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CONSUMPTION RESEARCH NORWAY (SIFO)

WOOLUME: Mapping the market for acoustic and sound absorbing products made of wool

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Summary

This report is the first deliverable from work package 2 of the WOOLUME project. The main goal of WOOLUME is to explore different ways of using wool from Polish Mountain Sheep to achieve better utilisation of resources and value creation. The aim of the report has been to map the market for acoustic and sound absorbing products made of wool to examine the potential to introduce coarse wool as a material. This has been done through desktop research and interviews with a focus on the qualities of wool as a natural product. Findings show that though man-made materials dominate the market for acoustic products due to lower prices, wool is preferred as a material due to its natural properties as well as aesthetics. Producers using wool consider their products to be high-end, intended for people who want very good quality products and who are willing to pay a higher price to achieve this. However, few producers use coarse wool in these products, and many are made of pure Merino wool. Using Merino wool which is often considered of very fine quality due to the low micron-count does not correspond with the ideal of good utilisation of resources. Therefore, we are proposing to utilise coarse wool which today is discarded as a mere by-product to meat-production. Merino could instead be used for products where fineness and softness are important factors such as for clothing. In addition, we argue for the rawness and uniqueness of the look of coarse wool as positive in terms of aesthetics and as something that adds to the position of acoustic products made of wool as high-end.

Keywords

Wool, acoustics, sound absorption, resource utilisation, WOOLUME, sustainability, Circular economy

Sammendrag

Denne rapporten er første leveranse fra arbeidspakke 2 i WOOLUME-prosjektet. Hovedmålet med WOOLUME er å utforske ulike måter å bruke ull fra polske fjellsau for å oppnå bedre utnyttelse av ressurser og økt verdiskaping. Målet med rapporten har vært å kartlegge markedet for akustiske og lydabsorberende produkter laget av ull for å undersøke potensialet for å innføre grov ull som materiale. Dette er gjort gjennom skrivebordsundersøkelser og intervjuer med fokus på ullens egenskaper som et naturlig produkt. Funnene viser at selv om menneskeskapte materialer som polyester dominerer på markedet for akustiske produkter på grunn av lavere priser, foretrekkes ull som materiale på grunn av dets naturlige egenskaper i tillegg til det estetiske. Produsenter som bruker ull anser produktene sine som eksklusive, hvor målgruppen er kunder som ønsker produkter av god kvalitet og som er villige til å betale en høyere pris for å oppnå dette. Imidlertid er det få produsenter som bruker grov ull i disse produktene, og mange er laget av ren merinoull. Bruk av merinoull som ofte anses å være av svært fin kvalitet på grunn av det lave mikronantallet samsvarer ikke med idealet om god ressursutnyttelse. Derfor foreslår vi å bruke grov ull som i dag bare blir kastet som biprodukt til kjøttproduksjon. Merino kan i stedet brukes til produkter der finhet og mykhet er viktigere egenskaper, som for eksempel i klær. I tillegg argumenterer vi for at råheten og unikheten ved grov ull er positivt med tanke på estetikk og noe som styrker posisjonen til ullakustiske produkter som eksklusive.

Stikkord

Ull, akustikk, lydabsorbering, ressursutnyttelse, WOOLUME, bærekraft, sirkulær økonomi

Preface

This report presents the findings from WP2 in the WOOLUME project. The project has received founding from the EEA research program POLNOR, as a collaboration between the Research Council of Norway and the National Centre for Research and Development in Poland. We wish to thank our collaborating partners in the WOOLUME project, Jan Broda, Monika Rom, Katarzyna Kobiela-Mendrek at the University of Bielsko-Biala in Poland. We are also much grateful to WOOLUME participants Ingun Grimstad Klepp and Tone Skårdal Tobiasson who meticulously read and commented the report.

The report has been reviewed and quality assured by Head of research Torvald Tangeland.

Oslo, June 2021

Consumption Research Norway (SIFO)

OsloMet – Oslo Metropolitan University

Executive summary

Introduction

The amount of wool wasted is high in Poland. During the last 15 years, on average 67% of greasy sheep wool has been lost. In the EU, unprocessed wool is classified as an animal by-product. In the International Resource Panel Report from 2017, utilisation of by-products from industry are mentioned as a way to reduce waste disposal and the need for extraction of virgin materials. The essence behind the WOOLUME project is to work towards the best utilisation of resources. From a perspective of resource utilisation, discarding wool is considered a waste since it is applicable as a material for many purposes. Using something that is already produced is better for the environment than producing new materials to fulfil that purpose. However, the price offered for sheep wool does not cover the cost of shearing. The objective of WOOLUME is to explore the potentials for utilisation of wool from Polish Mountain Sheep to create an economic incentive for not discarding useable wool. This report explores the European market for acoustic and sound absorbing products made of wool to assess the potential for utilising coarse wool in these types of products. Sheep wool has several positive natural qualities that contribute to a good indoor climate such as flame resistance and biodegradability, and it removes volatile organic compounds (VOCs) from the air. In addition, it provides products with a natural aesthetic with a raw and unique exterior look when used as a material. Previous research on the qualities of wool as a sound absorber concludes that the material holds good acoustic properties and may be used as a substitute or even compete with the more commonly used man-made materials such as mineral wool, polyurethane foam and polyester.

Method

This report is based on a mapping of acoustic and sound absorbing products in Europe using desk research and interviews with six European business actors. Searches for producers of wool products were carried out and they were reached out to for information. Additional information for mapping out the content of wool, prices and market uptake was also found during desk research. Potential interviewees were chosen based on information from their webpages. Producers that focused on and preferred wool as a material or had intimate knowledge about sound absorption were chosen. A total of six producers were interviewed either over email or on Zoom. A challenge was that several producers expressed hesitance towards answering questions, particularly about finances, due to a concern of market competition. Based on this, the approach was changed by adjusting the wording of the email request and carefully describing the interest in wool as a material and its potentials for use.

Results

The main categories of products for acoustic purposes made of sheep wool were found to be the following: felt, screens/dividers, wall/ceiling panels, rugs/carpets and other products, such as seat pads, cushions, furniture, insulation products, curtains etc. which are not meant specifically for acoustic purposes although some do have noise reducing properties. Custom-made screens and space dividers along with wall and

ceiling panels made up the high-end selection in terms of prices whereas other products made up the lower end. In addition, there was a significant price-difference between products made of sheep wool and products made of man-made materials. This was particularly evident when looking at sheep wool felt where prices were three to four times higher than for polyester felt. Information about the content of the wool in these products was limited and often only stating that the wool was merino or pure, new or virgin wool. This seemed to be related to a concern for “quality” (a word mention on several pages). For merino, this may have to do with the fineness of the wool which is often considered synonymous with quality. In addition, it was found that producers are highly dependent on the availability in the wool market where merino dominates. The value chain of a product is highly influential for who decides the type of wool used in production. For acoustic wool products, the value chains differ greatly depending on the size of the company. Products from larger companies with greater assortments tended to have a longer value chain while products from smaller, more specialised companies had a shorter value chain.

Discussion

This study has found that though man-made materials dominate the market for acoustic products, sheep wool is largely preferred as a material due to its natural qualities which aid in improving the indoor environment as well as the idea of wool as the more sustainable and local choice with better durability. However, due to the costliness of wool, it is difficult to compete with products made of man-made materials in terms of price. One possibility for lowering the price could be to utilise the coarser wool for the non-visible insides of the products with a thinner layer of finer wool felt on the outside. However, the position among producers and manufacturers towards their products was generally that they were meant for a high-end customer segment open to paying a little more but in return having the value of a more aesthetic quality product. By this definition, wool products seem to constitute a niche in the market for these products. Therefore, another approach is to integrate the varied look achievable from processing coarse wool into the brand of the product by establishing the aesthetic qualities as the benefits of a natural, raw and rustic exterior look. However, a cleavage exists between farm level and the receiving apparatus for this type of wool which needs to be closed before Polish Mountain Sheep wool can be integrated into production.

Conclusion

This report has discussed the qualities of sheep wool as a material and compared it to other, man-made materials commonly used for acoustic and sound absorbing purposes. Sheep wool holds several advantages in terms of sustainability and health concerns in addition to aesthetic qualities. The many different properties of wool and the variances between wool qualities have a potential to be sustained and taken advantage of in many new products, such as acoustic and sound absorbing installations. However, research on the acoustic properties of sheep wool remains limited and needs to be continued further in order to explore the full potential of wool as a material. Moving forward, further considerations need to be given to the issue of making it worthwhile for farmers to not discard the coarser wool.

Utvidet sammendrag

Introduksjon

Mengden av ull som kastes i Polen er stor, og i løpet av de siste 15 årene har i gjennomsnitt 67% av ubehandlet saueull gått tapt. I EU er ubehandlet ull klassifisert som et animalsk biprodukt. I rapporten fra det Det internasjonale ressurspanelet (IRP) fra 2017 er bruk av biprodukter fra industrien nevnt som en måte å redusere avfallsmengden og behovet for utvinning av nye materialer. Ideen bak WOOLUME-prosjektet er å jobbe for økt ressursutnyttelse. Fra et ressursutnyttelsesperspektiv er kasting av ull som sløsing. Å bruke noe som allerede er produsert er bedre for miljøet enn å produsere nye materialer for å oppfylle det samme formålet. Prisen for grov saueull er i dag så lave at den ikke dekker kostnadene ved klipping av sauene. Gjennom WOOLUME er målet å utforske potensialet for bruk av ull fra polske fjellsau for å skape et økonomisk incitament for å ikke kaste brukbar ull.

Denne rapporten utforsker det europeiske markedet for akustiske og lydabsorberende produkter laget av ull for å vurdere potensialet for bruk av grov ull i denne typen produkter. Det er dokumentert at saueull har flere positive naturlige kvaliteter som bidrar til et godt inneklima som flammemotstand og biologisk nedbrytbarhet, og det fjerner såkalte flyktige organiske forbindelser (VOC) fra luften. I tillegg gir den som materiale en naturlig estetikk med et rått og unikt utvendig utseende. Tidligere undersøkelser av egenskapene til ull som lydabsorbent konkluderer med at materialet har gode akustiske egenskaper og kan brukes som erstatning for de mer brukte menneskeskapte materialene som mineralull, polyuretanskum og polyester.

Metode

Denne rapporten er basert på en kartlegging av akustiske og lydabsorberende produkter i Europa ved bruk av skrivebordsundersøkelser og intervjuer med seks europeiske næringsaktører. Det ble søkt etter produsenter av ullprodukter og de ble kontaktet for informasjon. Ytterligere informasjon for å kartlegge innholdet av ull, priser og markedsopptak ble også kartlagt. Potensielle intervjuobjekter ble valgt basert på informasjon fra deres nettsider. Produsenter som fokuserte på og foretrakk ull som materiale eller hadde god kunnskap om lydabsorpsjon ble valgt. Totalt seks produsenter ble intervjuet enten via e-post eller på Zoom (videomøte). En utfordring var at flere produsenter var tilbakeholdende med å svare på spørsmål, særlig om økonomi, på grunn av bekymring for markedskonkurranse. Basert på dette ble tilnærmingen endret ved å justere ordlyden i e-postforespørselen og understreke interessen for ull som materiale og dets potensialer for bruk.

Resultater

Hovedkategoriene av produkter for akustiske formål laget av saueull ble funnet å være følgende: filt, skjermer/romdelere, vegg-/takpaneler, tepper og andre produkter, som sitteunderlag, puter, møbler, isolasjonsprodukter, gardiner etc. som ikke er spesifikt for akustiske formål, selv om noen har støyreduserende egenskaper. Skreddersydde skjermer og romdelere sammen med vegg- og takpaneler utgjorde det eksklusive

utvalget når det gjelder priser, mens andre produkter utgjorde den nedre enden. I tillegg var det en betydelig prisforskjell mellom produkter laget av saueull og produkter laget av menneskeskapte materialer. Dette var spesielt tydelig når man så på ullfilt der prisene var tre til fire ganger høyere enn for polyesterfilt. Informasjonen om innholdet av ullen i disse produktene var begrenset og handlet ofte bare om at ullen var merino, ren eller ny ull. Dette så ut til å være relatert til en ide om "kvalitet" (et ord brukt på flere sider). For merino kan dette ha å gjøre med ullens finhet som ofte betraktes som synonymt med kvalitet. I tillegg ble det funnet at produsenter er svært avhengige av tilgjengeligheten i ullmarkedet hvor merino dominerer. Verdikjeden til et produkt er svært bestemmende for hvem som velger typen ull som brukes i produksjonen. For akustiske ullprodukter varierer verdikjedene avhengig av størrelsen på selskapet. Produkter fra større selskaper med større utvalg hadde en lengre verdikjede mens produkter fra mindre, mer spesialiserte selskaper hadde en kortere verdikjede.

Diskusjon

Denne studien har funnet at selv om menneskeskapte materialer dominerer markedet for akustiske produkter, er saueull i stor grad foretrukket som materiale på grunn av dets naturlige egenskaper som hjelper til med å forbedre innemiljøet, samt ideen om ull som det mer bærekraftige og lokale valget med bedre holdbarhet. På grunn av ullens kostnad er det imidlertid vanskelig å konkurrere med produkter laget av menneskeskapte materialer når det gjelder pris. En mulighet for å senke prisen kan være å bruke grovere ull til den ikke-synlige innsiden av produktene med et tynnere lag med finere ullfilt på utsiden. Holdningen blant produsenter overfor produktene sine var dog generelt at de var ment for et eksklusivt kundesegment åpent for å betale litt mer, hvor de til gjengjeld får et mer estetisk kvalitetsprodukt. Etter denne definisjonen ser ullprodukter ut til å utgjøre en nisje i markedet for disse produktene. Derfor er en annen tilnærming å integrere det varierte utseendet som er oppnåelig fra bearbeiding av grov ull i produktets merkevare ved å etablere de estetiske egenskapene som fordelene med et naturlig, rå og rustikt utvendig utseende. Imidlertid eksisterer det et skille mellom gårdsnivå og mottaksapparatet for denne ulltypen som må lukkes før ull fra polske fjellsau kan integreres i produksjonen.

Konklusjon

Denne rapporten har diskutert kvaliteten til saueull som materiale og sammenlignet den med menneskeskapte materialer som ofte brukes til akustiske og lydabsorberende formål. Saueull har flere fordeler når det gjelder bærekraft og helse i tillegg til estetiske egenskaper. Ullens mange forskjellige egenskaper og avvikene mellom ullkvaliteter har et potensiale for å opprettholdes og utnyttes i mange nye produkter, for eksempel akustiske og lydabsorberende installasjoner. Imidlertid er forskning på de akustiske egenskapene til saueull fortsatt begrenset og må videreføres videre for å utforske ullens fulle potensial som materiale. Fremover må det tas hensyn til spørsmålet om å gjøre det verdt det for bønder å ikke kaste den grovere ullen.

Content

1 Introduction

The amount of wool wasted is particularly high in Poland. During the last 15 years, the average share of wool output was only about 33%, which means that on average 67% of greasy sheep wool is lost, perhaps more as this can be under-reported (Klepp & Tobiasson, Forthcoming). For years, only a small portion of the wool was sold to the owner of the scouring facility in Poland, a monopolist enterprise. Now, the price offered for sheep wool does not even cover the cost of shearing. The price also fluctuates greatly, which entails an unpredictable income for sheep farmers. For the very coarse wool from mountain sheep, the problem with finding a market and good end-products, will be similar to such wool anywhere. In this report, we focus on the potentials for utilising wool from Polish Mountain Sheep (see Figure 1-1) in acoustic and sound absorbing installations and products. In this section, we will describe the objectives of the report and the background for the WOOLUME project. Then we will go through the qualities of sheep wool as a natural material and previous research on wool as a sound absorber.

1.1 Project objectives and research questions

This report represents deliverable 1 from work package 2 of the WOOLUME project. The objective is to research what types of products are optimal for local wool from Polish Mountain Sheep and investigate the European market for acoustic and sound absorbing products. We have gathered information about what type of wool is commonly used in these products in order to establish to what degree said wool is "misused" or optimally used, and to aid in determining the potentials for Polish wool to be used for products which the project plans to develop. The work in this work package has consisted of a market-overview for sound absorbing panels and other interior products (rugs, carpets, curtains, decorative woven or knitted wall-hangings) that can be used in public and private places for acoustic attenuation. In addition, we have done a mapping of wool-content, prices and the market for acoustic products. Specifically, the work package sets out to address the following questions:

1. What are the potentials and implications of using coarse wool as input into acoustic and sound absorbing products?
2. How are acoustic wool products perceived by consumers in terms of quality and aesthetics?
3. How is the European market for acoustic wool products?

1.2 Background: the KRUS project

The WOOLUME project is a continuation of work started in the KRUS project lead by Consumption Research Norway (SIFO)[1]. The project thereby builds on insights gained from studying the connection between wool as a raw material and the finished products within the textile industry and among consumers. The KRUS project had two major aims: to improve the market for and the value of Norwegian wool and to map out the

[1] For information about the project see KRUS final report

potential for local production as a step towards sustainability in the industry. During the WOOLUME project, three of the collaborating partners went on a trip to Poland to meet with professors from the local Textile Engineering University. They visited the Beskid region in the Carpathian Mountains and its wool producers along with the centre for promotion and sales of products. The trip also included tours of the local textile museum, a hat factory and a weaving mill. During this pilot project, they found no use of local wool even though traditionally this had been an important part of their local textile industry. The Polish partners also travelled to Norway to see how collection and processing of wool takes place here. This laid the foundation for a Polish-Norwegian collaboration focused on utilisation of local Polish wool in new products.

Figure 1-1: A lamb of the Polish Mountain Sheep (photo: private)

Part of the KRUS project was to deliver to the marketplace new and exciting products. The project contributed to better training of producers and development of the system for collecting, evaluating and classifying wool from Norwegian sheep breeds, with several new products being made. They proved that wool from the older breeds is well suited for knitted products from both hand and machine yarns, and may be used to make high quality products (Klepp et al., 2019). During preliminary testing for WOOLUME it was found that wool obtained from Polish Mountain Sheep is not useful for soft fabrics and not suitable for clothing production and other delicate textiles and yarn. In addition, the wool has a very high content of kemp which makes it difficult to spin. Alternative products became the focus, as it was assumed that the wool may be used for products for which rough and coarse wool is better suited.

In a survey with sheep farmers from the KRUS project, it was also found that wool from the oldest Norwegian breed, “Villsau” (Old Norse Sheep), is not being utilized well enough, but is instead being discarded by farmers. This problem was most prevalent on the larger farms. Fifty percent of the Old Norse sheep farmers with larger herds (between 50 and 190 sheep) throw away the wool. Wool from older sheep breeds, such as the Old Norse Sheep, has meagre prices and lacks industrial up-take which means that is it often burned, thrown into the sea, dug down or disposed of in other manners. The survey found that when wool was kept, it was used for felted products such as seating pads as well as insulation and trenches, which indicates that it is possible to increase utilisation of the kept wool and possibly to reduce waste.

Additionally, this wool provided a fine yarn in small scale production of knitting yarn, and it proved to be highly usable for both hand knitting yarn and machine yarn but including a larger unusable share than for production from newer breeds. A conclusion from the KRUS project is that increasing demand for wool from the older sheep breeds is the best way to increase financial return and thereby the economic incentive for taking care of otherwise wasted wool. A way of doing this is to increase the quantity of wool-products focusing on the variation and good qualities of wool (Klepp et al., 2019). We take this notion as a backdrop for WOOLUME, as we focus on the positives of using wool for sound absorbing products.

1.2.1 Good utilisation

Norwegian wool is primarily a by-product of the meat industry, which impacts the quality, value and price. In the EU, unprocessed wool is classified as an animal by-product[2]. In general, a by-product is an output that is not waste but has a lower value than the products or co-products. It is defined as "a substance or object, resulting from a production process, the primary aim of which is not the production of that item"[3]. Legally speaking, wool may therefore not be defined as waste. However, as a material wool is being discarded instead of utilized and thereby still ends up as waste. In this report, when discussing wool as waste, we refer to the end-stage of the life cycle for wool as a material.

Circular economy has been a central part of EU politics since 2014. Several important policy documents published by the EU from 2011-2015 focus on resource efficiency and waste prevention as essential strategies. Though policies in practice have largely been focused on recycling and reuse of waste. However, looking at definitions of goals and measures, circular economy contains a wider political agenda than this narrow focus, which may allow for an emphasis on waste as an important resource. In the International Resource Panel Report (UNEP, 2017), utilisation of by-products from industry are mentioned as a way to reduce waste disposal as well as the need for extraction of virgin materials. An example of EU regulations including utilisation of waste from industry is the ban from 2019 on throwing overboard unwanted fish and other catch, such as sea turtles and dolphins, known as "bycatch" (Stokstad, 2019). In Norway, such a ban was instituted already in 1987 (Regjeringen.no, 2018). It is possible that similar regulations regarding by-products could increase utilisation of wool and decrease waste.

The essence behind WOOLUME is to work towards the best utilisation of resources. This does not only have to do with finding good use for by-products, but also about refraining from using something which is of unnecessarily high quality for purposes that other and lesser raw materials could be used for. It is essential in order to end up with the best possible product to use the raw materials in a way that properly exploits the specific properties of those materials in the best possible way as is discussed regarding for example leather and fur in the Jutulskinn report (Klepp & Haugrønning, 2021).There are many ways to optimise the use of wool fibres, depending on qualities

[2] For more information about animal by-products, see the official website of the European Union

[3] For more information, see the Waste Framework Directive of the European Union

like coarseness, fineness, strength etc. For example, it would not be optimal to use fine and soft merino wool in insulation materials, as the special quality of this wool is its softness, an attribute which is irrelevant for isolation. Better utilisation of resources entails using this wool for a purpose for which its special qualities are relevant, such as next to skin clothing or thin suits where merino wool is highly optimal.

As a global commodity, the diverse uses of wool in the market are vast, found in sectors such as apparel and fashion, activewear, flooring and interiors, aviation, architecture, manufacturing, medical use and protective apparel. In this way, wool as a material constitutes an asset in the textile industry. Exact statistics are not available for wool waste, but it is estimated that about 80% of wool is discarded in the EU due to lack of systems for and the high cost involved in handling the wool (Klepp & Tobiasson, Forthcoming). From a perspective of resource utilisation, this is considered a waste of resources since the wool is already produced and applicable as a material for many purposes. Using something that is already produced for a purpose for which the material is applicable and highly suitable, is better for the environment than producing new materials to fulfil that purpose. Leaving wool to rot or burning the wool also has adverse climate impacts.

1.3 The properties of Wool

Sheep wool has been suggested as a viable alternative to man-made materials for production of acoustic elements and other sound absorbing products. In this section, we will go through some of the physical properties of wool related to the structure and content of the wool fibre as well as the aesthetic qualities of wool. We will look at how these natural characteristics are connected ana the advantages of wool as a raw material.

1.3.1 The physical properties

Wool is a very complex fibre. It is composed of a single protein called keratin, which contains five main elements (hydrogen, carbon, oxygen, nitrogen and sulphur) and other elements. The layers in the wool fibre are composed of two types of cells; the internal cells of the cortex and the external cuticle cells (see Figure 1-2). What makes wool unique among textile fibres are the cuticle cells resembling scales which overlap like tiles on a roof. As the exposed edge of the cuticle cells points from the root of the fibre towards the tip, friction is created which helps to expel dirt and other contaminants from the fleece. This is also what makes felting of the wool possible, a characteristic not shared with other textile fibres (Allafi et al., 2020).

Sheep wool comes in the form of a corrugated fibre with a diameter of 16 to 40 µm and a total length of 35-350 mm depending on the breed, age, body part and shearing of the sheep. A sheep wool fibre of 16 µm correlates to that of mineral fibres while a 33 µm sheep wool fibre would be about the same size as PET polyester fibres (Del Rey, Uris, Alba, & Candelas, 2017). Different densities may be achieved through varying methods for processing (Ballagh, 1996). The British Wool grading system characterises wool based upon its style and characteristics. The style of wool is determined by its staple length, crimp, fineness, handle and lustre. There are six main styles of British Wool: fine, medium, mule, lustre, hill and mountain, in addition to a number of speciality

wool. Within each style of wool, fleeces are graded by quality with judgements made across a range of characteristics including colour, staple strength, uniformity, kemp, grey fibre, first/second shear and whether the wool comes from a hogg or an ewe (British Wool, n.d.).

In Poland, classification of sheep wool is very different from the British model as a formal system for collection and sorting does not exists. According to our Polish partners, there are only a few companies offering collection of wool (scattered across the country) but the owners need to deliver the wool on their own. There is only one mobile point collecting of wool in the whole country. Prices of wool in collection places do not depend on the quality, the purity of the fleece does not matter. Sorting of wool (if any) takes place during shearing, when black and white wool is separated. Depending on the size of the farm, the owners try to process the wool on their own or simply bury the wool.

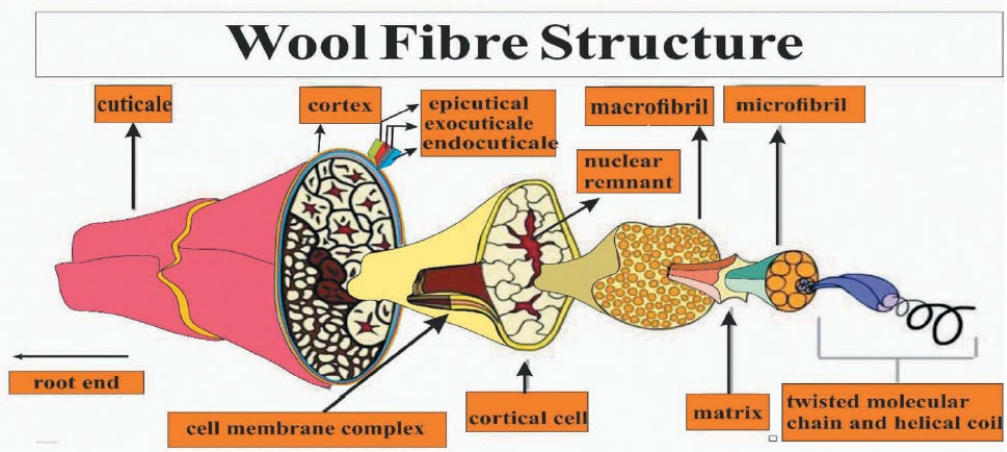

Figure 1-2: The wool fibre structure (adapted from Allafi et al. (2020, p. 2))

The WOOLUME project is focused on wool from Polish Mountain Sheep bred in the Beskids, the western part of the Carpathian Mountains. A characteristic feature of the native breeds of sheep in the Polish Carpathians is their exceptional resilience when it comes to climatic conditions and diseases. Due to a high density of their wool coat, composed of thin down fibres and much thicker medium and guard hairs, they are excellently protected against pro-longed rain (Klepp & Tobiasson, Forthcoming).Their fleece consists of coarse outer guard hairs, inner finer soft wool-fibres and stiff kemp. The particular content and properties of the fibres are, however, unknown and have been little studied and measured due to lack of interest in the wool.

As a part of WOOLUME, Selbu spinning mill in Norway and our Polish partners are testing the wool while this report is being written. Weaving with the yarn produced from the Polish wool has proved to be challenging. It has been suggested that it may work better to make tufted carpets as this will be a cheaper and easier process with the same final look (see Figure 1-3). Tufted rugs and carpets are made by punching U-shaped loops of yarn or wool through woven fabric using a tufting gun. Afterwards, the loops are sheared to make the carpet flat and smooth. First, Selbu spinning mill tried to produce a spun tufting yarn but due to the very high content of kemp in the Polish wool it is difficult to spin in the machines. The idea now may be to make rug yarn from the wool and use that for tufting, perhaps using a core of a different type of wool.

Figure 1-3: Some results of tufting tests done by our Polish partners with yarn made at Selbu spinning mill from wool of Polish Mountain Sheep (photos: private).

1.3.2 Flame resistant, self-extinguishing and biodegradable

The chemical features of sheep wool pertain to its advantages as a material, for example as the chemical bonding between proteins result in high strength (Alyousef et al., 2020) and the high sulphur amount means better treating properties and higher resistance to chemical impacts (Allafi et al., 2020). The scales and crimp of the wool lead to that textiles made of wool fibres contain a lot of air and therefore have a heat insulating ability. In addition, the epicutical (see Figure 1-2) acts as a natural water repellent membrane. Therefore, less chemicals are needed for processing to achieve this property in wool textiles (Arnesen, 2015). Wool is also naturally flame retardant. The material has a high ignition temperature of 570-600°C (in comparison, polyester ignites around 150°C) in addition to a low rate of heat generation (Røsvik, 2012). When wool does burn, it is slow and easily extinguishable. The self-extinguishing effect of wool is due to the high presence of nitrogen in the protein, as this increases the need for oxygen in the immediate surroundings in order to catch fire (Parlato & Porto, 2020).

Unlike synthetic fibres, natural wool is allergy friendly as it is highly resistant to dust mites which produce a strong allergen that many people react to. In addition, wool fibres are heavy enough to fall to the ground and therefore do not contaminate the air we breathe (Arnesen, 2015). Moreover, if wool fibres are inhaled, they are not hazardous to human health. Therefore, wool is also a safer and more pleasant material to work with (Ballagh, 1996). Wool elements may be installed without wearing special protective gear (Broda & Bączek, 2020). In addition, sheep wool has been proved to absorb volatile organic compounds (VOCs) and thereby improve the indoor climate when used for interior products or building materials in houses and homes (Mansour, Marriott, & Ormondroyd, 2016).

Another positive property of wool, which is often brought forward, is that production has lower environmental impacts than production of synthetic materials (Asdrubali, Schiavoni, & Horoshenkov, 2012). The energy required to process wool as a raw

material is lower compared to that required for synthetic materials (Borlea Mureşan, Tiuc, Nemeş, Vermeşan, & Vasile, 2020). Hassan and Carr (2019) found that processing 1 m^3 of sheep wool insulation produces only about 5.4 kg of CO^2 whereas the same quantity of mineral wool produces 135 kg of CO^2. Parlato and Porto (2020) argue for an additional environmental advantage of wool related to transport, as wool can be compressed allowing for big reductions in volume, and thereby for more wool to be transported at a time.

An important environmental advantage of wool is its biodegradable properties. In a humid environment, under the influence of enzymes secreted by microorganisms naturally present in the soil, wool keratin is broken down and consumed. Under ideal condition, buried wool products are completely degraded after six months (Swan, 2020). As a result of decomposition, nitrogen compounds are slowly released into the soil. In the soil, by the action of enzymes, organic nitrogen is transformed into mineral forms, which are easily absorbed by growing plants. Through the release or nitrogen, wool works as an effective fertilizer, which promotes intense plant growth. The topic of wool as a fertilizer will be dealt with in the subsequent WOOLUME report as a deliverable of work package 2.2.

The issue of the sustainability of wool as a material has, however, been contested, especially for clothing production. According to the Higg Index[4], sheep wool comes out in the top five of materials with the highest environmental impact from cradle to gate (Kerr & Landry, 2017). Wool scores particularly high on this index when it comes to emissions of greenhouse gases. In a recent publication, Horne (2020) similarly calls out wool as the definitely worst material in a strict climate perspective mainly because of methane emissions from sheep. These approaches to determining fibre sustainability have, however, been criticized among other things for solely focusing on production and not including the full life cycle of the fibre (Cook, 2019; Dove, 2017; Klepp & Tobiasson, Forthcoming). Following a life cycle analysis (LCA), use is of primary importance when it comes to the climate footprint of textile consumption. As wool clothes are used for longer and thereby washed less often than clothes made from other fibres, wool has some definite advantages (Klepp & Tobiasson, 2013). In addition, woollen products have been shown to have longer average lifespans than clothes made from other materials (Laitala, Klepp, & Henry, 2017).

1.3.3 Aesthetic properties

Sheep wool is a material rich in tradition and appreciated by many. A large number of handicraft and artisan traditions are built around the material as it is generally considered quality products. A quality of sheep wool is how it relates to almost all of our senses. In this report, we are focused on how wool interacts with sound and how this affects acoustics, but the material also interacts with at least three of our other senses: feel, look and smell.

Tests on clothing worn next to skin have shown that woollen garments have the least odour and lowest odour build up compared to other textiles made from fibres such as

[4] For more information about the Higg Index, see the Sustainable Apparel Coalition

polyester and cotton. In general, natural fibres smell less than synthetic fibres (McQueen & Vaezafshar, 2019). Smell may not at first sight seem to matter very much when dealing with acoustic elements. However, for some applications it may have importance, such as in gyms where sweat and other bodily fluids are prevalent, in kitchens where food is cooked and in kindergartens and primary school where the products may be exposed to physical contact making them dirty. As we shall argue later about sound, smell is very important for a comfortable environment. It may be relevant to consider how the smells given off from the materials themselves as well as from the external smells they trap affect the indoor climate at the spaces of application.

The feel of wool is mostly discussed in connection with clothing, such as the example of merino versus coarser wool. However, the feel of wool is also relevant for products like cushions, carpets, rugs and furniture which all potentially come in close contact with the body. Even acoustic products could very well have an exterior look that invites to be touched. Since wool is resilient as a material, wool products will not wear easily from touching. Wool products may invite to touching in the same way that certain children's books and toys meant for tactile stimulation do; with varying surface textures and shapes.

Figure 1-4: Outdoor Christmas decoration made of sheep wool which in the spring will provide materials for birds to build their nests (photo: private).

Look is the last sense we wish to discuss. A raw sheep wool surface may be considered "finished", whereas mineral wool, which is not meant to be touched or even looked at, needs to be covered with something else to be finished. Sheep wool is easily processed into something that is pleasant for both touch and look. Due to this quality, sheep wool is from time to time used for art installations and interior design products. Each will look (and perhaps feel?) different as wool is a natural product, particularly if a minimum of processing has been applied. Design is important to consider for acoustic and sound absorbing products as these are used in a way that makes them almost constantly visible. Using a material such as wool which provides a natural aesthetic and exterior look will partake in creating a pleasant indoor environment. The look of wool varies with breed and here thinner (and softer) wool may not necessarily be perceived as more appealing. Coarser and less treated wool can give a rustic, original,

genuine expression which is difficult to achieve with a finer wool. The different colours of wool also provide many possibilities for aesthetic variation, patterning and so on.

1.4 Previous research on acoustic wool products

A large proportion of acoustic products are made of synthetic or other man-made fibres, and when sheep wool is evaluated as a sound absorber it is often compared to these materials. The most common are:

- *Mineral wool*: a material made by spinning fine mineral or rock material into a fibre-like structure. Stone wool is a type of mineral wool, often known as Rockwoll, the name of one of the leading companies within insulation materials.
- *Glass wool*: a material made of extremely fine fibres of glass arranged using a binder into a texture similar to wool. This process traps many small pockets of air between the fibres which facilitates sound absorption and insulation.
- *Polyurethane (PUR) foams*: panels made from the polymer polyurethane and often shaped like egg cartons to create sound diffusion. PUR foams are synthetics and their main materials are raw liquids derived from petroleum.
- *Polyester*: a synthetic polymer made from petroleum and the most used textile fibre in the world. As a specific material, it most commonly refers to polyethylene terephthalate (PET) known from plastic bottles. Recycled PET is typically from plastic packaging like PET bottles.

When discussing the use of sheep wool for acoustic products, the advantages of wool as a natural product in contrast with these man-made products are mentioned as important factors (for example Allafi et al., 2020; Corscadden, Biggs, & Stiles, 2014; Del Rey et al., 2017). However, the qualities of wool related to its ability to absorb and attenuate sound are essential to consider before recommending wool for acoustic products. In this section, we will outline the technical attributes of wool as a sound absorber. Then we will present research arguing for the potential of sheep wool to compete with some of the more commonly used materials for acoustic products in terms of sound absorption.

1.4.1 Acoustics and sound absorption

Open space solution are becoming more and more widespread and are found for example in schools, libraries, office landscapes, lobbies and museums (Røsvik, 2012). This introduces a number of challenges related to both physical division and decoration of the space as well as noise and acoustics. Studies have shown that a comfortable acoustic environment assures easier communication, increases productivity and reduces illnesses of the occupants (Secchi et al., 2016). Noise control plays an important part in creating an acoustically pleasing environment, meaning that the intensity of sound is brought down to a non-harmful level for the human ear. It can be achieved through various techniques using different materials, one of which is to absorb the sound (Nordin, Wan, Zainulabidin, Kassim, & Aripin, 2016).

Sound absorbing materials absorb most of the sound striking them and are therefore very useful to control noise (Arenas & Crocker, 2010). Materials for sound-absorption are mainly defined through three categories: porous absorbers, membrane absorbers

and resonance absorbers. Felted wool, along with mineral wool and glass fibre, are part of the category of porous absorbers with a pore structure of continuously joined-up airspaces (Rom & Tonik, n.d.). Porous materials are usually the most sound absorbing due to the open channels of pores that sound waves are able to enter through (Arenas & Crocker, 2010). Furthermore, porous materials can be classified as either cellular, fibrous or granular based on their microscopic configurations. Felted wool, mineral wool and glass fibre are all categorized as fibrous materials, while for example polyurethane is cellular and concrete, sand and gravel are granular (Arenas & Crocker, 2010). Porous fibrous materials primarily absorb medium or high frequencies. The lowest frequencies are the most difficult to dampen since they have a very long wave length (Rom & Tonik, n.d.).

When testing the sound absorbing effects of wool, the interesting parameters to explore are density, fibre diameter and flow resistivity. Tests have shown that sound-absorption increases when density increases and when fibre diameter decreases. In addition, flow resistivity increases when density increases. With high density, low frequencies (below 500 Hz) are better absorbed but at the expense of the higher frequencies (above 2000 Hz) (Arnesen, 2015). Thickness of the material has a direct relationship with absorption of lower frequencies but at higher frequencies thickness has insignificant effect on sound absorption (Nordin et al., 2016). The frequency limits of audibility are from 20 Hz to 20,000 Hz. When we speak, it is in frequencies ranging from around 200 Hz to around 3000 Hz (Rom & Tonik, n.d.). Therefore, when testing the sound absorbing properties for wool with acoustic products for home and office in mind, the main focus for researchers will be to see how it performs in this range.

1.4.2 Wool as a sound absorber

Several studies of the qualities of wool as a sound absorber have concluded that the material holds good acoustic properties and may be used as a substitute for or even compete with the more commonly used, man-made materials (for example Allafi et al., 2020; Corscadden et al., 2014). One of the reasons for this conclusion is that wool is found to have broadly similar properties to that of fibres such as mineral wool and glass fibre (Ballagh, 1996) as well as polyurethane foams (Del Rey et al., 2017). Symons, Clarke, and Peirce (1995) found that sheep wool shows better sound absorption properties in comparison with mineral wool and glass fibre, while Arnesen (2015) argues that though wool does not measure up with glass fibre in terms of absorption, its abilities are sufficient for dampening normal speech. Broda and Bączek (2020) found that the sound absorbing abilities of wool are related to the sound wave frequency and conclude that sheep wool is a good sound absorber, especially at medium and high frequencies.

A challenge in using wool for production of sound absorbing products is that as a natural product, the material will have a range of different physical properties both within one and between samples (Ballagh, 1996). This may create variations in the fibre diameter. However, as the acoustic properties do not depend strongly on the fibre diameter (Arnesen, 2015), they should be maintained, unless the differences become substantial. In addition, man-made fibres, such as mineral wool and glass fibre, also contain variations within and between samples.

Research on sheep wool for acoustic products remains relatively limited. Therefore, potential for better utilisation of the fibre may exist that is yet to be discovered. Rubino, Bonet Aracil, Liuzzi, and Martellotta (2019) tested the use of a chitosan solution to bond merino wool waste fibres with positive results. It may also be possible to increase the range of the ability of the wool products to dampen the lower frequencies as well, by combining it with a membrane or resonance absorbent (Rom & Tonik, n.d.). Different ways of processing the wool may also grant different results. Arnesen (2015) tested different materials and applied different densities. It was found that glass fibre along with wool of low densities had better sound absorbing qualities than polyester and wool of high densities. Borlea Mureşan et al. (2020) tested hot- and cold-pressing the wool and found that hot-pressing the wool created better or at least equal sound absorbing properties as mineral wool. These examples indicate the potentials of further optimizing wool of different qualities and structures as a material for sound absorption.

2 Method

In order to attempt to map out the opportunities for utilizing sheep wool from remote mountain regions in Poland in acoustic and sound absorbing products as well as other wool products, we applied the following methods to make up our market analysis: desk research, short email-interviews and longer interviews using Zoom (a cloud-based video conferencing tool). In order to ensure relevance, we focused purely on the European market and interviewed only European business actors.

The purpose of the market analysis was to create an overview of the market for sound absorbing panels and other interior products to be used in public and private spaces to regulate acoustics. During the initial searches we discovered manufacturers of other alternative wool products, some of which we decided to reach out to as well. These include insulated packaging, furniture, mats, sleeping and sitting pads, and other smaller interior items made in wool. We ended up conducting 3 interviews over Zoom, 3 interviews over email and we looked through more than 25 webpages of producers and manufacturers.

2.1 Desk research

To get an overview of the market for acoustic and sound absorbing wool products, we began with desk research. This entailed, on the one hand, searching for producers of wool products to reach out to for information and potentially interview and, on the other hand, finding information useful for mapping out the content of wool in products, prices and market uptake.

2.1.1 Searching for producers

We carried out extensive searches using key search words in Google in Norwegian, Danish, Swedish, English and German. German was included at a later stage since we discovered that many producers of these types of products are based in Germany. From there, we were able to find several manufacturers as well as other sources pointing us in the direction towards producers working with wool in sound absorbing products. The search words used were:

- Acoustic products wool
- Sound absorbing products wool
- Wool felt acoustics
- Acoustic sheep wool
- Sheep wool sound
- Wool panel acoustics
- Rugs sheep wool
- Tapestry sheep wool
- Coarse wool product

A major source turned out to be a brochure of a so-called Wool B&B[5]. To mark the seventh annual Wool Week in 2016, the Campaign for Wool turned an entire house in London into a B&B where everything inside was made of wool. Many companies carrying wool products participated in this transformation and we were able to find their names in the brochure.

Another part of desk research entailed researching each producer prior to the interviews. The companies we found were both larger and smaller producers of a variety of products, as mentioned above. Below, we have added a small overview of the producers we found, table 2-1. They are sorted by size using the definition of the European Union of enterprise sizes[6] and by what type of products they make. Other products refer to interior products besides the three main categories like seat pads, coasters and decorations, as well as insulation packaging and even urns and coffins made of wool. The companies are based in the following countries: United Kingdom, Sweden, Germany, Denmark, Norway, Ireland, Austria, Netherlands, Switzerland, Iceland and Spain.

Table 2-1: Overview of producers by company size (number of staff) and type of products.

	Micro (<10)	**Small (<50)**	**Medium (<250)**	**Large (>250)**
Felt			1	1
Screens and panels	6	3	3	2
Rugs and carpets	2	1	2	2
Other products	2	2		

The majority of companies are micro and small in size. These tended, in addition, to be more specialized towards acoustic wool products whereas the larger companies also made other products of wool and/or products of other materials. We made an effort to know as much as was possible from the webpages before an interview in order to be able to ask specific questions and get as much out of the interviews as we could. This also applied to the shorter email-interviews as we adapted our list of questions to each interviewee.

2.1.2 Searching for information

In addition to researching the producers, we attempted to retrieve information from the webpages of producers and elsewhere about the market for acoustic wool products. Some producers had very detailed information available whereas others had less. Specific information about the type of wool used in the products was usually missing as the details would be limited to stating that the products were made of 100% (sheep) wool or sometimes 100% merino wool. Since an aim was to map out the wool content, we contacted producers to find out what they knew about this when it was not stated directly on the webpage. In terms of product prices, some had these on their webpages while others asked to be contacted regarding prices. This difference primarily had to do with differences in the types of deliverables. The companies that offered custom made

[5] For more information about the Wool B&B see the Campaign for Wool

[6] See SME definition of the European Union

solutions rarely had prices listed, whereas companies with finished products usually had prices available.

By using Google for searches we also gained an impression of the market for acoustic products in general. Our findings indicate that most acoustic products are made of man-made fibres and the fact that mineral wool or rockwool is commonly used complicated the search which is why many of our searches include the specification of “sheep” wool. However, this left out results that did not include the word “sheep” and we therefore still had to search only using “wool” and look carefully through webpages to discover the actual content of the products.

2.2 Interviews with major actors in the market

Since the market for acoustic products made of wool is relatively small, we contacted all companies and producers we came across during our desk research. Most producers we asked for a short email-interview, and a few were selected as potential interviewees for a longer Zoom-interview (30-45 minutes). When choosing informants, we opted for producers that seemed to focus on and have a preference for wool as a material or that seemed to have intimate knowledge about sound absorption, based on the information from their webpages.

We sent out requests for interviews using a standard form which we adapted as the project proceeded and we learned more. We, for example, left out questions about finances and specific inquiries about the companies such as yearly turnover, prices for products and number on employees since these types of questions seemed to make the producers hesitant to talk to us. In general, information about money and finances is often considered sensitive. Instead, we focused on the wool and its content along with questions about how the producers perceived the potential of using coarser wool for their products and what feedback they received from customers.

We had two standard interview guides; a short for email interviews and a longer for Zoom-interviews. We adapted the guides before each interview to fit with the producer as the relevance of the specific questions varied from interview to interview dependent on the size of the company and the type of products they carried. The short guide which was sent out by email was either in English, Norwegian or Swedish. For the longer interviews, we always stated our main areas of interest beforehand, but did not provide any specific question until the actual interview.

A total of six producers were interviewed through three email-interviews and three Zoom-interviews. For the email-interviews, we received replies from one micro sized company (less than 10 employees) and two small sized companies (less than 50 employees). These companies all produce acoustic screens and panels for walls and ceiling, two of them also make other textile products such as curtains, furniture and fabric. For the Zoom-interviews, we met with representatives from one micro, one small and one medium sized company (less than 250 employees), one specialized in acoustic panels and screens, one that made acoustic products in addition to other interior products and one was a producer of felt.

The Zoom-interviews were carried out by both researchers participating through individual computers at SIFO. We did not record the interviews. Prior to the interview, the interviewee had received a short summary about the project. We began each interview with an introduction of the project and ourselves. The interviewees were informed about how information from the interviews would be used, both verbally and written. During the interview, we focused on the type of wool used by the producer; type of wool, where it is from, how they purchased it, how they perceived other fibres used for production of acoustic elements and reflections about the market for these products. The interview was carried out as semi-structured, as we were interested in hearing what the producers perceived as important. As the final question, we asked them if there was something we had forgotten to ask about, in their opinion. This resulted in some very interesting information as well as insights into what is seen as important in the industry.

2.3 Methodological challenges

2.3.1 Recruitment and data collection

One of our greatest challenges was to obtain contact with the producers. We contacted all 27 producers mentioned above, but only nine replied. In addition, some of those who did reply expressed hesitance in terms of answering questions due to concerns of market competition. We were able to ensure a few that our interests were purely scientific, and that we had no commercial partners on the project. We also changed our approach by adjusting the wording in the initial email request and we carefully described that our focus and interest was wool as a material and its potentials for use. However, we expect that this concern related to competition may have been a reason why many producers never responded. In addition, SMEs are often pressured for time since they have to carry out several types of activities with few employees. This may have been another reason for low response rates.

Another challenge related to how to contact the producers. Some only had contact information regarding purchases or press inquiries on their webpages, and it could be difficult to find the right person to contact. Others had a built-in contact form on their webpages. We contacted four but received only one reply using this type of contact form.

Due to the producers' concern for market competition and the adjustment we made to the interview questions to accommodate this, we were not able to gather any specific information from the interviews about sales or finances. Therefore, results and analysis of this is based solely on what we were able to retrieve from webpages. Most of the companies were listed in public registers and some information was available through their Linkedin profiles which enabled us to determine sizes of the companies based on number of employees and yearly turnover.

2.3.2 Ethical concerns

Due to issues related to competition, as mentioned above, and anonymity for the interviewees, we decided to leave out any mentioning of specific producers, brands, design or products in the report. This decision was based on two considerations.

Firstly, since the market for acoustic and sound absorbing products made of wool is relatively small, we did not want the report to potentially distort competition between producers by highlighting some products in place of other. Secondly, naming producers or companies would make it difficult to distinguish between those we had interviewed and those we had just found online. Since we had assured our interviewees that they would remain anonymous and not be mentioned in the report, leaving out these companies and mentioning others, could potentially break their anonymity since there are so few actors in this industry.

In addition, we have chosen not to present full quotes in the report for three reasons. Firstly, we did not record and transcribe the interviews, so quotes would have to be comprised only from memory which would not make them exact quotes. Secondly, we chose to omit quotes due to issues of anonymity. The producers often spoke of specific products in their assortment or specific perspectives or values held by their companies which may have been used to identify them. By informing interviewees that they would not be quoted, we hoped that they would feel like they could speak freely and openly to us. Thirdly, we considered it of greater interest and importance to present an overall picture of challenges and experiences among producers than specific statements.

3 Results

In this section, we present results from the desk research and the six interviews. The primary results relate to the content of the wool used for acoustic products, the prices of the acoustic products and the market for these. The results will be discussed further in chapter 4. One important finding is that many of those dealing with wool, either manufacturers of acoustic products or producers of felt, care greatly about wool as a material and are concerned with raising the value of wool.

3.1 Content of wool in acoustic products

One of our main questions during interviews was related to the content of wool in the acoustic products as we found little specific information on the webpages of the producers and manufacturers. Sometimes it was specified slightly through stating that the wool was merino or pure, new or virgin wool. Pure wool means that it is 100% wool, whereas new and virgin means that the wool has not been used before, that it is not "shoddy". Shoddy is made by tearing up used wool and wool products into small pieces so that the fibres may be loosened and spun into new yarn (Klepp & Tobiasson, 2013). It is interesting that the fact that the wool is new and thereby not recycled is brought forward as a positive by producers of wool products when the opposite seems to be true for some using synthetic materials for their acoustic products. This will be elaborated on in section 3.3.

We gather from the information we found on the webpages that concerns for "quality" (a word mentioned on several pages) is one reason for choosing and advertising merino and new, virgin wool. For merino, this may have to do with the fineness of the wool which is often synonymous with quality. Merino wool has very fine fibres of as low as 17 µ and is often regarded as a very fine type of wool in terms of quality for clothing (Klepp & Tobiasson, 2020). In comparison, wool from the most common Norwegian breed, the crossbred, has a fibre diameter of 30-40 µ[7]. Some implications of this will be discussed later. For new wool, it is true that tearing up textiles and re-spinning fibres will produce a lower quality in that the materials will have lower durability and shorter fibres than materials made of new wool (Klepp & Tobiasson, 2013). This is essential for clothes that wear out but may be less significant for sound absorbing products. The use of shoddy could therefore be a positive in a resource perspective, in the same way as using wool which is unfit for spinning.

We found in interviews that producers have little say in choosing the type of wool they use and are highly dependent on what is available in the market. One interviewee from a company producing felted acoustic installations told us that they rely on their supplier of the felt for the choice of wool. They themselves played no role in deciding this and trusted that the supplier chose the wool they found best suited to produce good quality felt. A felt supplier told us that they choose wool based on the product for which the felt is intended but that they are also constricted by what is available in the market. Another

[7] For more information on Norwegian sheep breeds, see Hillesvåg Ullvarefabrikk

interviewee explained that their choice to use 100% merino wool was because of easy availability as well as the colour pallet they were able to achieve with this type of wool. When asked, interviewees said that their companies would be open to the use of coarser wool if it became available for purchase either as a raw material or felted.

3.2 Prices for acoustic wool products

The prices for acoustic wool products were not readily available through the webpages in all cases, as products such as room dividers, carpets and wall and ceiling panels often are custom made. We were, however, able to learn something about price ranges through webpages of retailers and in some cases producers had their own online sales outlet with prices. In this section, we will look at and compare some examples of prices for products from the following categories: felt, screens/dividers, wall/ceiling panels, rugs/carpets, and other products. We will also mention prices of some products made of man-made materials for comparison. Since we were not able to obtain prices from all producers for all products, this is not a definite estimate, but only intended to give some insight into the price ranges.

Figure 3-1: Example of acoustic wool space divider from the Wool B&B (photo: the Wool B&B Brochure)

Wool felt constitutes the material from which many acoustic products are made and is primarily sold as fabric both for making sound absorbing products and for other areas of use such as handicrafts and interior products. The fabric comes in many colours and thicknesses and prices vary accordingly. We found prices for the thinnest fabrics (about 1 mm) as low as 20 EUR per square meter whereas the thicker fabrics (about 5 mm) came to 97 EUR per square meter. In comparison, the price per square meter for 1mm

polyester felt was found to be about 6-7 EUR from the same supplier. PUR acoustic foam panels (5 mm) could be found in the price range of around 65-80 EUR.

Screens and space dividers are often used in offices to better the acoustics of the workplace and to create private workspaces for employees in open office landscapes (see Figure 3-1 for example). These are mostly custom made to fit the customer's needs both in regard to style, size and quantity. Therefore, there were few available prices on the webpages of producers, but it may be said that these products constitute high-end products both in terms of quality and price. As an example, we found a series of space dividers with a price range of 2,800 to 8,000 EUR depending on size with the smallest option fitting a workstation for one person. Of products made of man-made materials, we found a series of PET screen walls in the price range of 300-600 EUR. However, these two series differ in terms of design work as the PET screen are in a much more simplistic design than the sheep wool screen. Prices are therefore not directly comparable, but it may be an indication that products from these materials constitute different product categories for different consumer segments.

Figure 3-2: Example of floor runners made of wool from the Wool B&B (photo: the Wool B&B Brochure)

Wall and ceiling panels are installed for sound-absorption either alone as larger elements or as smaller tiles put together in clusters. They vary in sizes and shapes and are often designed in a way that either makes them blend in with the surroundings or where they constitute a form of decoration and thereby improve the aesthetics as well as the acoustics of the space. This was the product type within which we found the largest range of both styles and prices. We found prices as low as 68 EUR per square meter and as high as 393 EUR per square meter depending on style, thickness and additional features such as suspension brackets, structures for assembly and addition of other materials such as wooden backplates. The lower-priced panels had mainly

simple designs and consisted of single elements, whereas the costlier panels had more unique designs and consisted of tiles which together made up a larger panel. The same held true for panels made of man-made materials. We found a series of stone wool panels with a price range of 25-70 EUR per square meter, panels made from PUR foam with prices starting at 212 EUR per square meter and a series of PET panels with prices starting at 240 EUR per square meter.

Rugs and carpets are, in addition to their sound absorbing abilities, also used to improve aesthetics, temperature and comfort in a room (see Figure 3-2 for example). We found a selection of wool rugs and carpets from different producers. Some were wall-to-wall carpets whereas others were rugs and floor runners of varying sizes. The average price found was around 200 EUR per square meter, but prices varied between below 100 EUR and up to 600 EUR for the higher-end rugs. The market for rugs and carpets made of synthetic materials is vast with prices as low as 10-20 EUR per square meter.

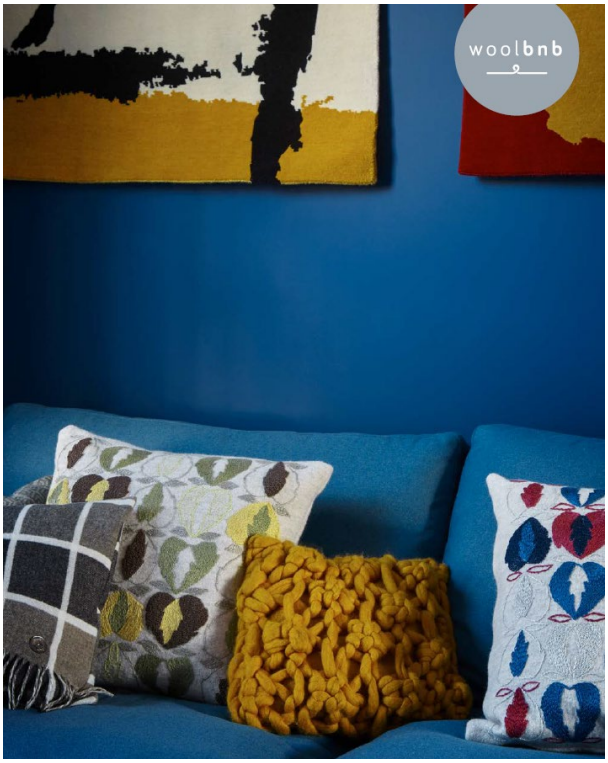

Figure 3-3: Examples of cushions and wall decorations made of wool from the Wool B&b (photo: the Wool B&B Brochure)

Other products include seat pads, sleeping mats, cushions, furniture, insulation products, coasters and place mats (see Figure 3-3 for example). These products made up the low-end selection of wool products in terms of price. In addition, these products are not produced or used specifically for acoustic purposes although some do have noise reducing properties. Pricing depended largely on the size of each product. The sitting pads we found were priced in a range of 12-20 EUR, coasters were lower priced, down to only 2 EUR, and place mats and cushions were higher priced, up to around 45 EUR.

3.3 Market for acoustic wool products

As mentioned above, some companies were reluctant to talk to us or share information with us due to competition concerns. As discussed, this may have been because they saw us as representing potential competitors in the acoustic wool products market. However, this reluctance speaks to the fact that there may be a high level of competition in this specific market. Since wool products are relatively higher priced compared to products made of man-made materials, the segment of buyers may be accordingly limited to those shopping for high-end products. The consequences of this for our conclusion about the potential of using coarser wool from Polish Mountain Sheep will be discussed further in chapter 4.2.

3.3.1 Different value chains

During desk research and interviews we found that products go through varying constellations of value chains from raw material before ending up as finished products. The value chain of a product is highly influential for who decides the type of wool used in production, how this is decided and thereby what is eventually decided. In Figure 3-4 below, we have illustrated some of the value chains we found among the producers we talked to. Each of them starts with the farm where sheep wool is produced as a raw material and ends with the customer. The customer may for example be a private person, a business or a public body. Products may later be recycled or reused, but as this is difficult to know and of less importance for the scope of this report, these possibilities have not been included in the illustrated value chains.

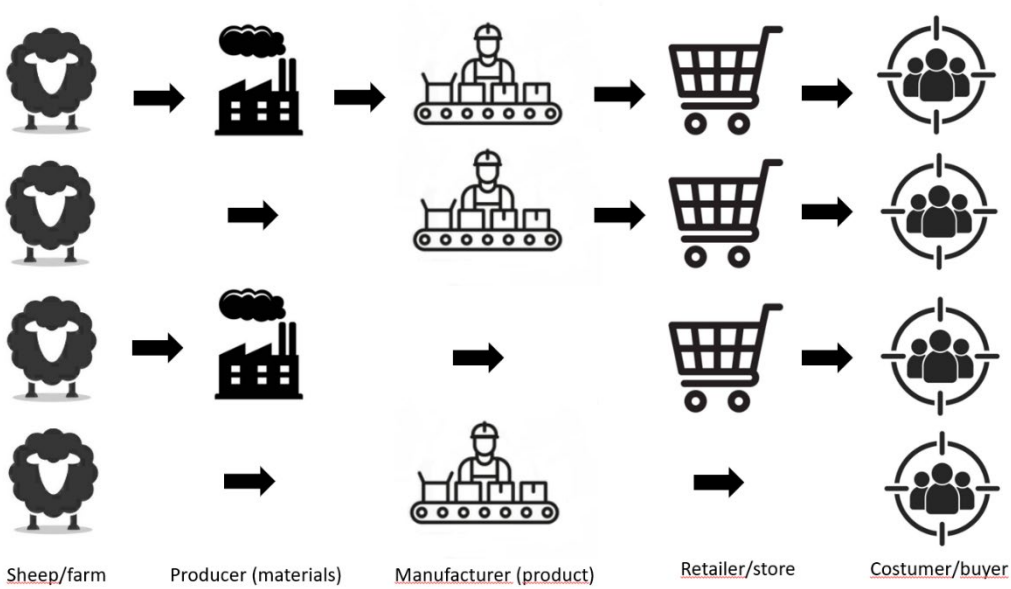

Figure 3-4: Illustration of different value chains for acoustic wool products (source: istockphoto.com)

Between the two points, farm and customer, the chain varies for many products. Some manufacturers buy the raw materials and process them themselves, whereas others buy processed materials such as textiles and felt from a producer. In addition, some manufacturers have their own sales outlet through their webpages whereas others sell their products through retailers with physical stores. In some cases, products are sold both through the webpages of manufacturers and in physical stores of retailers. The

size of the company and the value chain correlate as the smaller companies tend to have a shorter value chain than the larger companies. In addition, the larger companies tend to have a wider selection of products, in some cases also other products than acoustic products or products made of other materials.

Between farm and producer/manufacturer is a hidden link which is the European or Global trade market for wool where sheep wool is sold and bought. Before the wool enters this market, it has been classified by type and quality. When producers talk about buying “what is available in the market” this is what they refer to, in addition to the market for felt or other wool materials for further manufacturing.

4 Discussion

In this section, we discuss the potentials of using wool from Polish Mountain Sheep in acoustic products based on the results presented in the previous chapters. First, we compare wool as a material to other materials commonly used for producing these types of products regarding durability, aesthetics and sustainability. In these respects, wool comes out as the better choice, and coarser wool as the better choice in terms of best utilisation of resources. However, when we move on to discuss prices, wool is challenged in the competition with man-made materials. Therefore, we argue that acoustic wool products constitute a niche in the market, catering to a segment of the buyers interested in quality and who are willing to pay a higher price. In this way, sound absorbing wool products need not compete with acoustic products made from other materials. Instead, we argue that coarse wool, such as wool from Polish Mountain Sheep, may well be used for sound absorbing acoustic high-end products if it is introduced properly into the value chain.

4.1 Wool as a material

We discuss the use of sheep wool as a material in comparison with other materials used for acoustic products and findings related to content in products (often merino) with the ideal of best utilisation of resources. The aim is not to assert that wool should replace other materials, but rather to argue for the positive features of using wool compared to man-made materials based on our findings.

4.1.1 Quality, durability and aesthetics

Though merino wool often is regarded as the finest type of sheep wool as it is very thin and soft, it is not the strongest of the wool fibres (Klepp & Tobiasson, 2018). This is especially important to consider for products such as rugs and carpets which need to be produced of very durable materials. One interviewee mentioned that durability is also an advantage of sheep wool in comparison to man-made materials. Using sheep wool may enable them to produce products of high quality in terms of how long they last. Interestingly, when speaking solely of durability in terms of how long a material lasts, polyester is by far the strongest fibre. However, when durability includes aesthetics the topic becomes more complex as wool is often considered to “age with grave”. When polyester is considered less durable it therefore has less to do with the strength of the fibre, but instead social values and aesthetic preferences play in. This topic would be interesting to explore and develop further.

In the discussion of wool, expressions such as fine versus coarse wool are often used, but another expression for coarse wool can be ‘strong wool’ (NZ expression), which indicates that the coarser wool has properties that the fine wool does not have. The consideration of durability becomes less important for products where utilisation does not require high durability such as room dividers and panels. However, following the notion of best utilisation of fibre, even if merino wool is a higher quality of wool in terms of fineness and softness, using merino for acoustic products may not entail the best utilisation of wool. If the same level of sound absorption may be achieved using coarser

wool then this will entail a better utilisation of resources as merino wool in the low micron-range may instead be used for clothes or other products where softness is an important factor.

The world's wool trade is dominated by merino wool, the main product of the Australian Wool Innovation (AWI) (Klepp & Tobiasson, 2013). Therefore, we suspect that the reason why merino seems to be the popular choice for acoustic wool products has more to do with the availability of the material than the superiority of merino wool compared to other wool in terms of sound absorption. Merino has low fibre diameter and tests have shown that sound absorption increases with low fibre diameter and high density. However, it was found that density has the primary effect on sound absorption and that flow resistivity is unaffected by fibre diameter (Arnesen, 2015). Therefore, it is not possible to conclude that merino has better sound absorbing properties than coarser wool types.

Another important aspect which was brought forward by several interviewees is aesthetics. Sheep wool is to a very high degree preferred over man-made materials when it comes to the look and appearances of the products. Even though it was also mentioned how wool as a natural material will differ in look and how it is challenging to achieve an even surface of the product, the common sentiment was that sheep wool is preferred among buyers. For some products, the raw, more rustic and natural look which is obtained using coarse wool may even be desired. In tweed fabrics, for example, kemp fibres, which are often undesirable as dyeing is challenging, are used to provide character through texture and colour flecks (Robson, 2018). As the Polish Mountain Sheep wool has a high content of kemp, it may be possible to obtain a unique and distinctive look which is difficult to achieve from man-made materials (see Figure 4-1). One interviewee expressed that they, as a manufacturer, would be able to use felt made of coarser wool if this became available for purchase. In that case, they would need to rethink the type of products they could make from this as it would have a different look.

Figure 4-1: Test dye in peach colour of Polish Mountain Sheep wool from Selbu spinning mill (photo: private)

4.1.2 Sustainable and local

An interesting finding from one of our interviews was that potential customers were asking the producer about the sustainability aspect of using sheep wool as a material in comparison with man-made materials. Another interviewee highlighted the potential of wool to be discarded more easily than synthetic products where you had to apply greater consideration. This is important both for the end of the lifespan of the products but also for leftover materials from production. As explained in the introduction, the advantages of sheep wool in terms of sustainability have been debated, but these concerns from consumers show that this is something the segment of buyers cares about. In this way, coarse wool, which today is a poorly utilized resource (Røsvik, 2012), has a potential to be desired among consumers.

The inquiries about sustainability from buyers may be understood in light of the developments in the fashion industry related to the rivalry between fibres to be named the most sustainable and environmentally friendly. In a report by actors in the fashion industry, the Pulse Report, polyester was declared the sustainable fibre of the future, especially if recycled (Kerr & Landry, 2017). However, recycling of textiles today only takes place on a very small scale, and fibre-to-fibre recycling is rare. Almost all recycled polyester in clothing comes from PET bottles, which removes them from the bottle-to-bottle recycling loop (Klepp, Tobiasson, & Løberg, 2017). Recycling PET to polyester for clothing essentially entails downcycling as the then recycled polyester cannot be further recycled (Changing Markets Foundation, 2021).

The discussion regarding sustainability and fibre is complex and highly influenced be the potential winners and losers of the conclusions and results (Klepp & Tobiasson, Forthcoming). What can be said for sure is that wool is degradable and that wool from Polish Mountain Sheep exist as a material whether we use it or not. Utilizing this wool will therefore have minimal environmental impact because nothing is required for production, only for processing and using. How substantial the impact of processing will be, depends on whether the wool is dyed as well as where and how the different processes administered.

Another interviewee revealed that they were already testing a type of coarse local wool for their acoustic products. Buying locally is something that is often fronted along with sustainability today. The fact that buyers may be concerned with sustainability as well as buying local could be an advantage for the branding of wool from Polish mountain Sheep. We will go further into branding and the potentials for marketing of acoustic products made of coarse sheep wool in the following section.

4.2 Market and prices

In this section, we discuss acoustic wool products in the market and the potential for and challenges related to introducing wool from Polish mountain Sheep as a material for production. We argue that acoustic wool products represent a niche of acoustic and sound absorbing products and discuss how this affects the potential for coarser wool to be integrated into manufacturing and production. To reiterate, it is not our concern whether coarse wool can compete with finer wool or man-made materials, but rather to explore whether there is a place for the Polish wool in the market for sound absorbing

products. Using wool, and in particular, the coarser wool may not be the right choice for all acoustic products, but we find that there is definite potential to utilize it more than is being done today.

4.2.1 The acoustic wool product niche

In the previous section, we quoted some prices to illustrate the price ranges of acoustic products made of wool compared to other materials. A common sentiment among interviewees was that wool is a costly material to produce with, and thereby the product outcomes will be expensive for customers to purchase which makes it difficult to compete with products of man-made materials. One interviewee explained that they used wool from two different sources. From one trader, the wool was low-priced, but the treatment needed for this wool to achieve the aesthetically appealing look that they wanted was extensive and thereby expensive. From the other, the wool was costlier while the treatment was lower-priced than for the cheaper wool.

The position among producers and manufacturers towards their products was generally that they were meant for a particular customer segment. This segment is open to paying a little more but in return having both the value of a more aesthetic product in addition to the benefit of using a naturally recyclable and biodegradable fibre. By this definition, wool products seem to constitute a niche in the market for acoustic and sound absorbing products. Kotler (2005) defines a niche as a subsegment of a market segment and thereby as narrower. The producers in a niche market are specialised and know the wants and needs of their customers. The customers are, on their hand, characterised by a willingness to reward and apprize the producers which satisfy their needs with loyalty as buyers. This definition fits well with our discoveries during recruitment of interviewees. One interviewee responded that as the only commercial company producing absorbers in this way, they were wary about sharing information about their products and their company.

The niche facilitates a possibility for marketing of high-end products to customers willing to pay a higher price for a specialised product. The definition of a high-end product is that it is intended for people who want very good quality products and who are willing to pay a higher price to achieve this (Cambridge Dictionary, n.d.). It was apparent during interviews that producers were aware of the status of their products as high-end. Customers were concerned with the aesthetics of the product achieved by using wool as a material as well as the issue of sustainability related to utilizing a natural material. However, price was still an object. A large volume of material is needed to achieve satisfactory sound absorption and with wool being relatively costlier than man-made materials, products made entirely of wool become very expensive to make. Therefore, several producers found themselves needing to substitute parts of their products with synthetics or mixing wool with other, lower-priced fibres. It was emphasised by one interviewee that the percentage of wool in the products was important and that a higher percentage was preferred since the value of the product was based on the wool. A compromise was reached in several cases by making the base of the product in a man-made material or a synthetics and wool mix and covering this with a thinner layer of pure wool felt to achieve the desired visual look.

These insights could be transferred to the consideration of the application of coarser wool for acoustic products. One possibility for introducing coarser wool into this market is to lower the price of the materials for production. If this type of wool could be utilized for the non-visible insides of the products with a thinner layer of finer wool felt on the outside without compromising the acoustic abilities, it would potentially decrease production price while maintaining the desired aesthetics and additional positive properties of using a natural material. Coarse wool is lower priced than finer wool as for example merino so the cost of material will be lower compared to other wool types. Production will still be costlier compared to when man-made materials are applied, but for some customers the benefits of wool in terms of sustainability and health may outweigh the issue of price.

Another approach would be to integrate the different and varied look achievable from felting or other processing of coarse wool into the brand of the product. This may be done by establishing a correlation between the expression of the product as less “clean” and smooth with the notion of the product being rustic and having “soul”. According to professor of marketing Vincent Bastien (2015), the flaws of a product is what provides the product with soul. Some producers refer to this through their webpages by explaining that using a natural material such as wool will result in products where each will have a different appearance. This is a corner stone in marketing of high-end products; making the story behind the product stand out (Belch & Belch, 2003). This was also mentioned in one of the interviews as one of the main things that the company’s customers cared about; the origin of the wool and the story behind how the company started. In general, it has been found that people are becoming increasingly more interested in where products come from, how they are made and how they fit into an ideal of circular economy (Øvrebekk, 2021). Within this lies a potential for branding of products with wool from Polish mountain Sheep as part of the content.

4.2.2 Decisive moments for change in the value chain

A challenge in introducing coarse wool to the market for acoustic products is identifying the part of the value chain where change is possible and how this change may come about. Through the interviews we found that manufacturers of the end-products rely on producers of felt to choose the wool type which would work best for their product. The producers of felt, on their side, explained how they are reliant on what type of wool is available in the market, either from traders or from the wool exchange. Therefore, we conclude that it is not the case that coarse wool is being deselected in the market in favour of finer types of wool. Instead, the issue is that coarse wool is not available in the market in the first place. This leads us to suggest that the proper moment for change in the value exists between farmer and trader where the sorting of the wool is taking place.

One of our points of departure was that coarse wool today is being discarded by farmers as it holds no or very little value in terms of retail. Our aim was to explore products with a potential for incorporation of coarse wool to create applicability for the wool. We have found a potential for utilisation as well as a willingness among producers to include coarse wool into their production if it becomes available for purchase. However, we have also found the market for acoustic wool products to be a

niche market. This makes the demand for coarse wool for this type of application relatively smaller and more specific. During an interview it was suggested that the sorting and classification processes were removed from the farmer and done somewhere else. However, sorting the wool to separate the most contaminated and dirty wool must take place immediately after shearing to ensure cleanness and thereby quality. Packing up all the wool without sorting will contaminate the whole batch. Classification could potentially be done somewhere else, but this may not be needed for the Polish Mountain Sheep wool as it may potentially all be in the same class. Another approach suggested during interviews was for farmers to sell directly to producers of acoustic or other products where coarse wool is applicable. However, the only possibility for this is artisanal set-ups due to the low quantities of wool per farmer. These examples show that there exists a cleavage between farm level and the receiving apparatus for this type of wool which will be important to attempt to close.

5 Conclusion

We have discussed the qualities of sheep wool as a material in general and compared to other materials commonly used for acoustic and sound absorbing purposes such as mineral wool, polyurethane foam and polyester. Sheep wool as a natural material holds several advantages in terms of sustainability and health concerns in addition to aesthetic qualities. It is for example naturally degradable, flame retarding, allergy friendly and it absorbs VOCs. As a material, sheep wool is perceived by some customers as a better material for which they are willing to pay a higher price. In addition, we have reviewed the literature on acoustic research on sheep wool which establishes the potential of this material to be used for production of sound absorbing applications. However, research on the acoustic properties of sheep wool remains limited and needs to be continued further in order to explore the full potential of wool as a material. Different types of wool or different processing may grant even better results, and it has been suggested that combining wool felt with other materials may further improve the sound absorbing abilities.

In terms of the market for acoustic products, we have discussed the potential for introduction of coarse wool. The general conclusion is that there is a possible market for coarser wool within the production of acoustic products, but it needs to be considered how the best utilisation of coarse wool is combined with the requirements for aesthetics and the issues of price. We have argued that the market for acoustic and sound absorbing products made from wool may be considered a niche. This allows for marketing of acoustic wool applications as luxury products using the history of the wool as a main feature in the branding strategy and marketing towards particular segments who are more concerned with the positives of wool as a material and less with price. In addition, we have argued that the coarseness of the wool may be considered an advantage in some cases as it allows for a raw and more rustic exterior look which may be desired by some. Polyester and merino felts allow for a smooth surface, even colour and clean look whereas coarser wool provides a product with irregularities, roughness and flaws, and what some may consider personality and soul.

Moving forward, further considerations need to be given to the issue of making it worthwhile for farmers to not discard the coarser wool which today is being discarded. In this discussion section we suggested two potential approaches. However, these need to be explored further potentially through interviews with farmers and traders to learn more about the challenges from their perspective. Furthermore, our discussion and conclusions are based solely on desktop research and six interviews. In order to make recommendations for potential utilisation of wool from Polish Mountain Sheep further testing and research is needed. Technical testing of the actual properties of the wool and how this type of wool may be processed will be important. In addition, consumer surveys of the aesthetic aspects of the products will be important to develop products that contain desired benefits such as look, smell and noise reduction. These aspects are what separate the sheep wool products from other products in the market, and they were emphasised by producers as a main reason for customers to choose their products.

We argue that the many different properties of wool and the variances between wool qualities have a potential to be sustained and taken advantage of in many new products, such as acoustic and sound absorbing installations. Wool is a material rich in tradition which means that we carry with us ancient ideas about how it is best utilized and supposed to look. Much can be done through employing these traditions in a better way but also through breaking with them and developing new products not yet seen based on a fibre with so many possibilities.

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SIFOs core research areas are:

- Sustainable consumption (including food)
- Technology and digitalization
- Marked based welfare
- Clothing and textiles

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