BUILDING PRODUCTS MADE OF RECYCLED MATERIALS IN THE NORTH AMERICAN HOME BUILDING INDUSTRY

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ABSTRACT

Over the course of the last few decades, increasing interest and attention has been paid to constructing buildings that reduce natural resource depletion, waste disposal and pollution. As the building industry is a major consumer of raw materials, advancement in technology and products containing recycled materials have emerged to reduce the amount of waste generated. However, insofar as the residential construction market is concerned, adoption of these “green” building practices has been slow, partly due to a pervasive lack of knowledge about the properties, features, and long term costs of these products. Therefore, this report examines and highlights the construction material selection process as the key point at which decisions must be made to increase the level of sustainability in residences, and evaluates a variety of different products containing recycled content now available in the North American marketplace. The selection criteria based on recycled content involves examining other features by which materials should be evaluated such as performance and costs. Alternative products are proposed in the context of different building components from the foundation to the roof. Each section provides comparative materials charts to illustrate the potential advantages to home owners, builders and the environment. The findings in this report shows that such products are cost effective and are environmentally preferable not only because they reduce demand on virgin resources, but many also provide comparatively superior performance and offer additional benefits such as durability, energy efficiency, and support of healthy environments both indoors and out, when compared with traditional building materials.

RÉSUMÉ

Au cours des dernières décennies, l’intérêt et la conscience collective ont augmentés pour la conception de projets qui contribuent à diminuer l’épuisement de ressources naturelles, l’élimination des déchets et la pollution. L’industrie de la construction est une consommatrice importante de matières premières; cependant, l'avancement technologique et la fabrication des matériaux de construction, à partir de matières recyclées, ont émergé pour réduire la quantité de déchets générés. Néanmoins, pour autant que le marché de la construction résidentielle soit concerné, l'adoption de ces pratiques de construction “vertes” a été lente, partiellement due à un manque évident de la connaissance au sujet des propriétés, des caractéristiques et des coûts à long terme de ces produits. Par conséquent, ce rapport examine et précise le processus de sélection de matériaux de construction comme point important. Ces décisions doivent être prises pour augmenter le niveau de durabilité des immeubles résidentiels et évaluer une série de différents matériaux, comportant des produits recyclés déjà disponibles sur le marché Nord-Américain. Les critères de sélection basées sur le contenu recyclé, nous engage à examiner d’autres caractéristiques, telles que la performance et les coûts. On présente divers produits alternatifs dans l’ensemble du bâtiment résidentiel de la fondation jusqu’à la toiture. Chacune des sections fournissent des tableaux comparatifs des matériaux afin d’illustrer les avantages potentiels autant pour les occupants des bâtiments que les constructeurs et l'environnement. Les résultats du rapport montrent que les produits analysés sont abordables et sont écologiques parce qu'ils réduisent la demande sur les ressources vierges et de la même façon offrent des performances supérieures et des avantages supplémentaires tels que la durabilité, l'efficacité énergétique et le soutien des milieux sains à l'intérieur et à l’extérieur par rapport aux matériaux de construction conventionnelle.

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INTRODUCTION

1.1 RATIONALE FOR THE STUDY

The environment and resources for future generations can be negatively impacted by today's development. Waste generated by human activities during extraction, production, distribution and consumption of goods is one of such factors. People need to work, play, and eat, and these daily activities represent the accumulation of large amounts of waste such as jars, bottles, paper, cans, cardboards, and plastics which can be a major source of raw material for the manufacture of new products. In order to understand and be able to participate in a sustainable development it is important to know how much waste is produced, who produces it and where waste goes[1].

According to Statistics Canada (2005), more than 30.4 million tonnes of solid waste was generated in 2002. Of this total, as shown in Table 1.1, approximately 49% (or 15 million tonnes) of waste was attributed to industrial, commercial and institutional sources; 39% (or 12 million tonnes) was generated by residential sources; and only 11% corresponded to construction, renovation and demolition (CR&D) sources. Of the 15 million tonnes of waste produced by industrial, commercial and institutional sources, 23% (or 3.5 million tonnes) was diverted to recycling programs, while 77% (or 11.6 million tonnes) was sent for disposal. Of the12 million tonnes of waste generated by residential sources, 21% was diverted to recycling

[1] Sustainable development is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

programs, while the remaining 75% was disposed of in landfills or incinerators[2]. Only 16% of materials from CR&D activities was diverted (Table 1.2). As the aforementioned statistics from the residential, industrial, commercial, institutional, construction, renovation and demolition sectors demonstrate, the proportion of waste which is diverted to recycling programs is comparatively quite small. Indeed, about 78% of Canada's trash is disposed of in landfills and the remaining 22% is recycled or otherwise diverted.

Source	Waste Generated (tonnes)	Percentage (%)
Industrial, commercial and institutional	15,075,307	49
Residential	12,008,338	39
Construction, renovation and demolition (CR&D)	3,371,880	11
Total of solid waste in 2002	**30,455,525**	

Table 1.1: Solid waste generated in Canada in 2002. Waste from residential industrial, commercial and institutional sources represent the 88% of the total waste.

Source: Human Activity and the Environment Annual Statistics 2005, solid waste in Canada, catalogue no.16-201-XIE.

Source	Waste Generated (tonnes)	Disposal (tonnes)	Percentage (%)	Diversion (tonnes)	Percentage (%)
Industrial, commercial and institutional	15,075,307	11,563,999	77	3,511,308	23
Residential solid waste	12,008,338	9,455,204	79	2,553,134	21
Construction, renovation and demolition (CR&D)	3,371,880	2,816,528	84	555,352	16
Total	**15,380,218**	**23,835,731**		**6,619,794**	

Table 1.2: Generation, disposal and diversion of solid waste in 2002. Of the 30 million tonnes of waste produced about 6 million tonnes were diverted.

Source: Human Activity and the Environment Annual Statistics 2005, solid waste in Canada, catalogue no.16-201-XIE.

[2] Waste diverted refers to materials processed for recycling or reuse at an off-site recycling or composting facility.

One major problem in today's society is that with new technology and markets offering ever-changing possibilities, people have a tendency to discard objects easily. The overall rise in the amount of waste produced can be attributed to a number of different factors, including simple population growth and rising incomes which, in time increase the consumption of goods (Williams, 2005). It is unrealistic to expect that waste streams could ever be eliminated; however, the amount of waste which is disposed of in landfills and through incinerators can be reduced significantly by effective recycling initiatives. Recycling is an important component in the effort for a sustainable development that decreases the use of natural resources. It is an environmental solution that reduces the need for disposal capacity, lowers emissions from landfills and incinerators and reduces litter and improper disposal (Ackerman, 1997).

Recycling provides tangible economic benefits beyond the obvious environmental considerations. The recycling process that includes material collection, remanufacture and purchase of products creates economic activity, providing more jobs and business (Institute for Local Self-Reliance, 2006). Different studies have examined the advantages of recycling at the local and state level showing the recycling employment growth rates. For instance, the study "California Recycling Means California Jobs: A Library of Facts" (1994), reported that 18,000 jobs were created due to the recycling process. A study conducted by The North Carolina Office of Waste Reduction in 1995 titled "The Impact of Recycling on Jobs in North Carolina", found that recycling supported over 8,800 jobs in the State of North Carolina. Moreover, the study indicated that for every 100 recycling jobs created, just 13 jobs were lost in the solid waste and virgin material extraction sectors.

Recycling is not a new concept and has always being employed in one form or another. Even in the early days, hunters used parts of animals such as bones for tools; first civilizations

such as the Mayans used broken tools to create new ones. In preindustrial England, paper was made from recycled rags and it was a shortage of rags which ultimately lead to the production of paper from wood, as developed by the Germans in the 1840s and introduced in America in the 1860s (Ackerman, 1997). In Canada, the first paper mill was built in 1804 in St. André Est, Quebec; newsprint and wrapping papers were made of old rags and linen (Alberni Environmental Coalition, 2008). Resource shortages and economic depression in the World wars lead people to recycle. In World War II, Americans were asked to recycle metal, rubber, cardboard, paper, and other materials to support and provide war funds (Strasser, 2000). Nevertheless, industrialization and mass production has led to the growth and development of a consumer society and increasing quantities and types of waste.

Solid waste may be managed in one of several ways including landfill, incineration, recycling, composting and export (Statistics Canada, 2005). In Canada landfilling is the most commonly employed technique, but this has a highly negative impact on the environment. Landfills not only require large areas of land but also affect the environment with pollution and gas emissions. In 2002, solid waste disposal on land produced 22 megatonnes of emissions, accounting for 3% of all GHGs produced in Canada (Environment Canada, 2009). Landfills produce approximately 25% of Canada's methane emissions, a greenhouse gas (GHG) 21 times more potent than carbon dioxide (CO2) (Babooram & Wang, 2007). As a consequence, nowadays, government and citizens have become more aware of the importance of recycling and environmental issues. The contemporary recycling programs of today are, in part, a response to the shortage of landfill space and the environmental damaged caused by landfills (Alberni Environmental Coalition, 1991). According to a 2007 report of Statistics Canada entitled "Recycling in Canada", since the mid-1990s, "Canadian households are recycling larger

quantities of waste than ever before". Part of the increase is due to better access to recycling programs. Although residential waste production increased by 2.1 million tonnes (19%) between 2000 and 2004, the amount of household waste that was recycled increased from 19% in 2000 to 27% in 2004 (Table 1.3). "Households across the country sent nearly 3.6 million tonnes of materials for recycling in 2004, an increase of 65% compared to 2000" (Babooram and Wang, 2007).

Residential recycling			**Residential recycling rate**		
2000	2002	2004	2000	2002	2004
Tonnes			Percentage (%)		
2,173,326	2,789,669	3,582,301	19.3	22.8	26.8

Table 1.3: The residential recycling rate refers to the amount of residential waste diverted as a proportion of waste generated.

Source: Statistics Canada EnviroStats, 2007

Yvonne Bendo's article, "Steel is the most recycled material on earth" which was published in the Journal of Commerce (2007), explains the importance of steel in the recycling industry. One important property of steel is that it can be transformed and made into new steel products without compromising its integrity. According to the article, Dave Mackinnon, director of Codes and Standards at the Canadian Institute of Steel Construction, says that steel is made of 90% recycled material and 80% of steel is recovered from old construction projects, diverting it from the landfill. Mackinnon also points out that "the industry continues to find new ways to lessen its impact on the environment" (Bendo, 2007). Other materials such as concrete and wood have been used in housing for many years; nevertheless, through technologies and modern innovations those materials that have been discarded or lost their intended purpose can be collected and transformed into new products to extend their life. Waste material such as newspapers, bottles, metal, tires and others are also being taken out of the waste stream to be re-

used and converted into construction products offering a wide range of designs, colors, functions, sizes, styles and prices. Newspaper, for example, is used to create cellulose insulation which has both sound and thermal insulation properties (Figure 1.1). It can be used in walls, ceilings and attics and is resistant to fire, moisture, mold and vermin, (Figure 1.2).

Figure 1.1: Discarded paper is recycled, collected and processed as a main source of raw material to produce insulation.

Source: Retrieved June 17, 2009, from http://www.ecofriend.org/entry/recycled-paper-cellulose-the-best-recycled-insulator

Figure 1.2: Cellulose insulation in different applications. Recycled cellulose insulation averages a minimum of 75% recycled paper up to 85%.

Source: Retrieved June 17, 2009, from http://www.reedconstructiondata.com/companies/products/national-fiber-cellulose-insulation/

Recycled plastic can be converted into solid surfaces; objects such as shampoo, detergent bottles, and milk jugs which made of High-Density Polyethylene (HDPE) are used to manufacture decks replacing the use of hardwood (American Chemistry Council Inc., 2007). This material is called “Plastic Lumber” and can be mixed with other materials such as wood fibers, rubber, fiberglass or other type plastics to create stronger and more durable materials (ACC, 2007). Large quantities of paint are typically used in building interiors, and latex paints can be recycled and processed into a new material containing less harmful toxins than regular latex paints (Sano, Andrulis, Olijnyk, Grills & Marissen 2002). It can be used in both interior and exterior spaces and is applied the same way that any latex paint is applied (Boomerang recycled paint, 2007). Old carpets and plastic soda bottles made of polyethylene terephthalate (PET) are used to manufacture new carpets that are more resilient and colorfast than those made of virgin fibers (Toolbase Services, 2001).

Building products with recycled content are those which require re-processing before re-use. In order to understand such products it would be important to know key terms that are related to resource reuse (Calkins, 2009). Recycled content is classified in two groups: pre-consumer and post-consumer material. Pre-consumer or Post-industrial recycled material (also known as an industrial by-product) comes from manufacturing processes where virgin resources go to waste, and post-consumer material is derived from products that are no longer used for their intended purpose. Products may be comprised of sources including solely post-consumer material, solely pre-consumer material, or some combination of the two, but the more post-consumer materials used the better, because post-consumer material is more likely to be diverted from landfills. For example, steel offers high post-industrial and post-consumer recycled content and high recyclability. Recyclable products refer to those that can be collected at the end of their

useful life and remanufactured into new products (Calkins, 2009). Another important element to consider is that in the market there are materials that are downcycled, whereby a high-value product is recycled into a material of lower quality, and is less likely to be subsequently recycled again. Carpets, for instance, are recyclable and can be downcycled through one of three mechanisms: Chemically, in which the nylon is broken down and re-used into new carpet products; fiberizing, whereby carpet fibers are converted into backing, padding or matting products; and mechanical in which carpets are downcycled into different products such as automobile parts, geotextiles, fiberboard and parking barriers (National Parks Service-Pacific West Region, 2005).

Often times as buildings are renovated and demolished, large amounts of materials are discarded, increasing the amount of materials used and the level of waste in landfills. Waste from construction and demolition (C&D) activities represents 16% of the total waste produced in Canada (Statistics Canada, 2005). According to the U.S. Environmental Protection Agency (EPA) in their report *Using Recycled Industrial Materials in Buildings* (2008), there are industrial materials that can be recycled and used as raw materials for producing new products. For example, recycled asphalt pavement and recycled asphalt shingles can be used in asphalt concrete sidewalks; salvaged lumber or recycled wood can be used in wood flooring; concrete can be crushed and used onsite as structural fill; and gypsum can be recycled and used to manufacture drywall. Recycled steel and cement from industrial waste can be used to manufacture an alternative product to traditional drywall called “EcoRock”. This product does not use gypsum, can be used as a tile backer board, is more mold resistant, and generates less dust as compared to conventional drywall (Serious Materials, 2006).

The market offers different choices and consumers can help to create opportunities for more innovations. The benefits resulting from the use of recycled materials in industry include a reduction in energy use and related emissions, a reduction in extraction and manufacturing process impacts and emissions, and, of course, over the long term, value obtained from the conservation of raw materials (Ackerman, 1997). In other words, recycling saves a lot of energy and conserves natural resources. For instance, recycling plastics reduces demand for petrochemicals, recycling metal containers reduces the need for mining, and recycled paper reduces the demand for trees. It is worth noting that recycling one ton of paper saves 682.5 gallons of oil, 7,000 gallons of water, and 3.3 cubic yards of landfill space (iD2 Communications, 2009). In the end, recycled paper requires 60% less energy to produce than virgin timber paper (iD2 Communications, 2009). Furthermore, the use of steel in construction is very important because it is a strong, durable and workable material (Demkin, 1996). The steel manufacturing and fabrication industries are among the largest and most important consumers of energy and raw materials in the United States (American Iron and Steel Institute, 1991). Consequently, recycling steel reduces the need for mining iron ore, coal and limestone which are the major raw materials that are used to make steel (Demkin, 1996). However, the future of recycling depends on the market for the materials collected.

In order to achieve an effective and successful recycling system, it is important to “close the loop”; hence, buyers for products made of recycled materials are crucial. The Canadian Waste Materials Exchange (CWME) and provincial waste exchanges assist industries find ways to manage their wastes including contact with potential users (AEC, 2008). Many provincial governments such as Manitoba, British Columbia, Alberta, Ontario and Quebec have introduced or are developing environmental procurement activities to encourage the purchase of

environmentally sensitive products including those that are made from recycled materials (Energy Pathways Inc, 1994). Part of Manitoba initiative, for instance, is encouraging suppliers to provide recycled products at competitive prices (Government of Manitoba, 2009).

In a 2001 article called "Recycled Content or Bust" in *BioCycle*, Peter Grogan argues that although recycling has grown in general in the past two decades, manufacturers should increase the usage of recycle content. Grogan suggests "Progress will likely continue to plod along at a snail's pace unless there are serious commitments by specific industries to work on changing direction by replacing virgin materials with abundant recovered resources." On the other hand, despite all the advantages that recycled content products may offer, builders usually do not want to risk using new products and are not willing to incorporate such products into their projects if they are unproven. Moreover, the decision making in the selection of materials is usually driven by economic factors to reduce costs. Takahiko Hasegawa (2003), in his book "Environmentally Sustainable Buildings" discusses two important requisites for developing recycled building materials markets. First, "recycled materials should be competitive with virgin materials in terms of price and quality" and second, "potential buyers should be assured of the quality of recycled materials." He says that to achieve this goal there must be minimum standards for the use and quality of recycled materials, but admits that it is difficult to establish those standards. Lack of market and consumer awareness of the price and the quality of building materials is a major problem (CMHC, 2007). Although; builders, designers and homeowners have increased interest in new technologies, there is still a low adoption rate for sustainable buildings, due to lack of knowledge and misconceptions about the cost (Commission for Environmental Cooperation, 2008). Development of new materials will increase as their use becomes more

widely accepted. In that context, the author will explore the emerging materials and will provide an overview of their application and costs through a comparative analysis.

1.2 THEORETICAL FRAMEWORK

The use of recycled materials in housing is not a recent practice. There are architects and organizations that have demonstrated the quality and durability of different materials, some of which have been used as examples for further studies and have gradually contributed to the development of new products and technologies. For instance, Michael Reynolds, a Taos, New Mexico architect and visionary, has pioneered the use of waste tires in housing (Snell, 2004). He built his first house from recycled materials in 1972 and demonstrated how recycled materials such as steel beer, soft drink cans, and recycled paper pulp could be used in buildings (Earthship Biotecture, 2009). In his building technique "Earthship" proves how "the property that makes tires terrible trash makes them a great building material" and a wonderful building solution; they are durable and resistant to water, sun and insects (Snell, 2004). Reynolds suggests that the natural resources of today come from waste; for instance, aluminum cans, glass or plastic bottles can be used to create walls. However, his technique proposes materials that require little or no energy for manufacturing. In contrast, this section presents an overview of two pilot projects in USA and the Advanced Homes Program in Canada that used recycled materials that were processed into new products and contributed to improving the material building industry by proving their efficiency and showing new techniques. Additionally, the importance of the life cycle of building products is discussed to help understand the cost of materials in economic and environmental terms. Finally, as an evolution of recycled content building materials is occurring, the author explains their inclusion into the green building materials.

1.2.1 DEMONSTRATION PROJECTS

Architect Steve Loken, builder and funder of the Center for Resourceful Building Technology (CRBT) in Missoula-Montana is well known for his research on resource-efficient building methods and materials. His annual reference directory “Guide to Resource Efficient Building Elements” is a good source of information that provides a listing of manufacturers of resource-efficient products that contain either recycled or salvaged materials. "It's time for builders to start building houses that are not only energy efficient, but resource efficient," Loken says (Professional Builder, 1993). Loken argues that conventional materials are more costly due to the environmental impact of producing them and postulates that it is possible to build better structures with fewer materials and resources. Concerns about the conservation of natural resources lead him, in 1992, to develop ReCraft 90 (Figure 1.3), a demonstration homebuilding project. This single-family 223 m^2 (2,400 ft^2) home is located in Montana (United States) and uses building materials exclusively made of recycled-content (Balogh, 1997). Some of these materials included sidings from a mixture of cement, sand and cellulose; staircase made from clear fir doors; frames for kitchen cabinets made from discarded wood; interior doors made of wood waste, recycled paper and glue; carpet made from recycled plastic bottles; bathroom tiles from recycled fluorescent light bulbs; insulation made from newsprint, and paving tiles from recycled tires (Professional Builder, 1993).

Figure 1.3: ReCraft90 project. The house looks like a traditional American house and features recycled building materials in both the interior and outdoor space.

Source: Retrieved June 5, 2009 from http://www.lokenbuilders.com/parade.htm

Another pilot project, "The Resource Conservation Research House", was constructed in 1992 led by The National Association of Home Builders (NAHB). This two-story, 335 m^2 (3,600 ft^2) house is located in Bowie, Maryland, and consists of 80% recycled content material and includes innovative building techniques. Manufacturers and building associations were asked to participate and donate products which were then incorporated into the project (Balogh, 1997). Much like the ReCraft 90 project, The Resource Conservation Research House was not intended to be economically viable, but to demonstrate how recycled materials could be integrated into houses. Features of the house included a foundation-forming system made from polystyrene (fast food containers), steel frames constructed from recycled metal, wood siding made from wood fiber roundwood, wallboard made from 70% gypsum and 30% recycled scrap paper, deck and walkway pavers made from plastic bags, and sawdust giving an appealing appearance of wood (Figure 1.4).

Figure 1.4: The Resource Conservation Research House. The deck and walkway pavers feature Timbrex [TM] a wood substitute deck material made from plastic bags and sawdust.

Source: Retrieved June 5, 2009 from http://www.awci.org/cd/pdfs/9405_a.pdf

In 1992, other demonstration homes were built under the CANMET's Advanced Homes Program. This program sponsored the construction of 10 demonstration homes across Canada that were intended to use new technologies to reduce their impact on the environment and improve both energy efficiency and indoor quality (CIWMB, 2009). One of the main features was the use of sustainable building and recycled building materials. New ideas, concepts and product prototypes were achieved in collaboration with local and provincial governments along with builders, architects, designers, engineers, manufacturers, researchers, utilities, and local home builders associations. One example of these homes was the Kitchener-Waterloo Green Home. The 232m² (2500 ft²) single family home featured a wide range of recycled materials (CIWMB, 2009): cellulose made from recycled newspapers, drywall with 25% recycled content, exterior cladding made from scrap wood, roofing made from recycled steel, floor entrance and bathrooms used tiles made from recycled glass and carpets made from plastic soda pop bottles.

1.2.2 LIFE CYCLE OF BUILDING MATERIALS

The life cycle of building materials involves six different stages: Extraction, production, transportation, installation, maintenance and disposal of products (Figure 1.5). Each of these components affects the final cost of the product as paid by the consumer (Life Cycle Cost), but the entire process also entails an environmental cost (Life Cycle Assessment). Life cycle cost (LCC) focuses on the sum of all costs of building and maintaining a structure over its life cycle, and requires an economic analysis. There are, however, additional costs, not directly reflected in the purchase price of the product, but that also affect the environment such as fossil fuel and other non-renewable resource depletion, global warming, ground-level ozone creation (smog), stratospheric ozone depletion, nutrification/eutrophication of water bodies, acidification and acid deposition and toxic releases to air, water, and land (Carmody & Trusty, 2007). A life Cycle Assessment (LCA) is an evaluation of the environmental impact or performance of a product over its full life cycle. Life-cycle analyses are conducted by different organizations, including the Athena Sustainable Materials Institute that provides the Athena Environmental Impact Estimator and the National Institute of Standards and Technology (NIST) that provides the Building for Environmental and Economic Sustainability (BEES) 3.0 software. These programs "attempt to summarize LCA information in a manageable format specifically targeted to design professionals" and provide results including lists of environmental building products (Amatruda, 2007). Consequently, the energy required (Embodied energy) and the pollution generated by the production of materials from their extraction to disposal is a contributing factor to climate change and resource depletion.

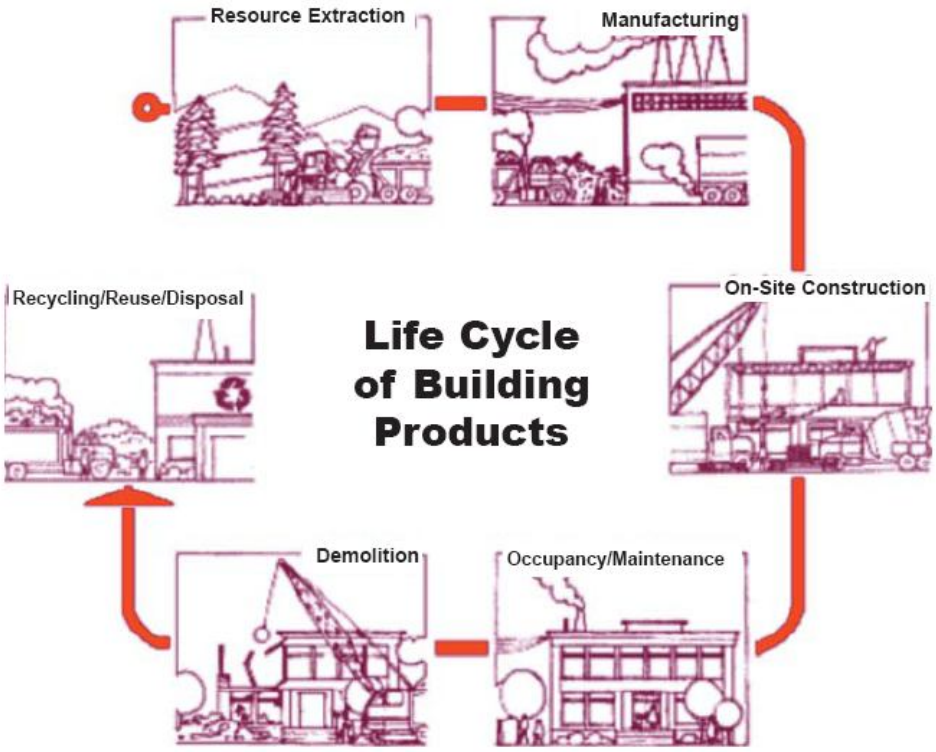

Figure 1.5: Life Cycle of Building Products. Raw materials are extracted and processed into new products to later be used in the building. Materials from demolition that are considered as waste can be used as raw material for other processes and products.

Source: Carmody and Trusty, 2007

Since recycled materials requires less energy to make and contribute to minimize the environmental impacts associated to the extraction of virgin materials, an adequate research of building products is important (Chiras, 2004). Therefore, the author will investigate the green building industry.

1.2.3 GREEN BUILDINGS

In recent years there has been increasing interest in the design of green buildings that incorporate environmentally-friendly, recycled materials. According to Spiegel & Meadows (2006), "green buildings materials are those that use the earth's resources in an environmentally

responsible way;" green building materials are non toxic, are made of recycled materials, are energy efficient and water efficient and can be recycled or reused at the end of its useful life.

In Canada different institutions promote green buildings such as the Canada Green Building Council (CAGBC) and Canada Mortgage and Housing Corporation (CHMC). A green building has become a good option for building for a number of reasons. According to the CAGBC, green buildings are the product of design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas: Sustainable site planning, safeguarding water and water efficiency, energy efficiency and renewable energy, conservation of materials and resources, and indoor environmental quality (CAGBC, 2006). Based on those components different projects and case studies have been developed in order to achieve sustainable development[3]. Recently-constructed residential buildings with recycled material content in Canada include:

The Silva, Vancouver, British Columbia; the first green residential high rise in Canada to be LEED (Leadership in Energy and Environmental Design) certified was built in 2005 (Figure 1.6)[4]. The Silva is a 16-storey, 68 unit condominium tower designed by Perkins & Company. More than 75% of the waste volume from demolition and excavation was recycled. It features environmentally friendly materials that not only contain high degree of recycled content but were, wherever possible, regionally sourced (thereby reducing the environmental impact of long-distance transportation).

[3] *Green Building in Canada: Overview and Summary of Case Studies,* 2006 in collaboration with Industry Canada, Canada Green building council (CAGBC) and Canada Mortgage and Housing Corporation (CHMC) is a collection of 10 case studies from across Canada that include key innovative features.
[4] LEED (Leadership in Energy and Environmental Design) is a rating and certification system that intend to promote more sustainable buildings.

Radiance Minto Gardens, the first green residential high rise in Toronto Ontario, designed by Page+Steele was built in 2004 (Figure 1.7). The 34 storey condominium complex had a waste diversion rate by volume of 77% and included recycled content materials into the design. In Toronto in the multi-residential sector only 12% of the waste is diverted due to the lack of facilities. As an innovative feature this project provides a separate chute on each floor dedicated to recyclables, alongside the traditional garbage chute.

Figure 1.6: The Silva, Vancouver, British Columbia.

Source: Green Buildings in Canada, 2006

Figure 1.7: Radiance Minto Gardens, Toronto, Ontario.

Source: Green Buildings in Canada, 2006

In Canada different institutional and commercial projects have been LEED certified by CAGBC. The residential sector (composed of high rise apartments and dormitories) accounts for only 1% of LEED projects (CAGBC, 2006), and no single homes have been LEED-certified as of yet (Figure 1.8). This low adoption for green homes is of particular interest to the author. CHMC has produced a wide range of publications about their projects promoting green buildings and the use of recycled content materials. Although the description and advantages of the

recycled materials are given, there is a gap in the cost knowledge. No research has been conducted so far to identify and compare the cost and properties of recycled products.

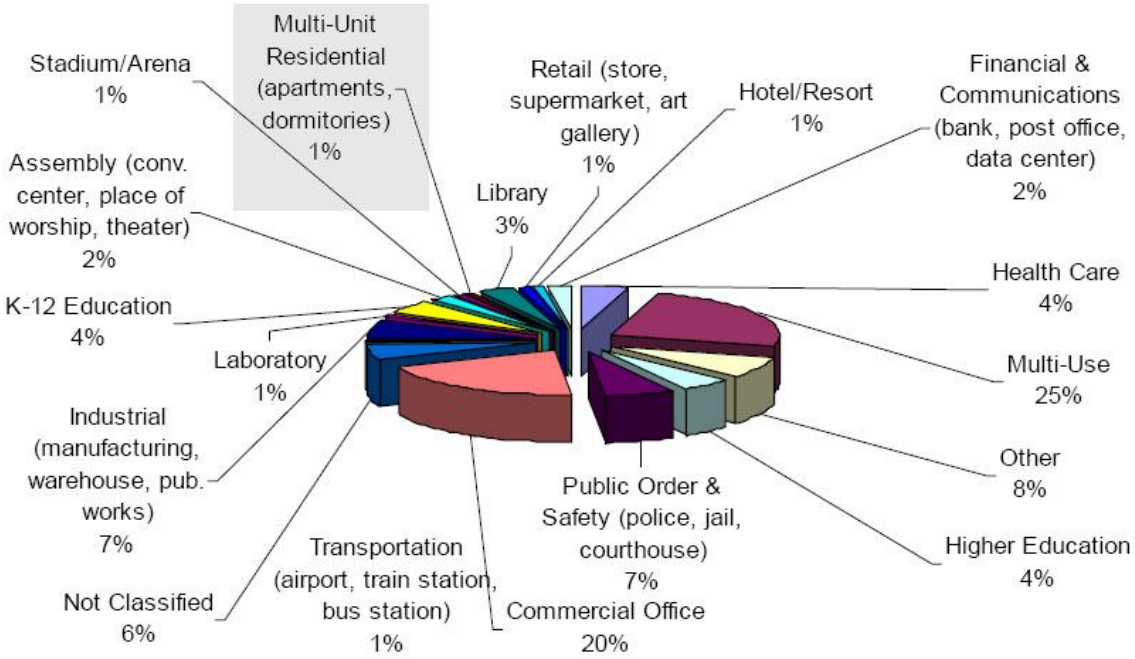

Figure 1.8 LEED Projects in Canada by Program.

Source: Canada Green Building Council, 2006

1.3 RESEARCH QUESTION

Having reviewed the different economic and environmental advantages of recycling and how building products made of recycled materials encourage sustainability it is the author's contention that there is still far more material that can be recovered from the waste stream than is currently recovered, and that a need exists to raise public awareness of the recycling products. With that in mind, the following question is proposed:

What products made of recycled materials are available in the North American homebuilding industry, and are they cost effective?

1.4 GOAL AND OBJECTIVES

The author's goal is to identify and analyze the different building materials made of recycled content and provide a guide with useable information about the advantages, properties, and costs of these materials in a North American context. The objectives of this research will be to:

- Gain a better understanding of the process of recycling and manufacturing products;
- Gain knowledge in the selection process of recycled building materials;
- Determine if the products made of recycled materials are as competitive as traditional materials currently being used, with respect to quality and cost.

1.5 INTENDED AUDIENCE

This report is intended to be read by manufacturers, builders and designers that want to increase the level of sustainability in their building practices in order to familiarize themselves and learn how to select building materials that are feasible and environmentally friendly in the North America homebuilding industry.

1.6 METHODOLOGY:

In order to respond to the research question, the author's methodology will be divided into four stages:

1. **Survey of technical literature**

   The author examines the building materials selection process in order to gain a better understanding of the technological issues and to develop a set of evaluation criteria guiding the author's decision in the selection process. The selection of materials is based on building components such as foundation, framing, cladding, insulation, roofing and

finishes. Besides recycled content other features such as dimensions, applications, durability, maintenance, installation, and recyclability are explored.

2. **Contact manufacturers and collect information**

   The collection of data and source for gathering information is achieved through manufactures by mail, catalogues, and published specification sheets. The data is compiled into a consistent format grouping potential materials with respect to price, performance and aesthetics. Then, depending on the material, detailed information sheets are produced for each product which provide information under the following headings:

   - General information such as manufacturer and application
   - Availability
   - Percentage of recycled content
   - Installation
   - Cost
   - Performance, including durability, standards, fire resistance etc

3. **Analysis**

   Once the material selection and classification by order from groundwork to roofing has been completed, a description of each product is presented along with a comparative analysis of the different alternative materials.

1.7 RESEARCH DESIGN

The structure of the report will be made up of four chapters organized as follows:

Chapter One: Introduction.

The author begins by providing essential background information explaining the rationale of the study, the waste generated in Canada, recycling and the industry of products made of

recycled materials. A theoretical framework is presented along with former studies. Then the research question, objectives of the research, intended audience and a methodology for the writing the report are discussed.

Chapter two: The delivery process of products made of recycle materials in the home building industry

This chapter presents the context in which building materials are handled with respect to the homebuilding industry, including their importance, innovation and barriers. The recycling process from the collection of materials to the manufacture of products is explained, including the parties involved in the selection process and the different factors that affect the choice and use of building products made of recycled materials.

Chapter three: Analysis of collected data

The information provided in this chapter focuses on the author's analysis from the research of building materials. A detailed product description is presented to understand its different sustainable features. In addition, comparative tables are presented to understand the different advantages or drawbacks of each product and an overall analysis is presented in each section.

Chapter four: Conclusions

The final chapter of the study concludes by answering the research question and drawing conclusions with comparative tables. The author hopes to contribute to environmental sustainability by increasing the information available on recycled materials with respect to their use, price and advantages.

CHAPTER TWO

THE DELIVERY PROCESS OF PRODUCTS MADE OF RECYCLED MATERIALS IN THE HOMEBUILDING INDUSTRY

2.1 INTRODUCTION

Products made of recycled materials have to undergo a long process following different stages starting from collection of recyclables to reprocess of products that are ultimately introduced back into the marketplace. In order to understand how products are made the author begins with an overview of such process including an example of how used tires are turn into new and useful products. The intention of this chapter is to assess the potential contribution the homebuilding industry could make to the use of more environmentally-friendly construction materials. Having understood the importance of the homebuilding industry in the Canadian economy and its environmental effects, the author explores the construction materials industry by examining the advantages of manufacturing new products based on recycled material, and the barriers that make it difficult to introduce such innovative products into the marketplace. Since the objective of the research paper is to examine the use of materials with recycled content, it is the author's belief that an understanding of the different players in the building industry and their roles are essential to comprehending their affect or contribution to the adoption and introduction of new products in the construction process. In addition, part of the research involves exploring different products that are now available in the marketplace; consequently, the author proceeds in this chapter to look at the different issues that need to be considered in the process of selecting materials.

2.2 THE RECYCLING PROCESS

In Canada the collection of solid waste from residential, institutional, industrial and commercial sources is accomplished through a diverse set of methods and programs, including curbside collection, Eco-Stations, Eco-Centres, recycling depots, buy back and drop off depots (Alberni Environmental Coalition, 2008). Recycling practices vary widely across Canada. For example, each municipality generally defines those items which it will accept for recycling, some require users to sort recyclables while others do not, some deliver recycling programs through the municipal government while others are delivered through private companies, and so on (Environment Canada, 2006). Programs that allow people to collect all type of recyclables in the same box are more cost effective because they bring together higher volumes of materials, simplify collection vehicles and reduce collection times and costs (Dubanowitz, 2000). The most common and successful program is curbside recycling in boxes, bins or bags that are placed in streets according to a collection schedule, where they are picked up by a municipal or private recycling agency. Materials of other types that cannot be collected through curb side programs are collected in recycling or drop-off depots (AEC, 2008). In some cases, the "buy back" method is employed, whereby people can take recyclables to places or centers that will pay money for them. In Montreal, Eco-Centres or community recycling centers have been established offering different waste diversion services for items such as asphalt, bricks, paints, soil, wood, metals (steel, iron, aluminum, copper) concrete, cardboard and tires (Ville de Montréal, 2009). As a second stage in the recycling process after collection, all the recyclables are delivered to materials recovery facilities (MRFs) where the material is sorted manually and mechanically

The Materials Recovery Facility is “a facility where recyclables are sorted into specific categories and processed, or transported to processors, for remanufacturing" (U.S. EPA, 1994). This process involves different stages, including mechanical (or automatic) sorting machines and hand sorting separation (Calgary’s Material Recovery Facility, 2009) (Figure 2.1).

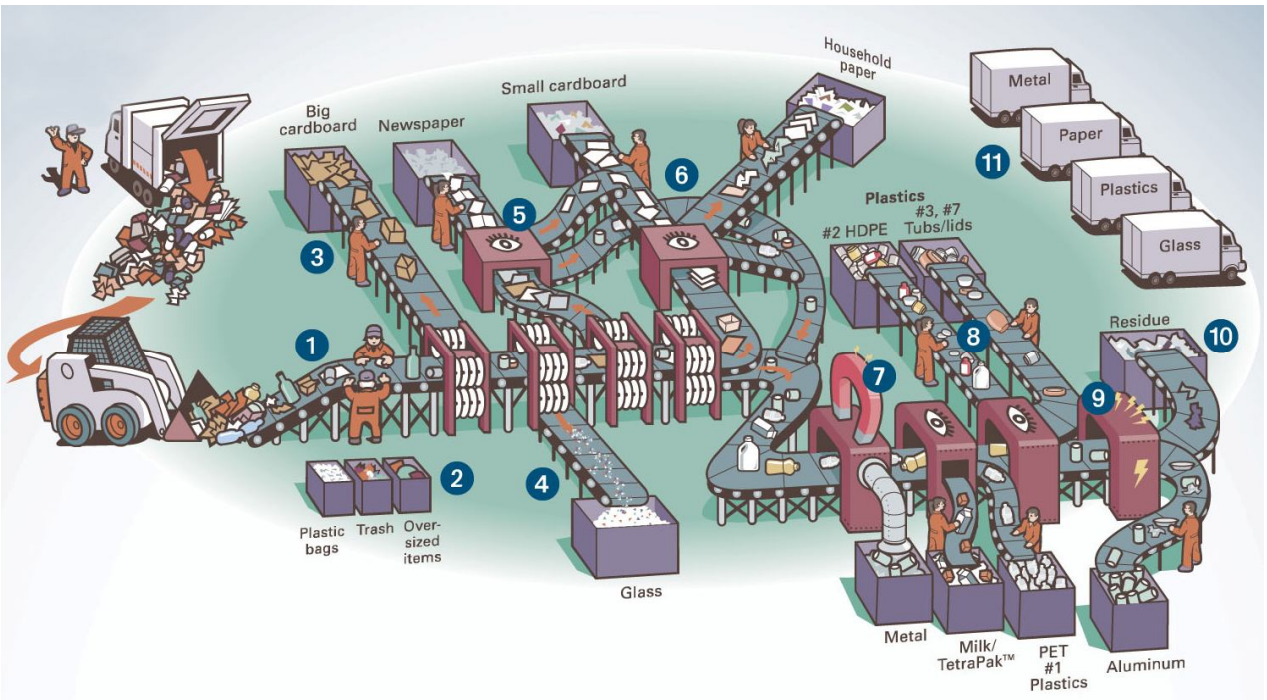

Figure 2.1: Recycling process in the Materials Recovery Facility. Materials are loaded onto the tipping floor then recyclables are sorted by category.

Source: Retrieved June 30, 2009, from http://www.calgarymayor.ca/files/pressreleases/2009/materials_recovery_facility_opening.pdf

Materials are loaded onto a conveyor to be pre-sorted, removing trash and oversized items. The conveyor carries recyclables over a set of 4 different disc screens removing different type of materials. The first set recovers big cardboard, the second glass, the third newspaper along with an optical sorter that detects other materials such as cardboard and boxboard papers and sends them to different processing lines. Another sorting line separates mixed fibre from

containers. Then, steel such as cans is removed by a strong magnet; plastics are recovered by two optical sorting machines and aluminum is removed by a strong electrical field around a magnet. Along with the mechanical system is a manual process performed by employees that check for quality and remove any contamination or material that should not be there. The final stage involves a quality control check that removes the remaining material to be recycled or sent to the trash. After the sorting process, when all items have been separated into different categories, the material is stored until enough material is accumulated to be baled, compacted and transported to markets that will turn them into useable resources.

Depending on the type of recyclables and their potential for re-use, materials go through different processes: cleaning, washing, grinding, heating and drying or shredding. For instance, glass is sorted by color, then crushed and ground into pieces (cullet), and finally any contaminant such as plastic or paper is removed from the glass cullet (All recycling-facts, 2009). Different materials can be made with glass granules; terrazzo products for instance are made by mixing the recycled material with a lightweight epoxy resin (Enviroglass, 2009). This combination is poured in place and gives a hard surface with no porosity and which is easy to maintain (Figure 2.2).

Plastic containers come in different types depending on the resin used; therefore, after they are compacted and baled, a sorting process is important in which material is selected according to type and color or rejected if is unclean (Alberni Environmental Coalition, 2008). Some plastics can be melted or ground and made into new products; others can be pulverized and used into composite materials (Canadian Plastics Sector Council, 2008). This process of taking plastic for re-use is called depolymerisation in which plastic molecules are taken apart by heat and chemicals (CPSCl, 2008).

Figure 2.2: Envirotraz. Colored glass chips from discarded bottles and other recycled materials such as mirrors, plate windows, porcelain chips, sinks and tubs are mixed with an epoxy resin giving the result of a durable surface that also offers a variety of designs and colors.

Source: Retrieved June 30, 2009 from http://www.enviroglasproducts.com/terrazzogall.asp

Aluminum cans are heated to remove paint, lacquer and labels; then, they are chopped, molten and finally formed into ingots for further reuse (American Institute of Chemical Engineers and Chemical Heritage Foundation, 2009). Paper is ground into fibers and put through a de-inking process in which ink is removed from the paper through a chemical washing process (General Mill Supply Co., 2007).

Other programs or recycling facilities promote the recovery of specific products collecting piles of materials. Examples of this are the recycling yards of construction and demolition debris, recycling companies for metal, carpets, steel, cardboard, or tires, among others. Every year, millions of tires are discarded around the world. Burning tires creates pollution and is harmful to human health and the natural environment (Spellman, 1999). In order to "enhance the effectiveness of scrap tire diversion and recycling across Canada" the Canadian Association of Tire Recycling Agencies (CATRA) was created in 1999 (Rubber Association of Canada, 2006). As a result, tires are accessible to recycling and reclaiming companies.

Depending on the intended end use of the tires the process of recycling can vary. According to CATRA in their brochure "Scrap tire recycling in Canada" the process of making new products with recycled tires follows different phases: Tires are sorted and can be shredded, crumbed and molded. Parts such as the sidewalls (the side surface of the automobile tire between the edge of the tread and the wheel) and treads (the part of the tire that makes contact with the road) are separated and can be used for many applications. For instance, tire sidewalls can be used as traffic cone collars and tire treads can be used as blasting mats for the construction and mining industries. Other products are made by a process of shredding whereby the tires are reduced to manageable size pieces (Figure 2.3). An example of shredded tire rubber application includes thermal insulation beneath roads. Then, after the shredding process, tire chips can be reduced to crumb rubber by a grinding process. Finally, crumb rubber is molded into different products through the use of heat, pressure and a binder. Examples of end products include: Patio blocks, pavers, playgrounds, horse arenas, walking and jogging paths, turf top dressing and durable roof shakes that give the appearance of other types of materials such as concrete or cedar (Figure 2.4).

Figure 2.3: Tires are fed into a primary shredder where they are reduced to smaller size pieces by rotary cutters.

Source: Retrieved June 30, 2009 from http://www.catraonline.ca/

Figure 2.4: Roofing product made of recycled tires.

Source: Retrieved June 30, 2009 from http://euroshieldroofing.com/

2.3 THE HOMEBUILDING INDUSTRY IN NORTH AMERICA

The homebuilding industry plays an important role in the Canadian economy, contributing approximately $80 billion annually (CMHC, 2006). The building industry is a major source of jobs and is a major purchaser of manufactured products. The industry is also a major consumer of raw materials and energy, contributing to greenhouse emissions in the local and global environment. Building in Canada accounts for a third of Canada's energy production, the utilization of half of our extracted natural resources, a quarter of our landfill waste, and 35% of our greenhouse gas emissions (Lucuik, 2005). As a result, it is an essential actor in the bid to mitigate climate change, meet environmental challenges, and provide industrial development and international recognition.

Two primary construction methods are used for building houses in North America: Site-built homes that comprise the traditional residential construction; and factory-built or prefabricated homes that are manufactured off-site and transported and assembled in standard sections. Each approach offers a wide variety of buildings, including single family, semi-detached, duplex, and row homes, apartments and condominiums. The factory-built housing industry may account for only a relatively small number of the houses built in Canada, but it is a growing industry, as factory-built homes are more commonly accepted in the marketplace (CMHC, 2006). Previously, homeowners often equated factory-built homes with the concept of cheap houses, poor designs and inferior quality products; however, today's factory-built homes offer modern designs, are larger, and utilized higher- quality construction materials than in the past (Figure 2.5). This sector is a potential contributor to new and innovated products. Producing a house in the factory has certain environmental advantages, as there are greater opportunities to minimize waste production and make more efficient use of resources.

Figure 2.5: Santa Monica's LivingHome, designed by architects Ray Kappe and Kieran Timberlake. The house has been manufactured in sections in a factory setting then shipped to the site. This process can improve the home quality and minimize the use of resources.

Source: Retrieved July 9, 2009 from http://www.livinghomes.net/homesCommunities.html

A good selection of building products is very important in the design and construction process; each material plays an important role and cannot be seen as an independent element. It is the integrated system that determines whether the entire building is a comfortable or unpleasant place to live or work in, from the structures that allow a building to last for many years (giving a sense of security to those who live there) to the finishing touches that provide a sense of warmness, or a sense of belonging in the place. Houses are fundamental for human life, and individuals look for comfortable, healthy and functional places; therefore, the building materials industry fulfills an important role in the physical environment and the standard of living and quality of life in Canada. Today, in order to achieve environmental goals, demand for innovative products is required; however, innovations and marketing in the materials building industry are not adopted quickly.

2.4 INNOVATION AND BARRIERS IN THE BUILDING MATERIALS INDUSTRY

"We shall require a substantially new manner of thinking if mankind is to survive."

Albert Einstein (Solar Institute Inc., 2008)

The building materials industry faces serious challenges in terms of global warming. The production, transportation, and installation of materials needed to build a house requires tremendous amount of energy and natural resources (Carnow, 2008). As more buildings are constructed, the emission of greenhouse gases (GHGs) increases. Although it is not possible to stop building, changes can be made to the materials manufacturing process to increase efficiency and save time, money, and waste. To increase the level of sustainability in buildings, it is important to change and create new products and innovations; as such innovation also attracts economic and social benefits. It creates new markets, generates employment, and encourages competiveness in production, improving quality and the performance of materials. For instance, the implementation of building codes has provided homeowners with a sense of safety and comfort; while the standardization of building products has enabled builders to save time, and energy. Efficiency innovations have contributed to the reduction in residential energy consumption (Hassel et al., 2003). However, the arrival and spread of innovative products is a difficult task.

New products can be more costly and may have difficulty competing with conventional products. Even when this is not the case, it often happens that a product could be competitive, if only it has the marketing support it needs in order to become well known (CMHC, 2007). It is the author's opinion that in order to understand the diffusion and adoption of innovative products

in the building industry we must examine three important aspects: cost, lack of knowledge and marketing.

2.4.1 COST

A builder's decision in the selection of the building materials is driven primarily by economic attributes. Canada Mortgage and Housing Corporation (CMHC) and the Canadian Home Builders' Association (CHBA) in their report "Challenges and Prospects for the Building Materials Industry in Canada" (2007) explains that thanks to new technologies (such as computer-aided design or manufacturing), the production of new products is more efficient in economic terms and quality. The industry offers a wide range of products, varying in quality, cost and performance; however, in order to reduce cost, builders tend to choose for lower-quality products because they are less expensive. Furthermore, builders do not often take the risk of using a new product that they do not already intricately know and understand. On the one hand, the time required for approval to use new products in projects is costly. Besides, manufacturers face the risk of financial loss due to a performance failure or a market rejection. This is a huge obstacle that must be overcome, and the participation of government on creating or implementing incentives that encourage innovation to offset the cost generated by this process is essential. Canada Mortgage and Housing Corporation in its report "Technology Transfer and Innovation in the Canadian Residential Construction Industry" (1990) points out that there is a lack of money to develop innovations, and builders tend not to incorporate innovations into their building process unless there are well-established, demonstrable advantages. It can be surmised that showing the benefits of innovative products will increase acceptance. Besides budgeting constraints, the lack of knowledge of innovative techniques and materials force builders to continue using traditional materials. Although small firms have limited financial ability to carry

out research and development (R&D) large companies are able to adopt new products and can influence other contractors and builders to use them as well, so communication is important (CMHC, 2006).

2.4.2 LACK OF KNOWLEDGE

Lack of knowledge on the part of home buyers, designers and builders decreases the interest for new products and ultimately affecting the demand of them as well. Manufacturers, suppliers, builders, owners, contractors, and stakeholders should share knowledge and information about the emerging construction technologies or experiences and advantages in the use of new products. As more builders and homeowners become aware of and request alternative products, manufacturers will need to develop new products and techniques in order to contribute toward a more sustainable future. Training and education are also important and affect the implementation of innovation, not only for builders or contractors that should be informed about the products, but also for the development of a skilled work force.

2.4.3 MARKETING

The adoption of new products requires an effective information transfer not only by the public sector but also by the private. Most manufacturers lack an effective information dissemination and marketing strategy to promote their products (CMHC, 2007). Many people and organizations are involved in this process and they can increase the industry awareness and promote the adoption of new materials. Since the price of products can vary, it is important not only to market the product with the initial price, but also to emphasize the value and quality of products in the long term, to encourage people to buy them.

'Green' buildings promote the use of recycled materials, and these high-performance buildings are perceived as new, different, and sustainable. Typically, such buildings are constructed as part of a larger project, because the building process is more complex. Unlike conventional buildings, green buildings require an integrated design process (IDP) and a multi-disciplinary team including skilled labor force and professionals who understand the different construction systems and products in order to optimize the building performance (Lucuik, 2005). The lack of knowledge about and analysis of affordable products make it difficult to builders or owners to buy and try different products.

The market equilibrium for building materials is determined by the intersection between supply and demand for them (Trump University, 2009) (Figure 2.6). In other words, the price level for any given product is determined by the point at which quantity supplied equals quantity demanded (Lipsey & Chrystal, 2007). Higher prices tend to decrease demand for a product. Prices of expensive products may go down as demand for them is increased

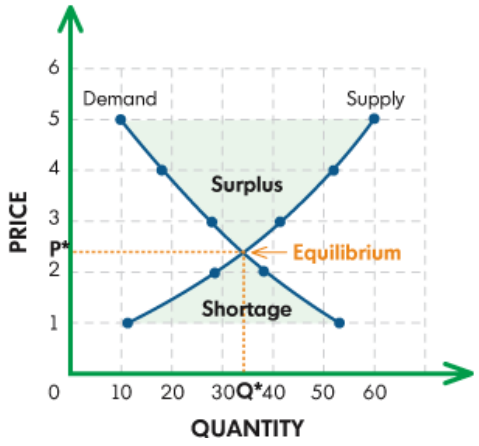

Figure 2.6: Law of Supply and Demand. The market price is determined when quantity supplied equals quantity demand.

Source: Retrieved April 14, 2009 from http://www.trumpuniversity.com/business-briefings/

Therefore, in order to manufacture more products and stimulate consumer demand for recycled materials, it is crucial to have good information not only from product manufacturers but also from the government and private companies. One dissemination strategy may be to increase their internal communication capacity through seminars and trade shows, and the promotion of programmes and sample projects to demonstrate the innovation of products and encourage builders to implement products and techniques (CMHC, 2006).

2.5 PLAYERS INVOLVED IN THE ADOPTION OF RECYCLED MATERIALS

The building process is a complex task that extends from the pre-design phase (that establishes the owner's needs) right up to the post-occupancy phase. Building involves many different actors and the importance and role influence in the decision-making process to use new products and techniques is significant (Figure 2.7).

Figure 2.7: Players involved in the selection of building products. Responsibility carried by all parties increases demand for more sustainable materials.

2.5.1 GOVERNMENT

The government is a crucial player in the promotion and implementation of environmentally-friendly construction practices. By continuing to encouraging recycling, manufacturers will be able to incorporate this source of material in their products. Recycled products are promoted by the green building industry and Canada offers different programs that provide federal grants and incentives to homeowners to help them to improve the energy efficiency of their homes and reduce their homes impact on the environment. Some national programmes that encourage sustainable living are R-2000 and ecoENERGY Retrofit. There are also federal programmes such as: Built Green (TM) Alberta Gold Label Homes, Novoclimat (MC) (Quebec), EnergyStar (R) (Ontario), and Power Smart (TM) (Manitoba).

In order for Canada to meet its Kyoto commitments, the National Climate Change Process (NCCP) created by the federal government promotes strategies to make single-family housing, multi-unit housing and commercial and public buildings more energy efficient, while simultaneously advocating programs that reduce, re-use, recycle and compost materials as appropriate (Tellus Institute, MRG & Associates, 2002).

2.5.2 CONTRACTOR / SUBCONTACTOR

The contractor is the person or entity who is engaged by the owner to physically design or construct the building in question. The contractor has the responsibility to meet the owner's needs and complete the project in the scheduled time. Contractors plan, organize and control the different activities in the building process. They employ subcontractors to do specialized work and they must coordinate the different plans and specifications with designers. When new products are included in a project, the contractor must address the challenges of new and

different specifications, and builders must be aware about these products. New products cannot be introduced easily if there is little or not enough information about them. On the other hand, recycled materials are part of the green building industry, and many builders are now more interested in green constructions. Acquainting oneself with them requires additional time in the design and construction phases, and few builders are able to spend time with unfamiliar materials. Nevertheless, as contractors and subcontractors play an important role in the selection of materials and they need to have enough knowledge about the products and their appropriate use; they can assist designers and suggest different products during construction.

2.5.3 THE DESIGN PROFESSIONALS

The design professional can be an architect or engineer and has direct contact with the owner. Designers serve as technical advisors to the developer and can bring forward new ideas and search for new materials. Some are interested and concerned about the environment; however, not all of them know about these products, where to find them and how to evaluate them. Searching those products requires time and additional cost. It is the responsibility of architects to monitor and supervise the selection and quality of the materials, however, in the residential industry, especially in the single family housing sector, professionals that are not registered as architects charge low rates and do not follow those procedures (Friedman, 1991). In many cases plans are used in different projects precluding the possibility of using alternative materials. It is the designer's responsibility to protect the health, safety, and welfare of the public, so that product selection is crucial (Kalin, 2003). Therefore designers should find products that fulfil the occupant's needs and safety. On the other hand, the efficiency of green buildings is achieved by the integrated design and collaboration of all players; therefore, architects should be involved in the construction phase (WBDG, 2009).

2.5.4 THE PRODUCT MANUFACTURER

When contractors and designers are unfamiliar with certain products, it is the manufacturer's responsibility to provide additional details and information such as installation and maintenance instructions. Recycled materials are developed by manufacturers who produce lines of green building materials. They are the experts on the products and will assist in the recommendation of products based on their knowledge (Kalin, 2003). Manufacturers contact consumers and market their products; but they must understand the design and construction process, provide technical information and be familiar with standard procedures in order to know how to get their product used on a project. However, "lack of good information from product manufacturers is a real problem" (Kalin, 2003). Consumers buy products that are designed to be environmentally-conscious; but if there is not enough information about the advantages of quality, price and functionality, most builders will not risk the adoption of new products. Therefore, it is vital for manufacturers to provide detailed specification information and increase consumer interest so they can create demand of new products.

2.5.5 BUILDING OWNER / OCCUPANT

The first decision in the housing construction process is taken by the owner or initiator (who may be a person or a company, private or public). Single-family homeowners may wish to build their own house; a land developer may wish to develop a group of houses and sell them for profit; and there may also be identified apartment owners whose intention would be to sell or rent the property. All of these groups are responsible for funding the construction of the project. The majority of building owners know the importance of protecting the environment; however, their main goal is almost always focused on building a project to meet a specific time and

budget. Home owners or individual building owners usually do not have the experience or interest in new products and about the materials selection process (Kalin, 2003). Such owners are mainly concerned with aesthetic value, visual importance and cost, and often contract a design professional and contractor to complete this task. However, homeowners can be influenced by information from other people if they are made aware of the different advantages of these products.

The building occupant or end-user of the building has less influence on the decision-making process in terms of the use or non-use of recycled products, despite the fact that it is this very end-user who will be affected by the choices made for the building. The lack of marketing and sub-optimal interest of consumers about the environment decreases the demand for recycled materials.

In conclusion the responsibility for selecting products with recycle content remains with all Government, building owner, contractor, subcontractor, the design professionals, the product manufacturer, the building occupant. Each of them contributes in different levels for a sustainable construction. In order to facilitate the research of such products it is important to know some issues that influence a good choice.

2.6 FACTORS AFFECTING CHOICE AND USE OF BUILDING PRODUCTS MADE OF RECYCLED MATERIALS

That the use of recycled materials goes hand in hand with the green construction and green product selection movements is a very important component of sustainable design. Recycled materials are part of the three R's of sustainability: Reduce, Reuse and Recycle.

- Reduce the amount of raw materials needed for the manufacturing process.

- Re-use raw materials that require significant energy consumption to produce, or that are typically attributed to large proportions of our landfill waste.
- Renew the environment by using materials that can be regenerated and materials offering environmentally friendly benefits.

The selection of building products is a complex task, because the cost and aesthetic value are only two issues that are important and need to be considered. Other significant factors include the building codes, the quality and durability of the product, and labels or certifications.

2.6.1 BUILDING CODE

The National Building Code of Canada (NBC) strives to "ensure that buildings are structurally sound, safe from fire, free of health hazards, and accessible" (National Research Council Canada, 2009). In order to protect the health, safety and welfare of people it is important to know the minimum standards of safety required in buildings. However, the NBC does not reflect many of the characteristics of green buildings. In contrast The Model National Energy Code of Canada for Buildings 1997 (MNECB) contains minimum requirements for energy efficiency in new buildings. The MNEBC contains information on how to achieve energy efficiency, and the minimum compliance levels that are comparatively easy to attain. The Canadian Building Incentive Program (CBIP) requires exceeding the MNECB requirements by 25%; however, green buildings usually exceed these requirements by 60% or more (Lucuik, 2005). On the other hand, the use of recycled materials may introduce new testing and development processes, such as fire testing, before a new product attains a wide market acceptance (White, 1997). Many recycled materials such as wood or polystyrene mixed with cement or concrete are more fire resistant than conventional materials.

2.6.2 QUALITY AND DURABILITY

Quality and durability are vital aspects of building materials. Non-durable building materials require maintenance or repair, increasing costs and environmental impacts (Kernan, Penner & Associates, 2001). Canada's extreme temperature fluctuations necessitate that the envelope of the building (roofs, walls, windows) be an important component in the life and operation of the building. For that reason is important to use more energy-efficient materials. Recycled materials are energy efficient (North American Insulation Manufacturers Association, 1997). For instance, Insulation products such as fiber glass and slag wool made of recycled materials save consumers large percentage of energy annually (NAIMA, 1997). Recycled polystyrene and wood blocks are more energy efficient than a conventional insulation wall, due to their insulation properties and to the large thermal mass of the solid walls (Rastra, Durisol 2009). Another such characteristic is that the poured cement prevents air filtration. Canadian Building Envelope specialists are recognized as world leaders in this field (Larsson, 2004). For buildings that are expected or required to have a long life, it is better to select products with the longest lifespan which in some cases may increases the initial cost (Kernan, Penner & Associates, 2001).

2.6.3 LABELS AND CERTIFICATIONS

An ecolabel is a label which identifies overall environmental preference of a product within a product category based on life cycle considerations (Global Ecolabelling Network, 2008). The three arrows of the recycling symbol that indicate a loop are use to identify products made from recycled material. However, the logo in and of itself is not enough, and other specifications should be included. Many misconceptions or exaggerations about products can be found in the

marketplace, a practice referred to as “Greenwashing” (Lucuik, 2005). These products’ environmental profile may be poorly defined such that it can be misunderstood by the consumer. According to a study made by TerraChoice Environmental Marketing Inc (2007), there are different aspects in greenwashing that should be considered: for instance, some products are marketed as “green” for their recycled content; however, they may have hazardous material content or poor indoor air quality; products with very little recycled content in them may be marketed as “green” when they really are not terribly different from their non-“green” counterparts; the logo may very well mean that the package itself is made of recycled material, and not the product contained therein. Besides, it is important to know if the product is 100% recycled material or less or if it is post-consumer waste or post-industrial waste. In order to mitigate this, the government has recognized that the development and implementation of environmental certification plays an important role in the green building industry providing consumers with a level of assurance that the product meets environmental criteria. In Canada there are a number of certification programs: Green Seal, the Environmental Choice program (Ecologo), The Forest Stewardship Council (FSC) and Energy Star.

2.6.3.1 GREEN SEAL

Founded in 1989, Green Seal is a non-profit organization that promotes the manufacture, purchase and use of environmentally responsible products and services (Green Seal, 2009). Green Seal provides Eco labelling for a wide range of products and meets the standards for eco labelling set by the International Organization for Standardization (ISO) 14020 and 14024 (Figure 2.8). Green Seal analyzes the full environmental impact at each life cycle stage of the product and their certification gives consumers confidence that products meet environmental standards and protect human health (Green Seal, 2009).

2.6.3.2 TERRA CHOICE ECOLOGO PROGRAM

Environment Canada established the environmental Choice Program (ECP) in 1988 “to guide consumers in making environmentally purchasing decisions” (Legault, L. n.d). The Environmental Choice label Ecologo is North America’s leading benchmark for environmentally responsible products and services. Certification is awarded for products that are made in a way that improves energy efficiency, reduces hazardous by-products, uses recycled materials or can be reused (City of Toronto, 2009). Ecologo symbol is represented by three doves intertwined that form a maple leaf (Figure 2.9). “Each dove represents a sector of society: consumers, industry and government all working together to improve Canada's environment” (City of Toronto, 2009).

Figure 2.8: Green Seal

Source: Retrieved April 15, 2009 from http://www.greenseal.org/

Figure 2.9: The EcoLogo

Source: Retrieved April 15, 2009 from http://www.terrachoice-certified.com/en

2.6.3.3 THE FOREST STEWARDSHIP COUNCIL

Wood is a renewable resource that needs to be harvested in a sustainable manner without causing damage to the forest ecosystem. Hence, wood from certified sources lessen the forestry

impacts such as loss of habitat, soil erosion, sedimentation of water courses, global warming. The Forest Stewardship Council (FSC) founded in 1993 is an international, non-profit organization that assures users that wood materials come from sustainable managed forests and verified recycled sources (FSC, 1996). FSC provides a list of certified wood product suppliers in Canada including products with recycled content (Figure 2.10). Other credible programs that promote green buildings that give preferences to wood certified are the American tree Farm System (ATFS), Canadian Standards Association (CSA) and Sustainable Forest Initiative (SFI).

2.6.3.4 ENERGY STAR

The energy used to operate buildings is one of the major facts that contribute to the global warming generating greenhouse gases emissions and air pollution. The energy used in buildings for heating, cooling, ventilation, and lighting is significant, so that building with materials that are energy efficiency is important. Energy Star is an international standard that identify and certifies energy efficient products (Figure 2.11). This program rates products in different categories including roofing, windows and doors (Energy Star, 2009).

Figure 2.10: Forest Stewardship Council

Source: Retrieved April 15, 2009 from http://www.fsccanada.org/

Figure 2.11: Energy star

Source: Retrieved April 15, 2009 from http://www.energystar.gov/

2.7 SUMMARY AND CONCLUSIONS

Recycling brings economic and environmental benefits. In order to be efficient the recycling process the three components of collecting, remanufacturing, and purchasing have to be in balance. It does not matter how much tonnes of waste is recovered if there is no enough market for materials and buyers for them. Population continues to increase so the demand for new buildings grows. Today, the fact that the process of building and manufacturing products affects the environment is a subject that interest and touches all the parts government, manufacturers, consumers, builders and designers. The adoption or implementation of environmental products is an important key to improve the way of building, the quality of life of the occupants and the protection of the natural resources.

One major problem is the Lack of market and consumer awareness of the price and the quality of products made of recycle materials; hence, certifications and labels play an important role allowing consumers to be confident about their choices. Products have been tested and certifications ensure that meet standards of sustainability. Communication is crucial to promote the acceptance of new products. Public and private sectors should work together to increase the demand and manufacture of new products. Government for instance can encourage widespread adoption of products with recycle content through demonstrations projects and promote the diffusion of their costs and benefits. Education and training is also important allowing people to get to know new products, their installation and the different advantages.

CHAPTER THREE

SELECTION PROCESS AND BULDING PRODUCTS MADE OF RECYCLED MATERIALS

3.1 CRITERIA FOR PRODUCT SELECTION

After reviewing in chapter II the different elements that need to be taken into account when selecting materials such as the performance and the environmental benefits, this chapter will focus on the selection process and the description of different building products made of recycled materials. In doing so, the author proposes a three-stage framework to record and analyze the data based on the Environmental Assessment and Specification of Green Building Materials (Froeschle, 1999): research, evaluation and selection.

3.1.1 RESEARCH

This step involves identifying the different categories of materials used in residences, based around typical components used in such buildings, such as foundation, framing, building envelope and interior finishes. Then, technical information on each product is to be evaluated. In order to be aware of current requirements, environmental trends and new developments, there are different sources of information such as the government, professional and trade organizations. Some sources of information with respect to sustainable building materials include Canada Mortgage and Housing Corporation (CMHC), Canada Green Building Council (CaGBC), the National Institute of Standards and Technology (NIST), the Environmental Protection Agency (EPA) and green products directories, among others. Technical information may be gathered from manufacturers or product representatives, and may include material safety data sheets (MSDS), brochures, and specification sheets. Product information can vary

depending on the material used and different aspects can be taken into account, including building codes, industry standards, green rating programs, certifications, product warranties, source material characteristics, recycled content data, and durability information.

3.1.2 EVALUATION

This step includes confirmation of the technical information and filling in information gaps. As the goal of this study is to identify different products that contain recycled materials, it is imperative that the products have otherwise similar characteristics and functions, in order to be able to compare products that have the same criteria evaluation. In this stage the collection of data will be summarized for each product in the following format:

- Type of product
- Company information
- Percentage of recycled content
- Performance, including durability, standards, fire resistance and installation
- Cost

3.1.3 SELECTION

This step involves selecting the product that best meets the environmental criteria and the most appropriate application for housing. In order to locate specific type of information, materials should be organized according to the CSI Master format[5]. However, this report will classify materials based on their application in the final structure, from the ground floor to the roof, for a better understanding of the building construction. The selection process of recycled materials is, in some respects, the same as for traditional materials, requiring the exploration of

[5] CSI Master format is compose of 16 divisions (i.e. Division 3. Concrete, Division 4. Masonry, Division 5. Metals, Division 6. Wood and Plastic, Division 7. Thermal and Moisture Protection, Division 8. Doors and Windows and Division 9. Finishes)

general aspects such as aesthetics, performance and cost. However, when choosing materials with recycled content, one should keep in mind the different environmental benefits that these products can provide and consider products that combine different attributes:

- Choosing the highest recycled content available. Some recycled products may only include 10% recycled material.
- Seeking the highest post-consumer recycled content available.
- Looking for materials that are not only recycled, but also recyclable or biodegradable at the end of their useful life.
- Maximising durability.
- Maximizing energy efficiency.
- Maximizing maintainability.
- Looking for local and regional resources and manufacturers.
- Minimizing embodied energy.
- Avoiding highly toxic compounds and choosing materials that improve indoor air quality.

For a complete understanding of the selection process, the author will explain the different materials that encourage sustainability in the following sections.

3.2 THE BUILDING COMPONENTS

This section examines different building products that are environmentally friendly and that are currently used in housing starting from the foundation of the building to the interior finishes. Before introducing the selected products made of recycled materials, it is important to understand what composite materials are and how they are related to building products.

Composite materials are the "combination of two or more materials that have quite different properties" (Australian Academy of Science, 2000). The physical process of composite materials occurs when two constituent materials are mixed: the matrix material which supports and binds together other constituents and the reinforcement materials that improve the mechanical properties of the matrix (Morva, 2006). The materials are mixed and bonded resulting in a system that offers superior properties: high strength and stiffness, durability, good fatigue performance, design flexibility, and lower maintenance costs (Dobson, 2005). Different composite building materials are made of recycled materials. Some examples include Natural Fiber Composites (NFCs) which are the result of natural fibers of wood or hemp combined with recycled plastics. The NFCs are molded into sheets, boards and frames (Morva, 2006). Other common examples are concrete (cement and aggregate), fibreglass (glass and plastic), cerment (ceramic and metal) and engineered wood made of layers of wood. Examples of composite structural materials include concrete, steel, and fibreglass (Dobson, 2005). In the following sections the author describes common building materials and proposes alternative products that include the use of recycled materials and offer other advantages. These products are analyzed and presented in a comparative chart in which the reader will be able to see their different technical aspects. In addition, the author's research has been focused on but not limited to materials that are locally or regionally manufactured.

3.2.1 OVERVIEW OF CONCRETE FONDATION

The foundation is one of the most important structural elements and the part of the building that can cause serious problems over time. The foundation supports the building structure; therefore, a long life and the safety of the construction depend on a good quality foundation. In order to protect the structure from water and avoid moisture problems, bridge

gaps, cracks, and voids, and to protect the building from winter weather and avoid heat loss; two aspects need to be considered: waterproofing and insulation. Concrete is one of the most common construction materials and is also one of the main components used in foundations. It incorporates four major materials: Cement, sand, aggregate and water (Cement Association of Canada, 2009). Recycled materials can be incorporated into this mix. Fly ash, slag cement, and silica fume are recycled materials from industrial by-products that can be used in place of a portion of cement (Portland Cement Association, 2009). Fly ash is a post industrial by-product of coal-fueled electric power. By using this supplementary cement material (SCM) the concrete can become stronger, less permeable, more durable, workable and more resistant to chemical attack (Headwaters Resources, 2008). According to the Cement Sustainability Initiative (CSI, 2009) "concrete is a durable building material that is also recoverable"; for instance, concrete can be recycled and reused as aggregate in new concrete conserving virgin resources and reducing both the waste going to landfill and the associated mining impacts. In addition, when concrete is recycled, steel reinforcing is removed and recovered.

There are generally two common types of foundations: poured concrete and block wall foundation (Sano et al., 2002). However, there are other alternative foundation materials that are currently being used in the construction industry providing structural safety and stability in a more sustainable manner, including the Insulated Concrete Form (ICF) and the precast concrete foundations.

3.2.1.1 PRECAST CONCRETE FOUNDATION

Precast concrete foundation system is a concrete structure cured in a controlled factory environment that allows a high-quality product (National Precast Concrete Association [NPCA],

2007). Precast wall panels are built with steel-reinforced concrete studs that provides strength to the entire structure; a rigid insulation board on the interior side; rebar-reinforced top and bottom bond beams; along with a concrete facing (Scutella & Heberle, 1999) (Figure 3.1). Although the system is insulated, additional insulation can be installed to increase the thermal resistance (R-value) of the foundation making it more energy efficient (Heekin, 2006). Precast wall system has been used in commercial buildings for many years, but it was only until 2007 that was approved by the International Residential Code (IRC) as an alternative wall system to traditional residential foundations (Stutz, 2009). The system offers different advantages (NPCA, 2009): The reinforced concrete studs include a treated wood nailer that allows the application of interior wall finishing materials (Figure 3.2); the precast panels are cast with 5,000 psi concrete and are inherently stronger and more durable than concrete block or concrete walls poured in the field; panels are dam proofing; the foundation can be installed in any climate zone; and the installation time is faster than that used in a formed concrete foundation. The panels can use up to 60 % less concrete than a traditional cast-in-place concrete foundation and are lighter and more cost effective to transport than a solid concrete wall (Heekin, 2006).

Besides energy efficiency, flexibility and superior strength and durability, precast concrete can contain recycled materials and is itself, recyclable (Prestressed Concrete Institute, 2009): The concrete can include industrial by-products such as fly ash, slag, and silica fume and the reinforcement can be made from recycled steel. Additionally, precast foundations have a long life as their components are individually engineered and can be rearranged and also reused; concrete can be crushed and recycled in the form of aggregate for use in new concrete and as base material for other applications in roads or sidewalks (PCI, 2009).

In conclusion, precast concrete system is a good option for foundations because it is cast off-site in a controlled environment, and this provides many advantages over cast-in-place foundations and concrete block foundations. It is stronger and lighter, and can reduce the amount of time and coordination required during construction. Nevertheless, cement is a very energy intensive material and a major contributor to CO_2 in the atmosphere (Wilson, 1993). Although the quantity of cement can be reduced by including fly ash in the mix, precast wall systems are basically composed of concrete. Unlike insulated concrete forms precast concrete does not include other alternative materials that increase the percentage of recycled materials. For that reason, the author has selected and analyzed ICFs as a sustainable option for foundations.

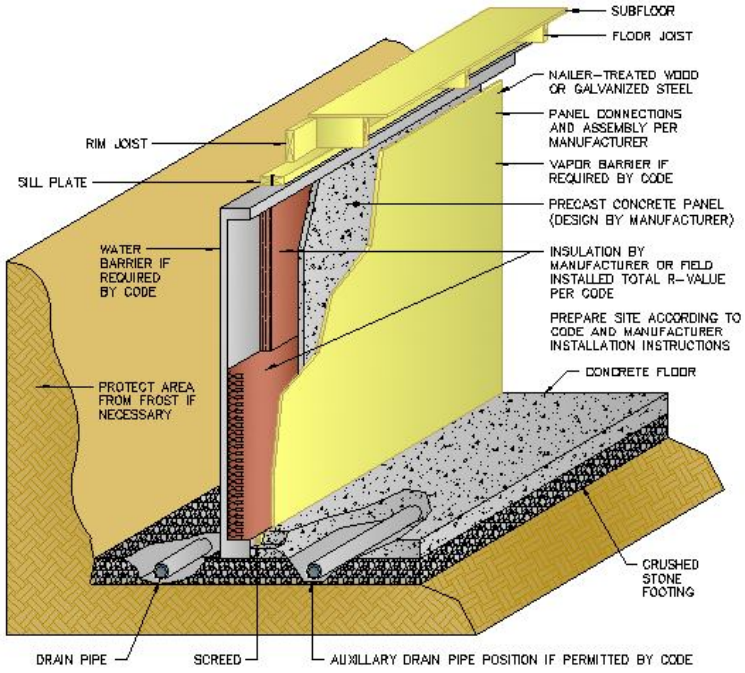

Figure 3.1: Pre-cast foundation panel in a basement application. The system can be placed on crushed stone or traditional concrete footings.

Source: Retrieved July 16, 2009, from http://www.toolbase.org/index.aspx

Figure 3.2: Precast concrete foundation wall. The system can be used on any foundation layout.

Source: Retrieved July 16, 2009, from http://www.precast.org/

3.2.1.2 INSULATED CONCRETE FORM (ICF)

ICFs are forms that are left in place after the concrete is poured for a foundation or wall (Portland Cement Association [PCA], 2009). The forms are generally made of foam insulation, such as expanded polystyrene (EPS) and are filled with reinforced concrete to create a solid structure (PCA, 2009). There are two types: preformed interlocking blocks or separate panels connected with plastic or metal ties. Each type offers a variety of designs (PCA, 2009). According to the Insulating Concrete Form Association (2008) there are different aspects that make ICF construction a good option for sustainable buildings which are summarized in five points: optimized energy performance, durability, recycled material content, local materials and improved Indoor Air Quality. The energy efficiency is due not only to the thermal mass of the concrete that helps to absorb and release heat slowly, but also to the air tightness and continuous insulation of the system (ICFA, 2008). Other benefits that provide the solid structure include sound isolation, resistance to fire, pest, storms and high winds (ICFA, 2008). The author has selected three types of ICFs in which manufacturers have used different materials: Quad-Lock which includes the typical EPS forms and Durisol and Rastra products which incorporate a mix of other materials to create innovative forms.

3.2.1.2.1 QUAD-LOCK INSULATED CONCRETE FORM

The Quad Lock system is manufactured by Quad-Lock Building a British Columbia based company which has distributed the product since 1994. Quad lock is composed of two panels made of Expanded Polystyrene (EPS) and ties made of High Density Polyethylene (HDPE) or Polypropylene (PP) (Quad-lock CSI Technical Specifications, 2009). The ties retain the opposing EPS panels, which form a cavity where reinforcement bars and concrete are placed

(Quad-Lock ICC Report, 2004). Ties are available in five standard lengths providing different wall thicknesses and can be combined with extender ties to make wider cavities. The system provides four panel configurations that in turn can be combined allowing 10 different configurations which range in R-value from R22 to R40 (Product Manual, 2008). Although the EPS is 100% recyclable the forms do not include recycled content. Recycled materials are not used for panels or ties, ostensibly because the strength of the material is critical and recycled materials may not meet the strict standards for quality (L. Little, e-mail message to author, 2009, Sep 2). However, substitution of fly ash or blast slag can be incorporated into the concrete mix (Product Manual, 2008).

3.2.1.2.2 RASTRA INSULATED CONCRETE FORM

Rastra wall ICF is manufactured in Scottsdale, Arizona. The product was first introduced in 1972 in Austria and since then has been improved and used in different places and types of climates including Europe, the Middle and Far East, North Africa and The Americas (Rastra, 2009). Unlike the panels made of polystyrene, Rastra is made of a material called Thastyron (Thermo-Acoustic-Styro-Concrete) made from a mixture of 85% recycled polystyrene and 15% cement (Rastra, 2009). The panels are composed of interior cavities that form a grid of 6" (152mm) diameter columns in which steel reinforcement and concrete are added to provide the wall strength.

The mix of polystyrene and cement creates a material that is not combustible, resistant to termites and acts as a natural barrier against air and moisture, reducing the need for extensive vapour barriers (Rastra, 2009). The porous material also allows sound to be absorbed, creating a sound barrier that reduces both outside noise and the movement of airborne sound from one

room to another (Rastra Technical information, 2009). Some considerations have to be taken into account, when installing the product, because the dust created during scraping or sawing may cause irritation of the eyes and upper respiratory system (Rastra MSDS, 1999). Furthermore, Rastra does not have plant in Canada; material has to be shipped from New Mexico increasing the shipping cost and the environmental effect of transportation. On the other hand, there are other materials that reduce the consumption of oil products, such as including recycled waste wood and concrete.

3.2.1.2.3 DURISOL INSULATED CONCRETE FORM

Durisol is a company based out of Hamilton, Ontario that manufactures wall forms made from a "proprietary cement-bonded wood fiber material that has only natural ingredients" (Durisol Concrete Wood Forms, 2009). Durisol products have been on the market since 1953 in different types of building applications. The forms are made of 80% recycled wood from post-industrial waste (Figures 3.3 and 3.4). Post-consumer waste or recycled demolition materials are not used to ensure the material's high quality (Durisol, 2009). The wood chips are neutralized, mineralized and bonded with Portland cement; then the material is compressed and molded into stay-in-place concrete wall form units (Durisol Wall Form Specification, 2000). The wood concrete material is porous, is more impact resistant than the foam ICFs, does not burn or melt, is highly breathable and facilitates improved indoor air quality (Durisol Wall Form system, 2008).

Another important consideration besides the use of natural ingredients is that Durisol is a free draining material allowing builders to drain the moisture of a very wet concrete mix ensuring that there are no voids and making the pouring process easy (Durisol, 2009). Furthermore, the material provides a high reduction of noise, as it absorbs sound (Noise

reduction coefficient) and isolates it (Sound transmission coefficient) (Durisol Sound Protection, 2009). The insulation value of a standard Durisol concrete wall form is R-8; nevertheless, additional insulation is made from mineral fibre and is placed towards the exterior for maximum thermal mass gains. Insulation values can range from R-14 to R-28. Therefore, the mix of wood and concrete material results in a stronger, more durable and more energy efficient product. However, cement dust can cause eyes and nose irritation; hence, safety glasses and dust mask should be used when sawing (Durisol MSDS, 2006).

Figure 3.3: ICF made of graded recycled waste wood bonded with Portland cement. These forms are porous, lightweight, durable and recyclable.

Source: Retrieved July 20, 2009, from http://www.durisolbuild.com/

Figure 3.4: The wall forms are interlocking modular units that are dry-stacked (without mortar) and filled with concrete and reinforcing steel.

Source: Retrieved July 20, 2009, from http://www.durisolbuild.com

In order to understand the different products and properties a comparison chart (Table 3.1) is presented including the materials used and the different technical aspects.

Product name	**Quad-Lock**	**Rastra**	**Durisol**
Company information	Quad-Lock Building Systems Ltd. 7398-132nd Street Surrey, British Columbia V3W 4M7 Phone: 604-5903111 www.quadlock.com/	Rastra Corporation 7621 East Gray Road Scottsdale, Arizona 85260 Phone: 866-272-7872 www.rastra.com/	Durisol Building Systems Inc. 505 York Blvd-Suite 2 Hamilton, Ontario L8R 3K4 Phone: 905-521-0999 www.durisolbuild.com/
Use	System for walls (below and above grade), floors and roofs.	System for walls (below and above grade), floors and roofs.	Wall construction below and above grade.
Applications	Residential, Industrial and Institutional	Single Family Homes, Multi-Family (Condominiums, apartments and hotels), Commercial Buildings	Residential (Single and Multi-Unit), High Rise, Industrial, Agricultural, Commercial, and Institutional.
Raw materials	Panels made of Expanded Polystyrene (EPS) and ties made of High Density Polyethylene (HDPE) or Polypropylene (PP).	Mixture of 85% recycled polystyrene (Styrofoam)) and 15% cement.	Panels made of graded recycled waste wood mineralized and bonded together with Portland cement. Mineral wool insulation.
Recycled content (%)	Fly ash (available for costumers demand).	85% Post-consumer and post-industrial expanded polystyrene (EPS).	75-80% Post-industrial waste wood.
Recyclable	✓	✓	✓
Thermal R-Value	R22 to R-40	R-20 to R-49	R-14 to R-28
Fire rating	4 HR self extinguishing	4 HR Non combustible	4 HR Non combustible
Indoor air quality	No off-gassing.	There are no VOCs or off gassing.	There are no VOCs or off gassing.
	Superior indoor air quality. Minimizes air infiltration.	Improves air exchange rate & climate control.	Provides humidity and atmospheric control.
Sound Transmission Coefficient (STC)	50-59	50	54-72
Noise Reduction Coefficient (NRC)	N/A	N/A	0.70 - 0.95
Installed wall cost ($)/ft²	$13	US $15	$12

Continue on next page

Product name	**Quad-Lock**	**Rastra**	**Durisol**
Warranty	Limited Warranty (replacement of defective products).	Three months Limited Warranty	One year Limited Warranty
Certifications	ISO 9001:2000	---	---
Energy efficiency	Qualified to Energy Star	Qualified to Energy Star	Qualified to Energy Star
Length of time on the market	1994	1972	1953
Additional factors	Flat panel & tie system requires bracing and alignment.	No extensive bracing required.	No extensive bracing required.
	EPS is vulnerable to termites.	Termite resistance.	Termite resistance.
	The combination of concrete and polystyrene acts as a natural barrier against air and moisture.	The combination of concrete and polystyrene acts as a natural barrier against air and moisture.	The system is vapor permeable but it does not act as a vapor barrier.
Note: Data comes from manufacturer' website, brochures, specification sheets, Material Safety Data Sheets. Prices come from manufacturers are approximated and for general comparison. Rastra and Durisol sell their products directly and Quad Lock provides different dealers across Canada and the globe.			

Table 3.1: Comparison chart Insulated Concrete Forms.

3.2.1.2.4. ANALYSIS AND RECOMMENDATION

The three types of ICF share common characteristics with respect to strength, durability, weight, energy efficiency and recyclability. The panels provide a surface for finishes on the inside for drywall and on the outside for stucco, lap siding, brick and other materials, potentially reducing time and labour costs. However, they differ widely in the component parts offering different advantages. For instance, the three products can be used for wall construction below and above grade; however, Rastra and Quad Lock elements can be also used to create floors and roofs. In addition these products provide a higher R-Value. One of the main advantages of the Quad Lock system is that because it is a flat panel & tie system, more wall area can be shipped or stored in a given amount of space, costing less compared to block systems; however, on

installation it requires more bracing and alignment which can be added to the required construction time (Figures 3.5 and 3.6). On the other hand the panels are made of virgin materials (Polystyrene, Polyethylene, and Polypropylene) that require demands for oil. In contrast, the Durisol and Rastra systems include the use of recycled materials and are resistant to termites and fire, while the foam panels are vulnerable to termites and, while they are self extinguishing, other components are required to meet fire codes. The characteristics between Durisol and Rastra are very similar and provide different advantages over the Quad Lock system. An important feature of Rastra and Durisol is that their components allow a slow interchange of air that helps to maintain good air quality and prevent condensation that leads to mold growth. On the downside, Durisol requires a vapour barrier and Rastra is manufactured in the USA. The cost of the three products is comparable, though Durisol may be the most cost-effective option for foundation walls, as its base cost is lower and it is regionally produced.

There are different aspects that one should consider when comparing ICF with other structural systems: the cost of materials, installation and the construction duration. According to Eric Hubbs (2003), explains the different advantages of ICF for exterior walls including a comparative analysis of three systems: ICF, Steel and Wood constructions. The outcome of this evaluation shows that ICF not only takes less time but costs less (including the cost of materials and labour installation) compared to steel and wood construction.

In conclusion, Insulated Concrete forms as an alternative building system provide significant advantages not only to builders but also to homeowners helping to conserve energy and reducing the carbon dioxide gases that contribute to global warming. The concept of the forms that include expanded polystyrene comes from 1968 (Rastra, 2009) and the wood concrete form from 1953 (Durisol, 2009); therefore, their efficiency is well proven. Since then,

manufacturers have improved and promoted their products for use in a variety of situations. The market for ICFs Systems is growing, as indicated by the Insulated Concrete Form Association's list of thirteen members, and the Portland Cement Association which provides a list of sixty two companies of producers and suppliers across North America. However, it is important to note that products such as Rastra and Durisol that have recycled content (around 80%) contribute to "closing the loop" (as advocated earlier) by using materials that otherwise would be destined for landfills.

Figure 3.5: Quad-Lock Forms and Rebar.

Source: Retrieved August 18, 2009, from http://www.quadlock.com/

Figure 3.6: Rastra Forms and Rebar.

Source: Retrieved August 18, 2009, from http://homestakeconstruction.com/project.htm

3.2.2 OVERVIEW OF BUILDING FRAMING

After the foundation has been completed, the next stage is the framing which is composed of three assemblies: floors, walls and roofs. Wood, steel and concrete are the three most common structural materials used in buildings, but in a residential context, wood frame construction is almost always used. In the previous section the different advantages of concrete were explained. This section will explain wood and steel constructions as traditional materials to understand their different attributes and will examine structural insulated panels as an alternative material in residential framing.

3.2.2.1 WOOD FRAMING

Wood frame construction is strong, durable, and easy to insulate (Canadian Wood Council, 2002). In addition, wood is renewable, recyclable and biodegradable. However, in order to reduce forestry impacts it is important to choose wood products from certified sources. Wood framed homes require less energy and have less impact on global warming as compared to steel and concrete which require 17% and 16% more energy respectively (from extraction through maintenance) (Consortium for Research on Renewable Industrial Materials, 2004). Furthermore, “wood’s cellular structure contains air pockets that limit its ability to conduct heat making it a better insulator than concrete and steel” (WoodWorks, 2009). This property helps to minimize the energy needed for heating and cooling. Wood frame construction comprises the walls, floors and roofs made of dimensional lumber or engineered wood products and structural wood panel sheathing (Canadian Wood Council, 2002). Nevertheless, structural materials such as composite wood products which are engineered and glued provide greater strength and larger dimensions than might be achieved from the raw material alone. Some examples include

Parallel Strand Lumber (PSL), Laminated Veneer Lumber (LVL), Oriented strand board (OSB) and wood I-beams (Florida Wood Council, 2005).

3.2.2.2 STEEL FRAMING

Steel is a strong and durable material that also meets sustainability criteria. Steel products are 100% recyclable and contain a minimum of 25% material (EPA, 2008). Steel as an alternative material for residential framing offers a number of advantages (Canadian Sheet Steel Building Institute [CSSBI], 1994): It is non-combustible; inorganic and not vulnerable to termites and mold, does not rot, shrink, swell, split, or warp; is free of resin adhesives and other chemicals that are used to treat wood framing products; produces less scrap and waste than wood; is a lightweight material that reduce foundations stress and problems; and is easier to handle and transport. Steel members are manufactured in different standard shapes and sizes offering flexible building options. However, steel conducts heat at a greater rate than wood; therefore, insulation should be well placed to control thermal bridging.

3.2.2.3 STRUCTURAL INSULATED PANELS (SIPS)

SIPs are panels with a core of rigid foam insulation between an exterior and interior skin (CMHC, 2002). The first SIP was built in North America in 1935 as an experiment in homes which were monitored over a thirty year period (Structural Insulated Panel Association, 2007). In 1969 SIPs were introduced in the marketplace and by the 1990s new technology such as computer aided manufacturing (CAM) and computerized architectural drawings (CAD) allowed for faster SIP production saving time and labour in the manufacturing process (SIPA, 2007). By 2007 SIPs were accepted into the International Residential Code (IRC) and today; they are produced in a variety of structural skin materials including oriented strand board (OSB),

plywood, fiber cement board or steel, and are available around different cores such as extruded polystyrene (XPS), expanded polystyrene (EPS) or polyisocyanurate foam (PIR). The system offers different advantages (SIPA, 2007): panels are custom designed, prefabricated and assembled onsite reducing job site waste, construction time and labour. The air tightness of the system allows minimum levels of air infiltration resulting in a solid structure with high thermal resistance and that can remain moisture free. In addition, the integrated system that includes structural elements and insulation brings superior transverse load resistance. Finally, SIPs conserve resources by requiring less wood than a conventional wood frame house and incorporating recycled materials into their manufacturing process. The author has selected three SIPs system in which manufacturers have used recycled materials including Foard and Enercept panels which are alternative materials to the traditional wood framing and Polycore panels to the steel framing.

3.2.2.3.1 ENERCEPT STRUCTURAL INSULATED PANELS

Enercept panels are manufactured by Enercept Inc., a South Dakota company founded in 1982. The system is composed of a solid layer of expanded polystyrene (EPS) laminated between two layers of oriented strand board (OSB) (Enercept ES Report, 2006). The manufacturer provides panels with Forest Stewardship Council certified OSB. Scrap EPS from the manufacturing process is reused in new panels which include up to 80% recycled foam (Enercept Green Building, 2006). The standard 6½" (165 mm) wall panel has an R-value of 25.47 and is comprised of 5/18" (7 mm) EPS insulation between two 7/16" (11 mm) OSB (Enercept Inc., 2006). However, 4½" (114 mm) wall panel with an R-value of 18 for garage and 8" (203 mm) wall panel with an R-value of 32 for higher thermal or structural performance are also available. Panels are produced in widths of up to 4'-0" (1219 mm) and lengths up to 24'-0"

(7315 mm) and feature a pre-installed connecting post that consists of 2x4 members separated by EPS insulation and nailed into the edge of each panel (Figures 3.7 and 3.8). This system brings superior strength and thermal performance (Enercept SIPs Wall Panels, 2006). In addition, Enercept panels provide a patented electrical system in which electrical chases are pre-routed making wiring easier.

Figure 3.7: Enercept SIPs

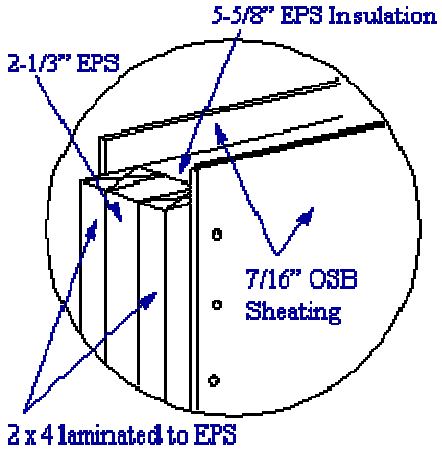

Figure 3.8: Enercept Insulated connecting posts

Source: Retrieved September 25, 2009, from http://www.enercept.com/sip_building_panel_types/sips_wall_panels

3.2.2.3.2 FOARD STRUCTURAL INSULATED PANELS

Foard panel is a New Hampshire company that has manufactured SIPs since 1983. The engineered system consists of a foam core insulation sandwiched between two pieces of 7/16" (11 mm) OSB (Foard Panel Inc., 2005). The company offers two insulation choices expanded polystyrene (EPS) and extruded polystyrene (XPS) (Figure 3.8). EPS cores in wall thicknesses of 4½" (114 mm), 6½" (165 mm) and 8½" (216 mm) offer R-Values of R14, R22 and R29 respectively. In contrast XPS panels provide R-Values of R19, R29 and R37. Panels come in standard sizes of 4'-0" (1219 mm) wide and lengths up to 24'-0" (7315 mm). The panels have

different environmental advantages including the use of 15% recycled polystyrene from post-industrial sources (Foard Panel-LEED for New Construction-Residential, 2009). In addition, the panels do not out-gas or lose R-value over time and OSB is FSC certified (made from fast growing farmed trees). Other advantages of XPS foam include a panel with superior strength and resistance to moisture absorption (CSRwire, 2008).

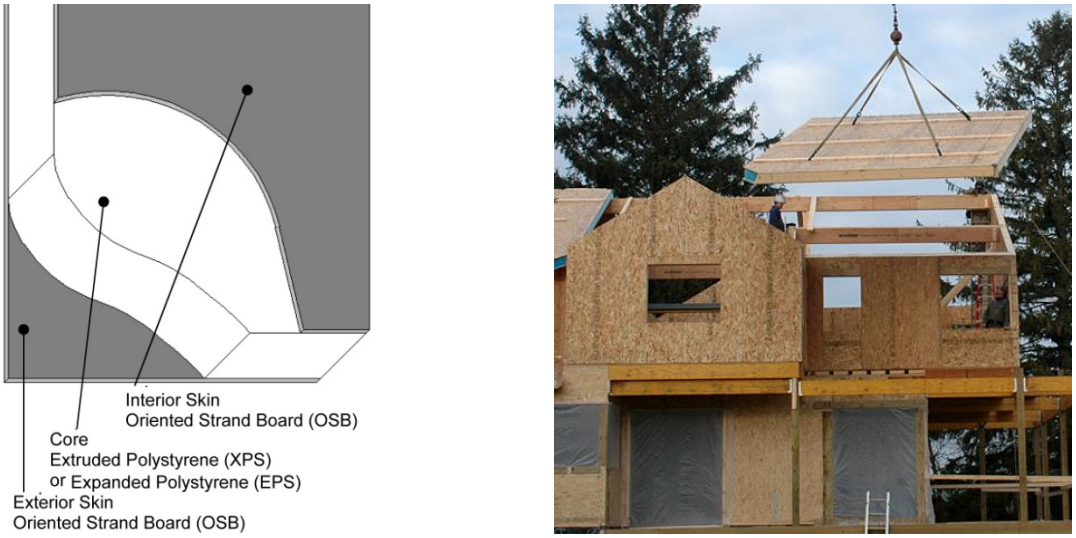

Figure 3.9: Components of the Enercept Structural Insulated Panel and first Built-for-LEED-Homes in Rhode Island built in 2008.

Source: Retrieved September 25, 2009, from http://www.enercept.com/

3.2.2.3.3 POLYCORE BUILDING SYSTEM

Polycore Canada Incorporated is an Alberta based company founded in 2002 (L. Simonin, e-mail message to author, 2009, Sep 23). The Polycore Building System is composed of a wall core made from EPS integrated with galvanized steel studs. The combination of steel and EPS result in a product that is thermally efficient, strong and lightweight. The insulated and structural building system does not require special skills or tools to install. Each panel can be handled by one person and the walls can be easily assembled by a small crew (Figure 3.9). Its

light weight also allows for easier and less costly transportation. Polycore sections are composed of 8" (203 mm) thick EPS combined with 3 5/8" (92 mm) of galvanized structural steel studs (Polycore, Residential Walls, 2009). The steel framing is pre-shaped for windows and the EPS foam has built-in channels for electrical wiring. Some of the advantages of using EPS include the fact that it is waterproof, does not rot, and is non toxic; however, it is considered combustible and thus Polycore includes a flame retardant that helps to sustain combustion. On the other hand, both materials (steel and EPS) are recyclable and include recycled content. The company provides two different methods of EPS recycling (L. Simonin, e-mail message to author, 2009, Sep 23): By-products of the manufacturing process are reused into new blocks including up to 30% re-grind material, and any excess of EPS from construction sites and other companies is melted down to make a raw plastic material for the manufacturing of different products in homes and offices such as laptops and cellphones. Steelform, the company that supplies the steel material claims the use of recycled material to be between 25% and 45% (L. Simonin, e-mail message to author, 2009, Sep 23).

Figure 3.10: Polycore building system made from EPS (Insulating wall core) and galvanized steel studs (structural component).

Source: Retrieved September 25, 2009, from www.polycorecanada.com/

Product name	**Polycore building System**	**Enercept**	**Foard**
Company Information	Polycore Canada Inc. 12112 - 67 St. Edmonton, AB T5B 1M7 Phone 780-477-2377 www.polycorecanada.com/	Enercept Inc. 3100 9th Ave. S.E. Watertown, SD 57201 Phone: 1-800-658-3303 www.enercept.com/	Foard Panel. PO Box 185 West Chesterfield, NH Phone: 603-256-8800 www.foardpanel.com/
Use	Walls, roofs and foundation floors.	Walls and roofs.	Walls and roofs.
Applications	Residential, commercial, industrial, agricultural	Residential, commercial and agricultural.	Residential, commercial
Raw materials	Expanded polystyrene (EPS) and integrated galvanized steel construction studs.	Expanded Polystyrene (EPS), OSB sheathing and adhesives.	Extruded polystyrene (XPS) or Expanded Polystyrene (EPS) and Oriented strand board (OSB).
Recycled content (%)	30% Pre-consumer recycled EPS, 25-45% recycled steel.	80% Post-industrial recycled EPS.	15% Certified pre-consumer recycled polystyrene.
Recyclable	✓	✓	✓
R-Value per panel thickness	R36 (8”), R63 (14”)	R18 (4½”), R26 (6½”), R32 (8”).	R14 EPS-R19 XPS (4½”), R22 EPS-R29 XPS (6½”), R29 EPS – R37 XPS (8¼”).
Size	Length: As tall as needed Width: 4’-0” (1219mm)	Length: 24’ (7315mm) Width: 4’-0” (1219mm)	Length: 24’ (7315mm) Width: 4’-0” (1219mm)
Fire Rating	Non combustible	1H	Class 1
Material cost ($)/ft²	$13.77	Not provided	$30
Labour cost	$20-30 lineal foot of wall	Not provided	Included with material cost
Warranty	5 year warranty	Limited Lifetime Warranty	20 year Limited Warranty
Certifications	N/A	Forest Stewardship Council (FSC)	Forest Stewardship Council (FSC)
Energy efficiency	EnerGuide Rated Built Green™ Homes	Qualified to Energy Star	Qualified to Energy Star
Length of time on the market	2002	1982	1983 (EPS), 2008 (XPS),
Additional factors	Member of Built Green™ (currently available in Alberta and British Columbia).	---	---
Note: Data comes from manufacturers’ website. Prices come from manufacturers are approximated and for general comparison. Polycore and Foard Panel sell their products directly. Enercept provides dealers across USA.			

Table 3.2: Comparison chart Structural Insulated Panels.

3.2.2.3.4 ANALYSIS AND RECOMMENDATION

SIPs are an alternative building system that can save energy, resources and improves indoor air quality. Unlike Enercept and Foard panels that provide two outer skins, the Polycore system is a type of metal SIP in which steel is embedded in the EPS. Although all the three products use different materials the composition of the system that includes framing and insulation into one step offers cost advantages reducing labour requirements and allowing a faster construction time compared to the traditional wood framing construction. R-values for each product are different and depend on the thickness of the panels and the type of core material that is used. The three products use EPS as the core insulation; however, Polycore wall sections which are offered in 8" (203 mm) thick EPS provide a higher R-value. Foard panels offer cores made of XPS which provide higher R-value per inch of thickness (R-5) compared to EPS (R-3.5) allowing the use of a thinner panel. According to the Structural Insulated Panel Association in their report "Green Building with SIPs" (2009) some of the environmental advantages of SIPs include a better use of resources by using FSC certified OSB facings and recycled materials such as EPS foam from post-industrial sources. However, the author was not able to find products with recycled content that were locally or regionally produced. This fact leads the author to conclude that not all manufacturers use that practice into their products. Insulpan a British Columbia based company claims that recycled material (EPS) is not used in their manufacturing process due to the fact that the structural properties might be affected reducing the reliability of the load carrying capacity (T. Mammone, e-mail message to author, 2009, Sep 28). Despite this claim, the three selected products presented in this report have improved, environmental sustainability through the use of recycled material, without compromising the quality of the products.

3.2.3 OVERVIEW OF THE BUILDING ENVELOPE

The building interior is separated and protected from the exterior environment by the building envelope, which is composed of different materials that are important determinants to the thermal performance of the building (Kernan, Penner & Associates, 2001). This section will discuss cladding, thermal insulation and roofing materials that contribute to energy efficiency allowing the house to be warmer in winter and cooler in summer.

3.2.3.1 CLADDING

The facade design is exposed to the exterior environment and protects the outer envelope assemblies. The cladding protects the home from outdoor elements and provides aesthetic qualities to the house. The use of durable and long-lasting materials is important in order to reduce replacement and maintenance costs. Sustainable alternatives to traditional wood siding includes common materials such as fiber cement, vinyl and engineered wood; however they differ in that manufacturers have integrated recycled materials into their composition.

3.2.3.1.1 FIBER CEMENT SIDING: WEATHERBOARDS CEDAR LAP

Fiber cement siding was introduced in the late 1980s (Louisiana Pacific Corporation, 2008) and has gradually gained market share accounting for 15% of all new homes (PCA, 2009). It is made from Portland cement, sand and cellulose fibers. It can have the appearance of wood, stucco, or masonry. According to the Portland Cement Association (2009), fiber cement siding provides different advantages: It is a low maintenance product, it requires painting but painted surfaces can last on average 7 to 15 years; it is durable, resistant to insects, impacts and weather fluctuations. Unlike other siding materials such as wood or vinyl, one main attribute of fiber cement is that is not vulnerable to fire. Manufacturers offer products guaranteed for up to fifty

years in a variety of textures, profiles and colors (PCA, 2009). However, there are some concerns when the product is not properly installed causing mold and rot in the sheathing or structural supports (Hardy, 2005).

CertainTeed Corporation, a leading North American manufacturer of building materials founded in 1904; with a Valley Forge, Pennsylvania based head office manufactures WeatherBoards™ Cedar Lap (CertainTeed, 2009) (Figure 3.12). WeatherBoards is a fiber cement siding product that is produced using a "multi-step high-pressure process" that includes Portland cement, fly ash, wood fibers and specialty additives (Specification Sheet, 2008). The product contains a minimum 30% recycled fly ash (Fiber cement Green Brochure, 2008). By incorporating fly ash the boards are lighter and it improves their strength and durability (Weatherboard Specification Sheet, 2008). In addition, the durability of the product involves not only the physical properties that give it resistance to fire, insects and UV rays but also a FiberTect® Sealant/Primer which protects it against moisture absorption (WeatherBoards Brochure, 2009). The product is available with a 100% acrylic latex coating that protects the finish against the elements. WeatherBoard are cut and installed like conventional wood siding (Specification Sheet, 2008). Dust generated from cutting, sanding or drilling may pose a health risk; therefore, adequate ventilation and equipment for installation is required (Material Safety Data Sheet, 2006).

3.2.3.1.2 VINYL SIDING: CEDARBOARDS INSULATED SIDING

Vinyl siding was introduced in the early 1960s and has grown in popularity since the 1970s, now accounting for more than 50% of the cladding market (Louisiana Pacific Corporation, 2008). Vinyl is made from PVC (polyvinyl chloride) plastic which makes it impact resistance and gives it rigidity and strength (Vinyl Siding Institute, 2009). The product provides

different advantages. It is: attractive, with manufacturers offering design versatility with a variety of profiles, shapes and colors; durable, being resistant to high winds, heat, cold, moisture and termites; cost-effective, because it does not require painting or caulking; and easy to maintain (VSI, 2009). However, vinyl siding expands and contracts; therefore, some considerations and proper installation are required (Dobson, 2007). On the other hand, vinyl siding provides environmental benefits, and much of the scrap from post-industrial and post-consumer siding can be recycled into new products (Radzinski, 2009). Furthermore, an innovative feature includes the integration of insulation into the boards such as expanded polystyrene (EPS), improving the performance of conventional vinyl cladding and the energy efficiency of the building with a higher R- value (Radzinski, 2009).

CedarBoards Insulated siding manufactured by CertainTeed Corporation (CertainTeed, 2009) is made of PVC (60% recycled material) extruded and fused with expanded Polystyrene (EPS) foam insulation (CedarBoards Insulated Siding Specification Sheet, 2009) (Figure 3.13). Boards come in 4 different profiles and are embossed with a cedar grain pattern that gives the vinyl a more natural cedar appearance (Specification Sheet, 2009). In order to achieve a high performance CedarBoards come with a STUDfinder™ Installation System; this method locates studs and aligns nail slots allowing an accurate installation and avoiding the danger of nailing into electrical wiring, plumbing or mechanical systems (CedarBoards Insulated Siding Brochure, 2009) (Figure 3.11). The rigid foam backing not only provides energy savings but improves strength and rigidity. The integral insulation prevents air infiltration, and absorbs sound, reducing noise infiltration (CedarBoards Insulated Siding Brochure, 2009). In addition, panels come with a post-formed lock design that ensures wind resistance. Dust from cutting or grinding

may cause irritation of the eyes, skin nose or throat; therefore, protective equipment should be worn (Material Safety Data Sheet, 2005).

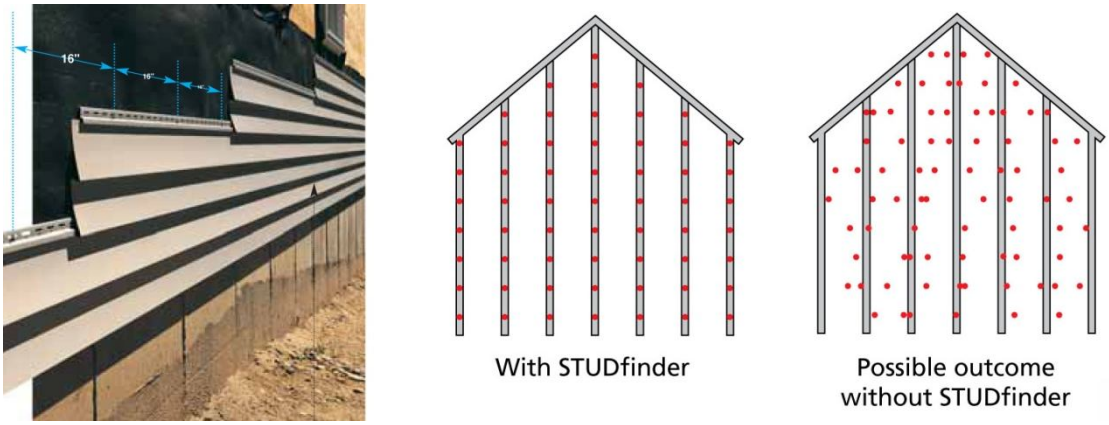

Figure 3.11: STUDfinder™ Installation System.

Source: CertainTeed Monogram Siding Brochure, 2005

3.2.3.1.3 ENGINEERED WOOD SIDING: NATURETECH

Engineered wood siding is made of wood fibers combined with bonding agents creating a composite lightweight product with superior strength. "These products are engineered to eliminate flaws, resist deterioration, and be cost-effective to install and maintain" (Faulkner, 2009). Engineered wood was introduced in the late 1990s and today accounts for 7% of the cladding market (Louisiana Pacific Corporation, 2008).

NatureTech Engineered Wood Siding is manufactured by KWP Building, a market leader in prefinished engineered wood products, located in Le Gardeur, Quebec (KWP, 2009). The product is made of 100% recycled pre-consumer content including recycled or recovered wood fibers with additives (KWP Green Fact Sheet, 2009) (Figure 3.14). The manufacturer offers six different profiles with panels of ½" (13 mm) of thicknesses and 12'-0" (3658 mm) in length. Profiles come in widths of 6" (153 mm), 8½" (216 mm), double 3" (76 mm), and double 5" (127 mm). Double 5" has a deep-grained cedar look and comes with 11" (279 mm) wide simulating

two 5" (127 mm). This feature results in a faster installation. The installation process consists of a Tru-Align™ panel interlock system that allows a precise horizontal alignment saving field and labour time (KWP Brochure, 2008). However, there are some issues with respect to the product installation that need to be considered (KWP Installation Instructions, 2008): In order to prevent moisture infiltration, siding should not be applied to structures where excessive moisture conditions pre-exist such as drying concrete or plaster. Furthermore, the product should not be applied to green or crooked structural framing materials to prevent buckling. Unlike CedarBoards and Vinyl siding, NatureTeck requires some care to maintain its appearance: It must be washed annually using non-abrasive household cleansers (KWP Installation Instructions, 2008). Otherwise, the siding is finished with 4 coats of acrylic paint baked on at high temperature which helps to protect it from the elements (KWP Brochure, 2008).

Figure 3.12: WeatherBoards fiber cement siding.

Source: CertainTeed WeatherBoards Brochure, 2009

Figure 3.13: CedarBoards vinyl siding.

Source: CertainTeed CedarBoards Brochure, 2009

Figure 3.14: KWP Naturetech engineered wood siding.

Source: KWP Building Products KWP Brochure, 2008

Type of siding	FiberCement	Vinyl	Engineered wood
Product Name	WeatherBoards™ Cedar Lap	CedarBoards™ Insulated siding	KWP Naturetech™
Company Information	CertainTeed Corporation 750 E. Swedesford Rd. Valley Forge, PA 19482 Phone: 610-341-7000 www.certainteed.com/	CertainTeed Corporation 750 E. Swedesford Rd. Valley Forge, PA 19482 Phone: 610-341-7000 www.certainteed.com/	KWP Building Products 101, rue de la Couronne, Le Gardeur, Qc J5Z 5E9 Phone: www.kwpproducts.com/
Raw materials	Mixture of Portland cement, fly ash, wood fiber and specialty additives	PVC extruded and fused with expanded Polystyrene (EPS) foam insulation.	Recycled and reclaimed wood fibers with quality additives
Recycled content (%)	>30% fly ash	60% Pre- and post-consumer recycled content.	100% Recycled Pre-Consumer Content.
Recyclable	N/A	✓	N/A
Colors	6 natural and wood grain stains or 13 factory-applied prefinished top coat colors.	Up to 18 low-gloss colors.	16 warm traditional earth tones.
Board Thickness	5/16" (8mm)	.044" (11mm)	1/2" (13mm)
Fire resistance	Non combustible-it does not melt in the presence of heat.	Self-extinguishing. Can melt or burn when exposed to significant heat or flame.	Combustible
Material cost/ ft²	$2.50	$1.82	$1.90
Maintenance	Product must be painted or stained. Low Maintenance (washed with a garden hose).	No need of painting, staining or caulking. Low maintenance (with a mild soap and water).	Shakes must be washed annually using non-abrasive household cleansers.
Installation	Same as conventional wood siding.	STUDfinder™ Installation System.	Tru-Align™ panel interlock system.
Warranty	50 year Limited transferable warranty. 15 year limited paint warranty.	Lifetime Limited Warranty in panels and color.	25 year warranty on the substrate an 15 years on the finish
Certifications	Sustainable Forestry Initiative (SFI)	---	Environmentally Preferable Product (EPP)
Energy efficiency	---	Qualified to Energy Star	---

Continue on next page

Product Name	**WeatherBoards™**	**CedarBoards™**	**KWP Naturetech™**
Length of time on the market	CertainTeed (1904), Fiber Cement (1998)	CertainTeed (1904), Vinyl siding (1969)	2004
Additional factors	Impact resistant	Insulated siding improves R-value and is more impact resistance than traditional vinyl siding.	Impact resistant
Note: Data comes from manufacturers' website, brochures, specification sheets, and Material Safety Data Sheets. Engineered wood and fiber cement prices come from distributors and vinyl price come from RS Means Residential Cost Data 2009. Prices are approximated and for general comparison.			

Table 3.3: Comparison chart siding products.

3.2.3.1.4 ANALYSIS AND RECOMMENDATION

WeatherBoards (fiber cement), CedarBoards (vinyl) and Naturetech (engineered wood) siding are products that contain recycled materials and offer superior longevity over solid wood siding. Unlike normal wood siding these products are impervious to insects and do not rot, crack or split. They are prefinished, eliminating the need for on-site jobs such as painting, and this reduces the amount of waste in the manufacturing process. Furthermore, they are not harmful to the environment. Fiber Cement (Weatherboards) and engineered wood (KWP Naturetech) siding; for instance, allow more efficient use of forest products. KWP Naturetech is EPP (Environmentally Preferable Product) certified assuring that the product is composed of 100% recycled and recovered wood fiber. However, as with all wood products it is combustible and susceptible to moisture, and thus some special care has to be taken. On the other hand, WeatherBoards siding is SFI (Sustainable Forestry Initiative) certified assuring that the wood fibers come from responsibly managed forests. Although the product does not include waste wood fibers from post-consumer or industrial sources, the 30% of recycled material that consists of cement substitution (fly ash) contributes to minimize the environmental impact of cement

production. In comparison, CedarBoards Insulated siding includes a higher recycled content (60%) incorporating both pre-and post-consumer recycled materials, and is itself recyclable. It shares Naturetech's easy, less labour-intensive installation characteristics. Insulated vinyl siding contributes to energy efficiency and is easier to maintain than wood and fiber cement because it does not require repainting or caulking, reducing its long term environmental impact. In addition the product is lighter than fiber cement and engineered wood, reducing demands on the structure and the environmental costs of transportation. Finally, the product is promoted to last longer than fiber cement and engineered wood and is offered with a lifetime warranty. For these reasons, CedarBoards insulated siding is the author's recommended product. There are three aspects that one should take into consideration when buying siding products: the cost of materials; the cost (especially for labour) of installation; and the maintenance required over its life cycle. As shown in Table 3.2 vinyl requires the least maintenance and, according to the R.S. Means Residential Cost Data (2007), Vinyl siding has the lowest installed cost as compared to fiber cement, wood and other siding materials. However, it is important to remark that all the three products have been developed by using different technologies that have lead not only to greater efficiency in the use of raw materials, but also to the creation of products that bring a variety of designs to the market that appear, to the casual observer, as real wood. Each of them offer different advantages and it is the author's opinion that as with vinyl siding, engineered wood and fiber cement market will continue to gain market share.

3.2.3.2 THERMAL INSULATION

According to the Thermal Insulation Association of Canada (TIAC), insulation is defined as those materials or combinations of materials which retard the flow of heat energy. Insulation materials are another important component that provides significant environmental benefits by

reducing energy use over the lifespan of the building. Nevertheless, the raw materials used for the manufacture of certain products involves both the depletion of limited resources (such as the petrochemicals used in foam plastic insulation) or pollution from mining of minerals such as the sand and limestone used in fiberglass (Wilson, 1995). However, the insulation industry provides a variety of products that do incorporate recycled materials such as glass, plastic, cotton or newspapers that contribute to a better use of resources. They come in different forms such as rigid boards, blocks, loose fill, rolls and batts depending on the functions and applications. Some products are more resistant to fire, rot, moisture or air leakage than others and require chemical fire retardants, adhesives or other additives. In order to understand the different products and their properties the author has selected and analyzed five types: cellulose, fiberglass, mineral wool, cotton and spray polyurethane foam.

3.2.3.2.1 CELLULOSE INSULATION: IGLOO

Cellulose insulation is made primarily from post consumer recycled newsprint, with recovery rates of up to 85% being typical (Cellulose Insulation Manufacturers Association, 2009). Today, Cellulose insulation goes through a fiberization process in which the raw material is broken down into individual fibers that are fluffier making the product cleaner and increasing the R-value (Bynum, 2001).

Igloo Cellulose insulation is manufactured by Igloo Cellulose Inc., a Quebec company, and is, in fact made 85% of post-consumer recycled wood newspaper (Igloo, 2008) that is treated with non-toxic borates chemicals and natural additives which make it resistant to mold, dust and fire (Igloo Cellulose Technical Data Sheet, 2009). Some of the attributes of the product include its porosity which helps to absorb sound acting as a noise barrier, and its high density helps to reduce air leakage increasing its effective R-value (Igloo, 2008). Nonetheless, the thermal

resistance of Cellulose insulation can be affected and it is prone to reduced performance once exposed to water (Fisette, 2008). Igloo Cellulose is a loose fill type that can be sprayed applied, or installed with a pneumatic blowing machine. Although it is easy to install requires a specialized contractor (Figure 3.15).

3.2.3.2.2 FIBERGLASS: PINK FIBERGLASS OWENS CORNING

Fiberglass is basically made from molten sand and glass under highly controlled conditions. The glass is melted, and then is spun or blown into fibers that are processed into the final product (Bynum, 2000). The basic components of fiberglass are sand and recycled glass and the manufacturing process itself requires a great deal of energy (Owens Corning, 2002). Production of fiberglass requires 12000 btu of energy to make 1 lb of it, while cellulose takes 750 btu/lb (Wilson, 1995).

Pink Fiberglass Thermal insulation is manufactured by Owens Corning a World leading company in glass fiber technology founded in 1938 (Owens Corning, 2009). The product can be made from post-consumer material (e.g. recycled glass from construction sites or blue boxes); and from post-industrial sources, which is composed of recycled glass from manufacturing plants (Pink Fiberglass Thermal Batt Insulation Data Sheet, 2007). However, the Quebec manufacturing facility produces fiberglass insulation with 60% post consumer recycled material (Product Data Sheet, 2007). In contrast, in Ontario it is made of 10% post industrial and 50% post consumer recycled material. Unlike Cellulose insulation, Fiberglass can be produced in batts, blankets and loosefill. Fiberglass is not absorbent, resistant to moisture and does not support bacterial growth (Owens Corning, 2002). However, the manufacturer recommends not to use Pink fiberglass thermal batt insulation in locations where can be exposed to water, humidity and wind (Product Data Sheet, 2007). Some of the benefits of Pink Fiberglass

insulation include the fact that it is non-combustible and does not require fire retardant chemicals (Owens Corning, 2002). However, concerns have been raised about the use of formaldehyde in the manufacture of fiberglass. Formaldehyde is a binder ingredient that helps to glue the glass fibers together (Owens Corning, 2002). This chemical has been classified as a "cancer causing substance by the International Agency for Research on Cancer and as a probable human carcinogen by the U.S. Environmental Protection Agency" (National Cancer Institute, 2009). Nevertheless, according to Owens Corning (2002) fiberglass contains low levels of formaldehyde that do not pose health problems. In fact, The North American Insulation Manufacturers Association (2002) states that they "do not consider the trace amounts of formaldehyde found in fiber glass insulation to be a concern to human health or the environment". In addition, Pink fiberglass is Greenguard certified for better indoor air quality. Nonetheless, safety measures for fiberglass application must be consider such as breathing masks, face, eyes and skin protection (Fiberglass insulation MSDS, 2009) (Figure 3.16).

Figure 3.15: WallBAR™ Insulation.

Source: Retrieved September 10, 2009, from http://www.rhoadesbuild.com/product.php?category_id=30

Figure 3.16: Fiberglass Insulating System.

Source: Retrieved September 10, 2009, from http://www.owenscorning.com/

3.2.3.2.3 MINERAL WOOL: ROXUL COMFORTBATT

Mineral wool is made of slag wool, a by-product of iron ore blast furnaces; it does not burn or melt thus it does not require extra chemicals to make it fire resistant. Wool insulation is produced by a centrifugal wheel process; the material is melted and then spun into fiber (Bynum, 2000). Similar to fiberglass, this manufacturing process has a high embodied energy component (Wilson, 1995).

Roxul Insulation is manufactured by Roxul Inc., which is part of Rockwool International, the world's largest producer of stone fiber insulation (Roxul Brochure, 2009). Roxul is a thermal insulation made of 94-99% mineral fiber (Roxul MSDS, 2007). The product contains basalt rock and 40% recycled slag (Technical Data Sheet, 2009). The combination of mineral fibers results in a product that has high density and provides both a dimensional stability and a barrier against noise (Roxul Brochure, 2009). The manufacturer provides two types for residential use: Roxul ComfortBatt which is used for exterior walls and Roxul Safe'n'Sound for interior walls. Besides its non-combustibility property, Roxul insulation is water repellent and vapour permeable (Technical Data Sheet, 2009) preventing moisture build-up which would otherwise reduce the R-Value. It is easy to cut (with a serrated blade) and install in three steps: Insert, compress and release (Figure 3.17).

3.2.3.2.4 COTTON INSULATION: ULTRATOUCH NATURAL FIBER

Cotton insulation is a batt type made of natural cotton fibbers which are composed of post industrial cotton and denim (Bonded Logic Inc., 2008). UltraTouch Natural Fiber Insulation produced by Bonded Logic Inc., an Arizona based company with 35 years of experience, contains 85% recycled material (UltraTouch LEED, 2008). The Cotton insulation manufacture

process involves different stages (Bonded Logic Inc., 2008): First, post-industrial material that comes from scraps and clippings from the manufacturing of blue jeans is processed and converted into the original loose fiber form; then, the material is treated with a non-toxic borate solution which gives it resistance to fire, pests and mold. Following this procedure, the cotton fibers are thermally bonded and formed as a solid batt. The manufacturer claims that the product requires a minimal amount of energy to manufacture. UltraTouch can be used for different applications such as interior and exterior walls, ceilings and attics (Ultra Touch Brochure, 2008). The cotton fibers provide excellent sound absorption qualities; additionally, its high density gives it high thermal efficiency. Installation is easy enough for even a "do-it-yourself" project (Figure 3.18). The product is manufactured in USA, but distributed in Canada by Twin Maple Marketing Ltd.

Figure 3.17: Roxul ComfortBatt

Source: Retrieved September 9, 2009, from http://thestar.blogs.com/onthehouse/2009/06/green-insulation-we-love.html.

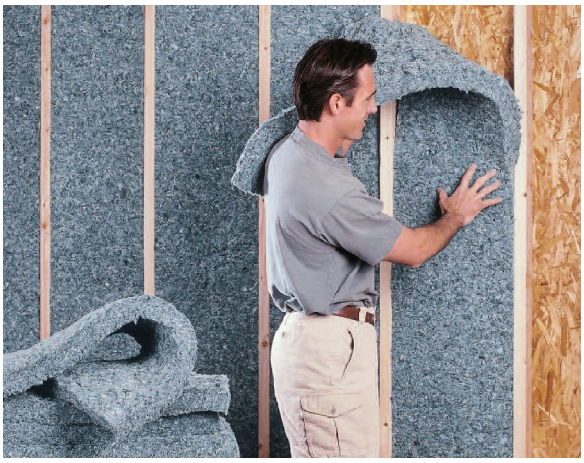

Figure 3.18: UltraTouch Natural Insulation

Source: Retrieved September 9, 2009, from http://www.bondedlogic.com/ultratouch-cotton.htm

3.2.3.2.5 SPRAY POLYURETHANE FOAM: HEATLOK SOYA

Spray Polyurethane Foam (SPF) consists of petroleum oils, plastics and resins which are heated at high pressure and mixed with a spray gun. The ensuing chemical reaction expands and cures as a foam (Envirofoam, 2009). Heatlok Soya is a Quebec product developed by Demilec a "leader in research, development, manufacturing and marketing of high quality spray polyurethane foam insulation" and the "first Canadian manufacturer of spray polyurethane to meet the requirements of the Montreal Protocol" (Heatlok Soya Press release, 2006). Heatlok soya is made from vegetable oils, 40% recycled material (1000 plastic bottles) and soya base ingredients (Heatlok Soya, 2006). It is inherently adhesive, and immediately attaches to the supporting frame without requiring additional mechanical fasteners, or tapes (Heatlok Soya, 2006). However, the application of the product requires specialized installers (Figure 3.19). The mix of recycled plastics, renewable natural oils and soya results in a product that provides not only the high thermal resistance qualities but also a vapour barrier function and an air barrier which exceeds (by more than 500 times) the National Building Code of Canada (NBC) requirements (Heatlok Soya Brochure, 2006).

Figure 3.19: Heatlok Soya in a block/bric Building application

Source: Retrieved September 10, 2009, from http://www.iowasprayfoam.com/picture2.html

Type of Insulation	Cellulose	Fiberglass Insulation	Mineral Wool
Product Name	Igloo Cellulose	Pink Fiberglass	Roxul ComfortBatt
Company Information	Igloo Cellulose Inc. 2999 Miller avenue Dorval Quebec H9P 081 Phone: 514 694-1485 www.cellulose.com/	Owens Corning Canada Inc. 3450 Mcnicol Ave Scarborough, Ontario M1V 1Z5 Phone: 416-292-4000 www.owenscorning.com/	Roxul Inc. 420 Bronte St. Milton, Ontario L9T 0H9 Phone: 905-878-8474 www.roxul.com/
Appearance and installation methods	Gray fibrous mass- Loose fill, spray applied.	Pink- blankets, batts, Loosefill.	Grey, green-fibrous semi-rigid batt.
Raw materials	Recycled newsprint, boric acid, natural additives.	Fibrous glass wool and cured binder.	Basalt rock and slag.
Recycled content	85% Post-consumer recycled newspaper.	60% Post-consumer recycled glass.	40% Recycled slag (by-product of steel production).
R-Value per inch	3.7	3.7	4.0
Embodied energy in Btu/lb	750	12000	6500
Installation	Fibers and dust may cause respiratory and eyes irritation. Respiratory protection is recommended.	Dust and fibers may cause irritation to eyes, nose, skin, throat and lungs. Respiratory, skin, eyes and face protection is recommended.	Dust and fibers may cause irritation eyes, skin and throat. Respiratory, eyes, skin and face protection is recommended.
Material cost ($)	$26 R12 covers 60 ft² (5.57 m²).	$46.17 R14 covers 67.81 ft² (6.3 m²).	$30.97 R14 covers 59.7 ft² (5.55 m²).
Warranty	Lifetime warranty	---	---
Certifications	ISO 9000-2008	Greenguard Indoor Air Quality, Scientific Certification Systems (SCS)	Children and Schools GreenGuard Indoor Air Quality Certified
Length of time on the market	1984	1938	1988
Additional factors	Should not be placed in direct contact with extreme heat sources and open flame.	Non combustible.	Non combustible.
	High resistance to air leakage.	Possibly carcinogenic.	Water repellent.

Continue on next page

Type of Insulation	**Cotton**	**Spray Polyurethane Foam (SPF)**
Product Name	UltraTouch Natural Fiber	Heatlok soya
Company Information	Bonded Logic Inc. 411 E. Ray Road Chandler, Arizona 85225 Phone: 480-812-9114 www.bondedlogic.com/	Demilec 870 Curé-Boivin Boisbriand, Quebec J7G 2A7 Phone: 450-437-0123 www.heatlok-soya.com/
Appearance and installation methods	White/Aluminum-batt.	Green-Spray Applied.
Raw materials	Natural denim and cotton fibers.	Recycled plastic and soya.
Recycled content	85% Post-industrial recycled denim and cotton.	40% Post-consumer recycled plastic.
R-Value per inch	3.7	6.0
Embodied energy in Btu/lb	Low	High
Installation	Safe. Contains no chemical irritants and requires no warning labels. No protective clothing required.	Safe. Requires a professional applicator. Protective clothing required.
Material cost ($)	$98 R14 covers 104 ft² (9.7 m²).	$3.20 ft² R15 (material and Installation included).
Warranty	---	Limited Lifetime warranty
Certifications	N/A	Greenguard Indoor Air Quality, Greenguard Children & school.
Length of time on the market	1974	2006
Additional factors	Should not be placed in direct contact with heat sources.	Resistant to air infiltration and vapour diffusion. It has zero impact on the ozone layer.
Note: Data comes from manufacturers' website, brochures, specification sheets, Material Safety Data Sheets. Roxul and Pink insulation are sold through Home Depot, Cellulose and SPF are sold by manufacturer and Cotton insulation is sold through a Canadian distributor.		

Table 3.4: Comparison chart building insulation materials.

3.2.3.2.6 ANALYSIS AND RECOMMENDATION

Igloo Cellulose insulation provides the highest recycled content (85%) from post-consumer sources. Its high thermal resistance, noise absorption properties and resistance to air

leakage make it a good option for insulation. Although the chemical treatment provides it with fire resistance properties the product cannot be placed in direct contact with heat sources such as chimney flues or light fixtures. There are some concerns about cellulose insulation long-term performance including the possible loss of fire-retardant chemicals, and that accumulations of dust and dirt could reduce the R-value (EBN, 1995). On the other hand Mineral wool insulation (Roxul) can withstand high temperatures because of its physical properties. In addition, it is water repellent, thus its R-value (which is inherently higher than fiber glass, cotton, or cellulose insulations) is not affected by moisture. Nonetheless, its recycled content is the lowest (40%) compared to the other products. In comparison, fiberglass insulation (Owens Corning) is 60% recycled glass, but energy intensive to manufacture. Cotton insulation (UltraTouch) has low bodied energy, high recycled content and unlike fiberglass and mineral wool does not contain harmful irritants. On the downside, the product cannot be placed adjacent to areas where it may be subjected to open flame. Additionally, it is not readily available because it is manufactured in USA.

Temperature and pressure differs from inside to the outside of the building. These differential conditions affect the building envelope by requiring materials that reduce the impact of air leakage, which can cause problems such as moisture in the walls, loss of energy and infiltration of rain. Hence, the air and vapour barriers are important components that improve the thermal performance of the building envelope. On one hand, the vapour barrier protects the structure and insulation materials from moisture, and it must be resistant to the flow of water vapour; on the other hand, the air barrier prevents heat loss and maintains energy efficiency (Quirouette, 2001). Spray Polyurethane Foam (Heatlok soya) acts as an air barrier providing superior thermal performance and as a vapor retarder reducing moisture infiltration. These

properties allow for a reduction of materials and labour costs, as there is no need for the application of additional materials. Spray Polyurethane Foam requires specialized installers; however, the product is manufactured on the jobsite reducing waste and making it possible to adapt it in different situations (Richmond, 2009). Furthermore Heatlok soya insulation does not impact the ozone layer; it is manufactured in Quebec, thus is readily available and contributes to minimizing the environmental impacts associated with transportation. Despite the high embodied energy and the high price, the superior performance of SPF that acts as an air/vapour barrier not only provides energy savings throughout the life of the building but also protects the environment through reduced emissions.

Based on the above observations, it is difficult to determine which product is "better" than the others. All of the products offer different advantages and their effectiveness depends on many factors such as the type of application, building, and proper installation. However, it is the author's opinion that all the products have a considerable percentage of recycled material that can contribute to the reduction of waste stream. Igloo Cellulose has the highest recycled content and is one of the most cost-effective products available, especially since it is based on waste paper from post-consumer sources, the second highest portion of residential waste (Statics Canada, 2005). On the other hand Heatlock soya and Pink fiberglass include plastic and glass (two other recycled materials that come from residential, commercial and industrial sources). However, Heatlock is costly and relatively new compared with the other products; but, its performance is well proven and as people continue using it, perhaps price could go down.

3.2.3.3 ROOFING

The roof protects the house from extreme temperatures, moisture and helps control air flow. Roofing materials receive the most direct exposure to wind, sun and snow; therefore, the

selection of roofing materials is crucial and several issues must be considered (Austin Energy Green Building, 2009): weight, heat-holding qualities, fire rating, durability, maintainability and installation. Heavier materials require stronger frames to support the extra weight, whereas lighter weight materials provide safety at the time of installation and in case of fire, earthquake or high winds. Lighter colours reflect the heat away from the building and contribute to the reduction of the urban heat island effects (Canadian Asphalt Shingle Manufacturers' Association, 2008). Furthermore, long-lasting materials reduce repair needs, replacement expenses and the environmental impact of this maintenance.

Roofing can vary in types such as slate, shingle, shake and tile and is available in a variety of different styles, sizes and colors. Some of the available choices include recycled content, offering advantages such as lightweight, durability and fire resistance. In order to understand the different products with recycled content, the author has selected six alternative materials that provide a “wood appearance”. It is important to note that wood roofing can rot, crack, warp, develop mold and is susceptible to fire. Although today’s wood shingles and shakes can be factory-made to offer better performance than in the past, wood roofing is expensive and contributes to the depletion of natural resources (Sano et al., 2002). Therefore, the following materials will be examined: metal roofing made of aluminum, rubber, plastic and asphalt.

3.2.3.3.1 ASPHALT SHINGLE: ARMOURSHAKE FIBERGLASS

Asphalt has been “the most popular roofing material in North America” for the past 150 years (Asphalt Roofing Manufacturers Association, 2009). There are different environmental benefits associated to this material (Canadian Asphalt Shingle Manufacturers' Association, 2008): It has a long life span; contains recycled material; can be installed over an existing layer

of roof; the scrap generated during the manufacturing process and reclaimed shingles can be used as a fuel/energy source and as a raw materials for paving roads, parking lots and driveways. There are two types of asphalt shingles: Fiberglass mat-based which are composed of glass filaments of various lengths and orientations, bonded together with inert binders and organic mat based which are made of cellulose fibers (IKO, 2008). Usually organic shingles are made of 85% recycled material while fiberglass shingles are 10% recycled material (IKO Residential Information bulletin, 2007). However, this section will examine Armourshake fiberglass based asphalt shingles (Figure 3.20) which provide the wood shake like appearance.

Armourshake asphalt shingles are manufactured by IKO Industries Ltd., an Alberta company founded in 1951. By 1959 the shingles manufacturing plant was opened in Brampton, Ontario and since then the company has expanded their market reach to include U.S.A and Europe (IKO History, 2004). The Asphalt shingles are made of three main components (IKO Guide, 2009): the reinforcement which is the structural base of the shingle (composed of a fiberglass mat); the asphalt coating (which is the water-resistant layer that protects the roof from the elements); and the top of the shingle, which is embedded with ceramic-coated copper granules which provide the color and protect the shingle from the ultraviolet radiation. The back surfacing has release tape and mineral powder to prevent any sticking in the bundle (IKO Technical Data Sheet, 2008). In addition, the fiberglass base asphalt shingle comes with a special accessory “Armour Starter” which consists on a flat strip embedded with granules and placed beneath the cutouts. The Armour Starter is designed to save installation time and labour (IKO Armourshake Brochure, 2009).

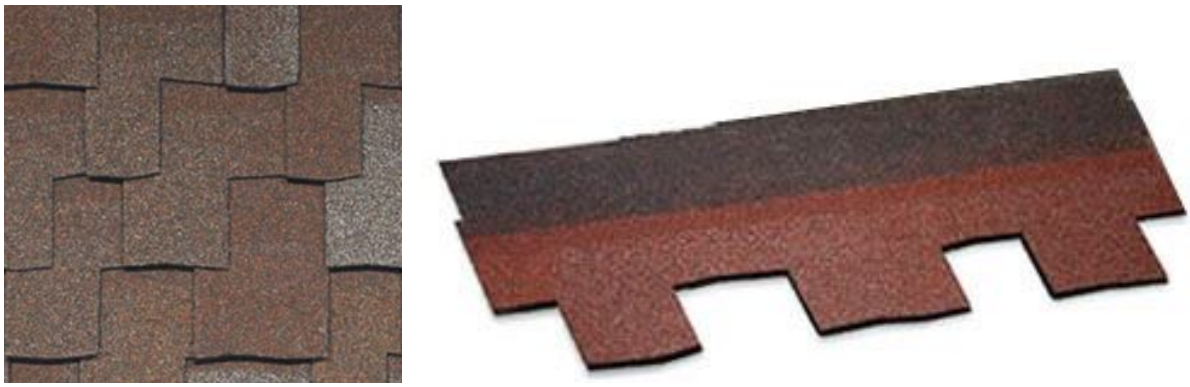

Figure 3.20: Armourshake Architectural Shingles.

Source: Retrieved September 9, 2009, from www.iko.com

3.2.3.3.2 ALUMINUM: INTERLOCK SHAKE

Aluminum is a light weight material that provides different advantages in roofing including a high recycled content, recyclability, and resistance to rust and corrosion (Metal Roofing Alliance, 2007). The Metal Construction Association (MCA) encourages the use of metal roofing for all the ecological benefits that it provides. It is durable because it is not affected by weather conditions such as windstorms, hail, snow and hot or cold extremes; it is a light weight material that contributes to structural savings and helps to extend the life of the building; it can be installed over existing roofing saving removal and disposal costs; and it is a safe, non-combustible and very energy efficient material.

Interlock shake manufactured by Interlock Roofing Ltd., a British Columbia based company and distributed by Les Toits permanents du Québec Inc., is a cool roof made of 95% recycled aluminum that meets the Energy Star performance criteria (Figure 3.21). The panels are embossed with a heavy grain texture and feature an Alunar® Coating System embedded with a Teflon surface protector; both elements give it protection from stains, moisture and organic debris (InterLock Shake Roofing System Specification Manual, 2009). In addition, the granular

coated metal roofing system reflects the solar energy and also re-emits the absorbed solar radiation (InterLock Brochure, 2009); therefore, it helps to reduce the summer cooling energy cost and the urban temperatures. Interlock shake panel is a two way interlocking system that allows an easy and fast installation (Figure 3.22).

Figure 3.21: Interlock Shake Roofing.

Source: InterLock Shake Roofing Specification Manual, 2009.

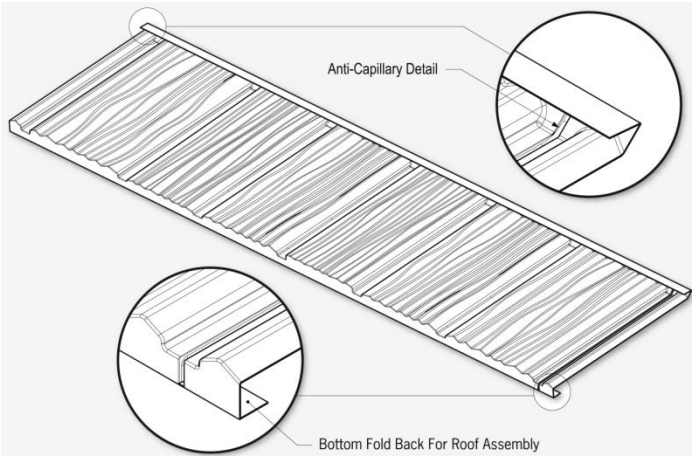

Figure 3.22: Interlock Shake Roofing.

Source: Interlock Shake Roofing Specification Manual, 2009.

3.2.3.3.3 RUBBER ROOFING: EUROSHAKE

EuroShield™ recycled rubber roofing products are manufactured by Global Environmental Manufacturing Inc., (G.E.M) founded in 1999. According to the company "on average, 800 tires are used in the production of material required to cover a single residential home" (GEM Inc, 2009). Besides the recyclability of the products at the end of their lifecycle, all the scrap materials generated from the installation or manufacturing process can be reused in new products (GEM Inc., 2009). Three different types are offered by the manufacturer: EuroSlate, EuroShake and EuroTile. EuroShake roofing provides the look of a wood roof and comes in two different profiles: The Heritage (Taper-Split) which has a rustic rough textured

look (Figure 3.23) and the Contemporary (Taper Sawn) which has straight-cut shallow ridges and a more subtle texture (Euroshield, 2009). EuroShake is an interlocking, pitched roofing system composed of 75% recycled tire rubber (GEM Inc., 2008). The reinforced rubber based compound provides extensive protection against all the elements, and affords energy benefits and savings (GEM, 2008). Installation is fast and easy (Eurotile Installation procedures, 2008); the interlocking panels "hold the leading edge in a lock-down position" and fit into each other (Figure 3.24). This system allows the corners not to lift, curl or blow off.

Figure 3.23: Euroshake Taper-Split

Source: Retrieved September 9, 2009, from http://www.euroshieldroofing.com/euroshake-taper-split.html

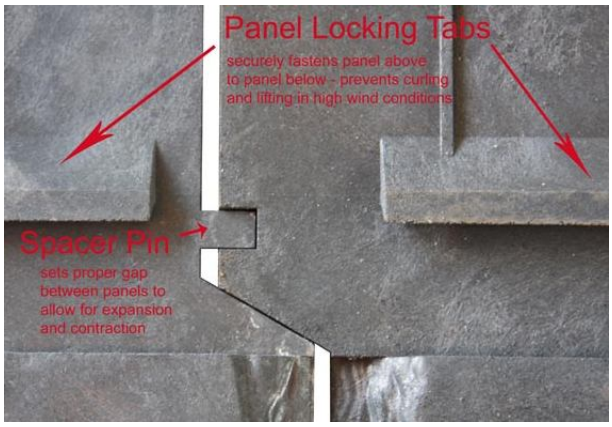

Figure 3.24: EuroShield Roof

Source: Retrieved September 9, 2009, from http://www.euroshieldroofing.com/technical.html

3.2.3.3.4 PLASTIC AND RUBBER ROOFING: ENVIROSHAKE

Enviroshake is a composite roofing product made of 95% reclaimed materials. Enviroshake features the look of a cedar shake and has been on the market since 1998. The product composition consists of a mixture of recycled plastics, rubber and cellulosic fibre materials (Enviroshake Material Safety Data Sheet, 2009). Besides the recycled materials used in the production of the shake, other components or additives are used to give it protection from UV degradation and the brownish grey color (Enviroshake, 2005). However, the initial colour

changes over a period of 6 months to a silver grey colour that makes it resemble to a real cedar roof (Figure 3.25). Enviroshake roofing is recyclable and all the remnants generated during the manufacturing process are recycled back into the system. One important attribute to consider is that unlike other roofing materials that require proper ventilation, Enviroshake is a synthetic product that does not need to breathe (Enviroshake, 2005). Installation is the same as wood shingles and hand split shakes (Figure 3.26). It can be installed over plywood sheathing, strapping or one layer of asphalt shingles (Enviroshake Brochure, 2009). Other benefits of the product include the resistance to wind, hail, mold and insects (Enviroshake Brochure, 2009).

Figure 3.25: Eviroshake Engineered Roofing.

Source: Retrieved September 9, 2009, from http://www.enviroshake.com/gallery.php

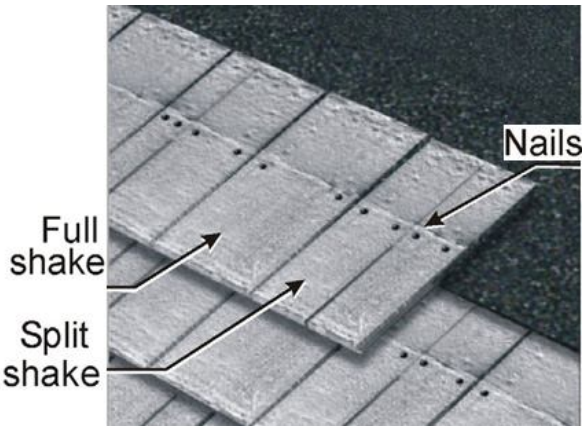

Figure 3.26: Enviroshake is installed in straight single courses.

Source: CCMC Evaluation Report 2009

3.2.3.3.5 PLASTIC ROOFING: RPM CEDAR SHAKE

Recyclable plastic scrap can be ground and processed into roofing products. Due to the light weight, low cost, durability and ease of installation, the plastic roofing market has grown the last few decades (Jarquio, 2007). RPM Roofing Canada Inc., an Ontario based company, has been manufacturing composite plastic products since 2000. The company offers three different types that simulate the appearance of Slate, Cedar Shake or Clay barrel tile (RPM Catalogue

2009). All the products are 100% recycled plastic. The Simulated Cedar Shake is manufactured in three sizes (keeping the same length but with different widths) that can be applied in a variety of patterns (Figure 3.27) (RPM Installation guide). The wood appearance is developed from actual castings of natural cedar shake. The mix of recycled plastics consists of polypropylene in a proprietary RPM formulation (RPM, 2008). This processing system includes a thermoplastic additive which enables the amalgamation of chemically incompatible polymers at lower temperatures reducing costs in the manufacturing process and therefore the final product (RPM, 2008). The combined composition results in a roofing product that looks like cedar shakes and has the strength of plastic polymers. It is lightweight but strong enough to resist hail, wind and water. There are some concerns about the use of plastic in roofing because the material can melt and fade with excessive exposure to the sun and because it might not cope well with changes in temperatures (Jarquio, 2007). However, RPM roofing is a member of the U.S. Green Building Council and their products are tested and approved by independent, accredited laboratories. Therefore, RPM Cedar Shake roofing complies with technical standards including a high resistance to fire (Class A), impact (class 4) and wind (90 mph) (RPM Catalogue 2009).

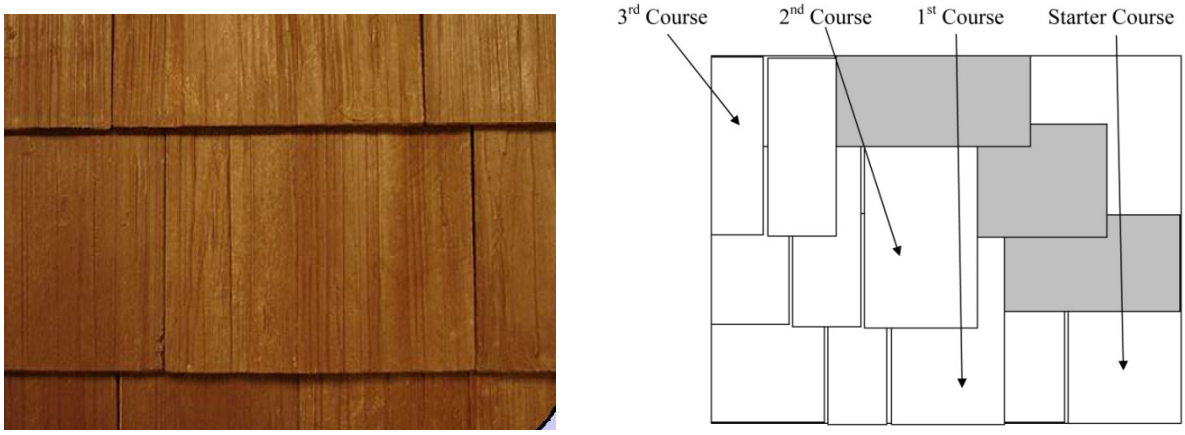

Figure 3.27: RPM Plastic Roofing.

Source: RPM Brochure & Installation Guide.

Product name	Armourshake	Interlock Shake	Euroshake
Company Information	IKO Industries Ltd. 71 Orenda Rd Brampton, Ontario L6W 1V8 Phone: 905-457-5321 www.iko.com	Interlock Roofing Ltd. 9969 River Way Delta, British Columbia V4G 1M8 Phone: 1-888-766-3661 www.interlockroofing.com/	Global Environmental Manufacturing Inc (GEM) 9330 - 48th Street SE Calgary, Alberta T2C 2R2 Phone: 403-215-3333 www.euroshieldroofing.com/
Recycled content (%)	10% recycled Fiberglass.	95% recycled aluminum.	75% Rubber from recycled tires.
Recyclable	✓	✓	✓
Panel size	Length: 37-3/8" (950 mm) Width: 18-1/2" (470 mm)	Length: 13 ½ " (343mm) *Width 50" (1270 mm)	Length: 36" (900mm) Width: 24" (600mm)
Color	Shingles are covered by colored granules to protect the asphalt from the sun. Five colours are available.	Protected by the Alunar Coating System. Nine colours are available.	The color goes all the way through the piece and changes slightly overtime. Two different profiles and three standard colors are available.
Fire Rating	Class A	Class A	Class C
Wind resistance	90 - 130 mph	---	---
Impact resistance	---	---	Class 4
Weight (lbs/100 ft²)	229-360	50 to 70	348
Material cost ($)/ft²	$1.00	$10.00 installed	$3.48
Installation	Armour starter system.	Interlock Connection	EuroTile System.
Warranty	Limited Lifetime warranty	Lifetime Ltd Warranty, Non-Prorated 50 Year transferable.	50 year Limited transferable warranty
Certifications	---	---	---
Associations	Asphalt Roofing Manufacturers Association (ARMA), Canadian Asphalt Shingle Manufacturers' Association (CASMA).	National Roofing Contractors Association (NRCA), Metal Roofing Alliance (MRA).	Built Green™-Calgary Home Builders Association.
length of time on the market	IKO roofing (1959)	1997	1999
Additional factors	Features an algae resistant granule.	Metal roofing can provide noise reduction when installed with solid sheathing.	Insulating and sound-deadening qualities.

Continue on next page

Product name	**Enviroshake**	**RPM Cedar Shake tiles**
Company Information	Enviroshake Inc. 650 Riverview Dr., Unit # 1 Chatham, Ontario N7M 5W8 Phone: 519-380-9265 www.enviroshake.com/	RPM Roofing Canada Inc. 7-800 Petrolia Road Toronto, Ontario M3J3K4 Phone: 866-602-5850 www.rpmroofing.ca/
Recycled content (%)	95% Post-industrial plastics, cellulose fibres and tire derived rubber.	100% recycled plastic.
Recyclable	✓	✓
Panel size	Length: 20" (508mm) *Width: 12" (304 mm)	Length: 23" (584mm) *Width: 12-1/8" (304 mm)
Color	One color available. Dark grey that converts in silver similar to a cedar roof.	Three colours are available. Shakes can be applied in a variety of patterns.
Fire Rating	Class C	Class A
Wind resistance	120 mph	90 mph
Impact resistance	Class 3	Class 4
Weight (lbs/100 ft²)	300	322
Material cost ($)/ft²	$4.40	Not provided
Installation	Standard roofing materials. Can be installed with power-nailer.	Standard roofing materials. Can be installed with a pneumatic nail gun.
Warranty	Limited 50 Year Non-Prorated Warranty	50 Year Limited Warranty
Certifications	ISO 9001 : 2000	---
Associations		Member of U. S. Green Building Council.
length of time on the market	1998	2000
Additional factors	No need proper ventilation.	May reduce Insurance premium.
Note: Data comes from manufacturers' website, brochures, specification sheets, Material Safety Data Sheets. Prices come from manufacturers are approximate and for general comparison. *Manufacturer offers different widths		

Table 3.5: Comparison chart roofing products.

3.2.3.3.6 ANALYSIS AND RECOMMENDATION

The roofing products that contain aluminum, plastic and rubber materials are environmentally sustainable utilizing a high percentage of recycled materials and being recyclable themselves. Asphalt shingles have the longest track record (1951) and are one of the materials most used in residential roofing (ARMA, 2009); however, fiberglass based asphalt shingles do not provide as much percentage of recycled materials as the other products. The rubber (Euroshake) and plastic roofing (RPM) are the most recent products, announced in 1999 and 2000 respectively. Industry tests have been conducted on all the selected products confirming their performance and that they are meeting the industry standards. In addition, all of them contribute to points in the LEED Green Building Rating System and are backed at least by a 50-year limited warranty assuring durability and longevity. Nonetheless, each product performance varies depending on the materials used in their manufacture. For instance, Euroshake and Enviroshake which contain recycled rubber, are more vulnerable to fire and carry a Class C rating. Enviroshake includes additional materials in their composition such as plastic and cellulose fibres but the colors offered are limited to only one. One important aspect to consider is that the quality of the roof depends on the quality of a good installation; therefore, some manufacturers offer special systems such as Armour starter by IKO, Interlock Connection by Interlock Roofing or EuroTile System by GEM making installation simpler and reducing labour costs. In addition, Euroshake panels are larger and allow a faster installation, but there are some who feel these types of panels can be less appealing over time when fading can become more visible (All Weather Products Ltd, 2009). Interlock roofing made of aluminum is highly resistant to weathering but has to be installed over a solid sheathing to reduce noise. It is lightweight and heat reflective; however, it is not cost-effective for different reasons: it requires

professional installation, is manufactured in British Columbia, and the material cost is higher compared to the other options. From a sustainability point of view, it is the author's belief that the synthetic roofing products are a good option not only because they safeguard the environment but also because they provide a good look, are durable and resistant to weather, minimizing long term costs. Even though asphalt shingles are less expensive with time and as recycled shingles increase in popularity prices may go down and could be the future of residential roofing.

3.2.4 OVERVIEW OF INTERIOR FINISHES

Interior materials are important components of the building not only because they cover the walls, floors or ceilings of the structure, but also because they give an aesthetic value to the internal space. However, most finishes emit volatile organic compounds (VOCs) that have an effect on the indoor air quality that in turn affects the health of the inhabitants (Kernan et al., 2001). The exposure to these airborne chemicals can result in different symptoms including a headache, eye irritation, various allergies, fatigue, anxiety and depression (Sustainable Building Sourcebook, 2000). Other aspects that must be considered in the selection of interior finishes are their durability and maintenance. Long-lasting materials require little or no additional finishes and minimal maintenance, so it is therefore important to choose materials that have not only aesthetic qualities but also provide durability and do not cause health problems. Besides the aforementioned features this section will examine countertops that include a high proportion of recycled content bringing other environmental benefits by keeping a lot of material out of landfills.

3.2.4.1 COUNTERTOPS

Countertops are aesthetic elements that come in wide range of materials and designs offering different advantages due to their high use. Traditional materials include concrete, laminate and granite. Concrete countertops are durable but energy intensive; laminate is economic but less durable; and granite is very durable but requires mining impacts (GreenHome Guide, 2006). Manufacturer developments have made it possible to create composite and recycled countertops taking into consideration energy savings in the manufacturing process and bringing homeowners products that are attractive, durable, and easy to maintain. Therefore, the author has selected three alternative choices that include recycled glass, paper and particleboard.

3.2.4.1.1 PAPERSTONE

PaperStone manufactured by Paneltech International LLC in USA, is composed primarily of 100% post-consumer recycled waste paper. Fabricator offers two types of recycled paper-based products: The original that is made from 100% post-consumer recycled cardboard and a certified version that is made from 100% post-consumer recycled standard office paper which is certified to FSC standard. Both products include a proprietary, petroleum free resin which is composed of cashew nut shell liquid. The cellulose fibers are saturated with the resins and pressed under heat and pressure. The end result is a non-porous and dense composite product that is durable, strong, and resistant to scratching, staining and water. The color goes all the way through the product and is determined by the recycled paper used and the natural phenolic resins which tend to darken and yellow over time. In addition, PaperStone is finished with natural waxes and a food grade mineral oil that help to preserve and protect the product from heat (up to 350° F), moisture and humidity. The material is offered in 3/4" (19 mm), 1" (25

mm) and 1-1/4" (32 mm) thicknesses and sheet sizes up to 60" (1524 mm) wide by 144" (3658 mm) long. PaperStone is produced in a variety of styles for different applications such as windowsills, millwork, cutting boards and toilet partitions among others (Figure 3.28) (Design and Fabrication Guide, 2008). PaperStone is not recyclable; however, manufacturer has developed a mouldable resin in which dust and saw trimmings can be used for the manufacture of sinks and shower stalls (Peterson, 2009).

Figure 3.28: PaperStone in different applications.

Source: Retrieved September 25, 2009, from www.jetsongreen.com/2008/02/paperstone-mult.html.

3.2.4.1.2 ICESTONE

IceStone, manufactured in Brooklyn, New York by IceStone, LLC and distributed in Canada by SIP Distribution, is a 100% recycled glass based composite surfacing embedded in a cement binder (IceStone Sustainability, 2009). The combination of these ingredients produces a visually interesting hard surface that is durable and resistant to heat and scratch (Figure 3.29). It can be used for a range of applications including vertical and horizontal surfaces such as walls and floor coverings (IceStone Specifications, Section 06614). IceStone surfaces can be used outdoor and do not fade with UV exposure (IceStone, Brochure). As with mined stone, IceStone

is porous and requires sealing which should be applied once a year to protect it from stains (IceStone Installation and Maintenance). The product is manufactured in 52" (1321 mm) by 96" (2438 mm) slabs that are 1.25" (32 mm) thick. IceStone comes in an assortment of colors that can be determined by adding pigments made from recycled iron into the cement matrix (IceStone Specifications, Section 06614). The process of IceStone manufacturing involves cleaning and sorting the glass by size and color; once the product is ready it is easy to cut and shape (Ice Stone technical Specifications). IceStone can be re-used and is 100% recyclable. The company accepts used surfaces and may cut them into new pieces or reform them into new products. Furthermore, surfaces can be also downcycled into tiles, landscaping material and roadbed aggregate (IceStone Sustainability, 2009).

Figure 3.29: IceStone in different applications.

Source: Retrieved September 25, 2009, from www.jetsongreen.com/2008/02/paperstone-mult.html

3.2.4.1.3 EQCOUNTERTOPS

EQcountertops is manufactured in Quebec by Belanger VT Industries, a company founded in 1965. However, the green initiative with EQcountertops was promoted in 2006 (Countertopics publication, 2008). EQcountertops are postformed laminate countertops that are made from 100% pre-consumer recycled wood fiber particleboard. The particleboard used is

SkyBlend which is certified by Scientific Certification Systems (SCS), is tinted light blue for field identification and is produced with a phenol-formaldehyde (PF) binder which emits lower levels of gas (Figure 3.30) (BuildingGreen, 2009). The manufacturer uses certified Greenguard laminates that are bonded to the particleboard with a water based adhesive (Polyvinyl acetate) (Product Guide Specification, 2008). This adhesive improves indoor air quality eliminating the unsafe Volatile Organic Compounds (VOCs) (EQcountertops Brochure). Therefore, the product is Greenguard Indoor Air Quality and Greenguard Children & school certified "meeting the most stringent emission standards" (Bélanger Laminés Inc, 2009). EQcountertops are 3/4" (19mm) thick and are available in 6 distinct edge profiles. The laminate material is vulnerable to heat; thus, hot items should not be placed directly on the countertop. Special care has to be considered as the surface could be scratch by sharped utensils or cracked by heavy impact.

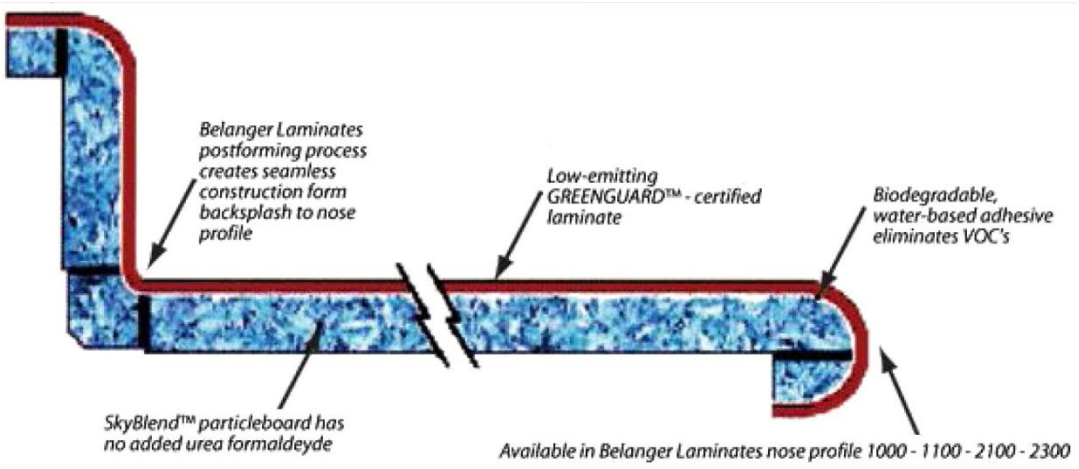

Figure 3.30: EQcountertops made of 100% pre-consumer recycled wood fiber.

Source: Retrieved September 25, 2009, from http://www.belanger-laminates.com/

Product name	**PaperStone**	**IceStone**	**EQcountertop**
Company Information	Paneltech International LLC 2999 John Stevens Way Hoquiam, WA 98550 Phone: 360-538-9815 www.paperstoneproducts.com/	IceStone, LLC 63 Flushing Avenue, Unit 283, Building 12 Brooklyn, New York 11205 Phone : 718-624-4900 www.icestone.biz/	Belanger Laminates VT industries Inc. 1435, Joliot Curie, Boucherville, Quebec J4B 7M4 Phone: 450-449-3447 www.belanger-laminates.com/
Applications	Commercial and Residential	Commercial and Residential	Commercial and Residential
	Interior countertops, wall cladding, conference tables, signs, cutting boards, window sills, toilet partitions, millwork, stair treads and risers.	Interior countertops, shower walls, tabletops, flooring, bar tops, conference tables, window sills, fireplace surrounds, wall cladding and commercial flooring.	Interior countertops.
Colors	6 colors from certified line and 5 colors from original line	24 standard colors	100 colors
Recyclable	---	✓	---
Raw materials	Cellulose fiber, proprietary, petroleum-free phenolic resin.	Recycled glass and cement.	High-Pressure Decorative Laminates (HPDL), recycled particleboard, water based polyvinyl acetate (PVA).
Recycled content (%)	100% Post-consumer recycled standard office paper or cardboard	80 to 100% pre-consumer glass, with the balance being post- consumer waste.	100% Pre-consumer recycled wood fiber particleboard.
Size	60" (1524mm) wide, 144" (3658mm) long.	52" (1321mm) wide, 96" (2438mm) long.	22 ½" (572mm) to 25 ½" (648mm) wide, 8". 10" 12" long.
Thickness	3/4" (19mm), 1" (25mm), 1-1/4" (32mm)	1.25"(32mm)	3/4" (19mm)
Weight	---	14.01 lbs/ ft²	---
Fire rating	Class A	Class A	---
Installed cost ($) ft²	$100	$125	$33
Warranty	15 years Limited Warranty	---	One Year Limited Warranty
Certifications	National Sanitation Foundation (NSF) and Forest Stewardship Council (FSC).	National Sanitation Foundation (NSF) and MBDC's Cradle to Cradle™ certification.	Greenguard Indoor Air Quality, Greenguard Children & school.

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Product name	**PaperStone**	**IceStone**	**EQcountertop**
length of time on the market	2004	2004	Belanger Laminates (1965), Eqcountertop (2006)
Note: Data comes from manufacturers' website and brochures. Eqcountertop is sold by manufacturer PaperStone and IceStone are sold through distributors in Canada. Prices may vary depending on design are approximate and for general comparison.			

Table 3.6: Comparison chart hard surfaces.

3.2.4.1.4 ANALYSIS AND RECOMMENDATION

PaperStone, IceStone and EQcountertops are products composed of 100% recycled material requiring less energy in the manufacturing process and minimizing the extraction of natural resources. PaperStone and EQcountertops are alternative materials to wood products that help reduce further depletion of forest resources and IceStone is an alternative material to natural stones such as granite or marble which are quarried directly from the ground causing several environmental impacts. These products are relatively new in the marketplace but offer different advantages including versatility and durability. PaperStone and IceStone can be used for numerous applications throughout the home and can be also used in exterior spaces. The physical properties of IceStone make it the most durable; but, it is the most expensive. However, it is easy to maintain and has a long life cycle, can be re-used after initial installation and can be recycled into a new product. This is unique to IceStone and not echoed in other products. In comparison, EQcountertop is less durable but with proper care could last decades. It is the most cost-effective choice that also provides different options in design and colors and is locally manufactured. For these reasons and because of the high recycled content and the low impacts on air quality, it is the author’s opinion that EQcountertops is an affordable choice that provides quality and could become renowned among the laminate products.

CHAPTER FOUR

CONCLUSIONS

4.1 INTRODUCTION

An increased understanding of how human activity affects the world has led to a change the way we build. The green building industry has played an important role by promoting building practices that are more environmentally friendly, that reduce factors which contribute to climate change, and which enhance people's health and comfort. One of the factors which contributed to the development of new, more environmentally-conscious and sustainable products was the energy crisis in the 1970s; however, the green building industry has really flourished since the early 1990s (Lucuik, 2005). It is also in this decade that the concept of utilizing recycled building materials has become concern among builders and manufacturers. As mentioned in chapter I, Steve Loken's ReCRAFT demonstration project (1992) was one of the first examples of using alternative materials with recycled content, and was successful in that it not only saved resources, but demonstrated durability and performance possibilities. This report has attempted to demonstrate the various types of products that are now available in the marketplace, and their different features and characteristics, and how these products can not only be good for the environment but also for homeowners and builders. In drawing conclusions from the analyses undertaken in the prior sections, the discussion will be based around four main points: recycled content itself, product durability, innovativeness and cost effectiveness.

4.2 RECYCLED CONTENT

The proposed alternative materials for foundation and framing are two types of building systems: Insulating Concrete forms (ICFs) and Structural Insulated Panels (SIPs). Each system

has an industry organization promoting and supporting it, those being the Insulated Concrete Form Association (ICFA), founded in 1995 and the Structural Insulated Panel Association (SIPA), founded in 1990. These associations support manufacturers and builders and are a good source of information for homeowners are considering the use of these building technologies. They provide a lot of information and a wide directory of different manufacturers. Part of their building initiative includes reducing the use of virgin resources by using recycled materials. Nonetheless, according to the author's research there remains a shortage of products that contain recycled content. The most common recycled material used is post-industrial Expanded Polystyrene. Insulspan and Quad Lock produce SIPs and ICFs respectively and have a large dealer network; however, they claim not to use recycled EPS because of the possible failure of a quality product. On the other hand, according to the ICFA in their Technology brief "ICF Points to LEED" (2008), post-consumer waste is generally not used "as the possible contaminants may jeopardize the function as a safe concrete forming material". Therefore one should conclude that the industry still has to overcome certain obstacles. However, the products selected for reviewing in this report are examples of companies that have been able to use recycled materials and offer good performance. As more people use these systems and market demand increases, more research and improvements could be conducted in the future.

Siding products with recycled content included fly ash, vinyl and wood fiber. Fly ash and vinyl are recycled materials used in siding products produced by CertainTeed. The company has developed a "Green Building Products Reference Guide" in which consumers are able to consult the different sustainable building options for everything from the foundation to the roof. KWP Naturetech, on the other hand, focuses specifically on siding products made from engineered wood and offers the product containing the highest recycled content from post-

consumer sources. In this sense, the company contributes to the conservation of natural resources through the sustainable use of wood. Wood is renewable and recyclable and by using recycled materials there are a number of advantages that can be accrued, including a lower demand for fiber from forests, and less pressure to harvest old growth trees (Nogueron & Laestadius, 2009). As shown in Table 4.1 the recycled materials most used are those that are associated with wood fibers: newsprint, cardboards and paper (not to mention the many building products used in housing that include the use of wood such as in framing, interior partitioning, siding or flooring, which do not necessarily include recycled materials in their manufacturing process). In the case of engineered products such as OSB, most of the manufacturers claim that their wood is sourced from carefully managed forests, but do not include recycled materials. The author was not able to find structural wood products with recycled content, though recycled wood and paper based products were more easily found in interior applications. These examples are shown in three products Igloo cellulose, PaperStone and Eqcountertops. These products offer a high recycled content and contribute to minimize the amount of methane emissions produced from paper sent to landfills.

PVC (polyvinyl chloride) is known as a durable and economical material and is used in different building applications including flooring, siding, and plumbing materials (among others). There are some concerns about the use of this material, as it can release dioxins throughout its entire life cycle, posing potential human health and environmental risks (Finaldi, 1993). However, according to the Vinyl Institute (2009), studies conducted over the past 30 years involving comparisons to similar products made of other materials have resulted in conclusions that PVC is highly energy efficient, durable, and has low footprint with respect to greenhouse gases. In fact, the Vinyl Institute states that “PVC is an extremely small source of

dioxin and impacts on the environment are comparable to or lower than most alternatives". Furthermore, in order to minimize these impacts, part of the effort involves taking waste back to the manufacturing process.

A wide variety of roofing products which incorporate recycled materials are now available. The most interesting feature is that the majority of the products not only contain high percentages of recycled materials, but also that they can be reused once they have reached the end of their life (Table 4.1). Asphalt shingles have been the foremost roofing choice in housing, and the waste generated from installation scraps and re-roofing is significant. However, today recycled asphalt shingles (RAS) can be reused. Some of the potential markets for asphalt shingles include hot mix asphalt (the largest current market), cold patch, temporary roads or driveways and new shingles (Shingle Recycling Org, 2009). In fact, by using RAS for hot mix asphalt, the pavements' performance can often be improved (Shingle Recycling.Org, 2009).

According to the Environment and Plastics Industry Council (2004), in their report "An Overview of Plastic Bottle Recycling in Canada," 235,086 tonnes of waste from plastic bottle material were generated in 2002 and of this, 84,709 tonnes (36%) were recovered and recycled. Therefore, roofing with recycled plastics may also help to recover large quantities of material from the waste stream.

Product		**Material Recycled**	**Post-Consumer Content %**	**Post-Industrial Content %**
ICFs	Rastra ICF	EPS	85	
	Durisol ICF	waste wood		75-80
SIPs	Polycore SIP	EPS		30
		Steel	25-45	
	Enercept SIP	EPS		80
	Foard SIP	XPS		15

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Product		Material Recycled	Post-Consumer Content %	Post-Industrial Content %
Siding	WeatherBoards FiberCement	Fly ash		30
	CedarBoards Insulated siding	Vinyl	60	
	KWP Engineered wood	Wood fibers	100	
Insulation	Cellulose	Newspaper	85	
	Pink Fiber Glass	Glass	60	
	Roxul	Slag		40
	UltraTouch	Denim and cotton fibers		85
	Heatlok soya	Plastic	40	
Roofing	Asphalt	Fiberglass	10	
		Cellulose fibers	85	
	Interlock	Aluminum	95	
	Euroshake	Rubber	75	
	Enviroshake	Plastics, cellulose fibres and rubber		95
	RPM	Plastic	100	
Finishes	PaperStone	Paper/cardboard	100	
	IceStone	Glass	20	80-100
	Eqcountertop	Wood fibers	100	

	Wood and paper based products

Table 4.1: Content levels of recycled materials.

4.3 DURABILITY

When talking about sustainability there are different issues that need to be considered. As discussed earlier, recycled materials contribute to sustainability by conserving natural resources, diverting materials from landfills, and reducing environmental impacts. However, this is only helpful if the products perform well, and aren't subject to extensive maintenance and

early replacements in the future. Therefore, the author has examined the reliability of the products selected in this report by evaluating 4 main aspects: warranty, certifications, LEED credits and Energy Star qualifications (Figure 4.2).

The outcomes of this study show that most of the manufacturers market their products with sustainable qualities through brochures which explain the different LEED requirements and how their products contribute toward achieving LEED credits. Although most of the roofing products are relatively new in the market, this group provide the longest warranties. Igloo Cellulose and Heatlock soya are products that require a specialized professional to ensure proper installation. Therefore; these products offer a warranty. In contrast, the other types of insulating products do not have control over installation and do not provide any warranty. On the other hand, IceStone countertops offer different benefits and require licensed installers; but, do not provide any warranty. All the proposed products for foundation and framing are qualified to meet the performance guidelines of an Energy Star home, which means that they contribute to saving energy, yielding better protection against moisture and noise pollution, and help to protect the environment.

All of the products have claimed the use of recycled materials; however, some carry third party certification of recycled content by independent agents which verify the accuracy of these environmental claims and ensure quality control. KWP Naturetech is certified by the composite Panel Association (CPA) with the Environmentally Preferable Product (EPP) certification launched in 2003. According to the CPA, environmentally preferable products are "products and services that have a lesser or reduced effect on human health and the environment when compared to other products and services that serve the same purpose". EPP certification ensures that the product is made from 100% recycled and/or recovered fiber and that it meets strict

formaldehyde emissions requirements. Pink Fiberglass is certified by the Scientific Certification Systems (SCS), founded in 1984. SCS certification assures that the product meets the minimum claimed recycled material content. IceStone is MBDC Cradle to Cradle certified assuring that the company meets human health and environmental requirements and includes design for material reutilization. According to the MBDC, Cradle to Cradle certification "helps customers purchase and specify products that are pursuing a broader definition of quality." In addition, products offer other certifications that are not related to the recycled content but also up hold sustainable principles such as protecting forests from destructive techniques, improving Indoor Air Quality and public health. In conclusion, it is the author's opinion that today we can find different strategies that could provide customer confidence which in turn could create demand for more products.

Product		Warranty	Certifications	Contributes to Achieving LEED Credits	Qualified to Energy Start
ICFs	Rastra ICF	3 months Limited	---	✓	✓
	Durisol ICF	1year Limited	---	✓	✓
SIPs	Polycore SIP	5 years	---	Not provided in website	✓
	Enercept SIP	Limited Lifetime	Forest Stewardship Council (FSC)	✓	✓
	Foard SIP	20 years Limited	Forest Stewardship Council (FSC)	✓	✓
Siding	WeatherBoards Cedar Lap	50 years Limited transferable. 15 years limited paint warranty.	Sustainable Forestry Initiative (SFI)	✓	---
	CedarBoards Insulated siding	Lifetime Limited Warranty in panels and color.	---	✓	✓
	KWP Naturetech	25 years warranty on the substrate an 15 years on the finish.	Environmentally Preferable Product (EPP)	✓	---

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Product		Warranty	Certifications	Contributes to Achieving LEED Credits	Qualified to Energy Start
Insulation	Igloo Cellulose	Lifetime	ISO 9000-2008	Not provided in website	---
	Pink Fiberglass	---	Greenguard Indoor Air Quality Scientific Certification Systems (SCS)	✓	---
	Roxul	---	Greenguard Indoor Air Quality	✓	---
			Greenguard Children & school	✓	
	UltraTouch	---	---	✓	---
	Heatlok soya	Limited Lifetime	Greenguard Indoor Air Quality Greenguard Children & school	✓	---
Roofing	Armourshake	Limited Lifetime.	---	✓	---
	Interlock	Lifetime Limited, Non-Prorated 50 Years transferable.	---	✓	✓
	Euroshake	50 years Limited transferable.	---	✓	---
	Enviroshake	Limited 50 Years Non-Prorated.	ISO 9001:2000	✓	---
	RPM	50 Years Limited.	---	✓	---
Finishes	PaperStone	15 years Limited.	National Sanitation Foundation (NSF) Forest Stewardship Council (FSC)	✓	---
	IceStone	---	National Sanitation Foundation (NSF) MBDC's Cradle to Cradle™ certification	✓	---
	Eqcountertop	One Year Limited.	Greenguard Indoor Air Quality Greenguard Children & school	✓	---

	Third Party Certifications focus on recycled materials
	Third Party Certifications focus on Indoor Air Quality
	Third Party Certifications focus on forestry impacts

Table 4.2: Product durability.

4.4 INNOVATIVENESS

Thanks to the advancements in technology, manufacturers have been able to include recycled materials into their products allowing a better use of resources. One of the strategies to increase the use of recycled materials is by promoting products that provide different features. Part of this process involves innovation. Therefore, this section will explain how long the different products have been on the market and how manufacturers have enhanced the performance attributes in their products to make them more desirable (Table 4.3).

Most of the innovative characteristics of these green products focus on energy efficiency, superior performance, durability and better or easier installation technologies. Certainteed, Owens Corning and IKO are large American companies with international markets, years of experience, and they provide a variety of building products, including the most commonly used materials (vinyl siding, fiberglass insulation and asphalt shingles respectively). These products have been in the marketplace for many years; however, what make these products different form their counterparts are the green initiatives that have been incorporated into their production. Other companies such as Polycore (SIP), KWP Naturetech (Engineere wood siding), Enviroshake (Composite Roofing) and RPM (Plastic Roofing) are Canadian companies that are specialized in specific products which have been launched in the marketplace in more recent years. Yet, they promote their products as "Green" in more ways than one and are as competitive as other traditional materials. RPM, for instance, claims that plastic roofing demands are increasing and this is reflected in a growth in overall sales of 30% each year (RPM, 2008). Heatlok Soya, which include three features in one application (energy efficiency, air and vapour barrier) was chosen as "the most innovative and energy-efficient new product in the market for 2006 by the Public Works and Government Services Canada" (Sanders, 2007). Other

innovative product is EQcountertop for its versatility, durability, low levels of gas and 100% recycled material. In conclusion, sustainable technologies have not only reduced the resources required in their production, but also the consumption of energy and production of toxic materials and substances.

Product		Length of Time on the Market/years	Innovative features
ICFs	Rastra ICF	37	Lightweight, integral Insulation, easy to assemble, faster construction, minimal bracing required, very low sound transmission
	Durisol ICF	56	
SIPs	Polycore SIP	7	Steel provides superior strength and EPS brings energy efficiency. No special skills or tools required. vertical and horizontal electrical feed channels included.
	Enercept SIP	27	Insulated connecting posts for superior strength and thermal performance. Patented electrical chase for routing wiring.
	Foard SIP	26	Thinner walls, higher energy efficiency and strength with XPS cores.
		XPS (1 year)	
Siding	Certainteed-FiberCement siding	11	Lighter weight and superior strength by using fly ash. FiberTect sealant/primer for superior moisture protection.
	Certainteed-Vinyl siding siding	40	TrueTexture technology for a natural cedar look. STUDfinder System for easy installation. DuraLock System for wind resistance. Rigid foam backing brings higher thermal performance, reduces exterior sound and adds strength and rigidity.
		Insulate Vinyl Siding (Not provided)	
	KWP Naturetech	5	Tru-Align panel interlock system for easy installation. Finished with 4 coats of acrylic paint baked on at high temperatures improves protection from the elements and reduce maintenance.
Insulation	Igloo Cellulose	25	Use of non-toxic borates chemicals and natural additives gives resistance to mold, fire and dust.
	Pink Fiberglass	71	
	Roxul	21	
	UltraTouch	35	
	Heatlok soya	3	High R-value, Include air and vapour barrier

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Product		Length of Time on the Market/years	Innovative features
Roofing	IKO Asphalt	50 Armourshake (Not provided)	Ceramic-coated copper granules provide color and protect the shingle from UV radiation. Armour Starter system for easy installation
	Interlock	12	Alunar Coating System gives protection from stains, moisture and organic debris. Interlocking System for easy installation
	Euroshake	10	The color goes all the way through the product. EuroTile System for easy installation.
	Enviroshake	11	No added expense of painting, treatment or preservatives
	RPM	9	
Finishes	PaperStone	5	Proprietary, petroleum free resin. The color goes all the way through the product. finished with natural waxes and a food grade mineral oil.
	IceStone	5	adding recycled iron into the cement matrix
	Belanger Laminates	44 EQ countertops (5 years)	No added urea-formaldehyde. Used of a water based adhesive to bind together particleboard and laminate.
			Companies with longer track record

Table 4.3: Innovative product features.

4.5 COST EFFECTIVENESS

The demand for products containing recycled materials is determined, at least in part, by the extent to which such products are durable and cost effective. Cost effectiveness of a product in terms of the initial purchase should not be the sole consideration, indeed, other parameters that involve long term costs such as maintenance and replacements must also be considered. In some cases products may have a high initial cost but could provide long term savings either because they are healthier, because they save energy or because they are more durable, or of a higher quality. In some such cases, these additional features may more than make up for any additional initial costs incurred. Such examples in this study are Heatlok soya insulation, IceStone

countertops which have a higher initial cost that includes installation assuring the quality and performance of the product. Heatlok Soya insulation offer long term savings by reducing heating and cooling loads and IceStone by reducing future replacements. Other examples include ICFs and SIPs which have a higher initial cost compared to wood framing.

Jessica Krippendorf in her article "ICFs and SIPs Saving Green on Insulation" (2008) states that "the biggest obstacle to seeing more ICFs and SIPs used in new build are perceptions about cost and installation, but manufacturers are conquering both." These building technologies are fast gaining market share in the construction industry for different reasons: structural integrity; saving builders' money minimizing worksite waste, labour costs and construction time; and saving homeowners' money with excellent insulating qualities that allow for a reduction in heating and cooling costs. Today leaders in both industries believe that working together and improving assemblies between walls (ICFs) and roofs (SIPs) will optimize the energy efficiency in buildings (Calabrese, 2009). According to the Structural Insulated Panel Association (SIPA), SIP production increased 12.1 % in 2005 and 6.1% in 2006 (Conbere, 2007). On the other hand, the National Association of Home Builders (NAHB) and the Portland Cement Association (PCA) claimed an increase in the use of ICFs in the residential market of 29% in 2001 (Trade News, 2002). In addition, according to the Insulating Concrete Form Association (2009), a house built with ICFs costs 4% to 5% more than a conventional, wood-framed building (with experienced contractors). However, the cost effectiveness of the product results when the cost of materials is offset by the energy efficiency of the house which is reduced to 30-40% per year (ICFA, 2009). In conclusion, ICFs and SIPs are gaining in popularity, are cost effective and are the base for further research into more sustainable practices. In addition it should be noted that

global warming and rise of energy costs will drive more builders and homeowners to use ICFs and SIPs.

The market also provides products that use recycled materials and can be cheaper than those that use virgin sources in their production. Fly ash, a by-product of coal burning power plants, is an example, whereby its addition to concrete, reduces the amount of cement needed and therefore the cost of the material and the carbon dioxide emissions generated by its production (Headwaters Resources, 2008).

Finally, one of the overlooked aspects of affordability (financial or environmental) is the transportation factor, which can affect the final cost of any given product. Regionally or locally produced materials support the local economy and reduce environmental impacts such as air pollution and fuel consumption. As shown in Table 4.4, all the manufacturing facilities are presented, showing what products provide energy savings with respect to transportation. Those products, for instance, that are manufactured in USA and do not provide any distributor in Canada can increase the overall price and can have detrimental environmental effects.

In the last decades, with the Green movement, the building materials industry has been facing different challenges to reduce its environmental footprint and introducing not only materials that provide healthier and more energy efficient environments, but that are also sustainable in the marketplace from an economic standpoint. Therefore, as recycled materials continue to improve and demonstrate that are competitive in performance and price it is the author's belief that interest among builders and homeowners will continue to grow.

Alternative Material		Material cost ($)/ft²	Manufacturing facilities
ICFs	Rastra ICF	US $15.00 installed	USA
	Durisol ICF	$12.00 installed	Ontario
SIPs	Polycore SIP	$13.77	Alberta
	Enercept SIP	Not provided	USA
	Foard SIP	$30.00 installed	USA
Siding	FiberCement	$2.50	USA*
	Vinyl siding	$1.82	USA*
	KWP Engineered wood	$1.90	Quebec
Insulation	Igloo Cellulose	$0.58	Quebec
	Pink Fiber Glass	$0.68	Quebec
	Roxul-Mineral Wool	$0.51	Ontario
	UltraTouch-Cotton	$0.94	USA*
	Heatlok soya-SPF	$3.20 installed	Quebec
Roofing	Armourshake-Asphalt	$1.00	Ontario
	Interlock-Aluminum	$10.00 installed	British Columbia
	Euroshake-Synthetic (GEM)	$3.48	Alberta
	Enviroshake-Synthetic	$4.40	Ontario
	RPM-Synthetic	Not provided	Ontario
Finishes	PaperStone-Paper	$100.00 installed	USA*
	IceStone-Glass	$125.00 installed	USA*
	Eqcountertop-Laminate	$33.00 installed	Quebec
Note: * Products provide distributors in Canada			

	Products manufactured in Central Canada
	Products manufactured in West Canada
	Products manufactured in U.S.A

Table 4.4: Products cost.

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APPENDIX ONE

Recycled Content Products Database

ARCAT, Inc.	http://www.arcat.com/
BuildingGreen, LLC: Recycled Content	http://www.buildinggreen.com/auth/productsByLeed.cfm?LEEDCreditID=26
Built Green: The Built Green Product Catalogue	http://www.builtgreencanada.ca/content.php?id=279
Composite Panel Association	http://www.pbmdf.com/Index.asp?bid=1087
Eco Green: Eco Products	http://www.eco-building.ca/index.html
Ecoinhabit	http://www.ecoinhabit.com/our-products
Ecologo: Green Products	http://www.ecologo.org/en/greenproducts/consumers/
Ecology Action: Green Building Materials Guide- Recycled content building materials	http://www.ecoact.org/Programs/Green_Building/green_Materials/recycled_content.htm
Energy Star Canada	http://oee.nrcan.gc.ca/residential/energystar-portal.cfm
Forest Stewardship Council Canada: Certified Wood Products	http://www.fsccanada.org/FindWoodProducts.htm
Green Market Canada: Material & Resources	http://www.greenmarketcanada.ca/Index.php
Green Seal Certified Products	http://www.greenseal.org/findaproduct/index.cfm
GreenerHomes.ca: Green Products List	http://www.greenerhomes.ca/Greenerproducts.php
GreenWorks Building Supply Inc: Products	http://www.greenworksbuildingsupply.com/learn/LearnBrands.html
Light House Sustainable Building Centre: Product Library Search	http://www.sustainablebuildingcentre.com/resources/product_library
MBDC's Cradle to Cradle™ certification	http://www.c2ccertified.com/
Raisingspaces: Green Building Products	http://www.raisingspaces.com/index.php/green-building-products/
Recycling Association of Minnesota: Recycled Products Guide	http://www.recycleminnesota.org/htm/ReProd2.htm
Recyclingmarkets.net	http://recyclingmarkets.net/products/index.html
Scientific Certification Systems: Certified Products-Recycled Content	http://www.scscertified.com/products/program.php?a=recycled
The California Integrated Waste Management Board: Recycled Content Product Directory	http://www.ciwmb.ca.gov/RCP/
U.S. Environmental Protection Agency (EPA): Product Resource Guides	http://www.epa.gov/epawaste/conserve/tools/cpg/factshts.htm
Weyerhaeuser Company: ilevel	http://www.ilevel.com/default.aspx

APPENDIX TWO

List of building products with recycled content selected in the report

ICFs	Quad-Lock Building Systems Ltd	www.quadlock.com/
	Rastra Corporation	www.rastra.com/
	Durisol Building Systems Inc	www.durisolbuild.com/
SIPs	Polycore Canada Inc.	www.polycorecanada.com/
	Enercept Inc.	www.enercept.com/
	Foard Panel.	www.foardpanel.com/
Siding	CertainTeed Corporation	www.certainteed.com/
	KWP Building Products	www.kwpproducts.com/
Insulation	Igloo Cellulose Inc.	www.cellulose.com/
	Owens Corning Canada Inc.	www.owenscorning.com/
	Roxul Inc.	www.roxul.com/
	Bonded Logic Inc.	www.bondedlogic.com/
	Demilec	www.heatlok-soya.com/
Roofing	IKO Industries Ltd.	www.iko.com
	Interlock Roofing Ltd.	www.interlockroofing.com/
	Global Environmental Manufacturing Inc (GEM)	www.euroshieldroofing.com/
	Enviroshake Inc.	www.enviroshake.com/
	RPM Roofing Canada Inc.	www.rpmroofing.ca/
Finishes	Paneltech International LLC	www.paperstoneproducts.com/
	IceStone, LLC	www.icestone.biz/
	Belanger Laminates VT industries Inc.	www.belanger-laminates.com/