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

An Investigation into Sustainable Alternatives for Building Components for the new SUB

Kenny Leung

Chun Gordon

Yeh Daniel Liu

University of British Columbia

APSC 262

April 2010

UNIVERSITY OF BRITISH COLUMBIA

An Investigation into Sustainable Alternatives for Building Components for the new SUB

APSC 262 – Project Report

Kenny Leung
Chun Gordon
Yeh Daniel Liu

Tutorial Instructor – Pat Crammond

Date Submitted – April 6, 2010

Abstract

Windows are a main component of any building to ensure air tightness and to reduce energy consumption. Many consumers will select the optimal window components according to the triple bottom line assessment, taking into account the social, economical and environmental impacts of different alternatives. This report focuses on three potential window materials: aluminum clad, vinyl and fiberglass. Aluminum clad windows are the least favorable material out of the three that are being compared. They are expensive and potentially harmful to the environment during the disposing and recycling process. Vinyl windows have comparatively lower cost than aluminum and fiberglass windows. However, vinyl does have the tendency to deform with weather changes and will need maintenance more often than fiberglass windows. Although the recycling of vinyl is a growing business, the production of vinyl is harmful to the environment as it requires many dangerous chemicals. Fiberglass windows are ideal for the SUB renewable project due to its durability and efficiency. Fiberglass does have higher initial cost; however, in the long term its low maintenance quality and energy saving characteristics will be an economically favorable window material for the new SUB.

List of Figures

Table of Contents

1.0 Introduction

The main objective of this report is to analyze a specific building component and research alternative technologies to improve the sustainability of this component using the triple-bottom line assessment. We have chosen to further examine different types of windows to be used in the construction of the new Student Union Building (SUB).

About 45% of a typical building's total energy consumption goes to heating and cooling the building (See Figure 1 below). Energy losses through the building envelope are mainly due to air leakage and heat conduction through the windows, doors, walls, ceiling, and floor. However, about 25 to 50% of the total energy loss is through the windows (Doren, 2007): therefore, improving the energy efficiency of the windows will greatly affect the energy losses through the building envelope.

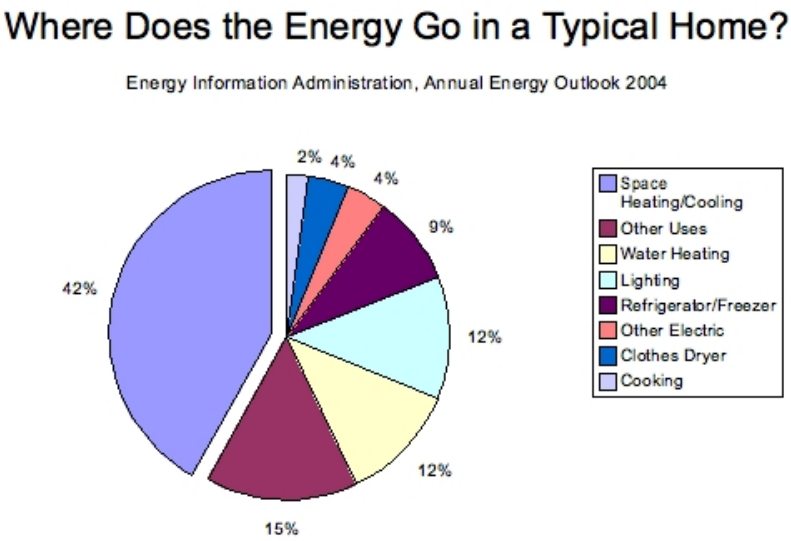

Figure 1 - Energy Distribution in a Typical Building (source: http://sunhomedesign.wordpress.com/category/windows/)

2.0 Comparison Parameters for Energy Efficiency

There are several factors used to compare the energy efficiency of different types of high performance windows: the U-value, Solar Heat Gain Coefficient (SHGC), and Low-e coatings (Doren, 2007). Although the window frame and glazing material are the main variables of these comparison parameters, choosing the "greenest" window depends greatly on the climate, whether or not the building is going to be passively heated by the sun, and also the direction that the window is facing.

2.1 U-Value

The U-value is related to the total thermal conductivity of the window, which is the ability to transfer heat by means of conduction. The lower the U-value, the more resistant the window is to heat transfer. This means that with low U-value windows, the building will retain more heat inside during the winter and repel heat from the outside during the summer. A low performance single-glazed aluminum window with a U-value of 1.30 will lose a lot of heat during the winter and use up a lot of energy cooling the inside air during the summer. High performance energy efficient windows typically have U-values ranging from 0.20 to 0.30 (Doren, 2007).

2.2 Solar Heat Gain Coefficient

The Solar Heat Gain Coefficient (SHGC) is the measure of how much radiant energy will pass through the windows. The sun produces radiation, which can be transmitted directly into the building through the windows, reflected from the ground into the building, or diffused in the surroundings. All these modes of radiation heat transfer works to heat up a building envelope. A window with a Solar Heat Gain Coefficient of 0.50 means that 50

percent of the heat energy that hits the window will be transferred into the building, where typical values of SHGC range from as low as 0.25 to over 0.50 (NRC, 2009). If passive solar heating is to be used, windows with higher SHGC should be installed on the southern exposure of the building in order to take advantage of the direct solar radiation during the heating seasons. This measurement is dependent on the size of the window frame, type of glazing, and also low-e coatings, which will be discussed in the next section.

2.3 Low-emissivity (Low-e) Coatings

Low-e coatings are thin, transparent metallic layers applied to the surface of the glass, and the main function of these coatings is to reflect energy that would otherwise escape or penetrate the building envelope. For example, during the summer season, the low-e coating will serve the purpose of keeping solar energy from entering the building, whereas the coating would keep infrared energy from escaping the building during the winter seasons. An effective low-e coating for climates dominated by cooling is one which reduce solar heat gain (reduce heat transfer into the envelope) without blocking an excessive amount of visible light (Doren, 2007). Although low-e coatings typically lower SHGC (reduce the amount of radiant energy from entering the envelope), some coatings especially designed for passive solar heating applications in climates dominated by heating will allow beneficial solar radiation into the building while still preventing longer wave infrared energy from escaping.

3.0 Selecting Window Material

In our triple bottom line assessment of the different types of windows to be used for the new SUB, three specific building materials used to construct the windows will be compared: aluminum-clad, vinyl, and fiberglass. In the comparison, social, environmental, and economical aspects will be considered.

3.1 Aluminum-clad Windows

Aluminum-clad windows are manufactured by roll forming a thin sheet of aluminum around the wooden window frame to cover and protect the exterior of the window. The aluminum is molded and, in some cases, painted before being fitted with the wooden frame (Crafton, 2010). Extruded aluminum is heavier weight and doesn't "wrap" around the window. Instead it often fits the wood it protects like a puzzle piece (See Figure 2 below).

Figure 2 - Cross-section of Aluminum-clad Window (source: http://detail.en.china.cn/provide/detail,1072663300.html)

Economic Factors:

Although aluminum-clad windows are generally more expensive than other alternatives, the aluminum cover reduces the maintenance of the window during its lifetime. The cladding protects the wooden frame from cracking, swelling, splitting, shrinking or even rusting. Though not essential, the wooden interior is often stained of clear-coated for further protection. It is important to size the window properly to prevent condensation from forming on the window, causing rotting or discoloration of the wood (Crafton, 2010). However, most clad windows have their wooden frames preservative treated to prevent this from happening. Many manufacturers, in fact, offer lifetime warranties on the wooden frame. The popularity of aluminum-clad windows results in the ease of purchasing such windows locally, thereby reducing transportation costs.

Environmental Factors:

Being a global leader in sustainable forest management, the logging industry in British Columbia is bounded by strict forest management laws, which means values such as wildlife habitat or scenic vistas take precedence over logging (BCFCCWG, 2008). Wood is a flourishing natural resource (about 1% of BC's forests are logged each year) and is available locally, making the use of the material for construction ideal. Aluminum, on the other hand, has for long been recognized as a toxic agent to aquatic freshwater organisms, making the disposal of the window after its useful lifetime potentially harmful to the environment. Today, large parts of both the aquatic and terrestrial ecosystems are affected by aluminum production (Rosseland *et al*., 2005). Aluminum by itself is not as good as an insulator as vinyl. The thermal properties of the wooden frame, however,

make the aluminum-clad window a viable option when looking for an energy efficient window.

Social Factors:

Aluminum-clad windows are lightweight, yet extremely strong and flexible, making the material very easy to work with. The wooden interior can also be stained with a variety of different colored semi-transparent stains, allowing the grains of the wood to be visible while protecting the wood from moisture. Its long-lasting exterior reduces the hassle of continuous maintenance, while its aesthetically pleasing wooden frame adds a sophisticated elegance to the structure (Crafton, 2010).

3.2 Vinyl Windows

Vinyl is made from two ingredients: petroleum and salt. Petroleum is put through a process, called cracking, to make ethylene, which is combined with chlorine to produce ethylene dichloride. Through another cracking process ethylene dichloride is transformed into vinyl chloride monomer. Finally, through a process known as polymerization, the gaseous monomer is converted into a fine, white powder called vinyl resin. Vinyl resin can be combined with many other chemicals to create desired end products such as window frames (Vinyl in Design, 2010).

Figure 3 - Cross-section of Vinyl Window (source: http://www.arrow2000.ca/windows.htm)

Economic Factors:

Vinyl trim windows are one of the most affordable types of windows available. One of the most important ways it saves money is that they eliminate the need to paint the windows inside and outside. It is not possible to paint vinyl windows with regular paint as they cannot bond to the vinyl (Vinyl in Design, 2010). The average window size is 30 inch by 48 inch and can range in average cost from $150.00 to $500.00 per window. Which is considerable cheaper compared to other types of trims which will cost from $300.00 to $700.00 (Vinyltek, 2010). Vinyl is an ideal material for window frames, due to its low thermal conductivity. However, they tend to expand and contract with the weather. Vinyl frames have many chambers to increase its strength. These chambers also trap air which allows it to improve its energy performance. Vinyl windows also require low maintenance due to their simplicity in design. Vinyl trims are also readily available

in BC so that shipping cost is eliminated. However, it is also important to keep in mind that the cost of any window will increase depending on how customized it is.

Environmental Factors:

Vinyl windows can be made to be energy efficient as well. A company called Vinyltek provides exceptional energy efficient windows. They offer more frame and sash chambers than most other windows, therefore, under the right selection providing the best insulating performance. Triple weather-sealed openings and multi-point locking; provide a snug, evenly distributed closing to seal in heat. Furthermore, XLEdge stainless steel spacers provide maximum energy savings by enclosing the windows completely. Furthermore, the fact that they do not require painting can also serve as an environmental benefit. It reduces the need for paint disposal, paint production and the use of other harmful chemicals associated with paint (Vinyltek, 2010).

Social Factors:

Vinyl windows being the more affordable choice could make it more available for consumers to own and operate (Vinyl in Design, 2010). Furthermore, the ability to make them environmentally friendly could serve as a plus for consumers choosing between different types of windows. In a social aspect, people would welcome anything that saves money and provides energy efficient qualities.

3.3 Fiberglass Windows

Fiberglass material is made from very fine fibers of glass. Its technical name is the fiber-reinforced polymer or glass-reinforced plastic. The fiberglass is used as a reinforcing agent for many polymer products. High-tech fiberglass lineals have all the advantages and none of the disadvantages of its competing alternatives such as metal, plastic, or wood frame windows (Fibertec, 2005).

Fiberglass is the ultimate window-frame material and it is manufactured using the "pultrusion" technique in which continuous strands of glass are formed in a thermoset resin and passed through a heated die. These continuous strands of glass are then pulled through the die rather than pushed or extruded through the die. Fibertec also fabricates these dimensionally stable window lineals into window frames by filling the fiberglass frames with foam insulation and glazing them with high efficiency insulating glass. Pultruded fiberglass is superior in five ways including dimensional stability, thermal insulation, durability, aesthetics, and environmental friendliness (Fibertec, 2005).

Social and Economic Factors:

Fiberglass windows have several advantages in terms of social factors. Unlike traditional window materials such as aluminum clad, or vinyl, fiberglass is resistant to warping, rotting, cracking and shrinkage. The company called Fibertec Window Manufacturing Limited produced the fiberglass windows with advanced technology. In addition, they

have developed the worlds' best energy-rating window system. Fiberglass windows are setting new standards of windows materials in the industry.

Fiberglass windows are very resistant to weathering and heat, cold, moisture and dryness which in turn ensure life-time durability. Homeowners prefer fiberglass windows due to fiberglass windows' following features and benefits:

- Ease of installation and smooth operation
- Ability to design large windows
- A reduction in moisture and condensation which in turn save costly wallpaper
- High resistance to sound transmission
- Consistent indoor temperature in large window areas
- Positive seal against frame to keep air, water and dust out of the room and energy in the room
- Lack of surface finish deterioration leads to prolonged longevity and consistently smooth operation during the lifecycle of the fiberglass windows
- Fiberglass windows can be painted with no restrictions to color. The paint can also act as a sealer that protects moisture and pollutants out of the room
- Stable performance in chemically sensitive environments and impervious to termites and other pests
- Unlike vinyl, fiberglass windows don't emit toxic fumes in case of fire

Fiberglass windows have become more and more widely accepted by homeowners and house builders due to the above features and benefits. Because fiberglass windows have a

very long life expectancy compared to that of aluminum, vinyl, they deter future service and maintenance costs. Although making fiberglass windows will have a bigger capital investment than other windows, the long term savings in the energy costs of heating and cooling will justify the initial investment (Inline Fiberglass, 2010).

Environmental Factors:

Fiberglass windows are the most environmental friendly windows. Fiberglass windows have around 60-70% fiberglass which is made from sand. Sand is very abundant in nature so that windows manufacturers can have easy access to it. In addition, pultrusion, the technique used to manufacture fiberglass consumes the lowest embodied energy compared to other materials do (Inline Fiberglass, 2010). Typical operating temperature of aluminum clad windows require heating up to 1700°F, that of vinyl requires 400°F, compared to that of fiberglass which requires only 200°F. Fiberglass windows barely create any waste during the cutting process and have a very long life expectancy which in turn requires minimal part replacement compared to the other two alternative materials. Because of its long life expectancy, people name it “the first 100-year window”. Lastly, fiberglass windows surfaces will not emit toxic gases whether they are painted or burned in a fire accident. Fiberglass windows are inert if disposal is necessary.

Conclusion

Throughout this century the technological advancements in windows components have depended on the innovations of the efficient windows. As windows become so important for houses to keep air tightness inside the room and to keep energy consumption on heating and cooling down, homeowners and home builders tend to select the optimal windows materials by following the social, economic and environment factors. In the triple-bottom line assessment performed in the previous sections, Aluminum-clad windows are eliminated from being the most efficient materials for windows components due to the high cost, inability to keep energy inside the room as efficient as the other two alternatives do, and potential hazards to the environment during the production and disposal stages.

Vinyl and fiberglass are still very ideal choices for windows materials. Although vinyl windows offer up to 3 times more insulation than fiberglass, they have many more weaknesses than fiberglass have. During the manufacturing process of the vinyl windows, a combination of different chemicals, plasticizers and pigments are used while the fiberglass windows generally are made from inert and inflammable glass fibers.

Considering the window components are used for the SUB renewable project, a high strength of the windows is important because the SUB is a public building which everyone has access to. Fiberglass has much higher strength than vinyl so that fiberglass windows will generally outlast the vinyl windows and have a much longer lifetime. Fiberglass windows also contract and expand less than vinyl windows in temperature

changes, and therefore suffer less from weather changes. Fiberglass windows are also superior in quality than vinyl windows because they are resistant to warping, rotting, cracking, bowing and shrinking in areas with severe weathers.

Fiberglass windows can be repainted due to different occasions such as Christmas. However, vinyl windows do not hold paint which means they do not need a repaint in the way they are made. Fiberglass windows are also more environmentally friendly than vinyl glass due to the technique and the raw materials used to make them. Although the capital investment in fiberglass windows will be greater than that of vinyl windows, the long term benefits such as minimal part replacement and savings in energy consumption people get from the fiberglass windows will justify the initial investment. Therefore, we have decided that the most efficient windows components for the SUB renewable project will be fiberglass windows.

4.0 References

BC Forestry Climate Change Working Group (2008). BC – Global Leader in Forest Management. Retrieved on March 20th from http://www.bcclimatechange.ca/bc-global-leader-in-forest-management/default.aspx

Bieber Windows (2010). Aluminum Clad Windows. Retrieved on March 15th from http://www.bieber-wood-windows.co.uk/products-aluminium-clad-windows.html

Crafton, Luke (2010). Taking a Look at Aluminum-Clad Windows. Retrieved on March 23rd from http://www.thisoldhouse.com/toh/article/0,,216569,00.html

Doren, John V. (2007). The Road to Energy Zero Homes – Understanding Your Energy Baseline. Retrieved on February 12th from http://sunhomedesign.wordpress.com/category/windows/

Fibertec (2005). The Fiberglass Story. Retrieved on March 18th from http://www.fibertec.com/fiberStory.php

Inline Fiberglass (2010). Fiberglass windows. Retrieved on March 24th from http://www.inlinefiberglass.com/

Inline Fiberglass (2010). Pultrusion Operations. Retrieved on March 24th from http://www.inlinefiberglass.com/pultrusionoperation.html

National Resource Canada (2009). The Ratings Game. Retrieved on February 14th from http://oee.nrcan.gc.ca/Publications/infosource/pub/renovate/windowsandDoors/section6.cfm?attr=4

Rosseland, B. O. *et al* (2005). Environmental effects of aluminum. Retrieved on March 28th from http://www.springerlink.com/content/t7386725417162k5/fulltext.pdf

Vinyl in Design (2010). History of Vinyl. Retrieved on March 27th from http://www.vinylbydesign.com/site/page_two_col.asp?CID=2&DID=3

Vinyl in Design (2010). Vinyl & the Environment. Retrieved on March 27th from http://www.vinylbydesign.com/site/page_two_col.asp?CID=5&DID=6

Vinyl in Design (2010). Windows & Doors. Retrieved on March 27th from http://www.vinylbydesign.com/site/page.asp?CID=18&DID=19

Vinyltek (2010). Vinyl Windows. Retrieved on March 28th from http://www.vinyltek.com/winfacts.html