CCWG Final Report

Project Title: Investigating the Feasibility of Wool Value Chain Development

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Sheep Producers of Nova Scotia (SPANS)

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Contents

1. Introduction

This report has been generated in response to the outcomes of a collaborative research project, the Wool Value Chain Development Project (WVCDP), undertaken by Farm Energy Nova Scotia's (FENS') Dr. Kenny Corscadden and the Rural Research Centre's Dr. Deborah Stiles. The WVCDP was funded by the Technology Development Program, with additional funding obtained through the Social Sciences and Humanities Small Institutional Grants. The WVCDP's purpose was to investigate the potential value chain development of wool in Nova Scotia, Atlantic Canada and beyond. Preliminary results indicate that there is the potential to add value, in the province of Nova Scotia, Atlantic Canada, and potentially Canada as a whole, to what is presently, in part, waste wool that is either discarded unused or under-utilized.

The WVCDP involved collaboration with industry associations, producers, researchers and academics, with funding support from Canadian Cooperative Wool Growers (CCWG) as well as the sources noted above. Other industry collaborators included the Sheep Producers Association of Nova Scotia (SPANS), which provided access to its membership database and its office space to conduct a portion of the research, and Jonathan Wort, Ruminant Specialist, Perennia, who provided valuable background on the industry as a whole. Additionally, individual producers, and business owners have provided input. Original project co-PIs Dr. Kenny Corscadden, NSAC's Industry Research Chair, Farm Energy Conservation, and Dr. Deborah Stiles, Director of NSAC's Rural Research Centre, have been joined by Professor Ashwini Kulkarni, lecturer and researcher in Engineering and staff researcher and DAL Economics Master's student Jaclyn Mosher for carrying out this research.

2. Background

Nova Scotia agriculture in recent years has contributed up to 2.2% to the total Canadian Agriculture and Agri-Food sector GDP (Agriculture and Agri-Food Canada, 2007). Nova Scotia's sheep sector, while thriving due to healthy lamb markets and sufficient fresh lamb processing capacity, is nonetheless a relatively small part of the overall agricultural sector, as cash receipts accounted, as of 2002, for only 0.5% of total farm cash receipts in the province (GPI Atlantic, 2008a). This makes the sector the smallest of all the major agricultural products, including dairy, poultry, floral/nursery, fruit, beef and hog, forest products and eggs, vegetables, potatoes, turkeys and grain.

There are concerns that the sheep industry may be subject to significant costly downturns (GPI Atlantic, 2008b; Stanford, 1999). The number of sheep farms in Nova Scotia, by way of illustration, went from 508 in 1976 to only 269 in 2006 (Statistics Canada, 2006), a 47% reduction in just thirty years. The average number of sheep per farm has also been declining since the early 1990's. In 1976, there was an average of 78 sheep per farm; this number increased reaching a peak in 1991, with an average 111 sheep per farm, but the number has since dropped to only 90 sheep per farm (Statistics Canada, 2006). The total number of sheep in the province has also declined from 15,900 in January, 1990 to only 12,900 as of January, 2011 (Statistics Canada, 2011a), representing a decline of 3,000 sheep or 18.9%. If these trends continue, the sector could decline to a point that it might not recover, resulting in a significant impact on producers, the local economy, and indirectly on many other sectors within the province. Therefore, identifying ways to increase the viability of Nova Scotia sheep farms is essential for sustaining this valuable industry.

Market lambs are the primary income source for sheep farms in the province, and cash receipts are substantially greater for lamb than for wool production. In 1981 cash receipts for lambs in NS were $1,184,000, while wool was $113,000. In 2007, lamb cash receipts increased to $2,641,000 while wool actually fell to $31,000, with farmers receiving only $0.55 per pound for wool (Statistics Canada, 2011b; Statistics Canada, 2011c). At present, Canada's main market for wool – 70% of that market, in fact – is China. Some Canadian wool is also going into the

U.S., Indian, and Uruguayan markets, as well as into domestic production (Wool Production in Canada, n.d.; CCWG, 2011).

The question of what might happen to the smaller producers of this region if current markets were to disappear is a daunting one. It is also sobering to note that the Canadian sheep and wool industry as a whole is a shadow of prior Canadian consumption and production rates. Peak year was 1945, when nearly 7 million kilograms of wool were produced. More recently, numbers have remained relatively stable in the range of 1,197.3 - 1,321.4 (-,000 kg) wool produced in the years 1996-2007(Wool Production in Canada, n.d.). Because 70% of wool production is presently going to one global buyer (China), there clearly has been little to no domestic market for wool. Yet wool is a joint output or byproduct from the production of lambs; therefore, as long as there is a market for lamb, there will also be a potentially marketable supply of wool. The development of a value chain to utilize wool for the production of wool insulation or other wool products could potentially increase the viability of lamb production by adding an additional source of income to farms. Appropriate-scale manufacturing also has the potential to shield Nova Scotia as well as the region's or country's industry as a whole from the vagaries of the current globalized wool market, as well as potentially creating employment within a more localized economy.

In Nova Scotia, and indeed in the Atlantic region as a whole, there is a great need for increased processing capacity, more small businesses, and specialized, entrepreneurially-focused training environments. The agricultural sector in particular is in great need of economic development, as it has been facing many challenges. In 2001, GPI Atlantic released a report that examined economic trends in the agricultural sector and warned of the increasing difficulty for small-scale farmers to make ends meet. At the time, farm net income in Nova Scotia had dropped 91%, and average farm debt had increased by 146% since 1971 (Statistics Canada, 2001).

Since the mid-20th century, the wool and textile industry in Canada has changed dramatically. In 1945, peak wool production hit 15 million pounds (Wool Production in Canada, n.d.). In contrast, the 2005 peak wool production in Canada hit only 3.1 million pounds (Statistics Canada, 2006). The Canadian sheep industry, while thriving, does not come close to prior Canadian consumption and production of wool. Canadian wool production tends to be heavily influenced by wider global trends in the textile industry. During the latter half of the 20th century, the two main competitors in the textile industry were cotton and polyester (Jarrell, 2011). Increasingly, North American companies began moving or outsourcing their operations to India and China where increased economic efficiencies could be obtained due to less regulated labour and environmental policies (Nordås, 2004; Jarrell, 2011). The production of textiles in third world countries allowed for lower production prices which undercut many Canadian wool producers.

Currently there is virtually no wool processing in Canada of any scale; only 10 percent of Canadian-produced wool is sold in Canadian niche markets (CCWG, 2011). The world textile industry has moved to Asia, and the Canadian Cooperative Wool Growers association now has four agents working on their behalf in China. Because of competition from the cotton and polyester industries, wool production in the past two decades has steadily shrunk. Indeed, the global wool industry now represents less than two percent of the textile market worldwide (Davidson, 2012). Aside from textile manufacturing, there is hardly any manufacturing of sheep's wool insulation in all of North America and the current sheep's wool insulation manufacturing occurs primarily in the UK, Ireland, Austria, Australia, and New Zealand.

The Rural Research Centre's Changing Paradigms in Atlantic Agriculture research programme has been examining the forces and factors transforming Atlantic agriculture. One key area of concern to emerge from the Changing Paradigms research process was that clear policy and practices divide larger-scale industrial, commodity-oriented and globalized agriculture - such as the current global market for wool and the suppression of wool prices - and smaller-scale, specialized, "niche" or localized farming and farming-related enterprises, with their particular policy needs and challenges for survival within a globalized context. This divide between large and small suggests that in order for Atlantic agriculture to not only survive but thrive in these challenging economic times, more attention needs to be paid to value chain development and to finding unique approaches for linking agricultural production, community, and economic development (Altieri, 2009; Stiles and Cameron 2009; Hanavan et al, 2010). Wool value chain development, in view of the continuing market demand for lamb, appears a fruitful avenue to explore.

Wool has begun to be diverted from textile use for conversion and application as insulation and for other purposes in the construction industry (Trancart, 2008). Although it is not known what percentage of wool is currently being diverted for these purposes, operations in Australia, New Zealand, Ireland and the UK have businesses are now using wool as a natural alternative to synthetic (mineral wool or fiberglass) insulation (Black Mountain Insulation, 2008; New Fibre Materials, 1995).

This report explores that potential, because Atlantic Canada is also ideal, from a ruminant forage production standpoint, for smaller-scale sheep and other pasture-based production (Papadopoulos et al, 1993). The WVCDP has also identified through its networking efforts, a small, but growing group of hand spinners, craftspersons and artisans who utilize some of the wool in the region, but who do not and could not utilize the wool presently being discarded as it is generally not suitable (due to the breeds of sheep being shorn) for most artisanal and craft market-oriented endeavors.

Assessing the feasibility of establishing specific value chains for wool such that wool producers and their product are able to grow their numbers—facilitating growth of the sheep industry in Nova Scotia, the region, and the country as a whole—is important in safeguarding the industry from its current vulnerabilities in the global marketplace.

The suitability of wool as an insulation product has also been addressed by other wool producing countries and has resulted in the creation of an alternative value-added stream for wool producers (Sheep's Wool Insulation, 2009). Because Nova Scotia, and, more widely, Atlantic Canada, has an excess of wool which is discarded each year as a byproduct of the meat lamb industry, developing an alternative value added stream for wool insulation appears to be part of a viable business model.

3. Objectives and Scope

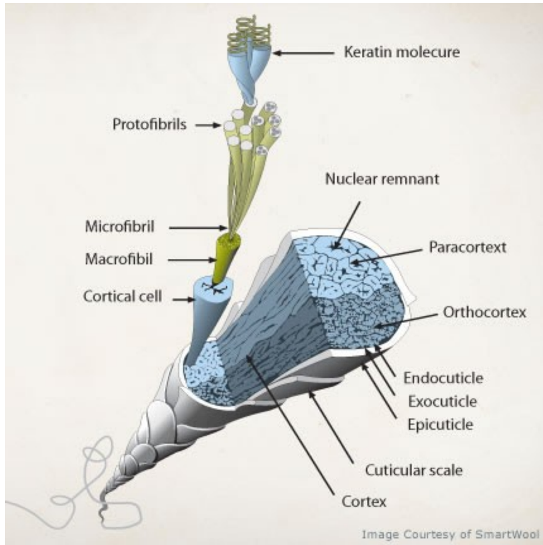
The objectives of the project were consonant with the objectives of Category C Priority Area, in that the study would, as outlined in the Technology Development 2000 guidelines, "...identify methods to increase activity and capacity for new product innovations and technologies". The research focus of the project was four-fold: to investigate the feasibility of developing an alternative or renewable product from wool, identify potential value chain options, determine scaling-up factors, and establish alternative product applications. The ultimate contribution from the research would be a more sustainable industry with a greater number of sheep producers, receiving a higher price for their wool, and an industry with an increased potential to attract new entrants to farming, and farming on a more viable scale for individual farmers/farm families.

4. Literature Review

Wool has begun to be diverted from textile use for conversion and application as insulation and for other purposes in the construction industry (Trancart, 2008). Operations in Australia, New Zealand, Ireland and the UK have businesses using wool as a natural alternative to synthetic (mineral wool or fiberglass) insulation (Black Mountain Insulation, 2008; New Fibre Materials, 1995; Sheep's wool insulation, n.d.a; Oregon Shepherd, 2011; Good Shepherd, 2011).

Wool has many physical attributes that make it an extremely attractive raw material for insulation. It is a 100% natural and renewable product with several advantages when compared to fiberglass or other synthetic insulation materials. Some advantageous properties include strength, high thermal performance, and being naturally fire resistant; wool also can help regulate moisture content in buildings (Sheep's Wool Insulation, 2009; Ye et al, 2006). The move toward stricter environmental regulations in building control and the introduction of green building certification such as Leading Energy and Environmental Design (LEED), US Green Building Council and Building Environmental Standards (BOMA BESt, 2011) have created a market for recycled and renewable materials for the construction industry, and wool insulation appears to show considerable potential in this regard. The suitability of wool as an insulation product has also been addressed by other wool producing countries and has resulted in the creation of an alternative value-added stream for wool producers (Sheep's Wool Insulation, 2009).

Wool batt as insulation has advantages when compared to conventional fiberglass insulation in many ways. Firstly, it does not cause irritation of the skin, eyes or respiratory tract. It can be installed without the use of gloves or protective coating (Sheep's Wool Insulation, n.d.b). Also, wool is a better thermal insulator than other fibers under typical weather conditions because of its ability to absorb and desorb moisture from the air. It can help keep a building cool in summer and warm in winter. When outside temperatures increase the wool is heated and releases moisture which has a cooling effect on the fiber and the building. This ability of wool to naturally regulate temperatures is due to the structure of the wool fibers, pictured below.



While the exterior layer of a wool fiber is hydrophobic (water-resistant), its inner layer, its cortex, is hydrophilic (water-loving). The cortex can absorb up to one-third of its weight in moisture, without feeling damp to the touch.

Although sheep's wool has many advantages, including being a renewable resource, naturally fire resistant, environmentally friendly and safe to handle, a greater thickness is required than fiberglass to achieve the same levels of insulation. While scholarly research in the area of sheep's wool insulation is still in its beginning stages, there has been research investigating and comparing thermal values of conventional insulation against sheep's wool and other forms of alternative insulation. This section reviews the literature on wool insulation performance in comparison to other insulants.

A 1995 Australian study compared various types of fibers to test for thermal conductivity. This study found that fiberglass batts required less thickness at any particular density to achieve target thermal resistance values (Symons et al, 1995). This study also found that sheep's wool is a highly variable material and that solely knowledge on the wool insulation density is insufficient to accurately predict thermal performance (Symons et al, 1995). A 2006 study examining alternative forms of insulating material for thermal conductivity found that hemp and sheep's wool of comparable densities produced similar rates of thermal conductivity

(Ye et al, 2006). In a recent study by Zach et al (2012), it was found that with regards to thermal conductivity, the lower the bulk density of the insulation, the higher the porosity of it, leading to increased air flow in the pore structure of the insulation. As bulk density of the insulation increased, the thermal insulating properties also increased and its sensitivity to temperature decreased. This also agrees with Ye et al (2006) who also found that the thicker the wool insulation, the higher the thermal resistance, provided density is above $11kg/m^3$. Symons et al (1995) and Trethown (1995) also found similar results.

Zach et al (2012) also found that sheep's wool is an excellent acoustic insulating material, reporting a positive relationship between increasing insulant thickness and sound absorption properties. However, once the insulation is over 170 mm thick, no acoustical benefits are obtained by increasing insulation thickness. This is in agreement with the research performed by Ballagh (1996), who reported that wool insulation can reduce sound index up to six decibels. Ballagh states that wool has similar properties to fiberglass, but insulating for sound using wool tends to be less expensive because a resilient chamber is not needed and therefore labour requirements are reduced. Ballagh also found that wool can isolate vibrations, such as in linings of timber framed walls, which improves sound insulation.

Although there is minimal literature on wool insulation, what literature that is available confirms wool is an acceptable medium to use for thermal insulation; however there are major challenges associated with product testing and standard requirements needed to meet the building standards within Canada. The main issue associated with building codes is that codes are issued provincially, rather than nationally. This presents a hurdle when selling product nationwide because since the building codes are handled provincially, having the insulation product approved for building in Nova Scotia, may not necessarily mean that it is approved for sale in Ontario, for example. Since wool insulation targets a niche market (due to the high price of the product), this presents a hurdle. That being said, most of the provincial building codes are based on the National Building Codes of Canada. Ontario and Alberta have created their own codes which have more stringent regulations than the National Building Code. There are Canadian Standards that products can be tested with to ensure product reliability but the approval process is long and tedious for an average person who may want to produce wool insulation batts on a small scale. There is a need for more research to be performed on the regulations surrounding approval wool insulation within Canada. See Appendix A for further information on building codes and the performance of wool insulation materials currently available.

Sheep's wool has such high fire resistance levels that it complies with the Australian Standards for Fire Resistance, and thus complies with national building regulations. In Nova Scotia, wool batt insulation also potentially complies with provincial building regulations. According to the Nova Scotia Home Builders Association (NSHBA), building regulations stipulate that insulation must have an R (resistance) value of 20 and a sheathe of solid insulation with a minimum R value of 4.

The three factors which are most important in the Nova Scotian insulation market are that the insulation is 1) easy to handle 2) is cut and fitted properly for standard building cavity sizes and 3) is priced competitively (NSHBA, 2011). Sheep's wool insulation is relatively easy to handle, as it is much less abrasive than conventional fiberglass insulation (Black Mountain Insulation, 2011). Sheep's wool insulation could be processed in existing insulation manufacturing facilities in the province so that it would comply with standard building cavity sizes. In terms of sheep's wool insulation price points, the cost is currently not competitive with fiberglass insulation.

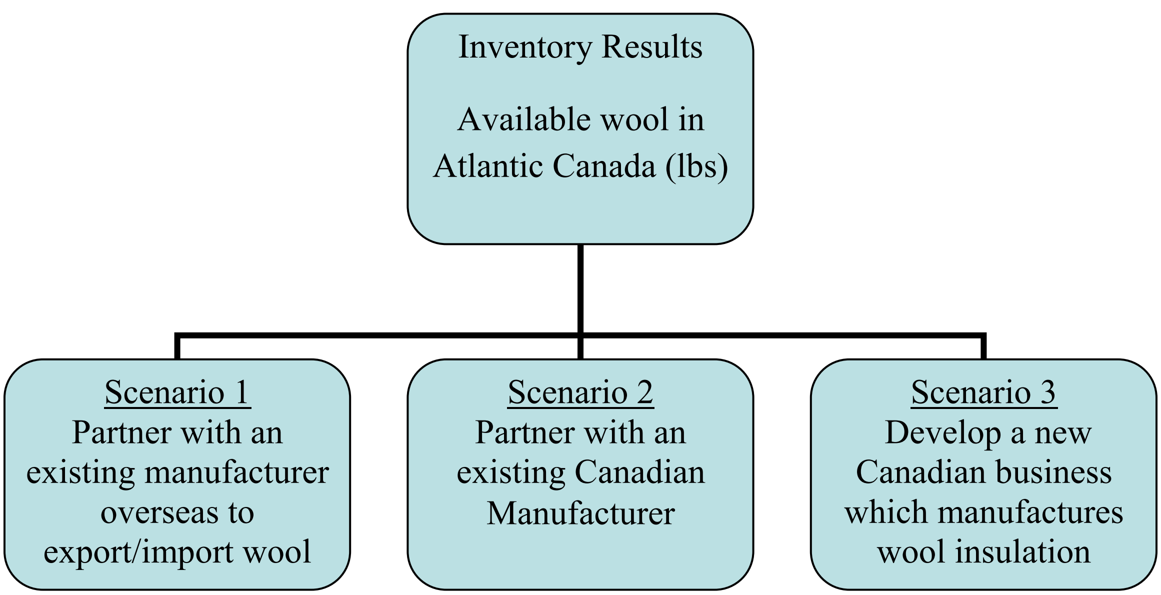
The current price of sheep's wool insulation at Ireland's biggest retailer is $92.00 CAD (EUR 66.90) for 97 square feet of insulation (Sheep's Wool Insulation, 2011). In contrast, the current price of fiberglass insulation ranges from $0.25 to $0.90 USD, depending on the thickness and R value. Four-inch thick insulation averages about $0.40 USD per square foot (B&B Cowie Insulation Ltd., 2011). This translates into an average cost of $37.10 CAD ($38.80 USD) for 97 square feet of insulation.

Although these prices are based on information from current retailers and may not be representative of the overall market, they do indicate that sheep's wool insulation is more costly than conventional fiberglass insulation. However, it is hoped that as increasing volumes of sheep's wool insulation enters the world market and as manufacturing capacity increases, prices will become more competitive.

Although sheep's wool insulation may be more expensive that conventional insulation types, there are many other advantages of sheep's wool, as previously mentioned, it is a renewable resource, naturally fire and pest resistant and environmentally friendly and safe to handle. Operations in Australia, New Zealand, Ireland and the UK are already using wool as a natural alternative to synthetic (mineral wool or fiberglass) insulation (Black Mountain 2008; New Fibre Materials, 1995).

5. Method and Materials

There were three main aspects of this project: inventory analysis, feasibility study and research dissemination. The first step was to perform the inventory analysis to determine how much wool is produced in the Atlantic Canada region, as well as what its current end uses are. This inventory analysis was completed via a mail-out survey that was distributed to the membership of SPANS. This provided the background information and confirmation of the hypothesis, that there was a substantial wool resource in Atlantic Canada that was being underutilized. This lead into the second portion of this project: to determine the feasibility of a possible wool insulation business, that was able to provide an alternative place for wool growers to sell their wool. Three possible business scenarios for the portion of the project were examined:



Scenario one involved partnering with an existing manufacturer to export Canadian raw wool and purchase it back as manufactured insulation batts. The second scenario involved partnering with an existing green insulation manufacturer and the third scenario involved developing a new Canadian business, which was modeled on a small, artisan scale as well as a large scale.

The third and final portion of this project was research dissemination through presentations and publications, which would allow the findings of our research to be distributed to various interested parties and this was achieved through several channels.

6. Results and Discussion

The results from the mail out survey to SPANS revealed there is approximately 62,000 lbs of wool being produced in Nova Scotia annually. Estimates of wool production in the remaining Atlantic Canadian provinces are as follows:

PEI: 19,800 lbs

Newfoundland: 18,000 lbs

New Brunswick: 21,000 lbs

With these estimates, there is a total wool resource in Atlantic Canada of approximately 121,000 lbs per annum. Of this amount, the mail out survey revealed that only an estimated 45% of wool produced is sold, primarily to two buyers: Canadian Co-operative Wool Growers and MacAusland's Woolen Mill, in PEI. Briggs and Little, located in NB and Legacy Lane also in NB, purchase small amounts of wool from growers. The survey conducted through the SPANS membership determined that original estimates were correct in noting that about 50% of wool was being thrown away in NS and 5% of wool was given away or used directly on farm and the remaining wool being sold. For Nova Scotia, this indicates that annually, there is approximately 31,100 lbs of wool going directly into landfills or being thrown away/discarded /stockpiled on the farm.

6.1 Scenario 1

Since there is such an abundance of underutilized wool, the possibility of using this wool for an insulation product is logical. The first scenario delved into the possibility of partnering with an existing wool insulation manufacturer, which would involve the exportation of raw wool from Canada, to an existing wool insulation manufacturer, where the raw wool would be processed into insulation batts and the final product (insulation batts) would be repurchased from the manufacturer as an end product and shipped back to Canada, where it could then be resold into Canadian markets. Before this scenario could be analyzed, a list of current wool insulation manufacturers was compiled. Although there are more insulation manufacturers in Australia, it was decided that it would not be feasible or environmentally friendly to ship wool that far only to buy it back. Therefore Table 1 is solely composed of North American and European manufacturers of wool insulation. This however may not be a complete list as it was challenging to find all small manufacturers, worldwide.

Table 1: Global wool insulation manufacturers (excluding Australia/New Zealand)

Scale	**Manufacturer**	**Location**	**Type**
Large	Black Mountain Insulation http://www.blackmountaininsulation.com/	United Kingdom	Batt
Small	The Good Shepherd http://www.goodshepherdwool.com/	Flordia	Batt – distributes Black Mountain product
Large	Sheep’s Wool Insulation http://www.sheepwoolinsulation.ie/	Ireland	Batt
Large	Thermafleece http://www.thermafleece.com/	UK	Batt
Small	Oregon Shepherd http://www.oregonshepherd.com/	Oregon, USA	Loose-fill
Small	Custom Woolen Mill http://www.customwoolenmills.com/	Carstairs, Alberta	Batt

The first scenario established the manufacturers of sheep wool insulation and the location of these businesses. The findings were surprising, as globally (excluding Australia/New Zealand) there appears to be a very limited number of manufacturers of sheep's wool insulation. As well, the companies that are apperating appear to manufacture in certain countries (possibly to avoid environmental regulations) and then ship their products all over the world to be sold. The major wool insulation companies that were discovered included 1) Black Mountain Insulation which is based out of the UK. This company makes a batt type of insulation that can be layered to achieve the desired R value. This company also distributes product in the USA via The Good Shepherd (a distributer of wool insulation); 2) Oregon Shepherd who buys wool from across the USA, ships the wool to Texas to be scoured (due to stringent environmental regulations in Oregon, washing the wool in Oregon proved not to be possible) and then shipping the wool back to Oregon, where it is manufactured into a loose fill insulation. One small woolen mill in Canada was found, Custom Woolen Mill, located in Carstairs, Alberta, who source most of their wool from Alberta. They also make insulation in batt form.

Black Mountain insulation was the only company willing to discuss the possibility of buying raw wool from Atlantic Canada and selling back insulation batts. However it was determined that it would not be cost effective for the Atlantic region to ship wool to Black Mountain Insulation,since one entire container would have to be purchased and shipped from Halifax NS, to Liverpool, UK. There was not enough waste wool in Atlantic Canada for this option to be economical, since 25 tonnes (55,115 lbs) were needed just to fill one container. It takes 10 days to travel from Halifax, NS to Liverpool, UK and one container load the differential cost (of shipping raw wool and buying back finished product) was $11,218.13 CAD to ship. This was deemed to be too expensive to pursue at this time.

6.1 Scenario 2

The second scenario involved partnering with an existing insulation manufacturer, who would add wool insulation to their current product line to process raw wool into insulation batts. This proved to be difficult since only one small wool insulation manufacturer was identified within Canada: Custom Woolen Mills, which was located in Carstairs, Alberta. Partnering with manufacturers of other types of insulation also proved to be difficult, since the manufacturing process was virtually unknown and startup capital cost were significant (for manufacturing equipment). However, recently, as more information became available through this study, Thermocell Industries Ltd., a manufacturer of cellulose insulation, located in Debert, NS was approached to discuss potential collaboration. Discussions are still underway and there appears to be interest by Thermocell for such a product, provided it could be added to their existing production. Theremocell currently processes approximately 4000 lbs of raw paper daily, to produce a loose-fill cellulose product. A main concern for Thermocell is the volume of raw wool available. As well, Thermocell uses an entirely dry process while processing paper, and consultations are in process surrounding the possibility of producing a loose-fill wool insulation through a dry process, rather than a batt type insulation product, as researched in this project (Appendix A). Discussions are continuing and it appears that this there is potential for this scenario to prosper in the future, provided manufacturing details could be aligned with their current production facility.

6.3 Scenario 3

The third scenario of developing a completely new business within Canada has also proved to be potentially viable. This scenario was assessed though the completion of a feasibility study. Both large scale and an artisan models were developed and Extendsim^{TM} software was utilized for modeling the manufacturing process and to optimize the processing segment of the business. The feasibility study encompassed the following areas:

- quality and grade requirements for wool insulation
- processing requirements
- potential markets
- evaluation of appropriate and possible business models for all aspects of the production/development/distribution elements of the product
- technical and organizational requirements as well as limiting factors for wool batt insulation production
- energy requirements for wool batt production
- aptitude

- regulatory issues related to use in retro-fits or new home construction
- sheep number issue - how to grow flock numbers while developing the industrial production side in order to ensure price stability
- financial overview
- human capital issues related to scaling up
- economic, environmental and social benefits of value chain development

Assumptions were implemented in the feasibility study to determine whether this could be a profitable business. This following assumptions were implemented: The Artisan Model assumes one piece of equipment for each part of the process (washing, picking and carding), with a running time of 8 hours a day for 253 days per year. The Large Scale Model optimizes the manufacturing process to eliminate lag time between processing steps and utilizes 8 pieces of equipment (4 washers, 1 picker and 3 carders), and operates 24 hours a day, 7 days a week. Both scales use Atlantic Canadian-manufactured equipment, purchased from Belfast Minimills. The assumptions used in the modeling were as follows:

- One unit equates to one wool batt, and is equivalent to 1lb of wool (post processing)
- One unit of standard R19 insulation is 5.25” thick
- One unit of standard R13 insulation is 3.5” thick
- There is a 35-45% loss during the manufacturing process
- The Artisan Model will not require the purchase or lease of a building
- A building is leased annually for $7 per square foot for the large scale model
- Employees are paid minimum wage of $10.15 per hour
- Interest rates for the equipment loan are 3.5% (from Farm Loan Board)
- Electricity cost is the fixed portion of the electricity. Variable electricity costs are incorporated into the variable production cost per unit
- Sheep producers are paid $1.00 per pound for raw wool

- Wool is collected by the manufacturer – farms located >80 km (return) for the artisan model.
- Wool insulation is sold for $5.74 per pound (post processing)

It was determined through discussion with current wool insulation manufacturers (i.e. Black Mountain Insulation and Oregon Shepherd) that wool needed for the manufacturing process did not need to be of high quality. Although these companies were unwilling to discuss their actual manufacturing process in detail, the general process of converting wool into insulation involves six major steps:

1. Skirting – this process involves removing the less desirable parts of the fleece, such as the belly hair or fleece contaminated with large amounts of plant material or animal waste. Ideally, this is performed after shearing and the wool purchased for further processing has already been skirted. Producers are only paid on useable wool.

2. Scouring – This is the washing process. There are two common scouring methods: the soap and water process and the carbonization process:

   2.1. The carbonization scouring process has been used in wool manufacturing plants in Nova Scotia and Prince Edward Island and involves adding sulphuric acid to the wool to neutralize it. This process turns the detritus, such as hay and manure, into black pieces of carbon which then get washed out of the wool with soap and water.

   2.2. The soap and water method involves washing the wool in hot soapy water to remove dirt, grease and dry plant matter from the fleece. The wool is rinsed at least twice to remove all of the unwanted detritus from the wool, before it is washed with soap once and then rinsed a final time.

3. Chemical application - The composition of wool fibres requires chemical application to protect fibres from pests. This typically consists of a borax solution that can be added during the rinsing process. Disodium octaborate tetrahydrate (Murphy and Norton, 2008) can be added at a rate of 3% of the weight of the insulation batt (Thermafleece, 2011).

4. Picking – This process involves the separation of wool fibers, by opening the locks to allow them to be processed further.

5. Carding - The carding process separates the wool fibres and “combs” them into the same direction in preparation for further processing. Any dry plant material still in the wool should fall out during this step. This is the slowest step in the manufacturing process (after washing is finished), and it is assumed that the equipment used in the feasibility analysis of this study can process 5lbs per hour.

6. Packaging – Packaging the final product is the last step in the manufacturing process, where the final insulation product is bundled into a form that can be distributed and sold to consumers.

For mass production of wool insulation, production companies typically have “scouring plants” where bales of raw sheep’s wool are brought. According to the Irish company Sheep’s Wool Insulation, these bales will be marked with the contents, describing the fiber thickness, length, colour and vegetable matter content. Each bale is typically press packed with over 400kg of wool. Bales of such high volume minimize the cost and energy required to transport the wool to the scouring plant. At the scouring plant, the bales are opened and the wool is mixed together to produce various blends. These blends then undergo a scouring process, whereby the wool is washed in warm water through a series of baths (Sheep’s Wool Insulation, n.d.a).

The WVCDP, through the funding obtained via the SSHRC SIG grant, examined opportunities to divert wool away from landfills and found that using wool for building insulation to be a feasible option on both the artisanal, and large scales. A model using Extendsim™ Software was built to model the manufacturing process as described previously, in order to assess the costs associated with developing a wool insulation industry in NS and two models were developed, an Artisan Model and a Larger Scale Model (see Table One, below).

Table 1 highlights the findings of the feasibility study from both the artisan and large scale models.

Table 1: WVCDP results for artisan and large scale wool insulation manufacturing in NS

Item	***Artisan Model***	***Larger Scale Model***
Raw wool received (lbs)	*10,000*	*40,000*
Units Produced	*6,000*	*24,000*
Fixed Costs:		
Building Mortgage	*$0.00*	*$32,500.00*
Equipment Loan installment	*$7,136.64*	*$21,112.56*
Equipment Maintenance	*$600.00*	*$1,400.00*
Heating	*$400.00*	*$5,000.00*
Electricity	*$182.00*	*$1,200.00*
Total Fixed Costs	***$8,318.64***	***$61,212.56***
Variable Costs:		
Packaging:	*$0.09*	*$0.09*
Raw wool cost/ unit	*$1.67*	*$1.67*
Collection cost/unit	*$0.15*	*$0.15*
Variable production cost/unit	*$2.46*	*$1.28*
Total Variable Costs/ unit:	***$4.36***	***$3.19***
Total Costs	***$34,949.36***	***$137,741.84***
Selling price per unit:	*$5.74*	*$5.74*
Profit:	***($54.36)***	***$18.16***

As shown, these models attempted to discoved the amount of raw wool required for processing that would allow these models to be viable, or to make a profit. Wool insulation manufacturing appears to be profitable at both the small, artisan scale as well as on a large scale basis, with only 10,000 lbs of raw wool required for the artisan model become feasible, wile 40,000 lbs of raw wool is required for the large scale model. There are some concerns however associated with these models, such as with the artisan model, it is assumed that a building is already available for use (this model represents the addition of wool insulation processing to a current business operation, as opposed to the startup of an entirely new woolen mill, just for processing insulation). Another concern lies with the availability of over 40,000 lbs of waste wool that is needed for a large scale model to break even, and enough wool may not be available within Atlantic Canada, for a business of this size to earn enough profit to attract investors. Also, these models assume that wool is purchased at $1.00/lb. If low grade wool is not available at this price, obtaining wool at a higher price lessens the profitability of these scenarios and increases the volume of wool required to break even. Another concern is associated with the marketing/sale of this product. It has been determined that wool insulation is currently being sold at a price that is almost three times higher than conventional (fiberglass) insulations and a niche market that is being targeted. The increased awareness of eco-friendly building materials and certifications such as LEED has helped create a market for both self-builders and green building companies. However, a further study on markets and distribution channels is needed – as both artisan and large scale models assume that 100% of the product that is produced is sold. If the market is not available, profitability of these ventures could be hampered substantially. In addition to marketing concern, the regulations surrounding the use of wool in buildings within the province and nation will have to be investigated further before this product would be able to be sold within the country.

7. Summary of Project Activities and Outcomes

7.1 Peer Reviewed Conference Presentations

Stiles, D., and Corscadden, K.W., "Food/Fibre/Fuel: Exploring Value Chains Through Wool", Avalon Agriculture Advantage: Growing Opportunities, March 24th 2011, Salmonier, Newfoundland

7.2 Industry Publications and Presentations

Atlantic Farm Focus: Potential For Maritime Wool Batt Insulation Being Studied, P9, September 2011, Dan Woolley

Corscadden, K.W. and D Stiles, “Investigating the Feasibility of Wool Values Chain Development”, *Annual General Meeting, Sheep Producers Association of Nova Scotia*, February 5th 2011 Truro, NS

Kennedy, C., Corscadden, K.W., Stiles, D. (2011). Can Atlantic Canada’s Waste Wool Heat Our Houses? Small Farm Canada, P.8, January/February 2012.

Kennedy. C., Stiles. D., Corscadden, K.W. and Kulkarni. A., “Scenario Development of Wool Insulation Business Models.”, *Annual General Meeting, Sheep Producers Association of Nova Scotia*, January 21st 2012 Windsor, NS

Mazerolle, O. 2012. Theoretical Report Regarding Sheep’s Wool as Insulation. Unpublished paper. Appendix A.

8.Conclusion

This project has addressed various business models related to the development of a wool insulation business in the Atlantic Canada region. It was determined that importing/exporting wool overseas to be manufactured and re-purchased was not a viable business option. However it was determined that the creation of both an artisan and large scale wool insulation business could be profitable. These models identified provincial and regional volumes of wool, and potential equipment, scale of production and costs associated with the creation of a potentially profitable value chain for wool. In addition economic modeling, networking efforts have resulted in interest from a local insulation manufacturer, Thermocell Industries Inc., who have expressed interest in pursuing discussions around the possibility of their company manufacturing a wool insulation product. These discussions are currently in preliminary stages to try to determine if wool manufacturing could fit into their current manufacturing process of cellulose insulation. As well, there has been interest from a distributer of green building products, Living Rooms:: Ecological Living + Building, to have a Canadian supplier of wool insulation, as currently the only wool insulation they distribute is from outside of Canada. These two factors demonstrate the interest in both the ability of manufacture and to sell a Canadian wool insulation product. The limitations of establishing a wool insulation industry in the area are that the details of the manufacturing process itself are still vague, since there is minimal literature on the subject due to company's proprietary policies.

Since industry support and interest in further research has been significant, it is suggested that the logical next phase of this research is the development of a Manufacturing Study Pilot Project (MSPP), to study the logistics, manufacturing process, and product development potential for a sheep's wool insulation or similar products for the emerging market of green building products.

The MSPP would analyze the potential for appropriate-scale manufacturing with the goal of providing economic and other benefits to the sheep industry and more generally the rural communities of Atlantic Canada. The MSPP would also investigate the potential for replication of the template devised in other areas such as in Eastern Canada and beyond, with the aim to see if such appropriate-scale manufacturing might result not only in economic benefits, but also the benefit of the diversion of a significant amount of wool from the waste stream, thereby creating an alternative revenue stream for sheep producers and possibly other spinoff industries (i.e. lanolin extraction and production) connected to wool fibre.

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Appendix A

Wool Value Chain Development

Theoretical Report Regarding Sheep's Wool as Insulation

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for the Rural Research Centre

June, 2012

Table of Contents

Abstract

This report has been written to calculate the value in terms of energy savings of using locally produced sheep's wool as insulation. It is meant to serve as a collection of data and points of reference regarding insulation made from sheep's wool as well as other renewable resources.

Executive Summary

This report uses information collected from various related research reports, and also from companies currently selling wool-based insulation products, in order to compare to the results acquired by the Rural Research Centre's own testing.

Research papers from 7 different groups or individuals explain attributes of using sheep's wool as well as indicating their nominal heat resistance and insulation value.

The test being performed includes four hotboxes, each insulated by a different material. These materials include glass wool batts, rigid polystyrene, sheep's wool batts and sheep's wool blown insulation. These wool materials were ordered from companies in Alberta, Canada and Oregon, respectively.

1. Introduction

Background Information on Current Insulation Using Renewable and Recycled Resources

1.1 Renewable materials:

1.1.1 Straw Bale

A whole construction system of its own, straw bale construction offers insulation values of R-40 [7 RSI] to R-45 [8 RSI] (R-55 [9.7 RSI] in the case of three-string bales).
There are two styles of construction when working with straw bale, post and beam and Load-bearing. The former, uses a structural framework made of wood, concrete and steel to carry roof loads, whereas the latter use the bale walls themselves to support the roof.
According to a report written in 2006, more than 50 straw bale buildings exist within the Atlantic Canadian region[1].

1.1.2 Hemp

Among hemp's long list of possible applications, there are two techniques currently being developed and used to insulate homes. The first is a mixture of hemp and flax fibers being produced into batts that offer a thermal resistance of 0.02564 RSI/mm.[2] The second method of using hemp for insulation applications it with "Hemcrete", a Hemp shiv (low-density cellulosic material that comes from the core of the hemp plant[3]) and air lime combination offering resistance values in the range of 0.0125 to 0.00769 RSI/mm.[4]

1.1.3 Wool

Sheep's wool insulation is being produced into insulation in three different formats: Batts, loose fill, and panels. In many cases, the wool is cleaned and have Borates added in order to add fire resistance to the material. In some cases, small amounts (up to 15%) of polyester adhesive are used to aid with bonding.[5]

The typical batts being produced are similar in shape to conventional mineral/glass wool batts and typically offer approximately 0.026 RSI per mm in thickness.[6] One company offers another format of batt that is comparable to quilt batting with a thermal insulance of 2.11 m^2K/W unrolled to fit a 3.5" thick wall.

[1] Straw Bale Construction in Atlantic Canada, Kim Thompson; p.59
[2] http://www.hemptechnology.co.uk/insulation.htm
[3] http://www.hemptechnology.co.uk/shiv.htm
[4] http://www.tradical.com/hemp-lime.html
[5] "THERMAFLEECE Original" fact sheet, Second Nature UK Ltd.
[6] ibid

The loose-fill insulation that was used for the testing was composed of a mix of small pieces of stained and darker wool that had borates added to it. When ordered, it arrives accompanied by a netting meant to be installed as a temporary barrier to keep the material in place from the moment it is being installed to when the interior finish (i.e: gypsum) is installed. This method of insulation offers an approximate value of 0.028 RSI/mm, depending on the thickness of the wall.[7]
WEKA Panels are 3”-think solid boards used as insulation produced in Italy and in Pennsylvania and offer an insulation value of 2.1132 m^2K/W.

1.2 Recycled materials:

1.2.1 Cellulose

Mostly composed of recycled newsprint and/or other shredded papers, this type of insulation is installed in retrofit scenarios by blowing it into a hole in the very top of the wall and in new building scenarios by first applying a temporary retainer or netting that is removed once the insulation has been applied to the adequate density. Cellulose insulation offers an approximate resistance of 0.025 RSI/mm.[8]

1.2.2 Cotton

Cotton clothing, particularly denim and cotton mill waste, is being recycled and made into batts for home insulation. This product has quite a bit of help from the general population in North America, including retailers and individual groups getting together to contribute to the *Cotton. From Blue to Green* campaign[9]. This campaign collects people’s unwanted denim clothing in order to shred them back into cotton fiber, add borates and shape into batts composed of up to 80% recycled material[10]. This product, including recycled cotton batts from other companies, offer between 1.94 to 2.64 m^2K/W for walls of 3.5”, and 3.35 m^2K/W for walls of 5.5”.[11]

1.2.3 Mineral wool

Mineral wool is a product mostly constructed of metal oxide base and is one of the most commonly used insulations these days. This category of insulation includes fiberglass (glass wool), stone wool (rock wool), and ceramic wool. The batts and granulated (for blown in applications) cellulose made of glass wool and other mineral wools, can contain up to 30% recycled glass and/or other recycled metals[12]. Mineral wool generally delivers an RSI/m value

[7] http://www.oregonshepherd.com/wp-content/uploads/2010/09/8-10-11-R-Values.jpg
[8] http://en.wikipedia.org/wiki/Cellulose_insulation#Thermal_performance
[9] http://www.cottonfrombluetogreen.org/
[10] http://www.bondedlogic.com/construction-products/ultratouch-denim-insulation
[11] http://www.insultechnology.com/cotton_insulation_2.html
[12] http://en.wikipedia.org/wiki/Mineral_wool

between 19 and 26[13] (approximately 0.0665 and 0.091 m^2K/W respectively in the case of 3.5” [nominal 4”] walls).

1.2.4 Glass

In addition to fiberglass batt insulation, another type of insulation has been developed in the United Kingdom that is composed 100% of glass, 68% of which is recycled from post consumer waste, industrial waste from the Fenestry industry and scrap production material. FOAMGLAS® is an insulation material composed of millions of completely sealed glass cells and claims to be waterproof, vapour-tight, incombustible, pest-proof and easy to cut with a saw blade or a hand saw. The thermal conductivity of these products range from 0.038 to 0.050 W/m*K[14](2.3684 to 1.8 m^2K/W respectively at 90mm in thickness [3.54”]).

1.3 Renewable and recycled combination:

1.3.1 Soy + recycled plastic

A spray-foam made from a combination of vegetable oil, recycled plastic and soy is offered by Demilec Inc. and claims to have a thermal resistance value of 0.0423 RSI/mm.[15]

[13] http://www.cmhc.ca/en/co/maho/enefcosa/enefcosa_002.cfm
[14] http://www.foamglas.co.uk/building/home/
[15] http://www.demilec.com/english/heatlok-soya-builders

2. Methodology

2.1 Testing

The tested insulation materials for this research have been purchased from multiple companies throughout North-America (Custom Woolen Mills [Alberta, CAN]; Oregon Shepherd [Oregon, USA]; Black Mountain USA [Pennsylvania, USA]).
The chosen testing method for this research is to construct a small series of 4’ x 4’ x 4’ cubes (hotboxes) framed at 16” o/c, each insulated with a different material among:

- Glass wool batts
- Rigid polystyrene
- Sheep’s wool batts
- Loose fill Sheep’s wool insulation

Within these boxes, there is a heating mechanism in place comprised of three light bulbs (2x 100W and 1x 50W) connected to a thermostat that tells these bulbs to turn on once the box’ temperature lowers from 21.5 ºC and to turn off once it has reached 21.5 ºC again.

In order to calculate the thermal transmittance (U) of each tested hotbox, the hotbox device is connected to sensors calculating the inside and outside temperatures as well as the frequency of the bulbs being on to heat the inside of the box. Using the information collected, it is possible to calculate the true thermal resistance and conductivity of the hotboxes simply by plugging values into the formula:

$$W = A * U * K$$

Or

$$U = W / A * K$$

K refers to the average difference in Kelvin (ΔT) between the outside and inside temperature, W refers to the wattage consumed to keep the inside at its constant temperature (this is measured by multiplying the 250 W produced by the bulbs with the amount of time they were on) and A refers to the total area of the outside surface of the walls.

Once the thermal transmittance (U) has been found, the formula U= 1/RSI can be used to inverse the answer into the thermal resistance value of each of the boxes’ walls.

2.2 Other Building Material

Building materials other than the tested materials are used in the construction of the hotbox devices in order to frame and retain the latter in place. These framing and sheathing materials also have certain thermal resistance. In this case, plywood (0.0087 RSI/mm), softwood lumber

(0.0087 RSI/mm) at 25.98 percent framing, and polyethylene vapor barrier (negligible) are used in the assembly.

Plywood -> 0.0087 RSI/mm * 12.7 mm = 0.11049 RSI
Lumber -> 0.0087 RSI/mm * 88.9 mm = 0.77343 RSI

Cavity

Plywood - 0.11049 RSI

Total RSI – 0.11049 RSI

Framing

Plywood – 0.11049 RSI
Lumber – 0.77343 RSI

Total RSI – 0.88392 RSI

$$RSI_{wall} = (RSI_{framing} * framing\%) + (RSI_{cavity} * cavity\%)$$
$$= (0.88392\ m^2K/W * 0.2598) + (0.11049\ m^2K/W * 0.7402)$$
$$= 0.31142712\ m^2K/W$$

It is possible to find the tested material's RSI value by using the formula above and subtracting its result from the thermal resistance calculated from the hotbox test, the difference will be the RSI value of the material exclusively.

2.3 Theoretical

By using the nominal heat resistance values mentioned in the Introduction and the same average ΔT's (difference in temperature) as those collected from the hotbox data, The table below estimates the Wattage that should be consumed in each hotbox. These values are useful in order to compare the actual value that have been collected by the hotbox sensors.

	RSI/mm	RSI	W/m^2K *	W	kW	kWh
Wool batt	0,0257	3,341	0,2738	30,6176	0,0306	3,4190
Wool loose-fill	0,028	2,8	0,3214	36,1269	0,0361	4,0342
Glass wool batt	0,022	2,86	0,3153	33,9990	0,0340	3,7966
Styrofoam	0,03	1,5	0,5521	59,3905	0,0594	6,6319

* $1 / (RSI_{material} + RSI_{Assembly})$

2.4 Other Notes

While the sheep's wool batts were easily torn by hand to correct length by tearing along the grain, cutting pieces to different widths was much more difficult since it involved cutting against the grain. In this case, freshly sharpened large wire cutters were used. An "exacto" type knife with a fresh blade could also be used but may need to be replaced over time.

Some burrs were encountered and picked out when handling the loose-fill wool insulation.

The loose fill sheep's wool settled fairly easily when installed for this test. And there was not enough material to refill all the creases on the top of the walls. To correct this, the floor of this hot box was insulated with the quilting style batt from Custom Woolen Mills to move more loose-fill material to the walls and top, where it is more probable to lose heat. It may be necessary to explore methods of installation to ensure the material stays in place for the long term.

3. Building Code

According to the Nova Scotia Building Code, the minimum thermal resistance required for walls other than foundation is of 4.23 m^2*K/W, 7 m^2*K/W for ceilings below attic or roof space and 5.46 m^2*K/W for roof assemblies without ceilings or roof space.

The National Building Code of Canada (NBCC) mentions nothing about natural wool in particular, but does specify standards to which any insulation material must adhere.
In terms of thermal resistance, The NBCC says to follow ASHRAE standards.

5.2.1.3.(1) ***Environmental Load and Transfer Calculations***

Calculations related to the transfer of heat, air, and moisture and the transmission of sound shall conform to good practice such as that described in the ASHRAE Hanbooks.[16]

[16] National Building Code of Canada 2005 Volume 1

Data in the following table has been extracted from *Table 5.5-6 Building Envelope Requirements for Climate Zone 6 (A,B)* in *ASHRAE Standard Energy Standard for Buildings Except Low-Rise Residential Buildings*.

	Nonresidential	Residential	Semiheated
Elements	Insulation Min. R-Value	Insulation Min. R-Value	Insulation Min. R-Value
Roofs			
Insulation Entirely above deck	R-20 c.i.	R-20 c.i.	R-10 c.i.
Metal building	R-13 + 19	R-13 + 19	R-16
Attic and Other	R-38	R-38	R-30
Walls, Above-Grade			
Mass	R-13.3 c.i.	R-15.2 c.i.	R-5.7 c.i.
Metal Building	R-13 + 5.6 c.i.	R-13 + 5.6 c.i.	R-13
Steel-Framed	R-13 + 7.5 c.i.	R-13 + 7.5 c.i.	R-13
Wood-Framed and Other	R-13 + 7.5 c.i.	R-13 + 7.5 c.i.	R-13
Walls, Below-Grade			
Below-Grade Wall	R-7.5 c.i.	R-7.5 c.i.	NR
Floors			
Mass	R-12.5 c.i.	R-14.6 c.i.	R-4.2 c.i.
Steel-Joist	R-30	R-38	R-19
Wood-Framed and Other	R-30	R-30	R-19
Slab-On-Grade Floors			
Unheated	R-10 for 24 in.	R-15 for 24 in.	NR
Heated	R-15 for 24 in.	R-20 for 48 in.	R-7.5 for 12 in.

4. Collected Data and Calculations

The data in the below table is calculated using a constant bulb wattage and area of 250 Watts and 8.91869184 m^2 respectively.

	Minutes on	% of time on	kWh used	AVG ΔT	Thick (mm)	RSI/mm	RSI	R-value
Wool batt	807	12,0%	3,3625	12,5387	130	0,0284	3,6944	21,0
Wool loose-fill	786	11,7%	3,2750	12,6034	100	0,0372	3,7151	21,1
Glass wool batt	569	8,5%	2,3708	12,0898	130	0,0273	3,5510	20,2
Styrofoam	1006	15,0%	4,1917	12,0625	50	0,0708	3,5422	20,1

It is apparent that the expanded styrofoam insulation is a much better thermal barrier per uniform thickness. The loose-fill sheep's wool is relatively more resistant than the glass wool batt and sheep's wool batt.

5. Summary of Current Availability

In Canada:

Alberta	- http://www.customwoolenmills.com/insul.htm

In North America:

Florida	- http://www.goodshepherdwool.com/
Montana	- http://hybridhomeliving.com/montana-green-insulation/
Oregon	- http://www.oregonshepherd.com/

Worldwide:

Ireland	- http://us.sheepwoolinsulation.com/
UK	- http://www.blackmountaininsulation.com/
	(Sales representatives in Ireland, Belgium, Netherlands, France, and USA)
UK	- http://www.thermafleece.com/
Italy	- http://www.woolboard.com/
	(Sales and production in Pennsylvania as well)

6. Concluding Remarks

It is clear that Sheep's wool insulation is comparable, and superior in certain cases, to other conventional materials with regards to thermal resistance and at first glance seems to be a great natural and safer alternative to those other materials being used today.

The sheep's wool insulation products tested for this report clearly conform to building codes as well as national and provincial standards. It would be worth wile to explore the environmental and economical repercussions of implementing a production line of similar products in the Atlantic region.