UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into the use of Rapidly Renewable Materials in the Student Union Building

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ABSTRACT

Stakeholders in the new Student Union Building (SUB) - including students, staff, and residents of UBC – value living socially, environmentally, and economically sustainable lives. As such, the team responsible for designing the new SUB is aiming to produce a building that meets the heralded LEED platinum standard. Using rapidly renewable and/or recyclable materials in the construction of the proposed building would contribute towards the achievement of this goal. This report conducts a triple-bottom-line analysis of two such materials, linoleum and wheat board, based on existing literature.

Linoleum is a sheet material that is primarily used for floor covering. When considering the total cost of ownership, linoleum is cheaper than vinyl flooring, yet more expensive than poured epoxy flooring. The social and environmental benefits of linoleum far outweigh those of vinyl and poured epoxy. Vinyl and poured epoxy are both hazardous to the manufacturing and installation staff; require more frequent replacement than linoleum; and are damaging to the environment upon disposal. Linoleum releases less VOC's than vinyl flooring; can be burned for significant energy when disposed; harmlessly degrades when landfilled; and contributes to multiple LEED point categories. For the aforementioned reasons, linoleum would be an ideal floor covering for the food service areas in the new building.

Wheat board is a pressed fiber board consisting of 100% wheat – as opposed to a traditional medium-density fiberboard (MDF) produced from wood products. Wheat board is comparable in cost and strength to its MDF counterpart, yet releases fewer odors

into its indoor environment. Wheat board would be an ideal material for constructing tabletops and cabinets in the new SUB building.

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LIST OF ABBREVIATIONS

DBP – Dibutyl phthalate

EU – European Union

IARC – International Agency for Research on Cancer

LEED – Leadership in Energy and Environmental Design

MDF – Medium-density fiberboard

MDI – Methyl diphenyl disocyanate

PVC – Polyvinyl chloride

SUB – Student Union Building

UBC – University of British Columbia

VOC – Volatile organic compounds

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1.0 INTRODUCTION

Due to the growing needs of the University of British Columbia (UBC) community, the university is in the process of designing and constructing a new Student Union Building (SUB). The design committee is aiming to produce a building that meets stringent environmental, social, and economic standards. A building's success along these axes can be quantified through the measurement of Leadership in Energy and Environmental Design (LEED) points obtained by that building. LEED is a certification system that allocates points for the degree to which a building's design: (1) saves energy, (2) increases water efficiency, (3) reduces CO_2 emissions, (4) improves indoor air quality, and (5) stewards resources and is sensitive to their impact. Along the theme of resource stewardship, the Canadian LEED system offers a significant number of points towards the use of rapidly renewable materials in a new construction. Rapidly renewable materials are plant-based materials that can be replenished within ten years. To determine which materials are worth pursuing, the design committee has commissioned different groups of students in our *APSC 262: Technology and Society* class to perform an analysis of different rapidly renewable materials available for use in the new building.

This report investigates rapidly renewable linoleum and wheat board as potential building materials to use in the new SUB. Our analysis proceeds as a triple-bottom-line analysis - concentrating on environmental, social, and economic issues – in contrast to a traditional single-bottom-line analysis which focuses only on economic issues.

2.0 LINOLEUM

Linoleum is a resilient floor covering made from linseed oil, pine tree rosin, wood flour, cork flour, limestone, pigments, and jute cloth. To manufacture linoleum, the aforementioned materials (except jute cloth) are processed into linoleum granules. These granules are then pressed into the jute cloth backing to form linoleum sheets, and curated for a number of weeks in drying rooms. Once dry, the linoleum sheets are a flexible yet resilient material for floor covering (Green Floors, 2011) (Gorrée et al, 2002). Cork, linseed oil, and jute backing – comprising between 32 and 75% of modern linoleum – are all rapidly renewable materials.

The following sub-sections serve to evaluate the use of linoleum as a flooring material in the new SUB. The merits of linoleum are contrasted against the merits of sheet vinyl flooring, and against the merits of poured epoxy resin flooring. The *Foodservice Schematic Design Report*, contained within the *New SUB Project: 75% Schematic Design Report* (2010), recommended these materials as preferred choices for back of house food preparation areas – for which linoleum could possibly act as a replacement. With 12% of the proposed SUB dedicated to food service operations, replacing vinyl or poured epoxy with a rapidly renewable material would have significant impact on the sustainability measure of the building. Although these benchmark materials were initially chosen due to their placement in the food services floor space, the following comparison may still prove valuable for decision making in other areas of the SUB. The following sub-sections present a triple-bottom-line analysis of the economic, social, and environmental merits to using linoleum – over sheet vinyl, and poured epoxy resin - in the new SUB.

2.1 Economic Aspects

Moussatche, H. and Languell, J. (2001) performed a lifecycle cost analysis of 20 different flooring materials used in Florida's elementary schools. Linoleum, epoxy resin, and sheet vinyl were a subset of the materials they investigated. The study was grounded on official construction documents, empirical data collection, and manufacturer material specifications. This was the best lifecycle cost analysis we found for these materials, because all data was obtained from within a single organization, so we are certain that valid comparisons can be made.

The lifecycle cost, over a 50 year period, for each of the flooring types can be seen in Figure 1 and Table 1. The total costs of ownership were calculated by taking the initial capital cost of installation, the accruing costs of maintenance, and the cost of periodic floor replacement and discounting all expenditures to the net present value (assuming 3% inflation). We can see that epoxy resin is the lowest-cost alternative, followed by linoleum as next lowest-cost, and finally vinyl as highest-cost. It is interesting to note that the capital cost for linoleum is over double the capital cost for vinyl sheet, yet linoleum is more cost-effective in the long run. The cost savings of linoleum stem from its long service life, and low cost of maintenance.

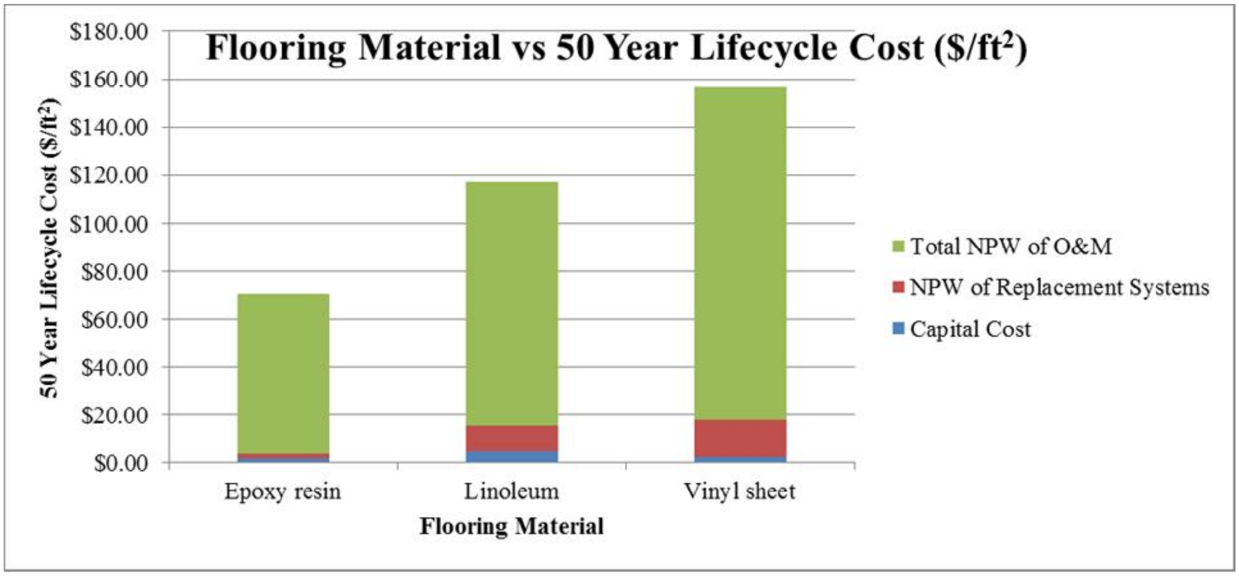

Figure 1 Lifecycle cost breakdown for epoxy resin, linoleum, and vinyl sheet flooring.

Table 1 Comparison between epoxy resin, linoleum and vinyl sheet flooring

Flooring System	Capital Cost ($/ft^2)	System Service Life (years)	Number of Replacement Systems	NPW of Replacement Systems ($/ft^2)	Maintenance as a Percentage of Capital Cost	Maintenance Cost ($/ft^2 per year)	Total NPW of O&M ($/ft^2)	Total Cost of System in NPW ($/ft^2)
Epoxy resin	$1.60	12	4	$2.28	37.00%	$0.59	$ 66.78	*$70.66*
Linoleum	$4.50	30	1	$10.92	20.00%	$0.90	$ 101.52	*$116.94*
Vinyl sheet	$2.05	15	3	$15.92	60.00%	$1.23	$ 138.74	*$156.71*

2.2 Social Aspects

Social issues surrounding the use of linoleum in the new SUB will be discussed in the following sub-sections.

2.2.1 Effects on workers

The first demographic exposed to any flooring material are the people responsible for the manufacturing and installation of that material. The Mayo Clinic staff (2010) placed users of epoxy resin on their list of occupations with the highest risk of developing occupational asthma, due to the presence of anhydrides. To make vinyl flooring flexible, manufacturing processes make use of phthalates as plasticizers. One commonly used phthalate is DBP. The EU published risk reports in 2005-2006 that highlighted DBP as a health risk when inhaled by workers (Buekens and Sevenster, 2010). Phthalate's have been linked with infertility, testicular damage, reduced sperm count, and a few other categories of reproductive and development damage (Thornton, 2000). This risk can be mitigated through proper air treatment and personal protective equipment – but is present nonetheless. Other research showed that the feedstock, additives, and by-products used during the production of vinyl can lead to the following health conditions for workers: (1) Cancer (2) Disruption of the endocrine system (3) Reproductive impairment (4) Impaired child development and birth defects (5) Neurotoxicity (6) Immune system suppression (Thornton, 2000). We did not find such widespread concern over the negative effects of the linoleum manufacturing process on its workers or installers.

2.2.2 Effects on indoor air quality

In modern society there is just as much emphasis placed on maintaining comfortable and healthy indoor environments as there is on the use of environmentally friendly building materials. Perceived indoor air quality is one comfort aspect of a building that is readily noticed by its inhabitants. It has been found that, as linoleum degrades over time, it emits small amounts of VOCs (including hexanal, propanoic acid, hexanoic acid, and various aldehydes) into its indoor environment (Knudsen et al, 2007). The emitted VOCs originate as a by-product of the oxidization process during production, and from inherent properties of the linseed oil (Jensen et al, 1995). For this reason, some sources do not recommend linoleum for applications with major exposure to children (Build It Green, 2007) – such as a child minding center. In one study, a panel of participants was commissioned to smell air chambers containing different building products, and report on the air quality contained within each chamber. Products containing linseed oil (including linoleum) were found to impact the air quality more negatively than their synthetic counterparts (Knudsen et al, 2007). Although linoleum does release VOCs into the indoor environment, the phthalates released by vinyl products appear to be more hazardous to inhabitants. Three separate studies have confirmed that prolonged exposure to vinyl significantly elevates risk of bronchial obstruction, wheezing, pneumonia, prolonged cough, and irritation of the nasal passages and eyes (Thornton, 2000).

2.2.3 Antimicrobial properties

The goal of hygiene is to reduce the levels of harmful microorganisms in an environment to an acceptable level. Proper hygiene lowers the likelihood of human infections and the contamination of food by pathogens. Linseed oil, and therefore linoleum, possesses natural antibacterial qualities (Gur et al, 2006). One study conducted on the survival of amoebae on building materials found that amoebae cannot survive on linoleum, whereas they can survive on many other common materials (Yli-Pirilä et al, 2009). These anti-microbial properties make linoleum an ideal candidate for the food services floor space.

2.3 Environmental Aspects

Environmental issues surrounding the use of linoleum are discussed in the following sub-sections.

2.3.1 Disposal

A floor covering inevitably reaches the end of its useful service life, and requires replacement. Linoleum is fully biodegradable and doesn't contain any harmful substances, such as chlorine, dioxins, or heavy metals. Therefore, when landfilled, it harmlessly decomposes back into nature. Alternatively, linoleum produces a calorific value of 18.6 MJ/kg when incinerated – energy comparable to coal (Green Floors, 2011). Vinyl flooring is not as easily disposed because it contains lead as a stabilizer. When incinerated, the lead is not destroyed, but is released into the environment as air emissions and ash residue. When landfilled, lead can cause neurological, development and reproductive damage to humans as it escapes into the environment through leachate run-off (Thornton, 2000). The PVC industry has taken strides towards removing heavy metals from PVC. They were able to phase out the use of cadmium in the late 1990's - but modern PVC will contain lead until at least 2015 (Buekens and Sevenster, 2010). Due to its natural composition, linoleum is much more environmentally friendly to dispose of than its synthetic counterparts.

2.3.2 LEED Credits

Linoleum is manufactured by Armstrong, Forbo, and Tarkett. With respect to the new SUB, linoleum products from all three companies are eligible for LEED credits in the categories of *Recycled Content*, and *Rapidly Renewable Materials* (LEED Canada for

New Construction and Major Renovations 2009, 2010). The product data relevant to achieving points in these categories can be seen in Table 2. Tarkett's product contributes the most towards the *Rapidly Renewable Materials* credit; Forbo's product contributes the most towards the *Recycled Content* credit.

Unfortunately, although Canada is the largest producer of the flax seeds used to create linseed oil, the new SUB is not be eligible for *Regional Materials* credits due to the locations of linoleum manufacturing plants. All linoleum manufacturing plants are located in Europe and Eastern North America, outside the range of the 800km regional boundary.

Table 2 Product data relevant to LEED accreditation (Holmes & Associates, Inc.) (Armstrong Commercial Flooring, 2008) (Tarkett Commercial).

Company	**Rapidly Renewable Materials**	Pre-consumer Recycled Content	Post-consumer Recycled Content	**Recycled Content Towards Credits**
Forbo	32%	0%	45%	45%
Armstrong	36%	35%	0%	17.5%
Tarkett	75%	0%	35%	35%

3.0 WHEAT BOARD

Particle boards made from agricultural product are becoming increasingly more popular as a result of a rising wood product demand and a falling availability of wood. Among all particle boards, wheat board is a distinctive composite material made from wheat straw – a rapidly renewable resource.

As a rapidly renewable material, wheat board is a recently developed substitution for MDF - a common material used to build furniture. After being invented in the 1960s, MDF has been a staple in both furniture and construction markets for several decades due to its durability, dependability, low cost and excellent mechanical properties. However, formaldehyde is required as a binder for manufacturing MDF. As a result, formaldehyde is emitted from the surface of MDF board as it ages, posing a health hazard to humans. Wheat board products are formaldehyde emission free in both manufacturing and daily use. Moreover, these environmentally friendly materials feature thermal and acoustic insulation, as well as fire and termite resistance. For these reasons, wheat board is becoming widely used in the construction of non-load-bearing ceilings, wall coverings, roofing, furniture, doors and flooring.

The following sections will first cover the manufacturing process and the mechanical properties of wheat board. Then economic, social and environmental impacts will be assessed.

3.1 Manufacturing

During the manufacturing of wheat board, wheat straw is first cross-cut. Then the resulting particles are screened into surface particles, core particles and dust waste. The surface and core particles are spread with glue and put through a series of processes that include prepressing, hot pressing, cutting, and cooling (Norford, 1999). Once cooled, the board is ready for use in construction.

3.2 Properties

The mechanical and physical properties of wheat board depend on a number of factors, including types of adhesives and press time. Table 3 lists the typical mechanical and physical properties of wheat board.

Based on the information in Table 3, it is obvious that the tensile strength and internal bond strength of wheat board are fairly low, meaning that wheat board possesses poor load-balancing ability. However, the modulus of elasticity is quite large, giving wheat board a relatively good ability to deform elastically. As a result, wheat board should only be used for interior applications.

Table 3 Mechanical and physical properties of wheat straw board (Mo et al, 2003)

Wheat Board		
Tensile Strength	11.45 MPa	
Modulus of Rupture	18.1 MPa	
Modulus of Elasticity	2281 MPa	
Internal Bond Strength	0.64 MPa	
Thickness Swell	2 hours	14.60%
	24 hours	27.30%
Water Absorption	2 hours	13.20%
	24 hours	47.50%

Moreover, from the table it can be observed that both the thickness swell rate and the water absorption rate are quite low. In fact, both the thickness swell rate and the water absorption rate for wheat board are lower than those of traditional MDF. This makes wheat board a better choice than MDF as an interior furniture material.

3.3 Social Aspects

As an alternative material to wooden MDF, wheat board can be applied in the new SUB building for many functions, such as laminate surfacing, painting and staining. Wheat board can even serve as a material for roofing, ceilings and doors. Thus, it is obvious that the new SUB project will require a great demand for at least one of these two materials. As previously mentioned, the biggest downside to MDF is formaldehyde emission. Inhaling formaldehyde is hazardous to humans – leading to irritation of lungs, eyes and mucous membrane. Moreover, the International Agency for Research on Cancer (IARC) announced that formaldehyde has been classified as a carcinogen under the 2A group. If MDF boards are used in this project, formaldehyde emissions could lead to a health crisis, especially since the SUB is in a location where MDF boards age rapidly. An application of wheat board would completely avert this potential crisis.

Moreover, even though wheat board is newly developed, its production is suited to the same machining methods as wooden MDF. Therefore, it is feasible for traditional MDF manufacturers to switch to producing wheat boards.

However, there are some disadvantages and limitations of wheat board. As mentioned before, wheat board can only function as an interior material due to its low strength. Moreover, since the wheat board product is not widely known about, there is a lack of local distributors and retailers.

3.4 Environmental Aspects

First of all, wheat board manufacturing use wastes from wheat harvesting, which is absolutely natural, rapidly renewable, and sustainable plant fiber harvested annually. If wheat board is adopted, the demand for timber is reduced, which in turn reduces the need to destroy forests. Moreover, by using an alternative adhesive, methyl diphenyl disocyanate (MDI), both manufacturing and use of wheat board cause absolutely zero formaldehyde emissions. Although MDI can still trigger certain allergens and sensitivities, we still think wheat board is a perfect material for the new SUB project.

Finally, applying wheat board in the SUB building will be an excellent fit for this green building project to pursue LEED certification. The LEED requirements relevant to the application of wheat board can be seen in Table 4.

Table 4 LEED credit requirements

	Credit Requirements	Points earn
A	20% of the building materials used must be made of recycled materials	2
B	20% of the materials extracted, process and manufactured regionally	2

Firstly, the raw materials used to produce wheat board are recovered waste from pre-consumer agricultural production. Therefore, a good percentage of wheat board usage will definitely contribute towards the two points in requirement A.

Secondly, Western Canada produces a considerable amount of wheat annually - resulting in sufficient local raw materials for wheat board production near Vancouver. Thus B should also be easy to achieve by finding a regional wheat board supplier.

3.5 Economic Aspects

Most likely due to the volume of board produced; the cost of wheat board is significantly higher than of traditional MDF. The cost of solid core wheat board is between $0.80 and $0.90 per square foot. The cost of MDF is around $0.675 per square foot (Kadam and McMillan, 2003). Although, since wheat board is lighter, its associated transportation costs are slightly lower, and therefore an accurate total cost would need to account for transportation costs.

4.0 CONCLUSIONS

Based on the information presented in this report, we would recommend using both linoleum and wheat board in the construction of the new SUB.

Linoleum is aptly suited for use in the food service area. The *New SUB Project: 75% Design Schematic Report* (2010) recommended sheet vinyl or poured epoxy for this area – but we feel that linoleum would be advantageous over both of these materials. Economic factors alone do not justify the use of linoleum – its total cost of ownership exceeds that of poured epoxy resin, but is lower than that of sheet vinyl. The environmental and social impacts of linoleum differentiate it from the alternatives. Although the antimicrobial properties of linoleum make it an appealing choice for the child minding center, we would recommend against this, because linoleum was found to emit small amounts of potentially harmful odors.

Wheat board is aptly suited for use in cabinets, tabletops, and other furniture. It's has a comparable strength and cost to a wooden MDF counterpart, yet is made from 100% rapidly renewable materials.

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