

Home Grown Houses: The potential for large-scale production of renewable construction materials from crops grown in the UK, and possible impacts.

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ABSTRACT: This paper makes an initial investigation into the potential for the large-scale production of construction materials from crops grown in the UK, and the implications for farming, the environment and the construction industry. An analysis of crop-based materials shows that many perform as well or better than conventional materials, and renewable materials excel in environmental performance. An investigation of agriculture in the UK gives the expected gross margins for the crops being considered. A survey of 1000 farmers in England and Wales is used to explore farmers' willingness to grow crops for construction, the barriers to growing non-food crops, the amount of raw materials available each year and their likely cost. A study is made of a hypothetical contract for the construction of 10,000 urban-style homes of identical design using each of the materials considered, which gives a rough quantification of the environmental benefits of using these materials and of the possible effect on farmers and the construction industry. Those materials best placed for imminent production and use are identified, and suggestions are made towards increasing the use of other materials. Areas requiring further action, such as research, legislation or education, are also highlighted.

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1. INTRODUCTION

There are many crop-based construction materials produced across Europe, but almost none are made from crops grown in the UK. Farmers in the UK are suffering from falling revenues so are being encouraged to diversify.

This paper investigates what products might be made from UK crops and whether farmers are willing and able to produce the raw materials. It also examines the effect that the widespread use of these materials might have on energy use, landfill, the construction industry, farmers' incomes and the rural economy.

2. ANALYSIS OF MATERIALS

2.1 Insulation Materials

Conventional insulation materials are made from oil or mineral-based products, for example fibreglass, rockwool or foamed polyurethane. These use large amounts of energy to produce, cannot be recycled or incinerated and can be hazardous to health and to the environment. For example, the production of polyurethane can expose workers to harmful polycyanates, foamed insulants are sometimes blown with ozone depleting chemicals such as CFCs, and protective equipment must be worn when installing fibreglass insulation [1].

Insulation can also be made from hemp, flax and wool. These are not as effective insulants as foamed polyurethane, but compare very favourably with rockwool and fibreglass. They also have higher hygroscopicity, meaning they can absorb more water from the air without an increase in thermal conductivity. This also makes the atmosphere more comfortable as they help to regulate relative humidity. They are biodegradable or can be burned for energy recovery and have much lower embodied energy than conventional materials (see Tables II and III) [2][3].

2.2 Structural Materials

In the UK, most urban homes are made from fired bricks and blocks, sometimes with steel elements. All these materials have high embodied energy and, unless they can be reused, are from non-renewable sources. Mining for the raw materials causes massive environmental damage which cannot be reversed [4].

Alternative materials include timber frames with hemp and lime or straw bale infill, load-bearing straw bale construction and prefabricated straw panels.

Timber frames are made from a renewable resource, perform predictably in fire (unlike steel), are relatively cheap and are easy to prefabricate. Straw is produced in large quantities as a by-product of cereal farming and hemp shiv is a by-product of hemp fibre production. Lime uses less energy in production and absorbs more CO₂ in curing than cement, and hemp / lime is potentially recyclable (see Section 5.3) [5].

Hemp / lime and straw provide insulation as well as structure and regulate the moisture content of the air making the home very comfortable. However, if used on their own the walls have to be thick to provide the necessary insulation, so these materials are less appropriate for an urban setting where space is tight. Despite that, hemp / lime houses have been built as part of a housing estate in Haverhill, Suffolk, and were found to cost only a little more than conventionally-built homes [6].

2.3 Smooth Flooring Materials

These are usually wood, vinyl, or laminated panels. Wood can be sustainable, but vinyl and laminates include oil-based chemicals which can be hazardous in production and disposal and are non-renewable.

An alternative product is linoleum, which includes linseed oil made from flax, wood flour, chalk, cork flour and wood resin. All the constituents except chalk are renewable, it has low embodied energy and is probably compostable and energy recyclable [7].

3. PRODUCTION OF CROPS

3.1 Flax

Flax has been grown in the UK for hundreds of years to produce fibre (linen) and linseed oil, but linen has largely been superseded by cotton and in the UK the agriculture of flax fibre has almost disappeared. Changes to the subsidies paid to farmers saw the acreage under flax grown for fibre drop from 20,200 ha in 1996 to 2,000 ha in 2002. Around 30,000 ha are still grown for linseed oil production which is far more profitable (see Table I). Most varieties of flax grown for linseed do not produce quality fibre and the straw is essentially a waste product. Ideally, a dual-purpose crop would be developed which would give good yields of seed and high-quality fibre, or the straw could be used in strawbale building [8].

3.2 Hemp

Industrial hemp (*Cannabis sativa*) is enjoying a renaissance in the UK as it is gradually accepted that it has no narcotic properties, unlike its relation *Cannabis indica* [9]. Around 3,000 ha of industrial hemp were grown in 2002 [10]. Hemp can be grown with virtually no pesticide or fertiliser and the retting process by which the fibres are separated (the harvested crop is left in the field to partially biodegrade) has been shown to return around 50% of the plant's nutrients to the soil. Winter wheat grown in a field following a hemp crop has shown increased yields, making hemp a good rotation crop [11]. It can also be grown on set-aside land.

Most hemp is currently grown for horse bedding and seed / oil production. Theoretically a crop could be harvested for both seed and fibre, but in practice the varieties grown for fibre alone give the best gross margin (see Table I). The long fibres can be sold for making cloth, composite materials or insulation and the short woody fibres can be used for horse bedding, or mixed with lime and used in construction (see Section 2.2).

3.3 Sheep's wool

Around 97% of the income derived from a ewe is in the form of selling her lambs for slaughter [12], so the sale of wool for use in construction is a side-issue for many farmers. However, since wool must be removed from sheep on welfare grounds, any new market which might drive up the price is attractive.

UK breeds tend to produce coarse wool, which is very suitable for insulation, and the most suitable types of wool are among the cheapest [13]. Prices vary from around £0.09 / kg to around £0.80 / kg and in recent years have been increasing, but it can still cost the farmer more to remove the wool than he is paid for it [14].

Prices are currently set by the Wool Marketing Board which has been criticised for skewing prices in favour of buyers rather than producers. Reform of the WMB and developing markets such as insulation could make the farming of some breeds more economically viable [15].

3.4 Cereal Straw

Around 9.5 million tonnes of straw is produced in the UK each year as a by-product of cereal-growing. The great majority of the income derived from farming cereals is from the grain, with straw selling for an average of £85/ha (depending on the season) [16].

Only about 30% of the straw produced is available for sale, since most farmers use the majority as soil conditioner and animal bedding. If straw was in demand for use in construction, alternative products would have to be found for these uses which might drive up the price of straw [17].

Table I: Comparison of gross margins for crops [18]

Crop	Gross Margin (£ / ha)
Flax (linseed)	340
Flax (seed and fibre)	232
Hemp (fibre)	405
Wool (per head)	<0 - 1.65
Wheat (grain)	500
Wheat (grain and straw)	512

4. RESULTS OF QUESTIONNAIRE SENT TO FARMERS

In order to assess the willingness of UK farmers to grow the crops required for the production of the materials being considered, the author designed a questionnaire which was sent by the National Farmers' Union to a representative sample of 1000 arable and sheep farmers in England and Wales.

From a population of around 300,000 farmers, 220 replies were received giving a confidence level of 95% with a confidence interval of 6.6%. However,

since some questions were specific to certain types of farm, not all the respondents answered every question and this increases the confidence interval to between 8% and 10% for these questions.

4.1 General Questions

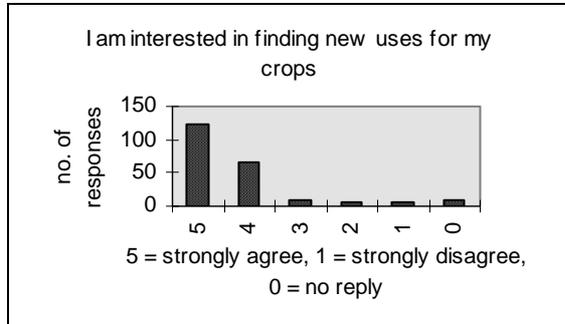


Figure 1

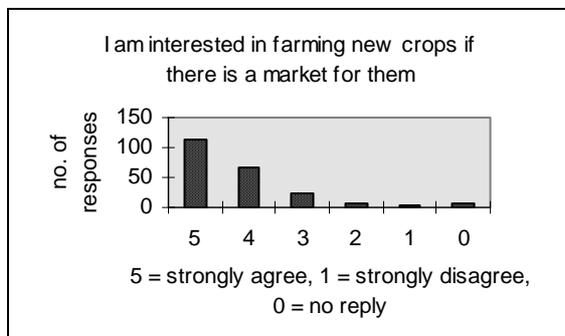


Figure 2

Falling revenues means that farmers are wanting to diversify. While there is a willingness to try new crops if there is a market, farmers are more keen to find new uses for existing crops than to try new ones (probably due to the unpredictability of the market).

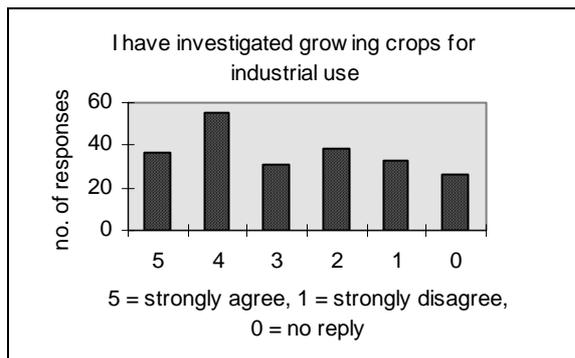


Figure 3

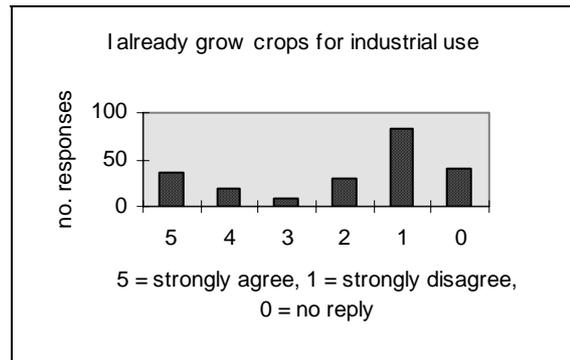


Figure 4

More farmers have investigated industrial crops than have actually started growing them. This could indicate conservatism in the industry, a lack of viable industrial crops or a very small market.

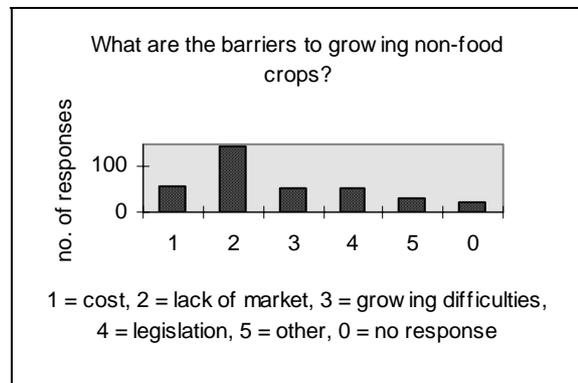


Figure 5

Frequently mentioned in the "other" category were lack of profitability, the need for new machinery and lack of Government support or political will. There were many comments regarding the need for Government support in the early stages of development of non-food crops.

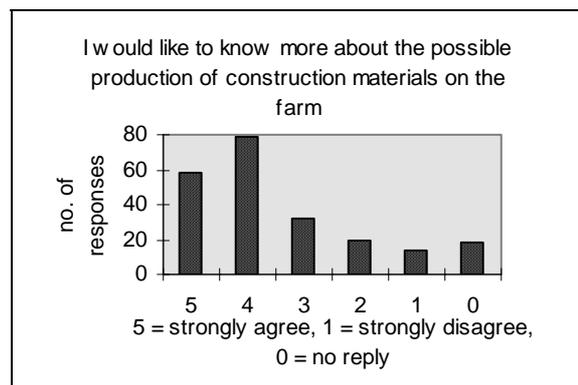


Figure 6

As well as wanting to diversify, farmers are keen to add value to their crops by processing them and this suggests that small local production facilities could be based on farms.

4.2 Arable Farmers

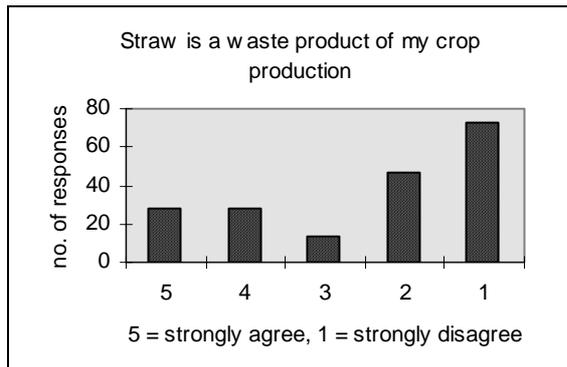


Figure 7

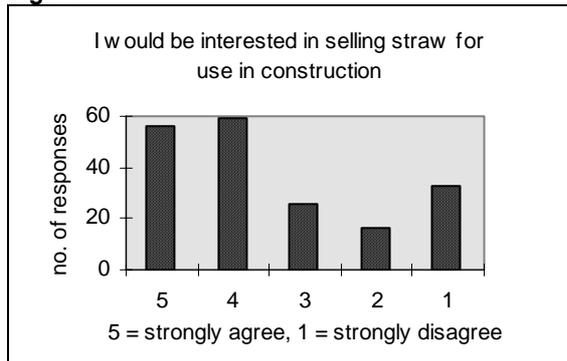


Figure 8

These answers contradict the popular belief that straw is simply a waste product of cereal production. If it was to be sold for construction then alternatives would have to be found for its current uses, e.g. soil conditioner and animal bedding. In some areas of the country, farmers are unhappy about competition for straw from the construction industry.

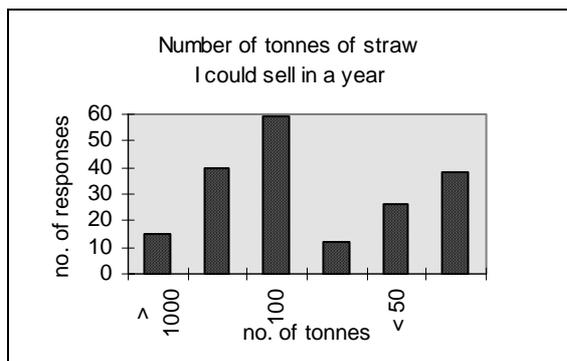


Figure 9

Together with data giving the area farmed by respondents to the survey, these figures can be extrapolated to show that around 3 million tonnes of straw would be available annually.

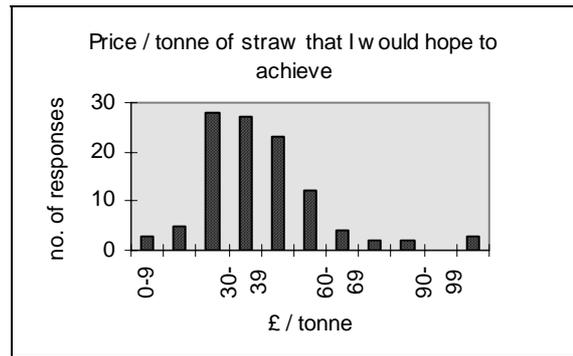


Figure 10

Over 75% of farmers would be happy with £45 / tonne, or around £1.60 / bale. This is about 10% more than the average price currently paid by straw bale construction professionals.

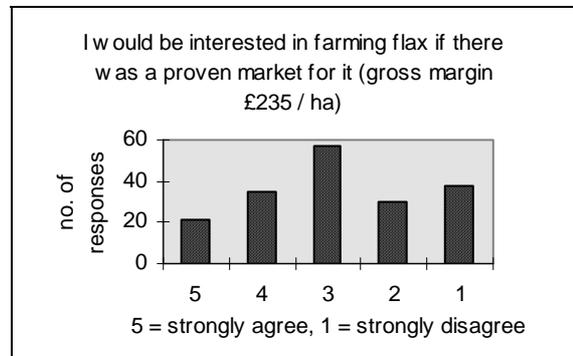


Figure 11

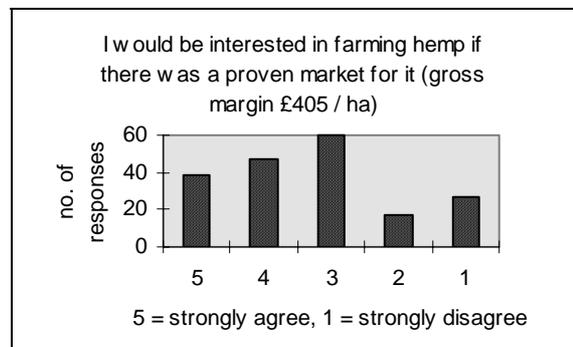


Figure 12

There is not enough profit in flax grown in the UK for most farmers to be willing to grow it, though a surprisingly large number are interested. Hemp is more promising but the majority of farmers are still negative or unsure. Despite this, extrapolating the figures suggests that over 100,000 farmers would be interested in growing hemp.

4.3 Sheep Farmers

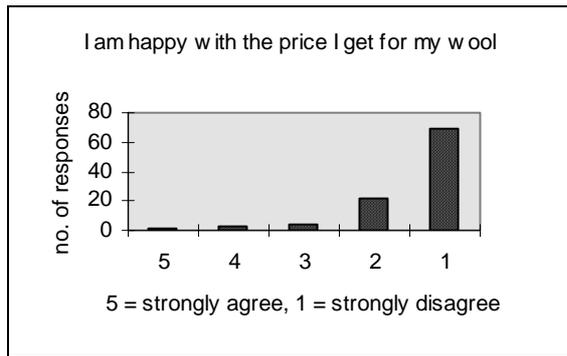


Figure 13

It often costs a farmer more to shear the sheep than he can get for the wool. In their comments, many farmers blamed the Wool Marketing Board for fixing prices below what they considered to be fair prices. On some farms wool is burned because it is not worth selling it.

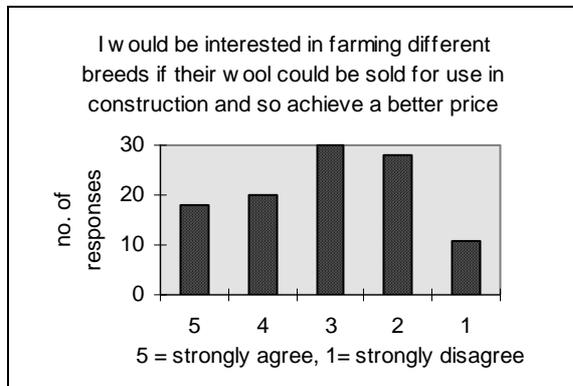


Figure 14

This would only be attractive if the alternative breeds produced as much meat as the existing ones, or if the price of wool for construction increased enormously. Since most farmers have selected their breeds for maximum meat production in their part of the country, they are sceptical that other viable breeds exist. Several suggested the development of a new breed that gave good meat yields and also insulation-grade wool.

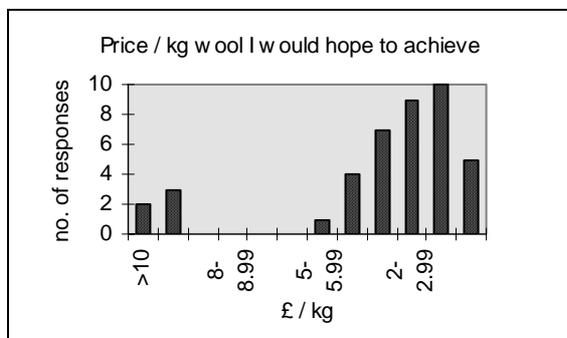


Figure 15

The average price of wool is currently 86p / kg. Most farmers would hope to achieve £1 - £3, which reflects the cost of shearing and baling.

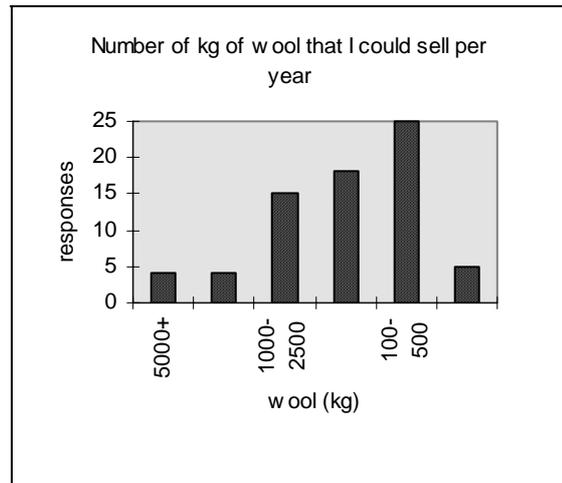


Figure 16

These figures can be extrapolated to suggest that around 80,000 kg would be available each year for use in construction. This is enough for around 130 of the "normal houses" described in Section 5, so clearly production needs to increase dramatically if UK insulation needs are to be met by UK sheep farmers.

5. PROJECTED IMPACTS OF LARGE SCALE USE OF CROP-BASED CONSTRUCTION MATERIALS

It has been shown that many renewable construction materials can compete with conventional ones in terms of performance, but are often more expensive. This is due to a number of factors, including artificially cheap raw materials for conventional products (since the true cost to the environment and society of extraction and energy are not taken into account). The price difference leads to lack of market share and lack of economies of scale of production, which further perpetuates the problem.

To "level the playing-field" in order to give renewable products a fair market share, the Government could provide grants towards its production and installation, but for this to happen there would need to be compelling environmental and social benefits from using these materials.

This section will compare various impacts on the environment, UK farmers and the construction industry of building "normal houses" with some elements made from crop-based materials rather than conventional ones.

5.1 Definition of the Normal House

The Normal House is a 5m-sided cube, therefore having wall area of 100 m² and floor area of 75 m². The walls are of brick and block construction, with a cavity containing 150mm thickness of mineral wool or fibreglass insulation. The floors are made of chipboard and insulated in the same way. In order to keep this exercise manageable, the roof, foundations and other elements will not be considered.

5.2 Embodied energy

Table II: embodied energy of different building elements [19]

building element	embodied energy (GJ)
walls	
fired brick / block and mineral wool	65.8
straw bale	7.9
hemp / lime	12.6
insulation	
fibreglass	23.52
mineral wool	14.7
hemp / flax	3.54
wool	3.63
flooring	
vinyl floor	1.36
linoleum	1.173

Clearly, the construction of houses using crop-based materials would save large amounts of energy. For example, if 10,000 houses were built using hemp instead of fibreglass insulation, around 4800 tonnes of oil equivalent would be saved.

5.3 Volume of waste sent to land fill

It is assumed that the Normal House is demolished after use and none of the conventional materials can be reused. It may be possible to reuse the render applied to the straw bale house, but not always. It is probable that linoleum can be partially composted / energy recycled (all constituents except the chalk); it is also probable that hemp / lime can be turned back into quicklime by heating and burning off the hemp, but both these need more research. Insulation made from hemp, flax or wool can be composted.

If these assumptions are correct, the volumes of waste sent to landfill are as follows:

Table III: volumes of waste sent to landfill (m³) of different building elements upon demolition

building element	volume of waste (m ³)
walls	
fired brick / block and mineral wool	37.52
straw bale	4.45
hemp / lime	0
insulation	
fibreglass	15
mineral wool	15
hemp / flax	0
wool	0
flooring	
vinyl floor	0.375
linoleum	0.135

If 10,000 houses were built using hemp instead of mineral wool insulation, this would reduce the waste being sent to landfill by 150,000 m³.

5.4 Implications for Farmers

Strong demand for these products because of their environmental and technical performance would benefit farmers by driving up the price of the raw materials. (It is unlikely to be commercially viable to import materials such as straw.)

Farmers could capitalise on the demand by carrying out some of the manufacturing processes on the farm. For example, a farmer processing hemp into chopped fibres ready for mixing with lime could sell the product for £700 / tonne instead of £110 / tonne for the raw material (based on the current cost of buying French hemp / lime product) [20].

Farmers producing a regular supply of uniform "construction-grade" straw bales could charge a developer building 10,000 straw bale houses an extra £18.6 million for the straw and the developer would still save £30 million on materials costs over the whole project.

Manufacturing products on the farm would also support local economies, and would provide training and employment for rural workers. The products could be used to build local affordable housing for these workers, who often cannot afford to buy a home in the communities in which they work. Using materials locally like this would reduce transport costs and associated environmental impacts. In addition, the production of these materials from UK crops would reduce imports and so benefit the overall UK economy.

5.5 Implications for the construction industry

Many of the materials can be used just like the conventional equivalent, but some (such as hemp / lime and straw bale) would require contractors to learn new skills. These skills could be taught on a short course which could lead to a recognised qualification and accreditation.

Some crop-based materials are more expensive than conventional ones, but this difference is small compared to the total cost of the house and would be reduced if these products were more widely used. In the mean time, consumers may be willing to pay more if they are made aware that their house is more environmentally-friendly and that its construction has benefited British farmers.

Informing the consumer in this way may require the production of a list of "ingredients" of a house, or a symbol similar to the "tractor mark" to indicate that British farmers have grown products used to build a new house. This could see the growth of a "home-grown house" sector similar to the organic food sector, where consumers are willing to pay more where they perceive a benefit to the environment and their health.

6. CONCLUSIONS

The materials with the most potential for production from UK crops are insulation made from

hemp and wool. These materials perform well in all areas and farmers want to grow the crops.

A by-product of hemp insulation production would be hemp shiv which could be used structurally with lime. This has great potential, but for it to achieve widespread use will require additional research and development and extensive training. Research into the possibility of recovering the lime by incineration would also be useful.

Linoleum performs well and linseed is a profitable crop, but it is much more expensive than PVC and so there is a limited market. Research into the composting or energy-recycling of linoleum might improve its environmental profile still further.

The increased use of these products would have great benefits in terms of energy savings and reduction in waste. Increasing the uptake of most of them requires a boost in consumer demand driven by education of the consumer or grants to make the products affordable. If the demand is there, the farmers are willing and able to supply it.

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