Fashion DIET

Sustainable Raw Materials and Textile Materials

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Learning Objectives

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After this lecture you should be able to:

- Demonstrate both basic and in-depth knowledge in textile raw materials.
- Illustrate central terms concerning fibres and their production.
- Describe and apply different research approaches to textile raw materials.
- Link your knowledge in the field of fibres and textile materials to sustainability aspects.
- Apply mindfulness and ethical thinking in this field of study.

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Content

- Definition and Classification of Textile Raw Materials
- Global Fibre Market and Megatrends
- Plant and Animal Fibres
- Down and Leather
- Manmade Cellulosic and Synthetic Fibres
- Environmental Impact
- Sustainable Standards and Certifications
- Alternative Resources and Processes

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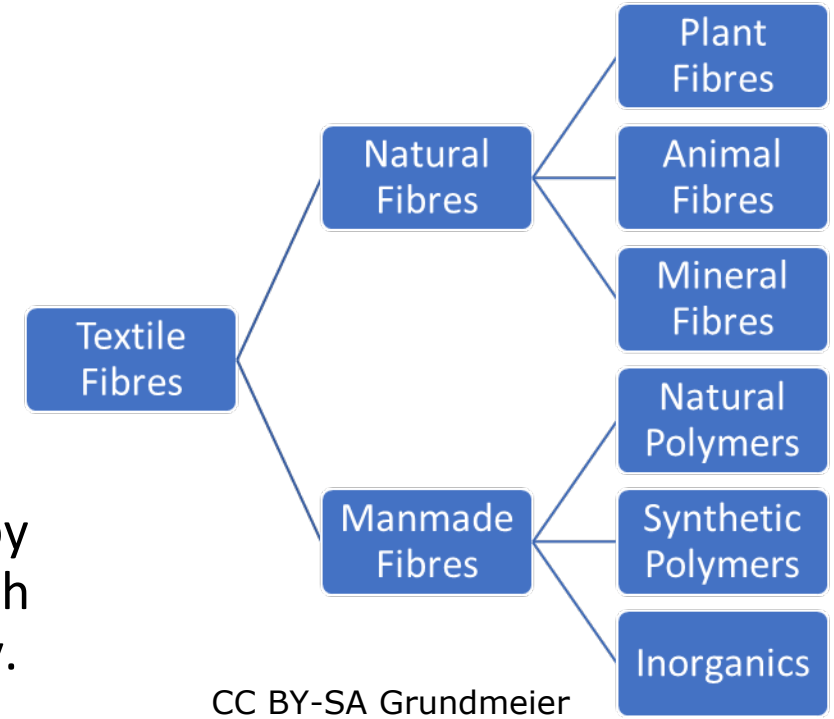
Classification of Fibres as Textile Raw Materials

- Based on their origin, textile raw materials are classified into two main categories: natural and manmade fibres.
- Natural fibres are provided by nature in ready-made form and need only to be extracted.
- Manmade fibres are generated by humans from raw materials which were not in fibre form previously.



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Natural Fibres

- Natural fibres have been used for thousands of years. They exist in fibre form and have mechanical or textual properties.
- Fibres obtained from plants, vegetables or animal sources are the dominant natural fibres. One of the most used mineral fibres was asbestos, but it has been banned in most countries because it is considered harmful to health.
- Plant-based fibres can be produced from plant leaves, seeds, fruit, grass, stalk or liber, e.g., the leaves of sisal and abacá, the bast of flax, jute, hemp, ramie and kenaf, the seeds of cotton and kapok.
- Animal fibres include cashmere, mohair, qiviut (musk ox), alpaca, llama, vicuña, guanaco, Bactrian camel, yak, bison, angora (rabbit) and silk. (Bunsell, 2018).

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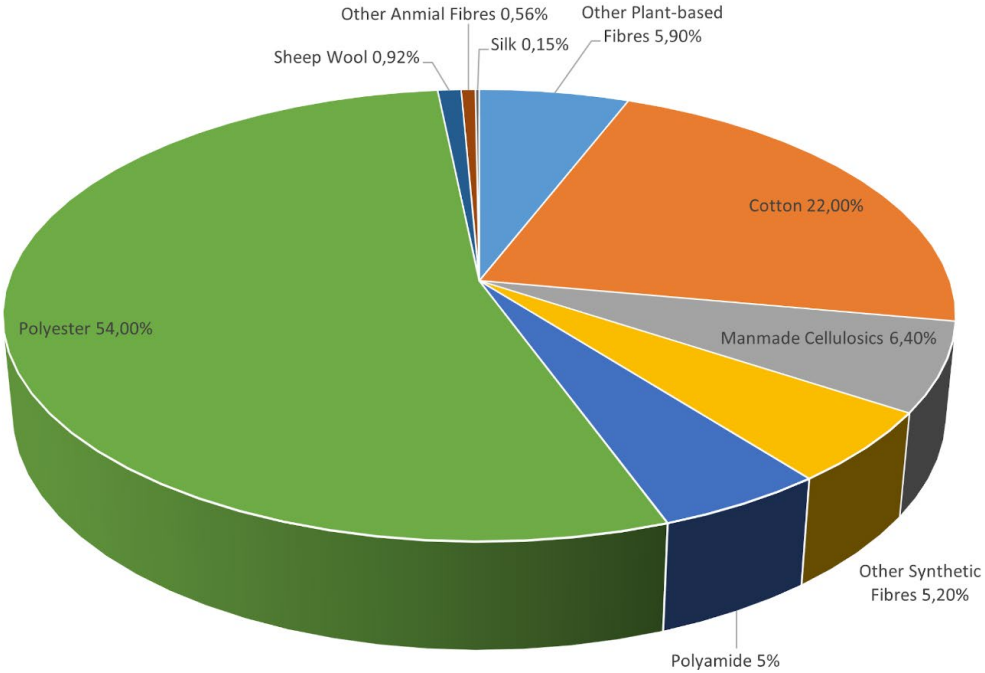
Global Fibre Market



In 2021, 113 million tonnes of fibres were produced.

Source of rounded percentage values: Textile Exchange, 2022a

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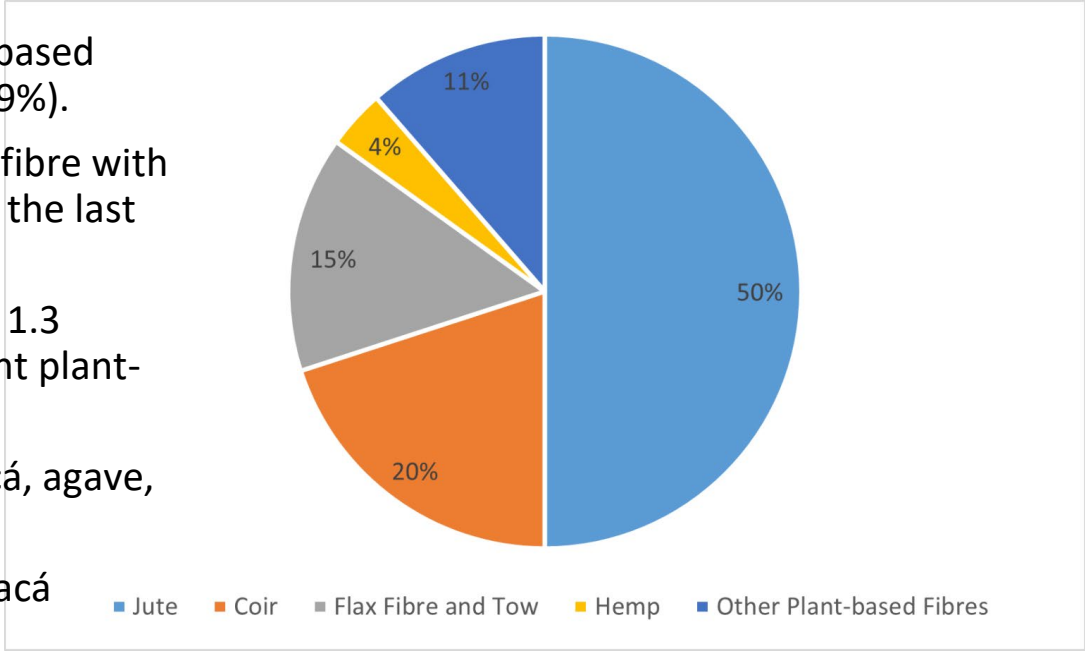
World Production of Plant Fibres

- In 2021, 31.4 million tonnes of plant-based fibres were produced worldwide (27.9%).
- Cotton is the most important natural fibre with approximately 24.7 million tonnes. In the last 10 years, its share fell to 22%.
- Besides cotton, jute and coir (3.4 and 1.3 million tonnes) are the most important plant-based fibres.
- Other plant-based fibres include abacá, agave, kapok, lotus, nettle, ramie and sisal.
- Some of the natural fibres such as abacá are mainly used regionally.



Source of rounded percentage values: Textile Exchange, 2022a

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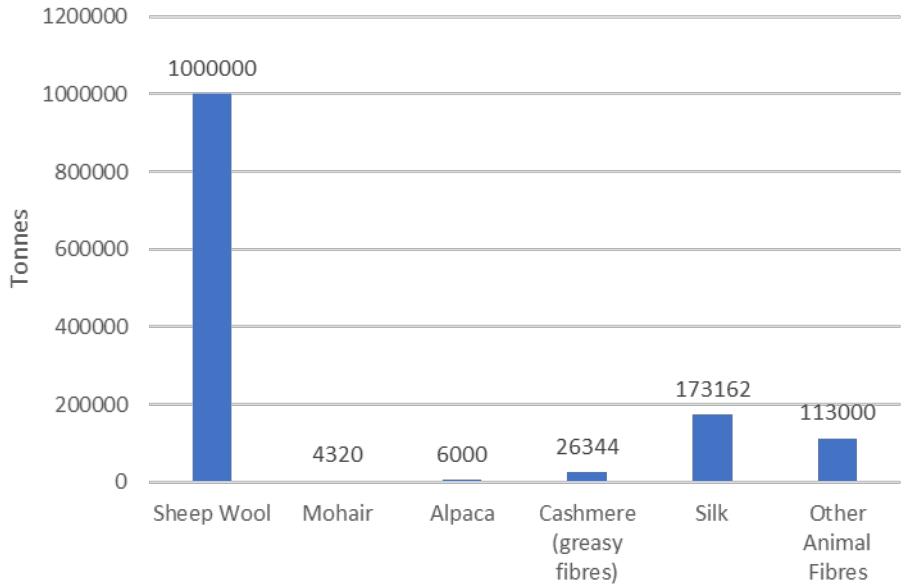
Animal Fibres

- Over the years, the global wool production has been declining, while the number of sustainable wool programmes has been increasing.
- In 2021, the greasy wool production was nearly 2 million tonnes.

(Textile Exchange, 2022a, p. 37)



Source of rounded percentage values: Textile Exchange, 2022a

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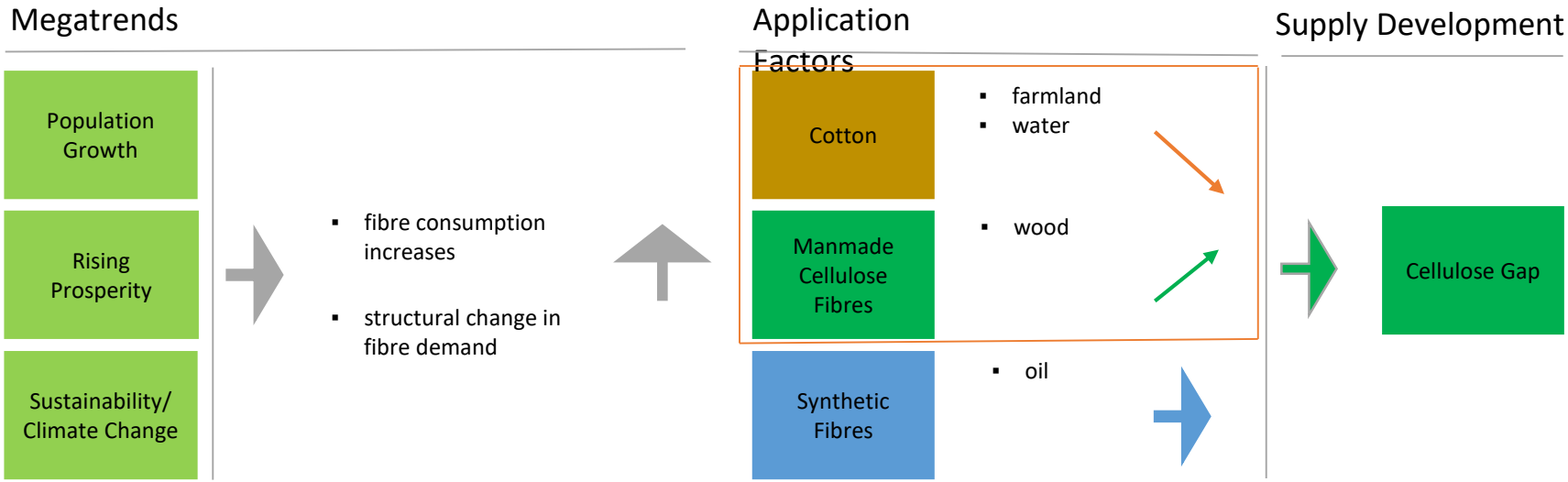
Megatrends of the Global Fibre Market



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Global Fibre Market Trends

- In the last 20 years, the global fibre production has almost doubled from 58 million tonnes in 2000 to 113 million tonnes in 2021. The global fibre market is expected to boom to 149 million tonnes by 2030 if business as usual continues.
- The global fibre production increased from 8.4 kilograms per person in 1975 to 14.3 kilograms per person in 2021 and is estimated to reach 17.5 kilograms per person in 2030.
- As the growth in fibre production has significant impacts on people and the planet, there is an urgent need for establishing a circular economy instead of the linear textile chain.
- Furthermore, we have to promote awareness and a more responsible use of resources and decouple growth from resource consumption especially in order to limit global warming to 1.5° Celsius. (Textile Exchange, 2022a, p. 9).

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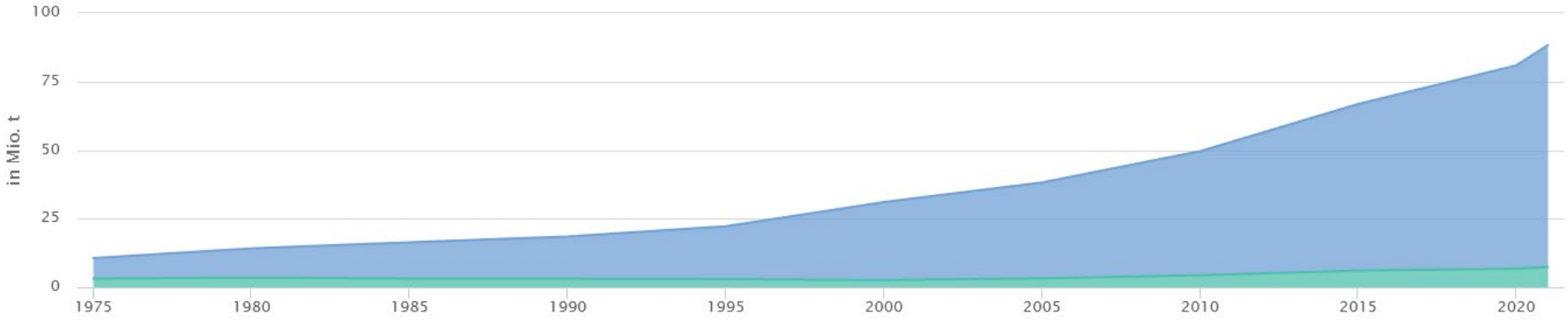
Development of World Production of Manmade Fibres



Synthetic Fibres
Cellulosic Fibres

© Industrievereinigung Chemiefaser e.V.,
https://ivc-ev.de/de/weltproduktion-von-chemiefasern-balkendiagramm

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Production Value of Synthetic Fibres

- Synthetic fibres have dominated the world market since the mid-nineties. This development is mainly due to the low price of fossil raw materials.
- Polyester holds the highest market share of any fibre with 54%, of which only 14.8% is recycled (Textile Exchange, 2022a, p. 72).
- Polyamide fibres have a market share of 5% and are thus the second most used synthetic fibres. The recycling rate is only 1.94% and still offers a lot of potential (Textile Exchange, 2022a, p. 81).
- Bio-based polyester and polyamide fibres have a very small market share of 0.02% for polyester (Textile Exchange, 2022a, p. 78) and 0.4% for polyamides (Textile Exchange, 2022a, p. 83).

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Facts of Cotton Cultivation

- Cotton helps alleviate poverty in some of the least developed countries and provides employment for millions of people around the world. Cotton is a source of income for over 100 million families worldwide, many of whom are smallholder farmers in rural communities in developing countries (UNCTAD, 2022).
- There are about 152 million working children worldwide, 71% of whom work in agriculture: cotton is one of the most common products that children are employed to harvest and process (Gemeinsam für Afrika, n.d.).
- Cotton is a plant susceptible to diseases and pests. According to the International Cotton Advisory Committee it is one of the world's most pesticide intensive crops (PAN, n.d.).
- The cotton plant also needs a lot of water during the growth phase. Huge amounts of fresh water are needed to irrigate the cotton plantations, as some of them are grown in areas that are too dry or the irrigation systems are not efficient.
- The loss of the Aral Sea, once the world's fourth largest lake, and the devastation of the surrounding area is one of the most shocking examples of the true costs of the cotton industry (Hoskins, 2014).

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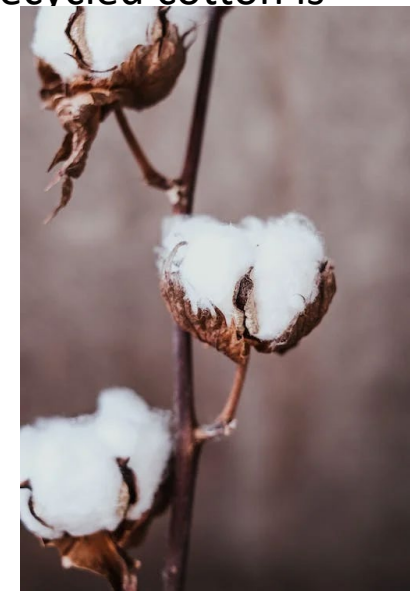
Data of Conventional Cotton

- In 2021, about 75% of approximately 25 million tonnes of cotton were produced conventionally worldwide. The global market for recycled cotton is just under 1%, sustainable and organically grown cotton accounts for about 24%. (Textile Exchange, 2022a).
- The ten largest producers are: China, India, US, Brazil, Pakistan, Australia, Turkey, Uzbekistan, Argentina and Mali (Shahbandeh, 2022).
- About 2.4% of the world's agricultural land is devoted to cotton production, but about 4.7% of the global pesticide market (herbicides, fungicides, insecticides) goes to the cotton industry (PAN, n.d.).



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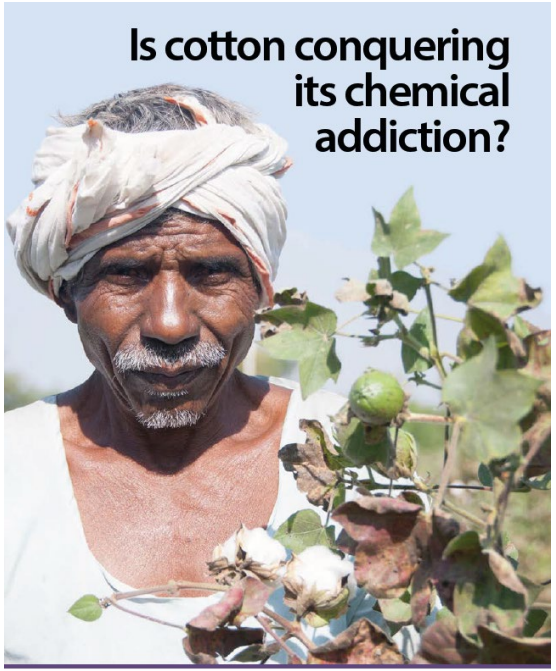
Effects of Pesticide Use on Health

- Global pesticide poisonings have risen from 25 million since 1990 to about 385 million. Based on 860 million people working in agriculture, about 44% of them are poisoned annually.
- Many more suffer from chronic diseases such as cancer and leukaemia, neurological diseases and reproductive problems such as infertility, miscarriages and birth defects. (Boedeker et al., 2020).



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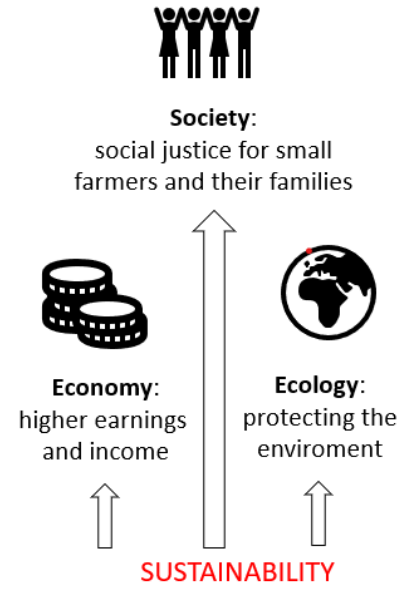
Aspects of Sustainably Produced Cotton

- There are various initiatives, projects and programmes for sustainable cotton production, but these are to be distinguished from organic cotton, cotton cultivation without pesticides and artificial fertilisers.
- Smallholder cotton farmers spend up to 60% of their annual income on pesticides. At the beginning of the season, they buy agrochemicals on credit. (PAN, n.d.).
- Often the yields at the end of the season are too low to pay for these costs. Even a poor harvest can plunge them into debt.



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Variety of Cotton Standards

- There are several initiatives to produce sustainable cotton, such as organic cotton, Cotton made in Africa (CmiA), Fairtrade Cotton and Better Cotton. They focus either more on environmental or social measures.
- Aid by Trade Foundation is an umbrella organisation for three cotton standards: CmiA, Cotton made in Africa Organic (CmiA Organic) and the Sustainable Cotton Standard (SCS), which is currently not used.
- These standards were developed to improve the living conditions of African smallholder farmers and the working conditions in ginning factories and to promote more environmentally friendly cotton production. (ATAKORA Fördergesellschaft, n.d.).
- Integrated pesticide management (IMP) means careful use of all pest control options to limit the use of pesticides as much as possible.
- Natural methods of pest control such as pheromone traps are preferred.

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Organic Cotton Standards

- Unlike terms such as “natural” or “sustainable”, the principles of organic farming are legally controlled. The criteria are set by governing authorities. The rules include requirements around soil health and the prohibition of artificial fertilizers, hazardous synthetic pesticides and genetically modified organisms.
- After the cotton has left the farm, it is not automatically covered by the same legal protections.
- Private standard-setting organisations offer voluntary standards that manage the chain of custody of the organic cotton from gin to the finished product.
- The most common of these finished product standards are the Global Organic Textile Standard The most common of these finished product standards are the Global Organic Textile Standard (GOTS) (Global Standard, 2021) and Textile Exchange‘s Organic Content Standard (OCS) (Textile Exchange, n.d.).
- Both standards accept organic cotton from farms certified by the International Federation of Organic Agriculture Movements (IFOAM – Organics International). (Textile Exchange, 2022b, p. 11).

© Global Standard

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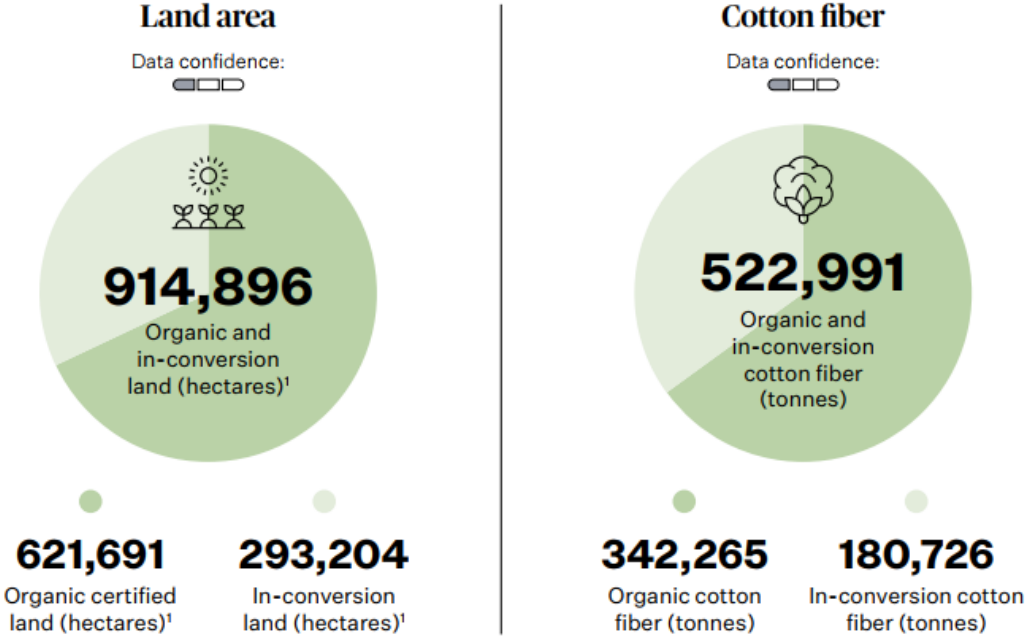
Global Organic Cotton Production

- Textile Exchange (2022b, p. 17) estimates that in 2020/21 342,256 tonnes of organic cotton fibres were produced on 621,691 hectares of certified organic land.
- 180,725 tonnes of in-conversion fibres were produced on 293,204 hectares.
- Compared to the organic cotton production in 2019/20, this represents an estimated growth of 37%. (Textile Exchange, 2022b, p. 17).
- Nevertheless, organic cotton has a share of 1.5% of the worldwide cotton market.



© Textile Exchange, 2022b, p. 17

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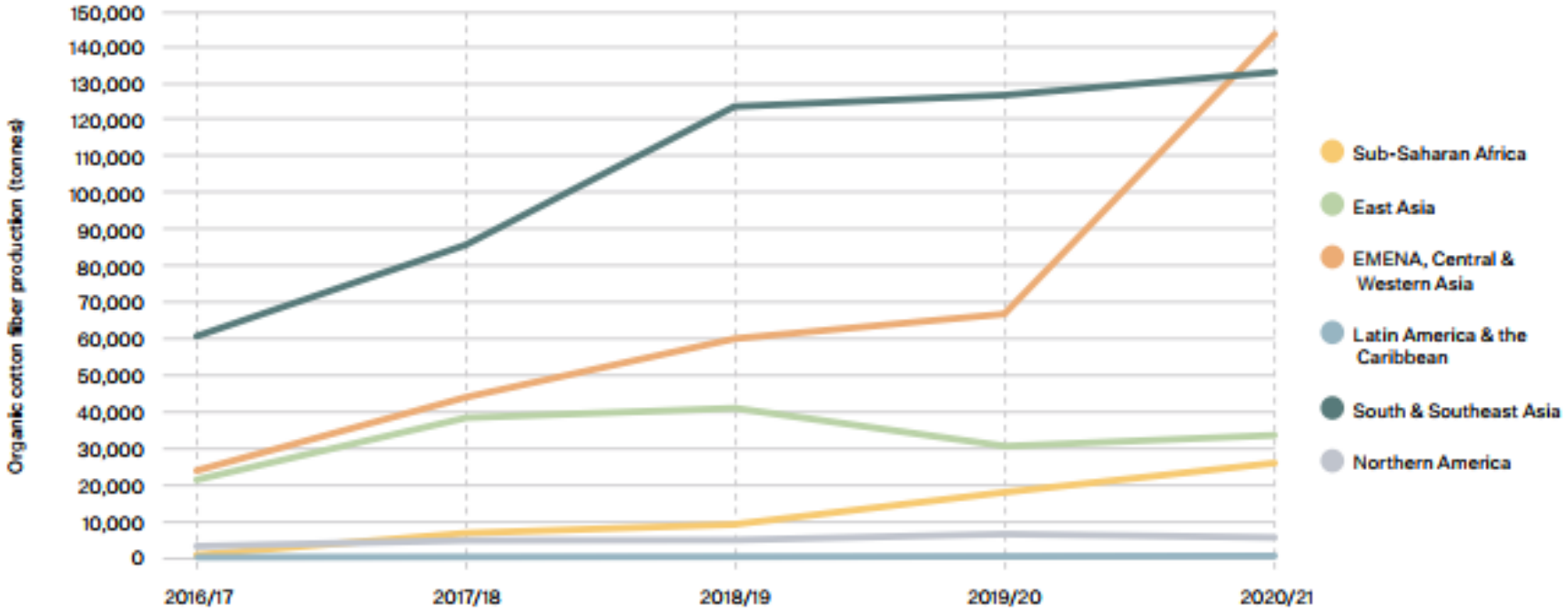
Regional Organic Cotton Production over the Past Five Years



© Organic Cotton Market Report, Textile Exchange, 2022b, p. 19

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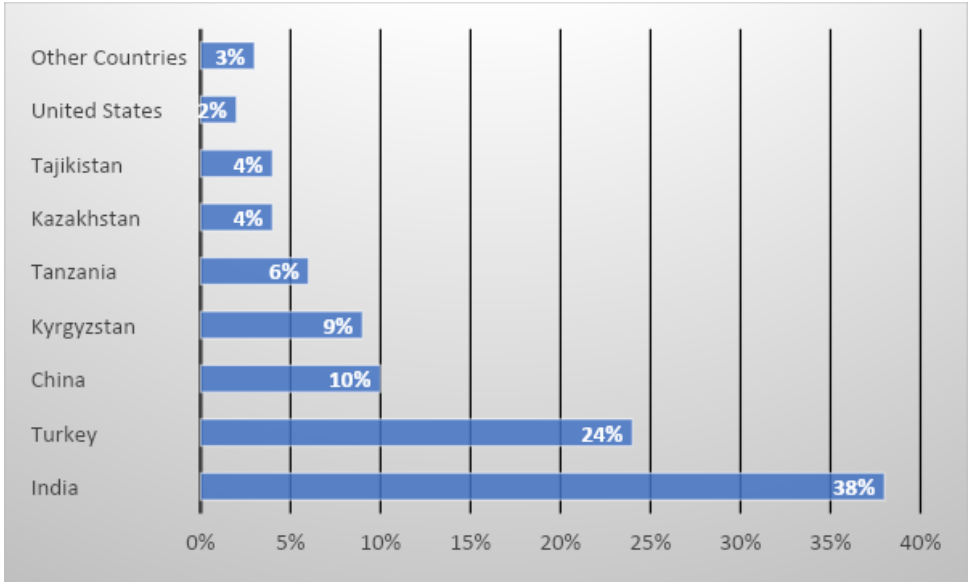
Countries Producing Organic Cotton

- 97% of organic cotton's global production comes from eight countries: predominantly India and Turkey, followed by China, Kyrgyzstan, Tanzania, Kazakhstan, Tajikistan and the US.
- Genetically modified cotton is grown on approximately 79% of the cultivated area. The land area planted with genetically modified cotton worldwide rose to 25.7 million hectares in 2019. There are 18 countries involved (Forum Bio- und Gentechnologie e. V., 2021).



Organic Cotton Producing Countries
Source: Textile Exchange, 2022b, p. 18

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Organic Cotton & Sustainable Development Goals

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Organic cotton farming plays a major role in helping countries achieve their SDGs. Find out how below or read Textile Exchange's full briefing here.

Organic cotton is a market-driven solution to poverty. Farmers can earn more, spend less on inputs such as agrichemicals, and reduce dependency on the commodity market.

Organic cotton is grown alongside and in rotation with food crops.

Organic cotton farmers and their families are not exposed to toxic chemicals.

Higher financial returns result in organic cotton farming communities being able to invest in education, often through the investments of supply chain partners.

Many organic cotton farmers are women, particularly in African and Asian countries. Approximately 10 per cent of certified organic farmers globally are women, and have control of their farms.

As organic cotton does not use toxic pesticides or synthetic fertilizers, it does not cause chemical contamination of local water sources.

Organic farming communities are increasingly using solar and biogas as an energy source, particularly where access to electricity is limited, as in some regions of Africa and India.

Globally, approximately 200,000 people are certified to organic standards, mostly smallholder farmers. Many more are farming to organic or agro-ecological criteria.

Organic cotton production is the basis for the new global textile infrastructure – sustainable, ethical, transparent, and verified.

In some countries (such as in Africa), organic production is considered pro-female. No heavy spray units to carry around or risk to pregnant women or mothers.

Higher financial returns, absence of toxic chemicals (and illness), alongside the satisfaction of working within farmer associations, encourages more people to stay on the land.

Organic "life choices", whether at the farm, the factory, in retail or in the home, promote healthy choices for all.

Organic soils sequester carbon as a key component in soil building and improved soil fertility. No dependency on fossil fuel based fertilizers.

By eliminating toxic and persistent pesticides, organic cotton production is a proactive contributor to clean and healthy water used locally, and which ultimately runs into the oceans.

Organic cotton farms build fertile soils and biodiversity by rotating crops, minimizing tillage, and planting cover crops.

Many organic cotton farming operations are cooperatives, respecting democracy, and working collaboratively to create shared value.

A fundamental element of organic cotton production is its strong commitment to global partnerships and cooperation - recognizing the interdependencies at play.

© United Nations, n.d. & Textile Exchange, 2016

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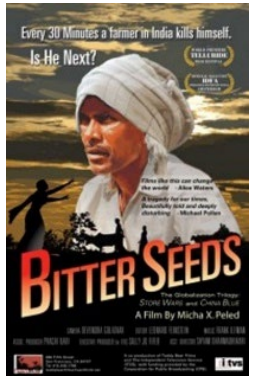
Genetically Produced Cotton

- Bt proteins are produced by the soil bacterium *Bacillus thuringiensis* (Bt) and have a very specific effect, i.e., they are only toxic to the relevant target organisms.
- If the corresponding genes are inserted into the genetic material of cotton plants, they produce Bt protein and thus repel insect pests such as the cotton bollworm or bollworm.
- Bt cotton needs three times as much water as conventional plants and therefore requires an artificial irrigation system.
- It is particularly susceptible to pests such as fungi, against which its poison is ineffective, and resistance develops.
- It is not possible to grow seed from the seeds. (Kathage & Quaim, 2012; Plewis, 2021).



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Production Data on GM Cotton

- The caterpillars of the cotton bollworm prefer to feed in flowers, shoot tips or fruits and bore into plant parts.
- Bt cotton was first grown in the USA in 1996.
- In 2019, cotton was planted on 32.5 million hectares. Genetically modified (GM) cotton is grown on approximately 79% of the cultivated area (25.7 million hectares). (Forum Bio- und Gentechnologie e. V., 2021).
- Only textiles made from certified organic cotton are guaranteed to be free from genetic engineering.

Photo: Caterpillar of the cotton bollworm
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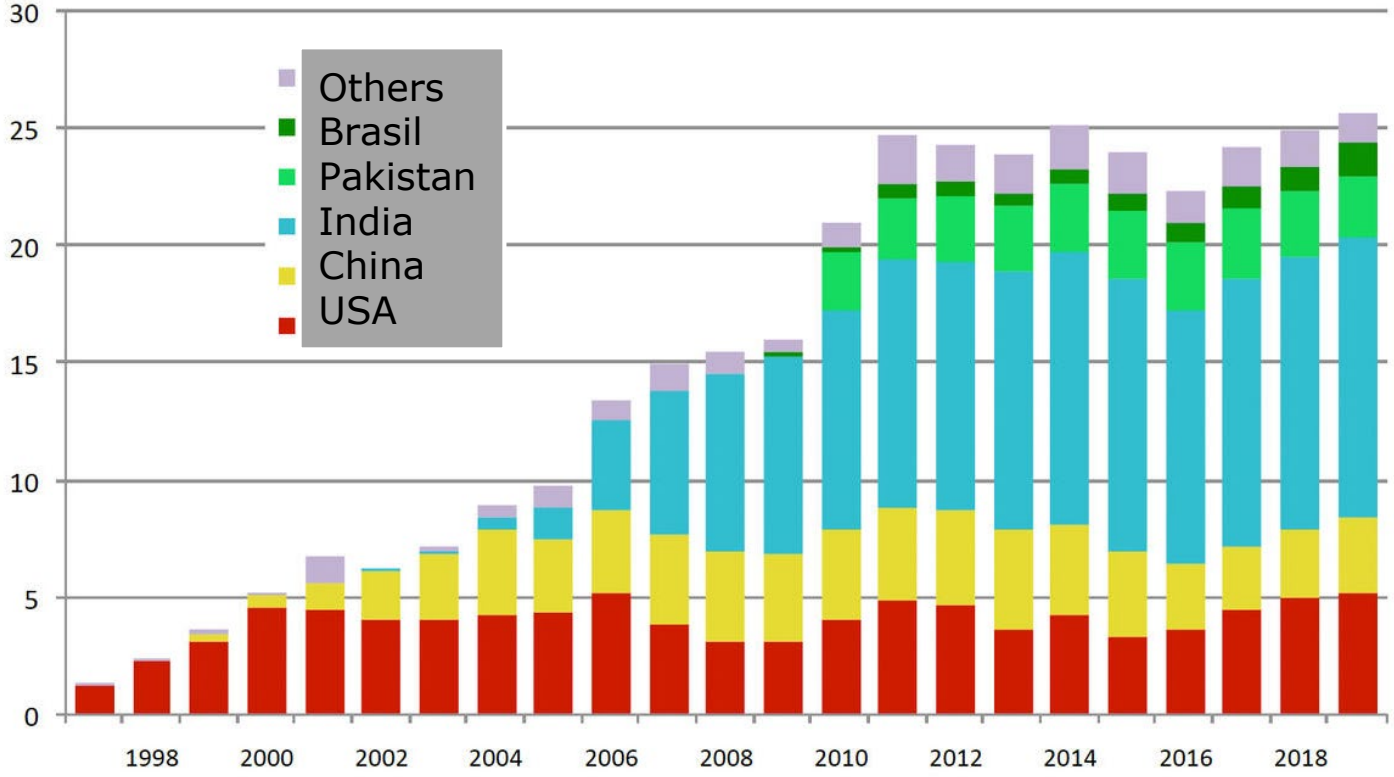
Cultivated Areas of GM Cotton



In million hectares
Source Figures: ISAAA
© Forum Bio- und Gentechnologie e. V.

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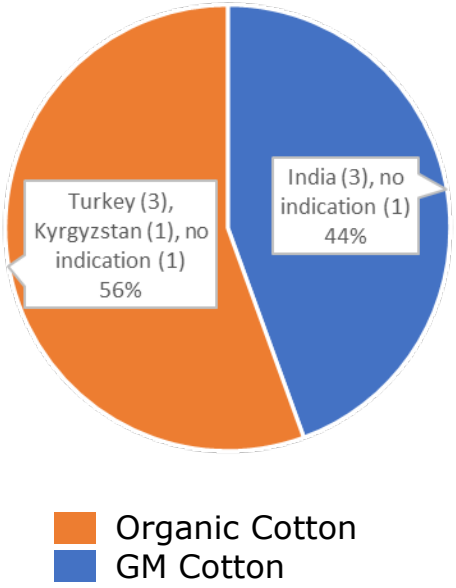
Testing for GM Cotton

- DNA verification for genetically modified cotton by radioactive measuring of genetically modified molecules.
- There are so-called marker genes for genetically modified cotton.
- The raw cotton is tested as the DNA becomes less and less detectable with further processing of the cotton.
- Certified organic cotton should not be genetically modified, but Indian cotton samples have shown that this is not always the case (Waiblinger & Martin, 2015).



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Coloured Cotton

- The originally coloured cotton is resistant to pests. It is organically bred and grown in the US.
- Sally Fox, a cotton breeder from California, had already rediscovered coloured cotton before the turn of the millennium.
- In her 40th year of work (2022), she is still finding new cottons in her breeding nursery.
- The natural reddish-brown and green shades of the cotton fibres become more intense after washing.

© Sally Fox, Vreseis Limited

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Organic Linen

- 80-85% of flax is grown in Europe, of which about 0.5% is organically controlled (Textile Exchange, 2022a, p. 27).
- In 2005, the German company *hessnatur* started a linen cultivation project with the Institute for Biodynamic Research in Darmstadt.
- *hessnatur* guarantees the acceptance of the harvest and takes care of the ecologically oriented further processing.
- The main focus is on high ecological quality because regional flax cultivation does not require the use of any chemicals.
- Today, linen can be produced using modern technologies and traditional processes such as the sustainable dew retting process on the fields (Chabbert et al., 2020).

Flax plants, CC0 Nennieinszweidrei

Dew retting on the field, CC BY-SA 3.0 Rilegator

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Hemp as a “New” Alternative Fibre

- Like flax, hemp is a very frugal plant that enables high crop yields.
- The global production of hemp fibre and tow is estimated at around 254,692 tonnes in 2021.
- The market share of hemp is thus about 0.2% of the total fibre market in 2021.
- Fibre-hemp is mainly grown in China, but there is more and more sustainable cultivation of hemp in Europe and the USA. (Textile Exchange, 2022a, p. 26)

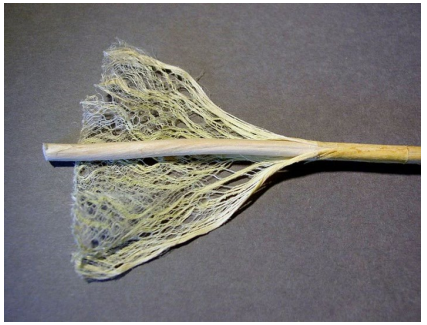

Photo of hemp harvest: CC BY-SA Lossenelin
Photo of hemp stalk: CC0 Natrij
Photos of hemp products: CC BY-SA Grundmeier

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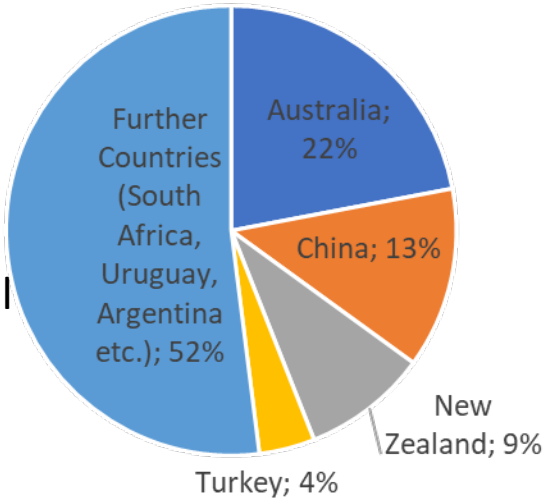
Wool Production

- Wool is produced in about 100 countries worldwide. The leading producing countries are Australia, China, New Zealand and Turkey. Further countries are South Africa, Uruguay, Argentina (Textile Exchange, 2022a, p. 39).
- Recycled wool has a long tradition. With an estimated production volume of around 70,000 tonnes, the market share of recycled wool is estimated at around 6% of the total wool market.
- The Italian district of Prato is a major producer of recycled wool, where approximately 22,000 tonnes of wool are recycled every year. (Textile Exchange, 2022a, p. 50).



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Source: Textile Exchange, 2022a, p. 39

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Ban of Mulesing

- Mulesing means the removal of wool-bearing strips of skin from between the hind legs of sheep – the so-called the “breech” area – to avoid problems of fly strike. This practice, which is very painful for the animals, remains a key issue of wool production.
- With the ban of mulesing in New Zealand in 2018, Australia is the only country where mulesing is still practiced.
- Regarding Australia’s high market share of the global clean wool market, the “risk of sourcing wool produced with mulesing practices remains high if no traceability system is in place to ensure that the wool is mulesing-free” (Textile Exchange, 2022a, p. 40).

Merinos, CC0 1.0

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Responsible Wool Standard (RWS)

- The Responsible Wool Standard (RWS), which has been in place since 2016, certifies the gentle extraction of wool.
- The living and shearing conditions of the sheep are assessed particularly strictly. Mulesing or other cruel practices are prohibited.
- The scope of RWS covers the entire value chain from farms to wool producers and garment factories.
- The inspection and certification of the sites is carried out through annual auditing. (Textile Exchange, 2021).

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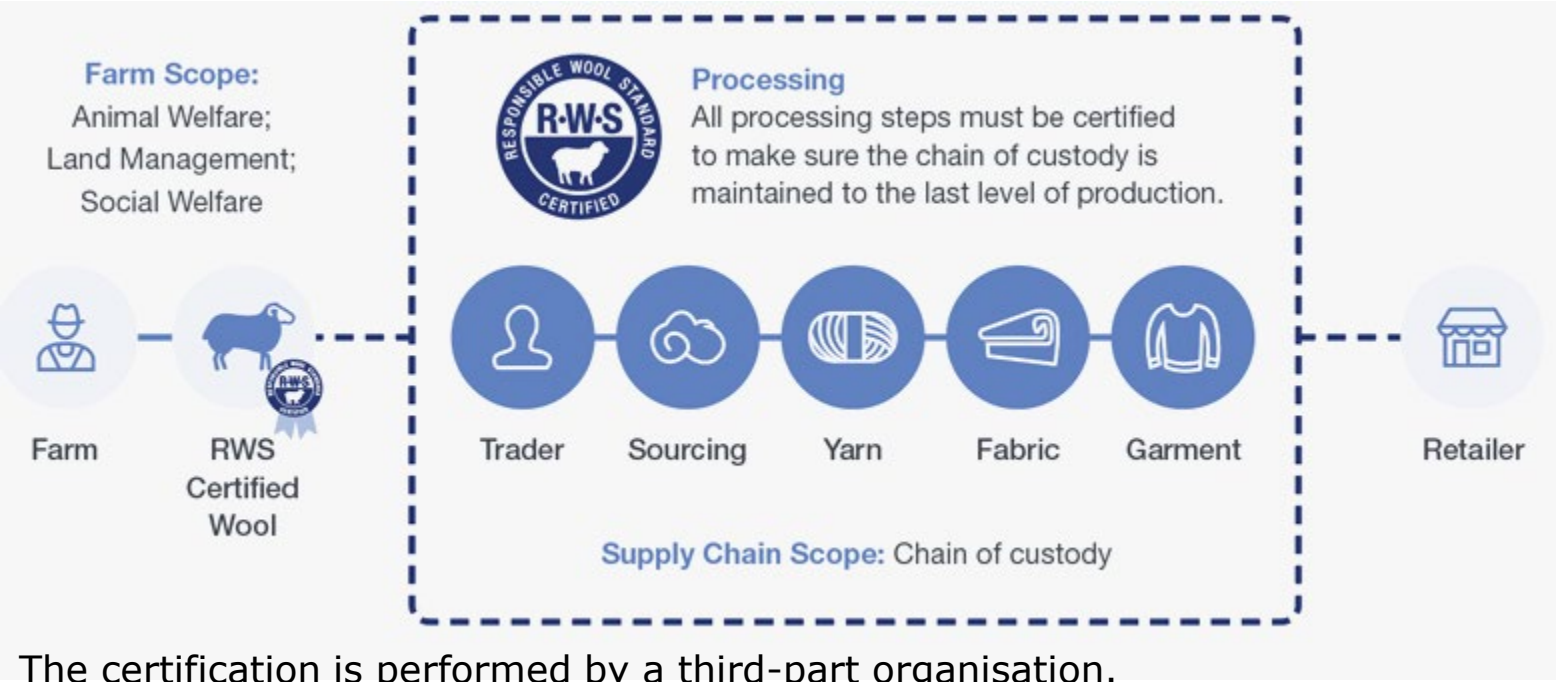
Process Chain for RWS



The certification is performed by a third-part organisation.
© Textile Exchange, 2021, p. 11

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Sustainable Animal Fibre Standards

- The RWS market share is about 2.6% - together with other certifications it is about 3 % - of the greasy wool production. The largest share of RWS-certified wool comes from merino sheep. (Textile Exchange, 2022a, p. 37-38).
- With the release of RWS 2.0, the supply chain certification for RWS, the Responsible Mohair Standard (RMS) and the Responsible Alpaca Standard (RAS) were combined in the Responsible Animal Fiber Standards (RAF).
- Silk programs include organic standards such as the Indian National Programme for Organic Production (NPOP), the Organic Content Standard (OCS) and the Global Organic Textile Standard (GOTS). (Textile Exchange, 2020).
- The aim of these standards is to ensure that the potential for high animal welfare for animals raised in extensive grazing and free ranging farming systems is realised.

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Wool from Controlled Organic Animal Husbandry

- According to the guidelines of organic farming, wool and animal hair can come from organic or controlled organic animal husbandry in accordance with the guidelines of IFOAM Organics Europe (n.d.) or the EC Organic Regulation (EC No 834/2007).
- No use of pesticides and ban on fattening aids.
- The animals reproduce naturally and any intervention on the animal, such as tail docking or mulesing, is prohibited.
- The use of pharmaceuticals for the animals is strongly decimated.
- Genetically modified feed and animal meals are prohibited.
- Grazing on meadows treated with artificial fertiliser is prohibited.
- The guiding principle in organic agriculture is a closed farm cycle. State-approved, independent inspection bodies annually inspect organic producers and processors for compliance with strict production and processing guidelines.

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Recycled Leather and Leather Alternatives

- Leather production in the form of animal hides from slaughter cattle such as sheep, goats and cattle amounts to approximately 12.5 million tonnes in 2021 (Textile Exchange, 2022a, p. 5).
- Around 800 thousand tonnes of leather waste are generated annually (Textile Exchange, 2022a, p. 58). To produce 150 kg of leather from 1000 kg of rawhide, 75 kg of tanning waste, 9 kg of finishing waste and up to 110 kg of cutting waste are produced and can be used for recycled leather fibres (European Outdoor Group (2019, p. 17).
- Most of the recycled leather is made from production waste and processed into bonded leather. It is either made from recycled leather fibres and binders or it is made into artificial leather by applying recycled leather fibres to the surface of a synthetic material.

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Pineapple Leaves for Vegan Leather

- The use of crop residues, such as rice straw, pineapple leaves, banana tree trunks and sugar cane bark, is an emerging field (Textile Exchange, 2022a, p. 28).
- The raw material that forms the base of Piñatex® is a by-product of the pineapple harvest.
- Dr. Carmen Hijos, a leather goods expert, is the founder of Ananas Anam, the makers of Piñatex®, a vegan leather made from waste pineapple leaf fibres. Their use creates an additional income for the farmers on the Philippines.

© Vegan Leather by Piñatex®

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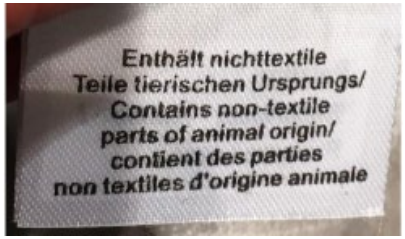
Animal Products in Fashion



Fashion DIET

- Real fur trimmings are in fashion. They are not only found on hoods as wind protection, but also on hats, as accessories, etc. They mainly originate from the Chinese tanuki, but also fox and mink, rabbit and other fur animals. One third of the fur produced in China comes to Germany.
- According to the EU Textile Labelling Regulation, real fur must be labelled with “Contains non-textile parts of animal origin” on products that consist of at least 80% textile fibres (Europäische Union, 2011, L 272/2 (8)). The type of real fur does not have to be specified. Parts of animal origin can be e.g., down, fur, leather or horn.
- Real fur can be recognised by the shine and the leather skin underneath the fur. In the case of a woven fur, you would recognise the fabric or knitted fabric by combing apart the pile.

Photo: © Deutscher Tierschutzbund

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Renouncing Fur in the Fashion Industry

- More and more fashion companies are renouncing the use of fur. They have been preceded by “vegetarian” designers such as Stella McCartney, who renounces the use of leather and fur in all her collections.
- In 2022, Latvia became the 15th EU member state to vote for a complete ban on fur farming (Michel, 2022).
- Woven fur or fake fur provide alternatives. These are fabrics with a high fibre pile of polyester or polyacrylic, which is introduced via fibre vents during fabric production.
- They can look deceptively real by being printed with patterns and the pile is sheared, thermoplastically formed over rollers and given an animal fur-like structure.

Fake Fur
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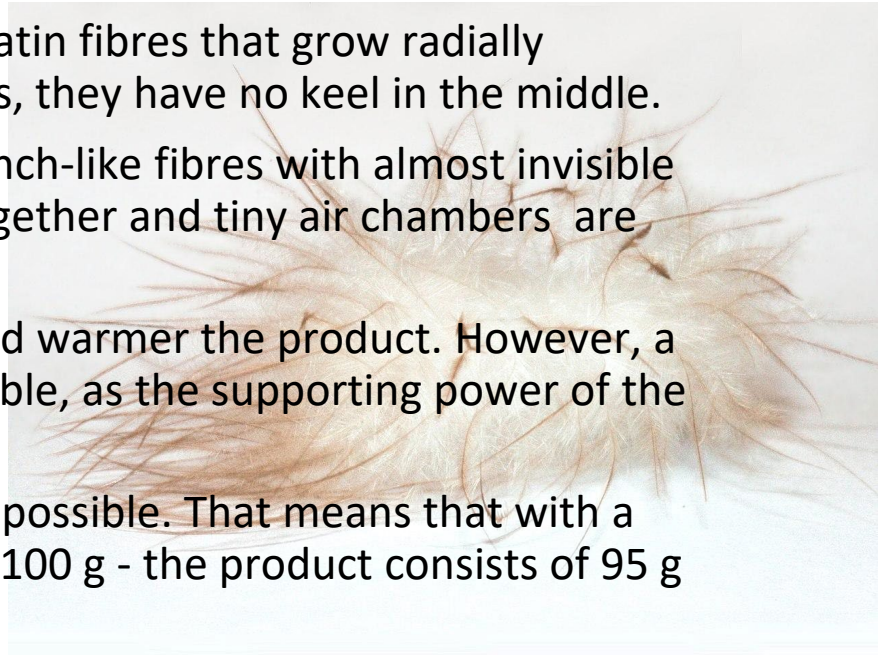
Down – Natural Heat Insulation

- Down is made of thousands of very soft keratin fibres that grow radially outwards from a tiny centre. Unlike feathers, they have no keel in the middle.
- The keratin fibres have countless small, branch-like fibres with almost invisible hooks. These ensure that the downs join together and tiny air chambers are created.
- The higher the down content, the lighter and warmer the product. However, a down content of 100% is practically impossible, as the supporting power of the feathers is needed.
- A maximum of 95% down is technologically possible. That means that with a mixing ratio of 95/5 - and a filling weight of 100 g - the product consists of 95 g down and 5 g feathers.



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Down Production

- The global production of feathers and down was estimated by Textile Exchange (2022a, p. 32-33) to be around 570,000 tonnes in 2021, with 70% coming from China (Future Market Insights, 2021).
- The eider duck lives in the coastal regions of Iceland, Greenland and Canada. Eider down, the finest and at the same time the lightest down, is collected from their nests, no more than 20 g from one nest.
- Around 500,000 to 1 million downs are needed for 1 kg. Real eider down is only available in very limited quantities.

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Down Plucking

- Most of the world's down and feathers are obtained through slaughter plucking. The animals, ducks and geese, are slaughtered and then plucked, mostly by machine, before the meat is sent for further processing.
- Live plucking, unless it is moult plucking, is often painful for the animals and is criticised by animal welfare organisations. Therefore, more and more companies are speaking out against it.
- Live plucking is banned in Europe, but the loophole of plucking during moulting remains for the poultry industry
- To avoid live plucking, the production chain is controlled.

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Sustainable Down Standards (1)

- Animal welfare awareness has led to a successful rise in animal welfare standards such as the Responsible Down Standard (RDS) by Textile Exchange (n.d.), which has a market share of 3.2%, and the Downpass with a market share of 1.2% (Textile Exchange, 2022a, p. 32).
- RDS is an independent certification standard that can be applied to all suppliers involved in down production. It aims to ensure the welfare of animals from chick to finished product and to change the down processing industry as a whole.
- The DOWNPASS (Traumpass e. V., n.d.) shall guarantee high quality and the certainty that down and feathers are ethically sourced and come from tightly controlled and traceable supply chains.

© Textile Exchange

© Traumpass e. V.

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Sustainable Down Standards (2)

- China is the largest producer of RDS certified down (Textile Exchange, 2022a, p. 32). In addition to external certifications, companies have introduced their own sustainable down standards.
- Criteria are the traceability from the parent generation or the rearing of the chicks with regard to animal welfare.
- Live plucking and force fed for foie gras production are prohibited. Controls along the entire supply chain ensure that these requirements are met by the suppliers. Only down that is purely a by-product of the food industry is used.
- The Global Traceable Down Standard (Global TDS) was launched in 2015 by the US non-profit organisation NSF International as a result of a collaboration between the outdoor brand Patagonia, industry associations, animal welfare organisations and other NGOs. The certification is not only carried out at the product level but looks at the entire supply chain. (Henkel, n.d.; Patagonia, 2022).
- Today, the Global TDS certifies that down in garments and other household and commercial products come from a responsible source that respects animal welfare and can be transparently traced (NSF International, n.d.).

© MCL Global

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Sustainable Natural Fibre and Material Trends

- Awareness of animal welfare has led to successful growth in the use of standards such as the *Responsible Animal Fiber Standards* (Textile Exchange, 2021).
- Until recently, the focus has been on the risks associated with leather processing (tanning, chemical use), but there is growing interest in animal welfare, deforestation, land use (and associated loss of biodiversity) and climate change.
- Textile Exchange (n.d.) has developed the Leather Impact Accelerator (LIA), which includes an incentivisation tool to enable companies to support farmers addressing deforestation and forest conversion, as well as animal welfare at all levels of cattle farming.
- Other fibres and materials - ranging from hemp to natural rubber - are often not in the industry's focus, despite significant sustainability potential and challenges.

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Vegan Fashion and Green Product Awards

- The animal rights organisation PETA (People for the Ethical Treatment of Animals, n.d.) regularly presents the Vegan Fashion Award in Germany for “stylish, innovative, sustainable and vegan clothing”.
- Products made from alternative raw materials such as plant-based leather substitutes or from renewable domestic raw materials such as flax and hemp as well as from recycled raw materials a
- Other criteria include ecologically fair production and product design that is both fashionable and long-lasting.
- The Green Future Club (n.d.) also awards sustainable bio products.

© PETA e.V. Deutschland

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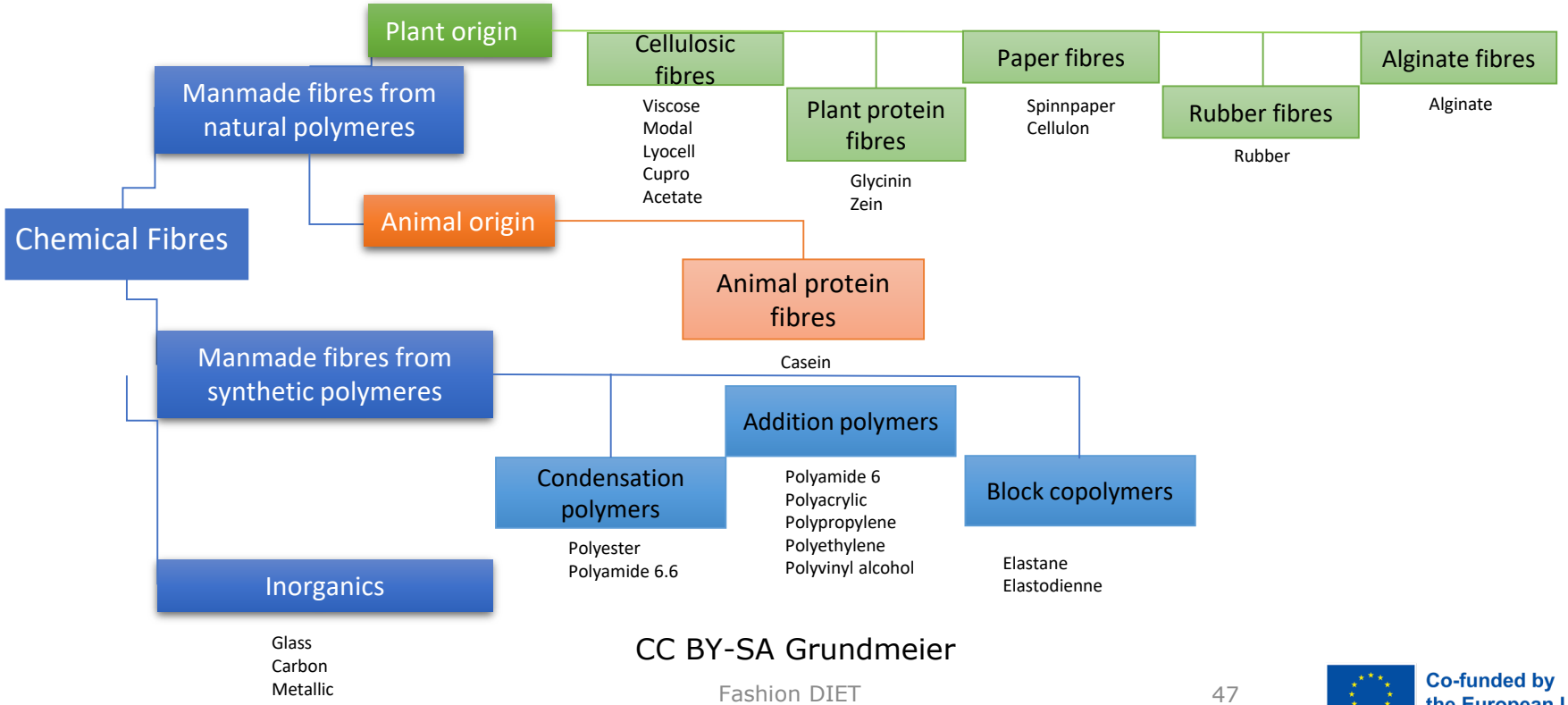
Classification of Chemical Fibres



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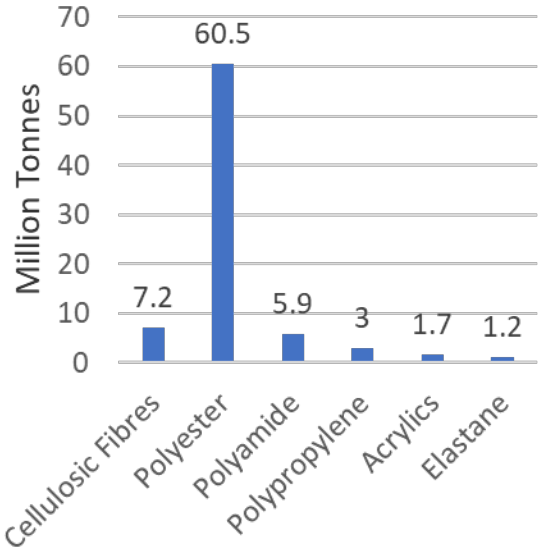
Market for Manmade Fibres in 2021

- The production of manmade cellulosic fibres (MMCFs) including viscose, lyocell, modal, acetate and cupro increased to 7.2 million tonnes.
- The production volume of polyester fibres increased to 60.5 million tonnes. Polyamide – the second most used synthetic fibre – accounted for 5.9 million tonnes.
- The other synthetics – polypropylene, acrylics, and elastane – had a market share of 5.2%, with a combined production volume of 5.8 million tonnes: polypropylene around 3, acrylics 1.7 and elastane 1.2 million tonnes. (Textile Exchange, 2022a, p. 10).



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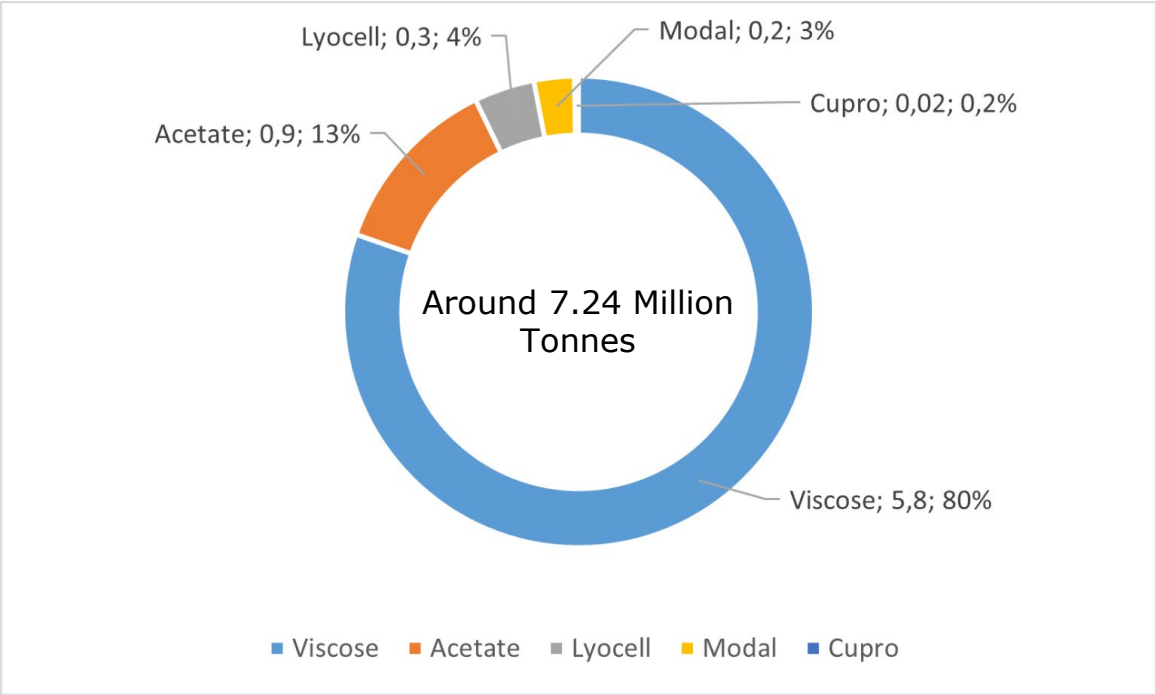
Gobal Market of MMCFs in 2021



CC BY-SA Grundmeier, Source: Textile Exchange, 2022a

Lenzing fibres, © Lenzing AG

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Manmade Cellulosic Fibres from Sustainable Raw Materials

- The market share of FSC- and/or PEFC-certified manmade cellulosic fibres (MMCFs) increased to around 60-65% of all MMCFs in 2021 (Textile Exchange, 2022a, p. 62).
- FSC, founded in 1993, is an international member-led organisation with standards for responsible forest management and chain of custody (FSC, n.d.).
- PEFC was founded in 1999. This global alliance of national forest certification systems holds the largest forest certification system worldwide. In 2018 the first PEFC-certified fabrics were launched. (PEFC, n.d.).

Beech forest, © Lenzing AG

- First MMCFs have also been certified according to the Organic Content standard (OCS) by Textile Exchange.
- The audits of Canopy are the leading assessment of MMCF suppliers on their raw material sourcing practices. Canopy's (n.d.) Hot Button Ranking and report is the primary fibre sourcing analysis tool for the fashion sector that focuses on forests (Canopy, n.d.).

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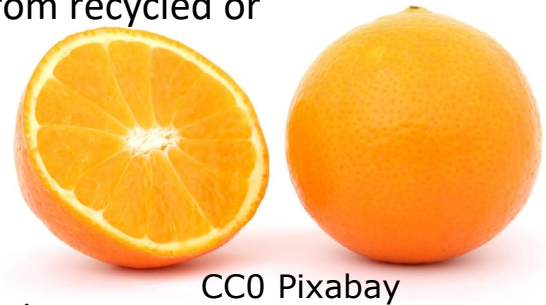
Recycling of Manmade Cellulosic Fibres

- MMCFs are primarily produced from wood. Less than 1% is made from recycled or alternative feedstock (Textile Exchange, 2022a, p. 61).
- Canopy (2020, p. 18) estimates that a recycling of 25% of global pre- and post-consumer cotton textile waste and 25% of MMCF waste could replace all wood fibres that are currently used to manufacture dissolving pulp.



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- Launched in 2020, the European Union-funded New Cotton Project (New Cotton Project Consortium, n.d.) is a three-year multi-stakeholder project which collects and sorts textile waste and chemically recycles it into new MMCF fibres that look and feel like cotton.
- There are further projects to produce MMCFs from non-textile residues such as cardboard, paper and agriculture residues like wheat or rice straw and biomass waste products for example from the food industry. The Italian start-up Orange Fiber (n.d.) extracts cellulose from the by-products of the citrus industry to produce fibres and fabrics.

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Standards for Pulp and Fibres

- The Bluesign Technologies AG (n.d.) developed specific criteria for fibre production sites that are added as annex for fibre manufacturing to the bluesign® criteria.
- The ZDHC Foundation (n.d.) has expanded the scope of its work for sustainable chemical management within the textile chain by including manmade cellulosic fibre production.
- Further standards for pulp and fibres include the Cradle to Cradle Material Health Certificate Standard, SteP by OEKO-TEX® Further standards for pulp and fibres include the Cradle to Cradle Material Health Certificate Standard, SteP by OEKO-TEX® (OEKO-TEX Service GmbH, n.d.)and the EU Eco Label (European

Pulp, © Lenzing AG

Lenzing fibres, © Lenzing AG

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Lyocell - Sustainable Manmade Cellulosic Fibre

- Cellulosic regenerated fibre
- Spinning: direct solvent process
- Raw material: mainly wood from renewable beech forests
- Brand name: TENCEL™, TENCEL™ with REFIBRA™ technology. Not only certified wood but also fabric residues from the cutting of cotton clothing are used as raw materials for this fibre.
- Disintegration time: 100 % in 16 weeks
- Areas of use: denim, outerwear, workwear, functional clothing, underwear, bed linen, *nonwovens* products (fleece) for hygiene and cosmetic articles. (Lenzing AG, n.d.; Lenzing AG, 2022).

© TENCEL™ Fabric, Lenzing AG

© Lyocell Production, Lenzing AG

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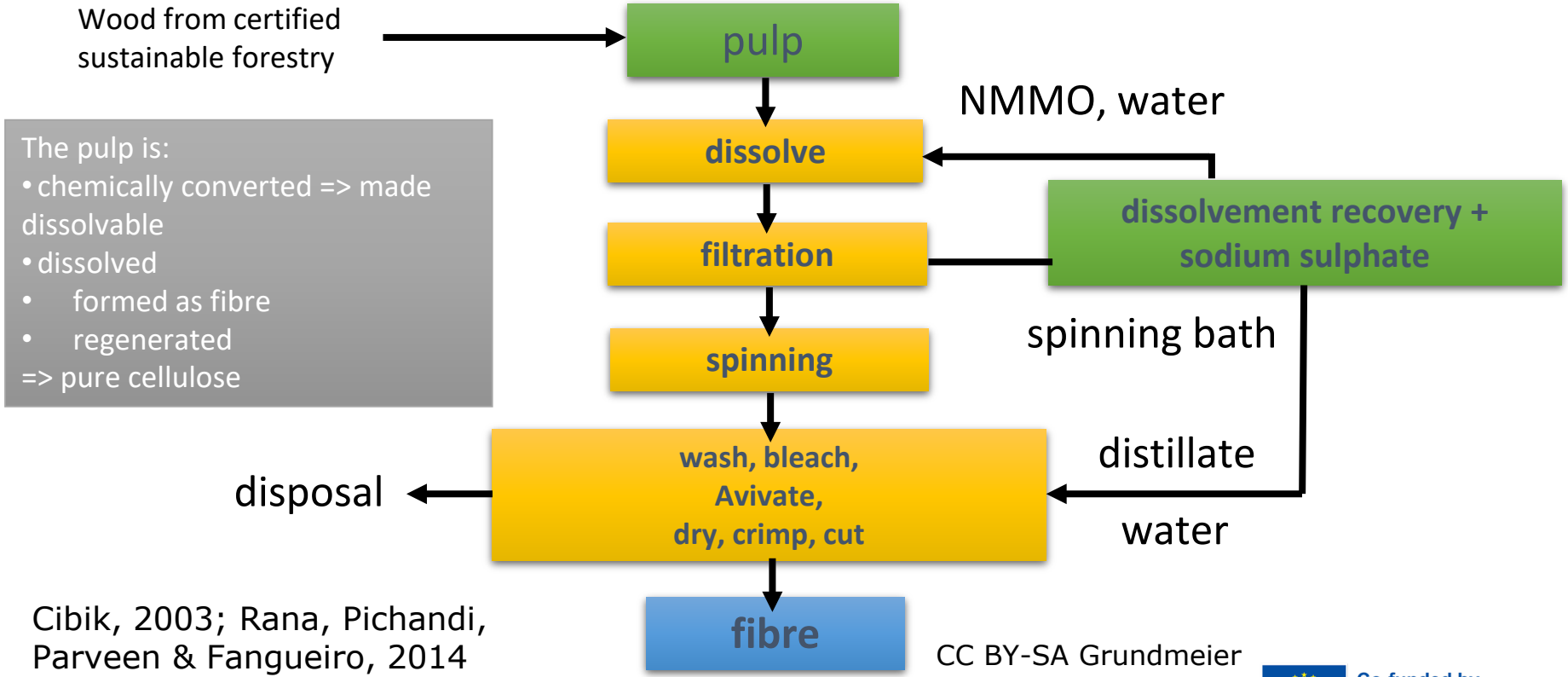
Process Diagram of the NMMO Process



The pulp is:
- chemically converted => made dissolvable
- dissolved
- formed as fibre
- regenerated

=> pure cellulose

Cibik, 2003; Rana, Pichandi, Parveen & Fangueiro, 2014

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Ecological Advantages of NMMO and New Solvent Processes and Resources

- Use of new cellulose resources such as hemp and hemp straw for a new very fine cellulose fibre called Lyohemp® (TITK, n.d.).
- Reduction of the number of necessary process steps and sulphurous chemicals. Use of ecotoxicologically favourable organic solvents like N-methymorpholine-N-oxide (NMMO).
- Limitation of chemicals to e.g., NMMO and sodium sulphate.
- Massive reduction of environmentally harmful waste materials.
- Recycling of the solvent through a recovery rate of approximately 99.7%. NMMO is 90% organically degradable. Recovery of sodium sulphate.
- There is research about new ionic liquids to dissolve cellulose without sulphur emissions. TreeToTextile invested in constructing a demonstration plant for upscaling the process technology for a new cellulose fibre (TreeToTextile, n.d.).

© TENCEL™ Luxe branded lyocell filaments, Lenzing AG

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Synthetic Fibres

- Synthetic fibres are mostly based on oil as a non-regenerative raw material.
- They are very important concerning their properties as thermoset and thermoplastic materials such as polyester and polyamide.
- Specially for technical applications these polymers are very important but also the recycling processes are of high significance (Camlibel, 2018) as synthetic fibres are resistant to rotting and therefore not biodegradable.
- Fibres cause plastic waste through used textiles. They also release microplastics through fibre abrasion, especially during textile care.

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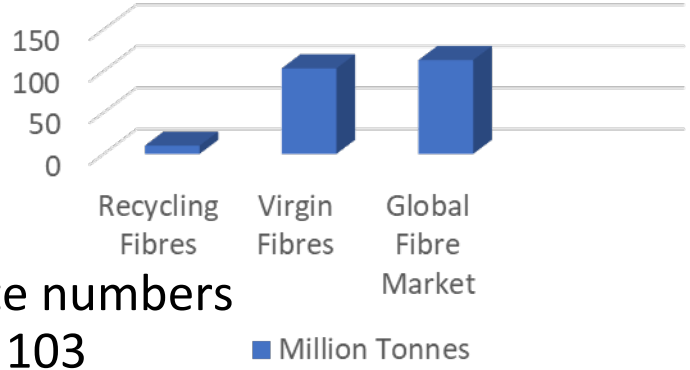
Global Recycled Fibre Market

- In 2021, the overall uptake of recycled fibres compared to the total fibre production was around 8.5% including 7.9% recycled polyester from plastic bottles and around 0.6% of all fibres including all other recycled fibres.
- Less than 1% of the global fibre market was from pre- and post-consumer recycled textiles.
- In 2021, the market share of recycled fibres increased to 8.5% and the percentage of virgin fibres decreased to 91.5% . However, in absolute numbers the virgin fibre production volume increased to 103 million tonnes in 2021. (Textile Exchange, 2022a, p. 12).



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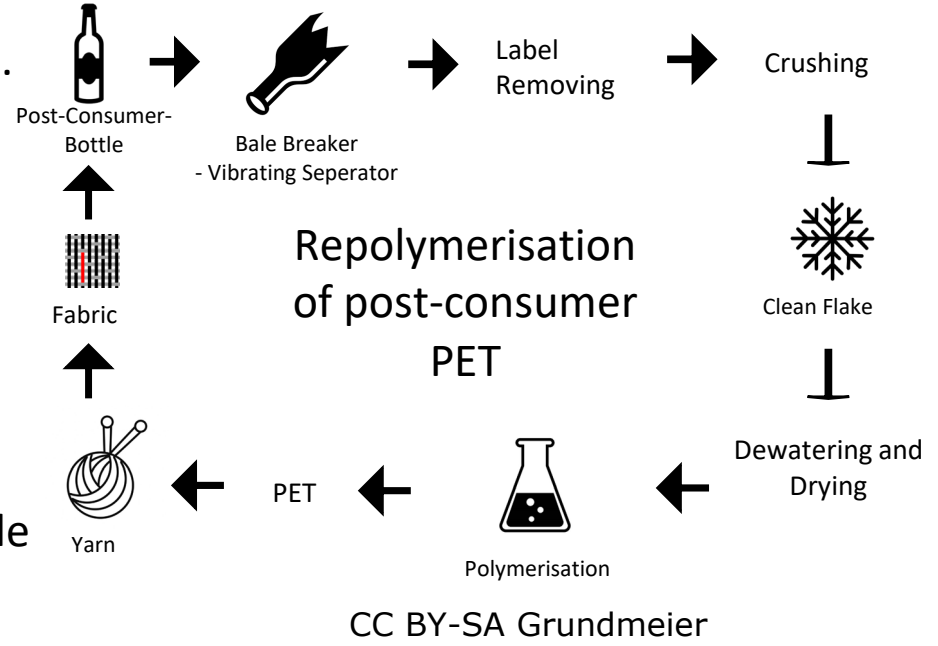
Polyethylene terephthalate (PET) Recycling

- 60% of the PET produced worldwide is used for fibre production (Lumitos, n.d.).
- Fibres made from recycled polyester (rPET) use 33 to 53% less energy (byewaste, n.d.).
- About 49% of the world's clothing is made of polyester due to the ongoing trend towards sportswear (Elven, 2018).
- Sustainable products obtained by recycling of PET are mainly used as textile fibres (Sarioğlu & Kaynak, 2018).



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Recycling of Synthetic Fibres in 2021

- With around 9 million tonnes (15%) in 2021, Polyester had the highest recycled fibre percentage. Around 99% of the recycled polyester was PET bottle-based (Textile Exchange, 2022a, p. 99).
- The main standards used for recycled polester are the Global Recycled Standard (GRS), the Recycled Claim Standard (RCS) and the SCS Recycled Content Standard (Textile Exchange, 2022a, p. 72).
- The market share of mechanically and chemically recycled polyester is less than 1% because of the overall costs and energy costs, technological challenges, feedstock suitability and availability (Textile Exchange, 2022a, p. 73).
- Textile Exchange (2022a, p. 12) estimated that the market share for recycled elastane was around 3%, for recycled polyamide around 2% and for recycled polypropylene around 0.2%.

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Sustainable Strategies

- At the moment the priority must be to keep synthetic fibres in a loop in order to avoid single-use plastic.
- As more than 8 million tonnes of plastic end up in the oceans every year, the number of initiatives working on the collection of plastic in the ocean as a feedstock for recycling increases (Parker, 2019; Sorrentino, 2022).

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- Abandoned Plastic Waste (OBP) comprises microplastics, mezzo-plastics and macro-plastics, located within 50 km from shores where waste management is inexistent or inefficient (Ocean Bound Plastic, n.d.).
- The European Textile and Clothing Trade Association EURATEX joined forces with CIRFS (chemical fibres), European Outdoor Group, FESI (sporting goods) and AISE (detergents) in 2018 to form an alliance against microplastic input from the washing of synthetic textiles. (see microplastics presentation)

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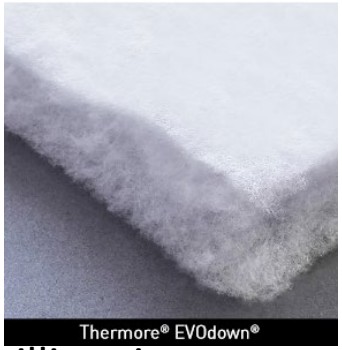
Thermore® EVOdown®

- The Milan-based company Thermore® (n.d.) specialises in batting/ warming fleeces with a high proportion of recycled fibres.
- The EVOdown® thermal fleece is made from 100% recycled PET bottles. The fibres are encased in two outer layers.
- A new fleece jacket can be made from about 25 PET bottles. Very little water is needed in the PET production process. In addition, the use of PET bottles helps to reduce waste and no new raw material is used. Every year, about 40% of PET bottles in Europe are processed into fibres.
- This reduces the daily waste mountain of plastic bottles by 10 million, i.e., approximately 200.000 tonnes of primary raw materials are saved. (Industrievereinigung Chemiefaser e. V., n.d.)


Thermore® EVOdown®

© Thermore®

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Engineered PET Depolymerase

- Polyethylene terephthalate (PET) is the most common polyester plastic, produced annually worldwide for the use in textiles and packaging.
- According to current estimates, 150-200 of the 359 million tonnes of plastic produced worldwide each year end up in landfills or in the environment.
- The main recycling process for PET, which is thermomechanical, results in a loss of mechanical properties.
- This raises the question of whether recycling within the same product cycle would not make more sense. When recycled polyester loses its buckling strength, more fibres enter the waterways and the environment through abrasion.
- Therefore, new processes with highly efficient, optimised enzymes to depolymerise PET within a shorter time are developed. (Tournier et al., 2020).

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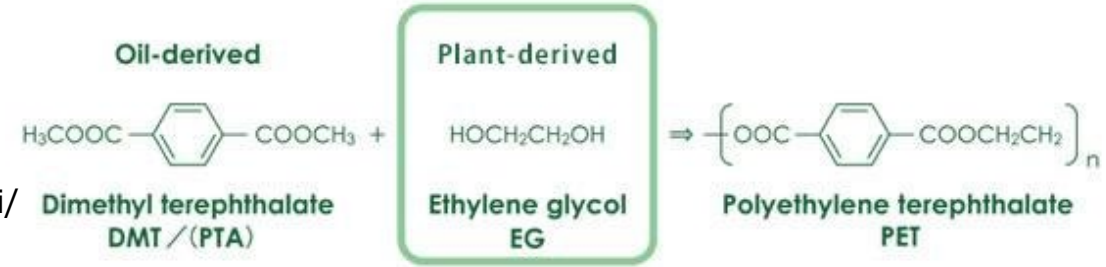
Alternative Bioplastics

- There are polyester fibres whose polymers are partly derived from plants by replacing some structural components of the PET polymer.
- Since the materials are partly of plant origin, they can help curb the consumption of fossil fuel resources and reduce greenhouse gases.
- The properties are similar to petroleum-based polyethylene terephthalate (PET). Bioplastics are not necessarily more biodegradable than synthetic plastics.

Illustration:
https://www2.teijin-frontier.com/english/sozai/specifics/plantpet.html



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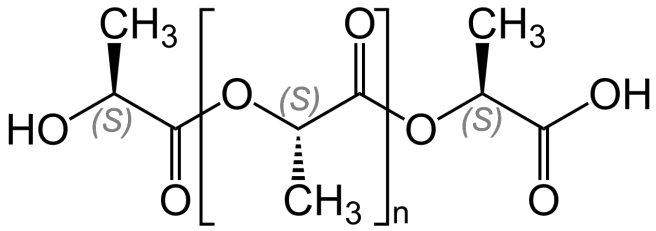
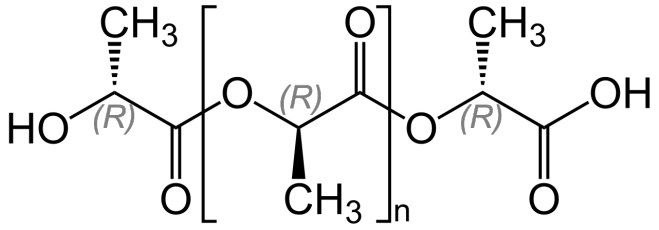
Polylactide (PLA)

- Polylactides (PLA) are synthetic polymers based on renewable raw materials such as sugar cane or corn, which belong to the polyesters.
- The material, which is made up of lactic acid molecules, is one of the biodegradable plastics - but only in industrial composting plants within a few months. PLA decomposes more slowly in nature. (Storz & Vorlop, 2013).





Polylactides of (S)-lactic acid (top) and (R)-lactic acid (bottom) $(C_3H_4O_2)_n$
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Recycled Fibres on the Rise

- The largest source of textile waste in Europe is discarded clothes and home textiles from consumers, which accounts for around 85% of the total waste.
- Therefore, consumers have to be informed why and how to keep their clothes in the loop and finally return their clothes and home textiles.
- A major problem for recycling are the fibre blends of used textiles. There are first companies developing technologies to separate cotton and polyester fibres for recycling.
- Fibre-to-fibre recycling technologies must further expand their ability to handle fibre blends, lower their costs, and improve their output quality as these are
  the bottlenecks which prevent the circular textile economy from scaling.
- By overcoming these barriers, fibre-to-fibre recycling could reach 18 to 26% of gross textile waste in 2030 (McKinsey Apparel, Fashion & Luxury Group, 2022, pp. 7-8)

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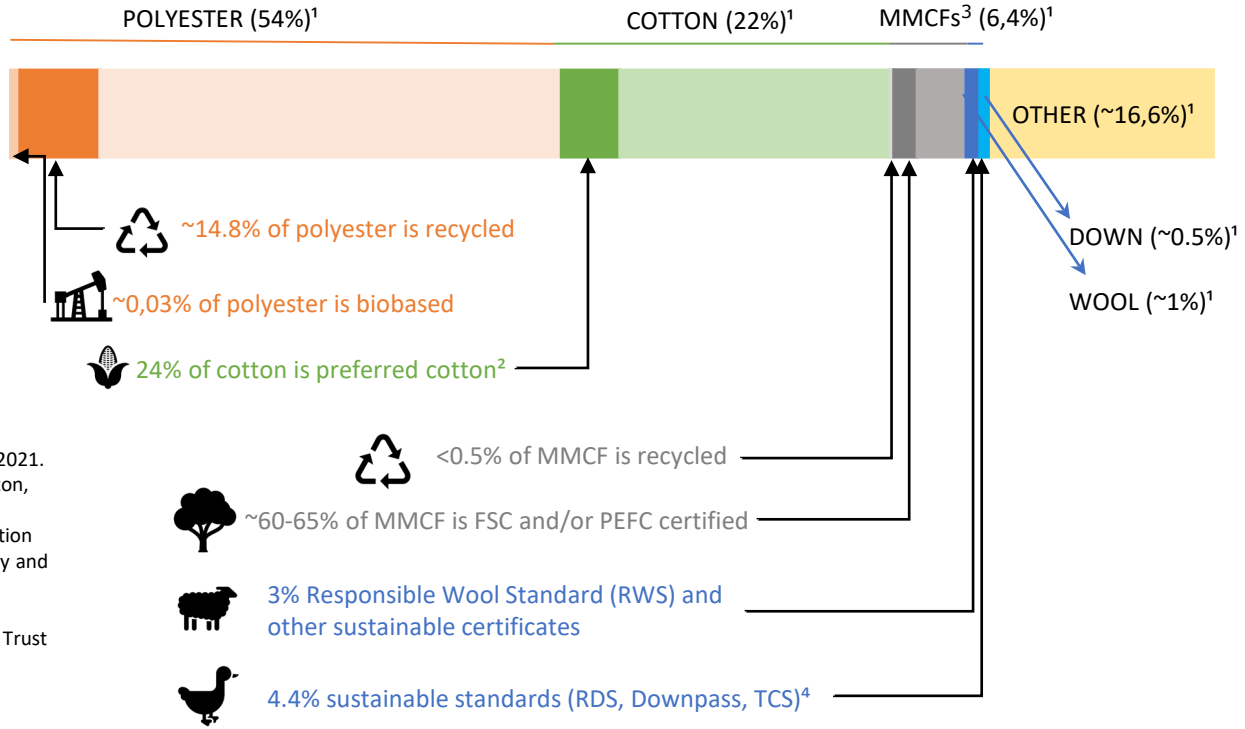
Key Facts and Figures in 2021

GLOBAL FIBRE MARKET OVERVIEW

113 million mt In 2021
+ 30% In the next 10 years
149 million mt In 2030 if business continues as usual
x 2 In the last 20 years

Only 7 years left until 2030

[1] Percentages of global fibre production volume in 2021.
[2] This includes BASF e3, Better Cotton, Cleaner Cotton, Cotton made in Africa (CmiA), Fairtrade, Fairtrade organic, in-conversion cotton, Israel Cotton Production Standard System (ICPSS), International Sustainability and Carbon Certification (ISCC), myBMP, Organic, REEL Cotton, Regenerative organic Certified (ROC), Responsible Brazilian Cotton (ABR) and U.S. Cotton Trust Protocol (USCTP).
[3] Manmade Cellulosic Fibres.



© Source: Textile Exchange, 2022a, p. 5-6

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Conclusion and Discussion

- How can the future of the fibre market be made sustainable?
- What strategies for natural and synthetic polymers do you think make sense to accommodate the idea of a circular economy?
- Discuss the following statement by Dr. Carmen Hijos, founder of Piñatex®:

"Design is a connecting tool between people, economics and the environment – and out of this communion, understanding and respect new ideas and products with integrity can come about." (Ananas Anam, n.d.).

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