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BUILDING FROM THE PAST – SOLUTIONS FOR THE FUTURE?

The social and legislative barriers to the uptake of construction products derived from agricultural materials.

Abstract

The purpose of this study was to investigate why agricultural materials used in construction, i.e. construction products based on plant or animal materials produced on farms, are not part of the mainstream building industry. These products were used traditionally but were displaced by industrial materials and are now not generally known to the modern-day construction industry. This issue is of concern because building materials grown from crops are renewable and therefore potentially more sustainable than the use of conventional products, which rely on non-renewable materials derived from petroleum or mining. Also, some modern building techniques have led to issues of poor indoor air quality of homes, whereas crop-based construction products can improve air quality.

The approach to the study was a review of the literature to obtain information on the products currently available and the potential barriers to their use, including legislative barriers. Case studies from the UK were used to illustrate the successful use of crop-based construction products and where there had been barriers to their use. Surveys were conducted in both the UK and Sweden to obtain information on attitudes to, and experience with, these products. A series of semi-structured interviews were conducted in the UK, together with brief telephone interviews in Sweden by a Swedish student. These were followed by web-based surveys in both the UK and Sweden.

There are a number of barriers to the uptake of crop-based construction products, some of which relate to lack of experience with these products and limited data on how they perform. These can be overcome but this will rely on support by Government and continuing work by the industry. Improved understanding of what makes a building sustainable will be important in devising regulatory standards that are also appropriate to these products.

If current progress is maintained then there is no reason why there should not be more housing based on straw bale or hemp and lime. These materials produce functional pleasant homes, with low embodied energy and low lifetime energy use, and excellent internal air quality. Building breathable houses that can maintain an even environment and buffer the changes occurring outside, without using large amounts of energy, will be important in our future adaptation to the effects of climate change.

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List of Abbreviations

ACTIN	Alternative Crop Technology Interactive Network
BERR	Department for Business Enterprise & Regulatory Reform
BRE	Building Research Establishment
BREEAM	BRE Environmental Assessment Method
BWMB	British Wool Marketing Board
CAT	Centre for Alternative Technology
CAT WISE	CAT's Welsh Institute for Sustainable Education
CE	Conformité Européene (introduced by Directive 93/68/EEC)
CIRIA	Construction Industry Research and Information Association
CPD	Construction Products Directive 89/106/EEC
CLG	Department for Communities and Local Government
Defra	Department for Environment, Food and Rural Affairs
Dti	Department for Trade and Industry, now BERR
EC	European Commission
EU	European Union
FSC	Forestry Stewardship Council
GIFNFC	Government-Industry Forum on Non-Food Uses of Crops
IENICA	Interactive European Network for Industrial Crops and their Applications
JUDP	Joint Unitary Development Plan (Pembrokeshire)
MDF	Medium density fibreboard
NDPB	Non-departmental public body
NNFCC	National Non-Food Crops Centre
THC	delta 9-tetra hydrocannabinol
VOC	volatile organic compound

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Introduction

The purpose of this study was to investigate why agricultural materials used in construction, termed crop-based construction products, are not part of the mainstream building industry. The definition of crop-based construction products used here is that used by both CIRIA (Cripps *et al*, 2004) and Defra, i.e. those construction products based on plants or animals, planted or reared on farms and excluding timber. Construction products are any component that goes to make a building, including interior finishes.

Crop-based construction products have a long history of use (Cripps *et al*, 2004), with many examples in the UK. Thatch has been used for roofs, and earth with fibre (cob) is used throughout the world. Cob was in used in England by the 13th century and only started to fall out of use when industrial bricks became cheap to transport in the late 1800's. Sheep wool has been used to insulate buildings for centuries. Hemp is the oldest cultivated fibre plant and has long been a source of industrial fibres because of its steady availability, strength and versatility. These products fell out of use when industrial materials became readily and cheaply available, and therefore the modern construction industry has not generally been aware of them.

There are a large number of small firms in the construction industry, with at least 500,000 sole traders and a total workforce of about 2 million (Cripps *et al*, 2004). Large companies work on the largest projects, but often subcontract to small firms. There are divisions of responsibility in relation to design, construction and costing. It can be difficult to understand the decision-making process. Also the construction industry has well-established ways of working and can be slow to change.

There are around 1400 organisations involved or interested in application and development of alternative crops in the UK, of which 50% are large global companies.

Defra's (Department for Environment, Food and Rural Affairs) Industrial Crops Division develops the policy framework to stimulate alternative uses for crops, e.g. energy, construction, packaging and pharmaceuticals. Defra and Dti set up the National Non-Food Crops Centre (NNFCC) in 2003 to stimulate market development of non-food crops. It does this by managing a programme of demonstration products and working with all parts of the supply chain to disseminate research findings. It also developed a communications strategy for non-food crops to provide information to consumers so as to influence behaviour; and to industry on new commercial opportunities (Defra and Dti, 2004).

As an employee of Defra the author had sought a research topic that would be of value to Defra. An investigation of the social and legislative barriers to the uptake of crop-based construction products was suggested by Industrial Crops Division (Perrins, pers comm., 2006). In addition, Defra was also involved in a joint UK-Sweden initiative on sustainable construction, which was trying to encourage MSc students to take on projects in the areas of sustainable building, renovation and demolition (van Heyningen, pers comm., 2006).

Therefore this study investigates the legislative and social barriers to the uptake of crop-based construction products. Although not a comprehensive review of current legislation, case studies and examples have been used to illustrate the impact of legislation. In addition the impacts of people's behaviour and attitudes to these

materials have been investigated in identifying the social barriers to uptake. These factors were considered in relation to refurbishment of existing homes and to new build homes. The use of and attitudes to crop-based products in the UK was compared to that in Sweden. Sweden was deemed a suitable candidate on the basis that it was considered to be a leader in sustainable construction and associated technologies and because of the joint UK-Sweden initiative already referred to.

The importance of identifying the barriers to the uptake of crop-based construction products relates to the potential for producing crops that can be used in construction or home improvement. Building materials grown from crops are renewable and therefore potentially more sustainable than the use of conventional materials, which rely on non-renewable materials derived from petroleum or mining. For instance, mineral fibre insulation is based on stone wool or glass wool, with expanded clay, perlite, and cellular glass also used. Polymer foam insulation is polyurethane or polystyrene based. Mineral fibre insulation has two-thirds of the UK market and polymer foams one-third. The use of crop-based alternatives could help to reduce the environmental impact of construction.

Also associated with modern building techniques are issues to do with poor indoor air quality of homes. Crop-based construction products have a role in improving air quality, management of moisture levels and reducing allergic reactions to various materials people come into contact with daily. For instance, insulation materials from natural fibres provide buffering of moisture and heat, producing a comfortable indoor environment (Cripps *et al*, 2004). However, the market share of such products is currently small, with more use in Germany than in the UK. Even in Germany and Austria, where uptake of these products has been encouraged, only 3 – 5% of the insulation market is based on alternatives to conventional insulation, mostly in the form of recycled newsprint, wood fibre and wood-wool boards (Cripps *et al*, 2004). BRE (2004a) considered that for crop-based construction products to compete there would be a need to develop efficient, integrated growing and processing to produce a long fibre in Europe at competitive prices.

The approach to the study was a review of the literature to obtain information on the products currently available and what were considered to be barriers to their use. This included consideration of the impact of current EU legislation and its implementation in the UK and Sweden. A number of case studies from the UK were used to illustrate the successful use of these products and where there had been barriers to the use of crop-based construction products.

In order to obtain information on attitudes to, and experience with, these products, surveys were conducted in both the UK and Sweden, using similar cohorts of population in each country. The techniques used were semi-structured interviews in the UK, followed by web-based surveys in both the UK and Sweden.

Chapter One:

Crop-based products – definitions, uses and case studies

This chapter explains what crop-based construction products are and briefly outlines how they might contribute to sustainable development. A brief section has been included on the crops grown in the UK that are suitable for use in construction, but the study does not dwell on the agricultural production of these materials, which was the subject of another thesis (Allen, 2003). A summary is presented on the current place of crop-based materials in the construction market describing materials in terms of the construction products produced from them, with details of some of the products currently on the market.

A section on case studies demonstrates where products have been used and how the techniques to use them have developed. These case studies also highlight some of the issues that have arisen in relation to the use of various crop-based materials, such as legislative requirements or difficulties in using by conventional construction techniques. The case studies are in four sections: eco-renovation projects; interiors; low-impact developments in rural areas; and new build projects. The latter two types of project have been influential in terms of the image of crop-based construction products and in providing data, or improving methodology, so that these are likely to have an impact on further uptake of these products.

Finally a section is included on the experience in Sweden, based on a report produced by another student (Breitholtz, 2006).

What are crop-based construction products?

The CIRIA 'Crops in Construction Handbook (Cripps *et al*, 2004) defines crop-based construction products as those based on plants or animals, planted or reared on farms and excluding timber. Construction products are any component that goes to make a building. It cites a long history of use of crop-based construction products throughout the world.

The Handbook states that in 2002 the construction product industry was worth £30 billion annually, used more than 300 million tonnes of material, and accounted for 40% of construction output and 20% of the UK manufacturing base. The UK was a net importer by £2966 million of building materials in 2002 and this could be reduced by UK production. For instance, the European market for glass fibre insulation was approximately 460,000 tonnes each year during the decade 1994 – 2004. There was a larger market for rock wool.

The CIRIA Handbook suggested that 66% of UK energy use could be accounted for in the construction and use of buildings combined. Therefore if crop-based products are grown close to where they are to be manufactured and used then they can take less energy to produce, i.e. their embodied energy is less, compared to conventional materials because transport energy is reduced. However, as the market share of products is small, products have to be imported, e.g. from Germany where they are

more used. This adds to costs and to the embodied energy of the products, making them less competitive.

The Handbook also cited environmental benefits from crop-based construction products in use in relation to improved air quality, natural management of moisture levels, and reductions in allergic reactions in buildings where they are used. Waste disposal was stated to be safer, easier and with little or no environmental damage.

Their contribution to sustainable development

The benefits identified above contribute to Government strategy on sustainable development in terms of Defra's five strategic priorities, set out in the Strategy for Non-food Crops and Uses (Defra and Dti, 2004), i.e.:

- Climate change, energy;
- Natural resource protection;
- Sustainable consumption and production;
- Sustainable rural communities;
- Sustainable farming and food sector.

In relation to climate change and energy, renewable plant materials contribute to a reduction in greenhouse gases where they substitute for fossil-based materials. The strategy states that the European Commission in 2001 under the European Climate Change Programme estimated that this could reduce European carbon dioxide emissions by approximately 8 million tonnes by 2010, but possibly by as much as 30 million tonnes. They also contribute to sustainable consumption and production by providing an alternative to non-renewable materials. This can reduce economic costs and environmental impacts and lead to reductions in energy use, pollution and waste.

The growing of the types of crops used in construction can affect agricultural habitats and their suitability for different species. According to Defra and Dti this was considered to be a neutral effect or to improve biodiversity of these habitats. Agricultural land is finite in amount but was stated to be capable of producing materials from crops in a sustainable way. This would then contribute to the sustainability of rural communities, and the farming and food sector by providing business opportunities in rural areas with new markets and opportunities. However, BRE (2004a) state that the tensions between conflicting land uses should be a consideration, i.e. between land for housing, food, fibre and fuel.

Crops used in construction

Straw, hemp, flax and sheep wool are UK-grown agricultural products used as construction materials. They are either grown as fibre crops in their own right, or the parts of the crop used are the by-products of food production, i.e. straw from cereals and sheep wool from lamb production.

<u>Straw</u>

BRE (2004b) refer to the use of straw bales as building blocks or walls. There are approximately 4 million tonnes of 'waste' straw produced in the UK each year, sufficient to provide 450,000 homes of 150m^2 each year. This would reduce the carbon dioxide emissions associated with the construction of conventional homes. In

addition, straw production sequestrates carbon dioxide during the cereal growing phase.

Flax

The bast (phloem) fibres within the outer layers of the flax stem go to make linen (ADAS, 2005). The longer fibres are used in textiles; the shorter fibres for reinforcements for plastics and concrete, asbestos replacement, panel boards and insulation. The fibre is hollow and can absorb up to 12% of its weight in water and its strength increases 20% when wet. It dries quickly, is anti-static, the fibres are twice as strong as cotton and 5 times as strong as wool.

Hemp

Hemp has a long history of production in the UK (ADAS, 2005). It produces 25% more long fibre than flax, produces long bast fibre, medium fibres, short shive fibres or hurds, and seed oil. The long fibre is stronger than cotton, has anti-mildew and anti-microbial properties and is biodegradable. The medium fibre also has anti-mildew and anti-microbial properties and is biodegradable. The short fibre is more absorbent than wood shavings and is biodegradable.

Hemp has been used for thousands of years and is recorded as far back as 4,500 BC used as a textile in China (Duckett, Lime Technology, 2007). The first paper from hemp was produced in 100 BC and there was a hemp paper industry in the UK in 1494. In 1535 Henry VIII passed an Act requiring that farms above a certain size produce hemp for canvas for ships. However, by 1928 it was banned in the UK and by 1955 in the USA on the basis of the narcotic properties of the related cannabis plant. It may also have been partly due to lobbying by the oil industry as hemp fibres provided real competition to oil-based plastics used in car body components. Therefore from a versatile plant grown over many centuries, hemp was discredited and fell out of general use.

This was until its potential was realised as a low input crop and eligible to be grown on Set-Aside land, provided an industrial contract was in place. Currently grown industrial hemp has no narcotic properties because of the low THC levels (delta 9-tetra hydrocannabinol) and is a legal commodity under the UK 1971 Drugs Act and the UN 1961 International Treaty of Narcotics (Groundwork, 2006). In 1993 the first UK Home Office licence to grow industrial hemp (< 0.2% cannabis) was granted to the company Hemcore and it is still grown under licence in 2007 (Duckett, Lime Technology, 2007). The whole plant can be used and consists of approximately 30% fibre (bast) on the outside and 60% woody shive in the middle, with the 10% dust used to produce solid fuel briquettes. The fibre is used for insulation and the shive for construction and in chipboard (50% lighter than conventional). It is grown as a break crop between late April to early August and production is currently expanding. It is estimated that the amount of hemp insulation that could be produced in the UK is only a small proportion of the insulation used. However, if all new houses were built using hemp and lime it would require only a third of Set Aside land to produce the hemp. It takes 6 tonnes of shive, i.e. yield from one hectare, to build a house.

Wool

The Government-Industry Forum on Non-Food Uses of Crops (GIFNFC) investigated alternative uses for wool (Bowles & Jones 2004). The principal drivers were that: (a) wool is a renewable fibre by-product of the UK sheep industry to which, potentially, substantial value could be added; and (b) the low prices received by wool producers

from sale of wool by the British Wool Marketing Board (BWMB) had been such as to encourage the destruction of fleeces rather than commercial use. Hill producers in particular had little incentive to improve the quality of their product; some farmers had received as little as 2 pence per kg, when the cost of shearing was around 50 pence per sheep (average fleece weighs 1-2 kg). Consequently sheep were no longer bred for quality traits associated with fleece production. Wool producers by law had to provide their fleeces for marketing by BWMB, although the legislation did allow an opt-out under agreement by the BWMB to take forward entrepreneurial activities. The BWMB mainly focused on the use of British wool for textiles and carpets, which was most problematic for the fleeces produced from hill breeds.

The novel alternative industrial applications of coarse-grade wool identified included the use of wool for insulation in cavity walls, lofts and underfloor, and for insulation in construction of low cost wood-frame housing. It makes an excellent insulation material because it can absorb, store and re-emit up to one third of its weight in water vapour. This makes it very useful in areas where there are variations in temperature, as wool is breathable and can absorb moisture with no reduction in thermal performance. Installation of sheep's wool insulation is easy and does not require any protective equipment to be worn by the operator, unlike fibre glass or synthetic products. The manufacturing process uses around 15% of the embodied energy used to make glass fibre insulation. As wool is produced on a yearly basis, it is an ecologically friendly renewable resource that has no major recycling problems after use. Wool insulation is around one third more effective than synthetic insulation and has the same sound insulating properties. Tests have shown that after scouring the wool does not contain any significant chemical residues. It is treated so as to be fire resistant and resistant to moths and other insects.

Non-UK crop-based materials

Other fibres that may be used in various construction products include cotton, jute, sisal, abaca (*Musa textilis*), ramie (*Boehmeria nivea*), coir, kenaf (*Hibiscus cannabis*), and animal fibres (ADAS, 2005). Many of these are imported long distances, such as from India or China, which will add to the embodied energy of the product. In addition, there are products harvested from other parts of Europe, such as cork and reed. Reed is obtained from Austria and Eastern Europe and because of the low costs of the raw materials the final product is relatively cheaper.

Coir is the strong fibres of the coconut husk and is sourced from Kerala, India. The fibres are removed by hand and softened in sea water, so that they can be woven into carpets (Alternative Flooring Company, 2006).

Jute comes from the stalk of the giant *Corchorus* sp. plants, grown in southern India and is used in floor coverings and as a backing to carpets.

Seagrass grows in the tropical parts of China and Vietnam, in coastal meadows on the banks of the rivers, where it is harvested by hand, dried and hand spun into cords before being woven into matting.

Sisal is extracted from the *Agave sisalana* plant, which is farmed in Mexico, Brazil and East Africa and used in floor coverings.

Cork is a natural product that can be harvested without harm to the tree. The Cork Oak (*Quercus suber*) can first be stripped of the outer casing of its bark when a tree is about 25 years old. Subsequently there has to be a minimum interval of 9 years before cork can be taken from a tree (Groundwork, 2006).

Crop-based products and their uses in the UK

Appendix 1.1 outlines the products that are available made from crop-based materials. It is subdivided by use in construction, rather than by agricultural origin or material. Within each section the individual products and materials are detailed. This gives a useful summary of the potential for crop-based products to be used in construction and indicates the current market range, based on products available. It is not claimed to be a comprehensive directory.

There are a number of uses for crop materials in the UK construction industry. This ranges from them forming the major part of a building structure, giving it its character, e.g. straw bale or hemp and lime, to interior finishes. Both straw and hemp can be used in the external structure as well as in boards, plasters and insulation, used in the interior of buildings. Flax produces suitable material for insulation as well as the basis for flooring and paints. Sheep wool and cork are also used in insulation and flooring, a range of plant fibres are used in carpets and matting.

Crop-based construction materials appear to be less readily available than conventional construction materials. Based on the examples, each type of product may only be available from one or two UK suppliers, and in some cases they have imported the product from other parts of Europe. Conventional construction materials such as rockwool insulation, plaster-board or MDF are usually readily available from nationwide networks of building suppliers or DIY stores, where a decision to use a product can be rapidly followed up with a trip to a local outlet to purchase it.

Case Studies - UK

The following section gives examples of the use of crop-based construction products. The individual case studies cite a range of experience and an attempt has been made to categorise them into four types.

The first section deals with the use of crop-based products in the interior of properties as part of a major renovation along environmental principles.

It was not clear whether the school project was a renovation or a new build and therefore this is in a category on its own. This again relates to use of crop-based products within an interior.

The third section relates to case studies that date back to some of the first use of straw bale building in the UK. However, these are used as examples of low-cost rural housing, and the planning issues that arose from the building of these settlements are discussed in Chapter 2.

Finally, there is a section on new build projects, which brings the review of case studies up to the present day.

The previous section on products available and this section on case studies is intended to give an indication of the extent to which crop-based construction products have a place within modern building. In reviewing the literature it was not always easy to determine whether crop-based products had been used, as generally there

was only reference to environmentally-friendly materials, without distinguishing between renewable and recycled materials.

Eco-renovation projects

Nottingham Eco-House

The Nottingham Eco-House was a Victorian house that was renovated to be more eco-friendly in terms of materials and energy performance (White, 2002). A number of crop-based products were used in the renovation (M S Architects, 2006) and therefore are examples of products that were considered to be eco-friendly by the renovators.

Wooden floors were cleaned, sanded and coated with natural hard-wax oil by OS Colour. Apparently this product was also used in the British Airways headquarters. It contains all natural ingredients, is water-based, free from allergenic petrochemicals and is as hard-wearing as many synthetic coatings. As it is based on 'soft' rather than 'hard' chemistry, it works together with the timber and allows it to 'breathe'.

A Victorian Minton tile floor was given a coat of linseed oil as a protectant. Similarly, Cornish slate floors were sealed with Revol natural floor oil, which is part linseed-based. Linoleum was used for flooring in some rooms.

A number of walls were plastered with clay based plasters, which had varying fibre content. The disadvantage was that they were slightly less durable than ordinary gypsum plaster. However, there were considered to be a number of advantages, i.e. there is no chemical set, and the process relies on the water evaporating off for hardening, which means that the materials can be wetted and reworked at any time but the working time is increased. Claytec undercoat was particularly suitable for patching and renovation work because of its flexibility and strength afforded by its straw fibre reinforcement; it was also used on a lathe and plaster ceiling. In most rooms Tierrafino was used as the finish, except in a bathroom where Claytec topcoat was used. It was finer than Tierrafino, and reinforced with fine fibres, it was more resilient, but the finish needed painting. Less energy would be used in manufacture of clay plaster than for gypsum plaster, but the products had to be imported from Germany and Holland.

Where partitions were used or pipes boxed in these were made out of studwork clad with Claytec boards as an ecological alternative to ordinary plasterboard. This board provided thermal mass and breathability and moderated internal conditions (humidity, temperature and odours) and so was suitable for a bathroom. Being a natural product it was biodegradable; its properties also helped reduce sound transmission. Claytec boards are made from reed matting tied together with wire and bound with un-fired clay and layers of hessian. It was expensive, because of the labour involved, but was considered a low tech, low impact, high performing material to use.

The Greenhouse, Norwich

The Greenhouse is an eco-centre within a Grade II listed building (White, 2002). The renovation included 50 mm cork insulation under the concrete floor in the shop, which is covered with marmoleum. The first floor had wall insulation of 50 mm – 100 mm cork on the South facing wall and 200mm - 250mm cork on the North facing wall. Similarly the top floor walls had 100 mm – 250 mm cork insulation and 100 mm wool insulation in the roof. Other products used included plant solvent paints and varnishes, and waxed floors (The Greenhouse, 2006).

Interiors

Nursery Unit, Cedar Integrated Primary School, Crossgar, County Down

Rachel Bevan Architects aimed to minimise the use of chemicals in the school environment and to avoid the off-gassing from conventional paints by specifying the Natural Paint Collection (Green Building Store, 2006). Although the natural paints were slightly more expensive than conventional products, they only represented a small element of the total building contract. The painting contractor had no problems with coverage, ease of application and mixing in the liquid mineral pigment colouriser. The paints sometimes took longer than conventional products to dry. The architects were satisfied with the quality of the natural paints and wood finishes and would consider specifying again provided clients were sympathetic. They point out that there is a need to plan ahead and take time to try out samples and experiment with colours before ordering. However, this is also done with conventional paints, where small pot samples are available to try.

Low-cost developments in rural areas

Brithdir Mawr

The Brithdir Mawr community was founded in 1994 at a farm on the side of a remote mountain in Wales with the ideal of embracing the principles of sustainability, simplicity and spirit (White, 2002; Brithdir Mawr, 2006). Eco-buildings were built on the site, including straw bale dwellings. Some time later in another part of the farm more straw bale huts were built and became known as Tir Ysbrydol. Initially these were not spotted or reported, but once they were the planning authorities tried to get them demolished (Woolley, 2006). The planning issues are dealt with in Chapter 2.

Tinkers Bubble

This community was also set up in 1994 in self-built low impact homes, including straw bale (White, 2002). They were first granted temporary planning permission in 1999, for a 5-year period. There is more discussion of the planning issues in Chapter 2.

New Build Projects

Straw Bale

Straw Bale Cabin, East Yorkshire

The cabin was built as a holiday home and was visited by author during September 2007. It is timber-framed with 450 mm walls made from locally-grown straw bales. There are three coats of render on the outside of the bales adding 25 mm thickness to the walls. Two coats are coarse and contain chopped hemp; the outer coat is finer and is a 1:1 mixture of lime putty and hemp. For the inside walls the first coat was a clay and water slip coat; the middle coat was coarse of clay and chopped hemp, with the final coat a fine clay plaster, a total of 25 mm.

The reasons that the cabin was built of straw (Atkinson, 2007) were that it is a locally available, plentiful material with low embodied energy and that acts as a carbon store. It gives a softer, more rounded look than conventional buildings and an internal atmosphere that is cosy and pleasant.

York ecoDepot, York

This scheme was a partnership between York City Council, Yorkshire Forward, contractor Carillion and architect White Design. This is Europe's largest timber framed and lime rendered straw building. It used Modcell's modular straw bale, i.e. comprising straw bales contained within a wooden frame, prefabricated locally using Yorkshire straw by Modcell Ltd and AgriFibre Ltd. This has a U-value three times better than required by the Building Regulations. It was estimated that it will provide a 76% reduction in energy use compared to a conventionally built air conditioned office, saving 155 tonnes of carbon dioxide per annum. There will be real time performance monitoring of the building (Lime Technology, 2006a).

Knowle West Media Centre

This organisation, based in Bristol, is engaged in developing the creative, educational and social potential of people within the surrounding community and the city as a whole. In 2007 they started the construction of a new purpose built media centre. The project has been designed by local young people, working with architects White Design. The building was due for completion in December 2007 (Knowle West Media Centre 2007).

It was being constructed using Modcells produced by Agrifibre Technologies. Each panel was made near to the construction site, optimising the use of local materials. The straw was stacked inside the wooden frame and then wooden nails driven through the straw to provide extra strength. Finally, a lime render was applied to the sides and then the finished Modcells were shipped to the building site.

The Footprint, Cumbria

Work began in April 2006 on the first straw bale building in Cumbria (National Trust, 2007) near Windermere in the Lake District, also the first to be built by the National Trust. The building had to be built and rendered, etc before the autumn frosts. The Trust worked with a Cumbrian-based, conventional construction company and a specialist straw wall building and training business. They also used volunteers by offering training courses in car tyre foundation building, straw and cob wall building, lime and clay plastering and finishing.

It has been built as an educational centre for schools, with an emphasis on environmental education. Using the centre has enabled school children to understand why the materials and design chosen for the build were used. This includes doing lifecycle analysis on timber, wool, straw, lime, clay and rubber, as well as environmental audits of in-life resource use.

Hemp and Lime

Hemp and Lime Houses, Haverhill, Suffolk

The project was started because of the enthusiasm of the architect, Ralph Carpenter of Modece Architects, who had seen hemp and lime building in France and brought it back to England, initially in renovation of a historic building. This was followed by the Haverhill project, which was a turning point for the uptake of hemp and lime building in the UK (Haynes, Lime Technology, 2007a)

Two hemp and lime houses were included as part of an affordable housing development of 18 houses and bungalows in Suffolk and were the first houses of this type to be built in Britain (Yates, 2002). These houses were compared with two brick and block houses and all the research houses were within a terrace of houses. One house of each type was occupied from December 2001; the other two were monitored empty.

The use of hemp and lime reduced the embodied energy used in construction, a factor that is becoming increasingly important as the energy used during a building's lifetime is reduced (Carpenter, CAT, 2007). It is estimated that the 50 m^3 of hemp and lime used at Haverhill sequestrated 10 tonnes of carbon dioxide.

Although the hemp and lime houses were regarded as a research project there was a need to show that they could comply with the Building Regulations (Yates, 2002). The architect worked with the Local Building Inspectors to check that they were in agreement with the approach being used and also to involve them in demonstrations to help them understand the construction. There was agreement that the houses should perform adequately and final approval was dependent on the outcome of the research.

Because of the research element of the project there was a need to obtain the cooperation of potential residents in relation to the monitoring that was needed. Those on the housing register were contacted to ascertain their interest in the project. Those that were interested were informed what commitment would be needed from them. From this group the four tenants were selected for the two hemp and lime houses and for the two conventional houses to which they would be compared.

The houses had 450 mm limecrete foundations, i.e. shallow, which was appropriate close to trees (Carpenter, CAT, 2007). However, there were issues at Haverhill with builders understanding the requirements for the foundations. The hemp and lime walls were 250 mm thick plus the lime render on the outside and the lime plaster on the inside. A time and motion study was used during the build by taking a photograph every 20 minutes. The first house took twice as long as the conventional houses, the second only 10% longer, which shows that there was quick learning by the builders. The cost of materials was higher in the case of the hemp and lime houses due to their small scale production (Yates, 2002). The materials for a brick and block house cost £4,845 compared to £8,375 for Hemp House 2. The costs for the other hemp and lime house were higher, but that did have an additional exposed gable wall. Labour costs were also higher for the hemp and lime houses, partly because the builder had to learn the building system. It was identified that there is a need to improve the efficiency of the building technique if there is to be greater take up.

The structure and durability of the hemp and lime houses was at least equal to brick and block houses and both types gave complete protection against water penetration (Yates, 2002). Hemp and lime walls were found to have a 'breathing' quality which gave a pleasant feel to them and the perceptions of comfort were greater. The buildings were thermally efficient leading to lower fuel costs and no condensation. The lack of surface condensation meant that the walls did not feel cold to the touch. Also the living environment was free of mould and so healthier than brick. The hemp and lime was resistant to fire and vermin.

The walls absorbed sound and so felt more comfortable than the hard brick surfaces, although in tests the hemp and lime walls were not as good as brick at between-room

soundproofing. There was a precautionary double skin party wall for acoustics, which gave a 58 decibel reduction. There was no echo, which meant that people did not shout; the acoustic test uses a shout volume (Carpenter, CAT 2007).

During the first winter the indoor temperature in the hemp and lime houses was higher than in the brick houses for the same amount of energy use. They would be expected to be warmer and drier once the walls had fully dried out (Yates, 2002). There had been an issue regarding the U-value of hemp and lime, which would be required to be built 300 mm thick in order to meet the Building Regulations (Haynes, Lime Technology, 2007a). However, it was clear that *in situ* the walls performed better than predicted; U-value is just a part of thermal performance and it only measures conduction. The test is done on dry materials, whereas when houses are built they may not be. U-value assumes heat is transferred out of the wall and it does not take account of thermal mass. Phase change of materials (e.g. water) is also likely to be important as energy is released as heat with change of state. Hemp contains moisture and as water changes from liquid to vapour and back again this may affect the thermal properties of the building.

The ability to mortgage was not an issue for this development. Tenants were not able to buy their properties and the housing association could not sell them.

Adnams Brewery Distribution Centre, Southwold

The project began in 2004 with the architects keen to use sustainable materials and the client was prepared to fund some research and development; it was these factors together that enabled the design. The site was a disused quarry which gave the potential for the building to sit low in the landscape. The design was a 60 – 75 cm brick plinth topped with Hemcrete and glulam beams with a green roof. Various options were researched before deciding on the blocks (Pritchett, Lime Technology, 2007). The materials were developed by Lime Technology in conjunction with Lhoist UK. The structural engineer was Lister Beare and the architects Aukett Fitzroy Robinson (Lime Technology, 2006a). The hemp was sourced from Hemcore.

The 8,000 m^2 building has diaphragm walls consisting of hemp and lime blocks, chosen so that the same codes of practice could be used as with conventional blockwork. However these blocks were found to be heavy and crumbled (Lime Technology, 2006c). They were infilled with lime hemp walling material and finished with lime render. The plan had been to build sections 2 metres in height and infill, but in practice some sections were higher before being filled. This was an issue because the infill could not be tamped down and therefore the moisture content had to be increased so that gravity ensured a proper fill. Also the sections had to be left 4 days for the lime mortar to go off before infilling, for which there was not suitable equipment and so led to delays in the project.

Tradical Hemcrete was approved as a building product under the Zurich Building Guarantee Scheme as a result of this project.

Lime Technology estimate that due to the absorbing properties of the hemp over 150 tonnes of carbon dioxide have been sequestrated in the 1000 cubic metres of wall, compared to 300 - 600 tonnes of emissions had the building been built with conventional materials (Lime Technology, 2006a & 2007a).

Adnams estimated that the cost of the build was 15 – 20% higher than it would have been with conventional materials. However, they have made substantial savings as refrigeration equipment is not needed in this building, but would have been required

in a conventional depot. The temperature had initially been high following building during hot weather, but it decreased and levelled out at a temperature that was suitable for storage of beer.

Lime Technology offices at Milton Park, Didcot

Lime Technology (2007a) then developed a spray application process for hemp and lime that allowed speed and consistency of application, reducing costs compared to shuttering and tamping. The aim was to enable an industrial scale availability of hemp and lime products. Their offices at Milton Park were the first structure where the spray-applied Hemcrete was used in the UK.

CAT WISE, Machynlleth

Under construction and due for completion in June 2008 is the Centre for Alternative Technology's Wales Institute for Sustainable Education (CAT WISE). This has been designed by architects Pat Borer and David Lea and includes a cast *in situ* hemp and lime walling system (Lime Technology, 2006a). This was chosen based on its use in France and at Haverhill (Borer, CAT, 2007). Lime Technology was chosen because of their use of air limes and the spray technology, i.e. it was no longer a craft technology. The planners accepted the use of hemp and lime on the basis of data from France and CAT's track record (Horton, CAT, 2007). The foundations will be limecrete and the limecrete walls will provide an insulating protective shell.

Three Gardens project, Suffolk

This project was funded by Orwell Housing Association, Elmswell Parish Council and Suffolk Preservation Society; the architects are Riches Hawley Mikhail Architects (Lime Technology, 2007b). The site has a history of old clay pits and brick kilns and so the architects have specified local materials (RHM Architects, 2007). The 26 homes will be cost effective to build and have low embodied carbon dioxide in construction and low lifetime energy use. Hemcrete is being sprayed onto a brick and block base plate, covered by a timber sole plate, for an airtight, moisture resistant exterior finish. This will also add thermal mass to lightweight, timber framed buildings. Sheep wool insulation will be used. The project is due for completion during 2008.

Lime Technology Blending Plant, Didcot

At their Didcot site Lime Technology (2007b) have a plant capable of producing up to 25,000 tonnes of Tradical HB, the lime-based component of Tradical Hemcrete. It is delivered to site in 22 kilo bags for mixing with the hemp shive, Tradical HF to form a bio-composite building material.

Conclusions on case studies

The materials used in the renovation and interior case studies were not necessarily chosen because they were crop-based, but for the properties they had. This may have included the fact that they were renewable, but what is made reference to is that the product used had the optimum properties for the job. In one case it was recognised that clay-based plasters were less durable than the conventional alternative, but this was outweighed by their positive attributes. The benefits appeared to also outweigh drawbacks such as additional cost and the need to import materials.

The low-cost, low-impact dwellings are examples outside of the mainstream construction industry and, to some extent, outside of mainstream society. This could make them less useful as convincing case studies to show the benefits of crop-based construction materials. However, as with many such communities that try to live in a different way to the rest of society, they highlight issues prevalent in modern-day society and offer possible solutions. In this case the issue is affordability of rural housing for those that grew up in such areas and would wish to continue to live and work in a rural enterprise, rather than be forced to move elsewhere and commute to work, or take on a different type of work in a city.

The building of straw bale buildings for use as holiday homes or education centres helps to increase the awareness of the general public to the existence of these materials used in construction. In addition, by using these buildings the public are experiencing the benefits they provide, such as improved internal air quality and how the insulating properties reduce the energy requirements. The availability of information to those using the buildings helps to draw attention to these benefits. Such buildings may help to reduce the barriers to uptake of these materials.

The first use of hemp and lime to build in the UK was met with concerns as to whether this material would meet the regulatory requirements in the same way as do conventional materials. Some determination was needed on the part of the architect to continue with this project and to provide information to satisfy the requirements and there would have been fewer obstacles to building with conventional materials. These hemp and lime houses also cost more to build, because of importing low volume materials and because of the additional labour costs due to the unfamiliarity of builders with using the materials. Another potential issue was the ability to obtain a mortgage or building insurance for such a property. Although these were barriers to the use of hemp and lime, the project showed that there were benefits to be gained in terms of indoor air quality and reduced heating bills.

Similarly, to build the Adnams distribution centre with hemp and lime required commitment from those involved to use the material and fund the generation of data. This was a building project with a strong research element, as method development took place as part of the build and problems were resolved during the project. This added to the costs, but again there were savings on lifetime energy use due to the properties of hemp and lime. Without the commitment from those involved in the project more conventional materials might have been used. Then it would not have been possible to move forward on improving the building methodology or to produce data on hemp and lime for planners. The approval of the hemp and lime product by Zurich removed a further potential barrier.

This work has led to the development of a spray technique, compatible with that used in producing concrete buildings. This should remove a barrier to use of hemp and lime in that this method of use is more accessible to the conventional building trade, who understand how to use it.

The experience over the previous years, cited in case studies, led to the decision to use hemp and lime in the CAT WISE building. The development of this material from a self-build craft technology to something more consistent that can be used with modern methods also influenced the decision. The need for a track record was also demonstrated in the decisions about CAT WISE, but in this case it was CAT's track record, rather than that of the material, that helped to convince the planners.

The use of hemp and lime in a new project in Suffolk is also encouraging with respect to uptake of this material. Again this is a social housing project, where properties will

be rented. The next step would be to see properties that are part of the housing market being built from hemp and lime. Although some of the insurance issues have been resolved, it is not clear whether a mortgage would be obtainable for such houses.

Sweden

Appendix 1.2 is a report by a volunteer student from Sweden on the experience of crop-based construction products. The following conclusions are based on that report.

There is not the same use of crop-based construction products in Sweden as there is in the UK. The historical use of materials such as birch, reed and straw are likely to have been based on local availability. For example, straw was only used in the south of Sweden, i.e. where the cultivated land is concentrated. Presumably it was in this part of Sweden that straw-boards, produced in a similar way to their wood-based equivalents, were developed. There appears to be a history of hemp being used for clothing and insulation.

There has been no use of crop-based products for the main structural element of buildings. The prevalence of timber production, i.e. ten times the area used for agriculture, means that wood is more likely to be used in construction, based on tradition and availability. It was only in situations elsewhere in the world, where timber was not available, and there was a surplus of straw, that alternative methods have developed, i.e. building with straw bale.

The small areas of flax and hemp that are grown are used to produce linseed-based paints and insulation respectively.

Chapter Two:

Impacts of Legislation in the UK and Sweden

This chapter includes some of the case studies discussed in Chapter One. However, whereas the previous chapter dealt with the social barriers to uptake of crop-based construction products, the subject of the current chapter is legislation. In particular, it examines the impact of EU legislation and its implementation, in both the UK and Sweden, on the uptake of crop-based construction products.

It does not catalogue all the legislation that impacts on the construction industry, as such a review would be more than could be achieved by this study. Rather examples in the literature and from Government department websites have been sought that could act as potential barriers to uptake of crop-based construction products. This review begins with general EU policy, and moves on to consider the potential legislative barriers in the UK. Finally a brief review of legislation in Sweden concludes this chapter.

EU policy on fibre crop production

IENICA Report 2005

In 2005 IENICA (Interactive European Network for Industrial Crops and their Applications) reported growth in the interest in natural fibres for the production of insulation materials in most of the then 15 Member States, with commercial developments in a number of countries, including Belgium and Germany. In many countries, this market was growing faster than the total market for insulation materials.

In 2002, less than 5% of EU hemp fibres were used for insulation; and it had been estimated that sales of flax and hemp fibres to the European insulation market would increase from 1,400 tonnes in 2000 to almost 25,000 tonnes by 2005. Plant fibre was considered to offer potential to replace glass fibre and rock wool as an insulation material. German figures showed that insulation from renewable materials accounted for 4% of the total size of the industry at 29 million m^3/year and that a market introduction programme had produced noticeable sales increases. A 10% market share was considered to be realistic, for both Germany and the EU.

Hemp drug policing was stated to be a serious limiting factor in 2005 with the identification of cultivars with zero THC (delta 9-tetra hydrocannabinol), and visual or simple field diagnosis tests for these types urgently required. This was still a major factor within the Accession states, e.g. hemp cultivation was prohibited in Lithuania. However, hemp had achieved greater acceptance in Western Europe in the last few years up to 2005.

IENICA recommended that to enhance the development of crop derived plant fibres and to meet International Agreements on Climate Change and Biodiversity an overarching and integrated EU legislative framework should be established. This

should be particularly aimed at extending the legislation to take account of the identification of sustainable and biodegradable products. IENICA also stated that communication of the new fibre products and their environmental benefits to industrial and domestic users would overcome their lack of knowledge, and enhance awareness and product demand. This was something that policy makers needed to be aware of.

EU incentives for production

Article 1673/2000, of July 2000, on the organisation of markets regarding hemp and flax grown for fibre production stated that the support for growth of the short hemp and flax fibre shall cease by the growth season of 2006/2007 (Breitholtz, 2006). After that support would only be given for traditional long fibre crops. Later, the planned 2005/06 reform of the hemp and flax sector was postponed until 2008, following an EU Commission report on the future of fibre processing aid, which recommended a two year roll over of the existing regime. This was in order to get a better picture of how the sector was operating under current CAP arrangements. The Commission report also recommended some technical adjustments which made hemp and flax, cultivated for industrial uses other than fibre, eligible for the single payment scheme, as well as hemp for fibre. These adjustments came into force in July 2006. The support for long and short fibres plus the support for flax in the traditional farming areas would therefore be prolonged until the farming year of 2007/2008.

Impact of EU Legislation in the UK

Construction Products Directive

There are rules governing products used in construction resulting from the European Construction Products Directive 89/106/EEC (CPD) and implemented in the UK through the Construction Products Regulations in 1991 (CLG, 2007a). The Directive is one of the 'New Approach' Directives intended to create a single European market by removing technical barriers to trade between Member States. Products meeting these requirements will be eligible for 'CE marking' and may be placed on the market anywhere within the European Economic Area (EEA). It also permits withdrawal of non-conforming products by national authorities. The CE marking is a manufacturer's declaration that the product complies with the "essential requirements" of the relevant European health, safety and environmental protection legislation". Under the CPD the route to CE marking is by complying with the relevant technical specifications, i.e. by meeting the national standards in the UK or by complying with a European technical approval. The CPD applies to any construction product, which is produced for incorporation in a permanent manner in construction works including both building and civil engineering works.

Impact of EU recycling requirements

The Government Industry Forum on Non-Food Uses of Crops (Defra 2003) is an advisory non-departmental public body (NDPB), sponsored by Defra, set up in March 2001. The forum was set up in response to a House of Lords Select Committee on Science and Technology report on non-food crops in November 1999. The forum provides strategic advice to government and industry on how to promote development of non-food uses of crops in the UK. In particular it promotes development of sustainable opportunities that stand to add value to UK economic activity. A key principle is that the areas considered must involve crops grown or

capable of being grown in the UK, and/or which could contribute to UK value creation through their subsequent processing or use.

The 2003 report of the Government Industry Forum on Non-Food Uses of Crops refers to the impact of legislation on uptake of crop-based products (Defra 2003). The forum stated that EU legislation was often introduced to address problems associated with materials already on the market and in an earlier report had identified cases where this had placed unfair restrictions on plant-derived products and produced significant barriers to their potential for commercial development. In the 2003 report they cite the EU's focus on recycling as an issue for crop-based products.

The forum's concern over the EU drive towards recycling was because this was often at odds with the use of renewable materials, which are not always suitable for recycling. Instead, composting of the material or the recovery of energy through combustion at the end of their useful life tend to be the more sustainable options. The forum referred to natural fibre case studies where the need to meet recycling targets conflicted with increased use of renewable materials. This was because the use of renewable materials does not contribute to recycling targets, and this carries a financial cost.

The forum recommended that government departments with responsibility for legislation on waste should ensure that the current drive to recycle does not disadvantage renewable raw materials, which have the same or reduced environmental impact over their life cycle.

Planning Issues

Section 106 Agreements

Section 106 of the Town and Country Planning Act 1990 allows a local planning authority to enter into a legally-binding agreement or planning obligation with a developer. A Section 106 Agreement is a tool used by Development Control as a way of binding the applicants for planning permission to carry out the development in the way specified in the agreement.

Agreements can cover a number of areas, but a relevant example here would be that the local authority restricts the development of an area of land, or permits only specified operations to be carried out on it in the future. They often require developers to minimise the impact on the local community and to carry out tasks, which will provide community benefits.

Hockerton Housing Project

The Hockerton Housing Project near Southwell, Nottinghamshire was the UK's first earth sheltered, self-sufficient ecological housing development (White, 2002). Although not built of crop-based materials it is of interest because of the planning issues the project raised. The project members live a holistic way of life in harmony with the environment, generating their own clean energy, harvesting their own water and recycling waste materials, so causing no pollution or carbon dioxide emissions. In August 1996 the Project made UK post-war planning history by obtaining special permission to build a sustainable housing development on agricultural land. The planning application was considered in May 1994, and approved subject to a Section 106 agreement. However this took a further two years to put in place delaying

construction until August 1996. The fact that the houses would be energy efficient was not sufficient on its own. The project in its entirety had to be seen as "a move towards Sustainable Development", which "could be seen as complementing the council's (Newark & Sherwood District Council) own energy/ environmental activities". Account was also taken of the social provisions of the scheme - "(it) is not just for the houses in an isolated situation but as a whole living project ..... the occupants of the dwellings will work on the site towards a system of self-sufficiency through sustainable employment with low impact on the environment."

Low-cost, Low Impact rural developments

A different sequence of events have occurred with other developments, such as the communities referred to in the case studies in Chapter One. These have created debate about what constitutes sustainable development in rural areas. An important element of this is the building materials used in these dwelllings, with straw bale being a frequent component.

Tinkers Bubble

The Tinker's Bubble community (2006) stated that the planning procedure is based upon a system where some areas are prescribed for development and others are proscribed, except for exceptional or agricultural uses. The underlying implication is that development is harmful for the environment, and should be constrained and restricted to certain well-defined areas. The community propose that some forms of development have less impact upon the environment than others; and that there may even be some forms of development that have a positive impact upon the environment and therefore should be encouraged.

Current planning law makes no distinction between different forms of development. "Change of use" from agricultural to residential is "change of use", whatever structure the prospective inhabitant wishes to build. The community state that this is not a sensible basis for assessing future development in the countryside, nor does it help to produce a thriving rural community. They suggest that the Government's planning departments should be investigating acceptable criteria for residential development for those who wish to live and work in the countryside. For those who may not demand, or even wish for, the sort of development that the planning system has been designed to regulate, but who may be interested in constructing something more in tune with the local surroundings. They state that poor local people and poor incomers face exactly the same problem; wages for work in the countryside are low, while the price of rural property is very high and that is because of the restrictions on development.

A number of planning applications have been put forward for Low Impact Dwellings outside the normal development area. The community suggest that after scrutiny and experiment, the concept of low impact development could be extended beyond temporary constructions, to more permanent structures that were not judged to be detrimental to the local environment. They go on to suggest that planning conditions for more permanent low impact dwellings might involve a technological restriction whereby the bulk of the visible structure was constructed from natural local materials. It would be up to the local council to define how local and natural these materials should be.

Brithdir Mawr and Tir Ysbrydol

Eco-buildings were built on the site, including straw bale dwellings, without reference to the authorities for planning permission. By 2005 several small straw bale huts had been constructed on these two parts of the site; the local planners were aware of them and they had been subject to enforcement orders.

The community challenged the Pembrokeshire Coast National Park's definitions of sustainability and appropriate housing. This led by, the end of 2005, to the Joint Unitary Development Plan for Pembrokeshire County Council and the Pembrokeshire Coast National Park (JUDP), a document outlining planning policy for the whole of Pembrokeshire. It included Policy 52: Low Impact Development making a Positive Contribution (Replacement Policy). This policy stated that low impact development that makes a positive contribution will only be permitted where a certain set of criteria are met. Early in 2006 supplementary planning guidance for the policy was issued for consultation and was adopted by Pembrokeshire Coast National Park Authority in May 2006 and by Pembrokeshire County Council in June 2006. The community was then in a position to make applications for approval of their dwellings.

The guidance set out eight specific criteria that needed addressing to comply with the Policy:

- The proposal will make a positive environmental, social and/or economic contribution with public benefit; and
- All activities and structures on site have low impact in terms of the environment and use of resources; and
- Opportunities to reuse buildings which are available in the proposal's area of operation have been investigated and shown to be impracticable or are incorporated ; and
- The development is well integrated into the landscape and does not have adverse visual effects; and
- The proposal requires a countryside location and is tied directly to the land on which it is located, and involves agriculture, forestry or horticulture; and
- The proposal will provide sufficient livelihood for and substantially meet the needs of residents on the site; and
- The number of adult residents should be directly related to the functional requirements of the enterprise; and
- In the event of the development involving members of more than one family, the proposal will be managed and controlled by a trust, cooperative or other similar mechanism in which the occupiers have an interest.

A management plan is required that sets out what materials the dwellings are made of and how the project will be reversible insofar as new buildings can be assisted in biodegrading without any adverse landscape impact or be removed to restore the land to its original or a more biodiverse state in the event of collapse of the project. A requirement is that buildings are to be constructed from materials that are recycled, reusable, and have low embodied energy or are from sustainable sources. There is clearly a role for crop-based construction products in such projects.

Woolley (2006) points out that although building without permission in a national park may not be supportable in some ways, these communities raised the issue of low-impact developments with the planning authorities. He points out that there are many who would want to live on the land, meeting their needs from the land in a sustainable lifestyle, and not as second home owners or commuters, to whom natural building techniques and materials appeal. However, there has been little change to

planning policies to allow such developments, and he states that in order to progress these issues there is a need to consider them at the national level and to develop a policy that would support sustainable living in rural areas.

Building regulations

The Building Act 1984 has stated as part of its purpose assisting in the conservation of fuel and power, and preventing waste (Tricker & Algar, 2006). It achieves this by imposing a method of building control by inspecting and reporting. It applies only England and Wales, with Scotland and Northern Ireland having their own legislation. The standards are then set in England and Wales by the Building Regulations 2000 and implemented by the Approved Documents, which provide practical guidance in relation to the Building Regulations. Local authorities are responsible for ensuring that these requirements are adhered to and can take enforcement action in the event they are not. Therefore these requirements have potential to impact on the use of crop-based construction products. The requirements of the Approved Documents are set out in Appendix 2.1.

Impact of the Building Regulations

The Sustainable Buildings Task Group (May 2004) considered that the lack of a statutory requirement for the Building Regulations to cover sustainability was a substantial statutory barrier to progress on the sustainability of buildings. They noted that some of the Approved Documents already cover sustainability but stressed that sustainable development needed to be within the scope of the Building Regulations. The Group recommended that revised regulations should require a minimum percentage by value (10% or more) of re-used, reclaimed or recycled materials in building projects. Government agreed that use of such materials should be encouraged in building projects but felt that the recommendation should be assessed against broader sustainability objectives. The Group also recommended a review of enforcement to ensure that regulators have the resources and training to conduct reliable post-completion checks on a proportion of all new and refurbished buildings.

According to a BRE report (2004b) the barriers to widespread use of crop-based construction products included legal barriers in relation to the Building Regulations. In addition, there were technical barriers relating to unproven performance. There was also a high level of caution in the construction industry with respect to using new materials. However, they concluded that these were not insurmountable barriers to the uptake of crop-based construction products, but that there were costs associated with providing a sufficient amount of technical data. There were also potential difficulties in demonstrating compliance to the satisfaction of Building Control Officers. This is particularly so if the material is the main part of the building or is to be used in a location that could impact on safety. Materials used in the structure of the building should be of limited interest to planners providing they are not contravening product regulations. BRE concluded that the omission of a material from the list of common materials used in building should not automatically exclude their use. The report suggested that problems could be overcome by a programme of testing and assessment as part of a demonstration project. This would ideally be a commercial project but could be supported with additional funding for training and monitoring purposes. This could then provide the data that could be used for other developments. The demonstration project could be supported or supplemented by an accelerated accreditation scheme. Then, as there were more approvals, testing and certification, more local authorities may take an interest in these products and dissemination of information would help the local building control body.

Under Part E acoustic insulation is required between outside and inside, between dwellings and between rooms (Cripps *et al*, 2004). In relation to sound insulation, batts of flax, hemp and sheep's wool absorb low frequency sound better than mineral-based insulation. It is usually this frequency of sound that is more of a problem. The performance is reversed at higher frequency sound but still high and the difference is less significant.

Haverhill project

Hemp and lime has been tested for conformance with the Building Regulations and complies with the three areas of Part A (Carpenter, CAT, 2007). Hemp and lime smothers fire and under Part B it is resistant to fire up to 1800ºC, compared to cement that shatters at 400ºC. BRE have tested it under Part C for moisture, where hemp and lime was sprayed with water for 72 hours and it penetrated to 80 mm. Hemp and lime meets the Part E requirements for sound resistance. Under Part F ventilation, it does not require mechanical ventilation in wet areas.

Ralph Carpenter did Part L tests on his own house and obtained a U-value of 0.072 $w/m^2.K$ for hemp and lime and also found that it resists overheating, limiting internal temperature to 26ºC with the curtains shut. U-values must comply with Part L of the Building Regulations (Cripps *et al*, 2004). For open blown loft spaces and partial fill floor cavities compliance relates to the settled thickness. Moisture is a good conductor of heat and the claimed U-values may not be realised. There are little data on this but it was thought to be a factor at Haverhill. In Germany, Austria and Switzerland the values are increased by a percentage to take account of moisture. The heat storage capacity of plant-based insulation materials is twice that of mineral-based materials. This means that these will respond more slowly to heating or cooling and therefore reduce temperature swings and produce a more stable room environment. This is important in the roof space and prefabricated timber construction.

The Haverhill Project demonstrated that it was important to get the local building control body involved as early as possible. In the case of this innovative building proposal there was no formal process for building control. This meant that the onus was on the applicant to justify the use of the product and provide quality data to convince the building control body. Therefore designers would need to be able to come up with a formal process or testing programme to demonstrate the acceptability of the product.

In the case of Haverhill test data, specification sheets and foreign approvals were available. However, British regulations were considered to be more stringent than the French equivalent (BRE, 2004b). There were concerns about structural stability and thermal acoustic performance. Part of the case to proceed was on the basis that if post-construction performance was poor it would be put right. Viewing UK tests as well as receiving the data was a useful reassurance. More recently the insurance company, Zurich, have agreed to insure hemp and lime buildings.

Code for Sustainable Homes

The Sustainable Buildings Task Group in their report 'Better buildings - better lives' (May 2004) recommended to Government that a single national Code for Sustainable Building be established, based on BREEAM (Building Research Establishment

Environmental Assessment Method) and incorporating clearly specified minimum standards in key resource efficiency criteria, including use of materials.

This recommendation was supported by Government and in December 2006 the Code for Sustainable Homes, a new national standard for sustainable design and construction of new homes was launched (CLG, 2007b). Since April 2007 the developer of any new home in England could choose to be assessed against the Code, i.e. it is not mandatory. The Code measures the sustainability of a new home against categories of sustainable design, rating the 'whole home' as a complete package. The Code uses a 1 to 6 star rating system to communicate the overall sustainability performance of a new home. In England the Code replaces the EcoHomes scheme, developed by the Building Research Establishment (BRE). The minimum standard in the Code exceeds the requirements of the Building Regulations.

The categories within the Code are: energy and carbon dioxide; pollution; water; health and well-being; materials; management; surface water run-off; ecology and waste. The categories of energy, health and well-being and materials appear to be of particular relevance to crop-based construction products.

In terms of energy and carbon dioxide a dwelling would gain a one star rating if it achieved 10% improvement on the Target Emission Rate (TER) set by the 2006 Building Regulation Standards, and a 5-star rating if it achieves 100% improvement. A 6-star rating is a zero carbon home. The rating also includes an element for the properties of the building fabric.

For materials to achieve a one star rating at least three of the following five elements are required to achieve a BRE Green Guide 2006 rating of at least D:
– Roof structure and finishes
– External walls
– Upper floor
– Internal walls
– Windows and doors
The rating refers to responsibly sourced materials, e.g. FSC timber, and to materials that are re-used or recycled. However, it does not refer to materials that are renewable or can be composted at end of life and so may disadvantage crop-based construction products. The BRE Green Guide does refer to some crop-based construction products, e.g. cork insulation and linoleum flooring.

There are no minimum standards for health and well-being in the Code. Crop-based construction products would be likely to score well against standards based on these attributes.

The Sustainable Buildings Task Group (2004) also recognised the need to make improvements to the existing housing stock as approximately two-thirds of the existing building stock pre-dates the introduction of any environmental requirement in the Building Regulations. Therefore they recommended that the Code should also apply to major refurbishment of existing housing stock. There are currently approximately 1.2 million dwelling sales per annum, with new build only a small part of this at approximately 150,000 units per annum. Therefore Government should encourage new owners to improve the environmental performance of their homes, by ensuring that good information is provided to the consumer, and offering financial incentives through grants or tax breaks. The aim would be to either encourage an individual who is already planning to carry out maintenance or refurbishment to a

building to do so using high environmental standards, or to stimulate the activity in the first place.

Sweden

Appendix 2.2 is a report on legislation in Sweden.

Conclusions on legislation

Back in 2005 there was clearly considered to be a potential for an increase in the natural fibre insulation market across the EU, provided the right market signals were in place. The continuation of subsidy payments for a further two years for such crops was likely to have had a positive impact. The concern was that in 2008 that this support will cease.

However, in spite of the EU support for these crops, hemp continues to suffer an image problem in some Member States, including Sweden. There are strict legislative requirements to be met in the UK before the crop can be grown on an individual farm.

Two potential barriers from the EU are the Construction Products Directive and the drive to recycling. The former means that a product needs to meet specific testing requirements to be marketed across the EU, and these could add significant costs. In addition, if the tests are designed for conventional products in standard conditions it could be harder for crop-based products to achieve the required results. The other barrier is the requirement to include a certain percentage of recycled material within a construction product, which acts against using renewable crop-based materials. An example of this is the UK Code for Sustainable Homes, which encourages the use of recycled materials but not of renewable materials.

The moves over the last 10 – 15 years to develop sustainable communities in rural areas have produced considerable challenge to the planning authorities. This has led to Section 106 agreements or bespoke policies that put stringent requirements on what materials can be used and what activities may take place in such developments. Often crop-based materials have been used in these settings and meet the criteria for low-impact homes made of degradable materials. However, as recommended by Woolley (2006) there needs to be a national policy for such developments to aid these local agreements.

It has been demonstrated that crop-based construction products can meet the requirements of the Building Regulations. However, there is a concern that the tests do not represent *in situ* conditions and therefore may not fully demonstrate the performance of these materials. For instance, there is moisture present in most housing environments and these materials act to maintain an even environment and to buffer external environmental conditions. Sweden has similar requirements and considered that provided products could meet the test requirements these regulations were no barrier to their use.

Chapter 3:

Survey methods

Introduction

The approach to the survey methods used in this study was based on Appendix 6 of the MSc AEES Thesis Workshop Book: Developing a Questionnaire by W.E.C. Gilham (UEL & CAT, 2006). This advised against devising a questionnaire without reference to the population to be surveyed. Instead it was recommended that there should be an initial survey of a sample of that population, e.g. using focus groups or semi-structured interviews with a few individuals. In this study it was decided to use semi-structured interviews to investigate issues that should be included in the questionnaires.

The procedures used are listed below:

1. Met with National Non-Food Crops Centre (NNFCC) to discuss their work;
2. Recorded semi-structured interviews by telephone or face-to-face;
3. Development of a questionnaire based on the information gleaned from interviews;
4. Testing of a pilot questionnaire on a selection of people;
5. Questionnaire modified on the basis of pilot survey, including development of three separate questionnaires;
6. Final questionnaires internet-based and email invitations sent out to survey sample, with follow-up email reminders sent to boost the response rate.

Timeline for questionnaire development

The process of developing the final questionnaires is set out in the table below:

Table 3.1: Record of questionnaire development

Date	Action taken
April 2006	Visit to National Non-Food Crops Centre (NNFCC), York to discuss their work on crop-based products in construction.
July 2006	Developed a list of contacts for semi-structured interviews.
August 2006 – January 2007	Telephone or face-to-face semi-structured interviews with architects, suppliers and users of construction products.
August 2006 – September 2006	Produced pilot questionnaire for testing based on outcome of early interviews.
September 2006	Tried out a pilot of the questionnaire at the Homebuilding and Renovation Show at Excel.
October 2006	Decision that 3 questionnaires would be better than a single questionnaire targeting specifiers, suppliers and users.
November 2006	Finalised 3 questionnaires – Specifier, Supplier, User.
	Further interview contacts made at NNFCC conference.
November 2006 – January 2007	Translation of questionnaires into Swedish and production of list of target companies in Sweden by student volunteer.
January 2007	Lime Technology seminar and final interview.

January 2007 – February 2007	Questionnaires developed on Survey Monkey, an internet tool, with the help of a volunteer experienced user.
February 2007	Launched questionnaires on Survey Monkey in UK and Sweden.
	Attended Ecobuild exhibition and conference to find additional people who were potential responders to the survey.
February 2007 – March 2007	Responses received on Survey Monkey; increased response rate obtained by sending reminder prompts by email.
March 2007 - April 2007	Analysis of responses downloaded from Survey Monkey.

Approach to questionnaire development

Prior to any work on questionnaire development a visit was made to the National Non-Food Crops Centre (NNFCC) in York to discuss their work and the current status of crop-based construction products. The NNFCC was established in 2003 and is the UK's single independent authority on renewable materials and technology, including crop-derived construction materials. It is a not-for-profit company sponsored by government, i.e. Defra and BERR. Its board consists of industry, academia, agriculture and government. Their aim is to help products get to market by building and strengthening supply chains, with a focus on whole supply chains. They support decision makers, such as Government, with comprehensive information from all renewable sectors. They also raise the profile of crop-derived products with the general public.

Recorded interviews were held at NNFCC with available staff from which an initial list of factors that could be affecting the uptake of crop-based construction products was developed (Appendix 3.1). One of those interviewed provided valuable information from their experience of building sustainable holiday homes.

The literature on the barriers to uptake of crop-based construction products was generally based on a limited number of interviews. Interviews can be valuable in providing useful information and insights based on the experience of an individual closely associated with the subject matter. However, one drawback for the interviewer is the time each interview takes to conduct and analyse. The analysis is more complex because each interview is individual and it may be difficult to draw general conclusions from such non-uniform data.

A questionnaire can be drawn up fairly quickly and distributed to a number of people at once as the surveyor is not required to be present. However, to produce a questionnaire without any reference to those who have experience of such products risks it being irrelevant and difficult to complete. Also as the surveyor is not present there is scope for questionnaires not to be returned, or for the questions to be misunderstood or approached in a way that was not expected. A pilot of the questionnaire tested on a small sample of people and with the surveyor present can give insight into such problems. Simple multiple choice or yes/no answer questions reduce the scope for wrong interpretation and make results easier to analyse. However, without some scope for free text comments this approach can mean that information is lost.

Therefore for the purposes of this study the approaches above were combined, with interviews used to inform the multiple choice questions included in a questionnaire placed on the internet. A pilot of the questionnaire was used to iron out problems with misinterpretation of questions.

Pre-questionnaire interviews

In order to conduct interviews a representative sample population needed to be identified. The aim was to select those who had some experience of crop-based construction products, e.g. architects who had specified these products or decided not to; retailers of products; and those who had used products. Suitable interviewees were obtained either from the literature (White, N, 2002); or by contact at conferences and exhibitions; and through buying products. People were asked if they would do a recorded interview, either by telephone or face-to-face, and those that consented were asked a series of questions (Appendix 3.2). These questions were intended to be a starting point and the conversation was allowed to flow from these, not to be restricted by them, i.e. a semi-structured interview.

A total of seven semi-structured interviews were recorded and analysed (summarised in Chapter 4, Annex 4.1). One of these interviews involved three people being interviewed together. Many of these interviews were used in producing a pilot questionnaire.

Pilot questionnaire

The pilot questionnaire (Appendix 3.3) was trialled at the Homebuilding and Renovating Show at Excel, London during September 2006. Four individuals on trade stands and a couple visiting the exhibition were willing to complete the forms at the show and one exhibiter provided their response by post later. It was a valuable experience to observe their approach to the questions and to note whether they understood the questions fully and answered them with care. Responders were also encouraged to make additional comments and not be totally constrained by the questionnaire, these remarks, where made, were helpful to future questionnaire development.

The limitations of the draft questionnaire were discussed with the Thesis Tutor and it was agreed that three types of questionnaire would be more appropriate. This was better than trying to make a single questionnaire fit several types of responder, i.e. Specifiers such as architects and designers, Suppliers such as producers and retailers, and Users such as builders and contractors. This also meant that each questionnaire would have fewer questions and be simpler to complete.

Web-based survey

The development work above resulted in three questionnaires, i.e. aimed at Specifiers, Suppliers and Users. These were produced in both English and in Swedish, i.e. six in total, and were placed on the internet via Survey Monkey.

An internet survey, rather than a postal or email survey was considered most convenient for users and a more straightforward and less expensive means to reach a larger number of respondents. Invitations to respond to internet surveys can be sent by email, which is widely used. A responder can access the survey instantly and respond without having to either print off and post, or save and email, a completed form, making the internet a convenient means to respond to survey requests. However, the surveys researched on the internet were not readily accessible and appeared expensive. Therefore the help of a volunteer with marketing experience was enlisted to access Survey Monkey and set up the first of the six questionnaires; the remaining five were set up by the surveyor. Email invitations were used to invite potential respondents to complete the surveys.

There were two sets of questions. The first section investigated the various factors that are important to a responder in choosing a construction product, not necessarily a crop-based product. The second section investigated the responder's particular experience of crop-based products. Both sections had a free text question at the end to add further information. The questions and their responses are analysed in Chapter 4.

Chapter 4:

Survey findings: interviews and questionnaires

Introduction

This chapter sets out the results from both the semi-structured interviews and the internet questionnaires referred to in the previous chapter on methods.

Semi-structured interviews, either by telephone or face-to-face, were held between August 2006 and January 2007. In total seven interviews were conducted, one of which was a simultaneous interview with three people, meaning that nine people were interviewed in total.

The semi-structured interviews had two purposes. The main one was to inform the questionnaire by bringing out factors that may act as barriers to the uptake of crop-based construction products. The information on barriers that was derived from discussions with the National Non-Food Crops Centre (NNFCC) were used to inform the questions used in the interviews, both the basic questions and the follow-up questions. The factors that came out of the interviews could then be investigated further with a larger sample of respondents by means of the internet questionnaire. However, the interviews also provide a valuable insight in their own right as anecdotal evidence of the factors that influenced those particular respondents and based on their experience. Therefore, these results are also drawn on in the analysis.

Invitations to complete online surveys were sent to a larger cohort of specifiers (architects, designers), suppliers (producers, retailers) and users (builders, contractors, homeowners). The questions were multiple-choice so as to limit the type of information obtained from the survey, making it more amenable to analysis of trends. However, the response was such that statistical analysis was not really possible.

Semi-structured interviews

Information on people interviewed

Fifteen organisations or individuals were approached regarding the possibility of a semi-structured interview. One or two either did not take incoming calls or their voicemail indicated that they were very busy. In other cases emails were sent but no response was received, even when there had been an initial telephone contact. The remaining respondents were very happy to help and good cooperation was received from the interviewees and their colleagues, who helped to identify and direct the request to the appropriate person to interview. Interviews were expected to take 20 minutes, however in general took from 40 minutes to two hours, due to the willingness of the respondents to share their experience.

A total of seven semi-structured interviews were conducted over the period August 2006 to January 2007. One of these was a simultaneous interview with three individuals and therefore nine people were interviewed in total. Details of the interviewees were as follows:

1. PPQ1 was an architect with nearly 40 years experience, which included both the commercial and domestic sectors. Their experience of crop-based construction products was described as limited. This was a telephone interview.

2. PPQ2 was an MSc student who had recent experience of using 'natural' paints. The interview took place at the student's flat, which had recently been painted with three brands of 'natural paints'.

3. PPQ3 was a user of various types of sustainable products in building, including some crop-based. They had built a cottage to include materials and technology that would reduce energy use, minimise external inputs and close resource cycles. This interview was by telephone and the quality of the recording was poor.

4. PPQ4 works for a supplier of environmentally friendly products that had been in business for approximately eight or nine years at the time of the interview. The interview was conducted at their business premises. This company supplied some crop-based products and had a good understanding of what was included in this category.

5. PPQ5 was a building surveyor, based with a firm in London, where the interview was conducted. They also had experience of using products on their own property in France and had a good understanding of what crop-based products included.

6. PPQ6 was a supplier mainly of paints, as well as wool insulation and books. Their experience at the retail level is supplying wool insulation and selling books on straw bale building; natural paints are a major item. The interview was conducted by telephone.

7. PPQ7 was three people involved in the manufacture, production and supply of hemp and lime for use in construction. This was a face-to-face interview with all three individuals together following a seminar.

The transcripts of the semi-structured interviews can be found in Appendix 4.1 to this chapter.

Findings from interviews

The following is a compilation of the points arising from the semi-structured interviews. The first section sets out the factors that may affect uptake of crop-based construction products as stated by those interviewed. This is followed by a section on the types of people that might be interested in crop-based products. The final section lists references to specific crop-based products, in relation to barriers to uptake and the interviewee's experience.

Barriers to uptake of crop-based products

One issue is that, due to the investment needed for projects, the construction industry is risk averse and therefore reluctant to try a product that is unfamiliar. Users will choose a product that they know how to use and are familiar with that is fit for purpose. It needs to be tried and tested as well as easy to install. A specifier will tend to use what they know to keep within budget, and one admitted that they probably do not promote the alternatives. Owners of buildings may be reluctant to try different products in case it affects their ability to rent the building. Tenants could have an influence but are likely to be most concerned about running costs. In addition there is a question over whether buildings will be insured or mortgages provided for them, and the general public perception.

Technical data are needed to show that a product complies with the Building Regulations, and data can also make a difference to planning decisions. There needs to be performance criteria available for comparison between products. This is a cost to the industry for a new product and Government grants for start-up, as well as funding for research, would help reduce this impact. Research projects could be used to take measurements and produce the necessary data. Legislation changes, e.g. adaptable Building Regulations, as well as tax breaks would encourage use of these products. Building Regulations criteria need to be about real buildings rather than laboratory conditions that do not reflect the environment a product will be placed into. For instance U-value is currently measured in static state, dry conditions; some materials do not meet the requirement but have a better overall thermal performance. The Building Regulations are based on conventional materials; and there needs to be flexibility for them to deal with other types of product. This has not been an issue before so it is only now that work is being done on this. There is not a culture of building and then testing the building to see whether it meets the expected standards. There is a need for demonstration houses and Government could lead by example by using these products in their new buildings or building renovation. Large projects are valuable in helping uptake of materials, e.g. BedZed, Adnams Brewery and CAT WISE. The latter two are discussed in Chapter 1 in the section on case studies.

For architects to specify a product they need data and legislative approval, they want British certification even where this is not a legal requirement and often will not accept certification from another EU country. They have to know how the product performs; have technical back-up readily available for customers and for the product to have an established track record, i.e. in use for ten years or more. Houses have a 200-year life and so there is a need for longevity in the components, a short guarantee will not instil confidence.

Contractors are less aware the green market than architects, comprising many small companies it is too expensive for them to attend conferences or training in new products. They are also concerned about track record; many conventional suppliers have been established for around 125 years, unlike green suppliers. Although crop-based products have been in use throughout history there was a move away from them, e.g. with the advent of readily available brick, and so they have had to be rediscovered. People are not taught building history and do not understand issues such as breathability. Similarly surveyors may not be up to date in relation to use of crop-based products; this was demonstrated with respect to perceptions during an interview about appearance and durability of straw bale building. Lack of understanding of materials is a barrier to their uptake and there is a need to communicate their properties to the clients and contractors. People need to be

educated to live in such buildings, e.g. in terms of managing indoor climate and using appropriate interior finishes that maintain breathability.

The ability to readily source a product from the supplier on time is a factor. Many contractors source materials at the last minute and if they cannot source the specified crop-based material will revert to the conventional product. Because many crop-based products are from other parts of Europe and this is a low-volume market there can be lead time issues in sourcing products, there are also few suppliers of these materials in the UK. If a source is not available it may not be easy to switch to another similar product, unlike for example the rockwool market. As well as sourcing easily it should also be possible to store the product on a wet rainy site until it is needed for use without damage.

Crop-based construction products in some cases cost more than their conventional equivalent. Customers have to make choices to stay within their project budget and so may rule out a more expensive choice. A supplier stated that cost may be an issue but once a customer has committed to use green products then environmental criteria become more important. One user cited the following factors as important in product choice: natural, easy to use, friendly to use, sympathetic to the building, which all came before economics.

Another factor is that the products are not visible to consumers in general, i.e. in the local DIY store, which was contrasted to the situation in France. However, the internet has made it easier to source these products.

Some interviewees referred to a need to be determined to use these materials in a building project. One in particular cited a difference between national policy and what was happening locally, where policy was meant to be implemented.

The self-build market is where crop-based products may often be used, as these people are closer to the build process and may want to use natural products. The television programme Grand Designs was noted to have an impact on sales, particularly if the feature included information on the reasons for using a natural product.

There is additional scope for use of crop-based products in that PPS7 (Planning Policy Statement), which sets out the Government's planning policies for rural areas, which local authorities should have regard to when preparing local development documents and when taking planning decisions, now refers to ground-breaking materials or design.

Something further that may favour uptake of these products is that when sustainable communities build they tend to meet a specification beyond that of the Building Regulations and may use crop-based materials. The regulations tend to gradually catch up with these higher standards, which can be met by such products.

Another factor is the embodied energy of a product, i.e. the energy used to produce the construction product. The Kyoto Agreement and the Stern Report were both considered important influences. Increasing energy costs are likely to favour those products less dependent on fossil fuels. However, an issue for the UK is that many products are imported from the rest of Europe.

Types of customer for crop-based products

Ecological customers
Their environmental criteria are not based on whether a product is derived from natural materials, for instance to be considered ecological a product can be based on recycled materials and is more likely to be technology based. Recycled materials tend to be cheaper compared to crop-based products.

These customers tend to have concerns about natural products in relation to longevity, strength and the effects of damp and rot. Durability of a crop-based product would be an area of concern that may be addressed with data. Others prefer technology, i.e. newer and better solutions, for a similar cost. Recycled products are seen as newer e.g. tyres are preferable to coconut mat. Another issue is that some crop-based products can appear to easily come apart when they are in the store. However, *in situ* the products will not be exposed and so wear and tear will not happen, but the customers are not reassured by this.

Natural customers
These customers are interested in crop-based products, but may also be concerned that natural products will be less durable. The natural customer is more concerned about interior finishes, i.e. carpets and paints, and what they are coming in contact with, as well as aesthetics. They are less concerned with what will be sealed away, the issues for them are partly health and partly green.

Health customers
These are a subsection of natural customers that are sensitive to certain products. They are interested in their own health, e.g. allergies and tend to favour crop-based products in order to avoid chemicals, but do have concerns about how they are grown. It can be difficult to certificate this aspect of a product due to lack of traceability.

Health aspects are difficult to substantiate and therefore it is difficult to promote crop-based products on this basis. There are also allergies to natural materials, including crop-based products. Customers tend to do a lot of research themselves and will know what they are allergic too. They also track back through manufacturers to get the best information.

Customers may buy carpets and paints on the basis of asthma issues. Clay is not crop-based but light clay bricks and undercoat use straw as a component, these absorb air moisture, regulate humidity, draw in odours so there are benefits for the asthma market.

Some customers ask for organic building products, which it is not possible to supply at present. Most products do not need chemicals in their production and producers are trying to limit the amounts used. However, proving this with certification is expensive and more difficult to do.

Product-specific information

Sheep wool insulation
This product looks good; but it is considered to be expensive. This was accepted by a supplier but it was stated to be as good or better than rockwool and easier to use. One user decided that it was better to insulate their property with glass fibre rather than not to insulate because of the cost of using sheep wool. According to one supplier Warmcell (recycled paper) is more popular than Thermafleece, which is

more popular than flax and recycled wood fibre. The acoustics are stated to be better with recycled insulation products.

Flax batts insulation
These are easy to use where the batts fit the structure of the building, e.g. on walls, but will need cutting where they are not an exact fit. The acoustics are stated to be better with recycled insulation products.

Hemp
This material has a lot of uses but has an image problem because of the drug association. This is an issue within individual countries and at the UN level. This is likely to mean that it will not be specified by an architect.

Hemp and lime
There has been interest in the carbon sequestration potential of this building composite. Interest has also been engendered by those who have pioneered the use of the material and persevered to be able to use it in building projects.

Straw bale
One specifier found that torrential rain meant that work had to stop; this was an issue because the builders still had to be paid. There was also an issue that mites came out of the straw after the building had been rendered. This latter problem was not reported in any of the straw bale case studies.

There was an anecdotal report of the proposed use of straw in a building being the reason for planning permission being refused, although this was not the official reason given. The resubmitted application was successful and did not include the straw bale element.

Natural paints
Two interviewees had a similar experience but with different outcomes, i.e. in terms of which product gave them the better finish. From these interviews it is concluded that the paint they used first gave the worst finish and that it was the amount of their experience of using the paint, rather than any differences between the brands, that affected the quality of the finish. Therefore it would appear that some experience needs to be gained with these paints compared to conventional paints in order to get good results. Once this was overcome the paints were considered to give a nice finish that seemed to reflect the colour of the surroundings (making the white less harsh), but there was a possibility that dirt was picked up more readily.

The range of colours could be limiting if a particular shade was wanted. Paints were also approximately 50% more expensive than conventional paints and colour added to costs compared to white paint.

A positive trait was the lack of smell for emulsions and the pleasant smell associated with gloss paints, which was much preferred to the conventional paint smell. Also the lack of volatile organic compounds (VOC's) in natural paints was seen as a health benefit as these paints were not off-gassing after application. This was important for allergy sufferers. However, there was an issue of other paint manufacturers making claims for their products, which could be misleading if a user was looking for a completely natural product.

Decorators who have tried natural paints have been persuaded of their qualities. They have usually come to them through customers' specifications, but once they have tried them they then persuade other customers to have them in their property.

Availability through the internet with delivery was considered positive.

To be used in commercial buildings there would need to be reassurance regarding the durability of paints. There was considered to be insufficient information on this.

Carpets
A user of sisal carpet stated that it was very comfortable for bathroom flooring, whereas a supplier stated that sisal carpets are rough and as people want soft carpets they tend to be only suitable for industrial spaces. As they are not treated with chemicals they are not easy to clean and so not so good for commercial spaces. A user had also experienced that sisal carpets collected dirt and needed regular cleaning.

Linoleum
This would be unlikely to be used in a commercial building because of an image problem.

Comparison between NNFCC discussion and interviews

When considering the points made above and comparing these with the factors arising from the NNFCC discussions (Appendix 3.1) it is clear that NNFCC had identified many of the factors that acted as barriers to uptake of crop-based construction products. It was not altogether surprising given the role of NNFCC that they should have a good understanding of the barriers to uptake of these products. It was encouraging that the information from the semi-structured interviews was consistent with this.

Internet survey in the UK and Sweden

The UK surveys were available online from between 8 and 12 February and were all closed on 25 March 2007. The Swedish surveys were available from 18 – 22 February and were closed on 27 March 2007. Several email prompts were sent out during the survey period to encourage participation and notice was given of the closing dates.

Overall response rate to online survey

Table 4.1 summarises the response rate to the survey. The percentage of completed surveys is given in relation to the total number of surveys sent out. This gives a lower figure for response rate as some of the email invitations elicited a non-delivery message. As it is difficult to know whether a non-delivery is due to a mailbox being full, or a block being put on certain types of email messages, then these have not been excluded from the survey total. There were very few responses declining the survey request in comparison with non-delivery receipts. UK Suppliers and Swedish Users had particularly high numbers of non-delivery receipts.

Table 4.1: Response rate to questionnaires in SurveyMonkey:

Survey	Completed survey/ surveys sent out	Declined survey or email non-delivery	Totals as percentage of surveys sent out; completed + declined
UK Architects	32/137	32	23% + 23% = 46%
UK Suppliers	13/111	46	12% + 41% = 53%
UK Users	7/43	19	16% + 44% = 60%
Overall UK	**52/291**	**97/291**	**18% + 36% = 54%**
Sweden Architects	13/129	15	10% + 12% = 22%
Sweden Suppliers	7/61	16	11% + 26% = 37%
Sweden Users	12/165	33	7% + 20% = 27%
Overall SWE	**32/355**	**64/355**	**9% + 18% = 27%**

It was not clear why the response rate in Sweden was around half that of the UK. One possibility is that most of those contacted in the UK were involved or stated they were involved in green or environmentally-conscious building. The range of organisations contacted in Sweden appeared more representative of the mainstream building sector.

Within survey response rate of respondents

Completion of questionnaires ranges from 12% - 23% of invitations sent in the UK, an overall average of 18%. In Sweden this was down to 7% - 11%, an overall average of 9%. This section now considers the within questionnaire survey response, as those responding to the surveys did not necessarily answer all of the questions. Table 4.2 shows that the questions requiring free text answers were less likely to be answered in both the UK and Sweden. In addition in Sweden more questions were answered in the section on choice factors than were in the section on crop-based products.

Table 4.2: Within questionnaire response rates

Question type	Number of respondents to questions		
	UK Architects 32 total	**UK Suppliers 13 total**	**UK Users 7 total**
Role	29	12	7
Experience of crop-based products	32	13	7
Factors – multiple choice	31	12	7
Additional factors	20	5	6
Crop products – multiple choice	30 - 31	10 – 12	7
Reasons for answers on crop products	20	6	7
	SWE Architects 13 total	**SWE Suppliers 7 total**	**SWE Users 12 total**
Role	11	7	11
Experience of crop-based products	13	6	5
Factors – multiple choice	11 - 12	4	10
Additional factors	4	0	7
Crop products – multiple choice	9 - 10	2 – 3	9 – 10
Reasons for answers on crop products	3	0	2

Table 4.2 can be summarised by percentage response rates as set out in Table 4.3.

Table 4.3: Overall within questionnaire percentage response rates

Question type	UK response %	Sweden response %
Role	91 – 100	85 – 100
Experience of crop-based products	100	42 – 100
Factors – multiple choice	92 – 100	57 – 92
Additional factors – free text	38 – 86	0 – 58
Crop products – multiple choice	77 – 100	29 – 83
Reasons for answers on crop products	46 – 100	0 – 23

As well as fewer of those people contacted in Sweden responding to the internet survey there was also a lower response rate on equivalent sections of the questionnaires. The free text questions were characterised by low response rates throughout, but the responses from Sweden were markedly lower than that from the UK. The low responses on questions to do with crop-based construction products indicate less familiarity with these products in the Swedish cohort compared to that in the UK. This could again indicate that the Swedish cohort was taken more from the mainstream construction industry than the UK cohort. It could also indicate that there is less familiarity in general with these types of product.

Type of respondent within each category

The first question in the survey asked people to set out their role and this information is included below.

UK

UK Specifier survey:

- 11 respondents describe themselves as an architect or specifier;
- 7 describe themselves as architects with a project management role;
- 4 describe themselves as having a role in sustainable construction or eco-design;
- 4 describe their role as specifiers but do not refer to themselves as architects.

UK Supplier survey:

- 2 respondents described themselves as suppliers of eco-friendly building materials;
- 2 respondents were suppliers of insulation;
- 2 were suppliers of lime-based products;
- 2 were manufacturers and suppliers of flooring materials;
- 1 was a supplier of natural paints;
- 3 supplied timber-based products.

UK User survey:

- 2 respondents described themselves as contractors;
- 2 as builders;
- 2 as project managers;
- 1 as an installer of insulation.

Sweden

Swedish Specifier survey:

- 5 respondents described themselves as architects;
- 2 as advisors;
- 2 had no role in choosing materials;
- 1 stated that they dealt with formation and function.

Swedish Supplier survey:

- 5 supplied building materials;
- 1 supplied insulation;
- 1 supplied plasters.

Swedish User survey
None of the Swedish Users explained what their role was.

UK responses to internet surveys

The summaries of responses to the questionnaires are set out in the following pages of tables in the order that they appeared in the survey. The UK and Swedish sections are dealt with separately.

Experience of UK respondents with crop-based construction products

Table 4.4 shows that UK Specifiers included in the survey generally do have experience with crop-based construction products, with only 9% having no experience. Similarly all UK Users had experience of using these products. The

outcome was more evenly spread amongst the UK Suppliers, between no experience, stocking products and recommending them. Within this group 8% had advised against the use of crop-based products.

Table 4.4: Experience of UK respondents in specifying, supplying or using products

What is your experience of recommending crop-based materials?	No experience	Have included these products in a building project.	Have recommended to others to use.	Have advised against their use.	Total Respondents
Specifiers	9%	69%	22%	0%	32/32
What is your experience of supplying crop-based materials?	No experience	Stock some of these products.	Have recommended products to others.	Have advised against their use.	
Suppliers	31%	38%	23%	8%	13/13
What is your experience of using crop-based materials and products?	Not aware of such products	No experience of using these products.	Have used one or more of these products.	Other (please specify)	
Users	0%	0%	100%	0%	7/7

Factors that affect product choice in the UK, not specific to crop-based products

Table 4.5 sets out the ranking of factors that affect the choice of product by UK Specifiers, Supplies and Users. This section of the questionnaire is not specific to crop-based construction products but is designed to determine what factors are important in general in selecting all types of products, i.e. conventional as well as environmentally friendly products.

The factors have first been ranked on the basis of scoring as Very Important to the responder. However, this was not considered to give a full picture, particularly as less than 50% of responders rated a factor as Very Important. Therefore, the Very Important and Important scores were combined to give a ranking and this usually resulted in the factor rated as first receiving more than 80% of the vote. As more than one factor could be given the same score within a question, e.g. Important, it was difficult to separate where one factor was more important than another. Originally it had been intended to ask respondents to rank factors within a question in order of importance, i.e. 1 to 4, but this option did not appear to be available on Survey Monkey.

Table 4.5: Ranking by UK responders of the factors that affect product choice (Percentages expressed as those responding to particular question)

Factor	Specifier	Specifier	Supplier	Supplier	User	User
	Very Important	Important scores combined	Very Important	Important scores combined	Very Important	Important scores combined
Cost	3rd (26%)	3rd (90%)	4th (25%)	3rd (83%)	3rd (29%)	1st (100%)
Can be stored on site &/or used in bad weather	4th (13%)	4th (71%)	n/a	n/a	4th (0%)	3rd (71%)
Proven track record	1st (39%)	2nd (94%)	1st (58%)	1st (100%)	1st (43%)	4th (57%)
Can be readily supplied when wanted	2nd (35%)	1st (96%)	1st (58%)	1st (100%)	1st (43%)	2nd (72%)
Demand to stock	n/a	n/a	1st (58%)	4th (75%)	n/a	n/a
**********	**********	**********	**********	**********	**********	**********
Made from recycled or re-claimed materials	3rd (42%)	4th (90%)	3rd (33%)	4th (58%)	4th (43%)	2nd (100%)
Made from natural materials	2nd (58%)	2nd (97%)	1st (50%)	2nd (75%)	3rd (71%)	2nd (100%)
Green product	1st (74%)	1st (100%)	1st (50%)	1st (92%)	1st (100%)	1st (100%)
Gives health benefits	4th (32%)	3rd (93%)	4th (25%)	3rd (67%)	2nd (86%)	4th (86%)
**********	**********	**********	**********	**********	**********	**********
Easy to use	3rd (13%)	3rd (84%)	3rd (25%)	3rd (83%)	2nd (29%)	2nd (72%)
You are familiar with product	4th (0%)	4th (32%)	n/a	n/a	4th (0%)	4th (0%)
Product has proven performance	2nd (45%)	2nd (93%)	n/a	n/a	n/a	n/a
Durable once in place	1st (61%)	1st (96%)	1st (67%)	1st (100%)	1st (71%)	1st (100%)
Does not require special training to use	n/a	n/a	n/a	n/a	2nd (29%)	3rd (58%)
**********	**********	**********			**********	**********

Factor	Specifier	Specifier	Supplier	Supplier	User	User
	Very Important	Important combined	Very Important	Important combined	Very Important	Important combined
Meets regulations, planning	1st (52%)	1st (97%)	n/a	n/a	n/a	n/a
Technical specification available	2nd (48%)	2nd (93%)	2nd (50%)	2nd (92%)	n/a	n/a
Has certification within Europe	4th (19%)	4th (77%)	3rd (25%)	3rd (83%)	n/a	n/a
Test data is available	3rd (35%)	3rd (83%)	n/a	n/a	n/a	n/a
**********	**********	**********	**********	**********	**********	**********
What it looks like	n/a	n/a	n/a	n/a	1st (14%)	1st (85%)
Wide choices e.g. colour	n/a	n/a	n/a	n/a	1st (14%)	2nd (57%)
What it feels like, touch /texture	n/a	n/a	n/a	n/a	1st (14%)	2nd (57%)
Modern not old-fashioned	n/a	n/a	n/a	n/a	4th (0%)	4th (0%)

Tables 4.17 – 4.18 further summarise the above data, giving the factors in absolute rank order, rather than within question rank order, with the percentage vote for each factor. Tables 4.15 – 4.16 compare these rankings for the UK and Sweden.

Additional Factors Cited by UK Respondents to Questionnaires

There was a free text section of the survey where respondents could set out factors that they felt were important that had not been included in the multiple choice questions. These are set out in the following sections. It was noted that some of the factors were included in the surveys, but possibly their inclusion in the free text section enabled respondents to give them more emphasis.

Additional factors cited by Specifiers

Table 4.6 lists the responses given by UK Specifiers, including the number of respondents listing each factor.

Table 4.6: List of additional factors – Specifiers

Factors	Number of responses citing this as a factor
Local availability	9
Lack of skills; training availability and cost	5
Costs and client budget	4
Client commitment, priorities, awareness	4
Issues with new materials	4
Appearance of a material	4
Technical information available and case studies	3
Embodied energy	3
Planning requirements	3
Professional judgement, wanting to influence demand and try new products; architectural image	2
Performance, consistency, buildability – fitness for purpose	2
Potential of product to be recycled in the future	1
Non-toxic, not harmful to use	1
Naturally occurring	1
Strength	1

The most cited factor was geographical availability, i.e. the proximity of production of a building material to the building site, as an influencing factor, with the emphasis on materials being locally available. A key concern was the lack of local or even UK manufacturers, and that many 'green' products have to be imported from abroad.

The next major factor cited related to the skills of builders and whether they are sympathetic to the use of a particular product. There is an issue when builders do not have the skills to use the specified products. Volume house builders do not have access to labourers with skills for alternative building methods. Training is not available and would be prohibitively expensive. Another response identified this as a big issue in terms of a skills and working knowledge shortage with many of these materials, which is gradually and slowly being addressed.

Costs are important, where products are 10 times as expensive they will not get used in sufficient volume to ever get established in the market. The client budget on a given project is a factor. Also cited in relation to the client were their commitment, priorities and preference. There were also comments that consumer awareness is increasing, even though this was still apparent in only a relatively small proportion of consumers, and the desire for environmentally benign products was becoming more mainstream.

One response stated that unfamiliar materials necessitate extra meetings with planners and prolong planning approval, another that building inspections are more straightforward with known materials. The view of another was that there was perceived to be no profit in using new materials. Another issue cited was that recent problems may have been experienced with a product from other sources or users or specifiers.

A factor, which had been included in the user survey but not in this one, cited in four responses, was what the product looks like. In particular this factor related to whether the material was visible and to non-technical issues, e.g. colour choice.

Technical advice on the use of the product is important, as are case studies and other recommendations. One responder does not mind specifying an unfamiliar product if technical information, particularly testing data, was available to show theoretical worth. This is the case even if it does not have proven track record in actual use. Another would use unfamiliar materials after first researching technical qualities to ensure compatibility with construction type and surrounding materials.

A factor that scored in the middle range of responses and perhaps should have been included in the survey was embodied energy of the material.

Of similar importance were the various requirements around the planning and inspection process. For example, external products must meet planner's requirements by conforming to the character of the local area. Increasingly environmental performance criteria require more stringent standards. One company finds that the main barrier to using natural or reclaimed materials for their houses and interiors are the certifications that the planning and building regulations require in order to sell them on the open market. Many eco products have not obtained BS certification or equivalent which they require. Buildings that are to be sold will also need to have insurance and the organisations that give the certification will only give this if the products are proven to last 40- 60 years. Many eco materials e.g. straw bales are perceived to be too inconsistent to guarantee that they will last 60 yrs or more. Similarly with cob building, even though there are cob buildings in Devon that have been there for 200 years.

In part, choice has been based on professional judgement and a desire to influence demand and test out new products. Related to this, another response cited contribution to architectural image.

One respondent stated that when specifying products they try to strike a balance between economy, performance, consistency and buildability. Similarly, another cited fitness for purpose as a factor.

Factors that were each cited in a single response are listed in the table and are linked to factors included in the survey. These include the potential of a product to be recycled many years from now; that a product should be non-toxic and not harmful to use; and should be naturally occurring whenever possible. Another factor cited was strength.

Additional factors cited by Suppliers

The factors listed below were given by separate respondents; none were given by more than one respondent. There were only five responses to this section of the survey.

- Product compatible for use by modern day skills base.
- It should give performance which compares well with existing products.
- It should satisfy the Building Regulations.
- Life cycle cost.
- The overall energy used in manufacture.
- Interior decoration products should be sustainably made, using renewable materials. Certified organic fibre can be a plus.
- In response to consumer pressure, the EU eco label and similar credentials are seen as a way to reassure the client and improve credibility.
- Availability of product.

Additional factors cited by Users

Apart from the first bullet point, none of the factors below were given by more than one respondent. There were only six responses to this section of the survey.

- The source of raw materials and the manufacturing process. Where the material is sourced and how far it has to travel to be used, local products are more attractive generally. Product should be locally grown, made or supplied
- Durability
- Insulation value
- Preservation/promotion of traditional craft skills
- Use of vernacular materials
- Aesthetics
- Sustainable
- Low impact
- Zero carbon as far as possible
- Must satisfy building regulations
- We are driven by the client's decision

Experience of UK respondents with specific crop-based construction products

UK Specifiers

Table 4.7 sets out the experience that UK Specifiers have had with individual crop-based products, e.g. sheep wool insulation, which are then summarised for the overall category, e.g. insulation.

Table 4.7: UK Specifiers' Experience of Crop-based Products
(Results expressed as percentage of respondents answering question matrix)

	Specified one or more products	Specified but was not used	Would in principle but not yet	Would not	% spoiled answers per matrix	Total % response per matrix
Sheep wool insulation	14%	4%	8%			
Hemp insulation	9%	1%	13%			
Flax insulation	4%	2%	16%			
Overall total	**27%**	**7%**	**37%**		**9%**	**80%**
Boards	17%	3%	27%			
Plasters	5%	3%	27%			
Overall total	**22%**	**6%**	**54%**		**2%**	**84%**

Hemp & lime	8%	1%	17%	1%		
Straw Bale	6%	3%	16%	1%		
Cob	5%	1%	17%	3%		
Overall total	**19%**	**5%**	**50%**	**5%**	**2%**	**81%**
Carpets	19%	2%	6%			
Linoleum	25%	3%	1%			
Paints	25%	3%				
Overall total	**69%**	**8%**	**7%**		**3%**	**87%**

Most experience was with specifying interior finishes such as paints and floor coverings. After this came insulation, with sheep wool being more specified than flax or hemp.

In all product categories a small percentage of specifiers had included crop-based products but they had not been used.

A number of specifiers stated that they would be prepared to specify crop-based insulation, boards and plasters, as well as straw bale, hemp and lime, and cob but that they had not yet done so.

It was only in relation to straw bale, hemp and lime, and cob that a small percentage of specifiers said that they would not specify these materials.

Free text comments by UK Specifiers

General comments
Responders referred to specifying natural, renewable and environmentally-friendly products whenever they can. In one response it was stated that the job does not always call for such products and there are always cost considerations to take into account. The main issue was that homes should be healthy for the environment as well as the occupiers, with health referred to in several responses and linked to natural materials. One response referred to natural materials being renewable and so less polluting, and also because they required less processing in production and disposal compared to conventional materials.

Only one response in this section was negative referring to reluctance on the clients' part because such products are perceived to be a bit hippy.

Insulation
Several responses referred to using rather than specifying natural insulations, sheep wool or hemp batts. One stated that they specified sheep wool and flax insulation regularly.

On the negative side the costs of 'green' products were said to be greater than oil-based products, so only committed green clients will go the whole way. Sheep wool was considered far too expensive for general use when there were other cheaper natural/recycled products (cellulose) available as options for insulation. It was also stated to be much more expensive than mineral wool for the same U-value.

Boards & Plasters

There were three responses; one indicating that flax-based boards and lime plasters were specified quite regularly and another that they had specified a clay/earth plaster, which may have had a crop binder. The other responses referred to using renders and lime plaster.

One specifier stated that crop based boards are starting to be used more but that the expertise to install them is limited; these skills are not generally available to builders/ contractors. Another stated that client commitment is critical in relation to specifying materials for internal walls due to cost and unusual character. It would be difficult to impose the materials as they differ so radically from the materials currently thought to be acceptable and long lasting. The skills necessary for constructing external and internal walls from these materials are not readily available. Also, that quality of construction is variable and prone to defects due to environmental conditions at the time of construction, such as too dry, too wet, too hot, or too cold.

Two responses related to costs, one stating that it is difficult to justify the cost of clay boards as they are more expensive than, and not as robust as, plasterboard. The other response stated that plasters are quite a lot more expensive and the skills to apply them limited.

Walls

One responder stated that they specified straw bale walls quite regularly. Another had also specified straw bale, which was locally farmed, for a temporary dwelling.

Four responses related to hemp and lime. One responder has been working with hemp and lime for 15 years and considered that it gave good insulation, breathes and also stores heat well. They are convinced that it is a very positive solution towards building carbon neutral buildings. Another responder had used hemp and lime. Less positively, hemp and lime is starting to be used more but the expertise to install them is limited, these skills are not generally available to builders/ contractors. Finally one specifier if given the opportunity would specify hemp and lime for a trial, on the basis that builders' lack of training and skills would not allow more.

Client commitment was stated to be critical in relation to external walls due to cost and unusual character. It would be difficult to impose the materials as they differ so radically from the materials currently thought to be acceptable and long lasting. The skills necessary for constructing external and internal walls from these materials are not readily available. Quality of construction is variable and prone to defects due to environmental conditions at the time of construction. The client's influence was referred to by another specifier, i.e. finding the right clients for using cob, hemp and straw bale is an important factor.

Referring specifically to cob, one response was that they would not normally specify cob for external walls as it is difficult to introduce insulation, but that they would do so if a way could be found. Another does not work in an area where cob is used, they considered straw unsuitable for the UK and that plaster cracking needs attention after time. Therefore, as an architect they could not guarantee a building with these products.

Floors

The six responses in relation to flooring materials were all fairly positive. There were a number of products that had been specified i.e. natural fibre carpets (wool, sisal, coir, and hemp), linoleum/marmoleum and cork flooring. Floor coverings are only

marginally more expensive and well tested. Which product is used depends on the surfaces, circumstances and the job.

Paints
Four responses were positive about paints and varnishes, etc stating that they are the type of products specified, as well as being used and sold.

One response did not consider the cost of natural paints an issue. This is because as the material element is only a small proportion of the total decorating cost, they are more readily utilised. This was countered by another who stated that natural paints are considered more expensive than standard and that for volume house builders these costs affect profit margins and are not recovered at point of sale.

Another response referred to using natural oils and waxes, and natural paints for private houses. However when these were specified for a Children's Centre they were not used due to budget cuts.

One response cited the problem as usually that cost of 'green' products is greater than oil-based products, so only committed green clients will go the whole way. Natural paints have improved in ease of use and colour ranges since the 1990's when they first used them, but they are still three times the cost of oil-based paints.

UK Suppliers

Table 4.8 sets out the experience that UK Suppliers have had with individual crop-based products, which are then summarised for the overall category.

Table 4.8: UK Suppliers' Experience of Crop-based Products
(Results expressed as percentage of number of respondents answering question matrix)

	Already stock one or more products	Would but cannot obtain supply	Never considered stocking	Would not stock	Do not stock	% spoiled answers per matrix	Total % response per matrix
Sheep wool insulation	8%		3%	3%	17%		
Hemp insulation	3%		5%	3%	14%		
Flax insulation	3%		5%	3%	14%		
Overall total	**14%**		**13%**	**9%**	**45%**	**8%**	**89%**
Boards	8%		12%	8%	17%		
Plasters	4%		12%	4%	17%		
Overall total	**12%**		**24%**	**12%**	**34%**	**8%**	**90%**

Hemp & lime	9%	3%	3%	6%	6%		
Straw Bale	3%	3%	3%	3%	6%		
Cob		3%	3%	3%	6%		
Overall total	**12%**	**9%**	**9%**	**12%**	**18%**	**9%**	**69%**
Carpets	3%	10%	3%	3%	7%		
Linoleum	13%	3%	3%	3%	3%		
Paints	20%			3%	3%		
Overall total	**36%**	**13%**	**6%**	**9%**	**13%**	**0%**	**77%**

A number of suppliers did not stock insulation products, boards and plasters, or walling materials at all.

Paints were the most stocked product by suppliers, followed by linoleum. The next group of most stocked products were sheep wool insulation, lime or hemp for hemp and lime walls, and crop-based boards.

Generally around 10% in each category would not stock these products, with a slightly larger percentage never having considered stocking these materials.

Free text comments by UK Suppliers

General comments
These were both negative, one responder stating they do not consider there to be a demand for the products listed that would provide commercial grounds for stocking them. Another that although termed 'natural', these products are unsustainable, taking energy and chemicals to make them suitable for use and that they are inferior to traditional products in use.

Insulation, Boards and Plasters, and Walls
Only one supplier commented on these products stating that people who can stock this type of item are usually big hardware stores and chains.

Floors
The same responder made the point that people who can stock such items are usually big hardware stores and chains; choice is too big to stock, but it is on display and available to order. They went on to state that rubber flooring is better than marmoleum because easier to lay. The DIYer can do it when this was not considered possible with marmoleum.

A manufacturer of most resilient types of floor coverings added that they tend to evaluate each bid based on the clients' requirements. As there is a group of specifiers and end users who prefer to use product manufactured from natural renewable raw material, the product best suited is Linoleum. However, they considered that, when end of life material, recycling and re-use are taken into account, vinyl starts to become a serious contender.

The third response was that linoleum has a specific niche market with certain specific properties which are not appropriate for large sections of the market.

Paints
The supplier of paints stated that they prefer to have them on display in the shop and order to demand.

UK Users

Table 4.9 sets out the experience that UK Users have had with individual crop-based products, which are then summarised for the overall category.

Table 4.9: UK Users' Experience of Crop-based Products
Results expressed as percentage of total possible responses, based on number of respondents answering question matrix

	Yes I already have	Yes I would in principle	Total % response per matrix
Sheep wool insulation	24%	9%	
Hemp insulation	9%	9%	
Flax insulation		9%	
Overall total	**33%**	**27%**	**60%**
Crop-based boards	14%	21%	
Crop-based plasters	28%	14%	
Overall total	**42%**	**35%**	**77%**
Hemp & lime	5%	14%	
Straw Bale	9%	19%	
Cob	5%	19%	
Overall total	**19%**	**52%**	**71%**
Natural carpets	19%		
Linoleum	14%		
Natural paints	28%	5%	
Overall total	**61%**	**5%**	**68%**

Most experience was with interior finishes, followed by boards and plasters, then insulation. Where users did not have experience of products they stated that in principle they would use them. There were no negative comments from users in relation to crop-based products.

Free text comments by UK Users

General
One response was that the user would always look to use the best performing product, providing they have confidence in the product and the supply chain and it is cost competitive.

There were two similar responses, one stating that health concerns were a reason, also style and the craft and skills implications. Similarly another considered environmental impact & health.

One respondent commented that their decisions are led by their clients and the user's recommendations.

Insulation
One responder had gone out of their way to utilise such natural products and on the whole were very happy with the result. They went on to say that the logistics of bringing in full shipping containers of Hemp Insulation from the south of Germany is an interesting consideration for contractors in the north of Scotland. The cited issues were where to put it and how to keep it dry. The other stated that the materials were good to work with and better for the finished internal environment.

Boards & Plasters, Floors and Paints
The response was that these materials were good to work with and better for the finished internal environment.

Walls
One responder stated that these materials were good to work with and better for the finished internal environment. Another responded that they use sustainable materials, mainly cob.

Swedish responses to internet surveys

The summaries of responses to the questionnaires are set out in the following pages of tables in the order that they appeared in the survey. The UK responses are in the preceding pages to this section, the Swedish responses follow.

Experience of Swedish respondents with crop-based construction products

Table 4.10 outlines the experience with crop-based construction products of the Swedish responders. Around half of Swedish Specifiers and Suppliers had experience of these products, whereas approximately one-third had no experience. This was in contrast to Swedish Users, where just over 80% had no experience of these products. Some specifiers and suppliers had advised against the use of such products.

Table 4.10: Experience of Swedish respondents in specifying, supplying or using products

Experience of specifying crop-based materials	No experience	Have included in a project.	Have recommended to others to use.	Have advised against their use.	Total Respondents
Specifiers	31%	54%	8%	8%	13/13
Experience of supplying crop-based materials.	No experience	Stock some of these products	Have recommended products to others.	Have advised against their use.	Total Respondents
Suppliers	33%	50%	0%	17%	6/7
Experience of using crop-based materials and products	No experience	Have used one or more of these products			
Users	82%	18%			11/12

Factors that affect product choice in Sweden, not specific to crop-based products

Table 4.11 sets out the ranking of factors that affect the choice of product by Swedish Specifiers, Supplies and Users. This section of the questionnaire was not specific to crop-based construction products but was designed to determine what factors are important in general in selecting all types of products, i.e. conventional as well as environmentally friendly products.

The factors have first been ranked on the basis of scoring as Very Important to the responder. However, this was not considered to give a full picture, and therefore, the Very Important and Important scores were combined to give a ranking and this usually resulted in the factor rated as first receiving more than 80% of the vote. As more than one factor could be given the same score within a question, e.g.

Important, it was difficult to separate where one factor was more important than another. Originally it had been intended to ask respondents to rank factors within a question in order of importance, i.e. 1 to 4, but this option did not appear to be available on Survey Monkey.

Table 4.11: Ranking by Swedish responders of the factors that affect product choice (Percentages are of those responding to particular question, rather than percentage of responders answering questionnaire as a whole)

Factor	Specifier Very Important	Specifier Important combined scores	Supplier Very Important	Supplier Important combined scores	User Very Important	User Important combined scores
Cost	2nd (17%)	1st (100%)	4th (0%)	1st (100%)	1st (60%)	1st (100%)
Can be stored on site and/or used in bad weather	4th (0%)	4th (58%)	n/a	n/a	4th (30%)	4th (80%)
Has proven track record	1st (67%)	2nd (84%)	2nd (25%)	3rd (75%)	3rd (40%)	2nd (90%)
Can be readily supplied	2nd (17%)	3rd (75%)	2nd (25%)	3rd (75%)	1st (60%)	2nd (90%)
There is demand to stock			1st (75%)	1st (100%)	n/a	n/a
**********	**********	**********	**********	**********	**********	**********
Made from recycled or re-claimed materials	4th (0%)	4th (50%)	4th (0%)	3rd (75%)	3rd (10%)	4th (40%)
Made from natural materials	2nd (42%)	3rd (75%)	2nd (50%)	3rd (75%)	3rd (10%)	3rd (80%)
Good for environment /green product	3rd (25%)	2nd (92%)	3rd (25%)	1st (100%)	2nd (50%)	1st (100%)
Will give health benefits	1st (58%)	1st (100%)	1st (75%)	1st (100%)	1st (80%)	1st (100%)
**********	**********	**********	**********	**********	**********	**********
Easy to use	3rd (9%)	1st (100%)	1st (75%)	1st (100%)	n/a	n/a
Product you are familiar with	3rd (9%)	4th (45%)	n/a	n/a	n/a	n/a
Proven performance	2nd (45%)	3rd (81%)	n/a	n/a	n/a	n/a
Durable once in place	1st (82%)	2nd (91%)	1st (75%)	1st (100%)	n/a	n/a
**********	**********	**********	**********	**********	**********	**********

Factor	Specifier	Specifier	Supplier	Supplier	User	User
	Very Important	Combined important	Very Important	Combined important	Very Important	Combined important
Meets regulations or planning requirements	2nd (45%)	2nd (90%)	n/a	n/a	n/a	n/a
Technical specification available	1st (73%)	1st (100%)	3rd (25%)	3rd (75%)	n/a	n/a
Certified within Europe	4th (18%)	4th (54%)	3rd (25%)	4th (25%)	n/a	n/a
Test data available	2nd (45%)	3rd (72%)	n/a	n/a	n/a	n/a
**********	**********	**********	**********	**********	**********	**********
What it looks like	n/a	n/a	n/a	n/a	1st (30%)	1st (80%)
Wide choice e.g. colour	n/a	n/a	n/a	n/a	3rd (20%)	2nd (70%)
What it feels like, touch/texture	n/a	n/a	n/a	n/a	1st (30%)	2nd (70%)
Modern not old-fashioned	n/a	n/a	n/a	n/a	4th (10%)	4th (40%)

Tables 4.19 – 4.20 further summarise the above data, giving the factors in absolute rank order, rather than within question rank order, with the percentage vote for each factor. Tables 4.15 – 4.16 compare these rankings for the UK and Sweden.

Additional Factors Cited by Swedish Respondents to Questionnaires

Additional factors cited by Specifiers

The response rate from Sweden was lower than from the UK, with only three specifiers commenting in the free text section.

One respondent had 33 years of experience based on their own business and with the knowledge of refurbishing buildings of cultural interest and churches, as well as other buildings in new production. Their view was that natural materials must meet standards to be called environmental. As a response to the multiple choice questions it was stated that the material being durable was of no relevance. In order to meet the requirements for durability the outer layer has to have a sacrificial layer, which can be renewed. This respondent considered that the most important thing was that materials are easy to repair. Also that they are hydroscopic, i.e. they can take up and release moisture in steam phase, a factor that is also important for compound materials in walls. They concluded that using environmental materials requires a whole new way of thinking that differs from what the modern building industry (short term) stands for.

A second responder stated that a specifier must find a client that is open to the arguments. Clients may want crop based construction materials and ecological

solutions in the beginning but they usually change their minds if there is any uncertainty to the products. This especially holds true when it comes to decisions that change habits and impact their wallet. They go on to state that the established companies' marketing and PR is so strong that new materials have difficulty getting on the market. A final comment that is not clear is that "too many people also connect to the progressive 60's as a defence".

The final responder referred to local traditions.

Additional factors cited by Suppliers

There were no free-text comments in this section.

Additional factors cited by Users

There were six responders in this section, two of which mentioned price, a factor already covered in the survey. Two also referred to delivery requirements, specifying short delivery times or handling costs as factors.

One referred to the lifetime of the product and whether it is easily replaceable. This was also picked up as forming stable materials. Another response was that there should not be problems in the future with products getting returned or refunds for complaints.

One responder was concerned that products meet technical requirements such as fire proof, sound insulation, safety requirements and low energy usage. They have an environmental handbook which allows them to choose the materials with the least environmental damage

Experience of Swedish respondents with specific crop-based construction products

Swedish Specifiers

Table 4.12 sets out the experience that Swedish Specifiers have had with individual crop-based products, e.g. sheep wool insulation, which are then summarised for the overall category, e.g. insulation.

Table 4.12: Swedish Specifiers' Experience of Crop-based Products
(Results expressed as percentage of total possible responses, based on number of respondents answering question matrix)

	Have specified one or more products	Specified a product but was not used	Would in principle have not yet	No would not	% spoiled answers per matrix	Total % response per matrix
Sheep wool insulation	0%	0%	17%	10%		
Hemp insulation	3%	0%	17%	10%		
Flax insulation	3%	0%	13%	13%		
Overall total	**7%**	**0%**	**47%**	**33%**	**3%**	**90%**
Boards	0%	0%	30%	10%		
Plasters	0%	0%	20%	15%		
Total	**0%**	**0%**	**50%**	**25%**	**5%**	**80%**
Hemp & lime	0%	0%	17%	10%		
Straw Bale	0%	0%	20%	10%		
Cob	0%	0%	10%	13%		
Total	**0%**	**0%**	**47%**	**33%**	**0%**	**80%**
Carpets	13%	0%	10%	0%		
Linoleum	27%	0%	0%	0%		
Paints	23%	0%	3%	0%		
Total	**63%**	**0%**	**13%**	**0%**	**17%**	**93%**

The only real experience evident from the survey was with interior finishes, i.e. carpets, linoleum and paints.

There was only limited experience with insulation but responders appeared willing in principle to specify these products. This was also true for the remaining categories, i.e. boards and plasters, and wall materials; although a third responded that they would not use these three categories of materials.

Free text responses by Swedish Specifiers

There was one positive response that linoleum flooring is what the specifier often uses and likes a lot.

On the negative side a specifier stated that they try to build with organic materials as little as possible as there can be a risk of health related problems. Although they do not mind using organic surface layers.

Also negative was the statement that there must be so much evidence on the materials that it is difficult with the contact between client and customer.

Swedish Suppliers

Table 4.13 sets out the experience that Swedish Specifiers have had with individual crop-based products, which are then summarised for the overall category, e.g. insulation. There were no spoiled answers for this group.

Table 4.13: Swedish Suppliers' Experience of Crop-based Products
Results expressed as percentage of respondents answering question matrix

	Already stock one or more products	Would but cannot obtain supply	Have never thought about stocking these	No would not stock these	Do not stock product type	Total % response per matrix
Sheep wool insulation					22%	
Hemp insulation					11%	
Flax insulation	11%				11%	
Overall total	**11%**				**44%**	**55%**
Boards	11%				22%	
Plasters					11%	
Overall total	**11%**				**33%**	**44%**
Carpets			11%	11%		
Linoleum			11%	11%		
Paints			11%	11%		
Overall total			**33%**	**33%**		**66%**

Around 10% of respondents stocked insulation and boards and plasters, otherwise there was no interest in crop-based construction products.

There were no free text comments in this section.

Swedish Users

Table 4.14 sets out the experience that Swedish Users have had with individual crop-based products, which are then summarised for the overall category. There were no spoiled answers for this group.

Table 4.14: Swedish Users' Experience of Crop-based Products
Results expressed as percentage of total possible responses, based on number of respondents answering question matrix

	Yes I have	Would in principle	No would not	Total % response per matrix
Sheep wool insulation		13%	7%	
Hemp insulation		23%	3%	
Flax insulation		23%	3%	
Overall total	**0%**	**59%**	**13%**	**72%**
Boards		35%	5%	
Plasters	5%	15%	5%	
Overall total	**5%**	**50%**	**10%**	**65%**
Hemp & lime		20%	7%	
Straw Bale		20%	3%	
Cob		10%	10%	
Overall total	**0%**	**50%**	**20%**	
Carpets	10%	17%		
Linoleum	13%	10%		
Paints	7%	20%		
Overall total	**30%**	**47%**		**77%**

With this group the most direct experience was with interior finishes accounting for nearly a third of responses. However, for all categories of product there appeared to be an interest in principle. Between 10% and 20% of responders stated that they would not use these products.

Free text comments by Swedish Users

Neither respondent has had experience of these materials, although one did state that they sounded exciting.

Comparison between UK and Sweden in relation to the importance of factors

'Very Important' scores

Table 4.15 ranks factors for the UK and Sweden and for Specifiers, Suppliers and Users so that comparisons can be made across all of these groups.

Table 4.15: Product factors scoring >50% for Very Important scores – UK and Sweden

	Specifiers	**Suppliers**	**Users**
UK	▪ Good for the environment /green product ▪ Durable once in place ▪ Made from natural materials ▪ Meets regulations or planning requirements	▪ Durable once in place ▪ Proven track record ▪ Can be readily supplied when wanted	▪ Good for the environment /green product ▪ Health benefits ▪ Made from natural materials ▪ Durable once in place
Sweden	▪ Durable once in place ▪ Technical specification available ▪ Proven track record ▪ Will give health benefits	▪ Durable once in place ▪ Will give health benefits ▪ Easy to use ▪ Demand to stock product	▪ Will give health benefits ▪ Can be readily supplied when wanted ▪ Cost of product

Durability was an important factor for all UK and Swedish responder groups, except for Swedish Users. Being good for the environment appeared to be slightly more important in the UK compared to giving health benefits in Sweden. A proven track record was only a key factor for UK Suppliers and for Specifiers in Sweden, who also listed a technical specification being available.

Combined 'Very Important' and 'Important' scores

Table 4.16 provides a similar matrix but for the combined important scores.

Table 4.16: Factors scoring >90% for combined Very Important and Important– UK and Sweden

	Specifiers	Suppliers	Users
UK	▪ Good for the environment /green product ▪ Made from natural materials ▪ Meets regulations or planning requirements ▪ Durable once in place ▪ Can be readily supplied when wanted ▪ Proven track record ▪ Technical specification available ▪ Proven performance ▪ Health benefits	▪ Durable once in place ▪ Proven track record ▪ Can be readily supplied when wanted ▪ Technical specification available ▪ Good for the environment /green product	▪ Good for the environment /green product ▪ Made from natural materials ▪ Durable once in place ▪ Made from recycled materials ▪ Cost of product
Swe	▪ Technical specification available ▪ Will give health benefits ▪ Cost of product ▪ Easy to use ▪ Good for environment ▪ Durable once in place	▪ Durable once in place ▪ Good for environment /green product ▪ Easy to use ▪ Cost of product ▪ Demand to stock product ▪ Will give health benefits	▪ Good for environment /green product ▪ Will give health benefits ▪ Cost of product

UK Specifiers gave high scores to a large number of the factors, compared to other groups. Durability was important to all groups, except Swedish Users. Proven track record was important for UK Specifiers and Suppliers. Meeting legal requirements or having a technical specification appeared only to be important to Specifiers and UK Suppliers. Being good for the environment was important for all groups and in Sweden health benefits are also important, as they were to UK Specifiers. Cost was a factor for all groups in Sweden and to UK Users.

Rankings of factors with percentage scores, UK and Sweden

Tables 4.17 – 4.20 in the following pages give the rankings and percentage votes for all the factors in both the UK and Sweden.

Table 4.17: Ranking of factors based on percentages of responders scoring Very Important - UK

% Specifiers	Factor in rank order	% Suppliers	Factor in rank order	% Users	Factor in rank order
74	good for environment	67	durable once in place	100	good for environment
61	durable once in place	58	proven track record	86	health benefits
58	made from natural materials	58	can be readily supplied	71	made from natural materials
52	meets regulations /planning	58	demand to stock	71	durable once in place
48	technical specification available	50	good for environment	43	proven track record
45	proven performance	50	made from natural materials	43	can be readily supplied
42	recycled /reclaimed materials	50	technical specification available	43	recycled /reclaimed materials
39	proven track record	33	recycled /reclaimed materials	29	cost
35	can be readily supplied	25	Cost	29	easy to use
35	test data available	25	health benefits	29	does not require special training
32	health benefits	25	easy to use	14	what products looks like
26	Cost	25	certification within Europe	14	wide range of choices
19	certification within Europe			14	what products feels like
13	can be stored on site			0	can be stored on site
13	easy to use			0	user familiar with
0	familiar with			0	modern not old-fashioned

Table 4.18: Ranking of factors based on combined percentages of responders scoring Very Important and Important - UK

% Specifiers	Factor in rank order	% Suppliers	Factor in rank order	% Users	Factor in rank order
100	good for environment	100	durable once in place	100	good for environment
97	made from natural materials	100	proven track record	100	made from natural materials
97	meets regulations /planning	100	can be readily supplied	100	Durable once in place
96	durable once in place	92	technical specification available	100	made from recycled materials
96	can be readily supplied	92	good for environment /green	100	cost of product
94	proven track record	83	easy to use	86	Health benefits
93	technical specification available	83	certification within Europe	85	what products looks like
93	proven performance	83	Cost	72	can be readily supplied
93	health benefits	75	made from natural materials	72	easy to use
90	made from recycled /reclaimed materials	75	demand to stock	71	can be stored on site
90	Cost	67	health benefits	58	does not require special training
84	easy to use	58	made from recycled materials	57	proven track record
83	test data available			57	wide range of choices
77	certification within Europe			57	What products feels like
71	can be stored on site			0	user familiar with
32	familiar with			0	modern not old-fashioned

Table 4.19: Ranking of factors based on percentages of responders scoring Very Important - Sweden

% Specifiers	Factor in rank order	% Suppliers	Factor in rank order	% Users	Factor in rank order
82	durable once in place	75	durable once in place	80	health benefits
73	technical specification available	75	health benefits	60	can be readily supplied
67	proven track record	75	easy to use	60	cost of product
58	health benefits	75	demand to stock	50	good for environment
45	meets regulations /planning	50	made from natural materials	40	proven track record
45	proven performance	25	technical specification available	30	what products feels like
45	test data available	25	good for environment	30	can be stored on site
42	made from natural materials	25	certification within Europe	30	what products looks like
25	good for environment	25	proven track record	20	wide range of choices
18	certification within Europe	25	can be readily supplied	10	made from recycled /reclaimed materials
17	can be readily supplied	0	made from recycled /reclaimed materials	10	modern not old-fashioned
17	Cost	0	Cost	10	made from natural materials
9	easy to use				
9	familiar with				
0	can be stored on site				
0	made from recycled /reclaimed materials				

Table 4.20: Ranking of factors based on combined percentages of responders scoring Very Important and Important - Sweden

% Specifiers	Factor in rank order	% Suppliers	Factor in rank order	% Users	Factor in rank order
100	technical specification available	100	durable once in place	100	good for environment
100	health benefits	100	good for environment	100	health benefits
100	Cost	100	easy to use	100	cost of product
100	easy to use	100	Cost	90	can be readily supplied
92	good for environment	100	demand to stock	90	proven track record
91	durable once in place	100	health benefits	80	what products looks like
90	meets regulations /planning requirements	75	proven track record	80	made from natural materials
84	proven track record	75	can be readily supplied	80	can be stored on site
81	proven performance	75	technical specification available	70	wide range of choices
75	can be readily supplied	75	made from recycled reclaimed materials	70	what products feels like modern not old-fashioned
75	Made from natural materials	75	made from natural materials	40	made from recycled materials
72	test data available	25	certification within Europe		
58	can be stored on site				
54	certification within Europe				
50	made from recycled /reclaimed materials				
45	familiar with				

Chapter 5:

Analysis of findings and identification of barriers

Introduction

This chapter brings together the findings from the review of literature reported in Chapters 1 and 2, and the semi-structured interviews and internet survey results reported in Chapters 3 and 4. An analysis of these findings is used to identify the barriers to uptake of crop-based construction products.

It is worth noting that most crop-based materials that are used for construction products are not new. However, in most cases such traditional materials went out of use in favour of industrial materials, e.g. when bricks became readily available. In some cases they were also discredited as a result of lobbying by industries that they were in competition with, e.g. hemp and the petrochemical industry. Therefore, there has been a need to rediscover and find uses for these materials again in the context of sustainable development.

Review of methodology

The literature search and visit to NNFCC could have been considered sufficient to identify factors to use in devising a questionnaire. However, most of the reports reviewed were from 2004/5 and this study was conducted during a time of increased awareness of these products, as demonstrated by the case studies and interviews. Therefore it was important to update the information and to gain a broader perspective than that of some of the reports.

The interviews also acted to validate the NNFCC views and the findings from the literature review.

Representativeness of semi-structured interviews

As well as the semi-structured interviews contributing information to use for the internet questionnaires, they also provided evidence in their own right.

The interviews provided experience from two specifiers, five suppliers, and three users; one interviewee was both a specifier and user. This was from one specifier interview, one specifier/user interview, 3 supplier interviews, and two user interviews. Therefore the balance of interviews was in favour of suppliers and this was due to the final interview, which was with three people, all involved in supply, rather than with one person.

A possible criticism might be that all those interviewed came from the green building sector and not from the mainstream construction industry, apart from the surveyor.

However, most of those interviewed worked with the mainstream building industry or were interested in reaching that market and so were more likely to come up against the barriers and be familiar with them. Whereas those in the mainstream construction industry may not have come across these products or considered these issues, and would be less likely to give their time to a topic of little or no interest to them. For these reasons they probably would not be able to contribute to a discussion of barriers. This view appears to be borne out by the results of the Swedish internet survey.

Another issue is that the interviewees could have their own agenda and ideas of what the interview can achieve for them. This might be influenced by how widely they believe that the report might be disseminated and to whom. However, the number of interviews conducted was likely to have balanced this factor such that no single interview carried undue weight.

Response rate for internet survey

Overall response

In Table 4.1 the percentage response was expressed as a total of all the invitations sent. As there was a large number of non-delivery receipts these could be ruled out of the survey. Non-delivery can be due to a wrong address, a full mailbox or to a spam email filter, all of which mean that the intended recipient never receives the invitation. Excluding non-delivery receipts gives the following response rates:

Table 5.1: Internet survey response rates (net)

Sample Group	Numerical response	Percentage response
UK Specifiers	32/105	30%
UK Suppliers	13/65	20%
UK Users	7/24	29%
SWE Specifiers	13/114	11%
SWE Suppliers	7/45	16%
SWE Users	12/132	9%

Overall the average UK response was 26% and the response from Sweden 12%. According to Gilham at least 50% response should be expected and below 30% would be considered poor. However, this referred to a postal survey and before email became a common form of communication. The response from the internet surveys was considered acceptable in terms of modern-day internet surveys (S. Seager, pers comm., 2007), where a response of 40% would be considered high, and might be achieved if there was an incentive to respond, e.g. gifts or a chance to win a holiday. A direct marketing campaign targeted via the internet would be expected to achieve a response of no more than 0.5%. In modern work environments individuals receive a large number of emails each day and have to prioritise what they deal with, this is in contrast to when post was the only incoming pressure. In addition, spam filters and similar screening may mean that emails from unknown addresses never reach the recipient.

Within-survey response

The within-questionnaire responses appeared to indicate less familiarity with crop-based construction products in Sweden compared to the UK. This was indicated by the lowest response being to the question regarding experience with crop-based products, the crop products multiple choice questions and the associated free text question.

Of those from Sweden that did respond to the question on experience with crop-based construction products, the majority did have experience, apart from users. However, this was not to the same extent as for the UK respondents, where nearly all specifiers and users and the majority of suppliers had experience. This was against a background of the lower number of respondents from Sweden.

The response for the other sections of the questionnaire was low from Swedish respondents. This was not considered to be due to language issues as the Swedish wording had been checked by another Swedish national. This difference might be a further indication that the survey went to the mainstream construction industry in Sweden not just to the green sector.

Review of findings of internet survey

A system requiring respondents to rank factors within each question would have been preferred but was not possible due to the internet survey mechanisms. However the results do show that it has been possible to separate out the individual factors in order of importance to respondents based on percentage vote (Chapter 4, Tables 4.15 – 4.20).

UK vote

Advantages
Being good for the environment and being made from natural materials were both Very Important to specifiers and users, and being good for the environment was Important for suppliers in the combined scores. In addition users thought that health benefits were also Very Important, although this factor just dropped out of the combined scores, but became a factor for specifiers. These factors could encourage the use of crop-based products. However, for suppliers none of the issues that were Very Important to them appeared to be an advantage for crop-based products.

Barriers
However, there were Very Important factors, or Important (combined scores), that may raise issues for crop-based products, either through perception or actual difficulties.

All groups considered it Very Important that a product should be durable once in place. The suppliers also considered Very Important a proven track record and that a product could be readily supplied when wanted, and these became factors in the combined Important scores for specifiers. In addition, specifiers considered it Very Important that a product meets regulations or planning requirements. In the combined scores the availability of a technical specification became Important for specifiers and suppliers, as well as proven performance for specifiers. In the combined scores users also considered that Important factors were that a product was made from recycled or reclaimed materials, and cost was a factor.

Swedish vote

Advantages
All groups considered that a product giving health benefits was Very Important. All groups gave combined Important scores for a product being good for the environment.

Barriers
Both specifiers and suppliers considered it Very Important that a product should be durable once in place. Specifiers also rated as Very Important the availability of a technical specification and a proven track record. Suppliers considered it Very Important that there should be a demand to stock the product and that a product should be easy to use; specifiers considered ease of use to be Important only. Users considered it Very Important that the product could be readily supplied when wanted. Cost was a Very Important factor for users, and came in as combined Important for specifiers and suppliers.

Overall analysis of factors affecting uptake of crop-based materials

Factors that may favour crop-based materials

From both NNFCC and the semi-structured interviews it was considered that the uptake of these products might relate to the prevalence of the self-build market. Similarly, Planning Policy Statement 7 was said to refer to ground-breaking materials or design, and so could be considered supportive of crop-based construction products.

Key factors for specifiers and users were whether products were good for the environment or made from natural materials. This included benefits such as being renewable and requiring less processing in production and disposal, so being less polluting. Clearly crop-based products can meet these criteria.

One UK respondent stated that they specified sheep wool and flax insulation products regularly, and others specified flax-based boards or clay plasters regularly. These were also the most frequently supplied and used products after paints and flooring. Another had specified straw bale walls regularly. Similarly there were two UK users happy to use such products. Generally these materials were considered good to work with and better for the finished internal environment.

Allergy sufferers may also prefer crop-based products but in relation to interior finishes. The health benefits of a product were particularly important to UK users. May (2007) explained that breathing buildings contain materials that are vapour open structures that prevent moisture being trapped in the external shell and are hygroscopic, so as to buffer peaks and troughs of moisture. The prevalence of asthma is linked to house mites, for which ideal conditions are high humidity, above 70%. If the humidity is kept between 40 – 60%, then this will prevent humidity pockets and bacteria, viruses and mites will not thrive. Breathability of houses and materials is therefore important to health and can be achieved with crop-based construction products.

The advantages of hemp and lime are its carbon sequestration ability, as well as giving good insulation, being breathable and thermal mass properties. It has also been demonstrated to meet the relevant parts of the Building Regulations.

Paints were the products most stocked by suppliers and these were frequently specified, as well as being used and sold. One specifier did not consider the cost of natural paints an issue because the material element is only a small proportion of the total decorating cost, therefore they are more readily utilised. Also decorators who have tried these products are said to prefer them, as do users because they do not smell or contain VOC's, and have a nice finish.

Linoleum was popular with suppliers. Specifiers referred to carpets, linoleum and cork being specified, and they were considered to be only marginally more expensive than alternatives.

Barriers to uptake

The large construction companies do not use alternative products as they represent a risk for the industry in terms of costs and meeting technical requirements. The industry is risk averse due to the investment costs required and so avoid what is unfamiliar. These issues are also linked to the ability to obtain insurance or a mortgage.

Another factor within the mainstream industry might be whether an architect is prepared to compromise their design to enable use of a specific material. Linked to this would be the original customer specification, which is an area where those communities concerned about their environmental impact have required high environmental standards that go beyond the regulations. Crop-based products also need to respond to any trend towards off-site construction, and an example of this happening is Modcell with straw-bale building, e.g. the York ecoDepot.

A very important factor in interviews and the internet survey, particularly for specifiers and suppliers, was that products should be tried and tested, i.e. with proven performance and a known track record. Although many crop-based materials have a history of use, these skills were lost when today's conventional materials became prevalent. Therefore they are now considered to be new with less of a track record than more widely available conventional products.

It was also important that a product was easy to use; any requirement for special skills to install a product would be a barrier to its use. For instance crop-based boards may be beginning to be used more but an issue is that the expertise required to install them is limited, and not generally available to builders or contractors. Also the quality of construction can be affected by the environmental conditions at the time, e.g. whether it is too cold or wet.

An issue that raised much discussion was the requirements of the Building Regulations and the technical data needed to show compliance with the regulations, particularly for specifiers and suppliers. Technical specifications and data are needed to demonstrate to the satisfaction of Building Control officers that these requirements are met, particularly if a material forms part of the main structure of the building. It has taken some time to produce evidence to show that some of these materials do meet the

regulatory requirements, but that evidence is there for both straw bale and hemp and lime.

The current Building Regulations rely on tests that have been devised to work with conventional products. This is not unusual in any area of testing required by Government as it is inevitable that those manufacturers that are producing products at the time when the tests are devised will also have the facilities and expertise to conduct and therefore devise suitable tests. The tests will tend to be as low cost as possible, in conditions that are reproducible in different laboratories and that give consistent results. However, hot box tests do not necessarily give a clear picture of thermal capacity because they were developed for lightweight materials. The thermal performance of crop-based materials may not depend on a single characteristic, such as U-value, but may be more complex than that. For this reason it was suggested that changes to the Building Regulations are needed so that the criteria are more appropriate to real buildings rather than laboratory conditions.

There is currently limited testing of the finished building to check against the theoretical performance, and when this has been done the actual performance of conventional buildings has not always matched the theory. In a seminar at EcoBuild 2007, May stated that many buildings once built do not achieve the U-value they were designed to, with more than 50% failing. Also many are not airtight and they get 30 – 50% worse after 4 years (May, 2007). However, crop-based building has been shown to perform well in real conditions.

Materials have to be of an approved source or quality, with short-lived materials considered unsuitable. The latter point may be an issue of perception for crop-based products, for instance reed boards look like they may come apart easily, but *in situ* this does not happen. The Construction Products Directive 1989 provided potential to reduce barriers if a product can meet the requirements of either conforming to a national standard or gain European technical approval. The product could then be marketed Europe-wide; however the costs of achieving this might be too high for low volume crop-based products. Also the product would have to meet a UK standard to be used in the UK, data from other parts of the EU, apart from European technical approval, are not generally accepted. As a number of crop-based products are imported from elsewhere in Europe the national standard of the country of origin is unlikely to be accepted in the UK, and therefore products would need to gain the CE mark. Acceptance of certification from EU countries, i.e. another country's national standard, by planners and building control would reduce this barrier to using crop-based construction materials.

The current Code for Sustainable Homes does not specifically encourage the use of crop-based materials. It may even discourage them due to the emphasis on FSC timber and on re-used or recycled materials, whereas crop-based materials are renewable.

There were some indications that the specific materials proposed for use in a project might affect the ability to obtain planning permission. It would be important to supply the technical data to support the use of such a material in an application. A concern that was very important to specifiers was that a product should meet regulations and planning requirements. There may be difficulties for individuals trying to obtain the data necessary to convince planners and the costs may be prohibitive. There was considered to be a lack of government grants for start-up in this area, and a lack of

funding for research to produce data. In addition, it was suggested that tax breaks would encourage use of these products, e.g. reduced VAT.

A number of attempts to build sustainable housing have been associated with working on the land, i.e. on agricultural land for which development is proscribed. There were cases where planning permission had been achieved but under strict conditions. There were other cases where dwellings were built without planning permission. This raises the question of whether these events had any impact on the image of such materials, e.g. straw bale, and led to this material being refused in some instances. Such developments were dealt with piecemeal by individual local authorities and there is currently no national policy on low impact development and sustainable living in rural areas. Such a policy would not only aid those who aim to set up sustainable communities in rural areas, but also those local inhabitants who find it difficult to buy a home in their own village. In both cases the use of materials, such as crop-based construction products, would reduce the environmental impact of such housing.

In 2004 BRE reported a lack of demonstration projects for crop-based construction products. They suggested that a programme of testing and assessment as part of a demonstration project would be useful to overcome the lack of listing of some of these products as a suitable material. It would be a commercial project, but supported with additional funding for training and monitoring, together with an accelerated accreditation scheme. To some extent this has been taken on board by the market by means of iconic projects that have developed the techniques, generated data, and drawn attention to these building materials. Examples of such iconic projects are the Adnams warehouse, York ecoDepot and, currently under construction, CAT WISE.

It was suggested that Government could do more to lead by example in this area by using crop-based products in its new build and renovation projects and then publicising what it had done. The Defra and BERR websites provide limited information on the use of crops in construction in relation to recent projects and their own use of products.

There is a lack of training and continuing professional development in the construction industry, which tends to result in the use of products that individuals are familiar with. In addition, there is a lack of understanding by customers and contractors of how traditional materials work compared to conventional materials. Therefore, in order to encourage use of crop-based products, there has to be technical back-up and customer support from the supplier.

Availability of these products is another issue for the construction industry and consumers. It was suggested by NNFCC and literature references that there was some reticence of producers to scaling up production to match the rate of building, particularly in relation to niche suppliers who were reluctant to see expansion as it might destroy their market. This was not supported by the interviews, although there was reference to the problems of sourcing a product readily and on time, which was related to the difficulties of sourcing from Europe. Being able to obtain a product when wanted was considered very important by suppliers and important to specifiers. There were few UK outlets for some of these products, for example two suppliers of plant-based boards were found, which is a limited supply compared to the ready availability of plasterboard and MDF. Similarly for insulation there appeared to be two suppliers of each product type. It was easier to obtain floor coverings and paints. Carpets and linoleum have a

number of retail outlets that can be found from main supplier's websites. There are few suppliers of paints but these can be obtained via the internet and delivered.

Lack of awareness of crop-based construction products is a barrier to their uptake. NNFCC considered that there was a lack of awareness of products by the construction industry. One supplier stated that they regarded the demand for such products to be insufficient to provide commercial justification for stocking them. They are not seen in DIY stores and so consumer awareness would be low, although there might also be a lack of consumer interest as to what a product is made of. Instead, they are more likely to be influenced by their peer group and therefore by what are available in DIY stores, on television and in magazines. For conventional products companies' marketing and PR is so well-established that it can be difficult for new materials to penetrate the market.

When these products are sourced there is an issue of cost, as they are perceived to be more expensive than conventional products. Two survey respondents considered that the impact of cost was that only committed 'green' clients would remain determined to use such products. Some specific examples were also cited in the survey, for instance sheep wool was considered far too expensive for general use when there were other cheaper natural/recycled products, such as cellulose available as insulation. It was also stated to be much more expensive than mineral wool for the same U-value. One respondent stated that it was difficult to justify the cost of clay boards as they were more expensive than, and not as robust as, plasterboard. Another stated that plasters were quite a lot more expensive and the skills to apply them limited. There also seemed to be some respondents that had cost issues with paints. These would not be used by volume house builders because there would be insufficient profit margin. These have also been removed from a project specification due to budget cuts.

Therefore those who want to use these products need to be determined. Client commitment was considered critical to specifying crop-based materials for internal and external walls due to their cost and unusual character. There was a need to find the right client for straw bale or hemp and lime. One respondent thought that it would be difficult to impose such materials because they differ so radically from what is currently thought to be acceptable and long lasting.

Crop-based construction products in general have lower embodied energy, which would favour their use. During its lifetime a building currently uses more energy than is used in production of and building with construction materials. However, if lifetime energy use can be reduced then embodied energy becomes more important (May, 2007). It has been stated in various presentations that a cubic metre of concrete is responsible for emission of 0.37 tonnes of carbon dioxide (CO_2), whereas hemp and lime locks up 31 g CO_2/m^2 in a 300 mm thick wall, and 53 g in a 500 mm thick wall (Woolley, 2007). It takes only one hectare of land to produce sufficient hemp to build a house, and this is a low input crop. However, if a product has to be imported then this will increase its embodied energy. For instance hemp is grown in the UK and therefore it should be possible to source hemp insulation produced in the UK, rather than importing it from Germany.

Another way to reduce embodied energy would be to use recycled materials, and these may be preferred to crop-based products for people trying to build in an environmental manner. This was an important factor for UK users in the survey, and one supplier

stated that rubber flooring was better than marmoleum as it was easier for the DIY-er to use. Another, that although linoleum met criteria for using natural, renewable materials, at the end of life it did not meet criteria for recycling and re-use, whereas vinyl fared better. The move to construction materials derived from recycled materials is being driven by the EU. Also the Sustainable Buildings Task Group recommended to the UK Government that there should be a requirement in the Building Regulations for ten per cent or more of construction materials to be re-used, reclaimed or recycled. However, the use of renewable crop-based materials would not contribute to such targets and therefore the Government's response took account of this need to consider the wider issues with respect to sustainability.

A product's durability was an issue for many of those surveyed, being very important for specifiers, suppliers and users. During the interviews the view was expressed that there might be concerns about the longevity and strength of a crop-based product and whether it would stand up to damp and rot. Also that short guarantees on a product would not be acceptable, and would emphasise these concerns. Allied to this may be a preference for technological new solutions, whereas crop-based products may be perceived to be 'hippy'.

Material-specific issues

The interior finishes were the products that most survey respondents had experience of, after that sheep wool insulation, followed by flax or hemp insulation. In relation to paints the issues that came up in interviews were that there may be a need to become familiar with using paints and that the colour range is limited, so if a particular shade is wanted it may not be available. There was a perception also that natural carpets may be more likely to pick up dirt. One supplier stated that linoleum has a specific niche market with certain specific properties, which are not appropriate for large sections of the market.

A small percentage of specifiers had tried to include crop-based products in projects but they had not actually been used. There seemed to be interest in specifying insulation, boards and plasters, straw bale and hemp and lime, but so far those interested had not actually specified these materials. However, there was a small percentage of specifiers that definitely would not specify straw bale or hemp and lime.

An issue specific to hemp was the association with drug use, and hemp drug policing was still an issue in 2005 despite the wider acceptance of the crop in Western Europe. Attempts have been made to produce varieties with minimal or no THC (delta 9-tetra hydrocannabinol). In addition, the EU proposals on flax and hemp aid led to instability in the market. This could have led to raw material shortages had the aid package not subsequently been extended. IENICA stated that the EU legislative framework needed to support the development of crop-derived fibres by increasing awareness, so that demand was improved.

Straw bale building may have suffered because of perceptions of problems in wet conditions, as was brought out in the interviews. Also there was no specific product and users had to source bales of the right size and quality direct from farms. As already referred to there may have been an association with low impact housing and conflict with planning regimes leading to image problems. However, these barriers should be reduced by the more recent examples of this type of building. The use of ModCell means that straw sections can be constructed and rendered off-site, reducing problems

with the weather. High profile buildings such as the York ecoDepot and the Knowle West Media Centre demonstrate the success of this method and the qualities of such buildings. Knowle West and the National Trust's Footprint also have a role in educating others about the benefits of these buildings, thus increasing awareness.

Building with hemp and lime had been a variable process with the use of hydraulic limes, unless the user had a certain amount of expertise. The development of Hemcrete meant that there was a product with a more consistent performance available to a wider range of users. Historically there were several important steps in reaching this stage of development and uptake. The Haverhill housing project was an important starting point because the commitment of the architect made it happen and the houses were built. This step inspired and reassured others, as well as producing and reporting valuable data in relation to performance. Such data were useful for those wanting to use the material, although costs were an issue and this factor drove further innovation. The Adnams building was iconic because of its scale and commercial use. Key factors were the enthusiasm of the architects to use sustainable materials; the willingness of Adnams to fund research and to take on the resulting extra costs. This project also yielded important information, such as the higher costs being offset by there being no requirement for refrigeration because of the properties of the material; that the use of a block system with infill was not ideal for this product. It also set the scene for approval under the Zurich Building Guarantee Scheme, i.e. the material can be insured. The development of a spray technique for Hemcrete was important to enable it to be used by the spray concrete industry, as speed and consistency allow industrial scale application. CAT WISE will be iconic as a building and for its educational role. The role of CAT and their use of the data that had been produced over recent years in convincing local planners were important in achieving acceptance of hemp and lime. The Three Gardens project will bring this material back to housing and will demonstrate how techniques have improved since Haverhill.

Sweden

Crop-based construction products do not feature so much in Sweden compared to the UK. There is no straw bale building or hemp and lime, although there is a supplier of hemp insulation. This may be due to the availability of timber and also because new build in Sweden tends to be concrete with recycled newspaper insulation. Linseed oil-based paints and varnishes, etc are widely used as this is a legal requirement, although one that is apparently not popular with contractors. Swedish homes do not tend to have carpets, preferring wooden floors.

There is considered to be no incentive to use crop-based products, except on small or experimental scale, and Sweden does not promote growing of hemp. Sweden has a high proportion of land producing timber, i.e. 60% of land area compared to 6% for agriculture. Therefore timber is more likely to be used in construction than agricultural crops.

Sweden has similar regulations to the UK Building Regulations and these were considered not to hinder the use of alternative materials, provided the product met the functional requirements. One specifier had 33 years' of experience refurbishing historical buildings and their view was that natural materials must meet the required standards in order to be called environmental. Another that using environmental

materials requires a different way of thinking compared to that for use of conventional materials. A specifier stated that clients may look for ecological solutions, but if there is any uncertainty about the product that commitment may be lost. Another expressed this as a need for evidence to reassure the client, but this can then be difficult and time-consuming to put across.

Of the general factors influencing product choice the health benefits of a product were particularly important in Sweden. In addition, cost was very important for users and important for specifiers and suppliers. Users also required a product to be readily available when wanted, with short delivery times and handling costs being factors. Suppliers considered it very important that there should be sufficient demand to stock the product.

Review of solutions to remove barriers

An important factor for many respondents was that a product was good for the environment and crop-based products meet this criterion. However, there has been much emphasis from the EU and the UK Government on use of reclaimed or recycled materials. Therefore there is a need to emphasise the qualities of crop-based materials in that they are renewable, have low embodied energy, carbon sequestration properties and do not create waste at the end of useful life. The UK Government needs to emphasise these issues in EU negotiations. It should also amend the Code for Sustainable Homes to include renewable construction materials.

Currently use of these products has been largely by self-builders and in social housing; there is a need for them to be recognised by mainstream builders. This will require generation of technical data to demonstrate the performance of materials and products, their compliance with regulations, acceptability across the EU, and ability to meet planning requirements. The costs of generating data are high and can be difficult for importers of products, or small construction companies. Therefore, there needs to be support to produce the data and, as a condition of this support, the data should be made widely available. This will enable those wanting to specify a material, a committed customer, or a planner to access the information they need to make decisions. It will also help in gaining approval from major insurers or mortgage companies.

Individual projects can have an impact on the perception of these materials, whether these are demonstration or commercial projects. There should be financial support or incentives for iconic projects using crop-based materials, e.g. CAT WISE, as these draw attention to use of these products. Also Government should be using these materials in new build and renovation work and publicising this in the same way as other projects are publicised. However, it is important that, as well as producing a building, the maximum data is generated and made available, to increase knowledge and awareness of these products. Such projects can also act as a training opportunity for local construction companies, e.g. The Footprint in Cumbria. Application methods that can be used by mainstream construction companies will mean that use of crop-based products is easier, quicker and based on familiar techniques, e.g. ModCell or spray Hemcrete.

Alongside this is a need to review the current testing requirements for the Building Regulations. There is a need for tests at reasonable cost, that are reproducible and that reflect *in situ* performance of materials, rather than laboratory conditions. There should

also be a requirement for post-occupation monitoring of buildings to assess real performance.

It is difficult for those on low incomes to obtain housing in rural areas. The desire to live in such areas may be based on wanting to live sustainably and derive an income from the land, or because this was the area where they grew up with family based nearby. The Government should develop a national policy on low impact development and sustainable living in rural areas. This would enable development of such communities without impacting on the rural nature of these areas.

A key barrier for hemp is its association with the drug culture. The Government has a role in educating the construction industry and wider public about the properties of industrial hemp and its wide range of potential uses. It should also support use of hemp in construction in EU negotiations, in addition to its support for the agricultural crop.

Although hemp is grown in the UK, some of the construction products derived from it appear to be mainly imported, e.g. insulation. There needs to be support for start-up of production of the end products, such as reed boards and hemp insulation. This would reduce the embodied energy associated with transport.

The health benefits of crop-based construction products are very important and, although emphasised by those in the green construction industry, are not more widely known. If these benefits were more widely disseminated and understood then there would be health benefits for the population, e.g. reduced incidence of asthma. This would have wider benefits in reducing costs to the National Health Service. Uptake of these products by the mainstream construction industry would result in improved indoor air quality in our houses.

Paints and flooring products have a niche market, partly because of the perceived health benefits from their use. Other product types are less well known, although insulation is becoming better known, e.g. reference to sheep wool insulation on the B&Q website. However, crop-based insulation is competing with the recycled cellulose product, which is generally cheaper. If the larger DIY stores were persuaded to stock some of these products then they would be both more visible, increasing awareness, and more available. Provided there is a demand that can be supported by an available supply then this may also help to reduce the costs.

Current action by Government

In 2004 the Government published its strategy for non-food crops and uses. In its response to the 2-year progress report on the strategy Defra (2007) states that Government's role is facilitation of this sector as part of its work to achieve Government's sustainability goals. Defra further states that although it may set a policy framework, it is for all those involved with the industry to determine the way forward in developing this sector. In addition to energy crops, crop-based construction products are recognised as having high potential for development.

Defra is working with the NNFCC to implement a communication strategy on renewable materials to raise their profile. Defra had already funded work by the Eden Project in Cornwall. The Eden Project has had an interest in non-food crops since 1998. In

developing exhibits they had worked with ACTIN (The Alternative Crop Technology Interactive Network), the forerunner of the NNFCC. In getting the message across Eden considered it important to link the plant to the product and to get over the message about biodegradability. This could include techniques such as a physical interactive element with a message attached or linking related exhibits across the site, with up to date, accessible material aimed at the public and those with a business interest.

The Defra response recognised that Government procurement can be used to increase demand for sustainable renewable materials by helping to develop supply chains and promoting wider confidence in products. The use of renewable construction materials in new buildings and major refurbishments on the Government Estate will be increased, where they help to reduce their carbon footprint. Defra and BERR are promoting the benefits of renewable materials to those involved in developing the 2012 Olympics, Thames Gateway, etc.

Defra will continue to support targeted research and development projects aimed at demonstrating use of renewable construction materials. This will include those that might be included in the BERR Technology Programme's Sustainable Consumption and Production Innovation platform, focusing on Low Impact buildings.

Defra will also publicise the results of lifecycle work on a range of renewable construction materials and ensure that relevant products are included in the BRE Green Guide to Building specifications (new edition due 2008) by the end of 2007. At the EcoBuild conference in 2007 Defra and NNFCC were credited with funding two projects on hemp and lime, i.e. a manual (Woolley, 2007) and a translation of a life-cycle analysis into English from French (Morton, 2007).

Defra, in conjunction with other Government Departments and industry, will carry out a scoping study to set a target for use of renewable building materials in construction in England.

Defra will continue to represent UK interests at natural fibres committee discussions in Brussels and consult the industry on all CAP reform proposals in 2008.

Chapter 6:

Conclusions

Introduction

This study investigated the social and legislative barriers to the uptake of crop-based construction products in the UK and Sweden. It did this by means of a literature review, interviews and an internet survey.

Chapter 5 used the findings of this work to identify the barriers that might be preventing crop-based construction products being part of mainstream building in the UK and Sweden. The reasons are different and in Sweden relate mainly to that country being a producer of timber, with little agriculture.

The main focus of Chapter 5 was therefore on the UK industry and identifying the barriers here, as well as discussing potential solutions to reduce or remove these barriers.

Conclusions on barriers to uptake in the UK

The barriers identified as a result of this study are as follows:

1. The construction industry is risk averse due to the high investment needed and therefore resistant to new products. Also these products may not be approved for insurance or mortgage purposes.

2. Construction products need a proven performance and known track record, which cannot be demonstrated in all cases with crop-based products.

3. Products need to be easy to use, without requiring special skills or training before they can be used.

4. Technical data are required to show that a product can comply with the Building Regulations and any planning requirements. The cost of generating such data can be high, and a lot of data may be needed to satisfy requirements where a previously untested product is concerned.

5. The testing required by the Building Regulations is not designed for materials with the properties of crop-based materials, where testing reflecting in use conditions would be more useful. In addition, monitoring of *in situ* performance would demonstrate the benefits of these materials.

6. There is a perception that crop-based products will not be durable, would be easily damaged or susceptible to damp or rot. Whereas in use these are not real issues as they are not exposed to such conditions.

7. The costs of obtaining EU-wide approval or certification for the UK are prohibitive and seem unnecessary where a product already has approval in another EU Member State from where it is imported. However, in general for use in the UK, only a national approval or CE mark will be accepted.

8. The drive towards recycled construction products is likely to discourage use of renewable crop-based products. For example, the Code for Sustainable Homes does not make reference to renewable materials, but does encourage the use of FSC timber and recycled products.

9. There is an image issue with both straw and hemp, being associated with a 'hippy', non-technological culture and for hemp there is also the association with drugs.

10. Government is not leading by example by using or publicising, where it does use, such products.

11. Crop-based products are not as widely available as conventional products and there is a lack of awareness of these products by the construction industry and wider public.

12. For those committed to 'green' building the cost of crop-based products can be an issue, and other environmental alternatives will be sought. This is exacerbated by the need to import many of these products and the low-volume market.

Conclusions on potential solutions

1. The environmental benefits of crop-based construction materials should be promoted, i.e. that they are renewable, often use the by-products of agricultural production, and there are minimal end-of-life waste issues.

2. The UK Government and the EU should not disadvantage these products with their regulatory requirements, e.g. the Code for Sustainable Homes should encourage the use of renewable products.

3. The Government should develop a national policy on low impact development and sustainable living in rural areas. This would enable development of communities that do not impact on the rural nature of these areas and would support building of dwellings built from renewable materials.

4. There should be support to generate the technical data necessary for these products to gain the approvals to allow their use by the mainstream construction industry. The data generated should be made available to all those who wish to use such products or are making decisions about the use of products.

5. There should be financial support or incentives for the use of these materials in iconic projects, for example 5% VAT instead of 17.5%.

6. There should be wider use of these products on the Government Estate to develop knowledge and awareness of crop-based construction products.

7. Opportunities should be taken to involve mainstream construction companies in projects as a means of training. Alongside this there should be development of improved methods that make the use of crop-based construction products easier, more rapid and based on techniques familiar to the wider industry.

8. The testing methods used for the Building Regulations should be reviewed and appropriate, reproducible methods at reasonable cost should be developed that better reflect real buildings. There should also be more post-occupancy evaluation of buildings.

9. The Government should ensure that a positive image is promoted for industrial hemp, so as to counteract its association with drug use.

10. The health benefits of crop-based construction products, such as reduced prevalence of asthma due to improved indoor air quality, should be promoted. This could be achieved by including a mandatory category in the Health and Wellbeing section of the Code for Sustainable Homes.

11. There should be incentives for DIY stores to stock crop-based products such as paints, flooring, insulation and boards.

Crop-based products in Sweden

The situation in Sweden is quite different to that of the UK, with only 6% of land used for agricultural production, compared to 60% for timber. Therefore it is unlikely that crop-based construction products would feature in Sweden when timber is readily available.

In spite of EU support for growing of hemp this is a crop that Sweden finds hard to support for cultural reasons. This is unlikely to change because, unlike the UK, it is not trying to find alternative outlets for its agricultural output.

Health issues are very important in Sweden and this is where there is be a niche for the interior finishes. In fact linseed-based paints and linoleum are used, but, culturally, floors are not generally carpeted.

In addition, any environmental product still has to meet the regulations to be acceptable, it would not be enough to have environmental benefits.

Overall conclusions

There are a number of barriers to the uptake of crop-based construction products and none of these materials are part of the mainstream industry. Although paints and interior finishes are more well-known and used than other types of crop-based product, these cost more and are less readily available than conventional materials.

A number of the barriers relate to lack of familiarity with products and lack of track record, with limited data to prove how they perform. These can be overcome but this will rely on Government putting in place appropriate support and incentives. It will also require continuing work by the industry to generate and disseminate the data from well publicised projects. The industry will also need to continue development to improve how the materials are used, making them more accessible to the mainstream construction industry.

If the current effort continues then there is no reason why there should not be more housing based on straw bale or hemp and lime. These materials seem unlikely to completely replace conventional houses at this stage, but they do have a place in mainstream building developments. They can be used to build functional pleasant homes, with low embodied energy and requiring low energy input during lifetime use. They would have excellent internal air quality, so providing health benefits for inhabitants. If these buildings were built using crop-based interior materials, such as boards, plasters and insulation then this would make the most of these benefits.

The generated data and the increased experience of building and occupying such buildings would dispel the negative images and serve to promote the benefits, particularly those experienced by living and working in these buildings.

Improved understanding of what makes a building low in embodied energy and require less energy to run will be important in devising appropriate regulatory standards for sustainable building. These issues become increasingly important as fossil fuel reserves and other non-renewable resources are depleted.

We will also have to adapt to the increasingly unpredictable effects of climate change. Building breathable houses that can maintain an even environment and buffer the changes occurring outside, without using large amounts of energy will be important in this adaptation.

Appendix 1.1

Examples of crop-based construction products available in the UK

External Walls

The following are examples of materials that can be used to form the external walls of buildings, i.e. the main structure of the building. These crop-based materials have been used to build homes in the UK.

Also included are products that are carriers for external renders. These would not be used as the outer exterior finish, but may form the next layer after the main wall structure.

Straw bale

Jones (2005) gives the history of straw bale building as going back to settlers in Nebraska during the 1800s, who used 'waste' straw in the absence of stone or timber to build with and found that rather than being temporary structures they were very acceptable permanent homes, some of which are still used as dwellings. This type of building went out of favour in the 1940s but was revived again in the USA in the 1970's, reaching the UK in 1994. By 2004 (BRE, 2004b) there were more than 70 buildings in the UK and around 1000 new structures being built annually worldwide.

Use of straw reduces the material requirement as it acts as the building block, thermal insulation and the surface for plaster (Atkinson, 2007). It has very good insulating properties, keeping the building warm in winter and cool in summer, as well as good acoustic insulation. The walls, which are plastered with clay or lime-based plasters, are airtight but there is good vapour permeability allowing moisture to evaporate, which creates good air quality within the building. In testing straw has achieved more than adequate results for fire resistance, compression, racking and wind load. Straw bale construction can create beautiful, yet practical and comfortable homes that have a minimal impact on the environment.

Use of straw bale as a building material has traditionally been the domain of self-builders but, as will be clear from the case studies, this material is at a turning point in terms of being taken up by other parts of the construction industry. This is due to its cost-effectiveness, sustainability, ease of construction and energy efficiency (Jones, 2005). Jones estimated that to build a 3-bedroomed house using straw bale would be £4,000 cheaper than using brick and block. There is a need, by means of foundation design, weatherproof render (not waterproof) and roof design, to protect against the UK climate, in particular splash back, rain causing high humidity for long periods, and wind-driven rain. Straw bale buildings have reduced lifetime heating costs due to the insulation provided by the walls, with the typical U-value being 0.13 W/m^2K (range 0.12 – 0.31). Indoor air quality is improved, with asthmatics finding the breathable atmosphere a healthier environment.

Hemp

'Isochanve' is processed hemp, which is combined with natural hydraulic lime and can be used to build walls within formwork and timber frame (BRE, 2004b). Hemp hurds

(shives) and lime produce cement stronger than concrete and five times lighter with excellent insulation and fire-retardant properties, that is resistant to insects and mould (ADAS, 2005). It can be used in foundations, walls, floors, ceilings, interior and exterior plaster.

There is a history of combining cellulose with lime binders in construction, e.g. horsehair or straw. Traditionally hydraulic limes were used in construction as the limestone source was rarely pure and this meant that the lime competed with the shives for the available moisture. Without the appropriate technical skills users could get inconsistent results. However, traditionally users understood the product and were able to make adjustments so that it was suitable for building. Lhoist UK who are the source of lime in the Lime Technology products use pure limestone and so produce air lime. This is a more consistent product and has the purity for a good chemical set. This is used with the shive, i.e. chopped up woody material, of industrial hemp produced by Hemcore (Haynes, Lime Technology, 2007).

Hemcrete is stated to be a blend of lime-based binder, consisting of pure hydrated air lime blended with Castle Cement and other mineral and organic additives, and specially prepared hemp shives (Pritchett, CAT, 2007). These form a biocomposite that can be used in walls, floors, roof insulation and plaster. Hemcrete is not a load bearing material (Lime Technology, 2006b), it is normally cast around a timber frame, which is relied on to carry the vertical loads of the roof and upper floors down to the ground. Hemcrete does provide the necessary racking strength for the timber frame and this means the timber frame, which usually sits in the centre of the Hemcrete wall, does not need additional diagonal bracing. Hemcrete provides treatment for the protection of timbers and there is no need for additional chemical treatments, provided vapour permeable surface finishes are used, having a minimum of 100mm cover of Hemcrete on the weather side of the timber. Construction with Hemcrete is not recommended when temperatures are below 5^{o} centigrade and it needs to be protected from extremes of weather while it is setting. It also needs protection from rising dampness by sitting on a masonry plinth containing a damp-proof course, and protected from falling rain by having an adequate roof overhang at the top of the wall.

Its properties are that it has low density, with a value of approximately 330 kg/m^3 (lime content 220kg/m3; hemp content 110kg/m3), and its strength after 90 days 0.9Mpa. It has high thermal and sound insulation properties and high thermal inertia with good water vapour permeability. Thermal conductivity values range from 0.06 – 0.12 W/m^2K, the U-value for a 300 mm wall is 0.26 W/m^2K and for a 500 mm wall 0.16 W/m^2K. In the UK the temperature fluctuates and there is a dynamic relationship between the inside and outside of buildings. The latent heat of water affects thermal performance; and amplitude suppression and phase displacement dampen these temperature variations. The high vapour permeability and absorption coefficient act to buffer high humidity conditions and combat condensation. Also walls feel warm and therefore less heating is likely to be used. In addition the hemp and lime behaves like thermal mass, and its monolithic nature makes it inherently airtight. These properties all help to create comfortable healthy buildings. The product is stated to reduce greenhouse gas emissions by carbon sequestration, i.e. the drying process takes up carbon dioxide in the transition from lime to chalk (Pritchett, Lime Technology, 2007).

Lime Technology and Modcell have been working on a hemp and lime-based product (Pritchett, CAT, 2007).

External renders and plasters

NBT (Natural Building Technologies Ltd, 2005) supply clay and straw undercoat plasters for both external and internal walls.

Reed Mat (NBT, 2005) and Claytec reed mat (Construction Resources, 2006) are reed mats bound with zinc wires that are used as an external render carrier. The reed mats can easily be cut using secateurs, and can be held in place using dabs of plaster without further fastening, before the main application of plaster. Laid crosswise the matting can be used to provide a suitable level surface.

In addition, 20 mm and 50 mm Reed Boards (NBT, 2005) are insulating reed boards bound with zinc wires. They are used as an external render carrier.

Internal walls, partitions, ceilings

There are a number of crop-based products, such as boards and plasters, which are designed to be used inside building structures. These would have the same function as plasterboard, gypsum-based plasters and products such as MDF (medium density fibreboard).

The HOK Guidebook to Sustainable Design (Mendler *et* al, 2006) list agri-fibreboards as formaldehyde-free alternatives to plywood, particle board, and MDF and state that these are resource efficient compared to plywood. The use of wood in particle board, MDF and oriented strand board accounted for 1.8 million tonnes a year (BRE 2004a) and was a significant proportion of the costs. A BRE report (2004b) referred to trials on the suitability of hemp, flax and other natural fibres for use in board building products. The separated, non-fibre component of flax and hemp can be used in particle board; specific products were hemp fibres used in MDF or in orientated strand board. To be suitable as an alternative to wood, crop-based fibres would need to be competitive on cost and performance.

Straw boards

Paper-faced compressed straw panels can be used as internal wall partitions as a flexible, low-cost option (Mendler *et* al, 2006). As these are solid panels they have inherent sound-absorbing qualities. They are biodegradable and use only heat and pressure to bind the straw. BRE (2004a) referred to two commercial systems in the UK using straw. In one chopped straw was compressed into boards for use in partition walls and roofing. The other was a particle board where straw was bonded with resins.

'Stramit Board', a compressed straw board, was developed in Sweden during the 1920's (BRE 2004b). The straw was tightly packed together and compressed with metal plates while heated to 260°C, which released the natural resins and glued the strands together. There were houses built in Australia using 'Stramit' that were from this period and still in use.

Stramit Industries Ltd (2006) has been manufacturing strawboard for 50 years, producing panels with facing liners of recycled paper. They can be used as a self

supporting, non-load bearing partition system, which is strong and robust, with good fire performance, and good acoustic and thermal insulation properties.

Invotek Strawboard supplied by Plant Fibre Technology Ltd (CAT, 2007) can be used in construction and joinery, e.g. flooring, partitions, carcassing, shelving and furniture.

Flax and Hemp Boards

Stramit Industries Ltd (2006) produces CanBerra Flaxcore Panels; which have a core of flax faced with hardboard, high pressure laminate or steel. These can be used in partitioning systems for clean rooms, computer suites or hard use areas.

Greenboard is supplied by Plant Fibre Technology Ltd (CAT, 2007) and produced from the particles from the woody core of hemp. It is suitable for joinery, such as furniture production, carcassing, partition systems and kitchen work-tops.

Clay products

Hessian-backed clay boards with reed reinforcement can be used in place of conventional plaster board or as a lathe and plaster substitute. NBT (Natural Building Technologies Ltd, 2005) supplied Clay Board and Construction Resources (2006) supplied Claytec clay board. Clay boards are heavier and thicker than gypsum plasterboards and have excellent thermal and vapour diffusion properties. The boards can regulate temperature, are able to absorb moisture, and at other times, gently give it off again. Clay also absorbs odours and is an effective sound insulator.

'Claytec' clay bricks are unfired hand pressed earth bricks, made from a mixture of clay, sand and straw, that can be used for non-load bearing walls (Construction Resources, 2006). They have good acoustic properties and can help regulate temperature and humidity, making them suitable for 'breathing' constructions. A clay brick wall can be built as a partition wall using clay mortar before being covered with a clay or lime plaster.

NBT (Natural Building Technologies Ltd, 2005) supply clay and straw undercoat plasters for both external and internal walls.

Reed mats

Reed mats can be used as a plastering base, similar to oak lathes or in place of metal lathes, with both modern and traditional plasters. They are light and easy to cut and to fix to a wall or ceiling, and suitable for refurbishment or new build. Reed mats have natural resistance to water (BRE, 2004b). Reed Mat (NBT, 2005) and Claytec reed mat (Construction Resources, 2006) are reed mats bound with zinc wires, particularly for lime, gypsum or clay plaster.

NBT (2005) also supply 20 mm and 50 mm Reed Boards, insulating reed boards bound with zinc wires. They are used as an internal and external render carrier and insulation board.

Flooring and wall-coverings

As well as what might traditionally be considered to be construction products, this study also included the internal finishes. Crop-based materials are to be found in carpets and other flooring, as well as wall-coverings.

Carpets and fibre mat floor coverings

Wool with jute backing is renewable and biodegradable, with the wool fibre being durable and naturally fire resistant, which reduces the need for treatments. Sea grass, coir, jute, cotton and sisal can be used in carpets. They are renewable and biodegradable, although durability is limited and they can be difficult to clean (Mendler *et* al, 2006).

The Alternative Flooring Company (2006) and Crucial Trading (2005) supply carpets, matting and floor coverings made from natural fibres backed with natural latex, felt or jute. Jute in carpets appears tweedy, with fine fibres that are soft underfoot, making it suitable for relaxing rooms. Sisal is hardwearing flooring suitable for hallways and stairs, carpets made from coir are also durable. Also available are 100% wool carpets and rugs, and matting made of Seagrass and Mountain grass.

Brockway Carpets (2006) specialise in wool-rich carpets, stating that wool is soil-resistant, crush-resistant and warm to handle. They no longer appear to offer a 100% wool carpet, although these were available in 2006. The company claim that the backing for all of their carpets has a low environmental impact. This is due to a backing system called Envirobac, which made a substantial energy saving whilst reducing effluent to very low levels. At the end of life such carpets are suitable for energy reclamation through incineration, thus avoiding landfill.

Linoleum

Forbo Nairn Ltd (pers. comm.) is the only UK manufacturer of linoleum and is certified to BS14001, and has the Nordic environmental label 329006 for the manufacture of linoleum (Groundwork Leicester & Leicestershire, 2006). Known as Marmoleum, it is made from linseed oil, pine resin, wood flour, cork flour, and jute, with chalk and natural pigments mixed in. It is used mainly as a floor covering, but also on counters and desks. It is said to be durable, colourful and easy to clean; as well as anti-static and bactericidal. Marmoleum has no adverse health affects, when installed with solvent free adhesives, and does not emit VOC's (volatile organic compounds). At the end of its life, which can be 40 – 60 years (Mendler *et* al, 2006), it can be added to landfill refuse sites, where it is fully biodegradable and does not release harmful substances or gases such as chlorine and dioxins. When burnt in an energy-recycling incineration plant, it produces a residual calorific value that is comparable to that of coal. The amount of carbon dioxide released during incineration is stated to be roughly equivalent to that taken up by the natural raw materials during the growing phase.

Cork

Deco Cork is a linoleum/cork floating floor system that is durable, easy to maintain and of low toxicity. It has recycled content, containing post industrial cork (Mendler *et al*, 2006).

C. Olley & Sons Ltd and Siesta Cork Tile Company Ltd are suppliers of cork floor tiles, including floor and wall tiles, and underfloor insulation. Cork floor tiles come in various thicknesses and finishes and can be finished with water-based varnishes that are virtually solvent-free. Cork is light, elastic, impermeable to liquid and gases, a good insulator to heat, sound, vibrations and electricity, and resistant to attack from various pests (Groundwork Leicester & Leicestershire, 2006).

Wall coverings

The HOK Guidebook lists various materials as wall coverings, including sisal, jute, cork and cork-linoleum (Mendler *et al*, 2006).

Paints

In their report BRE (2004a) maintain that the use of plant-based starch in paint is as economic as the use of synthetic derivatives. Being plant-based the feedstock for these paints is renewable; and any leftover paint can be composted so reducing waste. Their performance was considered similar to synthetic paints, except that plant-based paints are less water resistant and take longer to dry. In emulsions plant-based starch replaces up to 25% of acrylic or vinyl monomers. In alkyd paints plant-based starch-derived polyols replace oil-derived polyols. The CIRIA report (Cripps *et* al, 2004) states that paints based on a range of natural ingredients, such as plant oils and colours, produce little or no indoor air pollutants during application or normal use.

Paint products

Auro Organic Paints Ltd was founded in Germany by Dr Herman Fischer, who in 1999 produced a water-based paint that used natural plant and mineral materials and natural methods. Auro now produce a range of products including paints, woodstains, varnishes, adhesives and solvents. Auro aim to reduce the impact to the environment through selection of raw materials, production processes and packaging, and products are not tested on animals. To produce their paints needs only a fraction of the energy used to make the synthetic alternatives. The waste products are compost and oxygen. The raw materials come from sustainable, ecological, renewable and readily available natural solvent oils which do not contribute to the greenhouse effect (Groundwork Leicester & Leicestershire, 2006).

Construction Resources Ltd supply Natural Resin Emulsion for use on wall and ceiling areas. These are areas that can account for a large proportion of a building's internal surface area. The emulsion has a very high natural content and uses natural latex as the binding medium. It is completely solvent free, with no VOC’s and due to natural ingredients there are no chemical smells. It is fully biodegradable and there is a full declaration of ingredients (Groundwork Leicester & Leicestershire, 2006).

Nutshell Natural Paints produce products derived from renewable and natural raw materials such as plant oil resins and beeswax. Nutshell produces paints, wood treatments, oils, waxes, varnishes and wood stains (Groundwork Leicester & Leicestershire, 2006).

Osmo UK Ltd produces OS Color Wood Paints, which are natural oil-based wood finishes. Unlike conventional wood finishes, which form a plastic-like film sticking to the surface, the OS oil-wax combination penetrates into the wood and nets with the wood fibres. The micro-porous finish allows the wood to breathe, moisture can evaporate and the wood stays healthy (Groundwork Leicester & Leicestershire, 2006).

Insulation

The CIRIA report (Cripps *et* al, 2004) lists a number of crop-based materials that are suitable for insulation. Where horizontal thermal insulation is needed, e.g. lofts, then hemp, flax and wool are suitable. For a vertical surface, e.g. a wall, or sloping thermal insulation then fibre batts of wool, hemp and flax, etc are suitable. Hemp and flax batts and wool are also suitable for acoustic insulation as are coconut fibre, hemp or flax boards, and straw boards. For fire protection cork, reed, compressed straw and wool are suitable, and other materials may be used if treated.

Sheep wool

'Thermafleece' by Second Nature was the only available product at the time of the BRE report (2004b) and the Defra/Dti strategy (2004). It has British Board of Agrément (BBA) certification and is made from a blend of British coarse, coloured sheep wool, from Swaledale, Herdwick, Welsh Mountain and Scottish Blackface sheep. It does not use wool from lowland sheep, as this is of a higher quality and suitable for carpets. Manufacture is by cleaning, air laying and thermal bonding processing based on a European technology, which uses 14% of the amount of embodied energy that is used in the manufacture of glass fibre insulation. It is durable, fireproof and contains an insect and moth repellent. It has an ability to absorb and release water vapour, which improves its ability to retain warmth in winter and keep cool in summer compared to glass fibre. It is easier to handle and install than the conventional product. This product is listed on the B&Q website in a section giving advice on insulating the home, although B&Q do not currently appear to stock it (B&Q 2007).

Second Nature (2005) provides the following information on Thermafleece:

Table 1.1: Thermal resistance of Thermafleece

Thickness of Thermafleece, mm	Thermal resistance
50	1.29
75	1.94
100	2.58
150	3.87
200	5.16
250	6.45

Table 1.2: Properties of Thermafleece

Energy consumption in manufacture	14.6 MJ/jg or 136MJ/m^3
Thermal conductivity	0.039W/m.k
Water absorption (@100% RH)	40%
Mould resistance	0NORM B6010
Moth/beetle proofing	Based on ISO 3998
Ignition point	560 ºC
Spread of fire	BS 5803-4

Natural Building Technologies Ltd (2006) supply sheep wool batts for use in lofts, suspended floors, ceilings and walls.

Klober Ltd manufactures and distributes Woolbloc made from sheep wool suitable for use in roofs and timber framed walls. Processing was again claimed to use 14% of the embodied energy that is used to manufacture glass fibre insulation. At the end of its useful life, Woolbloc can be recycled and is biodegradable, containing no pesticides or formaldehyde (Groundwork Leicester & Leicestershire, 2006).

Hemp

NBT (Natural Building Technologies Ltd, 2006) supply an insulation product consisting of hemp and recycled cotton. The hemp is sourced from UK farms and the cotton fibres are waste from the textile industry that would otherwise go to landfill. There is 15% polyester fibre to give the product loft and stability. It is suitable for use in external walls in timber and steel frame buildings, and for all internal insulation uses, i.e. lofts, suspended floors, walls and roofs.

Plant Fibre Technology, Bangor (Newman, CAT, 2007) supplies Isonat insulation in the form of batts and rolls suitable for walls and roofs. It is manufactured in France from hemp grown on UK farms and waste cotton fibres from the French textile industry. It also contains 15% polyester fibres to give loft and stability. The thermal conductivity is 0.039 W/m.K, density 35 kg/m^3 and water vapour transmission is 4381 mg/(m^2.hPa) so has the product is breathable. It has Euroclass E rating for fire protection but in the UK is required to have a fire retardant added, and has excellent acoustic properties. It is easy to install, although not to cut, and does not irritate skin, eyes or respiratory tract. It is durable as it does not compress and is not attractive to insects or rodents because it is cellulose. However, transport during importation is an issue, as is inclusion of the polyester fibre, which accounts for 30% of the product's carbon footprint. It cannot be endorsed under the Energy Saving Trust product endorsement scheme because products have to contain mineral fibre to be included. However, it is still possible to get a grant for using this as insulation. Increasing demand is leading to reduced cost and increased interest from mainstream installers; this is in contrast to increasing costs for conventional products. The product is mostly sold to self builders and the least amount to volume house builders, the market being as follows: Self Build>Housing Associations>Small to Medium Property Developers>Public Sector>DIY>Volume House Builders.

The B&Q website (2007) refers to Breathe Natural Hemp Insulation in its DIY section on home insulation. The product is made from British-grown hemp plants and is naturally

breathable, absorbing and releasing moisture so improving insulation properties. It is stated to be ideal for topping up insulation and is available in a 75 x 375 x 1200mm 8-pack. However, the product did not appear to be available online or in stores according to the website.

Flax

Flax is used in roof insulation and there are various products in Europe: 'Heraflax' (Germany), 'Isolina' (Finland) and 'Natilin' (France). NBT Ltd (2005) supply 'Natalin' a flax-based insulation that comes as a roll for use in lofts, suspended floors and walls, or as batts for ceilings and walls. Heraklith UK, a division of the company RHI AG, is a supplier to the European building materials market of a range of products including insulating materials made of flax, manufactured at 14 production sites in 8 countries (Groundwork Leicester & Leicestershire, 2006). Heraflax insulation quilt is manufactured from natural flax (linen) fibres using the shorter fibres unsuitable for linen production. The fibres are interwoven with polyester fibre (approximately 1%) providing bulk and compactness. Heraflax achieves a thermal conductivity of 0.042 W/m^2K and is hygroscopic taking up and releasing moisture naturally. Heraflax is pleasant and soft to the touch and is resistant to insects and vermin without further treatment.

Cork

Euroroof Ltd produce Korklite Flat Roof Thermal Insulation System made from natural cork granules, steam and pressure bonded into boards using its own natural resins. For flat roofing it provides a fully bonded roofing system for maximum resistance to wind uplift, which is lightweight with high insulation value, enabling thinner boards to be used. Siesta Cork Tile Co. Ltd's product range includes underfloor insulation (Groundwork Leicester & Leicestershire, 2006).

Appendix 1.2

Ecological building in Sweden

From a report prepared by Carin Breitholtz (2006)

History

From the 1700's until the beginning of the 1900's peat was the most commonly used roof material in Sweden. The underlying waterproof material under the peat consisted mainly of birch bark; however, straw and reed have also been used. Straw roofs were very common in the southern parts of Sweden.

As the production of wood timber became a growing export the use of sawdust and cutter shavings became popular for insulation. In the 1940´s straw boards dominated the market. From the beginning of the 1950's mineral wool and glass fibre became the most prominent used material.

Modern building in Sweden

Most houses in Sweden are now built with concrete and insulated, generally with recycled newspaper. The most prominent builders building with ecological materials in Sweden are TEEG-hus and Eko-hus, who stated that their prices were nearly the same as normal house building prices. Kretsloppsårdet is an organisation dealing with environmental issues that aims to eliminate the harmful materials rather than to use alternatives. There are smaller companies, e.g. Öhmans in Ljusdal, which use natural materials, in both new buildings and renovations. There are also some enthusiasts who use older building works on a more traditional basis. There is no support given in Sweden to promote the usage of flax, hemp, etc.

Hemp and jute

A company (www.nordicnaturfibre.se) sells hemp insulation for walls and roof spaces, preferably for use in wood houses, in renovation of old houses and as sound insulation between walls and floors. Hemp shavings are also used for thermal and sound insulation.

In the Swedish building tradition jute has been used for inner sealing and as inner frame works.

Linseed

In Sweden it became common to use linseed oil in the beginning of the 1700's and by the end of the 1700's it was the most popular product used. Linseed oil was used on everything from furniture, woodwork, wood roofs and tapestries. In the early 1900's modern colours based on latex and acrylic became more prominent. However, in recent years interest in using linseed oil paints has grown. Today linseed oil can be used on the exterior of buildings by mixing together boiled linseed and pigments.

Paints

The Swedish insurance company Folksam conducted tests on colour finishes to show how durable the colours were after 7-8 years (Appendix 1.2). Folksam's tests revealed that mildew is a common problem with all colours on the Swedish market today. However, colours without mildew had problems with cracking and flaking. Some people claimed that the use of these new environmental colours has resulted in more mildew, and in more frequent re-painting of houses.

Information from interviews

In an interview a representative of the Swedish Farmers Union was asked why construction companies do not use crop-based materials in their buildings. This was not seen as a logical step when Sweden has so much wood. Only 6% of the area of Sweden is used for agriculture, on which mainly wheat, rye and oilseed rape are grown, and 60% of the area is trees. Flax is also grown on a small scale but it is only used for linseed oil in colours.

Hemp is also grown on a small scale; mainly for clothing fibres for traditional clothing. However, in Sweden they have always looked down upon people who take drugs. Even though the industrial hemp could not be smoked, most people probably thought it could. The government has been very against hemp, and even though Sweden has a long tradition in using the material in both buildings and clothing it seemed unlikely to be on the market in the near future.

In an interview with PEAB, a construction company, it was stated that they mainly use wood or concrete and that the most common trend in building is "funkis hus", made from concrete. Also that wood housing is not so common in new buildings; wood is mainly used for the interior. The company does use environmentally friendly paints, because that is the law now. They mainly use linseed oil based paints, although some contractors argue that these colours are more harmful than the old paints with arsenic. Today they have to repaint houses every seven years, in comparison to every 12th year before.

Appendix 1.3

Table 1.3: Results of tests by Swedish insurance company on durability of colour finishes

Producer	Colour	Colour kind	Mould	cracks	Peeling	grade	
Nordsjö	Tinova Oljetäckfärg	Acrylic oil					
Alcro	Nya Rödfärg	Waterbourne oil colour					Good
Tikkurila	Teho Oljefärg	Acrylic oil					
Engwall o. Claesson	Lasol Akrylat	Acrylate					Good
Caparol	Fasadakrylat	Acrylate					Good
Liwa	Uteakrylat	Acrylate					Good
Nordsjö	Tinova V Täckfärg	Acrylate					Good
Nordsjö	Tinova V Täcklasyr	Acrylate					Good
Teknos Tranemo	Visa Fasad	Acrylic oil					
Centrum för Byggnadsvård	Uula Linoljefärg	Linseed oil					Good
Engwall o. Claesson	Lasol Linoljefärg	Linseed oil					Good
Alcro	Målarfärg	Acrylic oil					
Caparol	Alkydoljefärg	Acrylic oil					
Göranssons	Äkta Falu Rödfärg	Mud/slime		All colours of this kind crack and peel, which is a normal behaviour of these kinds of paint.			Good
LIAB	Äkta Falu Rödfärg	Mud/slime					Good
Rötmotaverken	Äkta Falu Rödfärg	Mud/slime					Good
Stora Kopparberg	Äkta Falu Rödfärg	Mud/slime					Good
Teknos	Äkta Falu Rödfärg	Mud/slime					Good
Vadstena Färg	Äkta Falu Rödfärg	Mud/slime					Good
Jotun	Demidekk Täckfärg	Acrylate					
Liwell Kemi	Uteakrylat	Acrylate					
Jotun	Demidekk Optimal	Acrylate					
Teknos Tranemo	Äkta Linoljefärg	Linseed oil					

Tikkurila	Lin Linoljefärg	Linseed oil					
Norrön	Husfärg	Acrylic oil					
Alcro	Stugfärg	Acrylate					
Flügger	Exteriör Alkyd Emulsionsfärg	Waterbourne oil colour					
Flügger	Desko Primolin	Acrylic oil					
Jotun	Drygolin	Acrylic oil					
Wibo	Väderö Slamoljefärg	Waterbourne oil colour					
Engwall o. Claesson	Lasol Fasad Matt	Waterbourne oil colour					
Beckers	Tradition Linoljefärg	Linseed oil					
Liwa	Superdäck	Akrylat					
Fönsterhantverkarna	Linoljefärg	Linseed oil					
Gunnar Ottossons Färgmakeri	Linoljefärg	Linseed oil					
Kulturhantverkarna	Linoljefärg	Linseed oil					
Nordsjö	Tinova V Lasur	Waterbourne oil colour					
Nordsjö	Linoljefärg för utomhusbruk	Linseed oil					
Wibo	Wibo Gammaldags Linoljefärg	Linseed oil					
Alcro	Front V	Waterbourne oil colour					

Key

Mildew	Cracking	Peeling/flaking
No growth (0)	Nothing wrong (0)	No flaking (0)
	Some faults (1)	Some flaking (1)
Some growth (1)	More faults (2)	More flaking (2)
Clear growth (2)	Too much (3)	Too much(3)
Profound growth (3)	Profound cracking (4)	Profound flaking (4)
Massive growth (4)	Massive cracking (5)	15 % flaked surface(5)

Appendix 2.1

Requirements of the Building Regulations relevant to crop-based construction products

Approved Document A – Structure: 1994 Edition.
Safety in this case depends partly on the properties of materials, but also on loading, design and construction.

Approved Document B – Fire Safety: 2000 Edition.
Amendments 2002 to Approved Document B – Fire Safety.
Materials used for internal linings of a building should have a low rate of surface flame spread. Structural, loadbearing elements should be capable of withstanding the effects of a fire for an appropriate period without loss of stability. External walls should be constructed so that the risk of ignition from an external source and spread of fire over their surfaces is restricted.

Approved Document C – Site preparation and resistance to moisture: 1992 Edition.
Buildings should be safeguarded from the adverse effects of vegetable matter.

Approved Document D – Toxic Substances: amended 1992.
Fumes given off by insulating materials should not be allowed to penetrate occupied parts of buildings to an extent where they could become a health risk.

Approved Document E – Resistance to the passage of sound: 2003 Edition.
Dwellings shall be designed so that noise from an adjoining dwelling, or within the dwelling, does not affect the health of occupants and will allow them to sleep, rest and engage in normal activities in satisfactory conditions. Suitable sound absorbing material shall be used in domestic dwellings to restrict transmission of echoes.

Approved Document F – Ventilation: 1995 Edition.
Ventilation shall be capable of restricting the accumulation of moisture and pollutants originating within a building.

Approved Document L1 – Conservation of fuel and power in dwellings: 2002 Edition.
Approved Document L2 – Conservation of fuel and power in buildings other than dwellings: 2002 Edition.
Reasonable provision is made for the conservation of fuel and power by limiting heat gains and losses through thermal elements and other parts of the building fabric.

Approved Document to support Regulation 7 – materials and workmanship: 1999 Edition.
Schedule 1 of the Building Regulations contains a list of requirements for all new building work, i.e. putting up a new building or extending or altering an existing building. Any building work subject to the regulations should be carried out with proper materials. Provided the materials are from an approved source and are of approved quality, e.g. CE mark, then the choice should be unlimited. The exceptions are short lived materials and unsuitable materials, where local authority can reject the plans, or fix a period in which the materials must be removed, or restrict the use of the building. Short lived materials are those that in the absence of special care are liable to rapid deterioration. Unsuitable materials are those defined as unsuitable by the Secretary of State.

Appendix 2.2

Legislation in Sweden

From a report prepared by Carin Breitholtz (2006)

Laws governing the growing of hemp and flax

The Swedish and EU law have come into conflict regarding farming of hemp. Previously all applications to farm hemp have, in consultation with the Swedish Narcotics Agency, been turned down. All growing of hemp has been forbidden in Sweden since the 1960´s.

In a court case in Uppsala, in December 2000, the Pharmaceutical Agency approved the growing of long-fibre hemp as the courts had concluded that there was no need for permission to grow this sort of hemp. The EU, in a case on 16 January 2003 stated that a Member state cannot hinder their inhabitants from getting support which is given in the EU-system, by prohibiting all growing of industrial hemp. As farming of hemp for fibre usage was entitled to support, this farming was therefore permitted in Sweden.

The European Commission had also extended support to hemp grown for industrial usage other than usage for fibres. This change meant that hemp would be entitled to "gårdsstöd" (farm support) and would be permitted to be grown in Sweden. In Sweden it is a requirement to apply for gårdsstöd to grow hemp, otherwise it would be considered as a crime against the law on Narcotics. To do this the grower has to contact the Agricultural Agency before April 15th. If the grower does not fulfil the requirements, e.g. lacking a proper contract; their gårdsstöd will be affected. The varieties allowed to be grown are specified and the highest allowable value of THC is 0.20 %. The hemp has to be cut after the seeds are made or ten days after the hemp has blossomed.

The Swedish Government will be reviewing its position on the issue of hemp and flax and the Common Agricultural Policy to come to a conclusion by the time the current period of support ends, i.e. by 2008/2009.

Information from the Swedish Government

In Sweden the person in charge of building must make sure that buildings fulfil the technical requirements. These requirements can be found in article 2§ of the law on technical issues in buildings BVL (1994:847), and is as follows:

2 § Buildings which are to be built or changed shall, under the conditions of normal maintenance, under a reasonable economic lifespan fulfil the technical standards concerning:
1. Strength, and support,
2. Safety in case of a fire,
3. Safety with respect to hygiene, heath and the environment,
4. Safety in usage,
5. Safety against noise,
6. Energy and warmth insulation,
7. Be suitable for its end usage,

8. Accessable and usable for people with reduced movement- and orientating abilities and
9. Economic with water and waste.

The above requirements apply with the consideration attributes in chapter 3 10-14 §§ in the plan and building law (1987:10).

These rules can be found in Boverket's Building Rules (BBR) and Boverket's Construction Rules (BKR). The legal text can be found on www.lagrummet.se and the building rules on www.boverket.se, both sites have sections in English.

The building rules in Sweden, the rules of Boverket (referred to above), are based on function, i.e. they state how the finished products should work in the sense of damp, fire, and energy. There is nothing hindering the use of alternative material or technical solutions, as long as these requirements are fulfilled. However, in the opinion of the Swedish government there is currently no incentive for companies to use alternative building materials, i.e. such as crop-based construction products.

Appendix 3.1

Figure 3.1: Factors affecting uptake: derived from conversations with NNFCC staff

Legislative factors ▪ Do materials affect the ability to gain planning permission? ▪ Technical specification requirements under the Building Regulations. ▪ Difficulties for individuals in obtaining the necessary technical data. ▪ Fire regulation/safety requirements. ▪ Regulatory drivers.	**Consumer factors** ▪ No consideration or concern by consumers as to what a product consists of. ▪ Attitude of peer group. ▪ Costs. ▪ Availability. ▪ Influence of self-build – does uptake of products go with prevalence of this? ▪ What is the current demand? ▪ At what frequency are materials in a building replaced and what are the influences on the choice of materials, e.g. carpet vs wood floor?
Construction industry factors ▪ Ease of use of materials. ▪ Do products require particular skills to install in order to be functional? ▪ U-values on insulation. ▪ Industry awareness. ▪ Costs. ▪ Availability. ▪ Big builders not in the loop for alternative products. ▪ Willingness of architects to compromise their design to bring in materials. ▪ Risk for industry – cost, meeting technical requirements. ▪ What is the influence of tender specification? ▪ What is the influence of the trend to offsite construction?	**Producer/Retailer factors** ▪ Producers/retailers – control they have over the market. ▪ Reticence by producers. ▪ Scaling up production to match the rate of building. ▪ Niche suppliers reluctant to see expansion as it will destroy their market. ▪ Mechanisms to displace conventional materials. ▪ Influence of DIY market.

Appendix 3.2

PRE-PILOT QUESTIONNAIRE

Introduction

I am an MSc student and currently doing research for my thesis. I am investigating why there are not more crop-based products used in construction and renovation of buildings.

I would like to talk to you about this as part of my developing a written questionnaire that will be sent to a larger sample of people as part of my original research on the topic.

Would you be prepared to have a telephone conversation with me on this topic to help me to understand what factors might influence the use of these products. I have got your contact details from your website/business card/etc and understand that your organisation might have had some experience of these types of products. I would like to tape the conversation so that I can focus on what you are saying rather than trying to take notes while talking, would you be happy to allow that? I can give you further details about myself if that would help, or in case you want to contact me with further information. I would like to limit our time to 20 minutes.

Thank you for your help and time.

Questions

1. What do you understand by the term crop-based products used in construction? [***Give a definition if understanding is not clear***]

Examples are hemp and lime structural walls or straw bales; sheeps wool insulation, or hemp/flax based insulation; clay-reed boards; plant-based paints; linoleum; jute or sisal carpets, etc.

2. Can you tell me about your experience of the use of such materials in your home or in buildings that you have been associated with the design or construction of?

3. What influenced the choice of materials and to what extent do you know what components are made of or their properties?

4. Were crop-based materials considered and rejected for any reason? What were the reasons for choosing them where they were chosen?

5. Were there any issues in relation to planning permission or building regulations in relation to this project, in particular in relation to materials?

6. Have you needed to obtain technical data on any materials for any purpose – if so why was it needed and was it easy to find and obtain?

7. Did you find it easy to source the materials you wanted to use? Did you change a specification because something was difficult to obtain or for any other reason?

8. How did suppliers, builders, architects, designers influence your choice of materials.

9. What were people's attitudes or reactions to your choice of materials?

Appendix 3.3

QUESTIONNAIRE ON SOCIAL AND LEGISLATIVE FACTORS INFLUENCING CHOICE OF BUILDING MATERIALS AND INTERIOR FINISHES

Personal information:
This will not be included in analysis, but is needed in case there is a need to follow up on any information.

Name:

Contact telephone number:

Email address:

Questions:

This questionnaire is concerned with the factors that affect the uptake of crop-based building materials and interior finishes. Therefore some of the questions will be specific to these types of materials; other questions will be more general.

Q1: What would you classify yourself as; using the categories below, tick which one most applies?

- Architect ☐
- Builder ☐
- Building consultant ☐
- Building surveyor ☐
- Ceiling contractor ☐
- Construction contractor ☐
- Design consultant ☐
- DIY enthusiast ☐
- Floor layer/supplier ☐
- Householder ☐
- Insulation installer/consultant ☐
- Interior designer ☐
- Painter & decorator ☐
- Plasterer, screeder, dry liner contractor ☐
- Self-builder ☐
- Supplier Trade ☐
- Supplier Retail ☐
- Other – please specify ☐

Additional information _____

Q2: Which of the following products would you consider to be crop-based (Please tick all that apply):

Sheep's wool insulation □	Flax insulation slabs □	Hemp insulation □
Reed mats and boards □	Clay plasters □	Unfired clay bricks □
Agri-fibre board □	Straw panel/board □	Flax board □
Hemp and lime walls □	Straw bale wall □	Cob walls □
Jute carpet/rug □	100% wool carpet □	Sisal carpet/rug □
Wool/sisal carpet □		
Cork wall/floor tile □	Marmoleum □	Linoleum □
Natural paints □	Natural wood stain □	Natural floor wax □

Q3: Do you have experience of using, recommending or specifying any of the above (or any other) crop-based materials? Have you ever advised, or been advised, against use of any such products? Please tick all that apply:

Used □
Recommended □
Specification □
Advised against □
Other experience, please specify □
No experience □

Where such products have been used/recommended/specified, or where they have been advised against, please give product details and brief description of circumstances below:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Q4: What influences your choice of building products or interior finishes? Please list in order of priority for you – 1 for the most important and 2, 3, etc in decreasing order of importance:

Material is recycled or re-used	□
Material is natural	□
Material is good environmentally/'green' product	□
What the material looks like	□
Material will give health benefits	□
Cost of materials	□
Wide choice available for material	□
Recommendation by others	□
Material has proven track record	□
Whatever the contractor uses	□

Appendix 4.1:

Semi-structured interview transcripts

Interviewee PPQ1

Interviewee PPQ1 was an architect with nearly 40 years experience, which includes both the commercial and domestic sectors. The interviewee described their experience of crop-based construction products as limited.

An issue in building, whether building a single house, office or other buildings is the high cost and it is unlikely that the parties involved will not have to borrow some or all of the funding necessary. A building project is complex with many elements and things can go wrong, if they do then someone is responsible. Those lending money to such a project wish to eliminate risk as far as possible and if necessary would sue to get their money back. Thus parties involved will have indemnity insurance, but the consequence of claiming would be that premiums go up. The result of this is that all involved in a building project are linked into a conservative loop that reduces financial risk. Therefore it is unlikely in this climate that they would step outside normal practice to try something new, as it would be in no-one's interest. So it would be almost impossible to effect change without legislation.

An informed client, whether an individual or a company are in the minority, would be prepared to take some risk in using an unknown material or technology. However, they have limited budgets and could be paying 25% or more above standard prices. Therefore, to meet their commitment to build to an ecological standard they have to make choices in order to meet a budget.

In relation to the performance of materials the important issues are that a material is one that the individual knows well and how to handle, what it can be used with, they can get from supplier on time and it will not run out, and whether it is fit for purpose.

Whatever we use to build it will have an impact on the environment and there is a need to minimise this. Embodied energy is a useful measure of environmental impact as it boils down choice of materials to clear parameters.

In response to a question about the value of demonstration projects the view was put forward that these are of limited effect. More effective would be performance criteria for ecological materials for comparison with the alternatives. In discussing this point further the pros and cons of various materials were considered.

Recycled paper (not the subject of this thesis) is delivered on time, the installation method is tried and tested, it is easy to install and can be blown into cavity walls, there is no problem in storing it on a wet, rainy site for a month, and information on the product is available from the company.

Sheep wool costs more and is difficult to install. There are also concerns that the sheep market is volatile, the product was introduced when wool in the UK was of low value, and what would happen if the bottom went out of the market. Therefore, sheep wool may not hold its price over a decade, whereas 'Warmcell' more likely would. Sheep wool was

considered for use in a house as it looked great but the cost of both materials and labour to install was considered too high.

Flax batts are easy to use where there is plenty of wall area with structures at the right intervals to fit the batts. However, they need cutting where there is not an exact fit.

Hemp is a great material with a lot of uses, it feels great, and is an unmined resource. However, it has an image problem because of drug use and has had a bad name since the 1600's. This is not just in terms of individuals but also at United Nations and individual nation level there are policies against growing hemp. At present, in terms of being specified by an architect it is not good enough.

With respect to planning issues it was stated that the use and appearance of the building in the proposed location and the impact of that was the key issue, rather than the building materials used in its construction.

The Building Regulations are a different matter; there the issue is what materials are being used and what their performance is. This is positive in that the regulations are the proactive arm of government legislation and are doing a good job in driving standards, e.g. in thermal performance. In the last 12 months there has been a real shift in people's understanding of the environmental issues emphasised by high profile people publicly stating there is a problem. This will translate to government action and probably lead to more requirements both in the UK. Internationally there are individual agreements being signed where international agreements have not yet been reached.

It is difficult to relate the Building Regulations standards to a specific material that is less damaging. For example, performance criteria are specified, but that does not necessarily rule out products such as those that are oil-based. What might cause a shift to crop-based alternatives is if the oil-based products become more expensive over the next decade, as cost is an issue.

Nowadays everything on the market needs test data. BRE are a good source of information and certification of products, there are also European standards for products. Any industry in the beginning faces large costs to get something to market including testing. Government grants for start-up of ecological products would be helpful in getting to market.

An anecdotal example of building with straw bale was cited. Two weeks of torrential rain caused building work to stop, whereas with most materials it is possible to keep building in the rain. PPQ1 would not personally specify straw bale or rammed earth because of the issues of stopping work in the rain. The costs of this would be prohibitive because the builders would still have to be paid. After the building was built and rendered mites came out of the straw and into the house, this apparently was not uncommon and straw was sourced to the required standard.

Generally clients come to an architect with a specific idea. Then the architect usually has to achieve a compromise to meet the budget and reach agreement on what has to be taken out of the specification. In the case of sustainable communities, e.g. Findhorn, the client may require an ecological specification that is beyond the current Building Regulations minimum, and these regulations are only gradually catching up with such specifications.

Sourcing of materials has to be easy and in specifying a material an architect has to know the implications of that in terms of sourcing the material. It is not enough just to have read about a material, a specifier needs to know how it performs, what is its availability, extensive technical back-up and that it has been in use for 10 years or more. Houses last for about 200 years and therefore elemental components need to have similar longevity. A short guarantee for a construction material does not instil confidence in the product.

Over the last 100 years we have been reliant on petrochemical-based products, e.g. plastics. Crop-based products will come into their own with changing costs in petrochemicals and availability. There has been a 40% increase in energy costs in recent years and this will have an impact on the construction industry as the current status quo is not sustainable. There will be a whole range of uses of natural products that have not been considered yet.

Interviewee PPQ2

Interviewee PPQ2 was an MSc student who had recent experience of using 'natural' paints. The interview took place at the student's flat, which had recently been painted with three brands of 'natural paints'.

First I was shown the results that PPQ2 was not happy with. This was because there were brush strokes visible where the ceiling had been painted. A roller had been used on the wall and this resulted in a textured finish. The paint used was 'Auro Matt Emulsion' in white. Towards the end of the tub it was getting a bit thick and needed diluting with water, but this was not done. It had been too runny to be ideal for a roller earlier on. It was not gel-like as 'Dulux'-type paints, which were easier to use.

The next paint was 'Biofa Satin Gloss', which worked well. It comes out glossy but after 7 days it tones down to a satin finish and feels really nice. An undercoat and topcoat were applied, it was easy to use. The can stated that it contained aliphatical hydrocarbon, chalk, castor oil, linseed oil, soya oil and citrus oil. It was from the Green Building Store and was delivered.

The 'Ecos Emulsion' was smoother and incredibly easy to put on. Like the 'Dulux' paint it did not need dilution or stirring, it was just tipped into roller tray and went on really easily. There were not the same problems with the brush strokes or textured finish experienced with 'Auro'. In terms of usability 'Ecos' was so much easier, whereas 'Auro' was harder work. There was no information on the can about the ingredients in 'Ecos'. it states only that this is a solvent-free range of paints. Good ventilation was needed for drying, but the smell was fine with all the paints and the user could smell the difference compared to Dulux.

The user wanted more natural paint and did not want volatile organic compounds (VOC's) in the dwelling, a key factor apart from colour. The 'Auro' mixes offered could not achieve the colour wanted and 'Ecos' did not quite do the right colour. The user was very specific about the colour wanted and could only get this from 'Dulux'. Their view was that VOC's were being emitted even after the paint had dried, and that it was

probably still off-gassing. Of the natural paints there was said to be quite a nice smell from the gloss, and no smell from the matt paint.

The user was trying to be more eco-friendly in using these paints. Their view was that they could not tell other people to do it and then not try for themselves.

Obtaining paints was not a problem as the user wanted paints delivered as they were too heavy to carry and they preferred not to use the car. However, there was not quite enough paint to do more than one coat on the ceiling. It needed two coats even though it had been white before. The 'Ecos' paints came direct from 'Ecos', as they could not be obtained from the Green Building Store. Availability via the internet was a factor and the user had to take a gamble on which was the best paint based on information on the sites. The user only researched via the internet and did not do more extensive research. They did not question what natural meant and checked the marketing literature for information.

Those in the user's family or friends did not notice any difference; those asked felt it was the same as before. Even those visiting during decorating didn't notice any difference, even in smell.

The white reflects the light coming in and takes on colours from furniture, etc. This is probably in contrast to 'Dulux' where they probably add something to make it more optically white and may not get same effect.

The user considered the 'natural' paints picked up more dirt, this showed in the hallway where people come in with bags. It seems worse than with the previous paint and yet the same sets of people are visiting so there should be no difference.

Interviewee PPQ3

Interviewee PPQ3 was a user of various types of sustainable products in building, including some crop-based. They had built a cottage to include materials and technology that would reduce energy use, minimise external inputs and close resource cycles. The quality of the recording was poor for this interview.

The interviewee seemed fairly clear what the term crop-based products meant. They did not have much experience of these products apart from having used linoleum and paints, although they did not realise that these would be within scope.

When asked about the difficulty of obtaining such materials they stated that they were not really put off using particular materials, but that they did need quite a bit of determination.

In their experience planning permission was very much an issue, whereas the Building Regulations were not too bad. They had had to obtain technical data in some cases and considered that some of the inspectors were quite good but that this was a bit of a lottery.

The interviewee considered that in their experience there was a huge gulf between national rhetoric and the reality on the ground locally. There were a number of issues,

such as planning permission, lack of political will locally and implementation of policies locally. If an individual is determined and wants to try and do things differently it can be done, but they have to dig their heels in.

Interviewee PPQ4

Interviewee PPQ4 works for a supplier of environmentally friendly products that had been in business for approximately eight or nine years at the time of the interview. This company supplied some crop-based products and had a good understanding of what was included in this category.

From their experience the interviewee had observed that there were three categories of people as the end customer for their products, and these were described during the interview.

Ecological customers

These people are not concerned about how they meet this requirement in that a product does not have to be derived from natural materials to be considered ecological, for instanced a recycled product can be ecological. They tend to be more into technology and to have more concerns about natural products, having concerns about longevity, strength, and the effects of damp and rot with respect to natural products.

Durability is an area where such customers would expect to get test data and yet even so the ecological customer would be hard to convince. This is in contrast to the natural customer, who is happier to accept the data because of the basis of the product and because there are examples of buildings still standing. Some ecological customers are won round with data; others consider that a crop-based product may be appropriate but then compromise on costs means they will go for technology, i.e. newer and, to them, better solutions. Recycled products are seen as newer e.g. tyres are preferable to coconut mat.

An issue is that they can see how the crop-based products can come apart. Often in situ the products will not be exposed and so wear and tear will not happen, but the customers can see how they can come apart and so are not reassured and cannot see what stops it biodegrading *in situ*.

They would be happier with clay products but would tend to use them on top of recycled plasterboard rather than clay-reed board. Most of their construction products are derived from recycled components as the source materials are very cheap to work with and purchase, whereas crop-based products are more expensive.

Natural customers

These are happy with products such as reed-boards and are interested in crop-based products. However, they may also be concerned that natural products will be less durable.

The natural customer is more concerned about what is on the surface of a building, i.e. carpets and paints, and what they are coming into contact with. They are less

concerned with what will be sealed away, the issues for them are partly health and partly green.

They are also more geared to aesthetics so that paints and carpets tend to flourish more than other types of crop-based products. Wool carpets do well and form the majority of natural carpets purchased. Sisal carpets struggle a bit as people want soft carpets and these are rough, they are suitable for industrial spaces, but because they are not treated with chemicals they are not easy to clean and so not so good for commercial spaces.

Health customers
These are a subsection of natural customers that are sensitive to certain products. Their ecological arguments are limited and they are actually interested in their own health, e.g. allergies. They move towards crop-based products in order to avoid chemicals, but do have concerns about how they are grown. It can be difficult to certificate this aspect of a product due to lack of traceability. For instance sheep wool carpets are from a variety of sources, e.g. Icelandic sheep, shipped in from Germany.

Health concerns drive a lot of business to this supplier, but the health aspects are difficult to substantiate. It is difficult for this company to promote crop-based products on this basis as they cannot substantiate the health concerns. They get lots of questions in relation to paints and carpets. Customers tend to do a lot of research themselves and will tend to know exactly what they are allergic too. Other customers are hypersensitive to whatever they can detect through smell. Often customers are more expert on the supplier's own products than the supplier is as they have tracked back through manufacturers to get best information, and tend to do this for all types of products they are exposed to. The supplier finds that they get useful information from these customers. However, there are also allergies to natural materials, including crop-based products.

Customers may buy carpets and paints on the basis of asthma issues. Clay is not crop-based but light clay bricks and undercoat use straw as a component, these absorb air moisture, regulate humidity, draw in odours so there are benefits for the asthma market. However, health statements are difficult to substantiate as these products do not tend to be aimed at the health market.

The big swing to green has led to crossover between the green and health markets. People ask for organic building products, which it is not possible to supply as the costs are too high to certificate at present. Most products do not need chemicals in their production and producers are trying to limit the amounts used. However, proving this with certification is expensive and more difficult to do.

The discussion then moved on to the various types of insulation available as alternatives to rockwool. 'Warmcell' is quite popular and had effective advertising including television so that the layperson is more familiar with it. 'Thermafleece' also did quite well as a result of television advertising and still is popular. This supplier has moved away from sheep wool and flax more towards recycled products as the acoustics are better with non crop-based products, and there are also cost issues. The interviewee considered that 'Warmcell' was most popular, then 'Thermafleece', then flax, and then recycled wood fibre. 'Warmcell' is relatively cheap but not suitable for all places. The cost of

‘Thermafleece’ is dependent on the project; it can come in at a similar price to recycled insulation products, whereas other crop-based insulation is more expensive. There are so few players that it depends on what discount they give on a job in order to get the work. This makes it difficult to rank products in order of cost.

It is mainly architects that use the supplier. There is the Green Register of Architects for those that are particularly green, i.e. who lead the way and specialise in environmental building. But now every architect tends to make some claim to be green or sustainable in their mission statement, i.e. it is now the norm and customers demand it.

For architects to specify a product, test data and legislation are needed so that they cover themselves. They will require BBA (British Board of Agrement) certification even though it is not a legal requirement. The interviewee stated that European certification should be accepted, but usually an architect wants BBA certification, which is difficult and expensive to get in every country that a product is retailed in. Some regulators are uncomfortable with foreign documentation, the interviewee considered that they should be able to accept certification from another European country; they should all be valid in this country. Architects may pre-empt regulators and set requirements because they want to be safe as mistakes can be career-ending. Therefore architects are limited more by legislation.

This is in contrast to contractors of whom very few or almost none claim to be green. The volume and nature of the work does not support a large market in green building, there are a few freelancers and small companies focussing on the green market. The nature of the industry is such that all products try to replace standard, non-ecological, non crop-based products in order to get sales and make it easy for contractors, but there is not really the market or need for contractors to focus on green build, although this changes a bit for timber frame construction. Because there is not a green pound in that sector there is a fear from contractors, particularly of using crop-based and even recycled insulation. It is limited by the slowness of uptake, the average builder does not attend courses, and only in larger firms can they afford to send people to conferences. The small builders account for the majority of building work and for them a day out to attend a conference means a day not being paid plus the costs of attending.

The supplier is still pitching to a niche market, or where clients are government-funded, such as housing associations or schools. Occasionally they get commercial practices showing that they are green as part of their principle ethos. However, awareness is growing and contractors are aware of green products but not familiar with them. It is getting to a tipping point where everyone is aware of the green argument, but the question now is whether anyone wants to be first. There is now awareness that we have to be ecological and that is now possible. It will take half a decade to get beyond niche to increased uptake; to be able to say how long ago a product had been used is still standing, i.e. built up a track record. The supplier set up in 1997/8 as the first ecological builders’ merchant and is building up a track record, but compared to builders merchants that have been around for 125 years it does not really stand up. However, the supplier is growing every year and their products are taking up more of the market but they have to be aware of where they are in the market.

Crop-based products can have a basis in centuries of use and therefore it is possible to turn this argument around. However, the problem is that they have not been used for a period i.e. people stopped using these products, and standards have moved on and

people want an appropriate product. Presumably all products have had to go through this phase, including non-eco products.

Currently the ecological market is a niche market, with specific sections in magazines, etc. When this is no longer the case then the products will be mainstream. The architect press and end user or customer press have green sections but the contractors and building press do not have. Self-build is where the majority is currently going because the end customer is close to the actual build process, i.e. on site, project managing, dictating what is happening, therefore they want it and are happier to go with European legislation. Architects, contractors and builders' merchants are less keen. A lot of architects like to build ecological onto self build as they know they have free rein to use. For the more substantial, wealthier projects clients are excited by fact that the product is not so well known and brought in from Germany and accept European certification.

In past the supplier had stands at large conferences, to the extent of building a 2-storey stand. Their current business strategy is to spend less on marketing as they are at the tipping point in a niche market and have a pedigree so they do not need to actively go out and do things, people who want the products find them. They do attend local community fairs and the like rather than the large conference, the latter is not community-based and pushing green issues but is aimed at being a business event.

All products available should be able to satisfy planning permission and all are capable of achieving this, but do not in all cases. Many crop-based materials are naturally flammable and tend to have relatively low fire ratings, but class B2 is suitable for 90% of usage. The main problem is products being non-British and so they do not have British certificates. Rarely do products sold by this supplier hit a planning permission problem; if they do then it is a case of clarifying issues. There is not really an issue with these products, although architects may say different, but it is interesting how few hard cases there are of problems. Planning permission tends to be focussed on aesthetics, which can benefit crop-based products.

The majority of their work is providing technical data, and the majority of questions that a sale will hinge on relate to providing this. Data is out there and manufacturers have it but there can be language issue. There are more languages than the supplier has staff to cover.

There are no particular supply problems except that no-one in the UK wants to do it. Europe is ahead and so suppliers have to source products from there and this causes lead time issues. There is also an issue of shipping distance rather than local availability, which increases embodied energy. There are no special problems with crop-based products; any Europe-based products can have these same problems. However, with low volume products it can be difficult to switch and source elsewhere so more of an impact is felt. As far as their business is concerned once a supply problem has happened it has happened and even if they could source elsewhere they would not want to because they have a relationship with the supplier. If this is compared to rockwool a customer will still be able to get it at the builders' merchant because of the volumes on the market. There is not a particular problem with crop-based products for which supply may be more reliable than recycled as the source materials are available easily; it is only manufacture that can go wrong.

Interviewee PPQ5

The interviewee was a building surveyor, based with a firm in London. They also had experience of using products on their own property in France and had a good understanding of what crop-based products included.

Within the practice of building surveyors most of the work is on existing buildings in London and does not make use of crop-based products. They have a section of the business that deals with cultural heritage and they may give a different answer because they are dealing with conservation issues.

Their experience with crop-based products is personal, such as using sheep wool and hemp insulation in the same house to try them out. They tried sheep wool first and then found a supply of hemp that was cheaper and tried that in a different room. They have also used linseed oil for timber treatment externally and for terracotta tiling, and paints. Sisal flooring was used in one room because it was a cheap offcut and the user considered it brilliant. It does collect dirt so needs cleaning regularly, but is very comfortable in the bathroom. They would use more if they had a source and the money to fund it. Most of the interviewee's experience of use of crop-based products has been in France. In general products such as hemp are easier to get in France, whereas paints are harder to get. The sheep wool insulation came from Germany; there is only one supplier in the UK and they are expensive so they have not tried to go through them. There is a company based in the south of France in a woollen town, where there was the machinery to process wool, etc that was now used to process hemp.

Of the natural paints the interviewee had used 'Auro', 'Ecos' and 'Os' paints, and had just bought a clay-based paint from Precious Earth but had not tried it yet. 'Ecos' was the paint used first, but since then they heard negative views about how environmentally friendly it was. They found it fine to use, very acceptable, although sometimes brush application was a bit difficult. They found 'Auro' better to use, although both were easy compared to normal paints and a pleasure to use as there was no smell, vapour or fumes. This was true for both the emulsion finish and the gloss; the user did not notice a difference. We then discussed that experience of using natural paints may be an issue as this was opposite to the findings from another user interview. Another issue is that they cannot be obtained from just around the corner; there is a need to think ahead and go through a catalogue, which has a more limited palette. 'Os' was wonderful as a wood stain, so easy to use, with a lovely finish and can be used on unpainted or stripped wood. The next use will be to treat a floor which is unpainted; the product does not work on top of old stain. There are a lot of products out there including limewashes. The interviewee did not check all the ingredients of the paint products but had heard on a course that the 'Ecos' claims were suspect and noted that 'Auro' appeared to be better. This is a difficulty with marketing literature, it is not always clear whether there are mixed ingredients.

When asked about what factors were important as a user the interviewee cited natural, easy to use, friendly to use and sympathetic to the building, then, down the line, economics was a factor. In terms of performance all insulations were stated to be fairly similar so this was not an issue, the interviewee was happy to try both wool and hemp; although rockwool would be a non-starter.

When adding insulation to the roof space of their house in London they used 10 cm of glass fibre. They would have used wool if it had been cheaper but the cost difference was so considerable they went for the cheaper option. The trade-off here was the benefit of trying to improve insulation against using a not so environmentally-friendly product.

The interviewee had no experience of crop-based products in their day-job as a surveyor. Here they tend to go for what they know, economics and to work within the clients' budgets. There may be an issue of the company not pushing the alternatives enough, clients want a certain level of performance and are afraid of going for something different as the office space may not be taken up. Currently they have one client who has expressed an interest in greening operations and are looking at how they can refurbish in a green way. This has lead to a feasibility study and costing, but is only one client out of 100, and so virtually unheard of. The landlord is not concerned about energy and water costs as these are paid by the tenant and so the driver should be the tenant concerns over running costs. Once buildings are rated for energy use it will be possible to make an economic decision on the basis of direct comparisons, then insulation will be big factor. CLG (Department for Communities and Local Government) will keep ratcheting up standards and at present the commercial market is well behind; energy will be a key driver.

The interviewee was of the view that linoleum could not be used in a commercial building; there would be an image problem because of memories of history. Contractors would instead use recycled carpet tiles, there is a need to have something to reduce sound problems.

With respect to natural paints there would be a concern as to how durable they would be in a commercial building. There is no information available to answer this question. There is a fear of recommending a product that is of unknown performance. There is not enough information around and surveyors are not up to speed with the issues.

The nearest the interviewee has got to recommending environmentally-friendly products was to put sunpipes into a school, which made a huge difference to corridors and offices. The school did not need much persuading when putting in a new extension, the installation of sunpipes meant that there was no need to have strip lighting on all day, so the client was convinced. After a period of 6 months this was proved to be successful.

In terms of the Building Regulations, structure may be an issue, e.g. a straw bale house in Kensington may not be approved on the basis of appearance. There should not be a problem with internal use of a product, e.g. clay-reed board. Design can overcome any fire hazard issues. Buildings in the UK are put up to last and it would be assumed that straw bale buildings would have a short life. The interviewee was surprised that the USA has 150-year old straw bale buildings.

The interviewee did not consider technical data to be a barrier but rather that the issue was availability, these products are not visible to the general consumer. B&Q may stock low VOC paints and National Trust paints but they are not stocking 'Auro', etc, therefore these products are invisible. In France there are more magazines featuring natural materials and where an owner has older building there is a market that the magazines play to. Also in France a customer can go to the equivalent of B&Q and pick up lime. In the UK recycling, energy and water issues may have reached consumers but not these

products. There is a need to see people are using these products, in magazines and seeing buildings, so that people are not blinkered by client perception and regulation. Customers should see these are successful, but at the moment this is not coming across a lot. There is a need to know of these products to even research on internet.

Crop-based products have been used for centuries and are not new technology. At the suggestion these could be seen as old-fashioned, this was not thought to be the issue, as there is a demand for old properties in the countryside.

This history of use is not included in a syllabus and so people do not understand how the buildings work. This is even true of surveyors, for example covering breathable walls with an impermeable coating.

Sourcing of such materials is nearly impossible and a great excuse from the contractor. They do not order them until two weeks before they are needed and then say they cannot get them because of the long wait, and so use a conventional product. In addition there are not enough suppliers of these products, they can be counted on one hand and each specialise in the range they supply. A customer has to be committed and know where to find the information and source products. If customers came across these products in B&Q, then they would start looking at and buying them, however they are not available. A number of products are sourced from Europe and so this defeats the object of an environmental product because of the transport energy, so this is a compromise.

What will convince farmers to grow crops for products instead of what they usually grow?

The interviewee talks to colleagues about their experience of using natural products and gets only a superficial interest in what they have done. Some ask about cost or whether it works but the interviewee is never asked about where products can be obtained. People are resistant to quirky, they trust what they know. If it does not look like the most recent makeover programme on TV then people are not interested. There is a culture of stripping out everything and starting again, room makeovers on TV encourage the same. There are skips full of useable stuff outside houses, from which there is a certain amount of scavenging and reuse/recycle. Crop-based products are more able to be composted rather than reused/recycled at end of life.

Interviewee PPQ6

Interviewee PPQ6 was a supplier mainly of paints, as well as wool insulation and books. Their experience at the retail level is supplying wool insulation and selling books on straw bale building; paints are a big item.

There may be concerns from customers about finance but once they have decided to go this route the costs become less important. Instead ecology, being more carbon-neutral and environmental footprint becomes more important. There have not been problems with customer feedback regarding the products; sheep wool insulation is as good as or better than rockwool. Sometimes a couple will have a discussion and leave; it is uncertain whether they have come back later. Price is probably an issue, sheep wool is quite an expensive product but easy to use.

Their paints are about 50% more expensive than conventional paints. White paint is not too bad cost-wise; adding colour increases price. They are no more expensive than Farrow and Ball paints, some customers are happy to pay the price. The supplier is always asked about discount and tries to help but it is difficult.

They also try to provide information on products but it is difficult to be a one-stop shop and there are the claims of other manufacturers jumping on bandwagon. There is a need to look at pedigree and how long a product has been on the market, whether it is tried and tested. Some people will have been fooled by false claims. B&Q's move into the market supplying solar panels was seen as positive.

Lime has had a massive resurgence in terms of paints, the supplier keeps running out now whereas a few years ago they only had to order every 2 – 3 months to restock. Programmes like Grand Designs have an influence; just one programme had an effect as someone talked about why they used a product and the fact that they cannot use conventional paint on eco-surfaces.

The internet has had an influence with the ease of finding products through Google and buying them. The supplier spends a lot of time on the telephone giving information to people before they make buying decisions. People seek reassurance about the properties of products before they commit to buying. They ask about the ease of application, the interviewee did not think there was any difference compared to conventional paints, nor in terms of coverage rate. Lime paints are a bit different because of the need to mix a powder and use within 24 hours, but the need to give the supplier a call for advice is highlighted on the website. In terms of price there are trade discounts for some ranges, which have made a difference as sales are increasing. The company has been out there for 18 years now; good progress was made about 10 years ago, and then since 2004 figures were dropping compared to the previous 5 years, and in the last 2 years the figures are increasing. The increase is across the board and is true for other manufacturers. There has been a good press and lots of journalists ask for quotes and articles, etc.

Ingredients are an issue on which people want information. In terms of suppliers there are 'Light Greens' and 'Dark Greens', with this supplier categorising themselves as the latter. Some customers want solvent-free paints, others are allergy and asthma sufferers and go for water-based, natural paints. The supplier always suggests that the customer take a test pot before buying as they can never be sure what a product will trigger. People do their own research and the supplier tries to be transparent by offering ingredient information. Feedback has generally been positive; although a specific example is that some found the orange oil solvent to be quite aggressive and have given negative feedback.

An encouraging factor was that customers who employ decorators have insisted that they use natural paints. Decorators are traditionally hard-nosed and apply what they know, but when forced to use these products they have enjoyed the experience and want to use these paints. Customers asking for these products and decorators seeking them out come to the supplier, who currently has two decorators on their books. Also, decorators may have encouraged their customers to choose these products, but most of the pressure was from customers asking for products. A study on Danish painters has highlighted health problems for decorators. There is no decrease in the longevity of

paint with these products and there are no complaints about the company's paints. It is a good stable paint that has been around for a long time, with an established track record.

In relation to planning permission and Building Regulations there have been no issues for insulation or paints. Issues with fire safety on public buildings are because they do not have certification to a British Standard. 'Thermafleece' has to have rigorous testing and has BBA certification so is acceptable for the Building Regulations.

There was an issue with planning in relation to someone who built their own strawbale dwelling secretly without permission. A few years ago, 12 years after the dwelling was erected, the council made him take it down. The interviewee was not sure whether this would be the outcome now as this type of building is now better known and there are programmes on TV. The builder was probably a victim of time.

The supplier had planned an extension to their shop, the first plans were thrown away and it had been uphill for planning permission, but is now happening. The local council had insisted on apparently ridiculous requirements. There were stated to be real issues with the inclusion of straw bale, although the grounds for rejection were that it was not sustainable, there was not enough passing traffic for the shop to be built. The interviewee felt that this was nonsense and the council were just trying to find any excuse. The latest plans had been agreed, but it had taken several years. They had taken out the one wall of straw bale, which had made it look slightly different. The supplier felt it would have fitted into the landscape but the council clearly did not. The interviewee does not think that the strawbale proposal would pass planning now. They will be using 'Thermafleece', the building is intended to be a showcase of using as much sustainable material as possible.

Interviewee PPQ7

This was an interview with three people involved in the manufacture, production and supply of hemp and lime for use in construction. What got them started was different for each of them. For one it was a presentation by the architect involved with the Haverhill project. The interviewee was impressed with the material but it appeared to be hard work using a small scale mixer and manpower. They had also been interested in getting lime mortars viable on a larger scale, and considered that this could also apply to hemp and lime. For the hemp producer it was a case of finding an alternative use for hemp shiv, which led to the involvement in the current collaboration. The lime producer was looking at the restoration of buildings in France and observed the difficulties with natural hydraulic limes. As producers of air limes they looked at using these and when they had a material that worked they got into new build applications.

There are issues in ensuring that the product complies with the Building Regulations. Producing data to answer questions is important and they have got better at doing this so that it is improving all the time. Producing data is seen as positive as it is asking them to question what they know about the product. They will look for opportunities to obtain technical data by measurements or by reviewing the data of others. This need for data reflects a transition from previous workers using the material because instinctively it felt right; to the need to back this up with hard numbers, anecdotal and empirical

evidence. With respect to planning there is a positive benefit of having data where a project is borderline for planning this can tip planning in favour.

There have been changes to PPS7, which relates to one-off properties in the Green Belt and was in favour of large country houses. This now talks about groundbreaking materials or design so people are looking at using their product because it is groundbreaking and sustainable.

Everyone they work with is potentially a repeat customer, especially architects and so customer service and product delivery is a key part of their business strategy.

Architects are very interested when they discuss the carbon sequestration potential. Generally the reaction is positive although they have only been working on this for three years. They recognised that this success has been built on the work of others who have been pushing the material for the last 30 years. In addition, the drivers have changed; carbon dioxide is a daily news topic. Anything that is environmentally friendly, sustainable, or sequestrates is seen as very positive. The Government are aiming for zero carbon housing by 2016; they understand this concept and can offer zero carbon in-use and in-build. The key things that led to a changing in attitude were the signing of the Kyoto Agreement and the Stern Report. There is also flooding and extremes of weather that everyone is affected by.

There are lots of barriers to the uptake of these products; the question is whether they can be overcome. They have worked hard in the areas of public perception, technical data and insurance. Another issue is whether building societies will lend money to buy properties built with these materials. They would like to see faster legislation change to encourage use of these materials, such as tax breaks and building regulations adaptable enough to accommodate the materials, which are key issues.

It would be helpful if the Government led by example using these materials by building with innovative materials and using them in existing buildings and renovation work.

In addition funding for research is crucial for getting answers to climate change. They currently cannot go to market with solid data for renovation, they need projects so they can take measurements and get data. They have to invest carefully and seek funding and believe a pan-European approach is needed to obtain funding. It is not a case of them being told ‘No’ but they have not asked the questions. When they have asked, the mechanisms are there, but they want to move faster than the mechanisms allow. They would like to have person working to seek research funding but cannot afford to do that and the cost of them would not yield sufficient benefit. They are all too busy feeding the demands of potential customers to be able to seek funding.

They can achieve Building Regulations compliance, but they do not have a full understanding of what they are trying to achieve and how the materials can deliver. The U-value shows what happens in a laboratory in a static state in dry conditions, whereas criteria need to be about real buildings. Big changes could be made here, but research is needed and there is a cost in evaluations.

When it is considered what Haverhill and others achieved that was brilliant, but now there is a need to go the next step up, such as a small development of different types of construction. They try to do the same with their own office, each project is an

opportunity to obtain data and market what they do. This is a more positive time than they have previously known, including part-funding for a research associate.

It is estimated that ten million Euros would be needed to achieve what is required and this would need a pan-European approach. A considerable resource would be needed to make an application for funding and so investment is needed. The launch of any new technology requires money but the difference is that the construction industry yields low returns.

In relation to barriers to uptake there is a need for a better understanding of the product, and a need to communicate this information to the market, client and contractor. There is also a need to educate people how to live in such a building, to turn the thermostat down, install a smaller boiler and that some types of decorating product are not suitable, i.e. they need to be vapour permeable. Contract emulsion used on all new buildings is actually vapour permeable and so would be acceptable.

The barriers are falling away, they have identified a number and solved some, e.g. their material is approved by Zurich; they have trained concrete sprayers to use it; and they are getting a major supplier involved. Each milestone solves the problem for a period of time and then they look to improve further.

When asked whether the Building Regulations should be outcome based the response was that they may be going that way. However, there was not a criticism of the current system. The company are trying to focus and consider that they are underselling their wall, but they can get through the regulations, which is the first step. There is a focus on generating income so they can do further work, but this need not be a drain on commercial operations. They can see why there might be questions over using public money but there is a public good argument. When there are several houses built over the next 6 months there will be a much better argument for further funding.

BedZed was a major development and was pivotal. Adnams will be seen in a similar light. Milton Park is the only current example of sprayed hemp and lime. There needs to be the equivalent of BedZed somewhere, such as the Cat WISE project.

The Building Regulations are based on traditional materials; there will be a transition to coping with other types of product. There appears to be flexibility for this to happen. It would be helpful if there was a less rigid approach to U-value; some materials do not meet the requirement but have a better overall thermal performance. This has not been an issue before so no work has been done on it, but now work is being done. No-one fully understands the thermal performance of buildings. We are not used to building and then testing the building to see if it meets the expected standards. The standards are driven by the market; the companies that have all helped to draw up the standards have concentrated on U-value and thermal performance because their products (lightweight insulation) worked well. The interviewees believed that the Building Regulations are flexible enough for their products. The issue is those going beyond Building Regulations, this is a leap of faith and there is a need for demonstration houses.

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