SIFO PROJECT REPORT 18 2021

CONSUMPTION RESEARCH NORWAY (SIFO)

Woolume: Potential new products from vacant wool

Anna Schytte Sigaard, Lisbeth Løvbak Berg and Ingun Grimstad Klepp

OSLO METROPOLITAN UNIVERSITY
STORBYUNIVERSITETET

SIFO-REPORT 18 – 2021

Cover photos: Uurna

CONSUMPTION RESEARCH NORWAY - SIFO

OsloMet – Oslo Metropolitan University

Stensberggt. 26

PO BOX 4 St. Olavs plass 0130 Oslo, NORWAY

http://www.oslomet.no/en/om/sifo

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SIFO project report 18 - 2021

OSLO METROPOLITAN UNIVERSITY
CONSUMPTION RESEARCH NORWAY SIFO

Title	Pages	Date
WOOLUME: Potential new products from vacant wool	45	24.01.2022
Tittel		**ISBN**
WOOLUME: potensielle nye produkter av underutnyttet ull		978-82-7063-538-2
Author	**Project number**	**Signature**
Anna Schytte Sigaard, Lisbeth Løvbak Berg and Ingun Grimstad Klepp	201884	

Financed by

Norges forskningsråd

Summary

This report gives an overview of the market for alternative wool products with the perceived potential to be made using vacant wool. The work is based on a desktop study and interviews with manufacturers and distributors, focusing on products made of wool and their qualities. The report is the second deliverable from work package 2 of the WOOLUME project. The main goal of WOOLUME is to explore different ways of using wool from the Polish Mountain Sheep to achieve better utilisation of resources and value creation. Producers were identified that use wool as a material for products in the following categories: cultivation, soil improvement, insulation and personal hygiene as well as other new and alternative wool products. Findings show a range of products that take advantage of the many properties of wool, both aesthetic and technical. They also show that wool has the potential to replace synthetic materials in several applications and create truly circular products when treated in a way that preserves biodegradability. Though Merino wool dominates the wool market, several producers make use of other, local wool qualities and the interest for using the vacant wool, often discarded as a mere by-product of meat and dairy production, is growing. However, there is further potential for optimising resource utilisation in using vacant wool, in particular, non-spinnable wool with a higher fibre thickness, in products where the fineness and spinnability of merino wool are not required.

Keywords

Wool, resource utilisation, WOOLUME, sustainability, circular economy, product innovation

Sammendrag

Denne rapporten gir en oversikt over markedet for ullprodukter med et potensiale til å bli laget av underutnyttet ull. Arbeidet er basert på en skrivebordsundersøkelse og intervjuer med produsenter og distributører, med fokus på ullprodukter og kvalitetene til disse. Rapporten er den andre leveransen i arbeidspakke 2 i WOOLUME prosjektet. Hovedmålet til WOOLUME er å utforske om ull fra polske fjellsauer kan bli brukt for å oppnå bedre ressursutnyttelse og verdiskapning. Produsentene som ble identifisert brukte ull i følgende kategorier produkter: dyrking, jordforbedring, isolasjon og personlig hygiene, så vel som andre nye og alternative ullprodukter. Funnene viser en rekke produkter som utnytter ullens mange ulike egenskaper, både de estetiske og tekniske. De viser også at ull har potensialet til å erstatte syntetiske materialer i flere bruksområder og dermed skape virkelig sirkulære produkter, såframt ullen er behandlet på en måte som bevarer dens biologiske nedbrytbarhet. Selv om merinoull dominerer markedet, utnytter flere produsenter andre kvaliteter og lokale raser og interessen for å bruke underutnyttet ull, ofte kastet fordi det anses kun å være et biprodukt av kjøtt- og melkeproduksjon, er voksende. Likevel er det videre muligheter for å optimalisere ressursutnyttelse ved å bruke underutnyttet ull, spesielt ikke spinnbar ull med høyere fibertykkelse, i produkter der hvor finheten og spinnbarheten til merinoull ikke er nødvendig.

Stikkord

Ull, ressursutnyttelse, WOOLUME, bærekraft, sirkulærøkonomi, produktinnovasjon

Preface

This report presents the findings from WP2 in the project WOOLUME: Polish sheep wool for improved resource utilisation and value creation[1]. The project has received funding 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 and Ingvild Svorkmo Espelien at Selbu Spinneri. A special thanks to Jan Broda, who also read and commented on the report.

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

Oslo, December 2021

Consumption Research Norway (SIFO)

OsloMet – Oslo Metropolitan University

[1] Read more about the ongoing research in the WOOLUME project here.

Executive summary

Introduction

In Poland, it is not known how much wool is produced and how much of it is being used, but it is likely that more than half of the greasy sheep wool has been lost in the last 15 years. 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. Following from the first WOOLUME report “Mapping the market for acoustic and sound-absorbing products made of wool”(Sigaaard & Haugrønning, 2021)[2], not all coarse wool can be used in acoustic products, due to contamination and felting, and because these products constitute a small niche in the market. In this report, we focus on the positives of using wool as a material for products used for cultivation, soil improvement, insulation, personal hygiene and other new and alternative wool products. Our goal has been to identify products of as high a value as possible to encourage utilisation the sheep wool which ends up as unused and is not suitable for yarn or felting because it is too coarse, too felted, too contaminated, too pigmented, too short or in some other way not applicable for conventional use, and that we have chosen to call vacant wool. Sheep wool has properties that make it suitable for a range of products, including its ability to absorb volatile organic compounds (VOCs), biodegradability, nitrogen content, moisture absorption, thermal regulation, odour resistance and aesthetic qualities. These material properties create the potential for vacant wool to be used in a range of products, including products where synthetic materials are now being used.

Method

This report is based on a desk study and interviews: the products and producers described in this report were identified through conferences, seminars and workshops as well as desk research. 21 business actors were initially identified, and 19 potential interviewees were chosen and contacted based on information gathered through seminars and websites. They were chosen for their knowledge of and preference for wool and the perceived or stated possibility for using vacant wool. A total of 8 responded and were interviewed over email or Zoom. The companies ranged from craft-based to industrial scale, from start-ups to well-established businesses, carrying only wool products or a range of products including wool products. The report does not provide a complete overview of the market for alternative wool products but is intended to create awareness of the potential for use of vacant wool in a diverse range of products globally. Norwegian examples were excluded from this study due to ongoing research in the VerdifULL-project by NIBIO and NORSØK, expected to publish in February 2022.

Results

Alternative, innovative wool products were found in the categories: garden and cultivation, nature and soil, insulation, sanitary products and other new and alternative

[2] Read the first WOOLUME report here.

wool products. These include flowerpots, garden felt, fertilizer pellets, insulation for homes and vehicles, packaging, sanitary pads and diapers, make up-remover pads and face cloths, along with coffins and urns for burials, surfboards and furniture.

The producers highlighted different properties of wool as beneficial for their products. The use of wool for nature and soil has advantages such as balancing moisture, fertilising, decreasing problems with snails, and minimizing manual labour when replanting. At the same time, this use of wool replaces the use of plastic in the soil and can therefore contribute to reducing the amount of plastic that enters the natural environment and it also has aesthetic advantages where one works with soil and plants in a way that emphasizes respect for nature. Wool for various insulation applications not only has a temperature regulating function, but also beneficial effects like fire resistance, moisture absorption, water repellence, VOC absorption, and allergy friendliness. In sanitary products, wool can be used in both single-use and re-usable alternatives to conventional plastic products as it is both washable and bio-degradable. Using new treatment technology, the wool can become hyper-absorbent or be used as an ADL, outperforming the synthetic alternatives. It also contributes with additional qualities, such as odour resistance and temperature regulation. Further untraditional usage of wool in e.g. coffins and urns for burials and items made of fibreglass take advantage of the biodegradability, strength and aesthetic of wool. Some of the producers base their business models on using local wool, motivated by the desire to combat wool waste.

Discussion

The study has found that though the products presented may not be able to replace all their synthetic counterparts, they were often promoted as alternatives to synthetic materials with the benefits and additional qualities, technical as well as aesthetic, of wool as a material high-lighted as selling-points. Biodegradability was mentioned as a selling-point by most producers, either as an end-of-use solution or as a part of the product function, e.g., for fertilizer pellets. Producers of plant pots, garden felt, coffins, urns emphasized the aesthetic quality of the wool products, whereas producers of hygiene products and insulating products high-lighted temperature regulating and moisture-absorbing properties. Though the producers emphasized the superior qualities of wool, they found their products to be at a price a disadvantage compared to conventional products. It follows that vacant wool decreases the material costs, and several of the products were being made with coarse or vacant wool, but in some cases other obstacles then occurred, e.g. establishing local supply-chains and volume – gathering enough vacant wool to make larger-scale production viable.

Conclusion

This report has discussed how using the vacant wool in the researched products can contribute to waste minimization by decreasing wool waste, by not using spinnable wool suitable for clothing production for a purpose where other wool qualities could be used, and as well as by replacing some synthetic products with a bio-degradable alternative thanks to the many properties of wool. The wool products examined may not be able to replace all their plastic equivalents in the market due to factors such as price, supply and scale. Nevertheless, they represent good, viable alternatives where

the vacant wool can be utilised. A systematic review of how plastics can be replaced by other materials has not been done here and in general, we have little knowledge about the amount of waste created by using high-end materials where other materials would perform just as well, such as using merino wool where vacant wool could be used. Furthermore, there is little research done on the effect of conventional processing on the innate properties of the wool fibre, including its biodegradability. Examining traditional practices and technologies, in addition to current research on new technologies, would contribute to this fast-moving field.

Sammendrag

Introduksjon

I Polen vet man ikke hvor mye ull som produserer eller hvor mye av den som blir brukt, men trolig har mer enn halvparten av ulla gått tapt det siste15 årene. Målet med WOOLUME er å utforske mulighetene for bruk av ull fra polsk fjellsau for å skape et økonomisk insentiv for ikke å kaste brukbar ull. Som funnene i den første WOOLUME rapporten "Mapping the market for acoustic and sound absorbing products made of wool" (Sigaaard & Haugrønning, 2021)[3] viser, så kan ikke all grøvre ull brukes i akustiske produkter fordi den er tovet eller skitten, og fordi disse produktene kun representerer en liten nisje i markedet. I denne rapporten diskuterer vi de positive aspektene ved å bruke ull som materiale i produkter for dyrking, jordforbedring, isolasjon og personlig hygiene, og i andre nye, alternative produkter. Målet vårt har vært å identifisere produkter med så høy økonomisk verdi som mulig. Dette vil kunne oppmuntre til utnyttelse av ulla som i dag er ubrukt enten fordi den er for grov, for tovet, for tilgriset, pigmentert, for kort, eller på en annen måte ikke anvendelig i konvensjonell forstand. Det er denne ulla vi har valgt å kalle underutnyttet ull. Saueull har egenskaper som gjør den anvendbar i en rekke produkter, inkludert evnen til å absorbere såkalte volatile organic compounds (VOCs) fra luften, biologisk nedbrytbarhet, nitrogeninnhold, fuktabsorbering, temperaturregulering, lukthemming og estetiske kvaliteter. Disse materialegenskapene skaper potensiale for å bruke underutnyttet ull i en rekke produkter, inkludert produkter hvor syntetiske materialer dominerer markedet i dag.

Metode

Rapporten er basert på en skrivebordsstudie og intervjuer: produsenter og produkter ble identifisert gjennom konferanser, seminarer og workshops i tillegg til nett søk.. 21 bedrifter ble opprinnelig identifisert og 19 mulige intervjuobjekter valgt ut og kontaktet på grunnlag av informasjon samlet gjennom seminarer og internettsider. De ble valgt ut på grunnlag av deres kunnskap om og preferanse for ull og deres antatte eller uttalte mulighet til å bruke underutnyttet ull. Totalt 8 svarte og ble intervjuet enten på epost eller Zoom. Bedriftene varierte fra små håndverksbedrifter til industriell skala, fra gründere til veletablerte. Noen laget kun produkter i ull andre utnyttet ulike materialer.. Rapporten gir ikke et komplett bilde av markedet for alternative ullprodukter, men har som formål å skape bevissthet om potensialet for bruk av underutnyttet ull i ulike produkter i global målestokk. Norske eksempler ble utelatt fra denne studien på grunn av pågående forskning i VerdifULL-prosjektet ved NIBIO og NORSØK, med forventet publiseringsdato i februar 2022.

Resultater

Alternative, innovative ullprodukter ble funnet I kategoriene: dyrking, jordforbedring, isolasjon og personlig hygiene, så vel som andre nye og alternative ullprodukter. Disse inkluderer blomsterpotter, hagefilt, gjødselpellets, isolasjon for hjem og kjøretøy,

[3] Les den første WOOLUME rapporten her.

emballasje, menstruasjonsbind, sminkefjernings- og ansiktskluter, sammen med kister og urner for gravlegging, surfebrett og møbler. Produsentene trakk fram ulike ullegenskaper som fordelaktige for deres produkter. Bruk av ull i natur og jord har fordeler fordi det kan bidra til forbedringer på flere områder, slik som balansering av fuktighet, minimering av plager med snegler, gjødsling, og å gjøre arbeidet med omplanting enklere. Samtidig har ullbruken her også den fordelen at den erstatter bruk av plast i jord. Det kan bidra til å forhindre at plast kommer på avveie og vil også ha estetiske fordeler der det legges vekt på arbeid med jord og planter i pakt med naturen. Ull til forskjellige isolasjonsformål regulerer ikke bare temperaturen, men har andre fordelaktige egenskaper som å være brannhemmende, fuktighetsabsorberende, vannavstøtende, VOC-absorberende og allergivennlig. I sanitærprodukter kan ull bli brukt i både engangs- og flergangsprodukter som alternativ til plast da den både er vaskbar og komposterbar. Ved hjelp av ny teknologi kan ulla bli hyperabsorberende eller bli brukt som et transporterende lag, og utkonkurrerer da syntetiske alternativene funksjonelt. I tillegg bidrar ull med tilleggsfunksjoner som lukthemming og temperaturregulering. Utradisjonelle produkter i ull er produkter som erstatter hardere materialer som tre og metall i f.eks. kister og urner til begravelser. I slike produkter utnyttes ullas nedbrytbarhet, styrke og estetikk. Noen produsenter baserer forretningsmodellen sin på bruk av lokal ull, motivert av ønsket om å forhindre at ull kastes.

Diskusjon

Produktene ble ofte promotert som alternativer til syntetiske materialer og med ullas fordeler og ytterligere egenskaper, både tekniske og estetiske, som salgsargument. Nedbrytbarhet ble fremhevet som et salgsargument av de fleste produsentene, enten som en avhendingsløsning etter bruk, eller som en egenskap ved produktet i seg selv, f.eks. i gjødselpellets. Produsenter av plantepotter, hagefilt, kister og urner trakk frem ullproduktenes estetiske kvaliteter, mens produsenter av hygieneprodukter og isolerende produkter trakk frem de temperaturregulerende og fuktabsorberende egenskapene. Selv de la vekt på ullas overlegne egenskaper, så de at deres egne produkter kom ufordelaktig ut i forhold til konvensjonelle produkter når det gjaldt pris. Det er et potensiale til å redusere prisen gjennom bruk underutnyttet ull. I noen tilfeller kan det da oppstå andre problemer, f.eks. med å etablere lokale verdikjeder og ha tilstrekkelig volum – å få tilgang på nok råstoff for at produksjon i større skala blir økonomisk bærekraftig. Flere av produktene erstatter plast, og delvis er dette plast der bruken er særlig problematisk. Det er neppe slik at all slik bruk av plast kan erstattes med ull, men likevel viktig å få frem alternativer og samtidig utnytte den ulla som vi faktisk har.

Konklusjon

Rapporten har diskutert hvordan bruk av underutnyttet ull i de undersøkte produktene kan bidra til mindre avfall ved å få ned sløsingen med ull ved å ikke bruke spinnbar ull egnet til klær der hvor andre ullkvaliteter kan bli brukt og ved å erstatte noen syntetiske produkter med et nedbrytbart alternativ. De presenterte ullproduktene kan nok ikke erstatte alle sine syntetiske alternativer, på grunn av faktorer som pris, tilgang og omfang. Likevel representerer de gode, bærekraftige løsninger der underutnyttet ull

kan bli til gode nyttige produkter. En systematisk undersøkelse av hvordan syntetiske materialer kan bli erstattet med andre materialer er ikke gjort her. Det vil være et stort spørsmål innenfor områder så ulike som hygiene og jordbruk. Rapporten åpner opp en diskusjon omkring bruk av materialer med høy markedsverdi der hvor andre materialer ville gjøre den samme nytten. er svært mye vi ikke vet om dette og en systematisk undersøkelse av dette vil derfor være nyttig. Videre har lite forskning blitt gjort på effekten av vanlige etterbehandlinger av tekstiler på ullfibrenes naturlige egenskaper, inkludert nedbrytbarheten. Å undersøke tradisjonelle metoder, i tillegg til pågående forskning på ny teknologi, vil bidra til dette viktige kunnskapsområdet.

Content

1 Introduction

Wool is a raw material that varies broadly when it comes to length, thickness, crimp and several other properties. The “best” wool is sought after for yarn for clothes and felting, while the coarsest wool and wool that is felted, pigmented, or contaminated with faecal matter, plant residues etc. is more often thrown away. Production of yarn, knitwear and fabric entails many processes and in and between these, waste will occur. Good utilization of resources entails using all wool, also coarser fibre and wool with contamination. To ensure financial returns, it is important that it can be used in products that people are willing to pay for. It is an important ongoing work to find proper applications for wool, also the wool which is not suitable for yarn and other high-end products.

In this report, we focus on the sheep wool which ends up unused because it is too coarse, too felted, too contaminated, pigmented, too short or in some other way not applicable for conventional use. In Norway, this is called “downgraded wool”. However, since this classification is not universal, we use the description “vacant wool” in this report. This is to indicate that this wool is an underutilized resource available for use for the proper purpose.

Using vacant wool has gained a lot of attention recently and several end-uses have been suggested. This is the second of two reports investigating different options for utilization. In the first report, we researched the potentials for vacant wool to be used in acoustic and sound-absorbing products. In this report, we will present some of the most recent innovations related to the utilisation of vacant wool.

Research questions:

1) What is the status of the most recently developed wool products of vacant wool and wool products for which vacant wool could be applicable?
2) What are the natural qualities of wool that make it applicable for these products?
3) What are the potentials in replacing synthetic or other materials with wool?
4) What are the obstacles to improving the competitiveness of these products in the market?

1.1 Background

The WOOLUME project is a continuation of work started in the KRUS project[4] building on insights gained from studying the relationship between wool as a raw material and the finished wool products both in the textile industry and among consumers. Through the project, it was found that wool from the older Norwegian 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, however, it was found that wool from Polish Mountain Sheep is not suitable for clothing

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

production and other delicate textiles and yarn. In addition, the wool has a very high content of kemp which makes it difficult to spin. Therefore, alternative products became the focus, as it was assumed that the wool may be used for products where its roughness and coarseness was not a disadvantage.

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 some is instead being discarded by farmers. A conclusion from the project was that increasing the demand for wool from the older sheep breeds is the best way to increase financial returns and thereby the economic incentive for taking care of otherwise wasted wool. A way of doing this is to increase the number 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 as a material for products used for cultivation, soil improvement, insulation, personal hygiene and other new and alternative wool products.

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

For the WOOLUME project, three of the collaborating partners went on a trip to Poland to meet with researchers from the University of Bielsko-Biala. 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 the collection and processing of wool take place here. This laid the foundation for a Polish-Norwegian collaboration focused on local utilisation of Polish wool.

The priority of the project has been to identify products of as high value as possible for which vacant wool would potentially be applicable. The first report deals with the potentials for utilising this wool in acoustic and sound absorbing products. It was found 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 technical properties as well as aesthetics. However, few producers use coarse wool in these products, and many are made of pure Merino wool. Using Merino wool which is often considered to be of very fine quality due to the low micron count does not correspond with the ideal of

good utilisation of resources. Therefore, it was proposed to utilise coarse wool which today is discarded as a mere by-product of milk and meat production. Merino could instead be used for products where fineness and softness are important factors such as clothing. In addition, the rawness and uniqueness of the look of coarse wool were brought forward as positive in terms of aesthetics (Sigaaard & Haugrønning, 2021).

Not all coarse wool can be used for acoustic products. The very contaminated or felted wool is unsuitable for this type of production. In addition, acoustic wool products constitute a niche market and may not exploit all of the unutilised wool. Therefore, in this report, we will further investigate the possible areas of application for the difficult, coarse and/or contaminated wool through a series of product examples.

1.2 Best utilisation of resources

The uses of wool in the market are vast and diverse, found in sectors such as apparel and fashion, activewear, flooring and interiors, aviation, architecture, manufacturing, medical use and protective apparel. 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, 2022). 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 it is better from an environmental perspective to use than to produce new materials to fulfil the same purpose. The discarded wool also constitutes unnecessary waste.

Best utilisation of resources is not only reached through identifying unused resources and proper areas of use for these. Other obstacles include how the resources are classified, the definitions used to describe the resources, and the mode of production from which they originate. In this section, we will go through some of these obstacles specifically related to wool.

1.2.1 Classification

Following the EU definition, unprocessed wool is classified as an animal by-product[5]. A by-product is an output from the production process not defined as waste but with 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”[6]. Legally speaking, wool may therefore not be defined as waste However, its utility overlooked, much wool is being discarded instead of utilized and thereby still ends up as waste. In Norway, 60% of all wool sent to wool collections in 2019 was considered 1st class meaning that a large part of wool today end up as downgraded (McKinnon, 2021). Wool classified as 2nd class coloured wool contains a wide variety of wool from very fine wool with a little too much dirt in it to very coarse and dirty wool. This complicates the assessment of other areas of application for wool from this class.

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

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

The VerdifULL project will investigate the possibilities for increasing the value of downgraded wool and potentially increasing the proportion of 1st class wool[7].

In Poland today, a formal system for the collection and sorting of wool does not exist. The only sorting of wool sometimes takes place during shearing when black and white wool is separated. The price of wool in the few collection places that do exist does not depend on the quality or the purity of the fleece. A challenge in achieving good utilization of sheep wool in Poland, therefore, relates not to lack of proper classification but has a much earlier point of departure in the collection and sorting process (Sigaaard & Haugrønning, 2021).

1.2.2 Circular economy

The term circular economy is widely used but with varying content. The most basic understanding of a circular economy involves moving away from a linear model of production, consumption and disposal, towards a model without waste, i.e., using waste as a resource. In this economic model, economic growth is ensured by using raw materials again and again instead of relying on the continued production of virgin resources. The most widely used definition of circular economy is that:

The Circular Economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles (Ellen MacArthur Foundation, 2015, p. 2).

Circular economy has been a central part of EU policy since 2014 and important policy documents published around this time focus on resource efficiency and waste prevention as essential strategies. Later documents to some extent also include the product and consumer perspectives (Heidenstrøm et al., 2021). From a materials perspective, however, they are largely focused on just two of the three R's which constitute the core principles of circular economy: recycling and re-use of materials, essentially post-consumer waste management. For a circular economy to be truly circular, however, the third R, reduce, must be included. Without reducing resource extraction, it cannot hope to have positive environmental impacts and be "restorative and regenerative". Furthermore, as per the Circular Economy definition above, it is important to distinguish between technical and biological cycles. The biological cycle concerns flows of renewable materials, such as wool and "renewable (biological) nutrients are mostly regenerated in the biological cycle" (Ellen MacArthur Foundation, 2015, p. 7). It follows that a product's end-of-life solution is optimised when the materials can return to their respective cycles.

In the International Resource Panel Report (UNEP, 2017), resource efficiency, defined as more productive use of resources over their life cycle, is the main focus. Utilisation of by-products from industry is mentioned as a way to reduce waste along with the need for extraction of virgin materials. An example mentioned is how food producers may increase their production through utilising unused or underused resources.

[7] For more information about VerdifULL, see the project page at the NIBIO website

This resonates with circular economy ideas where the highest level of the waste hierarchy is in focus: preventing waste. One version of this model is The European Waste Hierarchy (see Figure 1-2).

The EU Waste Framework Directive uses this model and states that preventing waste is the preferred option, while sending waste to landfills should only be a last resort. The model is concerned with material flows and on the “prevention level”, everything is considered a product and thereby non-waste. The directive further distinguishes between waste and by-products, and supporting production based on by-products could be a way to decrease or even prevent waste production. Today, this is not part of any policy in the EU (or Norway) and the poor utilization rate of by-products such as wool is not attempted solved.

Figure 1-2: The waste management hierarchy (European Commission, n.d.)

1.2.3 Optimal use

The aim of WOOLUME is to work towards the best utilisation of resources. This does not only mean finding uses for by-products but also refraining from using a material with highly sought-after qualities for purposes where these qualities do make a difference and other materials could be used. For example, using spinnable merino wool in insulation materials would not be optimal, and coarser wool might be equally applicable. Better utilisation of resources entails using Merino for a purpose for which its special qualities of fineness and softness are relevant, such as next to skin clothing.

In addition, to end up with the best possible product, it is essential to use the raw materials in a way that properly exploits the specific properties of those materials. This is discussed regarding leather and fur in the Jutulskinn report (Klepp & Haugrønning, 2021). Following the industrialisation of production where products were mass-produced, focus on good utilization of materials has been replaced by standardisation and rationalisation to increase profits through increased speed and predictability in production. This leaves little room for a wider perspective on utilization as this will affect the financial aspects. This means that important materials and resources are lost, such as hair from leather production and coarse wool from sheep meat production. Small-scale production is often better at utilising variation and bringing forward good products also from raw materials which are difficult for the large-scale industry to utilize.

1.3 Properties of wool

Sheep wool has many different qualities which can be exploited when used as a material. Different qualities will be important for different applications. In this section, we will go through the properties and qualities of wool that correlate with the products will have chosen to bring forward as examples in the following chapter.

1.3.1 Chemical structure

Wool is a very complex fibre. It is composed of a single protein called keratin, which contains five main elements (carbon, oxygen, hydrogen, nitrogen and sulphur) and other microelements. 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). What makes wool unique among textile fibres are the cuticle cells resembling scales that 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).

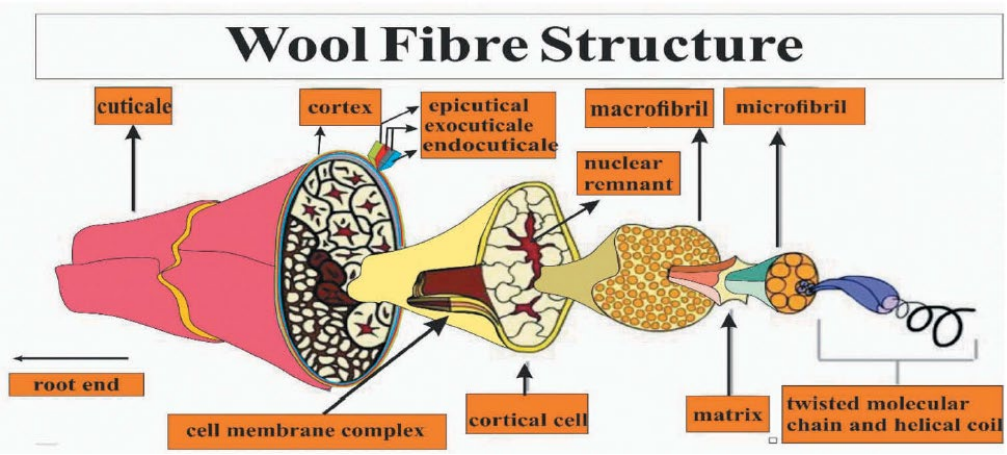

Figure 1-3: the wool fibre structure (adapted from Allafi et al. (2020, p. 2))

Before processing, scouring, a thorough washing of the wool is common practice. The fibre is usually dirty with three different components: animal grease (wool wax), suintin (sweat) and dirt from surroundings. Wool wax may be recovered and purified to obtain lanolin which is a highly valuable product (López Mesas et al., 2007). Lanolin is used for many purposes such as skincare products, rust treatment for cars and shoe polish. Extraction and processing of lanolin are, however, expensive and its use is further complicated by pesticide residues which may occur in wool wax making it unsuitable for use in cosmetics and baby care products (McKinnon, 2019). As such, non-pesticide-treated sheep are a potential source of non-contaminated lanolin.

Wool has good absorption abilities as the fibre contains chemical groups, such as amides, which attract water. The value of the absorption can be as high as 35% (Dénes et al., 2019). In soil, wool residues and other wool products can effectively absorb and retain moisture which facilitates water conservation (Zheljazkov, 2005).

Wool has desired thermal properties that contribute to indoor comfort and has therefore emerged as a niche construction product, specifically as an insulation material. In addition, sheep wool has been found to absorb volatile organic compounds (VOCs), such as gaseous formaldehyde (Curling et al., 2012). VOCs are frequently linked to what is termed “sick building syndrome” (SBS), which refers to a range of symptoms that include eye irritation, nasal congestion, dry skin, headache, fatigue, and difficulty in concentrating (Mansour et al., 2016). Mansour et al. (2016) found correlations suggesting that more darkly pigmented fibres and unscoured wool entails higher sorption capacities, though this varied between VOCs.

An important environmental advantage of wool is its biodegradable properties (Broda et al., 2016). 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 conditions, buried wool products are completely degraded after six months (Swan, 2020). Raw, unwashed wool has been found to decompose slower than scoured and washed wool due to the higher presence of fats and because it is hydrophobic and therefore the amount of water it absorbs is smaller (Gorecki & Gorecki, 2010).

Sheep wool can function as an organic fertilizer, as nutrients are included in the organic materials without the need for further applications (Ordiales et al., 2016). Keratin, the wool protein, is an easily available source of nutrients such as nitrogen, carbon and sulphur which play an essential role in plant nutrition, and can be used for the development of slow-release fertilizers (Gorecki & Gorecki, 2010). It degrades into simpler compounds that releases nutrients in the soil over a long period, and the high content of nitrogen and sulphur in wool stimulates plant growth and yields (Zheljazkov, 2005). 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 of nitrogen, wool works as an effective fertilizer, which promotes intense plant growth.

Tests on clothing worn next to the skin have shown that woollen garments have the least odour and lowest odour build-up compared to other textiles made from fibres such as polyester and cotton (McQueen & Vaezafshar, 2019). In addition, aeration has a good effect on the smell of sweat in wool, whereas this has none onsynthetic materials (Kjeldsberg et al., 2012). This is an important quality for personal hygiene products and potentially also for other products that come in contact with the skin such as upholstering in vehicles and furniture. Because of this resistance to smell, wool is often thought to be antibacterial. However, laboratory test show that bacteria actually persist longer on wool fabrics than cotton and polyester and in reality, we do not know why wool is odour-resistant (McQueen & Vaezafshar, 2019). A further useful property of wool, when worn on the body, is its allergy-friendliness after scouring. Though lanolin allergy has been confirmed, it is rare and highly unlikely with modern processing methods - the wool fibre itself will only produce cutaneous irritation (itching) depending on the coarseness of the fibre (≥ 30–32 µm) (Zallmann et al., 2017).

Finally, an important quality of sheep wool is how it relates to almost all of our senses: hearing, touch, sight and smell. In the first WOOLUME report, we argued for the

qualities of wool as a sound absorber and as a material with several aesthetic advantages. For some products in this report, these qualities will be equally important, such as insulation products also used for sound absorption and visible products such as non-woven fabrics used in the garden.

Further processing of wool affects the innate properties of the material and its ability to be part of a biological cycle. Common treatments for wool in clothing are scouring, dyeing and superwash treatment. Scouring will not have adverse effects on biodegradability, but both dyeing with synthetic dyes and superwash treatment with a polymer resin will affect the materials biodegradability. The treatments can also affect other important properties, creating both intended and unintended changes and both for first use and for the possibilities in the next lifecycle, e.g. for the recycling process. To what extent conventional processing alters natural we do not know, but researchers are seeing that certain fibres of natural origin are not decomposing in the natural environment: samples of microfibre sediments from southern European seas have been found to contain nearly 80% regenerated cellulosic fibres and dyed natural cellulosic fibres like cotton and linen (Cotton et al., 2020). In this report, we will give an example of an after-treatment changing the properties of wool to make it applicable for hygiene products.

2 Method

This report takes its point of departure in alternative wool products with the perceived potential to be made using vacant wool. Initially, many of these were discovered through wool conferences, seminars and workshops, including the International 'Virtual-Wool' Research Conference hosted by AgResearch, New Zealand and the 1st European Wool Day by the EWE Foundation (European Wool Exchange) and some through the desk research for the 1st WOOLUME report (Sigaaard & Haugrønning, 2021). We researched these further through online searches which led to the discovery of additional interesting wool products and producers. In addition to tips from producers about other products, we searched for "sheep wool for gardening", "sheep wool for insulation", "sheep wool and hygiene" and similar wordings in Google.

This section contains an overview of the companies we investigated and their wool products and a description of how the research for this report was carried out. The report is not intended to constitute a complete overview of all innovative, unconventional wool products currently in the market or under development. It does, however, provide an awareness of the potentials of utilizing vacant wool in good products by demonstrating the diversity and plurality of wool products already developed. Therefore, some products may not have made it into the report due to lack of time and capacity. Other uses for wool were omitted as they were outside the scope of the report. An example of this is using sheep wool for path groundings where the wool has not been made into a product but is used as a material. The EU project Ascent has tested this method on tourist trails in Hordaland, Norway with great success[8].

In addition, we discovered that others were working on the same topic and agreed to focus on different products so that our research would be complementary and not competing. Before contacting producers, we met with researchers from NIBIO and NORSØK who are working on the project VerdifULL: How to increase the value of downgraded wool and increase the proportion of 1st class wool?[9] During this meeting, we aligned the projects (in addition to other wool projects at our institutes) so that we would not be contacting the same producers. This also meant excluding Norwegian products and businesses from our selection.

2.1 Desk research

During the initial work on the report, which started in June 2021, we researched products online before contacting the producers for clarifying and elaboration. Below, we have inserted five tables presenting the products from each of the categories that we have chosen to focus on. We have divided them into five categories: garden and cultivation (Table 2-1), nature and soil (Table 2-2), insulation (Table 2-3), sanitary products (Table 2-4) and other products (Table 2-5). Some companies have the

[8] For more information about the Ascent project, see final report or youtube video

[9] For more information about the VerdifULL project, see project page

mentioned wool products as part of their product offering, some carry large assortments including some products made of wool and others again have the wool products as a side business next to their main business.

Table 2-1: Overview of wool products from the gardening and cultivation category which are looked into in this report.

Garden and cultivation		
Product	**Producer**	**Country**
GardenWool Plant Blanket	Gardener's Supply Company	USA
NutriWool Pots	Wild Valley Farms	USA
Sheep's Wool Garden Felt	Chimney Sheep	UK
Wool felt for gardening	Soven	Slovenia

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Table 2-2: Overview of wool products from the nature and soil category which are looked into in this report.

Nature and soil		
Product	**Producer**	**Country**
NutriWool Pellets	Wild Valley Farms	USA
FloraPell Wool Pellets	FloraPell	Germany
Slug Gone wool pellets	Vitax Corporate	UK

Table 2-3: Overview of wool products from the insulation category which are looked into in this report.

Insulation		
Product	**Producer**	**Country**
Batt or loose-fill insulation	Havelock Wool	USA
CosyWool Roll insulation	Thermafleece	UK
Insulation packaging for transport	Woolcool	UK
Bubble wool	Woola	Estonia
Wool duvets	Marcusholm	Denmark

Table 2-4: Overview of sanitary products made from wool which are looked into in this report.

Sanitary products		
Product	**Producer**	**Country**
neweZorb and neweFlex	Woolchemy	New Zealand
Sanitary pads and diapers	Seven Lambs Organics	Canada
Hygiene products (pads etc.)	nil.	New Zealand

Table 2-5: Overview of other products made of wool which are looked into in this report.

Other new products		
Products	**Producer**	**Country**
Wool Coffins	AW Hainsworth, distributed by Natural Endings	UK
Felted wool urns	Uurna	Denmark
Hembury Chair	Solidwool	UK
Wool boat	Logan Williams	New Zealand
Woolight surfboard	Paul Barron, the New Zealand Merino Company and Firewire Surfboards	US / New Zealand

2.2 Stake-holder interviews

After researching the products online, we contacted the producers to ask further questions about their products. We were primarily interested in knowing three things. What kind of wool are the producers using and why this type? Why have they chosen to make their products out of sheep wool instead of the materials which are more commonly used for the products? And what do they perceive as the advantages and challenges of using sheep wool? In addition, we aimed to explore how the producers perceived the possibilities of using coarser wool instead of the type of wool they were using at the time.

We sent out requests for interviews using a standard form. We had two standard interview guides; a long for email interviews and a shorter for Zoom interviews, adapted to a semi-structured interview approach. 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 longer guide which was sent out by email was either in English or Danish. For the Zoom interviews, we always stated our main areas of interest beforehand but did not provide any specific questions until the actual interview. A total of eight producers were interviewed through five email interviews and three Zoom interviews. We conducted email interviews with Havelock Wool, Natural Endings, AW

Hainsworth, Woola and Marcusholm, and Zoom interviews with Wild Valley Farms, Woolchemy and Uurna.

The Zoom interviews were carried out by both authors participating through individual computers at SIFO. 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 products and the wool used to make them by the producer; type of wool, where it is from, how they purchased it, and reflections about the benefits of using wool for their products. Depending on how developed the product was, we asked either about how the producers perceived the competitiveness of wool products like theirs in the market compared to the same products made of the more commonly used materials or about how they perceived the potential competitiveness once the product was on the market. For the products that had not yet been fully developed, we also inquired about the status of the launch of the final product.

2.3 Methodological challenges

2.3.1 Recruitment and data collection

We contacted 19 of the 21 producers or distributors listed above and received responses from 8 of these. We did not contact Vitax Corporate as they would be contacted by NORSØK/NIBIO and the Gardener's Supply Company as they were only the distributor of the product and other companies supplied similar products. The recruitment period coincided with the summer holidays for a lot of the companies, which may explain why some did not get back to us. We chose the interview mode for which we perceived the likelihood of receiving a response to be highest, email or zoom.

Another challenge related to how to contact the producers. A few only had a built-in contact form on their web pages. We received no replies using this type of contact method.

2.3.2 Ethical concerns

The aim of the report is to give an overview of potential wool products with the perceived potential for being made of vacant wool and not mapping all existing products with this potential. Therefore, there is a risk of overlooking products that may, in reality, merit our interest, or that the selection highlights the selection advantageously in this emerging market. However, within our desk research, presenting a range of different products for inspiration was prioritised and in reality, we found few producers that were directly competing with each other. Furthermore, because of the overlapping research from NIBIO and NORSØK previously mentioned, e.g. Norwegian products have been excluded. The issue of competition may have been resolved by anonymizing the companies and products. However, we would also have had to exclude important information like location and local wool types as some of the companies are the only producer of this type of product within their territory.

In addition, we have chosen not to present full quotes in the report for one main reason: 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. By informing interviewees that they would not be quoted, we also hoped that they would feel like they could speak freely and openly to us.

3 Results

In this section, we will describe some of the products made of wool that are gaining attention today and have the potential to be made of vacant wool. This list is, of course, not complete as many other products are being tested and experimented with for wool application. Therefore, this does not entail a complete overview of the market, but it does show that the possibilities for utilization of wool are many and that unconventional areas of use are still being discovered. A common feature for these products is that the qualities of wool are being taken advantage of. The important quality differs from product to product, which speaks for the versatility of wool as a material.

3.1 Garden and cultivation

Wool is used in the garden and for cultivation as a material in several different products. The most important qualities of the material for these products are biodegradability, temperature control and ability to absorb moisture. For many of these products, contamination in the form of faecal matter and other organic material will not be a problem. The products consist of felt covers for plants or raw wool for mulching. Covering plants is used as a method for weed- and temperature control as well as creating a barrier between the plants and potential soil-borne diseases. Non-wool garden covers, such as garden fleece, are usually synthetic and made from the polymer polypropylene. These synthetic materials will contribute to microplastic pollution if not removed but left to decompose. Furthermore, their aesthetic nature can be said to not blend well with that of nature.

Figure 3-1: Geotex 2000 landscape fabric made of polypropylene here used for erosion control when constructing new roads in Finnskogen, Norway (photo credit: private).

Using wool mulch as a cover in strawberry fields has been shown to dramatically decrease weeds in the fields (Hoover, 2000), greatly reduce variability in soil

temperature and help the soil retain moisture (Tepe et al., 2008). When the wool eventually begins to decompose, it adds nitrogen and organic matter to the soil. The wool can therefore remain in the soil after harvest and act as a natural fertilizer for next year's crops instead of being removed. When used as a geotextile for erosion control, wool has a sufficiently long decomposition time for plants to take root and start controlling the erosion themselves, and later provides nutrients and retains moisture for these plants (Broda et al., 2016).

Something may also be said for the aesthetics of using a natural material in nature - the GardenWool Plant Blanket from Gardener's Supply Company is branded on its natural heat-insulation which protects the plants from frost as well as decorativeness claiming that their product is "So much prettier than burlap"[10]. Wild Valley Farms, a family-run farm in Utah, USA, has developed a similar product, NutriWool Pots, made from recycled wool felt in bright colours[11]. They explain the benefits of these to be their insulating effects and that they allow the roots to breathe, in addition to their decorative nature. If so desired, the pots also allow for easy transplant without removing the plant from the pot as the pot will naturally degrade when placed in soil, decreasing the risk of transplant shock.

The UK based company Chimney Sheep produces garden felt out of wool from Herdwick sheep in a combination with a layer made of jute fibre[12]. Their selling points for the product are that it is hygroscopic, meaning that it absorbs moisture and releases it slowly, full of important nutrients and is biodegradable and compostable within about a year. The company also sell washed but otherwise unprocessed sheep wool for purposes such as mulching.

In Slovenia, the company Soven[13] processes unwashed and washed sheep's wool into products such as wool felt and unwashed sheep wool for gardening and mulching in an attempt to combat wool waste.

3.2 Nature and soil

Using wool as a fertilizer agent in soil takes advantage of several natural qualities in wool as a material such as degradability, nutritional content and water absorption. The positive influences of wool on the growth of grass and other crops have been widely established (Broda & Gawlowski, 2020; Broda et al., 2020; McKinnon, 2019). In addition to having a fertilizing effect, it has been found that wool added to soil provides favourable conditions for plant development. Wool absorbs excess water during rains and gradually releases it in the dry season. In this way, wool ensures a moist environment around the root system of growing plants. Sheep wool pellets may work as a water reservoir due to their ability to absorb water which secures a continuous delivery of nutrients as well as ground moisture. In addition, as they swell, pellets

[10] See website for more information on the GardenWool Plant Blanket

[11] See website for more information on NutriiWool pots

[12] See website for more information about Chimney Sheep's garden felt

[13] See website for more information about Soven

provoke soil loosening facilitating root growth. The pellets will be completely biodegraded after just a few years (Ordiales et al., 2016). The addition of non-composted wool to soil has been found to increase yields for certain crops, such as tomato, aubergine and basil (Gorecki & Gorecki, 2010; Zheljazkov, 2005).

Wild Valley Farms has developed a product that has received attention among US farmers. They started adding waste wool from their sheep ranch to the soil before leaving for vacation, finding that they were able to leave their plants without watering for a longer time. They saw the potential in this discovery and together with Utah State University they developed NutriWool Pellets[14], a fertilizer and water solution made of raw wool (see Figure 3-1). On their website, they claim that since their pellets absorb and hold water, they can reduce the need for watering while also protecting plants from over-watering. In addition, they increase porosity in the soil and add nutrients reducing the need for other additives. It is stated that the pellets are a 9-0-2 grade fertilizer meaning that they contain 9 per cent nitrogen, 0 per cent phosphorus and 2 per cent potassium, the three most important nutrients for plants in terms of quantity.

Figure 3-1: NutriWool Pellets from Wild Valley Farms made of 100% raw wool (photo credit: Wild Valley Farms

Wool is naturally high on nitrogen which is a vital plant nutrient as it plays an important part in photosynthesis. Phosphorus, however, does not occur naturally in wool. Though being a nutritional requirement for plant growth, phosphorus pollution has become a serious issue affecting nearly 40 per cent of Earth's land areas as nutrient runoff into water-waste causes blooms of harmful algae depleting waterways of oxygen. Low phosphorus content in fertilizer means no nutrient runoff and studies suggest that in places with long histories of overuse, crops can thrive on the stores of phosphorus built up in the ground (Rosen, 2020).

[14] See website for more information on NutriWool

In Germany, the company FloraPell[15] has developed sheep wool fertilizer pellets with a mineral content of 10-12 per cent nitrogen and 4-6 per cent potassium. Ordiales et al. (2016) tested the pellets on two crops, tomato and broccoli, and concluded that FloraPell can be used successfully as an alternative biofertilizer as it secures profitable yields for the farmers in a sustainable and environmentally friendly way.

Vitax Corporate, a family-owned business in the UK, is claiming that their product, Slug Gone wool pellets, in addition to working as a fertilizer and water source for plants also keeps away slugs and snails[16]. This is due to the felting-effect of the wool and its potassium content: as a slug climbs onto the fibres, the cuticle cells, being shaped as scales with small barbs on the tip, irritate the foot while the potassium salts absorb the slime of the slug's foot. This causes the slug to seek easier feeding elsewhere.

The use of wool for nature and soil has advantages because it can contribute to improvement on several levels, such as balancing moisture, fertilising, decreasing problems with snails, and minimizing manual labour when replanting by eliminating the need to remove pots before planting. At the same time, this use of wool replaces the use of plastic in the soil and can therefore contribute to reducing the amount of plastic that enters the natural environment and it also has aesthetic advantages where one works with soil and plants in a way that emphasizes respect for nature.

3.3 Insulation

The most important qualities in sheep wool when used as an insulation material are thermal performance and its natural ability for temperature regulation. In addition, the chemical bonding between proteins in wool fibre results in high strength (Alyousef et al., 2020) and the high percentage of nitrogen in the protein creates a self-extinguishing effect as it increases the need for oxygen in order to catch fire (Parlato & Porto, 2020). The ignition temperature of sheep wool is about 600°C in comparison to polyesters 150°C (Røsvik, 2012). These attributes make sheep wool an attractive raw material for insulation purposes. Unlike some of the more commonly used insulation materials, mineral wool and glass fibre, sheep wool insulation can be installed without protective clothing since it does not cause irritation to skin, eyes or respiration (Corscadden et al., 2014).

Indoor air pollution caused by VOCs has become a major concern in buildings where people reside for longer periods of time such as offices and homes. Wool has the ability to absorb volatile organic compounds (VOCs) (Seo et al., 2009). Mansour et al. (2016) found that different types of wool absorb different VOCs and conclude that wool product producers may be able to take advantage of this to develop tailored products that absorb a specific range of those VOCs which the air in a certain type of building is known to contain high levels of.

[15] See website for more information on FloraPell

[16] See website for more information on Slug Gone

One of the greatest challenges for insulation in vehicles is the reduction of mechanical noise (Cai et al., 2021).As argued in the first WOOLUME report (Sigaaard & Haugrønning, 2021), wool holds the quality of acoustic insulation. Several studies of wool as a sound absorber have concluded that the material holds good acoustic properties and may be used as a substitute for the more commonly used, man-made materials, such as mineral wool, glass fibre and polyurethane foam (Allafi et al., 2020; Arnesen, 2015; Ballagh, 1996; Del Rey et al., 2017). In addition, Cai et al. (2021) argue that sheep wool has the ability to isolate vibrations from the vehicle. Therefore, wool insulation materials can be used for floor, ceiling, seat and door coverings and in the engine compartment of the vehicle.

Havelock Wool[17], based in Nevada, produces insulation materials for homes and campervans out of sheep wool from New Zealand. The company is branding their products on their abilities for moisture management, sound and heat insulation, absorption of VOCs and biodegradability. These properties are attributed to the inherent properties of wool as a natural product, and it is claimed that no man-made insulation material performance as well as Havelock Wool. The company has explained that a large and growing cross-section exists that is interested in moving away from synthetic materials, and that Havelock Wool offers an alternative.

Figure 3-2: sheep wool insulation from Havelock Wool, for homes on the left and vans on the right (photo credit: Havelock Wool)

In the UK, Thermafleece[18] has been producing sheep wool insulation materials for more than 20 years. The company prides itself on offering a natural, sustainable, and high-quality insulation material as an alternative to conventional man-made materials. The product CosyWool Roll is made from 75% British Wool and 25% recycled polyester made from recycled plastic bottles. They also have insulation products made of hemp fibre.

[17] See website for more information about Havelock Wool

[18] See website for more information about Thermafleece

A new insulation product that takes advantage of the qualities of sheep wool is packaging materials. The British company Woolcool[19] has developed insulation packaging for transportation of temperature-sensitive goods such as foods and pharmaceuticals made of felted sheep wool. According to the company, their products have been tested and proved to keep the products within the required temperature range for at least 24 hours and up to over 120 hours. This is claimed to be due to the superior insulation effect of wool and its ability to absorb moisture from the air minimizing humidity and condensation to keep temperatures stable.

The Estonian company Woola[20] has developed packaging made of leftover sheep wool to replace bubble wrap and reduce plastic waste. They call it “Using waste to create a better solution” and are developing a circular system to keep the wool material in use for as long as possible, through re-use of packaging as well as recycling, with composting only as a final resort. The qualities of wool they are emphasising are its natural elasticity, water repellence and resistance to temperature extremes. The company explains that they wish to avoid the use of oil-based materials while also utilizing low-graded wool which is often going to waste by taking advantage of the many good and natural properties of sheep wool. In addition, Woola regards wool as a warm, homey material that makes people feel good.

The Danish company Marcusholm[21] has been producing wool duvets for the past three years. The founder is a former sheep farmer using their wool for felting and yarn and later learned how to craft wool duvets in the traditional way. The duvets are made from Danish wool, specifically Danish Shropshire wool, a 31-33 micron down type fibre wool with 10-15 cm long staples, chosen because it felts very little and can be washed at 30 degrees, with an Oeko-Tex Certified cover. They market their duvets as temperature regulating, antibacterial and allergy-friendly. They explain that they spend quite a bit of time explaining the benefits of wool but that they also receive a fair amount of interest - wool duvets seem like a novelty to many and something they would like to try out, though many are prejudiced against the material as “itchy” or “too warm”. Furthermore, customers have a habit of washing duvets biannually, though wool duvets do not require this and therefore the choice of wool was important.

Wool for various insulation applications, including buildings, cars, packaging, and bedding, not only has a temperature regulating function, but the innate properties of wool have beneficial effects like fire resistance, moisture absorption, water repellence, VOC absorption, and allergy friendliness. It also has the potential to be recycled and composted at the end-of-life of the product.

3.4 Sanitary products

Every hour, 20 million disposable diapers are produced creating over 38 million tons of plastic waste per year (Ellen MacArthur Foundation, n.d.). For sanitary pads and other

[19] See website for more information about Woolcool

[20] See website for more information about Woola

[21] See website for more information about Marcusholm

disposable menstrual products, the amount of waste created is difficult to track. In 2018, 5.8 billion tampons (a third of the global total) were sold in the US alone (Borunda, 2019). Globally, is estimated that 45 billion menstrual products are disposed of yearly (Barth, 2021).

Since the products contain a mix of materials in addition to the organic matter that they have soaked up, they are not possible to include in either synthetic or organic waste circuits. The majority of these will therefore end up in landfills. The products themselves, therefore, constitute a waste issue, as do the plastic wrappings and applicators in which they come. Disposable pads contain up to 90% plastic, including the absorbent filling, and tampons up to 6 %, excluding their wrappings and applicators (Notman, 2021). Plastic pads and tampons are, however not accepted as plastic waste due to sanitary issues. The products are disposed of through the general household waste destined for landfills or incineration, but many end up in oceans and waterways as they are flushed down the toilet. Sanitary towels are in the top five of the most common single-use plastic items found on beaches and in the marine environment in Europe and are categorized as products with none or difficult alternatives (European Commission, 2021).

Alternatives to disposable sanitary products have been developed such as period pants, washable pads and menstrual cups marketed based on claims of being sustainable and environmentally friendly. Some producers have started to recognize the positives of using sheep wool as a material for diapers and menstrual pads. The most important qualities of wool for products in the hygiene industry retain to that the products become compostable, washable, allergy-friendly, absorbent of fluids, and that smell is decreased compared to synthetic alternatives.

A company already making sanitary pads and diapers of wool is Seven Lambs Organics[22] based in Canada. The pads and diapers are produced using only the qualities of the materials themselves to absorb moisture without the addition of other technology. Both pads and diapers come in two pieces. The diaper covers are made of organic merino wool and the inserts are made from organic cotton fleece. For sanitary pads, the inner pads that attach to the underwear are made of an inner layer of organic merino wool and an outer layer of organic cotton fleece. The liners that are inserted into the pads are made of cotton fleece and bamboo velour; a viscose fabric made from bamboo. Pads may be used for longer periods of time and only the liners need to be regularly changed and washed throughout the day. The products are advertised as an alternative to single-use products.

The New Zealand based company Woolchemy has developed their nonwoven products neweZorb and neweFlex (see Figure 3-3), which can be used for diapers and sanitary pads. NeweZorb is a treatment process that relaxes the fibre structure of the wool, making the wool surfaces superhydrophilic and superabsorbent as it becomes up to 25 times as absorbent as regular wool (Nonwovens Report International, 2018). NeweFlex is a biocomposite acquisition distribution layer (ADL). An ADL is a nonwoven material in hygienic products, a layer designed to improve fluid management.

[22] See website for more information about Seven Lambs Organics

NeweFlex is made using a hydro-entangled process, making the 37+ micron New Zealand sheep wool they use feel soft. Taking advantage of the properties of sheep wool, neweZorb and neweFlex are claimed to be durable, washable, home-compostable, odour resistant and antibacterial. Their tests also show up to a 40% performance boost when exchanging the surge layer in diapers from 4 consumer brands with their wool neweFLEX layers. They further see a potential for wool to replace several components and processes commonly used in diapers, including chemicals for odour control. In addition, wool is the only fibre that has the ability to insulate and stay at an even temperature when it absorbs moisture, meaning that babies will not feel cold when sleeping (Tobiasson, 2021). The company moved away from their initial idea of creating their own line of diapers, to becoming a material/ingredient brand supplying existing manufacturers to improve the sustainability of their products, thus increasing the range of products the wool materials can be used in. They further differ from companies making re-usable cloth nappies and sanitary products in their view to make disposable products that are compostable, offering a single-use solution for replacing these plastic items.

Figure 3-3: illustration of neweFlex used as an ADL in a diaper or hygiene pad (photo credit: Woolchemy)

Another New Zealand based company nil.[23] have several products made of 100% organic wool, among other makeup remover pads, face cloths and body sponges. They are branding these products as being eco-friendly and waste-free as they are completely biodegradable and compostable.

In sanitary products, wool can be used in both single-use and re-usable alternatives to the conventional plastic products as it is both washable and bio-degradable. Using new treatment technology, the wool can become hyper-absorbent or be used as an ADL, outperforming the synthetic alternatives. It also contributes with its additional qualities,

[23] See website for more information about nil.'s products

such as odour resistance and temperature regulation. This is an important product area considering the amount of waste produced. However, little is known about the effects of the new treatments on the wool once it becomes waste and consumer attitudes towards these new products.

3.5 Other new products

Examples of several newly created products of wool prove that only imagination is the limit for what may potentially be produced of this natural material.

The British company AW Hainsworth[24] has produced a line of coffins called Natural Legacy made of new pure wool, a cardboard liner, and an organic cotton interior. The company brings forward the natural ability of being biodegradable as an advantage of using wool coffins for cremations and all types of burials. In addition, they say that wool makes for a gentler, more tactile product that is not as cold, hard, and final as a normal coffin. According to the company, this allows for a closer relationship for the family with the deceased for as long as possible. Using wool creates a comforting product that allows for greater reflection of the personality of the deceased. The low weight of a wool coffin was also brought forward as a positive, especially for parents of a deceased child carrying the coffin to the grave. A distributor of the Natural Legacy coffins, Natural Endings Funeral Services, say that customers chose them due to their softer, cosier and warmer aesthetics.

Figure 3-4: two Natural Legacy wool coffins made by AW Hainsworth (photo credit: AW Hainsworth)

Similarly, the Danish company Uurna[25] is producing a series of felted urns made of pure wool from local sheep farmers in addition to dyed wool from other suppliers. They also add finer Merino wool for better binding in the felt but work actively to find ways to blend and incorporate coarser wool types. These urns take about 5 years to decompose completely. The company uses degradability as the main selling point when marketing the urns as lifecycle is an important part of the brand. As with the wool

[24] See website for more information about AW Hainsworth's wool coffins

[25] See website for more information about Uurna

coffins, Uurna also emphasizes the warmth and comfort that the wool urns provide to the bereaved families. They described wool felting as a sensory craft where physical energy and warmth is applied which can be sensed by the relatives. In addition, the company offers to adjust the look of the urn to fit the wishes of the families. Though the customer may fall in love with a photo of an urn from the webpage or have a specific look in mind, their urn will not look the same as products made of sheep wool will hold variations. Uurna claims, however, that time is working to their advantage as people today tend to prefer something different, a handmade unique product.

Figure 3-5: the "Birk" urn and a selection of urns for pets from Uurna made of felted sheep wool (photo credit: Uurna)

Sheep wool has very recently been used for a very untraditional purpose. This year, in 2021, the very first boat made from wool was launched by New Zealand inventor Logan Williams. The inventor takes advantage of the qualities of sheep wool being light weight in addition to being one of the strongest natural materials. Williams claims that by making the boat in a natural material, they prevented 40kg of plastic from being used, corresponding to 7000 plastic bags (Boswell, 2021). In addition, the wool used in this boat is the strong, coarse, difficult wool that would otherwise be wasted. By combining coarse wool with an acid derived from corn starch, Williams has created a bio-degradable plastic replacement which he calls Keravos (McLennan, 2021).

Another wool invention from New Zealand which came out in 2018 was the Woolight surfboard produced by surfboard maker Paul Barron and The New Zealand Merino Company in collaboration with US-based Firewire Surfboards. In this product, the traditional refibreglass material is replaced with wool fibres (Skerrett, 2018).

In the UK, the company Solidwool[26] has similarly created a material resembling fibreglass but with sheep wool as the reinforcement instead of glass. The bio-resin they use contains 45% bio-based renewable content sourced from waste streams of other industrial processes, such as wood pulp and bio-fuels production. The material may be applied for several purposes. So far, the company has produced the Hembury Chair which is made by hand using the local Herdwick wool.

[26] See website for more information about Solidwool

Untraditional usage of wool represents an alternative and has the potential to replace synthetic materials in many applications, including coffins and urns for burials and items made of fibreglass. Here the many properties of wool are taken advantage of, including biodegradability, strength and aesthetic.

4 Discussion

Plastic pollution has become one of the most pressing environmental issues as about 8 million tons of plastic waste escapes ends up in the ocean every year (Parker, 2019). In the most recent EU circular economy action plan (2020), the reduction of plastic waste, and in particular single-use plastic products, is in focus. From July 3rd 2021, certain single-use plastic items such as straws, cutlery, cotton bud sticks, and food containers were banned from EU Members States' markets (European Commission, 2021).

Synthetic textiles are an important part of the increasing plastic waste problem. They contain environmental toxins added during the processing of fibre and fabric and contribute up to 35% of the released microplastics which have been shown to end up in lungs, oceans, animals and even placentas (Changing Markets Foundation, 2021; Henry et al., 2018, 2019; Klepp & Tobiasson, 2017; Klepp & Tobiasson, 2018). Furthermore, the shape of the fibres (long, thin and flexible) makes them highly unstable. Fibres from all textile materials lose some mass during use, but for synthetic fibres, this is a more serious issue because it contributes significantly to microplastic pollution.

Replacing plastic with other, more environmentally friendly materials may be part of a solution to the plastic pollution problem. In this section, we will discuss the potential of the wool products presented in this report to contribute to waste reduction by replacing conventional products. We will also discuss the challenges and obstacles in the development and marketing of these products.Waste reduction

Following the notion of best utilization of resources, using something that is already produced for a purpose for which it is suitable, is better than producing new materials or resources for this same purpose. Avoiding superfluous production of raw materials and resources is an important measure in reducing waste creation. The utilization of difficult, coarse sheep wool, an otherwise unutilized by-product, could therefore potentially contribute to achieving the preferred option in the EU Waste hierarchy: prevention.

In addition, one of the natural qualities of wool being biodegradability, using sheep wool as a material represents another positive in that many wool products will be compostable. For products meant for gardening and soil enhancement, and for wool coffins and urns, this quality is essential, and possibly also for single-use hygiene products. Wool pellets and pots dug into the soil will gradually decompose and even garden felt will eventually degrade and disappear. Not only does this entail waste prevention, but the decomposed wool even adds nutrients to the soil, eliminating the need for chemical applications. Compostable hygiene products may similarly contribute to soil improvement. Biodegradability has also been accentuated as an important quality of sheep wool by producers of acoustic and sound-absorbing wool products as it simplifies disposal of waste material (Sigaaard & Haugrønning, 2021).

The second most preferred option according to the EU Waste hierarchy is facilitating reuse. Sanitary and other hygiene and beauty products made of wool can be made washable and thereby instantly reusable in addition to replacing single-use products.

As mentioned above, wool products may be compostable and will not spread microplastics. Using wool felt to cover plants in the garden instead of plastic covers or geotextiles often made of the polymer polypropylene will therefore not create plastic pollution in the soil. Microplastic pollution caused in part by plastic mulch from agricultural activities has been found to cause significant damage to the soil ecosystem (Chae & An, 2018). In addition, sheep wool has, as mentioned above, several natural qualities which make it a good alternative to synthetic products as there is less need for chemical applications. This makes wool products safer to work with, also because wool is an allergy-friendly material. Replacing plastic products with wool products could therefore have positive environmental and health effects.

Sheep wool can also create a feeling of being closer to nature. As discussed in relation to acoustic products, the natural, raw and rustic aesthetics of wool was found to be one of the major reasons for choosing sheep wool as a material both for producers and buyers (Sigaaard & Haugrønning, 2021). This was also mentioned by producers of the visible products in this report. Particularly for coffins and urns, the exterior look and aesthetics seemed to be important. The feeling created by the wool felt of being buried with and eventually becoming one with nature was described by one producer. Wool gives a sense of warmth and comfort which materials like wood veneer, cardboard, fibreglass or steel do not. This aesthetic perspective on wool could be extremely important also for parks and private gardens.

An important point for several of these alternative wool products is that although they may not be able to compete with or completely replace the conventional products, they represent an important alternative. The range of approaches present within the hygiene product space, from re-usable to single-use increases this potential, as it allows for customer choice similar to the current plastic offerings. Even if just a part of the plastic products can be replaced by wool products, there may still be a noticeable positive effect. In addition, creating a focus on and showing the possibilities for replacing synthetic materials is important on its own. In the Jutulskinn report, Klepp and Haugrønning (2021) bring up issues of waste reduction, utilization of resources and local production through the example of a Norwegian tannery, showing how by-products and side streams from other production can be redirected into resources used for the development of good products. This may inspire others and shows that products development based on natural, underutilized materials have potential.

Returning to the subject of the circular economy, many of the producers presented high-light biodegradability as a main end-of-life solution, or a main function for their products. The exception is Woola, that are developing a circular system for wool, including both re-use of packaging and recycling of the material - keeping materials in circulation for longer - before composting. An important factor for these products is the relatively untreated state of the wool, where only a few of them are made from dyed wool and quite a few are made from greasy, unwashed wool. This means that the materials easily stay within a biological cycle and can safely biodegrade.

Considerations of wool processing methods and material combinations here play an important role. Insulation materials made with wool and polyester blends will be prevented from safely entering a biological cycle. Woolchemy however, mix their wool fibre with other natural fibres for their NeweFlex material and therefore maintain this possibility. In addition, their process changes the chemical structure of the wool to increase absorption without impacting its biodegradability.

Resource efficiency is not only a question of material but also what you do to the materials, and resources spent in those processes. Some of the products in the categories relating to soil and cultivation are made from unwashed wool. In this case, the scouring is an unnecessary process, and it would be a waste of energy, and thus resources to do this. Finding ways to minimise processing was highlighted by some of the producers as an avenue for reducing production costs. It is therefore interesting that a Norwegian carding mill, Løvli Naturull, are carding unscoured wool. This creates an opportunity to explore production that requires carding, but where a high lanolin content is an advantage[27]. There is a lot we do not know, but we expect more knowledge to be created in the projects "Ulla di!" («Your wool!»)[28], VerdifULL and other projects in Norway.

4.1 Development and challenges

In order to evaluate the potentials of these innovative wool products, it is important to consider several aspects such as how far they have come in the development, whether they are or when they will be available in the market, what their production scale is/could be and whether vacant wool can be used. The journey from research and development to store shelves can be long for a product and not all new and innovative products are financially viable or competitive in the market. Most of the products researched in this report are already on the market, with the sole exception of neweZorb and neweFlex from Woolchemy, which have been developed but are not yet being used in commercially available products. In addition, many producers already used coarse wool in their products, and some claimed that their products could potentially be made from coarser wool than what they are using today. Their reasons for using finer wool had primarily to do with supply and access. Woolchemy's business model, being an exception, is based on using New Zealand wool, which is according to them, 90% coarse wool, or "strong wool" as they call it. They have created their own supply chain working directly with local farmers instead of relying on wool auctions or middlemen. This corresponds with findings from the previous WOOLUME report (Sigaard & Haugrønning, 2021) where producers disclosed that they were primarily using Merino wool because of its availability in the market.

However, certain challenges exist for wool products to compete with products made from more conventional materials, such as synthetic fibres. The price of the final product was the main challenge brought forward by producers in interviews. This was also a finding during research on wool acoustic products (Sigaaard & Haugrønning,

[27] See website for more information about Løvli Naturull

[28] Read about the project "Ulla di!" here

2021). Since other materials generally are cheaper than wool, non-wool products will inevitably be cheaper to produce, making it difficult for the wool products to compete. As an example, Natural Endings Funeral Services disclosed that the wool coffins are more expensive than most other coffins. For comparison, their traditional wood veneer coffins are about £180, European willow coffins are about £400 and Natural Legacy wool coffins are about £550. Uurna expressed similarly that their urns are more expensive than conventional urns but added that their customers do not mind paying a little extra for a unique handmade product.

Price for transportation and the costs involved in making sure the wool is handled carefully also add to the costs of using sheep wool. This is especially challenging in the initial phases before the product and/or company have been established as a brand. As it was put by Havelock Wool: “Price is the major issue. It goes away with a fan base.” The company attributes much of their success as a small company to the market opportunities created by the segment of buyers who are looking for alternatives to synthetic materials but do not expect to be able to replace conventional materials such as fibreglass. The exception is Woolchemy, that explain that they can produce their materials at the price points of their synthetic counterparts and still pay the farmers above the 2.20 NZD/kilo they are currently receiving at auctions due to their direct-from-farmer purchasing model and their materials supplier model. This is important as currently the cost of shearing exceeds the price of the wool. They also believe there is further pricing potential for their materials as wool provides more functions than their synthetic counterparts, as described above. This creates a further potential to aim for a higher price point as they are in fact offering a superior product. Woolchemy also cites increasing interest in their materials from sanitary product manufacturers. This is in large due to the EU Directive on single-use plastics[29], where sanitary items have been designated as a priority product group.

Another challenge that was brought forward in several interviews was supply. It may seem contradictory since we know of the enormous quantities of unused wool going to waste. However, access to sheep wool had proven to be a challenge to producers in at least two ways. Firstly, for many of the products, large quantities of wool are required. At Wild Valley farms they had estimated that even if they collected all vacant wool in the USA, it might still not be enough for big companies to justify their investments in the project. This poses a substantial hindrance to the potential production scale. Secondly, many of the brands wish to take into use local wool, but in many cases, it has proven easier to import wool from other places. Wild Valley Farms, for example, has been attempting to expand internationally using the local wool in each place. But the companies they work with have found it easier to buy the pellets directly from Wild Valley Farms and repackaging the products before selling than to produce their own pellets. This was due to the pelletising process being complicated by variations in wool qualities and requiring an expert hand. For Uurna, the issue has been to obtain local wool from the area in which they are based. They are receiving some wool from local farmers but still need to import wool from Australia. AW Hainsworth also imports wool for their coffins. Though they used British wool at first, they changed to wool from New

[29] Read about the EU Directive on single-use plastics here

Zealand. Since the Natural Legacy coffins were their only product made from British wool, it fitted better with their supply chain to swap. Woolchemy, on the other hand, have based their business model on using the locally abundant New Zealand wool - New Zealand produces 8.9% of global wool - but they are currently manufacturing their textiles in China and Germany. They are facing the obstacle of financing pilot equipment to develop materials and a manufacturing facility in New Zealand to also produce their materials locally instead of shipping the wool abroad.

In addition to price and access, a third challenge was mentioned in several interviews. The customers need to experience the products before they can fully understand the advantages of using sheep wool as a material. For pellets, this pertains to the positive results of wool as a fertilizer and hydrator. This can be difficult to show potential buyers as they often prefer to see it in their own crops before trusting it. For the wool urns, it was explained as a challenge that people needed to feel the warmth of the wool in their hands to fully understand the reasons for choosing this product over conventional urns.

This challenge may be due to what was on several occasions during interviews referred to as “the traditional mindset”. Both AW Hainsworth and Uurna talked about how they experienced the reluctance to accept new products from different parts of the funeral industry. For Uurna this had to do with a very technical obstacle pointed out by the cremators: when the ashes are transferred to an urn, the machine will normally descend towards the urn and stop once it senses resistance. However, wool felt will not generate enough resistance to stop the machine so the urn will be crushed. The solution was to keep the urn in a box while being filled.

5 Conclusion

The wool products researched in this report have potential in terms of waste minimisation in at least three aspects. First, they contribute to the utilization of wool in good products with good value and thereby decreasing wool waste. Secondly, by respecting the innate qualities of all types of wool, one can avoid the waste engendered when using what the market currently perceives as the best quality wool - wool that can be spun into yarn for clothing - for applications where other underutilized qualities could be exploited and be more than good enough. And finally, they may potentially replace some products made of synthetic materials and thereby contribute to decreasing plastic waste and contamination of soil and water. Many of these wool products are fully compostable as they are not mixed with synthetic materials and few treatments are used in the production process. Therefore, they can be a part of a biological cycle and contribute to a circular economy. In some cases, the products are not only a feasible alternative but may even be better than plastic products due to the natural qualities of sheep wool.

To reach the circular economy goal of keeping “products, components, and materials at their highest utility and value at all times”, the choice of raw materials is important. By using unnecessarily fine wool, e.g., spinnable wool, where this property is not needed, other wool remains underutilised. Exploiting the variety of properties in a material, the example here being wool, will contribute to the circular economy. Such transformation also requires a shift in where and how large production units are - the advantages of e.g., plastics being not just price, but also the availability of large quantities with similar qualities. Vacant wool in Poland and other EU countries is, as this report has shown, is not at all useless, but the utilisation demands more cooperation, imagination, or development than standardized global raw materials. Hence the discussion about the circular economy also becomes a discussion of localisation of industry and the need for local value chains and smaller enterprises that can utilise the local raw materials.

However, these products will most likely not replace their plastic equivalents completely. Several challenges exist for wool products to make it in the market, primarily price for and access to sheep wool but the attitude towards the products is also influential. Several producers spoke of how they promoted the advantages of using wool but also of how people were hesitant to believe them without first seeing the results. Many had managed to establish themselves as brands and secure a customer base but upscaling production to the level of the conventional products is still unlikely for most. Nevertheless, even if they may not replace synthetic products completely, the wool products represent a good alternative that may result in some replacement and thereby contribute to plastic waste reduction, and the interest-driven by environmental concerns cited by the companies is encouraging.

In addition, the products are important beyond themselves as examples of how by-products may be utilized as resources, how waste may be reduced, how local resources can be taken into production and how natural resources have certain natural qualities that may be utilised. Furthermore, they not only represent market opportunities for vacant wool, but they also contribute considerably to the improvement

of the user experience, and choice, whether the recipient is a plant, a child, or a woman. These perspectives and ways of thinking will be important in terms of attempting to access and solve many of the important challenges of today.

The report shows that much innovation is happening right now regarding alternative wool products, and many more products exist and are being developed that did not make their way into this report. Producers and customers are still discovering many of the advantages of using sheep wool as a material and many are working to utilize the natural qualities of wool in products. We believe that these many and different qualities have the potential to be sustained and taken advantage of in many new products, such as those presented in this report. Wool as a material is 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.

The new products in this report represent untraditional usage of a traditional material, including unconventional processing. Herein lies another unexamined aspect of the wool industry; little knowledge of the effect of conventional processing on the innate properties of the wool fibre as well the implications of wool treatments for the life span of wool as a material. In a bigger picture, some of the products discussed have the potential to be the end-of-life stage for other wool products, but this requires consideration of all wool processing stages not to hinder biodegradability. Further research in this area would be beneficial to develop wool treatments that enhance its qualities, rather than inhibit inclusion in a truly circular economy, not using more processes than necessary or processes that hinder further processes or steps within a biological cycle, maximising resource utilisation further.

Moreover, this report is not a systematic review of how plastic can be replaced by natural materials like wool, but it shows some possibilities for better resource utilisation and material choices. Optimising the use of vacant wool and other by-products or waste materials is a field in development, with growing interest from scholars as well as industry. But in reality, we know little about the waste created by using unnecessarily high-end materials for applications where other qualities would be as good.

For better resource utilisation, there is potential both in using long-established and new technology in traditional or innovation of products. However, traditional practice and technologies have been little researched. As a rule, research and development of new technology and materials receive more funding than research for resource optimisation, development and change in use of traditional materials, though the latter are fundamental to the transition ahead. Here there is potential in examining and learning from past, traditional practice: Using wool as a lens through which to see important aspects of the contemporary world: corporate capitalism, consumerism, standardisation, and their opposites: localised crafts and practices, quality of life, sustainability. The book “Local, Slow and Sustainable Fashion Fibres: Wool as a fabric for change” (Klepp & Tobiasson, 2022) is a step in this direction, but it requires a complete rethinking of the relationship between natural materials, local production,

small scale resource optimisation and mote to fully take advantage of the potential that lies within good resource utilisation.

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Consumption Research Norway (SIFO), OsloMet **ISBN 978-82-7063-538 2**
www.oslomet.no/om/sifo