Richmond warehouse to UBC is about 23 km by truck.

3.5.2 BFS shipping

The potato wash for the BFS product is purchased in Oregon. From there 25% of it travels to Gresham, Oregon for manufacturing. The rest of the 75% is delivered to China. The distance from the point of purchase to Gresham is approximately 125km. The manufactured product in Gresham is transported to a BFS warehouse located in Renton, Portland and Hayward. It is assumed that Portland (central location) warehouse supplies the product to UBC. The distance from Portland to their distributor in New Westminster is about 500km. Finally the product travels 30 km from New Westminster to UBC.

For the potato wash delivered to China, it is estimated that the distance from the product site to the port is about 150km. From Portland to Hong Kong the distance by freight is about 10,500 km. It is assumed that manufacturing takes place very close to the port. So the product travels back 10,500 km before reaching Portland and from there it travels another 530 km to reach UBC.

3.5.3 Energy consumed in transport

Following were the energy estimates made through literature reviews-

Energy consumed by ocean freight= 0.2kJ/kg km

Heavy Duty trucks = 0.35 L/km. Heating Value of diesel= 38653 kJ/L

At full capacity the weight of product and fuel in the vehicle is assumed to be 20.384 tonnes.

Therefore for energy consumption of trucks = 0.6634 kJ/kg km

Supplier	Truck	Ocean Freight	Total	Percentage of BSI
<i>Distances (km)</i>				
BSI	2323	10300	12623	100%
BFS (Taterware)				
Oregon Option	680	0	680	5%
China Option	680	21000	21680	172%
Weighted Average	680	15750	16430	130%
<i>Energy Usage (kJ/kg of PLA)</i>				
BSI	2706	2060	4766	100%
BFS (Taterware)				
Oregon Option	460	0	460	10%
China Option	479	4433	4912	103%
Weighted Average	474	3325	3799	80%

Table 3.5.1: Energy consumed in transport. Source: Lee.

3.6 Overall energy analysis

Supplier	Agriculture	Manufacture	Transport	Total	Percentage of BSI
<i>Energy Usage (kJ/kg of PLA)</i>					
BSI	29986	4000	4766	38752	100%
BFS (Taterware)					
Oregon Option	0	4000	460	4460	12%
China Option	0	4000	4912	8912	23%
Weighted Average	0	4000	3799	7799	20%

Table 3.6.1: Total energy consumed. Source: Lee.

From the above table we can see that the BSI option uses the most amount of energy and BFS's Oregon option consumes the least.

3.7 LCA conclusion

The PLA products manufactured by BFS consume less energy throughout their lifecycle in comparison to the BSI products. The BSI products needed energy for the growth and

processing of corn while BFS just used a waste stream from another industry during the manufacturing of their product. Furthermore, the BFS products manufactured in Oregon required less energy input because of less transportation. In terms of energy consumption, BFS Oregon is the best available option. However, there is still scope for improvement such as better accuracy of estimates, assumptions and to include some other factors such as greenhouse gas emission and upstream fuel costs.

4.0 Stainless steel utensils

This section of the report assesses the use of stainless steel utensils. Stainless steel cutlery has been used since the 1600's. ("The Stainless Steel Family") A stainless steel fork is shown in Figure 4.0.1. With its portability and durability advantages, having steel-based cutlery for the Sub would be environmentally sound.



Figure 4.0.1: Stainless steel fork. Source: The Stainless steel family.

4.1 Environmental assessment

Stainless steel consists of at least 11% chromium content by mass. Known for not staining, corroding, or rusting, stainless steel cutlery presents durability and reusability that both plastic and bio-plastic cutlery lack. ("The Stainless Steel Family") The degradation of stainless steel cutlery within the environment is irrelevant to its use in a large scale at the new SUB as stainless steel utensils will be re-used rather than thrown away. This is the primary environmental advantage of using stainless steel utensils.

4.2 Economical assessment

The start-up cost of adopting the use of stainless steel utensils would be substantially more than disposable utensils. It can be argued that this difference in cost, over long-term operation, would eventually become negligible due to stainless steel utensils not needing to be replaced while disposable utensils must be repurchased regularly. While this is true for restaurants, which operate to generate profit, the SUB, a public area, will not be able to break even while

using stainless steel utensils. Restaurants on average lose about 20% of their utensils annually due to theft or wear-and-tear. (“Understanding Cutlery,” 2009) A public facility, like the new SUB, would have to estimate triple the losses of restaurants. Using stainless steel utensils would likely force the SUB into operating at a deficit. This debt could be avoided with the use of disposable utensils.

The implementation of stainless steel utensils would increase the annual costs of the Sub. Employees would be needed to wash the utensils as well as facilities within the Sub being needed to support the work of those employees. Proper tools and machinery would also need to be purchased in order for the employees to properly do this work. The costs needed to implement the above can be easily avoided with the use of disposable utensils.

4.3 Social assessment

While stainless steel utensils would be the most beneficial for the environment due to the insignificant amount of waste, the large-scale use of stainless steel utensils will lead to several social issues. Sterilizing the utensils would then require extra employees to wash them and new handling procedures for students using the utensils and a reduction of available space in the new SUB. As a result a utensil washing room would be required, which would either have to be added to the design or another room would have to be removed from public use to accommodate the washing of the utensils. Extra manpower and water would also then be required to support the washing of the stainless steel utensils to be used in the new SUB. The implementation of the use of stainless steel utensils would be very tedious. Theft of stainless steel utensils would occur as well as utensils accidentally thrown into garbage cans. In either case, the utensils become lost utensils. Customers at the SUB who purchased food “to go” would also not be able to use utensils supplied at the SUB, and would therefore be required to bring their own. Issues surrounding proper disposal of used utensils can be easily avoided with the use of disposable utensils.

5.0 Conclusion and recommendations

Based on the findings presented earlier in this report, it is recommended that the new AMS food services provide biodegradable plastic utensils for customers at the new SUB. It was decided that stainless steel utensils would not be appropriate for use in the new SUB because they are non-disposable. This eliminated stainless steel utensils for several reasons. First is that the use of stainless steel utensils would require much more support, for washing and sterilizing, which disposable utensils would not. Stainless steel utensils are also not appropriate because they must stay within the SUB whereas disposable utensils could be taken away by customers when purchasing meals “to go”. It is recommended that the AMS use biodegradable utensils that are manufactured in Oregon from BFS. These utensils are recommended because of the lower energy requirements to manufacture and ship the forks to UBC than the BSI, as well as the lower social impacts of having disposable utensils.

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