CAN NATURAL INSULATION COMPETE WITH NON-ORGANIC INSULATION?

ESSAY FOR MODULE CEM500

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INTRODUCTION

In order to help mitigate climate change to try to slow down global warming and to allow society to be more sustainable, it is important to reduce the amount of energy used from fossil fuels and to reduce carbon emissions.

Reducing the carbon footprint of buildings is becoming increasingly mainstream especially with the introduction of guidance such as the Code for Sustainable Homes and BREEAM ratings. It is widely known that it is important for homes to be well insulated so as to reduce the energy needed to heat it. As the energy use of buildings is being cut down due to insulation and airtightness, especially in ‘green builds’, it is then important to consider the embodied energy in the materials used.

Whilst eco housing often considers natural materials they are not yet widely used in the building industry. This essay will look at an overview of the factors which affect the choice of insulation material and if natural materials can compete with the familiar ones, and into the properties that make a material ‘green’.

5 types of natural insulation (2 rigid boards) will be compared with 3 of the most common of mineral and oil-derived insulations: mineral wool, polystyrene and polyurethane foam. These are cellulose, sheep wool, hemp, cork, and wood fibre boards. Straw bale was also considered but that is more of a construction technique than just an insulation material so is not really comparable with the rest.

No type of insulation is suitable for all applications, whether they are natural or not. This essay will compare insulations with a view for use in walls of a timber framed house, which is looking to be affordable and sustainable. The range of applications of the insulation will also be considered and comparisons will be made between natural materials and non-natural materials with similar applications.

CELLULOSE


Source: Excel, 2011

Cellulose insulation is made from recycled paper and whilst it is considered a natural and renewable material it contains additives borax and boric acid which act as fire retardants and fungicides. ‘The proportion of these additives is often as high as 18-25%’ (Berge, 2009: 289). It can also produce odour and formaldehyde off-gassing from inks on the paper, though this is containable through use of vapour control membranes (GreenSpec, 2011). During the production and installation of cellulose workers can be exposed to dust which contains the additives, though ‘once installed correctly the fibres should cause no problems for those using the building’ (Berge, 2009: 290).

The material is ideal for breathable wall construction and can be used loose or dry or damp sprayed. It can be used in timber frame construction and cavities in Closed Panel Structures (Warmcel, 2011). Cellulose, like most natural materials, is hygroscopic so controls humidity.

Thermal conductivity can be increased by the material settling but if installed properly this can be avoided. ‘At densities above 70 kg/m3 no settling should occur’ (Berge, 2009: 290), this can be achieved by applying a high pressure when blowing in the fibre.

Cellulose is reusable and recyclable after use if in good condition. The main environmental advantages are that it has a very low embodied energy and sequesters large amounts of carbon. It is also the cheapest of renewable materials. (Barton, 2008: 215)

SHEEP'S WOOL

Source: Black Mountain Insulation Ltd, 2011

The wool is combined with up to 15% non-renewable adhesive to bond the fibres together to maintain its thickness over the life of the product and treated with boron salts as an insecticide. 'Wool is naturally fire retardant; the material only chars since there is insufficient oxygen in the atmosphere to support combustion of wool' (Black Mountain, 2011).

Wool has a low embodied energy, the manufacture of Black Mountain insulation requires 90% less energy to manufacture than mineral wool insulation (Black Mountain, 2011). If the wool is imported the embodied energy is increased and the material may also contain pesticides (GreenSpec, 2011). It is reusable and recyclable. It is a hydroscopic material and can absorb and release a third of its weight in moisture without losing its insulating values. (Barton, 2008: 215). This makes it ideal for breathable walls and timber frame construction as well as retrofitting. Wool poses no health risks to installers or building residents (Natural Insulations, 2011).

HEMP


Source: Natural Insulations, 2011

Hemp insulation is made from hemp fibres, sometimes mixed with recycled cotton or wood fibres, and polyester is used as a binder. It is also treated for fire resistance (GreenSpec, 2011).

Although it is renewable it does encourage the use of fertilisers and pesticides which can be harmful to the environment (GreenSpec 2011). It has a low embodied energy although this is increased if it is imported.

The hemp slabs are fairly rigid which makes them suitable for use in timber frame construction, ventilated pitched roofs and breathable wall construction (Natural Insulations, 2011). Hemp is recyclable, reusable and compostable, it sequesters carbon and can regulate moisture without losing its thermal properties.

WOOD FIBRE BOARDS

Source: GreenSpec, 2011

Wood fibre boards are made from waste from sawmills, the waste is chipped and pressed into boards wet; the natural lignin in the wood acts as glue. Fire retardants are used and for external applications water repellents are added (Berge, 2009: 279). The boards can be used for breathable wall construction and external walls and roofs to prevent thermal bridging (GreenSpec, 2011).

Wood insulation boards can have a relatively high embodied energy, especially if imported, as the waste wood needs a lot of processing. It does however come from a waste material from a renewable source and is recyclable, reusable and compostable. It also sequesters carbon (GreenSpec, 2011).

Source: GreenSpec, 2011

CORK


Source: Cork Insulation, 2011

Cork insulation is made from cork bark that is harvested from the tree every nine years from 25 years of age. This helps prolong the lifespan of the tree, often up to 150 years (EnviroNomix, 2011). The cork granules are expanded and then formed into blocks, using the natural resin, through high temperature and pressure (GreenSpec, 2011). No chemicals or additives are used in the manufacture of cork; it is naturally waterproof and is not attacked by rodents, birds or insects. Cork does not burn as it does not support its own combustion and only chars slowly when subjected to a flame and does not release toxic gasses (Cork Insulation, 2011).

Cork insulation has a wide use of applications in construction; it can be used for external and internal walls, ground slabs and roof insulation and is resistant to compression.

It is reusable and recyclable and sequesters carbon. Cork is mainly grown in Portugal and can sustain a large variety of indigenous wildlife which is dependent upon the maintenance of the cork oak forests. The production of cork products also can help stabilise rural economies, populations and local culture in the poorer agricultural areas of Southern Europe (EnviroNomix, 2011).

Cork is very energy efficient to manufacture, and some suppliers claim it has the ‘Lowest embodied energy of all commonly used insulation materials’ (EnviroNomix, 2011). However it isn’t grown in the UK so importing it increases its embodied energy, GreenSpec says it has very high embodied energy.

Other downsides are that cork dust may be a health hazard during production, and can have small emissions of naturally occurring formaldehyde. Although it is water resistant wet cork can become mouldy which can lead to allergic reactions (GreenSpec, 2011).

Source: EnviroNomix, 2011

PERFORMANCE

In order to compare the insulation materials, it is important to think about why materials are chosen. The first thing to consider is the performance of the insulation; its purpose is to prevent heat loss through the fabric of the building. Thermal conductivity measures how well a material conducts heat, and for insulation, the lower the value the better. If the thermal conductivity of a material is divided by the thickness of that material then you get the u-value. It is easier therefore to compare the thermal conductivity; materials which have a higher conductivity would need to be thicker in order to have the same u-value as better insulators. Natural materials tend to have a slightly higher thermal conductivity than plastic based insulation.

Type of Insulation	Natural	Thermal Conductivity W/mK
Wood fibre boards	Yes	0.044
Cork	Yes	0.043
Hemp and recycled cotton insulation	Yes	0.039
Sheep's wool insulation	Yes	0.039
Cellulose insulation, recycled paper	Yes	0.035
Mineral wool	No	0.032
Rigid polystyrene insulation	No	0.029
Rigid polyurethane foam	No	0.022
Rigid phenolic foam	No	0.021

Source: GreenSpec, 2011

COST

The second criterion to consider is cost. This would be the biggest influence for most people when deciding between two materials with the same u-value. And cost is often the limiting factor when trying to achieve a highly insulated fabric without large thicknesses (see table below). Below a thermal capacity of about 0.02W/mK, materials become very expensive, such as Nano porous and vacuum insulations.

Material	Heat conductivity W/mK	Thickness needed to meet U=0.13W/(m²K) m
Typical insulation material	0.040	0.300
High insulation material	0.025	0.188
Nanoporous "super insulation"	0.015	0.113
Vacuum-insulation (silica)	0.008	0.060
Vacuum-insulation (high vacuum)	0.002	0.015

Source: Feist, 2006

Costs of different insulation materials found from online suppliers are listed below. The cost in most cases was given in pounds per m^2 for 100mm thickness of insulation. Where this was not the case it was worked out per m2. However, as the materials have different thermal properties, it is not meaningful to compare the prices in this way as different thicknesses would be needed to achieve the same u-value. In order to have comparable values the cost per m^2 to achieve a u-value of 0.15W/mK was worked out. This is the recommended u-value given by the Code for Sustainable Homes Level 4 (Garbutt, 2008: 95) and the limiting value for PassivHaus criteria (Passivhaus, 2011).

Type of Insulation	Cost per m^2 100mm thick	Cost per m2 to achieve u-value of 0.15
Warmcell 100 insulation, recycled paper	(loose) £2	£4.70
Polystyrene Sheet	£5.00	£9.70
Wickes Cavity Slab Insulation	£4.58	£11.30
Black Mountain Sheep Wool Insulation	£6.99	£18.20
Black Mountain Hemp Insulation	£7.75	£20.15
Thermafleece™ Sheep Wool insulation	£8.00	£20.80
Kingspan Insulation – Thermapitch	£15.60	£22.90
Rock Wool RW 5 Cavity Wall Insulation	£11.60	£24.75
Steico Therm Wood Fibre Board 100mm thick	£17.00	£49.90
Cork	£23.00	£65.00

Sources: (Building Materials, 2011) and (Natural Insulations, 2011)

It is commonly thought that natural insulation products are more expensive than the more common ones but it this is not necessarily true. From the above information of comparable values (which have their limitations) it can be seen that with the exception of cellulose, that non-natural materials are the cheapest form of insulation. These are polystyrene sheets and Wickes cavity slab (although there was no information about what material this is made from it appears to be mineral wool). These products are about half the price as the other branded insulations. It appears the branded insulations are more expensive, as branded products often are, but it is encouraging to see that the natural materials are competing with the others. Black Mountain Sheep's Wool insulation is cheaper than Kingspan polyurethane and Rock Wool is the most expensive of the non-rigid insulations. The wood fibre board is very expensive but has different applications from the other non-rigid materials. It is often used in thinner thicknesses in conjunction with other insulations as external insulation.

ENVIRONMENTAL IMPACT

If looking to build with less impact on the environment it is important to consider the embodied energy of the materials used. Generally natural materials, which have been processed as little as possible, have a low embodied energy. For example Sheep's wool insulation uses 40 times less energy to produce than plastic insulation (Shore, 2008: 197). It is also important to source materials locally to reduce the embodied carbon in them. Most natural materials also require less processing at the end of their lifespan. They can easily be recycled, reused or returned to the earth!

Type of Insulation	Natural	Embodied Energy kWh/m3 (Green Building Bible)	Embodied Energy MJ/kg (GreenSpec)
Wood fibre boards	Yes	-	17
Cork	Yes	-	26
Hemp and recycled cotton insulation	Yes	-	10.5 - 33
Sheep's wool insulation	Yes	30	20.9
Cellulose insulation, recycled paper	Yes	133	4.9 (UK product)
Mineral wool	No	230	49.6
Rigid polystyrene insulation	No	1125	108
Rigid polyurethane foam	No	1125+	101
Rigid phenolic foam	No	1125+	-

Sources: (Shore, 2008: 196) and (GreenSpec, 2011)

Another advantage of using plant based building insulation materials is that they sequester carbon. 'Each kilogram of plant matter contains about 0.5kilograms of carbon' (Berge, 2009: 34) which was absorbed from the air during its lifetime. 'This corresponds to sequestration of 1.8 kilograms of CO2 from the atmosphere' (Berge, 2009:34). This carbon will be stored in the material until it decays or is burnt. If the material is being sourced from sustainable sources and therefore being replanted then the overall amount of CO2 in the atmosphere decreases, helping to mitigate climate change. This 'buys time' as the carbon storage will last as long as the building survives which could be more than 100 years if properly constructed and maintained.

HEALTH

Living in a house built from natural materials, and if it uses natural finishes, is healthier for the occupant than living in a mainstream building. Natural insulation materials are ideal for breathable wall construction, as they themselves are breathable and regulate humidity by absorbing and releasing moisture. This prevents issues 'such as excessive dampness, condensation and mould growth, or health problems caused by very dry atmospheres' (The Natural Building Company, 2011). By sealing up the building it traps moisture and indoor pollutants such as 'formaldehyde-based glues, plastics, paints, asbestos, and fiberglass'. This can lead to Sick Building Syndrome with symptoms including fatigue, loss of concentration, nausea and irritation (NetWork Earth, 2011). However, natural insulations, even though made up mainly of natural and renewable materials, contain some additives and chemicals as fire retardants and pesticides. If properly detailed this should not cause health risks and as the materials are breathable there is no build-up of pollutants. Despite the additives natural materials still create a healthier environment to live in and are also healthier for the planet.

LIFESPAN

Materials such as cellulose, sheep's wool and hemp insulation can lose thermal performance over time though compaction and settlement. This can also occur in mineral wool insulation so is not just a problem confined to natural materials. If this is foreseen it can be avoided by correct installation and careful detailing. It is vital to consider the application when choosing a material. Natural materials, although breathable are not water resistant and can begin to decompose if permanently wet. They are ideal for timber frame construction, internal insulation, retrofitting and ventilated wall construction but not unventilated cavities and when the humidity is over 95% (GreenSpec, 2011). Good detailing is essential in ensuring insulation is ventilated and stays dry. Cork is the exception which is resistant to water. Wood fibre boards which are treated with water repellents can be used externally.

The life expectancy of the natural insulation products is either unknown or for the lifetime of the building. Timber frame buildings if correctly built and maintained so they stay dry can last 100's of years (Berge, 2009: 172).

CONCLUSION

From researching and comparing natural materials it can be seen that they can compete with the major insulants. If building a timber framed building, natural materials are just as good, if not better than using man-made ones. They are not suited to all applications, especially when exposed to water, but can be used in many circumstances, for example in pre-fabricated panels.

Even though natural insulations have a slightly higher thermal conductivity so may need to be slightly thicker, by about 50mm, this is a small sacrifice to make given their other benefits to the environment and occupants. Even cost wise they are not far behind, although it is hard to complete with suppliers such as Wickes who sell very cheap insulation, though it is hard to tell what it contains. Branded natural products are cheaper or around the same price as branded less-ecological ones such as Kingspan and Rockwool. Warmcel provides a cheap and more ecological method of insulating which is becoming more widely used.

Natural materials have a lower embodied energy but they still require processing so it is important not to forget the embodied energy in them. Wood fibre boards for example take a lot of processing. However they do sequester carbon which can cancel this out making them carbon neutral.

Although natural materials can create healthier and breathable buildings, they too contain chemicals and naturally can give off formaldehyde. Natural insulations are no more difficult to install, sheep's wool and hemp are in the same format as mineral wool insulation which fits between timber studs. Cellulose needs to be blown in and specialised installers are available to do so.

From the research done, it can be concluded that, for the walls of a sustainable and affordable timber framed house, that cellulose insulation is the best all-round option. It comes from a renewable and recycled source, has low embodied energy, a high u-value and is the cheapest raw material. It down sides can be minimised by good design detailing, ensuring that it does not get waterlogged it is well ventilated in case of off-gassing formaldehyde.

By insulating well and using local renewable materials instead of oil-derived ones we can help to reduce our dependence on fossil fuels making us more sustainable.

Over time as the effects of climate change increase and it becomes more of a political issue, environmental building techniques will continue to be become more mainstream. As demand for natural materials grows, hopefully the costs will come down as people think about where their building materials are coming from and what they are living in. As technology develops a divide in approaches to insulation materials can be seen, people choosing either to go the high-tech material route with very low u-values, or reverting back to nature, using natural materials and methods of building to lower our impact on the environment.

In the long run, climate change may have a larger impact the way we build. If fossil fuels were to run out then the by-products would not be available to make plastic insulation with. Then there would be little choice whether to use natural and renewable materials. If global warming increases the temperature of the planet by a significant amount then perhaps we will not actually need to insulate our houses to the same level as we are doing now.

LIMITATIONS

The type of insulation used depends entirely on the application and individual circumstances of a project, so it is impossible to reach a definitive answer. However when natural materials can be used, in timber frame construction for example, they are just as good as other insulation.

This has been an overview of the major types and brands of insulation that are available, there are so many more which may have slightly different properties. When choosing insulation it is important to get the accurate information from the supplier. Composite materials have not been looked into, which often combine the best properties from different materials.

It is difficult to compare the cost of insulation in a reliable way for a number of reasons. The original prices were found from internet suppliers, but cheaper prices could possibly be found if dealing with a contractor or supplier directly. Also the price per m^2 can reduce if bought in large amounts as it would be for a whole building. The prices listed to not include installation or delivery charges, just the raw material costs, which does not give the whole picture.

Data such as embodied energy of materials is varied and can depend on so many factors, such as where and how it was produced.

Using information from suppliers can be biased as they are trying to sell their product so this has just supplemented information from more neutral sources such as GreenSpec and the Green Building Bible.

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