UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Rapidly Renewable Materials – Soy and Bio-Diesel

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ABSTRACT

The University of British Columbia's (UBC) is hoping to have its new student union building (SUB) be granted platinum Leadership in Energy and Environmental Design (LEED) certification. LEED is a point based system which gives applicants points for meeting certain building criteria. The criteria on which lead points are gained are organized into the following six categories: sustainable sites (SS), water efficiency (WE), energy and atmosphere (EA), materials & resources (MR), indoor environmental quality (EQ), and innovation in design (ID). Using Rapidly Renewable Materials in the construction and furnishing of a building potentially grants points in SS, MR, EQ, ID areas in the LEED system

A Triple bottom line analysis was conducted on Soy based spray foam and bio-diesel furnaces. Soy based spray foam and biodiesel furnaces were considered as an option in insulating and heating of the new SUB. Triple bottom line analysis takes into consideration environmental, social, and economic impact of a given project. Following a triple bottom line analysis framework, soy based spray foam insulation is compared with other industry accepted insulations and bio-diesel furnaces are compared to petroleum and natural gas based furnaces.

Following the triple bottom line analysis Soy based spray foam insulation was found to be a preferable and viable alternative to any other insulation material commonly used on projects similar to the new SUB. Soy based spray foam R value is directly comparable to the R values of other insulating materials while providing the environmental and social benefits that of an RRM. Bio-diesel furnaces were found to be a suitable alternative to petroleum based and natural gas powered furnaces given the social and environmental benefits.

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GLOSSARY

Triple Bottom Line Analysis	Is the analysis of a system taking into account economic, environmental and social factors.
Rapidly Renewable Materials	Materials which are regenerated within ten years of harvesting
LEED	Leadership in Energy and Environmental Design is a system in which LEED points are granted for green building methods and materials
Bio-diesel	A vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl) esters
B20	A blend of diesel (20% bio-diesel 80% petroleum diesel)
B100	A blend of diesel (100% bio-diesel)
Emissions	CO_2, CH_4, N_2O, S, P
Fossil Fuels	Fuels formed by prehistoric, decomposed and dead organisms
R-value	Measure of thermal resistance used in the building and construction industry. It represents the ratio of temperature across the boundary.

LIST OF ABBREVIATIONS

RRM Rapidly renewable resource

LEED Leadership in Energy and Environmental Design

CO_2 Carbon Di-Oxide

BTU British Thermal Unit

GGE Gasoline Gallon Equivalent

CNG Compressed Natural Gas

CFC Chlorofluorocarbon

GHG Greenhouse Gas

1 INTRODUCTION

The University of British Columbia (UBC) has many initiatives for campus sustainability, to that end the UBC administration and students wish the new Student Union Building (SUB) to achieve Platinum Leadership in Energy and Environmental Design (LEED) certification. LEED is a point based system in which points are awarded for various construction methods and materials used. One such way to receive LEED points is by using Rapidly Renewable Materials (RRM) in the construction and furnishing of the new building. RRMs are construction materials that can be rapidly replenished as they are used. Some examples of RRMs are cork, bamboo, and soy based products. Another way in which LEED points are gained is by the sourcing of the materials used for construction and furnishing. LEED points are given if a construction material is produced within 500 miles of where it will be used.

This report conducts a Triple Bottom Line analysis of two RRMs, soy based spray foam and bio-diesel furnaces for use on the UBC's new SUB. In a triple bottom line analysis framework, soy based spray foam is compared with many conventional insulating materials, and bio-diesel furnaces are compared with petroleum and compressed natural gas (CNG) fed furnaces. The results of our analysis can be used to determine the viability of using soy based spray foam, and bio-diesel furnaces to help the new SUB achieve LEED Platinum certification.

2 BIO-DIESEL

2.1 INTRODUCTION

Bio-diesel is considered an RRM because the raw materials which go into its production can be regenerated within 10 years. It is a fuel alternative to petroleum based diesel whose combustion yields a smaller quantity and lower toxicity of emissions. Bio-diesel is growing in popularity and is able to involve the general population in the fuel life cycle. Given the benefits of bio-diesel, it should be considered for use in the Student Union Building.

A bio-diesel furnace which will heat the new SUB is a great application of bio-Diesel. This paper will - in a triple bottom line analysis frame work - compare bio-diesel powered furnaces to diesel and CNG furnaces, as well as bio-diesel in general. Given UBC's desire to have the new SUB be platinum LEED certified, the use of a furnace fuelled by bio-diesel which is processed from recycled material from local sources will help the project's application for LEED platinum certification.

2.2 ECONOMIC

When compared to diesel and CNG, bio-diesel has a significantly higher principle cost given the large amount of raw ingredients (labour intensive farming), processing and minimal market supply. The higher cost of bio-diesel is shown in table 1 below.

Table 1- Cost Comparison per million BTU (Vern Hofman, 2003)

	Unit	Price per unit (USD)	BTUs per unit	Price per million BTU (USD)
Natural Gas (CNG)	GGE	1.93	121,600	15.87
Diesel	Gallon	3.45	128,700	26.8
Bio-diesel (B100)	Gallon	4.05	117,093	34.59

Note that these prices are from "Alternative Fuel Price Report - January 2011" using the national average in the US. Also, for CNG the conversion is used: 1 GGE is 126.67cu ft.

It is clear from the above table that B100 Biodiesel is the most expensive (EnergyBible.com, 2010), whereas CNG is the cheapest. As acceptance of bio-diesel increases and production levels increase the market price will drop. It is economically not feasible to operate on bio-diesel given its increased operating cost over petroleum based diesel or CNG. However, once the many environmental and social benefits of operating on bio-diesel are taken into account, it becomes more justifiable to operate on bio-diesel.

Bio-diesel has a lower flame temperature than diesel fuel, also bio-diesel furnaces currently are not as efficient as regular diesel furnaces (Gustavo Rodrigues de Souza, 2009). Given the current limitation on bio-diesel furnace technology it is more costly to operate a bio-diesel furnace. In the future as bio-diesel furnace designs are improved and their efficiency problems are resolved it will be much more economically viable to operate bio-diesel furnaces.

Figures 1 and 2 demonstrate the lower thermal efficiency of bio-diesel compared to diesel.

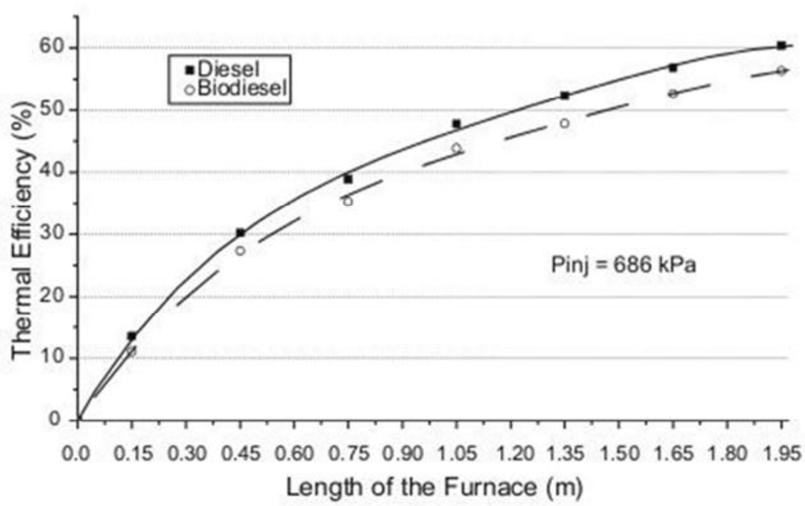

Figure 1-Thermal efficiency per length (Gustavo Rodrigues de Souza, 2009)

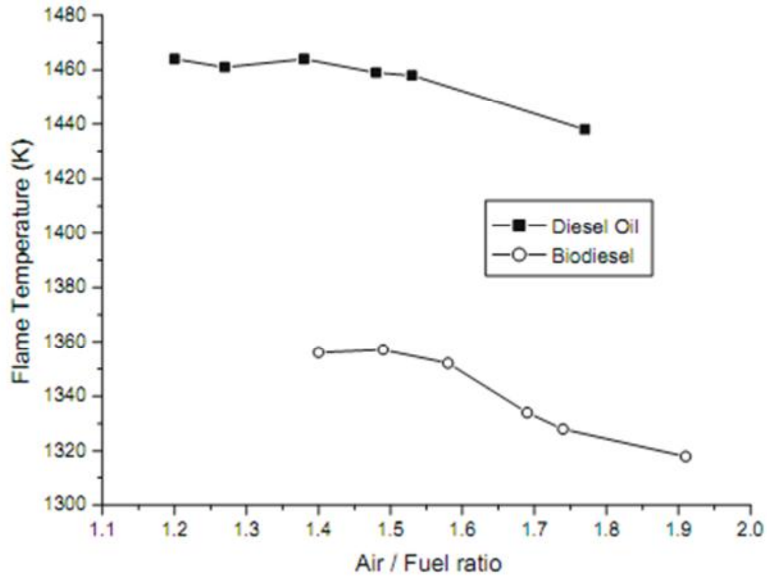

Figure 2-Comparison of flame temperature (Gustavo Rodrigues de Souza, 2009)

2.3 ECOLOGICAL

Net Energy Balance (NEB) is an important measure as it compares the output energy of bio-diesel with the fossil fuel energy input used to produce it. The NEB for bio-diesel is large, (Jason Hill, 2006) as shown in figure 3:

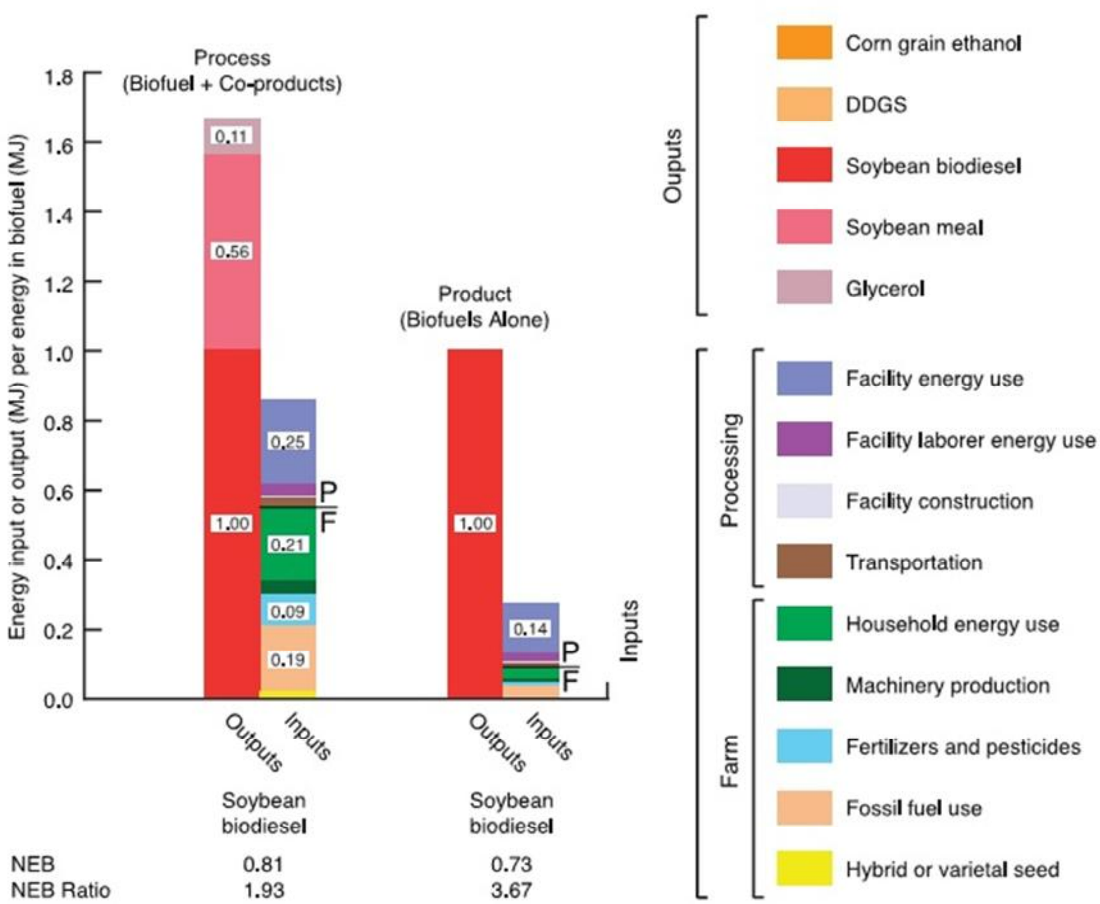

Figure 3-Net energy balance for bio-diesel (Jason Hill, 2006)

The energy inputs and outputs are expressed as per unit energy of the biofuel. For the bio-diesel alone, 3.67 units of bio-diesel energy can be produced with an input of 1 fossil fuel energy unit (Jason Hill, 2006). This makes bio-diesel a favourable alternative from an environmental standpoint as it reduces the need to use fossil fuels.

CO_2 is a major contributor to the greenhouse effect which causes global warming. An important environmental benefit of bio-diesel is it's reduced CO_2 emissions. Compared to petroleum based diesel, bio-diesel emits 78% less CO_2 thus is far less damaging to the environment (Jason Hill, 2006).

Table 2 - Emissions of Bio-Diesel compared to Diesel

EMISSIONS	100% Bio-Diesel	20% Bio-Diesel
CO	- 43.20%	- 12.60%
HCs	- 56.30%	- 11.00%
NOx	+ 5.80%	+ 1.20%
CO2	- 78.00%	- 15.70%
Particulates	- 55.40%	- 18.00%
Air Toxins	- 60 to 90 %	- 12 to 20 %
Mutagenicity	- 80 to 90 %	- 20%

CO_2 is a major contributor to global warming; however, it is not the only damaging emission. Many toxic chemicals are emitted when petroleum diesel is burned. Some chemicals which are released are benzene, arsenic and formaldehyde (Assessment, 2007) . Combustion of bio-diesel produces less of the aforementioned chemicals and thus is a preferable fuel.

Bio diesel can be produced from 100% recycled materials (Vern Hofman, 2003). Used vegetable oil can be processed into bio-diesel. The recycling of waste oil into useable bio-diesel reduces the amount of waste produced.

2.4 SOCIAL

There are several social benefits to using bio-diesel as compared to standard diesel and CNG. Bio-diesel can involve the community, promotes agriculture, increases knowledge of renewable energy sources and reduces dependence on foreign fossil fuels. In contrast, petroleum diesel and CNG are non-renewable energy sources which require a great amount of energy to be extracted from the earth, then refined and shipped to consumers.

The UBC community can be utilized in the production of bio-diesel. For instance if UBC residences, cafeterias, and restaurants across campus systematically collected all their waste cooking oil, they can deposit them at a local bio-diesel reactor. A local bio-diesel recycling program in conjunction with a local bio-diesel reactor effectively brings all campus residents and businesses into the fuel supply chain. With the community's involvement in the fuel supply chain, a greater emphasis will be placed on conservation.

There are several debates about bio-diesel production competing with food sources. This is true if bio-diesel is produced from soy or corn. However, as discussed previously, bio-diesel can be made from waste oil and even algae. Bio-diesel derived from algae is a promising prospect as estimates state that significantly more bio-diesel can be produced by an acre of algae production, compared to an acre using conventional terrestrial plants (Algaewheel Technologies, 2011).

3 SOY SPRAY FOAM

3.1 INTRODUCTION

When asked about soy, most people will probably mention the soy latte they had that morning. Soy, or more precisely, soya bean, is a species of legume that is widely cultivated for the edible bean inside the casing. This is why most people's initial perception of soy is as a food product, not a building material; however, a strong case can be made as to why soy can, and should, be used as an integral part of all green buildings in the near future.

Soy as a resource is used in a wide variety of products, ranging from the mundane like the wax in crayons to being used as the majority crop (80%) for the production of bio-diesels in North America (National Biodiesel Board, 2008). For the purpose of this report and its relevance to the new SUB project, our group has chosen to do research into the usage of soy as an insulating material and method since it is the most easily adaptable usage of soy. The soy product being used here is actually soybean oil and is harvested annually from soya bean plants. LEED certifies a material as being rapidly renewable if the material can be re-grown and harvested within 10 years, so soy certainly applies to this. The soybean oil is inert and as such does not attract rodents or insects and cannot be eaten as nourishment. The oil is used as a replacement for other oils in spray foam insulations, which is how we are suggesting soy to be utilized in the SUB.

Like all spray foams, soy-based spray foam consists of two components: the A-side, which is essentially the catalyst that causes the foam to expand and harden, and the B-side, which contains all the chemical components of the foam (Urethane Soy Systems). These two components mix upon spraying, like epoxy, to combine together to form the final product. However, unlike other spray foams, Soy-based spray foams use soy to replace up to 15% of the petroleum commonly used (Levin, 2009). Different companies will have different recipes for their B-side, but they all roughly have the same final results. Another material property of soy insulation is that the blowing agent used to liquefy the product before expansion is water (Urethane Soy Systems) instead of potential ozone-depleting gases used in other sprayed products.

3.2 ECONOMIC

The majority of the economical discussion surrounding soy foam will be based upon its ability to insulate and prevent heat loss; after all, that's the primary function of any sort of insulation. If soy is able to provide efficient thermal insulation, then it will, in the long run, provide cost savings.

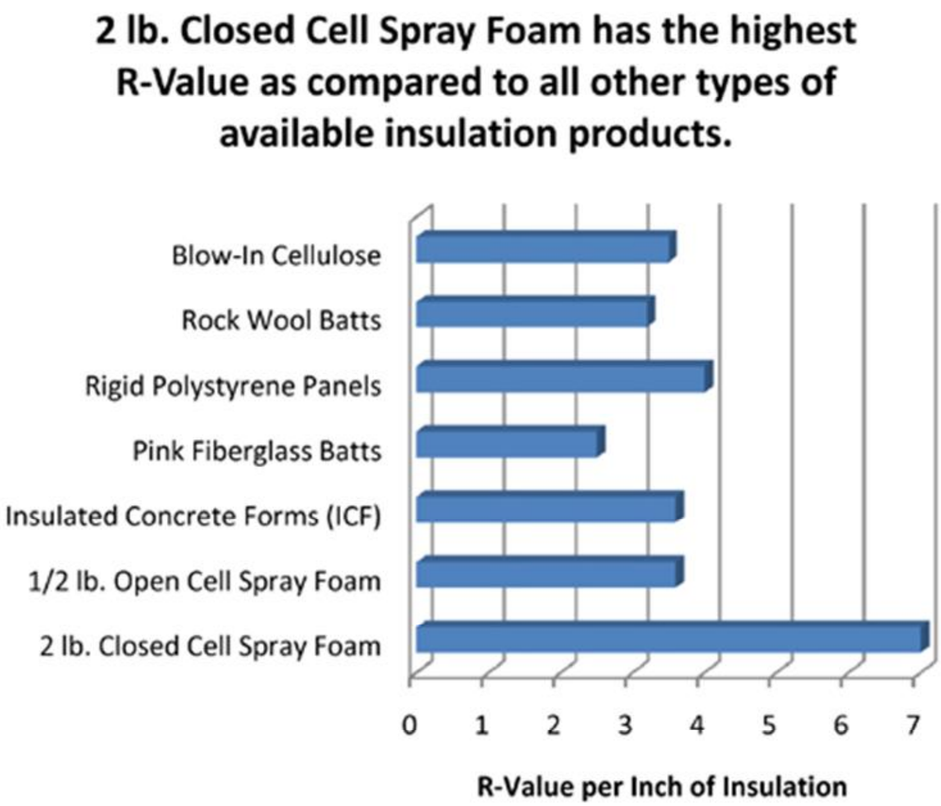

Figure 4- Comparison of Closed Cell Soy Foam Insulation with Popular Insulation Choices (Enviro Foam Insulation, 2008)

As seen in the figure above, closed cell spray foam has a significant advantage when it comes to comparing R-Value to its most common competitors. In fact, soy foam is more than double in R-value than pink fibreglass batts, which are the most common residential home insulators. With this superior insulation, the SUB can expect a 50%-80% deduction in the amount of energy required to heat itself

(Enviro Foam Insulation, 2008). The reason why soy-foam insulation is able to provide such efficient insulation is because of its closed-cell nature. Because of the closed-cell structure of soy foam, just a quarter-inch thickness of the insulation will prevent 99% of convection currents since it is not permeable to air, which account for 80% of heat loss in a typical home (Enviro Foam Insulation, 2008). Although most companies state that the cost of installing soy foam is three to four times more expensive than installing fibreglass insulation (Enviro Foam Insulation, 2008), the investment will promptly pay itself back over the years through the reduced heating costs. Another cost reduction is that because soy insulation is so efficient, a smaller or less intricate heating system can be used in the new SUB with negligible downside.

There are also other factors of soy foam insulation that are beneficial to the new SUB project. One of the major differences of soy foam insulation when compared to others is that it is a hard, dense product, unlike fibreglass, cellulose, or new-materials like cotton. The closed-cell structure of soy foam allows it to sustain its shape and can be a valuable component to the construction of the SUB. Because walls can be filled with soy foam, their shear strength can be increased by 300% depending on the size and shape. (Ewing Solutions, 2009). Since the soy foam can essentially perform two tasks, it can significantly impact the construction plans and budget. Not only is soy foam strong, but it is durable and does not require maintenance or replacement until something drastic happens to it.

3.3 ECOLOGICAL

As mentioned before, the soya bean oil replaces petroleum in traditional spray foam; this saves having to dig up and refine the petroleum for use. The obvious impact of this is that soy foam has a significantly smaller carbon footprint than regular spray foams. In fact, only 2.2 pounds of carbon dioxide is used per pound of spray foam (Urethane Soy Systems), which is nearly nothing at all considering the amount of energy used to refine petroleum. Although only the beans are used to produce the oil, the rest of the plant can be used to make compost or other products making the soya bean plant a very efficient system.

There are other areas of the environment that soy foam is good for as well; since water is the main blowing agent in soy foam, it does not contain otherwise harmful CFC's used to propel it which would harm the ozone. Soy foam specifically does not contain formaldehyde, bleach, or any other volatile organic compounds so that it may maintain its LEED certification. (Enviro Foam Insulation, 2008) Furthermore, in the 2003 NRC Survey of Household Energy Use, it was found that the average 2000 sq. ft. home can reduce its Greenhouse Gas (GHG) emissions by 4.1 tonnes. This is equivalent to removing 676 SUV's off of our roads, which when applied to the SUB would be substantially more.

Another benefit of using soy is actually seen from the usage of the plant itself. Farmers in the US have been using the soya bean plant to control the runoff of nitrogen in the soil due to intense rain fall (Stalcup, 2010). By planning ahead and planting soy bean plants, the nitrogen contained in run-off waters get contained by the soya bean plants, which act as a filter to slow down the run-off waters.

3.4 SOCIAL

The social implications of soy being used are also very interesting to consider when talking about soy because it's a topic you can tackle from many directions. To begin, from a health standpoint, soy insulation provides a great advantage in that there are substantially less toxic chemicals in the B-side of the spray (Urethane Soy Systems). This isn't only good for the environment, but since it isn't applied using the traditional mixture, as the insulation ages, it won't give off any toxic gasses (Enviro Foam Insulation, 2008) which would be dangerous for people that work inside the new SUB.

Another aspect we can look at is its ease of application. Soy uses water as a blowing agent, and not only is this good for the environment, but it'll also allow architects to be more liberal in their designs. The water liquefies the foam upon initial spray, allowing it to reach into tight spaces or otherwise difficult areas to install typical insulation. This will give the architects a lot more freedom in the way they choose to position rooms or how rooms will be shaped. Whether or not this will give the new SUB more interior space or just more interesting shapes will be decided by architects, but soy foam will give them that option. Since the foam will expand to fill up all of the space, there is the advantage that any small cracks or potential spaces where air can leak will be sealed. This will help to seal the building from foreign particles that would travel through air leaks, along with preventing insect or rodent infestations. The soy used in the insulation is in an inert form and hence is not eaten by anything.

4 CONCLUSION

In this report two RRMs, soy based spray foam and bio-diesel furnaces are compared in a triple bottom line analysis framework. Soy based spray foam is compared to many other common industry accepted insulating materials and bio-diesel furnaces are compared with standard petroleum diesel and CNG based furnaces.

Following the triple bottom line analysis of soy based spray foam, the following economic, environmental, and social benefits can be realized if soy based spray foam is used on the new SUB. Economically, soy based spray foam is comparable to other industry standard insulating materials such as inorganic spray foam and fibre glass insulation. Ecologically, soy based spray foam is superior to petroleum based spray foam as it does not require fossil fuels in its manufacturing process. The new SUB should incorporate soy based spray foams given the many social benefits including healthier living spaces and the creation of jobs.

The triple bottom line analysis of bio-diesel shows that bio-diesel furnaces are notably more costly to operate, however given the social benefits (increased community involvement, reduction of dependence on fossil fuels, increased awareness of renewable resources, and promotion of agriculture) in addition to the ecological benefits (lower emission, lower toxicity of emissions, recycles waste, and less fossil fuel energy is required to produce bio-diesel), we believe the new SUB should be heated with a bio-diesel furnace.

5 BIBLIOGRAPHY

Algaewheel Technologies, L. (2011). *Renewable Energy From Algae Biomass*. Retrieved March 14, 2011, from Algae Wheel: http://www.algaewheel.com/usage/renewable-energy/

Assessment, O. o. (2007). *Air Toxicology and Epidemiology*. Retrieved March 14, 2011, from OEHHA: http://oehha.ca.gov/public_info/facts/dieselfacts.html

EnergyBible.com. (2010). *EnergyBible.com*. Retrieved March 14, 2011, from Bio Energy: http://www.energybible.com/bio_energy/fuel_comparison_chart.html

Enviro Foam Insulation. (2008). *Frequently Asked Questions*. Retrieved March 27, 2011, from Enviro Foam Insulation: http://www.envirofoaminsulation.com/faqs.php

Enviro Foam Insulation. (2008). *Why is Foam Better?* Retrieved March 27, 2011, from Enviro Foam Insulation: http://www.envirofoaminsulation.com/why-is-foam-better.php

Ewing Solutions. (2009). *Frequently Asked Questions*. Retrieved March 27, 2011, from Ewing Solutions: http://www.ewinginsolutions.com/FAQ.html

Gustavo Rodrigues de Souza, A. M. (2009). Evaluation of the performance of biodiesel from waste vegetable oil in a flame. *Applied Thermal Engineering*.

Jason Hill, E. N. (2006). Environmental, economic, and energetic costs. *PNAS*.

Levin, H. (2009, February). *Soy Based Foam Insulation: What It Is, and Why You Should Use It.* Retrieved March 26, 2011, from The Greenest Dollar: http://www.thegreenestdollar.com/2009/02/soy-based-foam-insulation-what-it-is-and-why-you-should-use-it/

National Biodiesel Board. (2008). *Sustainability Fact Sheet.* Retrieved March 26, 2011, from Biodiesel: http://biodiesel.org/resources/sustainability/pdfs/SustainabilityFactSheet.pdf

Stalcup, L. (2010, March). Reduce Runoff. *Corn & Soybean*, pp. 11-12.

Urethane Soy Systems. (n.d.). *Insulation.* Retrieved March 26, 2011, from Soyol: http://www.soyol.com/insul.htm

Vern Hofman, E. A. (2003, FEBRUARY). *County Commissions, North Dakota State University and U.S. Department of Agriculture cooperating*. Retrieved March 12, 2011, from Biodiesel Fuel: http://www.ag.ndsu.edu/pubs/ageng/machine/ae1240w.htm