Biobased textile sector

State-of-the-art and potential role in the EU bioeconomy

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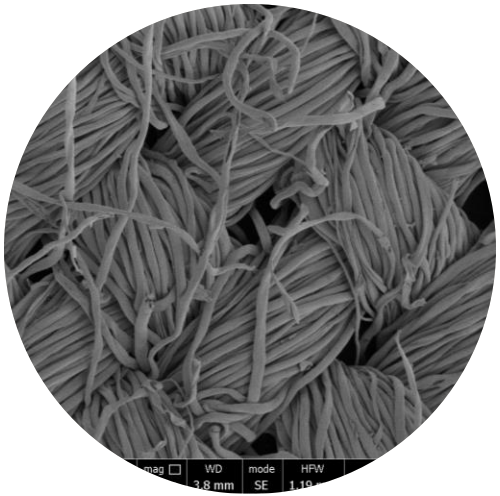

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What is biobased textile?

Textile industry: 3 value chains to produce 3 fibre types

1 Natural fibres

Biobased **fibres** of biological origin formed by plants, animals

Resources: Produced by farmers that produce fibre crops or breed animals for their hairs

Fibres: Cotton, flax, hemp, wool etc

2 Semi-synthetic fibres

Man-made fibres of biobased **polymers** (cellulose), often called regenerated cellulose fibres or MMCFs

Resources: Produced by forests owners that produce wood

Fibres: Viscose, lyocell, cupro etc.

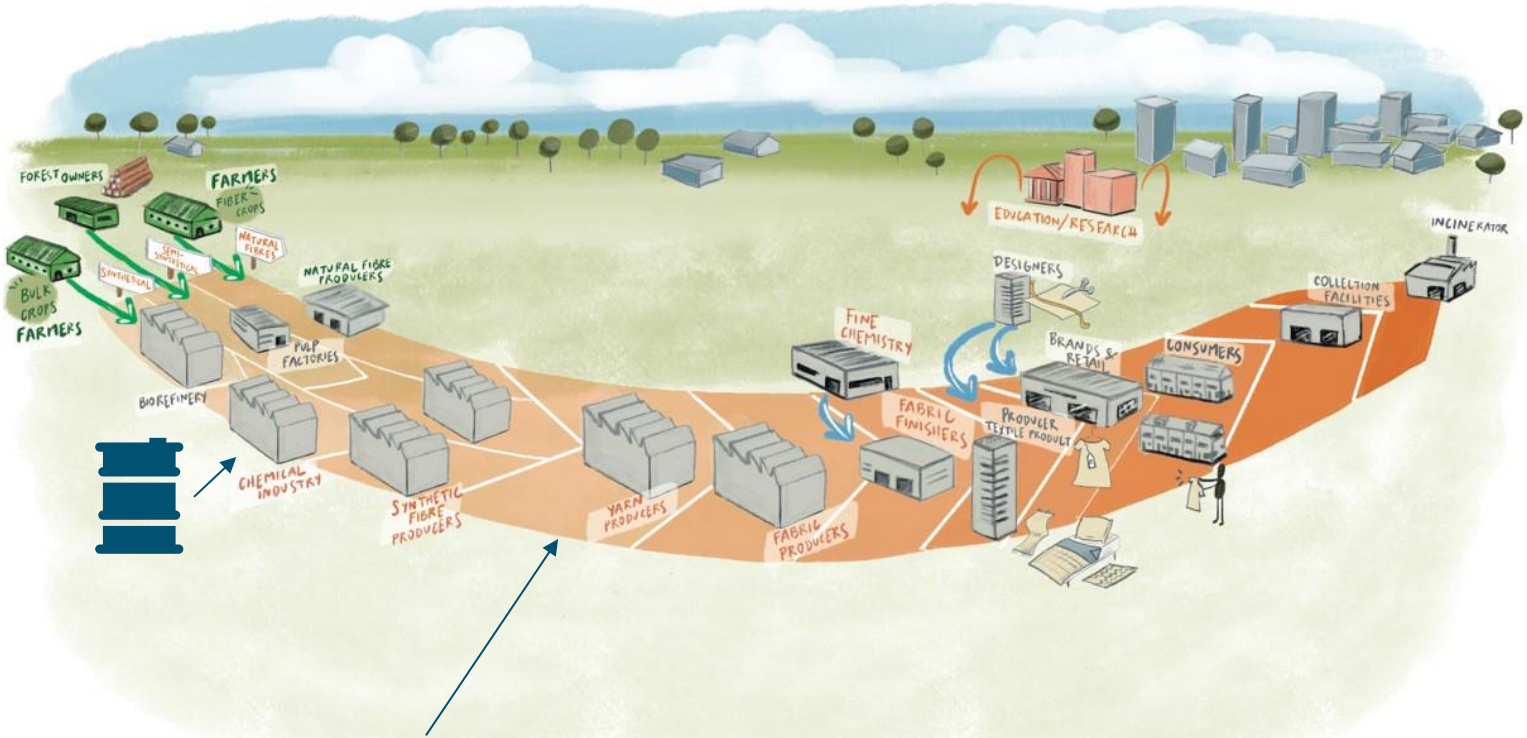
3 Synthetic fibres

Man-made fibres made by polymers build up from **monomers** (fossil or biobased)

Resources: Mainly fossil oil, but also biobased options

Fibres: Polyester(s), polyamide(s), elastane etc.

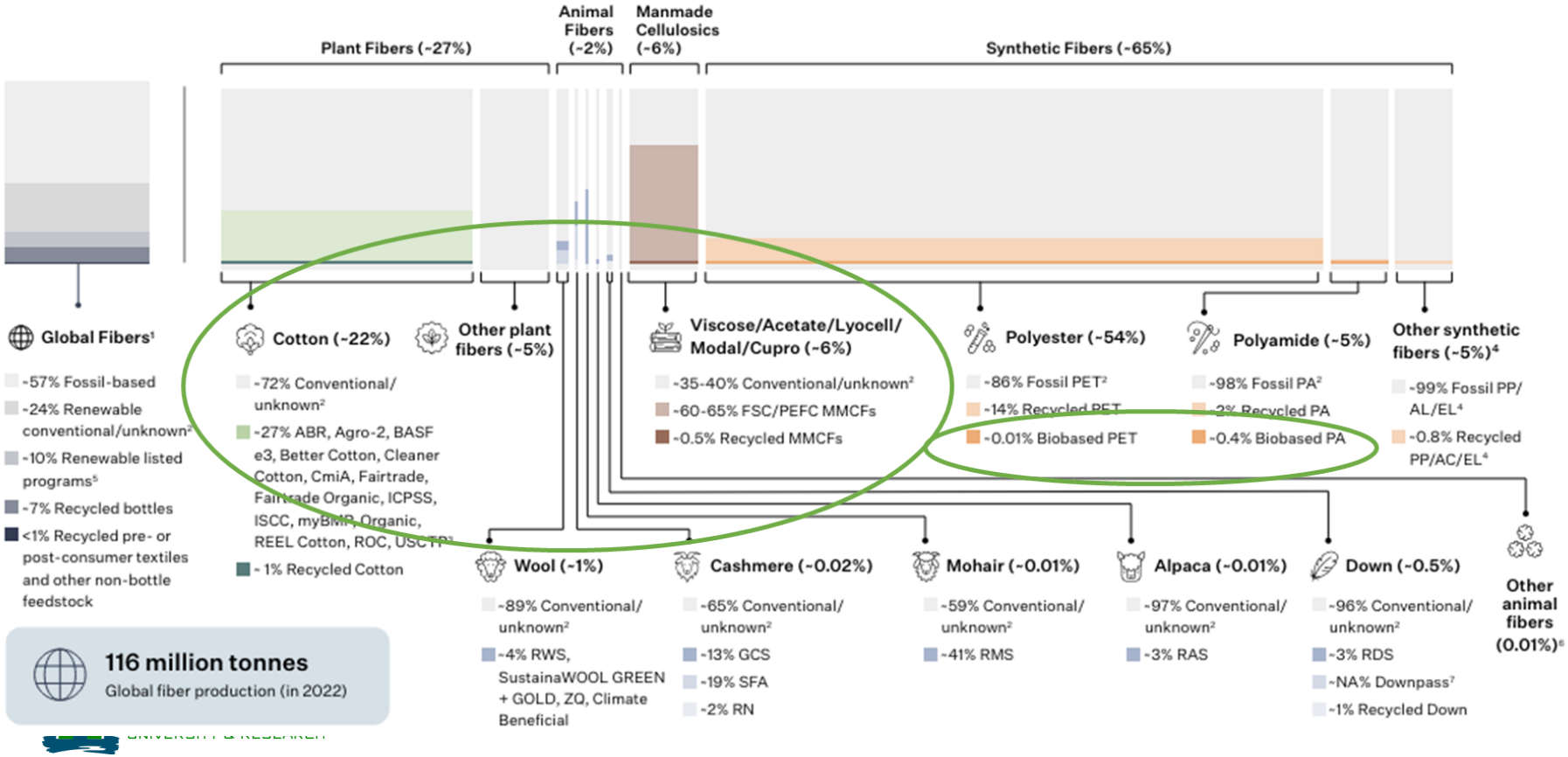
3 Value chains – 3 Fibre types



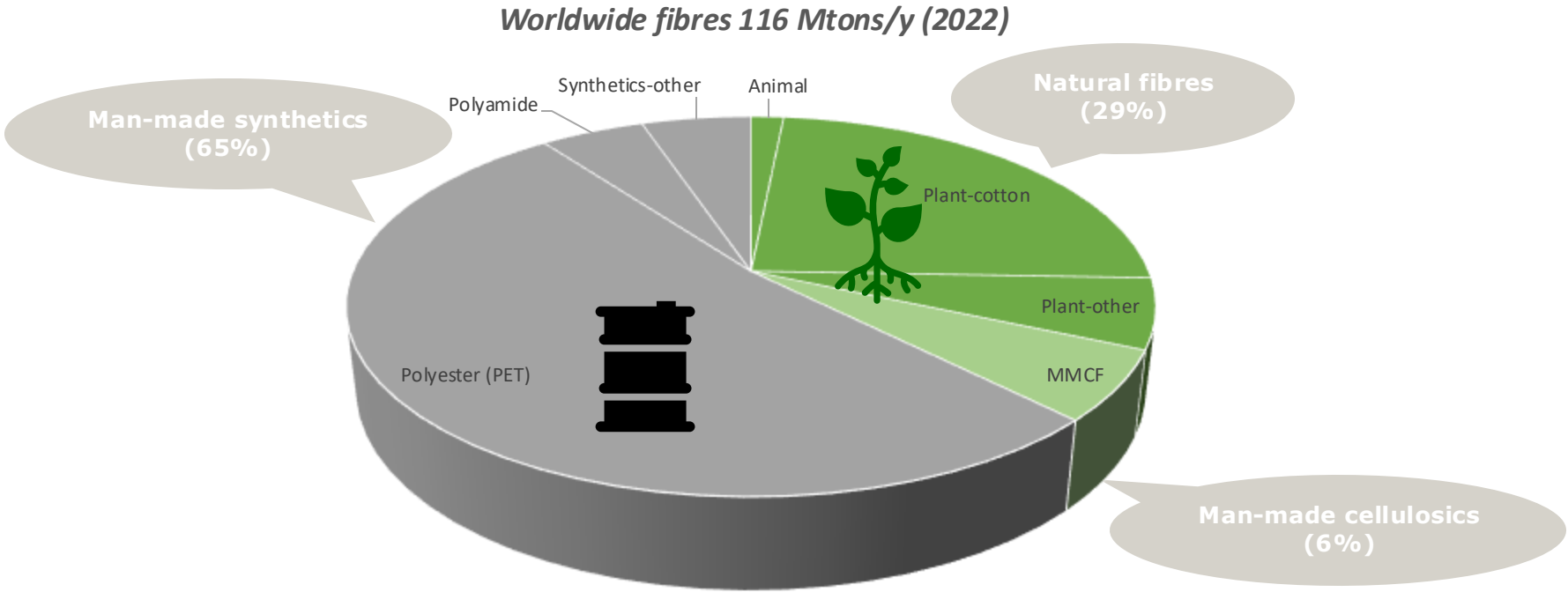
At a certain point in the value chain the 3 fibre types come together in the creation of textiles

Natasha Sena - claspvisuals.com

The global fiber market 2022: Program overview[2]

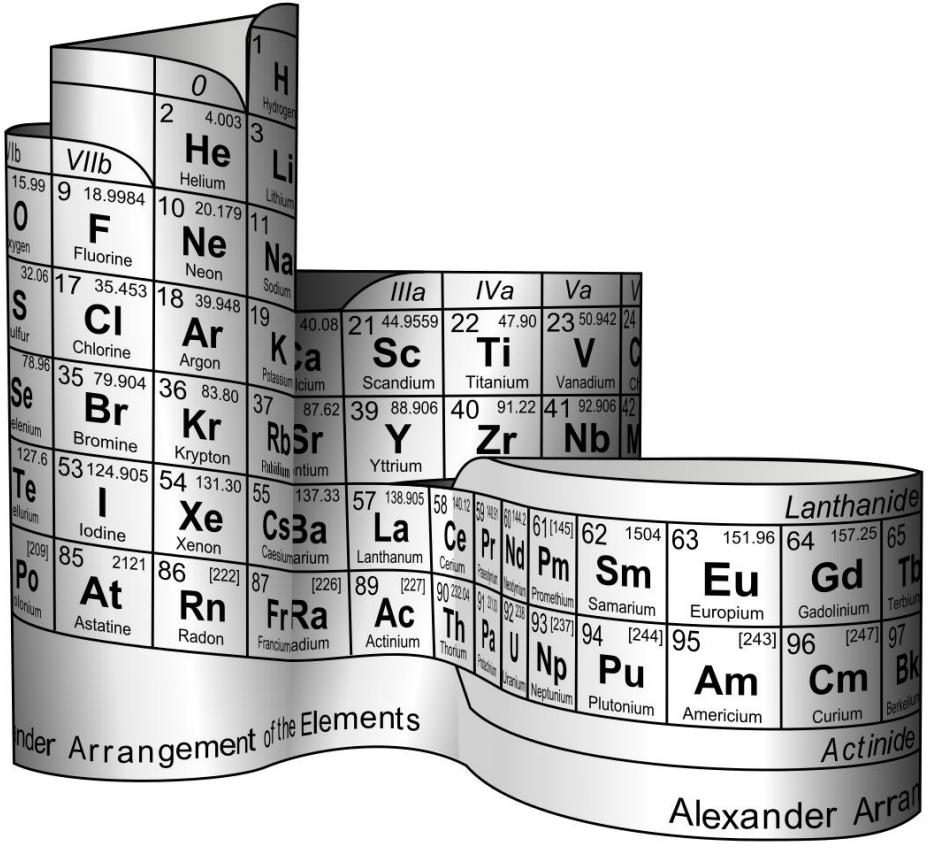


Resources for textile fibres



Textiles are made of carbon

- From fossil carbon to renewable carbon:
  - How and where do we source the carbon-based feedstock?
- What needs to change in production and use of textiles to make them circular?



Harmsen, P., W. Post and H. L. Bos (2022). *Textile for circular fashion. Part 2: From renewable carbon to fibres*. Wageningen, Wageningen University & Research.

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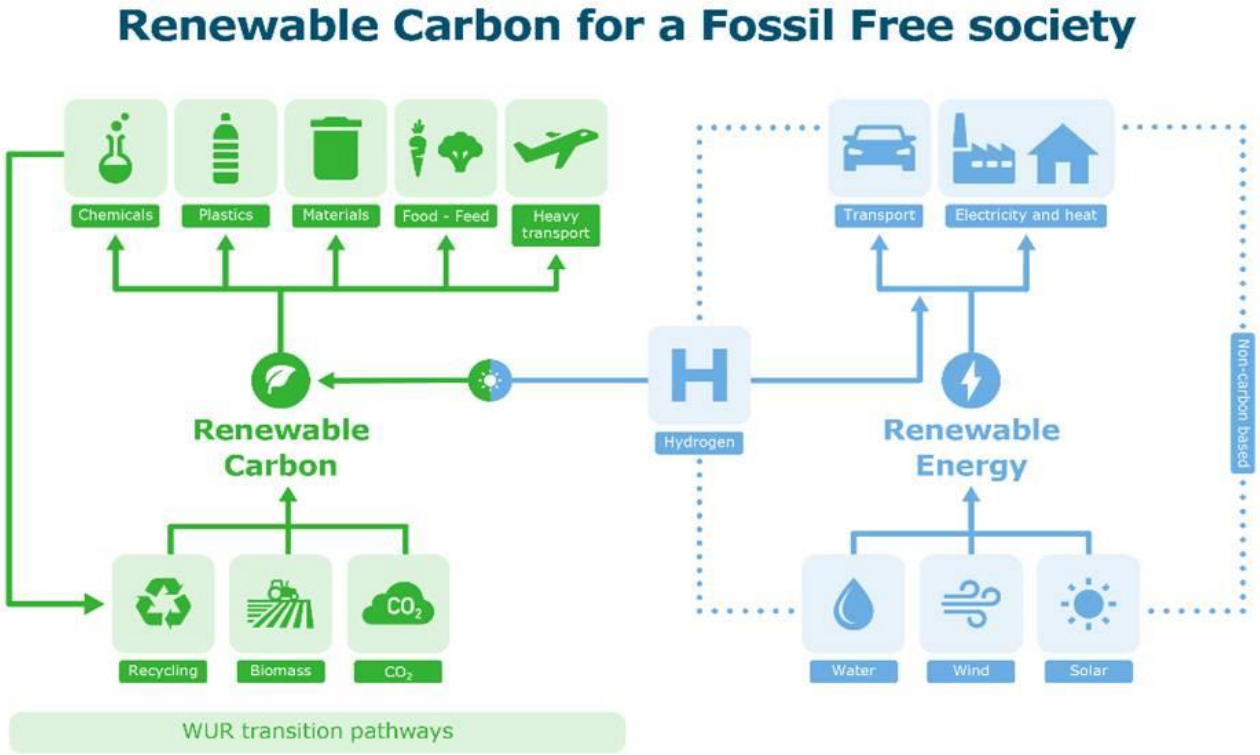
Sources of renewable carbon

TRANSFORMATIVE Bioeconomies

Towards a materials transition that phases out fossil feedstock



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Carbon sources for future circular textile fibres

- For circular textiles we aim to
  - Reduce the use of (virgin) resources
  - Phase out fossil resources
  - Prevent the release of harmful microfibres to the atmosphere
- As renewable carbon source we have three options
  - Biomass
  - Recycled content
  - CO_2

Today & Tomorrow

Today	Fossil	Biomass	Recycled	CO_2
Natural fibre	Not possible	Mature	In development	Not possible
Semi-synthetic fibre	Not possible	Mature	In development	Not possible
Synthetic fibre	Mature	In development	In development	In development

Tomorrow?	Fossil	Biomass	Recycled	CO_2
Natural fibre	Not possible	Mature	In development	Not possible
Semi-synthetic fibre	Not possible	Mature	In development	Not possible
Synthetic fibre	Mature	In development	In development	In development

1 Natural fibres; common characteristics

- Production
  - Production start with farmers
  - Requires land, water, pesticides
  - Harvest is labour intensive
- Consumers
  - Cotton is accepted, bast fibres (linen, hemp) less attractive
  - Wool and other animal hairs less attractive for vegetarians/vegans
- Environment
  - Fibres are biodegradable

Overview natural fibres

Fibre name/Material	Explanation	fibre type	polymer class	specific polymer	sources
Abaca	A hard fiber from the leaf stems that form the trunk of the abaca plant, Musa textilis. Of the s	Natural fibre	Polysaccharide	Cellulose	Biobased
Agave	A genus of plants native to the western hemisphere that has been distributed worldwide an	Natural fibre	Polysaccharide	Cellulose	Biobased
Alpaca	A domesticated cousin of the llama and a member of the camel family, native to the high An	Natural fibre	Polyamide	keratin	Biobased
Angora goat	A small, hardy animal that can find nourishment in rough brushland where other animals are	Natural fibre	Polyamide	keratin	Biobased
Angora rabbit	A breed of rabbit originally raised in North Africa and France and now raised in Great Britain,	Natural fibre	Polyamide	keratin	Biobased
Bamboo fibre	Fiber that can be produced from the bamboo plant grown in China, India, and Indonesia as w	Natural fibre	Polysaccharide	Cellulose	Biobased
Banana fibre	Fibers, which are obtained from plants of the banana family. Abaca, obtained from Musa test	Natural fibre	Polysaccharide	Cellulose	Biobased
Bast fibre		Natural fibre	Polysaccharide	Cellulose	Biobased
Camel	A large ruminant mammal used in the deserts of Asia and Africa as a pack animal and for ridir	Natural fibre	Polyamide	Keratin	Biobased
Cashmere	1. A fine, soft, downy wool undergrowth produced by the cashmere goat, which is raised in tl	Natural fibre	Polyamide	Keratin	Biobased
Cotton	A vegetable seed fiber consisting of unicellular hairs attached to the seed of several species	Natural fibre	Polysaccharide	Cellulose	Biobased
Feather	Feathers are epidermal growths that form a distinctive outer covering, or plumage, on both a	Natural fibre	Polyamide	Keratin	Biobased
Flax	A slender annual plant, Linum usitatissimum, the bast fiber of which also is called linen. The	Natural fibre	Polysaccharide	Cellulose	Biobased
Hair	Used interchangeably with fiber in reference to vegetable and animal fibers. It is difficult to	Natural fibre	Polyamide	Keratin	Biobased
Hemp	A coarse, strong, lustrous bast fiber obtained from the inner bark of the hemp plant, Cannabi	Natural fibre	Polysaccharide	Cellulose	Biobased
Hennequen	A hard leaf fiber obtained from the henequen plant, Agave fourcroydes, of the Amaryllidace	Natural fibre	Polysaccharide	Cellulose	Biobased
Hop fibre	A bast fiber obtained from the stems or vines of the hop plant, Humulus lupulus. It is woven	Natural fibre	Polysaccharide	Cellulose	Biobased
Jute	A bast fiber obtained from the round pod jute, Corchorus capsularis, or the long pod jute, Co	Natural fibre	Polysaccharide	Cellulose	Biobased
Kemp	A short, coarse wool or hair fiber with a large (>60% of fiber diameter), unevenly developed r	Natural fibre	Polyamide	Keratin	Biobased
Kenaf	A soft bast fiber similar to jute, obtained from the inner bark of the kenaf plant, Hibiscus can	Natural fibre	Polysaccharide	Cellulose	Biobased
Linen	Linen is one of the oldest known textile fibers. Archeologists in the country of Georgia in 200	Natural fibre	Polysaccharide	Cellulose	Biobased
Llama	1. Lama glama, a ruminant animal native to the high Andean regions of southern Ecuador, Pe	Natural fibre	Polyamide	Keratin	Biobased
Milkweed	Milkweed plants, Asclepias incarnata and A. syrica, yielding a floss and a bast fiber. The floss,	Natural fibre	Polysaccharide	Cellulose	Biobased
Mink	Fur or fiber from animals in the genus Mustela.	Natural fibre	Polyamide	Keratin	Biobased
Mohair	1. A long, white, lustrous hair obtained from the angora goat. It ranges from 4 to 12 in. (10 to	Natural fibre	Polyamide	Keratin	Biobased
Muskrat	Animal fiber from the muskrat, genus Ondrata, usable in textiles	Natural fibre	Polyamide	Keratin	Biobased
Nettle fibre	A fine, sort bast fiber obtained from two species of the stinging nettle, Urtica dioica and Urtic	Natural fibre	Polysaccharide	Cellulose	Biobased
Palm fibre	Any fibers obtained from plants or trees of the palm family. See palmetto, palmyra, piassava	Natural fibre	Polysaccharide	Cellulose	Biobased
Pineapple fibre	A fine, strong, white, lustrous leaf fiber obtained from the pineapple plant, Ananas comosus,	Natural fibre	Polysaccharide	Cellulose	Biobased
Raffia	1. A leaf stalk fiber obtained from the raphia palm, Raphia ruffia, in the Democratic Republic	Natural fibre	Polysaccharide	Cellulose	Biobased
Rattan	A lightweight, very tough fiber obtained in strips from the woody stems of plants of the genu	Natural fibre	Polysaccharide	Cellulose	Biobased
Rubber, natural	A raw material (polyisoprene) obtained from the sap (latex) of the rubber tree (*Hevea sp.*). T	Natural fibre	Rubbers	Polyisoprene	Biobased
Sheep hairs	Ruminant quadruped mammal of the genus Ovis whose likely ancestry has been traced to th	Natural fibre	Polyamide	Keratin	Biobased
Silk	Continuous protein filament (fibroin) produced by the larvae of various insects, especially m	Natural fibre	Polyamide	Fibroin	Biobased
Sisal	A hard leaf fiber obtained from the sisal plant, Agave sisalana, of the Amaryllidaceae family.	Natural fibre	Polysaccharide	Cellulose	Biobased
Vicuña	The smallest species of South American camel family, the vicuña, Auchenia vicugna, is native	Natural fibre	Polyamide	Keratin	Biobased
Wool	Traditionally, fibers covering the skin of sheep, Ovis sp. However, as defined in the Wool Pro	Natural fibre	Polyamide	Keratin	Biobased

1 Natural fibres; challenges/gaps

- Cotton
  - Sustainable production
- Bast fibres
  - European crops, is growth possible?
  - Improve isolation of bast fibres (retting processes)
  - Invest in European processing facilities
- New alternatives
  - What are promising new crops that can grow in Europe?

2 Semi-synthetic fibres; common characteristics

- Production
  - Production starts with forest owners or farmers
  - Requires land, water, pesticides?
  - Based on cellulose; mainly wood, but also other (fast growing) crops like bamboo can be used
  - Processing to cellulose pulp and spinning to fibres are chemical processes
- Consumers
  - No big issues, accepted by customers
- Environment
  - Fibres are based on cellulose and thus biodegradable

Overview semi-synthetic fibres

Fibre name/Material	Explanation	fibre type	polymer class	specific polymer	sources
Cellulose, acetate		Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Cellulose, carbamate		Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Cellulose, cold alkaline		Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Cellulose, ionic liquid		Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Cellulose, microfibrillated		Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Lyocell	Generic classification for solvent-spun cellulosic fiber approved for use in the U.S. by the FTC	Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Milk fiber	Milk fibers are regenerated protein fibers made from a chemical substance and casein, which	Semi-synthetic fibre	Polyamide		Biobased
Modal	British generic fiber category for manufactured fibers of cellulose having a high breaking stre	Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Rayon	A generic fiber category defined by the Federal Trade Commission as “a manufactured fiber c	Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Rayon, Cuprammonium rayon (Cupro)	Rayon yarn or staple made by the cuprammonium process. It is a regenerated cellulose. In th	Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Viscose, wood	One of the three types of rayon and that which is produced in the greatest quantity and diver	Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased
Viscose, bamboo	Regenerated cellulosic fiber produced from bamboo.	Semi-synthetic fibre	Polysaccharide	Cellulose	Biobased

2 Semi-synthetic fibres; challenges/gaps

- Use of land, water, pesticides
- Growth is possible, based on European crops
    - Invest in European processing facilities?
- Not only cellulose but also proteins can be processed into semi-synthetic fibres (e.g. based on milk protein)
    - Is there potential?

3 Synthetic fibres; common characteristics

- Production
  - Mostly outside Europe
  - Starts with the fossil industry
  - Monomers and polymers are produced by the chemical industry
  - Dominated by one type of polyester (PET)
- Consumers
  - Attractive for consumers due to price, availability and performance
- Environment
  - Fibres are often not biodegradable, accumulate in nature (microplastics)

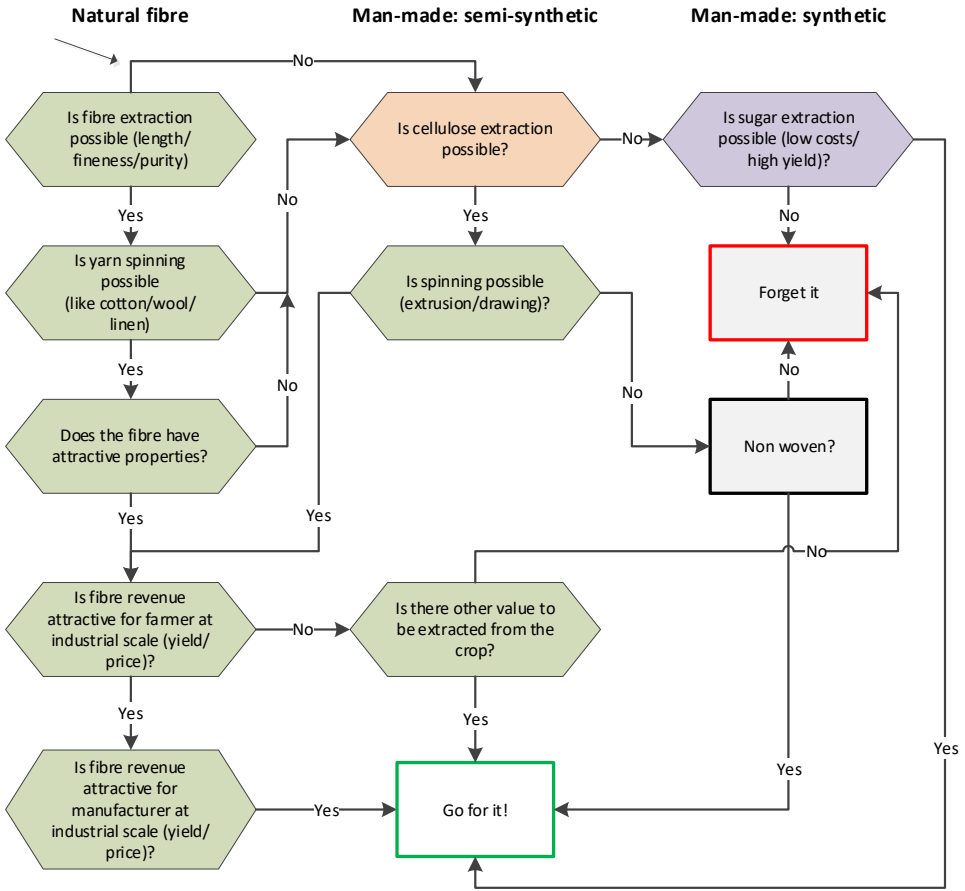
Overview synthetic fibres

Fibre name/Material	Explanation	fibre type	polymer class	specific polymer	sources
Acrylic		Synthetic fibre	Polyacrylic	Polyacrylic acid	Fossil (oil)
Aramide		Synthetic fibre	Polyamide	Aramid	Fossil (oil)
Elastane		Synthetic fibre	Polyurethane	Elastane	Fossil (oil)
Elastodiene	(British usage) A generic name for fibers of natural or synthetic rubber	Synthetic fibre			Fossil (oil)
Elastoester	A generic name for fiber defined by the FTC as at least 50% by weight aliphatic polyether and	Synthetic fibre			Fossil (oil)
Elastomer	A synthetic rubbery material, which has the excellent stretchability and recovery of natural r	Synthetic fibre			Fossil (oil)
Fluoropolymer	Generic name for fiber defined by the Federal Trade Commission as “a manufactured fiber co	Synthetic fibre			Fossil (oil)
Micropolyester	More absorbent, breathable, and more comfortable.	Synthetic fibre	Polyester	olyethylene terephthalat	Fossil (oil)
Neoprene	A generic name for a type of synthetic rubber made from the monomer chloroprene. Can be	Synthetic fibre	Rubbers		Fossil (oil)
Nylon 11		Synthetic fibre	Polyamide	Nylon 11	Fossil (oil)
Nylon 4		Synthetic fibre	Polyamide	Nylon 4	Fossil (oil)
Nylon 6		Synthetic fibre	Polyamide	Nylon 6	Fossil (oil)
Nylon 6,12		Synthetic fibre	Polyamide	Nylon 6,12	Fossil (oil)
Nylon 6,6		Synthetic fibre	Polyamide	Nylon 6,6	Fossil (oil)
Nylon fibre	A generic fiber category defined by the Federal Trade Commission as “a manufactured fiber i	Synthetic fibre	Polyamide		Fossil (oil)
Polyacrylate	Any addition polymer based on one or more esters of acrylic acid, CH2 =CH–COOR. Various pc	Synthetic fibre	Polyacrylate	Polyacrylic acid	Fossil (oil)
Polyacrylic acid	Addition polymer based on acrylic acid, CH2 =CH– COOH. Used as a water-soluble sizing mate	Synthetic fibre	Polyolefin	Polyacrylic acid	Fossil (oil)
Polyacrylonitrile (PAN)		Synthetic fibre	Polyacrylic	Polyacrylonitrile	Fossil (oil)
Polybutadiene		Synthetic fibre	Rubbers	Polybutadiene	Fossil (oil)
Polybutylene furanedicarboxylate (PBF)		Synthetic fibre	Polyester	butylene furanedicarboxy	**Biobased**
Polybutylene succinate (PBS)		Synthetic fibre	Polyester	Polybutylene succinate	**Biobased**
Polybutylene terephthalate (PBT)		Synthetic fibre	Polyester	olybutylene terephthalat	Fossil (oil)
Polyester fibre	Generic name for “a manufactured fiber in which the fiber-forming substance is any long-cha	Synthetic fibre	Polyester	olyethylene terephthalat	Fossil (oil)
Polyester Recycled fibre	Recycled polyester (rPET) is a synthetic textile fiber and is obtained by melting the plastic an	Synthetic fibre	Polyester	olyethylene terephthalat	Recycled
Polyether fibre	Manufactured fiber from a polymer containing ether (R–O–R) groups. Various experimental f	Synthetic fibre			Fossil (oil)
polyethylene (PE) fiber	Olefin fiber made by extruding polyethylene. For many years, the features of a low melting p	Synthetic fibre	Polyolefin	Polyethylene	Fossil (oil)
Polyethylene furanedicarboxylate (PEF)		Synthetic fibre	Polyester	yethylene furanecarboxyl	**Biobased**
Polyethylene terephthalate (PET)		Synthetic fibre	Polyester	olyethylene terephthalat	Fossil (oil)
Polyimide fibre (PI or PEI)	Manufactured fiber that is used in high temperature, flame-retardant applications. The polyn	Synthetic fibre			
Polyisobutene		Synthetic fibre	Rubbers	Polyisobutene	Fossil (oil)
Polyisoprene		Synthetic fibre	Rubbers	Polyisoprene	Fossil (oil)
Polylactic acid (PLA)	A manufactured fiber in which the fiber forming substance is composed of at least 85% by we	Synthetic fibre	Polyester	Polylactic acid	**Biobased**
Polyolefin	Any long-chain synthetic polymer composed of at least 85% by weight of ethylene, propylene	Synthetic fibre	Polyolefin		Fossil (oil)
Polypropylene (PP)	Olefin fiber manufactured from the addition polymer of propylene, CH3 –CH=CH2, obtained f	Synthetic fibre	Polyolefin	Polypropylene	Fossil (oil)
Polystyrene (PS)	A manufactured fiber made of melt- or dry-spun polystyrene. The fiber has low to medium te	Synthetic fibre	Polyolefin	Polystyrene	Fossil (oil)
Polytetrafluoroethylene (PTFE)		Synthetic fibre		Polytetrafluoroethylene	Fossil (oil)
Polytrimethylene terephthalate (PTT)		Synthetic fibre	Polyester	ytrimethylene terephthal	Fossil (oil)
Polyurethane (PU) fibre	A synthetic fiber that was produced in Germany during the Second World War and later the s	Synthetic fibre	Polyurethane		Fossil (oil)
Polyvinyl alcohol (PVA)		Synthetic fibre	Polyolefin	Polyvinyl alcohol	Fossil (oil)
Polyvinyl chloride (PVC)		Synthetic fibre	Polyolefin	Polyvinyl chloride	Fossil (oil)
Rubber, synthetic	A manufactured elastomeric polymer. Includes synthetic polyisoprene, polybutadiene, certa	Synthetic fibre	Rubbers		Fossil (oil)
Spandex	A generic fiber category that has been defined by the Federal Trade Commission as “a manuf	Synthetic fibre	Polyurethane	Elastane	Fossil (oil)

3 Synthetic fibres; challenges/gaps

- Production
  - Fully biobased polyesters (PLA, PEF, PHAs) and partly biobased polyesters (PET, PTT, PBT) available/in development
  - Application of new polyesters in textiles in development
  - Biobased polyesters/polyamides volumes low due to price, availability (land use) and questions about sustainability
- Consumers
  - Drop-ins are no issue, as materials are similar
  - Fully biobased alternatives (PLA, PEF, PHAs)?
- Environment
  - Drop-ins not biodegradable, fully biobased ones are being investigated

Biomass decision tree



Overarching challenges

- Biomass discussions for food, energy and biobased products (e.g. textiles)
    - What if fossil resources are phased out? 2/3 is of fibres is now fossil-based
    - Food vs fibre discussions; Building vs textile discussions
- Consumer behaviour
    - Price, availability, properties
    - Not level playing field (import China)
- Circularity
    - R-ladder
    - End-of-life options

Outlook (in my view)

- Growth of biobased fibres for textile in Europe is possible
    - Land use is a big puzzle; competing uses
        - #Ha?
        - Which biomass streams/fibre crops?
        - Which fibre types in particular?
    - Gaps in processing infra-structure need to be solved
    - Consumer behaviour/acceptance needs to be addressed
- All is dependent on the availability of fossil resources in the future

Thank you

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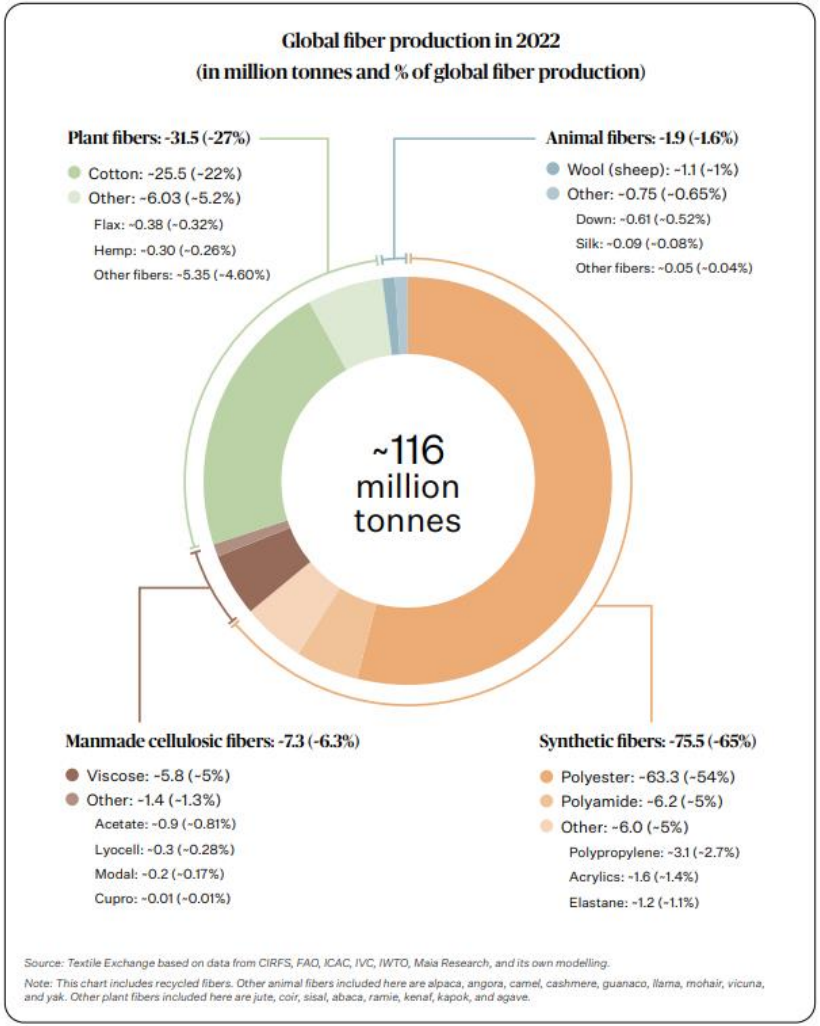
Wageningen Food & Biobased Research

Global fibre production*

*Apparel, home, footwear, others

- Natural fibres 29 wt%
  - Plant 31,5 M tonnes
  - Animal 1,9 M tonnes
- Semi-synthetics 6 wt%
  - MMCFs 7,3 M tonnes
- Synthetics 65 wt%
  - Polyester (PET) 63,3 M tonnes
  - Polyamide 6,2 M tonnes
  - <1 wt% is biobased

App. 1/3 of the global fibre production is biobased



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