

An Investigation into Packing Materials for the New Student Union Building

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List of Abbreviations

EPS – Expanded Polystyrene

SUB – Student Union Building

ABE – Acetone, Butanol, Ethanol

Abstract

In search of a packing material that is sustainable environmentally, economically, and socially, the report utilizes three materials, corrugated cardboard, bubble wrap, and packing peanuts as possible candidates for packing materials in the new SUB. The report focuses on materials which can be used for bulk shipping non-food items for retailers that are coming into the new SUB. After researching using various online sources, cardboard was found to be versatile, serving its purpose for exterior packing very well. Cardboard is largely recyclable, adding environmental and social values, while also being inexpensive to produce. Bubble wrap has two choices of materials: plastic polymer and biodegradable wrap. Biodegradable bubble wrap has the environmental advantage over the polymer wrap, while costing just a little more than the polymer counterpart. Packing peanuts is also divided into two types of materials: polystyrene and starch based peanuts. While starch based costs more than the polystyrene based, these peanuts have the environmental advantage in decomposition, and also had possible uses as biofuels, after the initial purpose of packing has been served. In conclusion, cardboard was determined to be the prime candidate for exterior packing, while containing packing peanuts inside for products which need extra protection. The use of packing peanuts were found to exhibit a greater overall advantage than bubble wrap, given that its potential to be reused as biofuel overcomes the economic advantage that bubble wrap has.

1.0 - Introduction

Packaging can be classified into three different types: primary, secondary, and tertiary. Primary packaging can be defined as the packaging for each of the individual components. It is the packaging which comes in contact with the actual product, and is typically the form of packaging that consumers receive. Secondary packaging is the packaging of small groups and clusters of primary packages, and is also a form of packaging from a consumer's perspective. The tertiary level of packaging typically refers to the packaging for bulk handling. This level of packaging is the type used for shipping from warehouses to retailers.

The aim of the report was to assess and evaluate the most commonly used packing material types according to the triple bottom line assessment. Common materials were chosen as the focus since the ease of access of these materials would likely decrease the barriers to entry for retailers. As this report is focused on the possible packing materials for the retailers in the new SUB, the scope was narrowed to three types of tertiary packaging: corrugated cardboard, plastic bubble wrap, and packing peanuts.

2.0. Corrugated Cardboard

2.1. General Overview

Corrugated cardboard is a widely known packing material used for shipping and storing materials safely. Mainly made from paper pulp, cardboard is lightweight, durable and provides the opportunity for multiple reusability. Much of the cardboard can be recycled, and in fact, a large portion of cardboard production includes recycled paper pulp. However, cardboard is the same as any paper product in that it can be recycled a limited number of times before the pulp no longer holds together. As such, it is inevitable that creating cardboard will always provide a demand for virgin pulp, and thus require the harvest of additional timber.

2.2. Environmental

The corrugated cardboard, from the fact that the main material is paper pulp, can be biodegradable and incinerated when it has finished serving its purpose. These actions, however, come at the price of creating methane when placed in landfill (Confederation of Paper Industries, 2010). Decomposition of the cardboard, when compared to other materials, is shorter, clocking around 6 months (See Figure 1). Incineration of the cardboard will release carbon dioxide (Confederation of Paper Industries) along with other pollutants (Leigh, 2009). Another option for disposal of cardboard is recycling. About 70%-90% of used cardboard can be recycled (Postpack, 2012). A large portion of recycled cardboard then gets used as cardboard again (McCurry, 2010), allowing a very efficient life cycle of the material.

Material	Life span
Steel	Over 100 years
Aluminum	200 to 500 years
Ceramic	Not determined
Chewing gums	5 years
Nylon ropes	30 years
Long-life packages	100 years (aluminum)
PET bottles	Over 100 years
Sponges	Not determined
Cigarette butts	5 years
Polystyrene	Not determined

Chinaware	Not determined
Rubber gloves	Not determined
Metals (machine parts)	Around 450 years
Paper and cardboard	Around 6 months
Plastics (packages, utensils)	450 years
Tires	Not determined
Plastic bags	Over 100 years
Glass	Not determined

Figure 1: Decomposition time of various commonly discarded materials. (On-line Environmental Education for All, 2013).

The creation of cardboard also affects the environment. In order to make cardboard from virgin pulp, trees need to be cut down. This action will release sulfur dioxide into the air, fusing with gases in air to create sulfate, a harmful gas for both people and the environment (Leigh, 2009). Although the careless procedure in cutting down trees could also result in the destructions of forests and ecosystems, more companies are leaning towards collecting trees in sustainable woodlands (Postpack, 2012). Trees such as pine or birch can be sustainably cut down as they are plentiful and do not have a significant impact on the ecosystems of a forest (Wheeler, 2012). However, cardboard does not need to be made from virgin pulp only, as much of the recycled materials can contribute to its creation, making the production energy-efficient (Wheeler). These recycled materials could be from used cardboard, corrugated cartons, and old newspapers (Heritage Pioneer Corporate Group, 2013).

Some other environmental effects of cardboard include the fact that cardboard can accept non-toxic water-based inks, and it can be processed without bleaching (McCurry, 2010). Secondary packing or overwrapping, “according to the New York State Department of Environmental Conservation” (McCurry), is not needed in cardboard use. The inserts which may come with cardboard are usually recycled materials as well (Postpack, 2012). Cardboard is also created in many locations and the ones in use are usually from local producers, reducing the transportation cost and the environmental effects transportation brings (Black, 2013).

2.3. Economical

The use of corrugated cardboard gives great benefits economically. First, as aforementioned, cardboard use usually eliminates any overwraps or secondary packaging (McCurry, 2010). This

means the cost of using cardboard is mainly decided by the production cost of the cardboard itself rather than other additional costs. As one of the biggest segment in packing industry (McCurry), corrugated cardboard has the advantage of a well established economy, granting lower costs due to competition, than materials that do not have a very well developed economy. In addition, cardboard is produced in various locations, allowing users of cardboard to access the producers locally or regionally (Black, 2013). This close access can help grow the local economy to be wealthy, allowing the company which uses the cardboard products as packing material to grow together. The fact that the producer is close to the user also means lower transportation costs from the board's production to usage, compared to other materials which may not necessarily be produced in a nearby area.

The general cost of the corrugated cardboard is also economically beneficial. Since cardboard is so widely used and developed, the machines which create and shapes the cardboard is relatively cheap to access and to own. Thus, the cost of labor and tools in manufacturing the cardboard is cheap and readily available (Heritage Pioneer Corporate Group, 2013). The raw material of cardboard is generally lower than that of other materials. This is due to the fact that a large portion of the production of cardboard is utilizing recycled materials (Postpack, 2012), such as used cardboard, old newspaper, or other paper products, all of which get recycled at a relatively large scale.

Finally, the corrugated cardboard, especially when used as a packing material, can be reused for two to three years (Wheeler, 2012). This reuse of cardboard will avoid and delay disposal costs for a long time from the initial purchase time of the cardboard. The cardboard, however, may come with maintenance cost when reused. This cost is necessary when cardboard becomes 'contaminated', meaning if the cardboard previously contained contaminants such as "wax coatings, plastics, food, garbage, metal fasteners, staples, and nails" (Recycling Council of British Columbia, 2004).

2.4. Social

The use of corrugated cardboard has a number of social impacts. Firstly, cardboard provides numerous uses in people's daily state of affairs (PackagingPrice.com, 2007). People are familiar with what cardboard's purpose is and how to use the cardboard effectively to their desires. This means workers with cardboard can easily use the material to its maximum efficiency. There are

many locations that collect cardboard for recycling (McCurry, 2010). This widespread image of cardboard recycling can be helpful in making the companies which use cardboard as packing material appear more environmentally sustainable than their competitors. The public transparency of green, recycling, and sustainable intentions could help people choose such companies (Rebox Corp, 2012), in order to make a sustainable impact socially.

As mentioned above, the inks used on cardboard boxes are mostly water-based and non-toxic. In fact, more than 97% of boxes contained these non-toxic inks, which increases the safety of their usage (Recycling Council of British Columbia, 2004). Also, cardboard boxes, when not in use for packing, may be used for storage (Recycling Council of British Columbia), as having the versatility to fold them flat provides a practical means of storage. In fact, the density of the uncompacted cardboard boxes increase from 30 - 90 kilogram per cubic metre, to 180 - 300 kilogram per cubic metre when compacted (Recycling Council of British Columbia).

3.0. Bubble Wrap

3.1. General Overview

In a \$196 billion plastic packaging market, bubble wraps occupy \$3.5 billion (Peerun, 2013). Non-environmentally friendly materials such as plastic polymer film occupy the majority of the bubble wrap market. UBC is seeking to practice more sustainable methods of importing and exporting goods to/from the new SUB and set a new standard for suppliers and shipping companies to deliver goods with sustainable and environmentally friendly packaging. There are many different plastic packing products available in the market, such as: shrink-wrap, custom molded plastic cradles, windshield wraps, and bubble wraps. Most plastic products are very toxic to the environment when placed in landfills but new innovative products and processes are being developed to reach a more environmentally friendly standard (Rogers, 2012). This section will focus on bubble wraps and how their usage will impact the environment, economy and consumer attitudes.

3.2. Environmental

There are two different types of bubble wraps that are available in the market today, including: plastic polymer film bubble wraps, and biodegradable bubble wraps. Both materials must be analyzed and its sustainability compared in order to select the best choice for bubble wraps. Thus each material is studied in critical detail below.

3.2.1. Plastic Polymer Film

The well-known plastic polymer film bubble wrap has advantages and disadvantages when compared to their biodegradable counterpart. Its advantages include its availability, durability, and reusability. Companies that produce bubble wrap promise that these advantages mean that less wrap is needed, as it can be reused more frequently and be kept out of landfills. Nevertheless, these bubble wraps are, in practice, not as reusable as advertised, largely due to consumer behavior. These wraps are often thrown away, lying around in homes, or left back in the box to be stored away, instead of being sent back to the distributor. The low rate of reuse is also caused by the fact plastic is sticky and tends to stick to the product when removed from the packaging. Some people claim that popping bubble wraps is actually therapeutic and there are

celebration days for this purpose (King, 2012). The disadvantages of the polymer-based wraps are as follows: it is considered to be ecologically toxic due to the fact that it takes hundreds of years for the plastic to degenerate in landfills (Rogers, 2012). This is caused by the slow breakdown rate of plastic polymer films. Given that most of the bubble wraps used to pack and ship materials do not end up reused or recycled, it is obvious that a large portion of them end up in landfills, providing major hazards to the environment and those living within it. Unfortunately, the majority of the brands that sell packing materials are currently using the polymer-based formula.

3.2.2. Biodegradable Bubble Wrap

There are a few companies that now offer 100% biodegradable bubble wraps, namely EcoBox, and GreenLiving to name a few. EcoBox offers both plastic polymer film bubble wraps and biodegradable bubble wraps. An interesting fact about the BioBubble offered by EcoBox is that it is as durable and strong as the polymer based version. It contains a proprietary formula called d2W which is added during the production process of the bubble wrap. This additive will help the bubble wrap break down quickly in heat, sun light, and water (EcoBox, 2013). EcoBox claims that the only byproducts are small amounts of CO₂, H₂O, and biomass, which are very useful for soil and plants. A disadvantage of this alternative bubble wrap is that the claims made may not be very practical. Since landfills stack their waste, there is a possibility that the bubble wrap that ends up in the bottom of the stack may not have the necessary conditions to degrade. Therefore, these claims may be more of a marketing tool than a sustainable effort on the part of the manufacturers. Nevertheless, the overall product is of good quality and more ecologically friendly than the plastic polymer film variant.

There is no question that the strengths of the biodegradable version of the bubble wrap outweigh those of the plastic polymer film kind. Some companies also offer recycled versions of the product claiming to contain 30%, 50%, and up to 75% recyclable material (Sealed Air, 2011). No information is provided as to how degradable these recycled bubble wraps are, but knowing information on other recycled material, they presumably contain hazardous properties that keep the recycled material together.

3.3. Economical

The bubble wrap market generates an impressive \$3.5 billion a year, a large portion of that revenue coming from plastic polymer film bubble wraps. With the new introduction of the biodegradable counterparts of the product, the expectation is for the price to be higher than the polymer based version. Looking at history, new introductions of environmentally sustainable variants of a material usually come at higher costs.

Plastic Polymer Film Bubble Unit: 1 Roll of ½” x 24” x 25’ Price: \$10.39	BioBubble Bubble Wrap Unit: 1 Roll of ½” x 24” x 25’ Price: \$10.75
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Figure 2. Cost comparison between plastic polymer film bubble wrap and BioBubble bubble wrap (EcoBox, 2013).

Unlike most products that offer both environmentally dangerous and environmentally friendly solutions, the BioBubble is almost identical in cost to their landfill toxic counterpart. Although an additive has to be added to create the biodegradable bubble wrap, it only accounts for 3% of the product, hence there is only a small difference in price between the plastic polymer and biodegradable bubble wrap (EcoBox, 2013). In addition to its cost, the biodegradable wraps are also as strong and durable as the polymer based.

3.4. Social

Both types of bubble wraps have very dangerous properties around fire. Even though the material itself requires 500 degrees Fahrenheit of heat to become flammable, the structure and design of bubble wrap is the source of potential danger (Rogers, 2012). Since each roll of bubble wrap contains thousands of oxygen filled pellets, if it is brought in contact with fire, these bubbles can pop and trigger fires that spread very rapidly. This is a very serious problem since most consumers either leave the wraps lying around their homes or at work. Furthermore, bubble wraps are also very inefficient in the way they are stored. Since bubble wraps rely on air filled packets to protect the product, once rolled up, it can take up a considerable amount of space. Notably, most people are familiar with the small bubble wraps that they have seen in popular household products, but in commercial use, the size of each individual bubble can be very large and therefore very difficult to store. In addition, both polymer based and biodegradable bubble

wraps will eventually breakdown when exposed to heat and light, thus their shelf lives become shorter when stored in hot storage facilities such as restaurants and bakeries.

4.0. Packing Peanuts

4.1. General Overview

Packing peanuts are a form of loose fill packaging. Packing peanuts consist of two types of materials: a polymer and a blowing agent. A variety of polymers are used, all of which fall under two categories: expanded polystyrene (EPS or otherwise known as Styrofoam), and starch. A common blowing agent is water, although other proprietary materials and compounds may also be used. Peanuts are made in one of two methods: extrusion or baking.

Extrusion mixes together the polymer and blowing agent under high heat and pressure conditions. The mixture is then extruded through a small opening in the machine, and as it exits the machine, the blowing agent quickly expands and vaporizes, leaving behind an inflated polymer peanut. Packing peanuts can also be made by placing a starch-water mixture into a hot mould. Within this mould, the mixture gelatinizes, expands, and takes on the shape of its mould (Shogren, Lawton, Doane, & Tiefenbacher, 1998). The concentration of blowing agent can affect the baking time and density of the resulting peanut.

4.2. Environmental

4.2.1. Expanded Polystyrene (EPS)

Regular polystyrene is a petroleum product (Stanford University, 2007) that is non-polar and contains no hydroxy (-OH) groups, which makes it insoluble in water (Cook, Hall, & Donahue, 2003, 1288A-1288B). It can however be dissolved by some organic solvents such as acetone.

However, acetone is toxic when inhaled, and when it makes contact with the skin or eyes. It has also shown to have slight toxicity when exposed to aquatic and plant life. Since EPS loose fill is over 99.6% air, there is concern regarding the amount of space taken up in landfills by these peanuts (Plastic Loose Fill Council, n.d.). However in reality, EPS loose fill takes up less than 0.25% of the total landfill volume (Stanford University, 2007).

Recycled material has gained popularity in EPS packing peanuts. Peanuts are color coded according to its amount of recycled content (Green, n.d.):

- White: contains at least 70% non-recycled material
- Green: contains at least 70% recycled content
- Pink: chemically treated to reduce static cling

EPS packing peanuts can also be disposed of in one of the follow manners:

- EPS drop off site
- mail back
- reuse for loose fill; can bring to a local shipping office

4.2.2. *Starch based*

Starch based loose fill contains polar hydroxy (-OH) groups, which makes it soluble in water (Cook et al., 2003, 1288A-1288B). As such, starch packing peanuts are biodegradable, with no leftover residue aside from starch. It is generally made entirely from organic matter using either corn, wheat, potato or some vegetable starch as the polymer. In one study of starch based packing peanuts, the material composition of the packing peanuts of two different companies are as follows (Oregon Department of Environmental Quality, n.d.):

Company 1:

- 85-87% corn starch
- 13-15% proprietary biodegradable material

Company 2:

- 92-94% wheat starch
- 1-2% talc
- 4-7% a natural and biodegradable plasticizer

Since starch based packing peanuts are purely organic and biodegradable, they can be safely disposed in a variety of methods. They can be reused for packaging by returning it to a local shipping office, placed into compost, dissolved in water, or simply disposed in garbage. Starch packing peanuts, when decomposed in an oxygen-free environment, can produce a large amount of methane gas. However, most landfills are equipped with methods of capturing the methane produced and are capable of utilizing it as fuels to power homes, buildings and vehicles.

4.3. Economical

4.3.1. Expanded Polystyrene (EPS)

Expanded polystyrene packing peanuts are not naturally bio-degradable, although additives may be added to amend for this. EPS packing peanuts are very durable, capable of being reused up to 20 times without any significant impact on performance. It is not very recyclable however; the cost to process recycled EPS is an estimated \$3,000 USD per ton (Bothereau & Joffe, 1992). It would actually cost more money to recycle and process EPS than it would to manufacture from new materials.

Packing peanuts do not keep items in place, and as such do not offer extensive cushioning properties. Therefore, they are not well suited for handling delicate items. EPS packing peanuts are prone to generating static electricity, and have a tendency to cling to objects and apparel. In general, they are a light, waterproof and inexpensive method of filling the gaps when packaging (Faceless39, 2012).

4.3.2. Starch based

Starch based packing peanuts are generally heavier than EPS peanuts, which equates to a higher cost of purchase, as well as a higher cost for shipping (see table 1 for cost comparison). Starch packing peanuts are naturally low-static as it is made from corn and/or other vegetable matter such as wheat or potato. Starch's water solubility acts as a disadvantage when considering this material's reusability – not only are starch based packing peanuts vulnerable to moisture, they also tend to have lower resilience when compared to EPS (ExpandOS, 2012). It should be noted that in certain cases, such as for StarchTech's Might I, starch based packing peanuts have actually shown to have superior compression and strength (see figure 1) when compared to similar polystyrene alternatives.

Research has also been conducted to examine the viability of reusing starch based packing peanuts for the production of biofuels. In one experiment, a solution with a peanut concentration of 80 g l^{-1} , and a starch concentration of 69.9 g l^{-1} , was fermented for 110 hours (Jesse et al., 2002, p. 117-123). Following fermentation, 5.7 g l^{-1} of acetone was produced, along with 15.7 g l^{-1} of butanol and 0.3 g l^{-1} of ethanol, equating to a total ABE output of 21.7 g l^{-1} and an ABE

productivity of 0.20 g I⁻¹ (Jesse et al.). It may become possible to offset some of the premiums of buying starch based packing peanuts by reusing them as biofuels.

Material	Cornstarch	Material	Recycled Polystyrene
Volume	7.5 cu. ft.	Volume	7.5 cu. ft.
Properties	Reuseable Biodegradable Water soluble Anti-static	Properties	Reuseable Biodegradable 100% Total Recycled Content (green) Anti-static
Cost (USD)	\$36.75	Cost (USD)	\$16.76
Cost per ft ³	\$4.90	Cost per ft ³	\$2.23

Figure 3. Sample comparison of cost between starch and polystyrene packing peanuts (Grainger Inc., 2013)

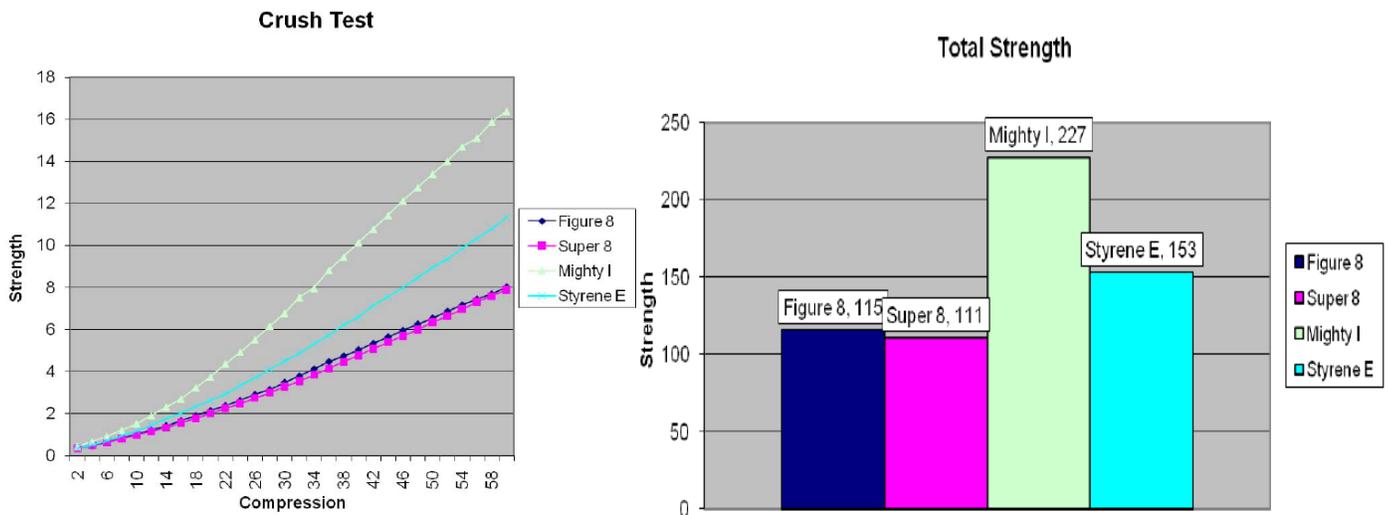


Figure 4. Crush test and strength comparison between starch based Mighty I and polystyrene competitors Figure 8, Super 8, and Styrene E (Starch Tech Inc., 2009)

4.4. Social

4.4.1 Expanded Polystyrene (EPS)

It has been found that prolonged exposure to the material styrene can adversely affect the nervous system, possibly causing fatigue, weakness, nausea, depression and loss of concentration. Acute health effects include irritation to the skin, eyes and upper respiratory tract

(Canadian Centre for Occupational Health and Safety, 2013). The static nature of EPS packing peanuts has also been found to be highly irritating to customers.

It is estimated however that processing recyclable material creates 10 times more jobs per ton of waste, and companies that use recycled materials tend to employ 60 times more workers than landfills (Green Plus, 2011). As such, the production and manufacturing of EPS packing peanuts can potentially help to create a large number of new job opportunities.

4.4.2. Starch based

Starch based packing peanuts are purely organic and non-toxic. They do not have any adverse effects on health; in fact they can even be safely ingested. Perhaps the largest concern regarding starch based loose fill is the fact that it is made using food matter. Questions may arise regarding whether these food resources should be allocated elsewhere for consumption use rather than for industrial packing purposes. However, according to one starch packing peanut company Starch Tech, the company alone uses over 13,000,000 pounds of starch annually for the production of packing peanuts. However, that amount is less than 2% of the total amount of corn produced worldwide which amounts to millions of metric tons (Starch Tech Inc., 2012).

5.0 – Conclusion

From our investigation into corrugated cardboard, it was decided that the best application would be for external packaging. As an external container, corrugated cardboard remains one of the most versatile materials. Made entirely from natural, biodegradable materials that are reusable and recyclable, and in addition its overall benefits, cardboard is an ideal material for storing and managing goods.

After the analysis of bubble wraps, it can be concluded that biodegradable bubble wraps are in fact an advantageous packing product. The only shortcoming of bubble wrap as a packing product is its limited shelf life and the possibility of fire hazards that it fosters. Furthermore, the reusability of bubble wraps in practice is quite low, due to its sticky property and proposed therapeutic characteristic. On the other hand, a promising advantage is the small and nearly negligible discrepancy between the cost of the biodegradable versus the plastic polymer based bubble wraps. Nevertheless, claims that biodegradable bubble wraps are 100% degradable in landfills could be questioned since current and traditional landfill practices are not tailored to the degradation conditions of this material. Also, manufacturers have not made it as much of a priority to state the specifics of how and when biodegradable bubble wraps actually decompose. Similarly, it is evident that the overall benefits of starch-based packing peanuts outweigh the advantages of EPS packing peanuts. Traditional EPS peanuts are very durable, very light, and inexpensive to purchase. However, it is not degradable so it would only take up space when placed in landfills. Also, prolonged exposure to EPS can cause adverse side effects, which is a serious social concern, particularly with respect to the health of the workers making EPS packing peanuts. On the other hand, starch based peanuts are fully biodegradable, and offer many different environmentally friendly methods of disposal. From an economical perspective, starch based loose fill does not offer the same level of resilience or reusability as EPS, and comes at a higher cost than EPS. However, it does have the potential to be reused as biofuel which could help offset the premium paid for starch based packing peanuts. Additionally, since locally grown corn can be used to make starch based peanuts, more money can be invested to improve the local economy.

Between the two possibilities of biodegradable bubble wrap and starch based packing peanuts, the superior material choice is not immediately evident. As discussed above and summarized in figure 5 below, both materials have their respective strengths and weaknesses. Ultimately,

starch based packing peanuts appears to be the better option as it offers better all around value than the biodegradable bubble wrap.

Material	Durability	Cost	Reusability	Degradability	Social Impact
Biodegradable Bubble Wrap	+	+	-	-	-
Starch Based Packing Peanuts	-	-	+	+	+

Figure 5. Comparison between the performance of biodegradable bubble wrap and starch based packing peanuts.

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