MAKING THE MOST OF NORTHERN IRISH WOOL: REPORT ON QUB STUDENT PROJECTS 2018 -2021

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ppre & Macroscopia

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Background

This paper reports on work carried out by postgraduate students at Queen's University Belfast between 2018 and 2021. All the students had agreed to do projects with the QUB/UU Science Shop which promotes community engagement by students as part of their studies. Some students were from the School of Mechanical and Manufacturing Engineering, some were from the Gibson Institute, School of Biological Sciences Master's in Leadership for Sustainable Development and one was from the Management School. The community organisations hosting the projects were ppre and Macroscopia. They are both Community Interest Companies. ppre has been in existence since 2003 and promotes public policy, practice, research and education. ppre has been working with the Science Shop since 2014 on teaching students about policymaking. Macroscopia was started in 2015 promote better public policy and social change through evidence-based interventions. It has a particular interest in developing practice around sustainable development. It has been looking at the future prospects for wool. John Eversley is managing director of both companies.

Thanks to the students for all their work, to their supervisors and to the readers of an earlier draft of this report for their comments.

Northern Ireland context

Sheep farming in Northern Ireland

Just under 10,000 (38 per cent) of Northern Ireland's approximately 26,000 farms have some sheep. There are about 50,000 farmers and farm workers (DAERA, 2021a)

There are a little under 10,000 farms in Northern Ireland, which employ more than one part-time farmer. There are more than 14,500 farms which employ the equivalent of a half-time farmer or less – many of these are sheep farms. Based on a sample of a little less than 3% of farms of all types, farm incomes declined in 2019/20, the latest period for which figures are available. More than a third of farms had an income of less than £10,00 per year. Seventeen percent made a loss (DAERA,2021b).

The total number of sheep is stable at about two million. About half are lambs which will be slaughtered for meat. Most of the rest are ewes which have lambed or are being kept for breeding. Just under 30,000 rams are kept for breeding. Just under two-thirds of farms have less than five hundred sheep. About 30% of sheep are reared in County Antrim. Using local authority areas, the vast majority are in six of the eleven areas (DAERA, 2021a)

Official data combines information for cattle and sheep farms which means the income of sheep farms is not identifiable but sheep farms, especially upland ones, have the lowest incomes. Without government subsidies sheep farms would generally make a loss. The profitability of sheep farming depends on the price of sales of lamb and wool, but also on the variable costs – of feed, vets' bills etc. In Disadvantaged and Severely Disadvantaged Upland areas, farmers generally get lower prices for their meat and fleeces, they also get less meat and fleece per sheep, but their costs are similar or higher than lowland farmers. Some of the differences are explained by differences in which breeds can thrive in upland areas and how long they can be kept outdoors and fed on grass. Twenty-eight percent of farm businesses had no off-farm income, but the majority had income, particularly from spouses' employment (DAERA,2021b).

The Wool Initiative (trademarked as Drumlin) was set up a group of farmers to conserve and promote rare and traditional breeds of sheep for their fleeces. They have thirty breeds. They supply raw and prepared fleeces and yarns and work closely with makers.

Sheep for meat

Given that sheep in Northern Ireland are primarily reared for meat, the strategy for making wool a more valuable and sustainable product, also needs to address making the meat more valuable and sustainable. Closing the gap between poor and best practice in sheep farming would make it more profitable and improve animal welfare (UFU, 2019). WRAP estimates that unused sheep products in the UK are worth £48m (Bajzelj et al, 2019). Some farmers are switching to practices such as Agro forestry which prolong the period which animals can be reared outside (Woodland Trust & National Sheep Association, 2018). Both in order to enhance the value and for animal welfare reasons, shortening the distance live animals go for slaughter, having smaller numbers of animals processed and maintaining the distinctiveness of flocks, mobile or boutique abattoirs may be useful (Kennard and Young, 2018; Menzies et al, 2020).

Sheepskins

Before turning to wool, it is also worth noting that sheepskins are another part of the sheep with potential value but there very few tanneries in the UK. The conventional tanning process poses a number of environmental challenges but there may be more sustainable alternative processes (Moorhead, 2014).

Wool

Ulster Wool which is a cooperative of farmers (and part of British Wool) handles over 1.2 million kg of wool, from almost 3,500 producers (Ulster Wool, 2021). This is probably a little more than half the fleece produced in Northern Ireland. The rest is generally sold through private buyers, usually wool brokers who buy to sell on who pay cash. There are a number of Wool Brokers in Donegal but some of them are no longer collecting from Northern Ireland which may be a consequence of Covid and/or Brexit.

Ulster wool sells the graded fleece at auction. Although farmers do not get paid until after the auction, they probably get a better rice because the wool is graded consistently, and the auction means more buyers are involved.

The price fleece fetches depends on a variety of factors such as

- The style or characteristic of the wool
- The breed of sheep
- Where and how the sheep is reared
- Whether it is wool from the first time a lab is shorn – “lamb wool” or “Second Shear”
- The length of the fibre or staple
- Whether the wool is certified as organic or not
- Whether the wool is damaged, discoloured, contaminated or excessively marked
- The market conditions (Ulster Wool, 2021)

In 2020 The fleece sold through Ulster Wool varied from 250 pence per kilo down to 5p per kilo with an average of 33p (Ulster Wool, 2021; Cowling quoted in Cafolla, 2021).

The prices achieved during 2021 at the British Wool auctions are:

(British Wool, online)

At the end of July 2021, the Department of Agriculture Environment and Rural Affairs announced a COVID 19 Wool Support Scheme to compensate Northern Ireland farmers for losses due to low wool prices. It was calculated as at flat rate of £1.40 per ewe with a maximum support payment of 80% of losses and a cap of a little over £210,000 including payments made under various other schemes such as the DAERA Covid-19 Sector Support Schemes, Bounce Back Loans and NI Executive Covid-19 Grants (DAERA, 2021c). The structure of the scheme meant that farmers with higher costs (for instance because they need to house sheep for longer indoors in the winter or use artificial feeding supplements) or who could have expected higher prices for better quality fleeces would receive less proportionately for their losses than farmers with larger flocks with low quality fleeces and even if they kept them for meat rather than wool. As there are very few large flocks in Northern Ireland the cap, was probably not significant.

As part of the collection of background information for student projects, the Gibson Institute and Macroscopia also collected information from various sources, especially from an event backed by the Ulster Farmers Union (UFU), the Department of Agriculture, Environment and Rural Affairs (DAERA) and the College of Agriculture, Farming and Rural Enterprise (CAFRE) on 'future proofing' sheep farming (UFU, 2019) which identified a number of key things which could be done to enhance the value of sheep farming including:

1. Agro forestry which can enhance carbon capture and create jobs in planting, maintaining and logging woodlands.

2. Better use of grasslands by rotational grazing, matching supply and demand for grassland better; encouragement of seeding more diverse grasslands

3. Reducing unnecessary inputs and waste: re-seeding and use of prepared feeds with consequent phosphate waste and costs to farmers.

4. Better stock selection: recorded rams; genetic selection; use of breeding and sales records

5. Better housing of sheep, when necessary

6. Care for sheep through best practice in handling, fleece care and health checks e.g. for OPA

7. Better relationships between farmers, processors and end users of meat and wool

8. Selection of when, which and where lambs sent for slaughter

9. Data collection to set targets for growth rates, days to slaughter, grass quantity and quality yields

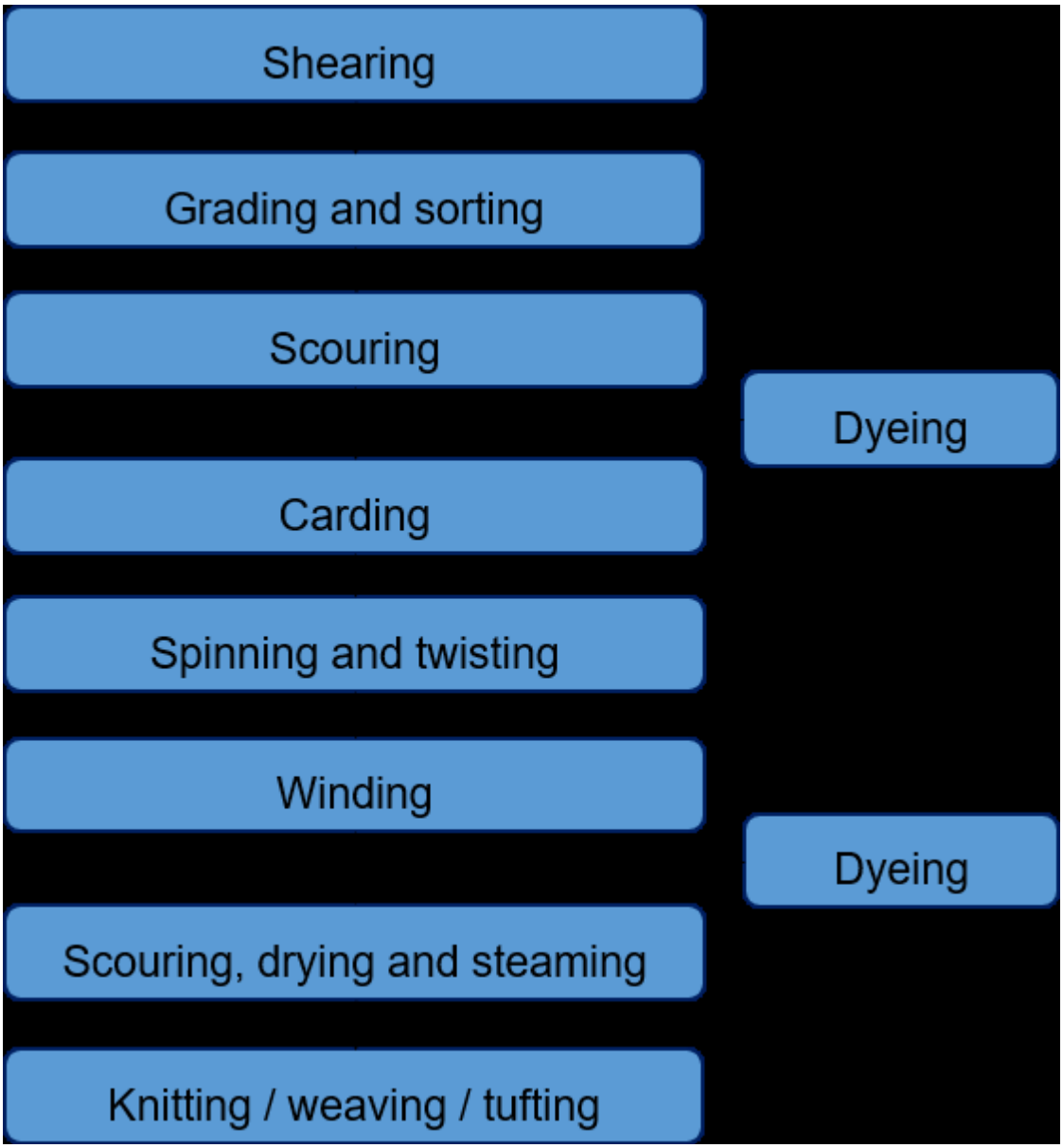
10. Promote provenance to identify meat and wool as from specific breeds or flocks reared in specific ways which may involve 'boutique' or mobile abattoirs for some farms.

The Resilient Farms project in the glens of Antrim took a broad approach to the development of (sheep) farming looking at the integration and interdependency of economic, social and environmental issues through a farmer centred, bottom-up approach (Gaynor and Mathers, 2017).

One issue may be that there have only been limited opportunities for farmers and would-be farmers to learn about why sustainable farming is important to both them and the planet, and how it can be done. CAFRE recently started a Sustainable Agriculture degree course and there are other opportunities run by farming and environmental organisations.

Processing

The processing of wool goes through a number of stages



(Torrens, 2019)

The farmer will normally pay specialist sheep shearers. In 2019 the average cost of shearing a sheep was £1.30 which yields an average of 2kg of fleece (obviously there are variations based on breed etc). The shearers are paid a price per sheep. The costs of shearing the wool and transporting it to a depot for sale can exceed the value of the wool. Some farmers are willing to barter shearing for the wool or may give away the wool.

After the initial shearing, sorting and grading, processing is not generally carried out on the island of Ireland. It is mostly done in England, China, Italy etc. The negative environmental impact of transporting

fleece and wool to and from Britain internationally could be reduced by local processing. The cost to ship a 300kg bale of raw wool from Northern Ireland to mainland UK was estimated in 2019 to be approximately £25 with a similar cost to return the processed wool (In Brown, 2019).

Scouring is the initial process of cleaning the wool: There are only two commercial sheep scouring plants in the UK. Most of the rest is processed in China. Souring is generally done using synthetic chemical detergents and hot water. The process generates some waste which is toxic and some which is potentially valuable. It is also energy intensive. The 'grease' in wool is lanolin which has a number of uses. Wool dust which is treated as 'dirt in conventional scouring has potential uses, for example as fertiliser. An alternative method of cleaning wool – dry scouring – uses the by-products (Leitat et al, 2015). Historically in the west of Ireland scouring using urine (containing ammonia) was maintained into the 20th century (Bielenberg, 2013).

Carding is the process of aligning the wool fibres which can either be turned into flat webs for felting or quilting or continuous untwisted strands of fibre called sliver.

Spinning is the process of twisting the threads to give them added strength

The environmental footprint of carding and spinning can be reduced by using renewable energy.

Dyeing: some wools can be used in their natural colours and in some uses the colour does not matter. However, for many uses dyeing is necessary, and most dyeing uses synthetic dyes using fossil fuel derived chemicals and producing toxic waste. Dyeing of the wool may be undertaken before blending, as a loose wool (the 'sliver') or after winding into 'hanks'. Dyeing the loose stock is more suitable for large volumes. It requires less water and energy, compared to hank dyeing. Hank dyeing is more suitable for small manufacturers and makes it easier to adapt to customer demand.

The amount of processing depends on the final use of the wool:

The processes required for the production of woollen products

Clothing	Yarn	Insulation	Carpet
Dyeing	Dyeing	Blending	Dyeing
Blending	Blending	Carding	Blending
Carding	Carding	Bonding	Carding
Spinning	Spinning		Spinning
Winding	Winding		Winding
Steaming	Steaming		Steaming
Knitting/weaving			Tufting

(From Torrens, 2019)

The development of the Northern Irish wool industry

Historically manufacturing using Irish wool was less developed in the northeast of Ireland than in other parts of the island (Bielenberg, 2013). Despite the fact that woollen products imported from England incurred Union Duties until the 1820s, domestic production, particularly of finer wools was quite limited. After that imports from England increased but from the mid-19th century to the beginning of the 20th century the number of factories in Ireland producing wool increased. For the first time mechanised

woollen mills in what became Northern Ireland were established, generally on sites used previously for grain milling, flax spinning or bleaching linen. At the end of the 19th century, partly through the work of the Congested Districts Board, exports from Donegal to Britain and globally, increased. The Irish 'Cultural Revival' movement and the First World War both contributed to increased domestic demand as well as innovation in products (Bielenberg, 2013; Eapen Babu, 2020). The border (and Second World War) created problems in the supply of yarn manufactured in Northern Ireland going to Donegal for weaving (Dáil Eireann, 1943).

The contemporary market for Northern Irish wool

For the UK as a whole the use of wool is as follows: carpets 60%; knitwear/hand knitting 18%; cloth 8%; bedding 8% and Other 6%

The wool produced from Northern Ireland sheep is mostly used for carpets with some used for woven or knitted goods. In 2018 it was reported that 55% of wool goes to carpet manufacturing (an increase from 50% from 2017), 23% to knitting [as yarn], 8% for clothing and 6% for other uses (Martin quoted in Brown, 2019). Generally, wool from the island of Ireland is not processed into items made into “Irish wool” items though there are exceptions (Allen, 2021).

In terms of the traditional uses of wool – clothing and soft furnishing materials or finished articles, Northern Ireland can either compete with other countries making the same products as other places, or it can identify distinctively ‘local products. The success of the ‘Aran’ style of woollen clothing is an example of what is possible. It was invented as a commercial brand in the mid-20th century, after a self-conscious ‘saving’ of patterns in the 1930s (Mitchell, 1997). Although originally wool knitted and woven in in the west of Ireland came from sheep reared locally, now, most of the wool used is imported Merino wool (though recently Galway Suffolk has started to be used). It is generally processed in other countries. In some cases, garments may even be knitted outside Ireland but by marketing the patterns as Irish and finishing the products in Ireland, Aran jumpers have become a highly successful export and symbol of “Irishness” though as it has become more successful as global brand, its connections to the Aran Islands have become more tenuous (Carden, 2018; Corrigan, 2019). The examples of Shetland Wool and Lakeland Herdwick sheep show that Protected Designation of Origin (PDO) which protects products which are produced, processed and prepared in a given geographical area using recognised knowledge can be applied to wool (Herdwick, online).

Protected Geographical Indication (PGI) can also be applied for in relation to agricultural products and foodstuffs closely linked to the geographical area, when at least one of the stages of production, processing or preparation takes place in the area. Farmers in North Ronaldsay applied for PGI status for their wool and mutton, on the basis of the island’s seaweed-eating native sheep (The Orcadian, 2016). Traditional Speciality Guaranteed (TSG) highlights traditional character, either in the composition or means of production- watercress, Wiltshire Ham and Bramley Apple filling are among the UK products with TSG status (DEFRA, online). In relation to wool some kind of designation could be sought either in relation to a wool such as Donegal Yarns or a style of product such as Ulster tartan, the Ulster coat or the Dungiven costume (Torrens, 2019).

There are many artisan wool users in Northern Ireland. Some do all of the wool processing themselves. Others do part of the process. The Ulster Guild of Spinners Weavers and Dyers in ‘normal’ times do demonstrations s at craft and farming shows and also sometimes hold workshops and exhibitions There

is not an equivalent of the Makers and Practitioners Group in Wales. There are a number of larger scale wool users such as Mourne Textiles and Ulster Carpets.

The relative roughness of Irish wool compared to, say, merino wool means that for clothing, bedding etc it is frequently blended with softer wools. This and the fact that it is generally processed in England is often seen as a dilution of authenticity as "Irish" wool. Rather, than treating this as a negative or a problem, we could treat it as positive: a niche product e.g. *Ulster New Zealand wool* Reflecting Northern Ireland- New Zealand ties or *Bronte wool*: much of the scouring of Irish wool is done at Haworth Mills, actually in Bradford, but reflecting the home of the Brontes who were originally from Rathfriland in Co. Down. Patrick Bronte was actually a Brunty from Co. Down. Charlotte's curate husband had a strong connection to Ballinasloe in co. Galway.

Wool's most well-known property is it is good for thermal insulation but often this is thought of in terms of keeping people and things warm. It is also useful for keeping things cool, so is increasingly used in food transport. other properties include that it is water, dye and odour absorbent. It is also water repellent, but when it does get wet exposed to warm air it also dries quickly. It can be very strong, but it can also be soft and flexible. It is fire retardant. Wool 'has a comparable sound absorption performance to that of mineral wool or recycled polyurethane foam' (del Rey et al, 2017). It decomposes quickly and then can be used as a fertiliser. The grass eaten by sheep and grazing can contribute to carbon sequestration. Many of its properties are enhanced by combining it with other materials.

There are many potential uses for Northern Irish wool which have not yet been explored or exploited. It can be mixed with polymers to create a fibre glass like material for solid objects like furniture car bodies of aeroplanes; it can be used as a construction material including insulation for buildings. Wool has antiseptic properties and potential medicinal uses (Brown, 2019). It has potential use as a fertiliser though it is important to note that it has different properties to other fertilisers in use and may need supplementing

Wool processing produces waste fibres as well as chemical effluent. Waste created during the process of turning fleece into wool can be captured and turned into products such as insulation or mattress stuffing. Lanolin – the grease in wool – is sometimes used but could be used more. It is probably possible to reduce the amount of water used in scouring and treat it in a more environmentally sustainable way. Wool from products such as clothing can be repurposed at the end of their initial life.

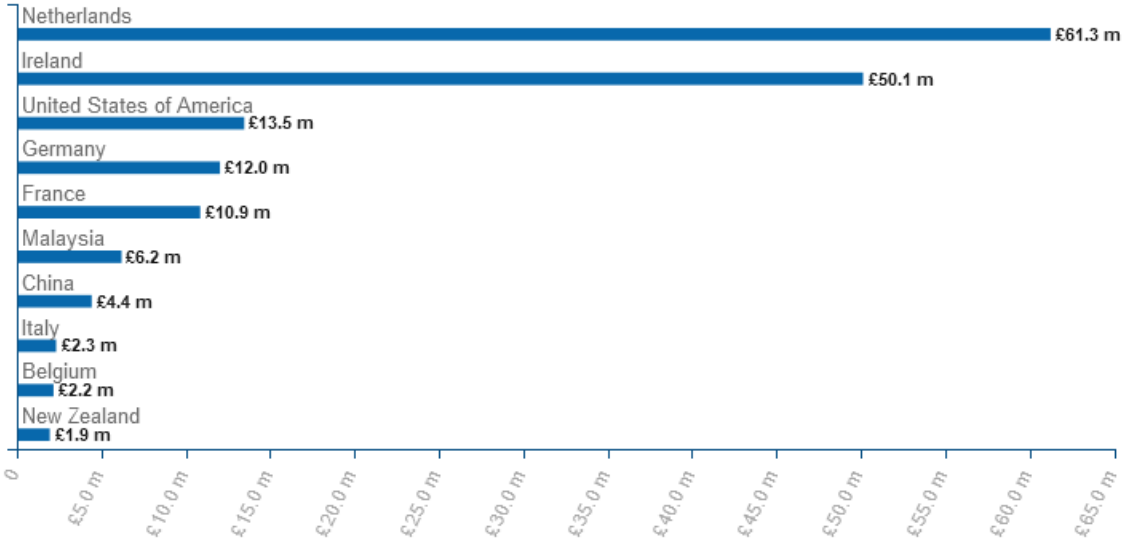
As well as wool itself, there is tourism potential because of interest in industrial heritage, in watching craft demonstrations etc.

Textile fibre exports from Northern Ireland

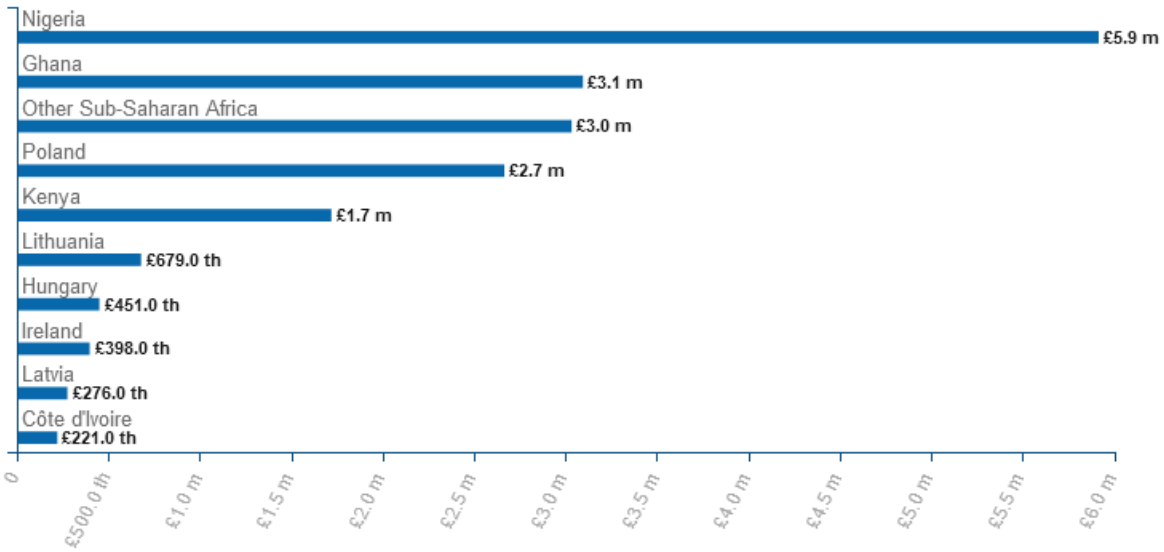
English Legislation in the 17th century prevented Ireland from exporting wool manufactured products

Wool is not separated from other fibres in the textile fibre statistics that the Northern Ireland Statistics and Research Agency (NISRA). However, it can be seen that the export market for made-up articles is more valuable than not manufactured fibres & their waste. The non-manufactured and waste sector is probably dominated by waste recycling.

Northern Ireland - Top-10 export markets for Textile yarn, fabrics, made up articles etc in 2019



Northern Ireland - Top-10 export markets for Textile fibres not manufactured & their waste etc in 2019



The impact of Brexit

The UK leaving the European Union has a number of potential impacts on the supply of and demand for wool. Some of the impacts are UK wide and some may be specific to Northern Ireland because of the Northern Ireland Protocol and also the specific structure of Northern Ireland sheep farming. The UK no longer has to follow the Rules of the Common Agricultural Policy. That could lead to changes in the

amount and structure of farm subsidies. So far, the changes have been minor. Trade Agreements could make it easier or more difficult to import or export sheep products and could affect quality standards.

Ireland context

Sheep and Wool in the Republic of Ireland

There were 3.877 million sheep in the Republic of Ireland in 2020, a small increase on the 3,809 million in 2019. In 2019 nearly one in eight registered flock keepers saying that they did not have any sheep at the time of the official census, but at the same time meat production is increasing. Donegal, with over half a million sheep has the most sheep (Geary, 2020, 2021; ADHB, 2021). 93% of lamb is exported with France the biggest market. In 2020 the value of Irish lamb exports increased. This is explained by a decrease in imports from New Zealand (because of Covid) and from the UK (because of Brexit) (Wyatt, 2021).

The situation for wool in the Republic is more complicated. On the one hand the value of wool has fallen over decades with an even sharper decrease during Covid, as demand, particularly from China fell. 95% of the wool clip is heavier wools most suitable for rugs and carpets. Imports of finer wool for weaving in Ireland are increasing (O'Brien, 2021; Leahy, 2021). According to Pheilim Molloy of the Irish Natura [sic] and Hill Farmers' Association (INHFA), in 1984, Ireland exported almost 6,000 tonnes of wool at a value of around €30m. In contrast, 5,600 tonnes were exported in 2019 at a value of just under €7m. The INHFA, through the sheep census, has estimated that there is 10m kilogrammes (10,000 tonnes) of wool available annually in Ireland (O'Brien, 2021).

On the other hand there are a number of initiatives by government and within the sheep and wool industries to bring about positive changes, which are discussed in the sections below.

Sheep breeds

Sheep Ireland and Teagasc (the Irish Agriculture and Food Development Authority) say the major breeds in Ireland are Belclare, Charollais, Texel, Suffolk and Vendeen (McHugh et al, 2016). A study in 2006 said the major breeds were

Suffolk- X (Crosses)	51% of all ewes
Scottish Blackface	14%
Cheviot	11%
Texel –X	10%
Charollais-X	4%
Leicester-X	2%
Belclare-X	3%

Belclares are a breed developed by an Irish scientist, starting in the 1970s crossing Finnish Landace, Galway and Lleyn Sheep (Belclare Sheep)[1].

It is important to note that the breeds are not evenly distributed geographically with Scottish Black Faces and Cheviots being the dominant breeds on the hills of the western seaboard and east coast respectively (Keady and Hanrahan, 2016). The metrics for assessing the quality of sheep used by Sheep Ireland all relate to their value for meat (Sheep Ireland, 2021). From a wool perspective, there are a number of smaller breeds which are of interest, as evidenced by comments on the

Irish Wool Discussion Group Facebook page which has 760 members including some farmers, but most of the people who post on it are wool spinners, dyers, felters, weavers of one kind or another.

Ryelands were brought to Northern Europe either by the Romans or by Spanish monks - most likely originating from Merino sheep. They got their name from the fact they could be reared on rye grass.Their yarn was known as Leominster Ore , because of the gold they brought their in their producers in Herefordshire (Herefordshire County Council). They were introduced, for example, to County Longford in 2013 (Crowndrummin Heritage) and are reared in Co. Kerry too (Sheep Ireland, 2021).

Romney/ Blue Faced Leicesters are capable of producing a finer yarn than most Irish sheep (Romney and Blue Faced Leicester Natural Wool Ireland).

Valais Blacknose sheep, which originated in Switzerland, are reared both in Northern Ireland (Elaine and Michael Boyle, Newry) and, for example, in County Limerick (BoPeep Valais Blacknose)

Border Leicesters are another breed considered very suitable for yarn wool (The story of Doulton Border Leicesters.) with at least one flock in Ireland in Leitrim (Sheep Ireland, 2021)

*Galway: p*erhaps the most important sheep breeding initiative for wool is the Galway breed. The origins of the breed were probably in Southdown and Merino brought into Ireland in the eighteenth century and the Suffolk breed (itself a hybrid) in the nineteenth which led to a breed identified as the Roscommon breed which emerged in the second half of the nineteenth century but dying out by the 1920s but gave rise to the Galway breed, which in turn was dying out by the mid-1990s when it was consciously revived Galway Sheep Breeders Association - The Galway Breed - Origins and the Future. It is usually described as Ireland's only indigenous breed. Although it is softer than many breeds reared in Ireland, by itself it might be considered too rough for use in clothing but can be mixed, for example, with imported merino. Part of its success is in making itself part of the Aran brand (Aran Sheep) and entering into a processing agreement with Donegal Yarns (Direct market for wool secured by group of farmers - thatsfarming.com).

Wool processing

The Irish Wool Discussion Group Facebook page often highlights innovations in wool processing which are either required or which have been introduced already. For example drawing attention to the Olann mini Mill in Cavan which uses one of the Belfast Mini Mills – Posts | Facebook, mentioned in the student projects below. They also feature examples of repairing, restoring or upgrading old machinery,

[1] Hyperlinks are given to sources which are generally trade bodies, individual producers or campaigning bodies where the assertions made have not been independently verified

for example using 3D printers to make new parts for old electric wool spinner or adding modern technology e.g. computer aided design (CAD) for knitting patterns.

The absence of commercial scouring facilities in Ireland and the toxic waste from traditional scouring are also a frequent topic. In 2020 the Irish Sheep and Cattle Farmers Association hosted a meeting to discuss the feasibility of setting up a scouring plant in Ireland . There are relatively small-scale projects to scour without using chemicals such as Caoirigh Farm at Ballyglunin Tuam Co. Galway.

There are many artisan natural dyers in Ireland with some larger-scale enterprises such as AppleOak FibreWorks in County Clare. Its natural range uses Ryeland wool. There are a number of woollen mills which try to use local resources such as Kerry Woollen Mills and Donegal Yarns

Supply chain

Galway wool is important not just as a source of yarn but it has also developed a business model of a virtual farmers' cooperative - Galway Wool - which has sold direct to a wool processor – Donegal Yarns: Galway Wool and Donegal Yarns. Ériu is also working with Donegal Yarns to produce baby blankets made of Irish wool.

Killala Woolcraft is another company trying to establish more local supply chains. It uses yarn which is a blend of Shetland, Hampshire Down and Coloured Ryeland from Co Mayo as well as UK Castlemilk Moorit wool, dyed at Kerry Woollen Mills. Their wools are blended on a traditional drum carder and hand spun on an Ashford Traditional spinning wheel.

Wool products and uses of wool

There are a variety of different approaches to innovation in uses of wool. The major initiative is the review or feasibility study commissioned by the Department of Agriculture which is described by the leader of the consortium which has won the tender to carry out the work as:

> *…"an opportunity to work with key industry stakeholders and primary producers to identify new opportunities to create value-add products from Irish wool that are environmentally and economically sustainable and further contribute to the Irish Circular Bioeconomy."*
>
> (Patrick Byrne quoted in Cunnane, 2021)

The consortium, called the Agile Executive, is comprised of experts from Munster Technological University and Donegal Yarns. It is expected to report in the first quarter of 2022 (Cunnane, 2021). Among other things it will explore wool composites which are also being explored through Intertrade Ireland – which will also benefit Northern Ireland. As far back as 2005, Intertrade Ireland was looking at an all-island plan for the development of clothing and textiles (Intertrade Ireland, 2005).

In terms of specific products, innovations include

- Many of the innovations in design using wool have been showcased by Project Baa Baa
- Yarn Vibes is based in Cork, sourcing organic wool from County Kildare, which is scoured in England, spun at Donegal Yarns and dyed with natural dyes in Co. Clare
- Markree Woolcraft in Co. Sligo which uses Aberfield wool (A cross between Blue Faces Leicester and Texel), with Indian Eri silk

- Larkfield Pellets make fertiliser and slug pellets from a variety of organic materials including Wool Pellets Organic Fertiliser & Slug Repellent – Larkfield
- Woolow make wool pillows
- Laurence Pierce (Wool Merchants) make wool yarn as well as Sheep Wool Insulation fifteen as a way to make use of black wool insulation for houses (Leahy, 2021)
- Aiga Tone is a Latvian living in Kinvarra, Galway, Ireland who is making felted slippers with Irish wool and alpaca
- Wool has also been used to repair footpaths in Co. Leitrim, a technique which goes back to the Romans (Roman road building technique revived in Co Leitrim; Ancient fleece paving method used to protect soft peatland route)
- Wool as art: Deborah Stockdale is a Donegal-based textile artist who has produced a number of woollen quilt depicting, for example the history of wool and sheep and various conflicts; Donegal Yarns worked on an art installation for the Irish language TV station TG4's Creative Company series

Promotion of Irish wool and marketing

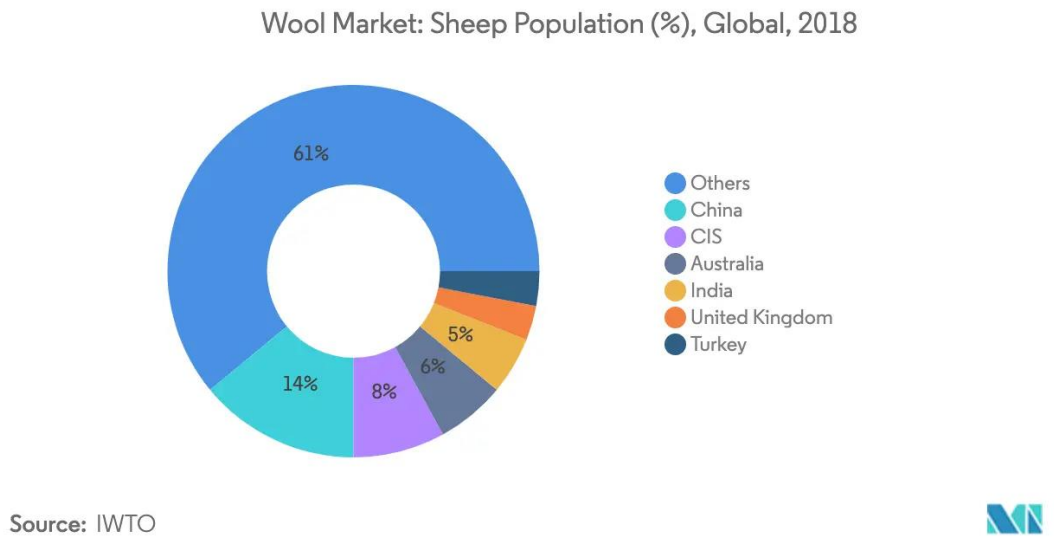
Part of making the case for Irish wool, is to highlight the drawbacks of other products with the negative environmental impact of other products (both synthetic and other natural fibres) featuring prominently and for example contributing to the Public Consultation on the environmental assessment of the Draft CAP Strategic Plan 2023-2027 . The social importance of wool to sustaining rural communities is also argued. More controversially, campaigners for Irish wool are often critical of producers and retailers who market products which are made of wool which comes from sheep reared in other countries, which are scoured, spun dyed and even knitted or woven elsewhere. Irish design, 'inspiration' or finishing can be enough to qualify as 'Irish' under current legislation but sometimes sellers cross the line and, for instance the Advertising Standards Authority of Ireland finds adverts are misleading.

Skills

An important part of maintaining and developing an Irish wool industry is to make sure that the necessary skills are retained and taught to a new generation. In the 1950s An Grianán, in County Louth, under the auspices of the Irish Countrywomen's Association was an important player in this. It's current offering of courses does not appear to include anything specifically on wool. However a number of wool related businesses such as The Muddle and AppleOak FibreWorks do.

Global trends in fibre and wool production and exports

Although world fibre production is generally increasing, synthetic fibres are increasing faster than natural fibres and among natural fibres, the growth is particularly in cotton and silk, with animal fibres production falling (Including cashmere and mohair, for example, as well as sheep's wool). Flax production, for linen, also fell. Italy is the biggest exporter of wool fabric (30.5% of world exports), China, the second (21.1) with the United Kingdom, the third largest exporter, with 7.7%) (IWTO, 2021) Wool production shows a slightly different pattern because a lot of wool is produced for domestic consumption:



(Mordor Intelligence, online)

Because Covid impacted on production and consumption, the price of wool globally fell in 2020, though it may have picked up slightly since then (IWTO, 2021).

The students and their projects

Alistair Brown B Eng Mechanical Engineering (2020) *A study into the feasibility of bringing an old woollen mill back into production to facilitate the production of Irish wool products*

Boney Eapen Babu MSc in Mechanical Engineering with Management. (2020) *Techno Economic appraisal of developing a woollen mill in Northern Ireland: Literature Review*

Piera Cafolla MEng Mechanical Engineering (2021) *An Assessment of Sheep's Wool as a Natural Substitute in Biocomposites for Aviation, Energy and Automobile Applications*

Ivy Group (Yuemin Chen, Nadja Lane and Hangting Xu) Master's in Leadership for Sustainable Development (2020) *Sheep types most suited to wool production in a Northern Irish climate*

Hassan Javed MSc Management, Queen's Management School (2020) *Evaluating the opportunities and challenges in marketing eco-friendly wool mattresses in hospitals of Pakistan: A market analyses* [sic]

Aileen McGrotty BEng Mechanical Engineering (2021*) An analysis of the potential to produce ethical biobased dyes from food waste*

Orange Group (Leo Arcay, Hongyu Zhao, Camille Wood, Seamus Girvan, Ross Mawhinney, Catriona McAllister and Shannon Mc Loughlin) Master's in Leadership for Sustainable Development (2019) *Wool this work? Assessing the feasibility of production and marketing of a wool product in Northern Ireland*

Michael Torrens M Eng Mechanical Engineering (2020) *Carry out a study on the feasibility of bringing an old mill on the Antrim Coast back into use to facilitate the production of Irish woollen products*

The Projects

Wool Processing

Brown (2019) and Torrens (2019) explored the capital costs of buying new or second-hand processing equipment versus the cost of processing by a third party

Brown calculated the costs based on an output of 150kg per week based on the maximum output from the carding machine. The smallest scouring lines have a capacity of 100kg/h which means it would only be in operation for 2.5 hours a week. This would only be worth doing if the facility replaced significant amounts of wool currently scoured elsewhere. Alternatively, a smaller scale and less intensive and depletive process needs to be developed. Other machines e.g., for dyeing might have surplus capacity which could be sold to other users. Although no used textile machinery dealers in Northern Ireland were identified, suppliers in England, Scotland were found.

Process	**Approximate cost**
Scouring	Commercial scouring line (capable of 60kg/hr) = €55,000/ £46,750 Scouring agent (per 25ltr barrel) £50 Chemical handling licence = £1500 Effluent treatment unit (850ltr) £2000 Cost to have scouring process completed by third party 200kg-500kg: £2/kg 501kg-1000kg £0.75/kg

	1001kg-2500kg is £0.5/kg 2500kg and over: £0.3/kg
Carding	New carding machine £40,000 Vintage carder/w condenser (pulley wheel exchanged for motor) £14,000 Cost to have completed by third party £5/kg
Spinning	Commercial spinning line (small second hand) £16 -20,000 Cost to have completed by third party£16/kg
Dyeing	Equipment for package dyeing (100kg vessels) £7,000 Dye (standard colour) = £4-£7/kg Cost to have completed by third party 10/kg

Energy requirements for wool processing

Although several of the students explored how much energy individual stages of wool processing used, a clear picture of overall energy use in production from wool, especially compared to other materials, did not emerge.

Bringing disused mills back in to use

Brown (2019) explored the possibility of bringing disused mills back in to use. There are over four thousand disused mills in Ulster (the Historic Province). They were used for a variety of purposes including flax and wool processing (Graham, online). Many were originally powered by water - a sustainable form of energy. The mill buildings are limited in terms of space and the costs of restoration and adaptation simply for sustainable production of wool is not generally economically viable. However, as heritage, tourism or educational and production facilities projects, they could be feasible. Wind Partners Ltd, purchased and restored Lawrencetown mill outside Banbridge, installing two 50kW hydro stations. They advised that the approximate cost to buy and restore a medium sized mill building which is in fairly good condition would be £500,000 (Brown, 2019).

Using waterpower

A mill with a mill race with and adequate head and flow of water could be powered by hydroelectricity.

(Based on Brown, 2019)

Historic mill races may or may not have the necessary flow depending on what has happened to the water source in the intervening period. The efficiency rating of modern hydro turbines is much higher than traditional mechanism, but for heritage reasons, it might be preferred to use refurbished or replica old mechanisms. However, the costs of hydropower, even using a modern hydro turbine are generally higher than a modern wind turbine (Brown, 2019). The added costs of restoration of a traditional water mechanism coupled with less efficiency mean that the justification for doing so has to go beyond simple production needs.

In terms of traditional designs original or replica water wheels may be under-, breast- or overshoot-wheels. This refers to where the water hits the wheel. Over-shoot wheels are the most efficient. There are manufacturers of water wheels in the UK, but the time taken to repay the costs of installation may be 7.5 – 8.5 years – longer than for other sources of renewable energy (Torrens, 2019).

Using agricultural or commercial industrial buildings

Rents for agricultural buildings were estimated at £2-3/sq. ft compared to commercial light industrial rental rates of £4 per square foot in East Antrim (Brown, 2019) or £2.50 on the edge of Belfast and £2 for a larger unit in Bangor (Cafolla, 2021).

A new build unit could be more environmentally sustainable if zero or low carbon building methods and materials were used, and it could have lower running costs. However, existing buildings' energy efficiency could also be improved, for instance by using wool insulation.

System power Hydro	**Estimated annual system output Hydro**	**Approx. system and installation cost of hydropower**		**Estimated annual system output Wind**	**Approx. system and installation cost of Wind**
5kW	22,000kWh	£25,000-£50,000		2.5kW	£12,500
25kW	110,000kWh	£100,000-£200,000		10kW	45,000
50kW	220,000kWh	£250,000-£350,000		15kW	£70,000
100kW	440,000kWh	£400,000-£500,000		100kW	£345,000

Mini Mills

Belfast Mini Mills are a Canadian firm which make "mills in a box" (a container). Torrens (2019) identified the parameters for a mill based on their products:

- The mill would be able to handle a micron range from 29µ to 35µ which would be suitable for clothing, carpets or rugs for example. Torrens compared the payback period for yarn and woven products and found that yarn products would have a payback period of 2.7 years. Woven products would have a payback period of 4.58 years

- Fleece could be sourced through Ulster Wool or direct from farmers. Torrens assumed that if it came direct from the famers, the mill would probably pay for the shearing and pay little or nothing for the fleece
- Two sizes of set-up were costed. The larger would have an output of 7kg of yarn per hour and would require an input of 97kg of raw wool required per day or about 24,350 kg per year – a little over 2% of the wool which passes through Ulster wool each year
- The production rate of the mill is constrained by the speed of the carding machine
- An area of 180m^2 would be enough space for all machinery required as well as a drying area for the wool. Additional space would be required to store unprocessed and processed wool
- Energy to power the mill was calculated for a 48-hour week of constant production. The kilowatt hours for the year needed would be 20,000 kWh. This is equivalent to the energy used by four people living in a house
- The washer uses 100L for each wash. Based on an estimate of two washes per day for 251 days of the year, the water usage was calculated to be 50,200L. This is equivalent to 50.2m^3
- Instead of using raw wool, it could be sourced from one of the scouring companies in Britain. This would cut the capital costs but add to the variable costs and would have to be managed carefully if 'provenance' were an important selling point for products. Torrens found that buying scoured wool would lead to the quickest payback period (2.7 years) compared to raw wool from Ulster Wool (3.01 years) or from a farm (3.58 years).
- The mill could be sited in in existing agricultural, industrial, or historic mill building, or a new purpose-built energy efficient building powered by renewable energy. Although the historic or purpose-built buildings would have higher initial costs, the heritage dimension might attract funding and revenue and the sustainable building would have lower running costs. Torrens found the payback period for a rented industrial building was 2.7 years compared to building a new mill, which would take 7.91 years

Torrens notes that the conclusions about the returns on different options are sensitive to the price of raw and scoured wool and how successful at selling the products, the mill is. Fluctuating costs of energy and/or selling excess renewable energy to other users could also be factored in. The energy and water costs are only a small proportion of costs of the overall costs, but the washing (scouring) process incur both capital and energy costs.

Machine & services	Cost US $	Machine & services	Cost US$
Tumbler	4,500	Tumbler	4,500
Washer	11,000	Washer	11,000
Dye Vat	8,000	Dye Vat	8,000
Picker	8,700	Picker	8,700
Small fibre separator	25,000	Small Fibre Separator	25,000
Carder	45,000	Carder	45,000
Draw frame	11,500	Draw Frame	11,500
4 spindle spinner/ plyer	25,000	8 spindle spinner	32,500
Skein winder	6,000	4 Spindle Spinner/plyer	25,000
CE Certificates	6,000	Steamer	3,500
Consumables	8,000	Cone Winder	9,000
Delivery, set up & training	20,000	Skein Winder	6,000
Total	**178,700**	CE Certificates	7,500
		Consumables & Spare Parts	8,000
Total £	**131,970**	Delivery, set up + 2 trainings	25,000
at Nov.21 Exchange rate			
		Total	**230,200**
		Total £	**170,523**

Weaving

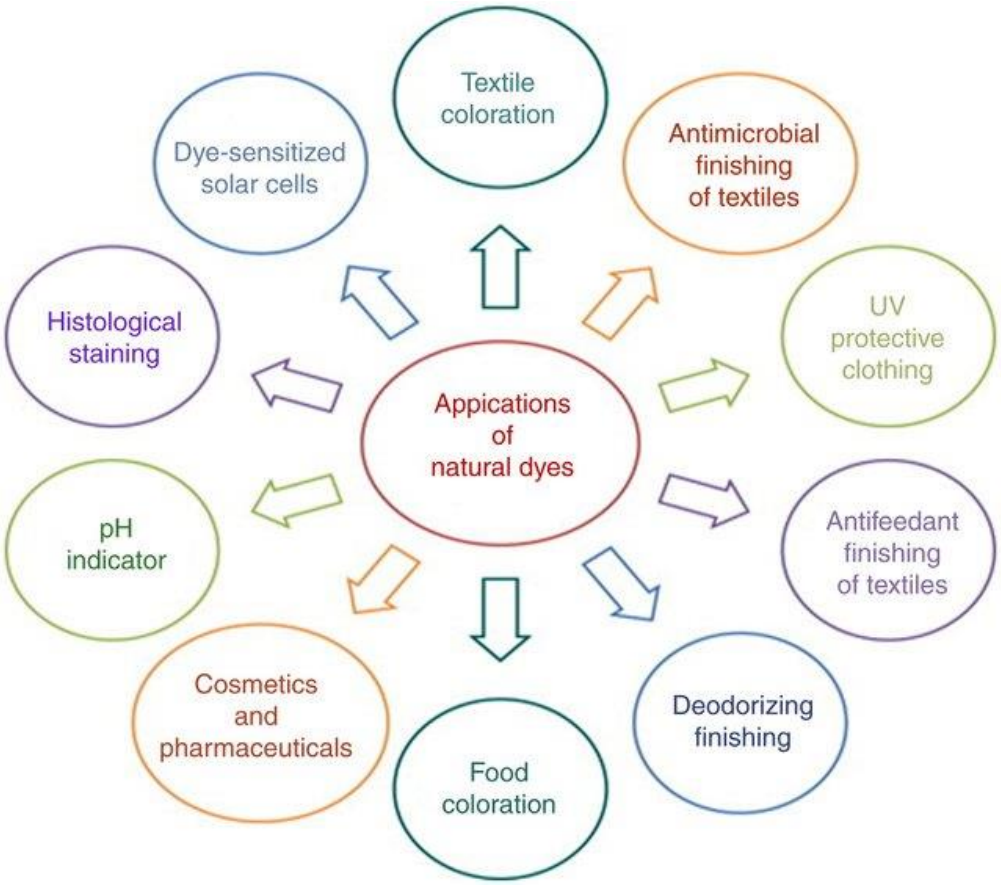
For woven woollen products such as scarves, Torrens proposed a Griffith rapier loom. This loom is pedal operated so there is no need for extra energy to run the machine. He did not look at the costs and benefits in any detail.

Dyeing using food waste

Technically there is a distinction between dye and pigment. Dye is a substance used to change the colour of food, textiles, leather, and paper. Dye ensures the colour it creates on new materials is not affected by heat, light or washing. Pigments are finely ground solids dispersed throughout a liquid like blended with other materials, ink, or paint. However, dyes may become pigments after application and organic pigments may be chemically similar to dyes (Abrahart and Stothers, 2016). There are significant differences between types of dye and pigments resulting from their chemical composition, which impact on how they work as colourings but also their environmental impact. Although the distinction between 'natural' and 'synthetic' dyes is an important one, it is not as simple as saying one is 'better' than the other for the environment or human health. Natural dyes can be harmful to human health or the environment. Not all synthetic dyes are equally harmful, however they are almost all derived from coal tar and the extraction and production processes generally create problems for human and environmental health. Historically wool in Ireland was dyed with a variety of plant-based dyes including indigo, birch bark, walnut, elderberry, wild mignonette and lichen (Mitchell, 1997). Natural dyes also come from insects, and other plants including seaweed, tea extract and other fruit, vegetables and flowers. (McGrotty, 2021). How effective they are as dyes also depends on what substance they are to be applied to: for example, protein-based fabrics such as wool or silk (from sheep and silkworms) require dyes with different properties to those to be used with flax, hemp or cotton. Recent research

has thrown a lot of light on how different dyes work and therefore where they will be most useful. For example, the orange in carrot comes from carotenoid, which is also present in annato, saffron and marigolds (Yusuf, 2013).

Uses of Natural dyes



(Source: Shahid et al, 2013)

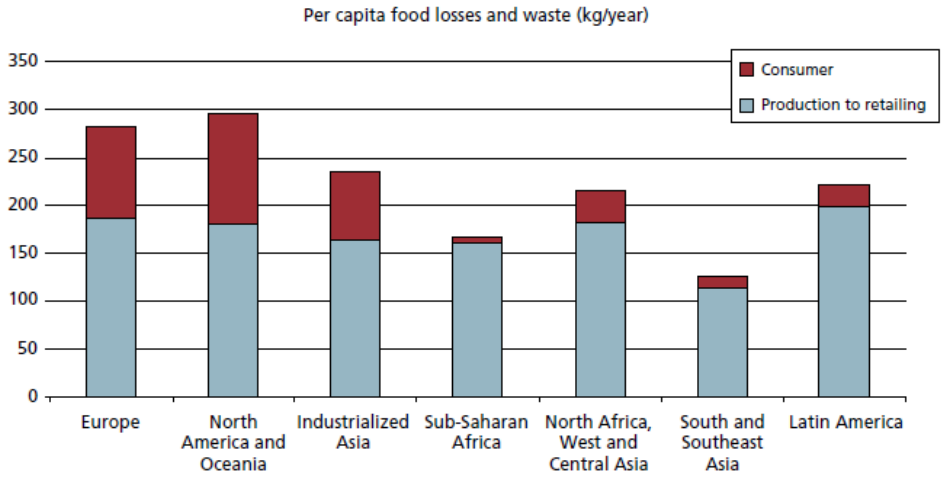
There are two distinct reasons for exploring dyeing using food waste.

The first is the environmental and social impact of synthetic dyes. The use of fossil fuels, the toxic waste produced by them during production (and probably at end-of-life) cause problems for people who make them and consumers, as well as the impact on the environment. This applies to dyes used in foodstuffs as well dyes used in materials for clothing, manufacturing, construction etc. Textile effluents (liquid waste or sewage discharged into a river or the sea) include salts and chlorinated compounds. Wastewater that includes dyes may include of dyes that are mutagenic and highly toxic. Any dyes which darken the water decrease light penetration through the water, and which reduces photosynthetic activity, casing oxygen deficiency, making it more difficult for desirable organisms to live in the water, undermining the antiseptic properties of sunlight and therefore impacting on water for use in irrigation

and use by humans for washing, drinking or use in food preparation etc. Treatment of the water is not always possible and even where it is, it adds to costs and use of energy and chemicals. Estimates of how much dye ends up in effluent vary from 10% to 50% of the dye (Chequer et al, 2013). Dyes and pigments which are used in food or drink or applied to the skin (e.g. tattoo ink) pose additional risks. Natural dyes cause fewer of these problems.

The second issue is probably of even more immediate importance in Northern Ireland. The literature makes a distinction between *food losses* which happen at the production, postharvest and processing stages in the food supply chain and *food waste,* which is what happens during distribution, retailing and during and after consumption at the household level. What is measured is usually the food which could have been eaten by humans. It is counted as loss or waste if it is used as biofuel or eaten by animals (Gustavsson et al, 2011). When alarming figures such as "one-third of the world's food is wasted", frequently this is based not only on out-of-date and partial data, but also is referring to losses as well as waste though the image may be of food going mouldy in the fridge or leftovers from the takeaway. Globally most food loss and waste happen during production and distribution. However in the global North, the proportion wasted by consumers is higher:

Per capita food losses and waste, at consumption and pre-consumptions stages, in different regions



(Source Gustavsson et al, 2011, but note that the data are, at the latest from 2009 and in some cases much earlier)

For the main food production categories in Northern Ireland - *roots and tubers* (e.g. potatoes and carrots), *fruit and vegetables* (e.g. strawberries and apples, though apples for cider are excluded from the global data), most of the loss is at the food production, post-harvest and processing stages, primarily because of the 'quality standards' set by retailers, but loss at the household stage is higher than in the global South. For *meat*, *dairy* and *fish*, much higher proportions are lost at the consumption stage (Gustavsson et al, 2011).

Total Mass of Fruit Crops in NI

Fruit	Mass (Thousand Tonnes)	
	UK	NI
Dessert Apples	206	8.6
Culinary Apples	79	3.3
Pears	27	1.1
Plums	7	0.3
Cherries	5	0.2
Strawberries	141	5.9
Raspberries	16	0.7
Blackcurrant	13	0.5
Other Soft Fruit	10	0.4

(Source: McGrotty, 2021)

Total Mass of Vegetable Crops in NI

Vegetable	Mass (Thousand Tonnes)	
	UK	NI
Carrots	758.2	7.7
Parsnips	80.1	0.8
Turnips and Swedes	72.1	0.7
Onions, Dry Bulb	356.9	3.6
Onions, Spring	15.0	0.2
Brussels Sprouts	33.9	0.3
Cabbage, Spring	23.3	0.2
Cabbage, Summer & Autumn	25.4	0.3
Cabbage, Winter	104.0	1.1
Cauliflower	89.4	0.9
Broccoli	60.0	0.6
Beans	19.2	0.2
Peas	153.1	1.6
Asparagus	5.0	0.1
Celery	54.2	0.5
Courgettes	22.8	0.2
Leeks	38.0	0.4
Lettuce	98.7	1.0
Baby Leaves	12.1	0.1
Rhubarb	14.7	0.1
Watercress	2.4	0.0
Others	115.5	1.2

(Source: McGrotty, 2021)

Estimated/assumed waste percentages for each commodity group in each step of the FSC for Europe incl. Russia.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution: Supermarket Retail	Consumption
Cereals	2%	4%	0.5%, 10%	2%	25%
Roots and tubers	20%	9%	15%	7%	17%
Oilseeds and pulses	10%	1%	5%	1%	4%
Fruits and vegetables	20%	5%	2%	10%	19%
Meat	3.1%	0.7%	5%	4%	11%
Fish and seafood	9.4%	0.5%	6%	9%	11%
Milk	3.5%	0.5%	1.2%	0.5%	7%

(Gustavsson et al, 2011)

In 2019 researchers for WRAP estimated that across the UK, sugar beet, potatoes, and carrots made up more than 50% of the overall estimate for food waste in primary production (by weight). Based on a middle value estimate (i.e. not the highest or lowest estimate) carrots produced 152,000 metric tonnes of waste or loss, worth £24m across the UK. For strawberries it was 14,000 tonnes and £30m (Bajzelj et al, 2019).

McGrotty calculated the loss or waste in Northern Ireland as 424,652.9 kgs for strawberries and 3,848,465.3 kgs for carrots. The annual value lost from not selling as food was calculated at £1,443,820.00 for strawberries and the annual value for carrots in NI, £1,962,717.30,

Many of the solutions quite properly focus on preventing waste and maximising the food available for human consumption. This is important for the UN Sustainable Development Goals of 'Zero Hunger' but it is also important because of the other consequences of food waste. Bajzelj et al (2019) argued that much of it could be used for animal feed. McGrotty (2021) explored the potential for using waste for dyes.

In 2015 The UN published an estimate of the impact of food waste (sic: they were including food loss as well) on Climate Change. Again the data is very old, but the overall conclusion that if food waste was a country, it would be the third highest emitter of carbon after China and the USA and not much less than transport emissions. Fruits and starchy roots (including carrots) emitted less carbon than the proportion of waste they generate. Cereals and vegetables were the biggest emitters, roughly in proportion to the amount of waste. Meat emitted much more carbon than the proportion of waste. The carbon footprint was calculated to include the impact of methane emissions [Methane should really be considered separately in terms of what its impact is] The climate change impact of food loss and waste is much greater in the industrialised countries of Europe, North America and Asia than in the Low- and Middle-Income Countries (FAO, 2015).

As the global data show, the real issue is the food loss and waste in production, processing and distribution which is not identified in locally available data. However McGrotty was able to estimate that thirty-eight thousand kgs of carrots were wasted annually and having forty-three thousand kgs of strawberries in NI (McGrotty, 2021).

Anaerobic digestion

Biodegradable waste from households going to landfill, which includes garden as well as food waste, is decreasing in Northern Ireland but it is a bit over 12.5% of all the waste collected by local authorities. That means it accounts for at least a quarter of what is collected as 'general rubbish ("black bins"). This is the domestic rubbish which is worst for the environment. The food waste which goes into recycling bins (e.g. "brown bins") goes for composting, usually through anaerobic digesters (ADs). Northern Ireland has proportionately more ADs than other parts of the UK. Only about one in five ADs in Northern Ireland process food waste. Most use feedstock from animal waste, energy crops and sileage. While alternative methos of disposal of animal waste, particularly, may be even more harmful to the environment ADs can cause significant ammonia emissions. Northern Ireland produces a disproportionate amount of the UK's ammonia emissions in 2020, primarily because of its agricultural production. Ammonia is a source of nitrogen which can cause damage to valuable ecosystems through nitrogen enrichment or eutrophication, as well as acidification of waterways causing damage to aquatic biodiversity. Issues of traffic, air and noise quality have also been raised in relation to ADs in Northern Ireland. Almost all Special Areas of Conservation in Northern Ireland exceed the critical level of ammonia

which is harmful (Pike, 2020). Further research on the environmental impact of ADs which process food waste would be worthwhile.

Processing food waste for dye

McGrotty identified County Armagh/Armagh, Banbridge and Craigavon as having the largest area of horticultural crops in Northern Ireland. In order to minimise transport costs, she proposed siting a food waste processing facility in that area. She identified the distance of strawberry and carrot producing farms from a proposed location. The process she proposed is to

- Wash, chop and boil the carrots with a vinegar fixative
- Wash chop and boil the strawberries with a salt fixative, once the dyes are made from boiling the products with water and fixatives
- Strain using a colander
- Package the liquids

The machinery capital costs were

Washing machines

Etornuo ETOVR750B-19 with a capacity of 750 kg/hr for strawberries priced at £4,632.93

HONGLE HL-QXJ with a capacity of 1000kg/h for carrots priced at £4,705.64

Chopping Machines

Damatic CHD100 to slice the carrots with a capacity of 1000 kg/hr priced at £1,416

iMaker LV-615 with a capacity of 100 kg/hr priced at £1,085.80 to chop the strawberries.

Boiler

YITAIKEJI Industry stainless steel cooking and boiling tank pot with a capacity of 2000 litres priced at £3,622.12 which separates the carrots and strawberries from the dye produced

Liquid packing

LianYuan SJIII-ZF Series with the SJ-ZF4000 with a packing capacity of 2000 ml priced at £1,664.75 each for four sets

The energy, water and labour inputs required for each machine and collecting the raw carrots and strawberries were calculated. With rented premises, vehicles etc, the initial start-up costs could be minimised. The value of the output was calculated using the price of commercial (synthetic) dye alternatives. No payment to farmers was included. This business model could, in principle, work if either they avoided costs of waste disposal or benefited from selling dyes. Although the figures for the capital and running costs are plausible, the uncertainties about whether the waste comes free and whether there would be a market willing to pay the same price as for commercial dyes means that more work needs to be done before it can be said that this is a viable project.

Expanding the market for Northern Irish wool

There are several ways in which demand for Northern Irish wool could be increased including:

- More intensive or extended marketing of products already being made with Northern Irish wool e.g. carpets
- Promoting NI wool as an alternative to wool from other sources…this could include making an argument for local supply chains for cost and/or environmental reasons or where local provenance or design is part of the brand – tourist souvenirs or association with other local brands, goods and services such as clothing associated with Game of Thrones, sporting or leisure activities, soft furnishing for local hotel chains or insulated containers for food or drink. As
- Promoting wool as an alternative to other materials

Various student projects have explored this:

Clothing

Doyle and colleagues (2021) have suggested that globally future demand for wool garments will come from new and emerging markets (for example East Asia) for next-to-skin skin knitwear and the athleisure market. Wool's characteristics such as such as breathability, resisting odour, moisture-wicking capabilities and suitability for some sensitive skins make it an attractive material. Positioning it as an environmentally friendly material is also important. However, they warn that production costs may mean that it is a 'luxury niche' product.

Heritage clothing

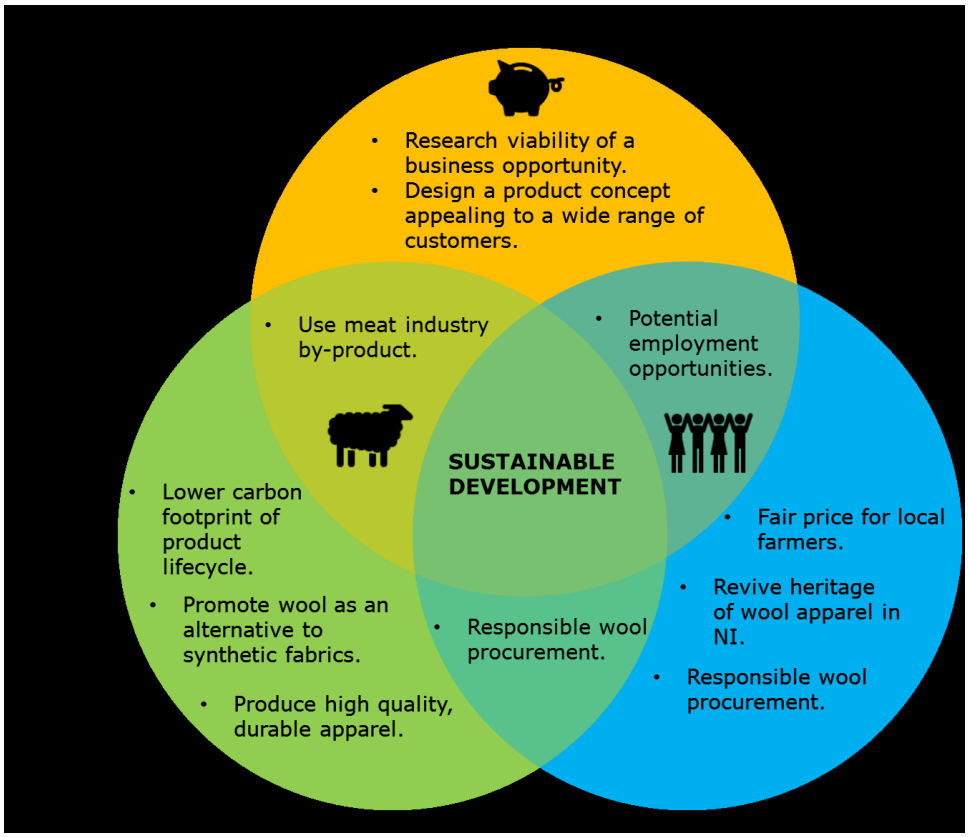
Torrens (2019) suggested possible heritage products to build on such as the Ulster coat, the Dungiven costume or Ulster tartan.

The Ulster Coat was invented by John Magee of Belfast in 1866 It was worn as an alternative to the Inverness Cape by the fictional Sherlock Holmes and the equally fictional Mr Powers in James Joyce's Dubliners. A lighter version, the Ulsterette was also created (McCoy, 1985).

The Dungiven costume is the name given to the clothing and shoes found in a field near Dungiven, Co. Londonderry in 1956. The costume is now in the Ulster Museum. There is a lot of argument about exactly where the clothing came from (Horning, 2014). It would be possible to make modern replicas or costume inspired by it. 'Ulster Tartan' is one such interpretation or reconstruction by the (Scottish) firm Kinloch Anderson (online).

Outdoor Clothing

Orange group (2019) explored whether an outdoor leisure jacket could achieve goals of economic, social and environmental sustainability. The relationship between the three domains is illustrated below:



Although they found that there would be a market for a garment costing £150-200, it was not clear that a high specification garment made locally with local wool could necessarily be produced for that sort of price. They suggested that alternative products that may be more affordable and appealing to a wider audience should be investigated. However they identified a number of characteristics of a production and marketing strategy based on the idea of a local, sustainable and ethical brand which may have wider applicability:

- Close links between farmers and manufacturers to identify the brand with a particular geographical area, such as the Glens of Antrim, specific breeds of sheep, animal welfare standards and fair prices for farmers with the possibility of obtaining Protected Designation of Origin (PDO) status and Responsible Wool Standard certification to legitimise marketing claims and cruelty-free status
- Partnering with other brands such as a local hotel chain to enhance product visibility

Bedding

There is some evidence that woollen sleepwear, bedding and mattresses improve sleep compared to other materials. The research is often funded by promoters of wool, but the research methods used are legitimate (Amrit, 2007; Shin, 2016; Chow, 2019). Specifically, in relation to healthcare, the importance of beds is underlined by the fact that the American Food and Drug Administration has designated some bedding and mattress covers as medical devices and is specifically concerned with claims for anti-

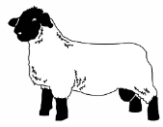
bacterial or anti-viral properties (FDA,2020). It is also worth noting that medical grade sheepskins can reduce bed sores and ulcers (Jolley et al, 2004 and subsequent literature). Disposal of mattresses is a particular problem: they are bulky to transport, to store and take up a lot of space in landfill; they are labour intensive to dismantle; the fire retardant is toxic (Hawley, 2014).

Blankets or rugs

Ivy Group (2020) investigated which breeds of sheep which could thrive in the conditions prevalent in Northern Ireland would be most suitable for producing woollen blankets or rugs. The three breeds which they focused on were Clun Forest, Suffolk and Gotland sheep.

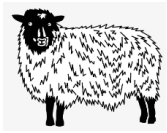
Clun Forest

At the time of their research there were only 120-150 registered pedigree Clun Forest sheep in NI. They are suitable for small lowland or upland farms with outdoor rearing.



Suffolk

At the time of their research there were 9,283 registered pedigree Suffolk sheep in Northern Ireland. They are fast-growing and early maturing, usually growing mature enough to be sold or continue to breed after 9 to 12 weeks of feeding, so the feeding cycle is relatively short. Suffolk sheep can adapt to varying environmental conditions. Suffolks produce a high level of fine lean meat content, making them very suitable for consumption. Galway Suffolks are being reared to be used for Aran and Donegal wool (Allen, 2021).



Gotland

No Gotland sheep flocks were identified in Northern Ireland, but flocks were located across the UK in comparable conditions. They were considered easy to manage, adaptable and resistant to cold with strong adaptability. As well as producing a good quantity and quality of meat, their wool is relatively soft, delicate and shiny.

Work in the Republic on sheep breeds suitable for conditions here suggests that that hybrids need to be developed Breeds which might be part of the mix include Texels, Galway Suffolks and Lleyn from the peninsula of that name which has similar winters to uplands on the island of Ireland.

Mattresses for hospitals in Pakistan

Hasan Javed (2020) explored the potential to sell woollen mattresses in Pakistan. Mattresses currently in use are generally polyurethane foam, which may or may not be viscoelastic foam (“memory foam”).

There are issues about the environmental impact of the production and disposal of foam mattresses. They have to have fire retardant added to them to be safe in use. There are however advances in the design of polyurethane mattresses which are improving their versatility. Wool has several advantages over foam: it is naturally fire resistant; it is good at regulating temperature; it has anti-bacterial properties; it is biodegradable though, as noted above the production process may produce toxic effluent. Based on a survey of 145 patients in eight hospitals in two cities, Javid found more than a quarter were dissatisfied or very dissatisfied with hospital mattresses they had experienced. The study did not explore why they were dissatisfied. Qualitative interviews with eight hospital administrators found, unsurprisingly, that although quality (including durability), comfort and safety were important, so was cost. The study covered both private and public hospitals. Through private hospitals were more cost-conscious, they were also more sensitive to patient satisfaction because of the threat of competition. On the other hand state hospitals are a bigger market and may be more sensitive to environmental concerns. Javed argued that the marketing needs to be based on patient comfort and safety, durability, environmental and economic sustainability but that the budget holders for hospital supplies were not necessarily patient-centred, environmentally aware or required to think about environmental impact. They would need a demonstration or test of the value of wool mattresses.

Composites

Piera Cafolla (2021) explored the potential of wool-based composites. Fibre Reinforced Polymers (FRP) are compounds of different materials. By combining different the compounds have distinctive physical and chemical properties. Composites have been used in the automotive industry since the 1950s. They are now used extensively in manufacturing aircraft, road vehicles and wind turbines for example. Glass fibre reinforced polymers (GFRP) account for more than 90% of fibrous composites currently produced, but due to their inability to biodegrade, pose a serious threat to the environment. Carbon fibre reinforced plastic (CFRP) is increasingly being used. Wind turbine blades use both, but importantly a number of other materials too, which cannot easily be separated at the End-of Life. Currently they are, essentially not recyclable. With projected increases in the amount of energy generated using wind turbines and existing turbines coming to the end of their lives, the waste they will create is going to be major problem and one which undermines their claim to be ‘sustainable’ (Brown et al, 2019: Bank et al, 2019; Fraile & Walsh, 2020).

Biocomposites for Aviation, Energy and Automobile Applications

Biocomposites or natural-fibre-reinforced-polymer (NFRP) biocomposites use natural fibres. They are potentially biodegradable, can be carbon neutral and may have comparable mechanical properties to synthetic composites. Both synthetic and natural polymers are usually lighter than alternatives such as steel which is a huge advantage economically and environmentally in reducing fuel costs in vehicles on land, sea and in the air. Natural polymers include bast (bark) fibres such as flax, jute and kenaf. Jute and Kenaf are both from the Malvaceae or Mallow family. Although most composites used in the automotive industry are synthetic, jute and kenaf are used in door panels and interiors of luxury cars (Pradeep, et al., 2017, quoted in Cafolla, 2021). Other sources of natural polymers include sisal, coir, hemp and bamboo. Some fibres are flammable (not wool: see IWTO, n.d), variability of the natural fibres can be an issue and binding the materials together can also be more difficult than for synthetic polymers.

Broadly there are three ways of combining materials into composites:

1. Laminar - made of layers of materials held together by the matrix binder

2. Particulate - composed of particles dispersed in a matrix body

3. Fibrous - composed of reinforcing fibres in a matrix material.

Compared to other natural fibres and synthetic polymers wool is less dense, better at absorbing moisture, more elastic but will deform or not return to its original form at lower levels of stress or strain (Pickering, et al., 2016 in Cafolla, 2021). So, depending on the context in which it is used and what properties are most useful, wool may be more or less suitable as component of a polymer. Depending on what and how natural fibres are combined to make polymers, what it gains in mechanical properties, it may lose in its biodegradability or use of finite resources. Thermoplastic Resins (such as Polypropylene - PP, LDPE or PET) soften when heated and have a reversible curing process. This allows them to be remoulded and recycled. Thermoset Resins are irreversibly hardened by curing. They retain their strength when heated. They are hard and rigid. While they are well-suited for materials designed for a long-life, their stiffness may be a liability when exposed to extensive vibration. Bio resins (such as PLA) energy efficient; they remain non-toxic as they degrade; they are made from renewable sources. However, they are costly to produce, currently and brittle, relative to other resins. Different types of resin set at different speeds which has implications for production capacity. The dominant model for use of composites for fast and mass production in aviation and the automobile industry is injection moulding, for which thermoplastic resins have been found to be most effective.

In order to use wool as a composite, the scouring process needs to be particularly thorough to remove impurities. The carding process need to ensure that the fibres are of standard sizes. The wool needs to be treated to reduce moisture absorption and it may be necessary to add flame retardant for some uses.

Cafolla looked at the international specification of standards for the aviation and automotive industries and the polymers already in use to see whether a wool-based polymer could reach the necessary standard. She looked at producing an interior composite car door panel which would be supplied at just under £50. Cafolla proposed that the wool polymer should be made with the thermoplastic resin polypropylene. Based on modelling, this had the best mechanical properties of the eight resins examined. Compared to other wool polymers it scored highest for lightness, strength, stiffness, flammability, cost and melting temperature. However polypropylene is not fully biodegradable. This analysis was not based on actually testing materials.

Much of the machinery, labour and premises requirements for wool composites would be similar to other wool uses (scouring, drying, carding, sliver cutting) but in addition space, staff, machinery and additional materials for compounding and injection moulding would be required. Cafolla considered various options on the scale of operations, whether scouring should be in-house or third party and different energy sources including solar or wind. Like Brown and Torrens, she concluded that in-house scouring added to the costs, lengthening the payback period without adding to the profitability of the enterprise. Neither a wind turbine nor solar panels on the scale explored would meet all the energy needs of the enterprise but the wind turbine would meet a higher proportion. The scale of operations Cafolla explored varied from less than 5% of the potentially suitable and available wool through to over 40%. This was based on sourcing lower quality (and hence cheaper) wools from Ulster Wool.

Further work

1. Examine ways in which best practices in sheep farming, including agro forestry can be spread more widely
2. More work on breeds which are sufficiently hardy to survive, all or most of the year, in upland areas and which are suitable for the various future uses discussed here possibly working with the Wool Initiative and specialist sheep breeders' associations to produce a sheep breeders and fleece users' directory similar to the one produced by Sheep Ireland but focusing on fleece use, building on Zoe Fletcher's work
3. Research on what education and training on sustainable sheep farming is available in NI and elsewhere
4. Examine potential for mobile or boutique slaughtering arrangements
5. Examine alternatives to conventional tanning for sheepskins
6. Analysis of how farming subsidies could be restructured to promote more sustainable ways of sheep farming
7. Analyse opportunities and threats arising from Brexit
8. Explore PDO, PGI or TLG status for wool or wool products from Northern Ireland
9. Explore whether the use of scouring facilities in England and imported wool could be turned in to a niche brand
10. Carry out analyses of innovation in sheep farming and wool production and products in England, Scotland, Wales and the 'Rest of the World'
11. Explore the potential to link wool products to strong local brands - products or services: hotel chains; local food and drink; local attractions; sports fan ephemera
12. Develop a clear picture of overall energy use in production from wool, especially compared to other materials
13. Explore ways of reducing the environmental footprint of scouring e.g. by dry scouring or lowering the environmental impact of transporting fleece to and from Britain
14. Overall analysis of energy use in wool processing covering both conventional and alternative processing methods
15. Reducing the environmental footprint of carding and spinning by using renewable energy
16. Look further at sources of sustainable dyes for wool
17. Research on the environmental impact of Anaerobic Digesters which process food waste
18. Investigate the costs and benefits of different looms for weaving
19. Research and Development on uses for Northern Irish wool which have not yet been fully explored or exploited e.g.
    - Testing different compounds of wool polymers including bio-resins
    - As a construction material including insulation for buildings
    - Potential healthcare uses
20. Examine ways to re-use, recycle or repurpose wool products
21. In all studies use Life Cycle Analysis to consider the environmental, economic and social impact of proposals

References

Abrahart, E.N. and Stothers, (2106) J.B. *Dye* Britannica.Com dye | Definition, Uses, Properties, & Types | Britannica

ADHB (2021) *Irish cattle herd shrinks, sheep numbers grow* 10 March Irish cattle herd shrinks, sheep numbers grow | AHDB

Allen, C. (2021) 'Donegal Yarn secured as wool group's first customer' *Agriland.ie* June 6 Donegal Yarn secured as wool group's first customer - Agriland.ie

Amrit, U. (2008) 'Bedding textiles and their influence on thermal comfort and sleep' *AUTEX Research Journal. 8 No 4, December* http://www.autexrj.com/cms/zalaczone_pliki/4-07-4.pdf

Bank, L.; Arias, F.; Gentry, R. & Al-Haddad, T.; Tasistro-Hart, B. & Chen, J-F. (2019*) Structural analysis of FRP parts from waste wind turbine blades for building reuse applications*. Paper at SEMC Conference: Cape Town, South Africa pdf(2)

Belfast Mini Mills Belfast Mini Mills | We grow with you

Bielenberg, A., (2000) 'British Competition and the Vicissitudes of the Irish Woollen Industry: 1785–1923', *Textile History*, 31(2), pp.202-221

Böhme, M.; Pinker, I.; Grüneberg H. and Herfort, S. (2012) 'Sheep Wool as Fertiliser for Vegetables and Flowers in Organic Farming' *Acta Horticulturae* March

British Wool (2016) *Information for Show Commentators* Information for show commentators 2016 Final.pdf

British Wool (online) *Price Indicator* Price Indicator | British Wool (accessed 4th November 2021)

Carden, S. (2018) 'The Aran Jumper' in Stuart Walker, Martyn Evans, Tom Cassidy, Jeyon Jung and Amy Twigger Holroyd (eds) *Design Roots Culturally Significant Designs, Products, and Practices* London: Bloomsbury Visual Arts

Chequer, F.; Rodrigues de Oliveira, G.; Anastácio Ferraz, E.; Carvalho Cardoso, J.; Boldrin Zanoni M. and Palma de Oliveira. D. (2013) 'Textile Dyes: Dyeing Process and Environmental Impact in Gunay, M. *Eco-Friendly Textile Dyeing and Finishing* London: Intech Open

Chow, CM.; Shin, M.; Mahar, TJ.; Halaki, M. and Ireland, A. (2019) 'The impact of sleepwear fiber type on sleep quality under warm ambient conditions' *Nature and Science of Sleep*, 11:pp. 167-178 The impact of sleepwear fiber type on sleep quality under warm ambient | NSS

Corrigan, V. (2019) *Irish Aran, History, Tradition, Fashion*, Dublin: O'Brien Press

Cunnane, C. (2021) 'We must change the way we look at wool' – Hackett' *That's Farming* 19/11/2021 Wool products review: Minister appoints The Agile Executive

Dáil Éireann (1943) *Adjournment Debate*, Committee on Finance 11th March Committee on Finance. - Adjournment—Donegal Warp-Yarn Supplies. – Dáil Éireann (10th Dáil) – Thursday, 11 Mar 1943 – Houses of the Oireachtas

del Rey, R.: Uris, A.; Alba, J. and Candelas, P. (2017) 'Characterization of Sheep Wool as a Sustainable Material for Acoustic Applications' *Materials (Basel). Nov; 10(11): 1277.* materials-10-01277.pdf

DAERA (2020) *Northern Ireland local authority collected municipal waste management statistics 2019/20 annual report* Belfast: DAERA Northern Ireland local authority collected municipal waste management statistics 2019/20 annual report | Department of Agriculture, Environment and Rural Affairs; lac-municipal-waste-2019-20-data-tables_0.xlsx

DAERA (2021a) *Agricultural Census in Northern Ireland 2020* Agricultural Census 2020 Publication.pdf

DAERA (2021b) *Farm Incomes in Northern Ireland 2019/20* 2. FARMING INCOMES - Farm Incomes in Northern Ireland 2019-20 Final (PDF).pdf

DAERA (2021c) GUIDE TO 2021 COVID 19 WOOL SUPPORT SCHEME Covid-19 Wool Scheme - Guide - 28 July (003).pdf

DEFRA (Online) *Protected geographical food and drink names: UK GI schemes* Protected geographical food and drink names: UK GI schemes - GOV.UK

Doyle, E.; Preston, J. McGregor, B. and Hynd, P. (2021) 'The science behind the wool industry. The importance and value of wool production from sheep' *Animal Frontiers* March 2021, Vol. 11, No. 2 science behind the wool industry. The importance and value of wool production from sheep | Animal Frontiers | Oxford Academic

FAO (2015) *Food wastage footprint & climate change*, Rome: FAO bb144e.pdf

FDA (2020) *Hospital Beds, Stretchers, and Mattresses During the COVID-19 Pandemic* 6 October Hospital Beds, Stretchers, and Mattresses During the COVID-19 Pandemic | FDA

Fraile, D. and Walsh, C. (2020) *Accelerating Wind Turbine Blade Circularity* Brussels: WindEurope WindEurope-Accelerating-wind-turbine-blade-circularity.pdf

Gaynor, B. Mathers, R. (2017) *Glens of Antrim Resilient Farms Project* Glens-of-Antrim-Resilient-Farm-Project-Report.pdf

Geary, M. (2020) Map: How many sheep were there in Ireland in 2019? *Agriland.ie* May 17 Map: How many sheep were there in Ireland in 2019? - Agriland.ie

Geary, M. (2021) 'Value of Irish sheepmeat exports increased by 12% to €360 million in 2020' *Agriland.ie*. January 15, 'Value of Irish sheepmeat exports increased by 12% to €360 million in 2020' - Agriland.ie

Graham, S. (Online) Mills of Northern Ireland - Home

Gustavsson, J.: Cederberg, C.; Sonesson, U.; van Otterdijk, R. and Meybeck, A. (2011) *Global food losses and food waste – Extent, causes and prevention*, FAO: Rome i2697e.pdf

IWTO (online) STATISTICS - International Wool Textile Organisation

IWTO (no date) *Wool and Fire* IWTO_Wool-Fire.pdf

Intertrade Ireland (2005) Cutting Our Cloth: A review of the. All-Island Clothing and Textiles Industry A-Review-of-the-All-Island-Clothing-and-Textiles-Industry.pdf

Hawley, J. (2014) 'Chapter 15 - Textile Recycling' in Worrell, E. and Reuter, M. eds *Handbook of Recycling*, Amsterdam: Elsevier, pp 211-217,

Herdwick (Online) Lakeland Herdwick PDO » Lakeland Herdwick PDO

Horning, A. (2014) 'Clothing and colonialism: The Dungiven costume and the fashioning of early modern identities', *Journal of Social Anthropology* Vol 14, Issue 3, 2014

Jolley, D.; Wright, R.; McGowan, S.; Hickey, M. Campbell, D.; Sinclair, R. and Montgomery, K. (2004) 'Preventing pressure ulcers with the Australian Medical Sheepskin: an open-label randomised controlled trial' Medical Journal of Australia Vol 180 5 April 2004 pp 324- 327 https://www.mja.com.au/system/files/issues/180_07_050404/jol10222_fm.pdf

Keady, T. and Hanrahan, K. (2016) *The Sheep Industry – its recent evolution* Teagasc The-Sheep-Industry-its-recent-evolution-2-Aug-2016.pdf

Kennard, B. and Young, R. (2018A *Good Life and a Good Death: Re-localising farm animal slaughter*. Sustainable Food Trust Re-localising-farm-animal-slaughter.pdf

Kinloch Anderson (online) *Ulster* Ulster Tartan - Kinloch Anderson

Leahy, B. (2021) *Irish Wool is at a Crossroads* Teagasc 17 June 2021 2021 - Irish Wool is at a Crossroads - Teagasc | Agriculture and Food Development Authority

Leitat Technological Center et al (2105) *Eco-Efficient Wool Dry Scouring With Total By Products Recovery*. Available: LIFE 3.0 - LIFE Project Public Page

Martin, R. (2018) 'Market diversification: Are natural wool carpets the next niche?' quoted in Brown, 2019

McCoy, J. (1985) 'The Ulster Coat' *Irish Arts Review* Vol. 2, No. 4 (Winter, 1985), pp. 18-23

McHugh, N.; Berry, D.; McParland, S. Wall, E. and Pabiou, T. (2016) *Irish sheep breeding: Current status and future plans* Current_status_future_plans.pdf

Menzies, B.; Wood, D. and Dimambro, M. (2020*) Assessing the Viability and Sustainability of Mobile Abattoirs in Scotland* Edinburgh: Scottish Government assessing-viability-sustainability-mobile-abattoirs-scotland.pdf

Mitchell, G. (1997) *Deeds not Words – the Life and Work of Muriel Gahan* Dublin: Town House and Country House

Morehead, S. (2014) 'The Sheep Value Chain and 'Wool Out' Sheepskin as a Sustainable Material' In: *Transition: Re-thinking textiles and surfaces*, 26-27 November2014, Huddersfield The Sheep Value Chain and Wool Out Sheepskin as a Sustainable Material.pdf

Mordor Intelligence (online) *Wool Market - Growth, Trends, COVID-19 Impact, and Forecasts (2021 - 2026)* Wool Market | 2021 - 26 | Industry Share, Size, Growth - Mordor Intelligence

NISRA (online) *UK Regions Imports and Exports of Goods by Country and World Region* UK Regions Imports and Exports of Goods by Country and World Region | Northern Ireland Statistics and Research Agency

O'Brien, D. (2021) Innovative possibilities for wool 7 November *Irish Farmers Journal* https://www.farmersjournal.ie/potential-for-irish-wool-market-it-just-needs-to-be-exploited-588086

The Orcadian (2016) *North Ronaldsay aims for protected status for wool and mutton* February 10, North Ronaldsay aims for protected status for wool and mutton - The Orcadian Online

Pike, J. (2021) *Anaerobic Digestion in Northern Ireland* Belfast Northern Ireland Assembly http://www.niassembly.gov.uk/globalassets/documents/raise/publications/2017-2022/2021/aera/2921.pdf

Shahid, M., Islam, S., Mohammad, F. (2013) Recent advancements in natural dye applications: a review. *Journal of Cleaner Production* 53, 310-331

Sheep Ireland (2021) *Guide & Directory of Breeders* SHEEP-IRELAND-GUIDE-DIRECTORY-2021-reading-view.pdf

Shin, M.; Halaki, M.; Swan, P.; Ireland, A. and Chow CM. (2016) 'The effects of fabric for sleepwear and bedding on sleep at ambient temperatures of 17°C and 22°C.' *Nature and Science of Sleep*;8: pp121-131 The effects of fabric for sleepwear and bedding on sleep at ambient te | NSS

UFU - Ulster Farmers Union (2019) *Future-Proofing your Sheep Enterprise* Conference October 2nd and 3rd

Ulster Wool (2021) *Ulster Wool Producer Information & Wool Values May 2021* Ulster Wool Producer Information & Wool Values May 2021 LR.PDF

Woodland Trust and National Sheep Association (2018) *The role of trees in sheep farming* role-of-trees-in-sheep-farming.pdf

Wyatt, D. (2021) *EU sheep meat market summary, 2021 so far* ADHB 4 November 2021 EU sheep meat market summary, 2021 so far | AHDB

Yusuf, M. (ed) *Handbook of Renewable Materials for Coloration and Finishing* Beverly, MA: Scrivener WileysHandbookofRenewableMaterialsforColorationandFinishing.pdf