NEW HORIZONS FOR WOOL

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1 INTRODUCTION

1.1 The Economic Position of Wool

Since 1950, the economic position of wool fibre and sheep production in the UK and the EU has changed dramatically. It is frequently forgotten that at that time the development of man-made fibre was only at its very early preliminary stages, when only the cellulosic fibres were starting to emerge on textile markets. Therefore wool has been regarded until much later as a leading commodity fibre competing in world markets with cotton and linen by industry and consumers. However, the formation of the EU (EEC) in 1972 has changed the direction sheep breeding objectives entirely to the production of meat, with serious consequences for the quality and volume UK and EU wool production. Since then, wool has represented merely a by-product of meat.

Wool fibre varies widely in its physical attributes, in length, fibre fineness, in its crimp (waviness), colour, and handle. Although exploited almost exclusively for textiles, the applications for which wool is valued vary according to the wide variation in physical attributes.

In the UK the attributes of the annual clip is the product of a tiered crossbreeding system for the exclusive purpose of producing meat through a crossbreeding system which exploits four main breed types [1]:
(1) Hill and Mountain (with relatively coarse and lightweight wool fleeces);
(2) Longwool breeds (typified by their very long stapled fleeces);
(3) Down breeds (generally producing the more valuable wool and heavier fleece weights); and
(4) Crossbred ewes (F1 hybrid - Mules) for the production of “fat lamb” for the table.

In this context wool production represents less than 2% of income per animal, and is regarded by UK and European sheep producers largely as an expensive waste product. Nevertheless, wool is produced annually, in considerable volume and with considerable variations in quality.

1.2 Competitive Pressures

There are three major competitive pressures for wool:
(1) Variability of wool fibre: Wherever it is produced, annual wool supply is neither consistent in volume nor homogeneous in quality, and cannot be. Even within-breed wool homogeneity is prevented by variations in animal health, fodder, climate and other uncontrollable variables.
(2) Mass volume strategy: Now, the competitive pressures on mass volume manufacture places considerable emphasis on fibre performance to gain strategic advantage in the market. Machine efficiencies expected to achieve competitive market price do not marry easily with the normal variations in quality found in the natural fibres.
(3) Wool blends: The marketing agencies for wool expend considerable time and costs on blending wool fibres into acceptable mixtures to suit identified machine and market needs as nearly as possible. By contrast, man-made fibres are readily produced to specification. It is a context which increasingly threatens the markets for wool fibre. Nor can wool fibre compete with the fierce price competition between the many cellulosic and synthetic fibre qualities.

1.3 The Alternative – Marketing Wool for Specialist Applications

The total annual world wool consumption is now estimated at less than 2% of total fibre consumption and can no longer service a mass production market, whereas wool's historic position as a main volume textile fibre holds it back from a full exploitation of its extraordinary properties into new and unique development into new market applications, including acoustics and architecture. On the other hand, the variability of the wool supply base positions it for exploitation of its physical properties into high value specialist market application. In particular, current concerns over the environment, and the relative unsustainability of synthetic materials within new EU restrictions opens potential new opportunities for this highly unusual, misunderstood and underdeveloped animal fibre.

The aim of this paper is therefore to explore the possibilities and potentials of using wool in acoustics. The paper first analyses the wool market and outlines the wool properties. It then discusses its acoustic potentials, followed by a brief sustainability analysis.

2 WOOL FIBRE MARKETS

World sheep numbers are estimated to have fallen steadily since 1990 from 1,990 million sheep to around 1,000 million animals by 2005, with substantial losses expected in Australia, given the current drought conditions.

Total global clean wool supply has fallen since 1990 from 1,900mkg to 1,220mkg in 2006. Of this volume the consumption of clean wool supply for apparel purposes has fallen since 1995 from 858.5mkg to 633mkg – or just over half annual global wool supply. At this point it is significant that a relatively small proportion of the global flock are merino – the main supply base for apparel wool – most of which are found in the southern hemisphere.

Figure 1 shows the textile fibre use in Western Europe, and the diminishing exploitation of cotton and wool fibre in the face of increasing manufacture of synthetic and cellulosic fibre types. In terms of sustainability, there are trends which need interventions, in view of the considerably dirty environmental outcomes of man-made fibre manufacturing technologies.

Figure 2 shows the wool supply/demand in Western Europe. This illustrates a surprisingly stable trend line in the production of wool fibre. However, the stable supply derives from the primary use of European sheep for meat, in which context wool is considered a waste product of low value (in contrast to the less myopic view taken by New Zealand sheep meat producers). Meanwhile, mill consumption of wool fibre has fallen over the same period, as the industry has gone off-shore to take advantage of economic conditions in new developing territories offering low land and labour costs. Meanwhile, in the face of aggressive marketing/pricing of products made from man-made fibres, consumer demand for wool product has also declined over the period.

A comparison in wool mill consumption between Western Europe and China is shown in Figure 3. This highlights the long term trend of textile migration eastwards to exploit the advantageous conditions of newly developing economies as suitably stable conditions emerge for the establishment and development of textile manufacture as a primary economic lever. While it allows for low cost textile production for a limited period, inevitably other incoming industrial activities compete for the same labour market, thereby raising costs and product price. After China, therefore, where does textile manufacture find additional low cost economies to foster low cost production? Or do more sustainable practices offer an alternative future?

Recent figures produced by the British Wool Marketing Board show total net weight (greasy wool) produced in 2005 (May to April incl.) at 37,498,205kg, and in 2006 at 38,510,273kg, although annual wool clip weight can vary substantially. The greatest volume of wool is available from the F1 hybrid mule animals.

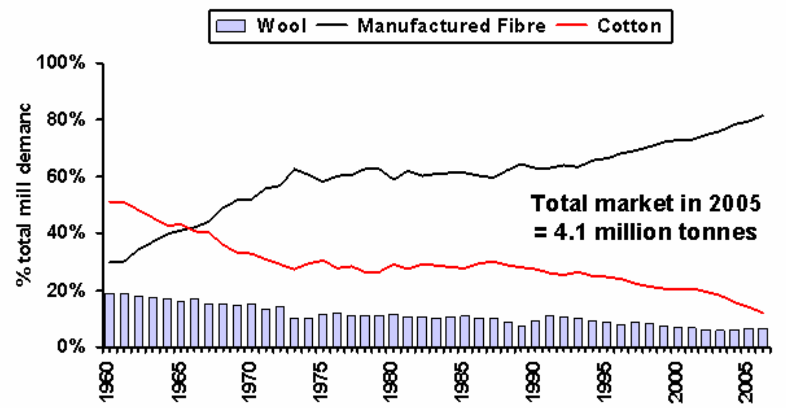

Figure 1: Western Europe textile fiber use (mill demand) [source: textrends.org].

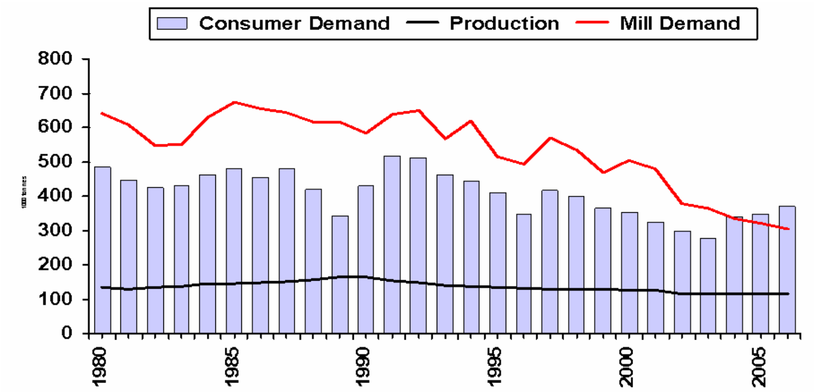

Figure 2: Western Europe wool supply/demand [source: textrends.org].

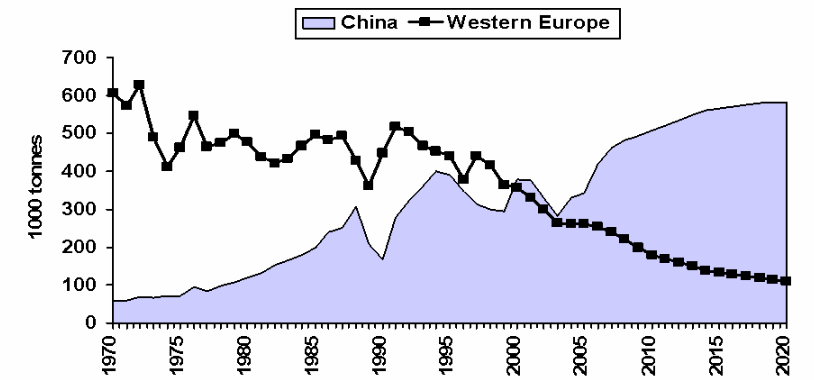

Figure 3: Western Europe vs. China wool mill consumption [source: textrends.org].

3 WOOL PROPERTIES AND NEW EXPLOITATION

Three types of fibre are grown from the groups of follicles, although follicle groups include only two types of follicle: primary follicles, and secondary follicles [2]. Kemp and hair fibres are both produced by the larger primary follicles, usually being associated with the production of kemp. Both fibres are collectively termed hair fibres. True wool fibres, which are the finest fibres to be found in fleece, are grown by the secondary follicles.

In the fleeces of wild sheep [3,4], kemp fibres represent a considerable proportion of the fibres present; and by contrast, there are modern breeds which are highly evolved in which kemp fibres are rarely found. The Merino strains are examples of the latter. Most British breeds of sheep, however, contain some kemp in their wools, and it is especially prevalent in hill and mountain breeds.

Kemp is the coarsest type of hair fibre found in fleece, and contains a large internal core, the medulla, which occupies most of the width of the fibre and is mainly filled with air supported by a latticed cellular structure of keratin. The presence of this structure reflects light and imparts a characteristic chalky appearance to kemp. The presence of kemp is undesirable in textile manufacture.

Hair fibre, grown from smaller primary follicles tends to be of a smaller diameter than kemp. The medulla of hair fibres is usually completely hollow, and occupied by air. Hair fibre possesses an outer cuticle composed of scales which are arranged with a smooth reflecting surface. This imparts a lustrous sheen, from which the term “lustre Longwool” is derived. The greater length of hair fibre is able to increase the strength of yarns and have been exploited in attractive, lustrous and hardwearing fabrics.

True wool fibre - this term is used to distinguish the fibre grown from the secondary follicles. These are the finest of all three fibre types, possessing no central medulla. By contrast, wool fibre possesses a complex internal structure (cortex) which is illustrated above, showing that the cortex is composed of a number of macrofibrils, which in turn are composed of micro- and protofibrils, imparting the elasticity and recovery properties of wool fibre. The cortex is divided down the length of the fibre into two halves: the orthocortex and the paracortex. It is the relationship of the orthocortex to the paracortex which is responsible for the curled, waved or crimped feature of wool fibres. Heavily crimped wools can impart to wool yarns a springy “lofty” handle.

These fine wool fibres tend to be shorter in length compared to hair fibre. With some breeds of the hill and mountain type such as the Scottish Blackface, these fibres provide a finer undercoat in fleeces of a two-coated variety, where the outercoat is composed largely of longer hair fibres. In such fleeces, the shorter finer wool fibres provide an insulating layer of trapped warm airpockets, which maintain the animal’s body at a relatively constant temperature, in many breeds the outer coat of long hairs is not evident, as in Down and Merino fleeces, when the density of the fine wool fibres alone provides the necessary insulative properties.

Figure 4 shows an exploded view of a wool fibre, while the mix of follicle types for contrasting wool fibre qualities are shown in Figure 5. As explained above, the mix of follicle arrays from which a group of fibres (wool staple) emerges is repeated across the skin of an animal, and dictates the particular quality (and value) of the resulting fleece. Considerable variations in fibre length, diameter and other factors characterise the fleeces of specific breeds (over 100 breeds in the UK).

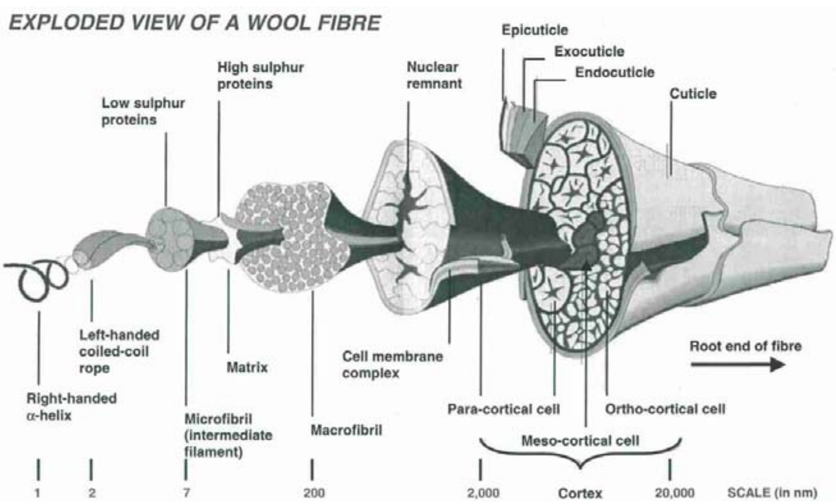

Figure 4: Exploded view of a wool fibre [source: www.wronz.org.nz].

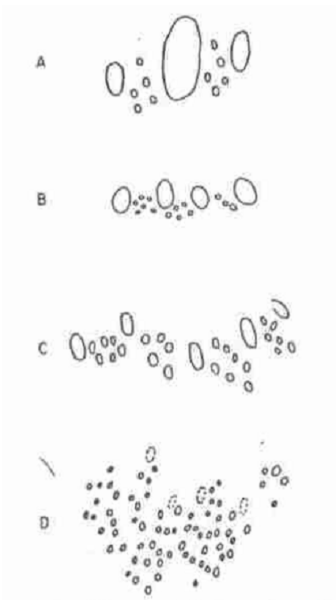

Figure 5: Wool fibre groups: A, in wild sheep; B-D, found in parchment from the Dead Sea Scrolls; B, hairy sheep; C, medium-woolled sheep; D, fine-woolled sheep [2].

Although wool has been exploited by man over many centuries [4,5], it is unlikely that the full potential of wool fibre for sustainable application has yet been exploited. Instead, the financial parameters of current mass production have forced wool fibre to compete in price with modern man-made fibres of considerably reduced textile benefit. None of these can replicate the potential of a wool fleece to maintain a 10 degree centigrade differential between the sheep's body and the external ambient temperature in the Sahara or in Siberia. Neither are they able to offer the sustainable and extensive properties of wool.

The properties of wool fibre are unique and include [7]:

(1) Wool fibre is naturally crimped, allowing air to be trapped in the spaces between the huge number of fibres contained in a yarn or textile made from wool, and to insulate the wearer from external draughts and changes in temperature.
(2) Wool is naturally moist, and absorbs water from the air (or releases water vapour to the air if wet) until an equilibrium level of moisture within the fibres is reached (known as regain).
(3) In fact wool fibre can absorb up to 30% of its weight in moisture without the wearer feeling damp. In addition wool has the remarkable ability to generate heat. Through the formation hydrogen bond within wool, wool fibre gives out heat as water is absorbed. In comparison, nylon, polyester and acrylic fibres have less than one-quarter the ability to absorb water vapour from the air, and so are less efficient at generating warmth
(4) By contrast, as wool fibre releases moisture in warmer and dryer conditions, so the wearer is cooled down.
(5) Wool will not burn, and has substantial fire-retardant properties. This characteristic has been exploited in military and other uniforms, in public transport upholstery, in floor coverings and insulation.
(6) Wool's recovery properties allow the fibre to spring back into optimum position after considerable pressure and abrasion over very long periods.
(7) Wool is nearly twice as tough as steel, toughness being the energy input per unit mass required to break the fibre.
(8) Wool does not rot readily, and reportedly has been used historically as an appropriate basis in marshy areas for the support of various structures such as bridges.
(9) No energy is used in the production of the fibre, in contrast to the energy used in synthetic and cellulosic fibre production. Energy requirement in wool exploitation is limited to the processes which exploit the fibre in a broad range of product application.

4 ACOUSTIC POTENTIALS

Figure 6 compares the sound absorption coefficient of wool with various configurations of glass fibre. The comparison between sheep wool and rock wool is similarly made in Figure 7. It can be seen that the absorption of sheep wool is similar to, if not better than, fibre glass and rock wool. Figure 8 shows the effectiveness of using wool as a banner for sound absorption compared with other kind of curtains [8,9].

While the data of wool sound absorption are limited, in Figure 6 and 7 the absorption coefficients of various configurations of fibreglass and rock wool are shown, and these indicate that a range of absorption coefficients which can be achieved. In turn they also indicate the potential of using sheep wool for effective sound absorption. In terms of the mass, sheep wool has a nominal density of 25kg/m^3 [10]. In addition, as discussed in the Sections 3, for sheep wool there are more parameters which can be controlled, to adjust the absorption.

An alternative use of sheep wool for acoustic purposes has already been demonstrated in the form of filling materials in cavity walls, to increase sound transmission loss. Some products have been developed for this purpose. In this regard, Figure 9 shows a comparison between a stud wall with an empty 100mm cavity, and the same construction, but with a 100mm wool in the cavity, in which the studs are 100mm x 50mm timber at 600mm centres, and screwed to each side is 1 x 15mm Lafarge plasterboard (10kg/m^2) [9]. The diagram demonstrates clearly the superior effect of sheep wool.

Sheep wool has already been used for sound absorption purposes in floor underlays, and as carded battings in automobiles. When the objective is for improvement of room acoustics, the advantage of using wool, as compared to the inherent dangers of handling of fibre glass or rock wool for the same purpose, is that with the latter materials wrapping materials are usually required, whereas with wool fibre such precautions are not normally necessary.

Furthermore, insulation materials consisting of wool fibre benefit from wool's considerable fire resistant properties. In this regard sheep wool insulation has already achieved a B2 fire protection classification in accordance with DIN 4102 [10,11].

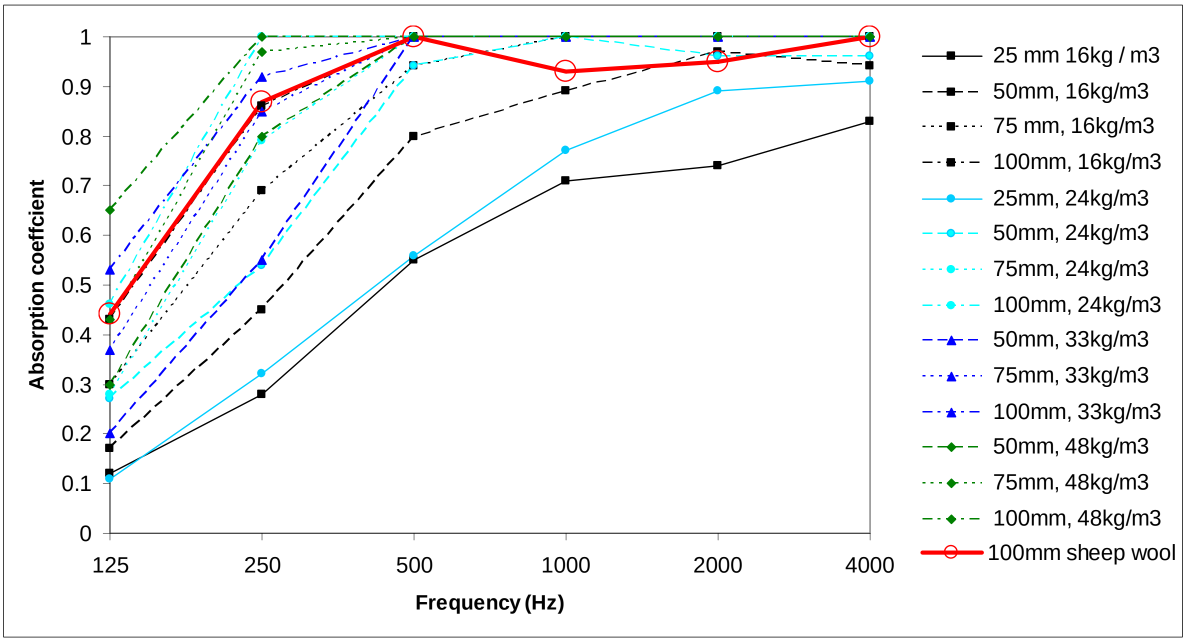

Figure 6: Absorption coefficient of various configurations of glass fibre compared with sheep wool, data adopted from [8,9].

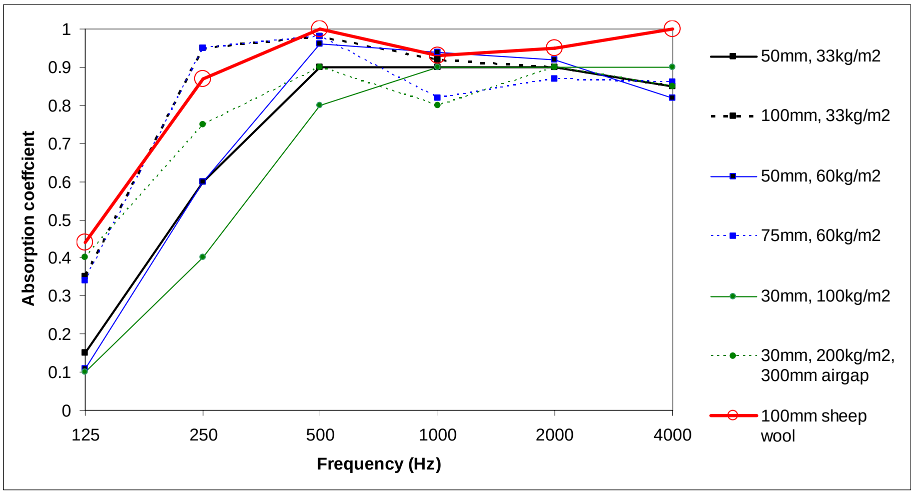

Figure 7: Absorption coefficient of various configurations of rock wool compared with sheep wool, data adopted from [8,9].

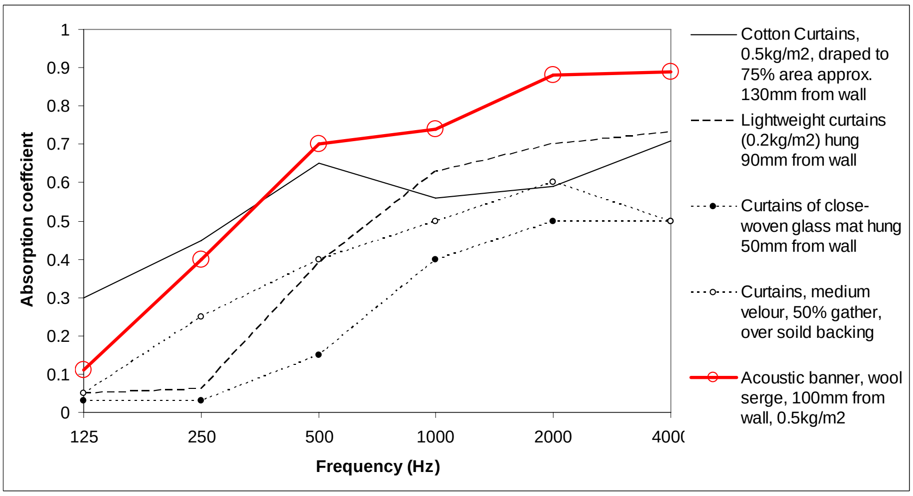

Figure 8: Absorption of an acoustic banner with wool serge, compared with other materials, data adopted from [8].

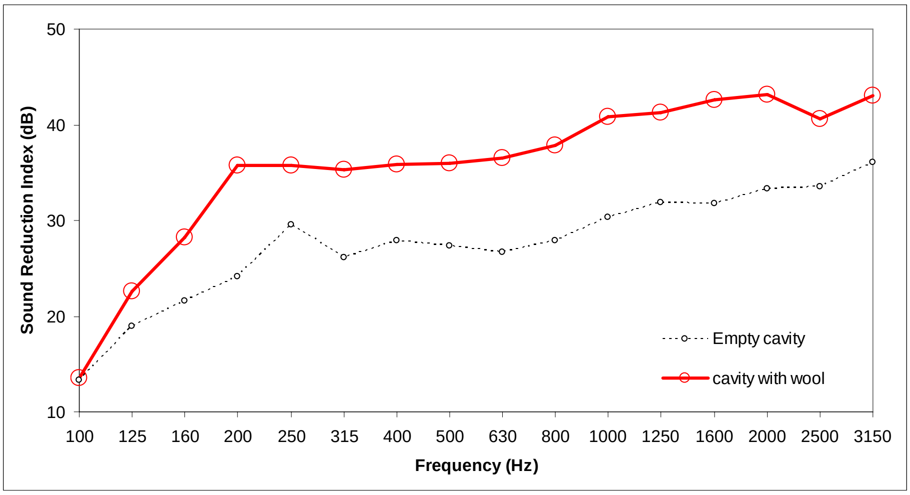

Figure 9: Comparison in sound reduction index between a stud wall with an empty 100mm cavity, and the same construction, but with wool in the cavity, data adopted from [9].

5 SUSTAINABILITY POTENTIALS

The software package Envest [12] was used to study the environmental impacts of wool compared with other materials. The results of Envest are shown in various aspects of environmental impact, which include climate change, acid deposition, ozone depletion, human toxicity air, ozone creation, human toxicity water, eco toxicity water, eutrophication, fossil fuel depletion, minerals extraction, water extraction, and waste disposal. The results are also shown in terms of an overall Ecopoint, where the data in 13 impact categories are multiplied by the agreed weight for each category and combined to produce a single score. To aid interpretation, Ecopoints are derived so that the annual environmental impact caused by a typical UK citizen creates 100 Ecopoints. More Ecopoints indicate higher environmental impact. Both embodied Ecopoint in structure/construction and operational Ecopoint can be considered. In Table 1 a comparison in Ecopoint between sheep wool and other materials is made. It can be seen that sheep wool has a considerable lower Ecopoint.

Table 1: Comparison in Ecopoint between sheep wool and other materials.

Materials	Ecopoint
Nylon Carpet with natural fibre underlay	94
Wool/Nylon 80/20 with natural fibre underlay	92
Wool carpet with natural fibre underlay	71
Wool carpet with recycled rubber crumb underlay	83
Wool carpet with sponge rubber (SBR) underlay	348

6 CONCLUDING REMARKS

Despite centuries of exploitation, wool fibre remains a relatively unexploited and misunderstood fibre. Because of its long history of use primarily as a textile fibre, it has figured until the mid-20th Century as a commodity fibre, competing for position with cotton, and latterly with the man-made fibres. It is the only fibre with the particularly broad array of performance characteristics described above, which offer substantial advantage to new applications, with the added advantage of sustainability [13] in the context of current environmental concerns. It is, therefore, a fibre offering broad specialist and high value applications, and particularly in its use in acoustic materials as a sustainable alternative to glass fibre and rock wool.

7 REFERENCES

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