The Thermal Properties of Wool Carpets

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- Wool carpets are effective thermal insulators, saving 8-13% of heating and cooling costs, with the greatest thermal insulation provided by thick carpets on underlays
- Wool carpets increase personal comfort and can be used with under-floor heating
- The thermal advantages of wool carpets stem from wool's low thermal conductivity, high crimp, and the release/absorption of heat that accompanies the absorption/release of water vapour
- The superior resilience of wool means that wool carpets retain their pile height, a key factor in the insulation value of carpets, for longer

Introduction

The thermal properties of wool carpets make important contributions to energy efficiency by insulating floors (and even walls [1]) and making people feel more comfortable at a given air temperature. When choosing a floor covering, these thermal advantages should be considered along with other technical and environmental benefits, and the less tangible attributes of prestige and aesthetics [2]. Some technical benefits contribute to personal safety, such as wool carpets' high resistance to burning [3], removal of indoor air pollutants [4,5] and reduction of the frequency and severity of falls [2,6]. The outstanding acoustic properties of wool carpets are also well documented [7]. Benefits to the environment include maintenance requirements that have a low environmental impact [8], biodegradability in land and sea, and options for closed-loop recycling [9].

Wool's thermal properties contribute to the high level of thermophysiological comfort experienced with wool bedding and clothing [10]. The excellent inherent thermal characteristics of wool and its eco credentials have led to non-woven wool building insulation materials becoming well-established [3]. This publication is part of a series prepared to highlight developments in wool textile science and technology [2,5,7,9].

Insulation and the transmission of heat

Heat is transmitted in three ways: conduction, convection and radiation, and wool carpets reduce all three. The thermal conductivities of different fibres are compared in Table 1. Wool is one of the least conductive (most insulating) of the fibres. Still dry air has very low conductivity, which is why effective air trapping is critical to good thermal insulation and light bulky textiles such as duvets are so warm. The millions of wool fibres in the pile of carpets trap pockets of air, creating a natural insulation barrier, while the fibres' high crimp (bulk) effectively restricts the flow of air through the pile and therefore heat loss through convection. The scales on the surface of wool may cause aerodynamic drag and help to trap air. The thermal insulation values (R-values) of different household materials are compared in Figure 1. Carpet ranks very highly, i.e. PVC tile has only 1.3% of the insulation of wool carpet. Wool carpet had a higher insulation value than comparable carpets of other fibre types.

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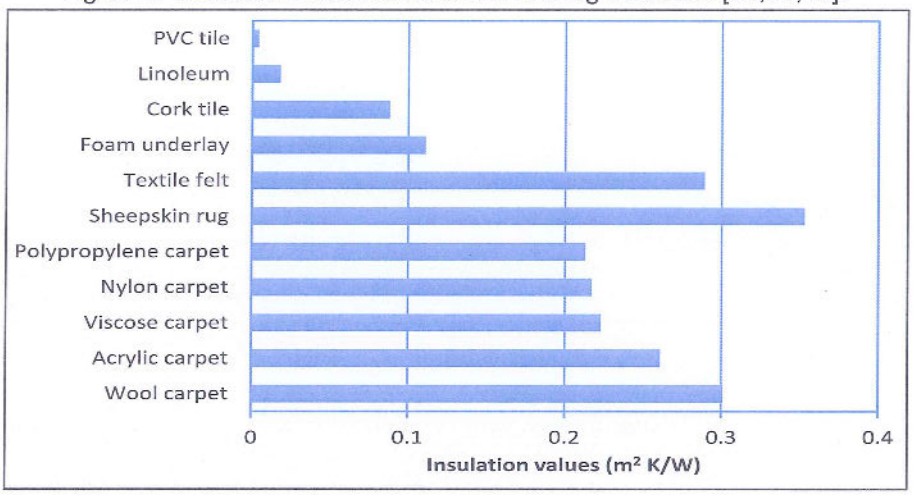
Table 1. Thermal conductivities (mW/m K) of fibres and air [11,12].

Air	26		Acrylic	200
Polypropylene	117		Nylon	243
Polyester	141		Viscose	289
Wool	193		Cotton	292

Figure 1. Insulation values of common flooring materials [13,14,15].*



* Insulation per 1000 g/m^2 of surface pile weight

The thickness of a carpet is the major factor determining its thermal insulation efficiency, the thicker the carpet the greater the insulation provided. Bulk density and construction also have some effect. Flattening or compacting of the carpet pile through wear, will reduce its thickness and thus its insulating propensity. However, the natural resilience of wool fibres, which results from the spring-like structure of its internal proteins [16], gives them better recovery after compression than alternative fibres, so that the pile of wool carpet retains its height and insulating properties for longer.

Carpets save on heating and air conditioning costs and should be considered along with curtains and double glazing etc. as part of the overall thermal design of a building. Additionally, an underlay beneath the carpet can further increase this thermal insulation effect [15].

Wool carpet heightens thermal comfort

Radiant heat loss from a room occupant's body to the floor is very low for wool carpets compared to hard floor coverings like stone, wood, or ceramics. Since 60% of body heat is lost through radiation, people feel more comfortable in a room with wool [15]. Comfort is also increased by wool carpets reducing the loss of heat from the feet by conduction. Moving air increases heat loss by hastening the evaporation of perspiration and assisting convection. This is known as the wind chill factor. Carpets trap a layer of still air just above their surface, thereby reducing drafts and making feet feel warmer.

While wool is well known for its natural ability to repel liquid water (due to the types of lipids and proteins on its surface [17]), wool can also absorb a large amount of water vapour from the air. In what may be the first published account of this, Benjamin Thompson, in 1787, reported measurements of the ability of wool to stabilise humidity and reduce unpleasant highs and lows [18]. We now know that water vapour

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can diffuse through the water repelling surface of the wool fibre into the water absorbing interior. There is significant thermal buffering associated with the absorption/desorption of water vapour; in cold damp conditions (high relative humidity) moisture is absorbed and heat is given-off [10,19]. Each gram of water taken up by wool (at 15% regain) from the atmosphere liberates 277 Joules of heat [12]. In warm dry conditions, moisture is desorbed from wool, giving a cooling effect. These effects are far more pronounced for wool than for any other fibre and give discernible increases to thermophysiological comfort [10,19].

Wool carpet contributes to energy savings and good health

As around 10-20% of heat loss from rooms occurs through the floor [20], carpet can help reduce energy costs for heating. Experiments in Japan using two identical "model" houses, one with wool carpet, the other without, resulted in savings of heating energy of 8 to 13%, increasing with increased pile height and overall carpet thickness (Table 2) [21]. These savings were made without underlay, which would further enhance thermal insulation performance [15]. Savings of up to 12% were also found for cooling under the same conditions [21]. Similar energy savings have also been found in actual situations; for example, Rees reported the case of a school in the USA, where carpeting reduced fuel consumption by 5-13% compared to a very similar uncarpeted school [22].

Table 2. Energy savings due to installation of wool carpet [21].

Pile height (mm)	Thickness (mm)*	Weight (g/m^2)*	Heating saving (%)	Cooling saving (%)
5.0	7.3	1,722	9	8
7.0	9.2	1,963	11	10
10.0	11.7	2,257	13	12

* Carpet and backing. 100% wool, cut-pile Wilton.

A carpeted floor, particularly a wool one, feels warmer underfoot and does not require the heating that a smooth surface may, adding further energy savings. It has been shown that the perceived temperature in rooms with textile floorcoverings is approximately 1-2°C higher than in rooms with hard floorcoverings [23], resulting in savings of heating costs of approximately 6% [15]. In addition, because wool carpet feels warmer, further energy savings can be made since heating can be switched on later in the autumn, and off again earlier in the spring.

The World Health Organisation Regional Office for Europe has recognised maintaining healthy indoor temperatures as a priority area [24]. A number of housing studies have cold homes as a major contributor to cardiovascular, respiratory and other health problems. [25,26].

Underfloor heating

For many years, wool carpets have been used with underfloor heating, showing no deterioration from the higher localised temperatures. Foregoing an underlay will reduce the overall thermal resistance, but will adversely affect carpet wear and walking comfort. The alternative is to use an underlay with a low thermal insulation value.

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