focus paper

Responsible production

Issue April 2024

Naturally positive

Lenzing
Innovative by nature

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Overview

This focus paper "Responsible Production" describes the biorefinery and fiber production processes. It provides an overview of the Lenzing Group's manufacturing processes with particular regard to environmental aspects.

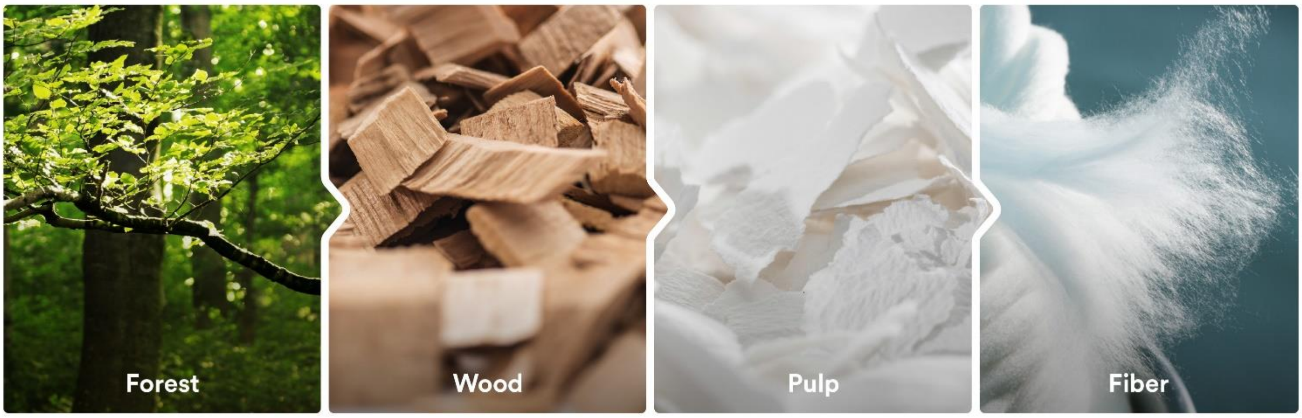

Figure 1: Schematic process stages of fiber production from wood.

In recent years, interest in regenerated cellulosic fibers has increased due to their sustainability credentials. When the source of raw material is from sustainable forestry, as proven by forest certificates and state-of-the-art production processes are applied, regenerated cellulosic fibers can have a very favorable environmental footprint.

Regenerated cellulosic fibers are produced from the natural polymer cellulose. Production starts with wood or other plant-based materials, extracts cellulose pulp from them, and then shapes the polymer into fibers and filaments using different technologies (viscose, modal, lyocell). The final fiber product mainly consists of the natural polymer cellulose, with a chemical structure identical to natural fibers (e.g. cotton, linen).

A range of regenerated cellulosic fibers are biodegradable in freshwater, marine and soil conditions as well as compostable in home applications and industrial facilities and therefore provide an environmentally responsible alternative to fossil-based plastic materials in textiles and nonwovens, but also in packaging and other applications.

Shaping of cellulose pulp into fibers requires a special quality of pulp, referred to as dissolving wood pulp, which must meet different requirements from those for paper pulp. Among other things, dissolving wood pulp must have a higher pure cellulose content of over 90 percent, lower impurity levels, be bleached to a higher level of brightness and have a more uniform molecular weight distribution. Dissolving wood pulp is the most important raw material used in producing regenerated cellulosic fibers, including Lenzing's fibers.

The Lenzing Group's current dissolving wood pulp production capacities are located in Austria, the Czech Republic and Brazil. In addition to its own dissolving wood pulp production, Lenzing procures dissolving wood pulp in the global market, mostly under long-term supply contracts.
Fiber production capacities are located in Austria, United Kingdom, USA, Indonesia, Thailand and China. See Figure 2 for more information on production sites and office locations.

Numbers = Nominal capacities as at December 31, 2023

Figure 2: Lenzing Group locations

Lenzing contributes to Sustainable Development Goal (SDG) 12, “Responsible consumption and production”, with sustainable sourcing, efficient use of raw materials, longstanding experience with biorefineries, life cycle thinking along the value chain and a long pipeline of innovative and sustainable products.

Biorefinery – Pulp production in the Lenzing Group

Figure 3: The biorefinery product LENZING™ Acetic Acid Biobased is widely used in the food industry.

A biorefinery is a facility for sustainable processing of biomass into a spectrum of marketable biobased products as well as bioenergy.

Lenzing's biorefinery process ensures that 100 percent of wood constituents are used to produce dissolving wood pulp for fiber production, biobased products, and bioenergy, thereby maximizing value creation from an economic and environmental perspective.

Dissolving wood pulp production at each Lenzing pulp site is not only self-sufficient in terms of meeting its own energy demand but the process actually generates more energy than needed. This surplus green energy is used on-site (e.g. for integrated fiber production) or fed to the local power grid. Lenzing pulp sites also produce biorefinery products such as acetic acid, furfural and magnesium lignosulfonate, increasing the total yield from wood as well as creating additional economic value and reducing impacts to the environmental.

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Pulping technologies

In the pulping process, logs are debarked, chipped and treated in a cooking liquor. Cellulose is a major component of wood – around 40 percent of the wood substance – and is separated as raw pulp in this process. This pulp is then washed and screened to remove the residual cooking liquor, knots, and impurities. The raw pulp is bleached in a totally chlorine-free (TCF) process and turned into pulp sheets or flakes. The other wood constituents remain within the thin liquor together with other cooking chemicals. The cooking chemicals are recovered and recycled from the liquor and the organic components are converted into bioenergy (steam and electricity).

Pulp bleaching in the Lenzing Group

Bleaching is necessary to yield a dissolving pulp quality suitable for regenerated cellulosic fibers, such as viscose, modal, and lyocell. Most dissolving wood pulp producers use elemental chlorine-free (ECF) pulp bleaching processes.

Lenzing's three biorefineries produce pulp using a TCF (totally chlorine-free) bleaching process without using any chemicals containing chlorine, but with oxygen-based substances.

Due to the omission of chlorine-based bleaching methods, dissolving wood pulp produced in the Lenzing Group not only has less impact on the environment and human health but also ensures the high quality required for fiber production. The technology at all three plants complies with the EU Best Available Techniques (EU BAT)

In addition to its own pulp production, Lenzing procures pulp on the global market (ECF). Not all fiber types offered by Lenzing can be produced using Lenzing's own totally chlorine-free (TCF) pulp because they require specific pulp qualities.

Table 1: Bleaching process at Lenzing, Paskov and Indianópolis

Site	Lenzing	Paskov	Indianópolis
Nominal capacity (tons per year of air-dry pulp)	320,000	285,000	500,000
Biorefinery products	Acetic acid, furfural, xylose, magnesium-lignosulfonate, soda (sodium carbonate), hemilye, mother liquor	Magnesium-lignosulfonate, soda (sodium carbonate)	
Use of energy surplus	Used for fiber production at the site	Electricity delivered to public grid	Electricity delivered to public grid
Main wood source	Beech	Spruce	Eucalyptus
Sustainability features	TCF bleaching		
Production technology	Magnesium bisulfite process		Prehydrolysis Kraft process
Pulp cooking chemicals used	Magnesium oxide, sulfur dioxide		Sodium hydroxide, sodium sulfide
Bleaching chemicals used	Oxygen, ozone, hydrogen peroxide, sodium hydroxide		

Biorefinery plant in Lenzing, Austria

The facility in Lenzing, Austria, is the largest integrated pulp and cellulosic fiber production plant in the world. Integrated dissolving wood pulp and fiber production not only provides exceptional economic benefits, it also offers many environmental advantages and savings compared to non-integrated mills. For instance, there is no need for transportation of pulp because of the short distances involved, which itself eliminates the need for energy-intensive drying and packaging of pulp.

The Lenzing plant produces dissolving wood pulp required for fiber production on-site. Traditionally, wood for pulp production at the Lenzing site consists mainly of beech (*Fagus sylvatica*)[1]. Marketable biorefinery products such as acetic acid, furfural, and xylose are obtained in further processing steps. More than half of the wood is transformed into pulp and other biobased products.

Pulp production at the Lenzing site is self-sufficient in terms of meeting its own energy demand. Surplus energy (steam and electricity) is used on site, for instance for fiber production. Lenzing's expertise in integrated dissolving wood pulp and fiber production is the basis for future opportunities towards carbon neutrality and to contribute to the greenhouse gas reduction target.

Organic chemicals from pulp production waste streams are extracted early on in the biorefinery process at the Lenzing (Austria), Paskov (Czech Republic) and Indianópolis (Brazil) sites which significantly reduces the chemical oxygen demand (COD) of effluent water. This is one example of best practices where potential waste streams are converted into useful products, thereby avoiding pollution and reducing the amount of wastewater to be treated at wastewater treatment plants.

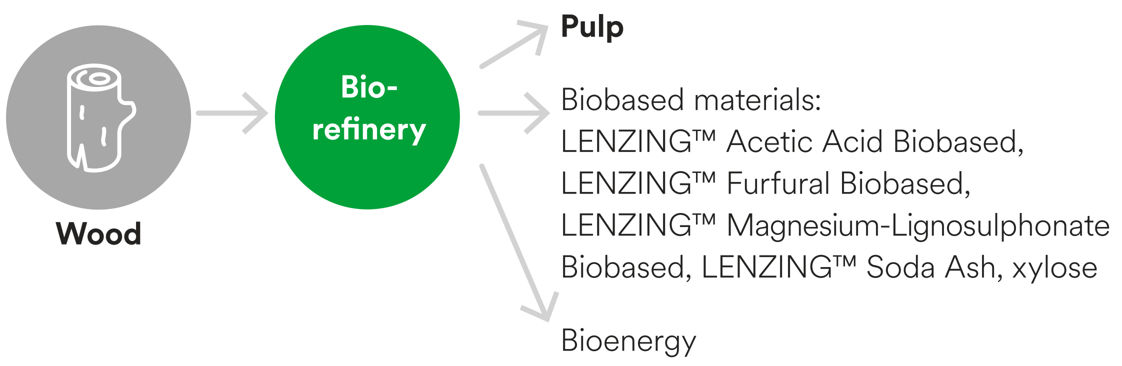

Figure 4: Highly efficient use of the raw material wood at the Lenzing site, Austria.

[1] For more information on wood used by Lenzing, please see the Wood and Pulp Focus Paper.

Biorefinery plant in Paskov, Czech Republic

The raw material base for the facility in Paskov is spruce wood (*Picea abies*) in the form of logs and chips. The dissolving pulp production process based on magnesium bisulfite is similar to that employed at the Lenzing site (Austria). The other two major components of wood – lignin and hemicellulose – are dissolved in the liquor. The insoluble remainder is crude unbleached pulp. This pulp is then washed and screened. Further, deeper removal of lignin and hemicellulose is performed by means of alkali extraction and a TCF bleaching process. After final fine screening, the pulp is dried in sheets, baled, and dispatched. The Paskov site is completely self-sufficient in terms of heat and electricity generation and supplies its surplus electricity to the public grid.

Pulp production at the Lenzing, Indianapólis and Paskov sites is not only self-sufficient in terms of meeting its own energy demand, it actually produces surplus energy. This surplus energy (steam and electricity) is either used on site or fed to the public grid. All pulp produced at Lenzing pulp production sites is totally chlorine-free.

Biorefinery plant in Indianópolis, Brazil

Lenzing's newest pulp mill performed well in its first full reporting year in 2023. It has a capacity of 500,000 tons dissolving wood pulp and is a joint venture with the Brazilian Dexco (formerly, Duratex) group. Lenzing holds a 51 percent stake, while Dexco has a 49 percent stake. The industrial capital expenditure (CAPEX) in the joint venture was approximately USD 1.4 bn.

Key aspects that compelled Lenzing to enter into the LD Celulose joint venture with Dexco in Brazil were its track record and reputation for environmentally responsible forest management, its tradition of respect for the environment, its experience in responsible and productive forest management, and its extensive knowledge of the Brazilian Forestry Code, which is one of the most stringent in the world. Lenzing only works with certified and controlled wood sources to ensure supply chain sustainability. The mill adopts Best Available Techniques (EU BAT) and Best Environmental Management Practices (BEMPs), aiming at reducing air emissions, liquid effluents, noise and solid waste generated by the industrial processes. In addition, more than 50 percent of the electricity generated by biomass at the site is fed into the public grid as renewable energy. The produced pulp is 100 percent FSC® certified and totally chlorine-free (TCF).

Fiber technologies

Lenzing's product portfolio extends from dissolving wood pulp as a basic raw material to generic fibers and innovative specialty fibers as well as energy, biorefinery products and co-products from fiber production.

The Lenzing Group combines comprehensive expertise in operating pulp and biorefinery processes with decades of experience in three major fiber process technologies:

- Viscose (rayon)
- Modal
- Lyocell

Based on the lyocell process, three new process technologies have been developed in recent years: REFIBRA™ technology for textiles, Eco Filament technology and LENZING™ Nonwoven technology. For more information, please refer to the chapter "Further technologies", page 17 of this focus paper.

Lenzing's high-quality fibers are supplied to the textile and nonwoven industry as well as for industrial applications. Each of the fiber types has its special properties valued in textile, nonwoven and industrial applications and is therefore an integral part of the product portfolio.

Two-stage production process

Regenerated cellulosic fibers are produced from wood in a two-stage process. In the first stage pulp is produced, very similar to the production of paper. In a second stage, pulp is dissolved and cellulosic fibers are regenerated from the solution into a shape suitable in diameter and length for use in textile and nonwoven applications. The final product consists mainly of natural cellulose and a broad range is biodegradable in soil, fresh water and marine conditions as well as compostable in home applications and industrial facilities (see Focus Paper "End of product use").

Fiber types on the world market

In line with its strategic focus on specialties, the Lenzing Group offers a portfolio of different fiber types on the basis of the technologies described above. In order to meet the broad range of requirements for textile, nonwoven or other industrial applications, regenerated fibers from Lenzing can be offered.

- With different fiber fineness, from the finest microfibers to coarse fibers for carpets;
- in various cut lengths (from shortcut fibers for special applications in wipes or as reinforcing material in fiber composites to long staple fibers for wool blends);
- with modified cross-sections;
- or as tow.

Furthermore, regenerated fibers can be functionalized by incorporating certain compounds into the spinning mass. Examples include flame retardant agents, spin dyes, dulling agents etc.

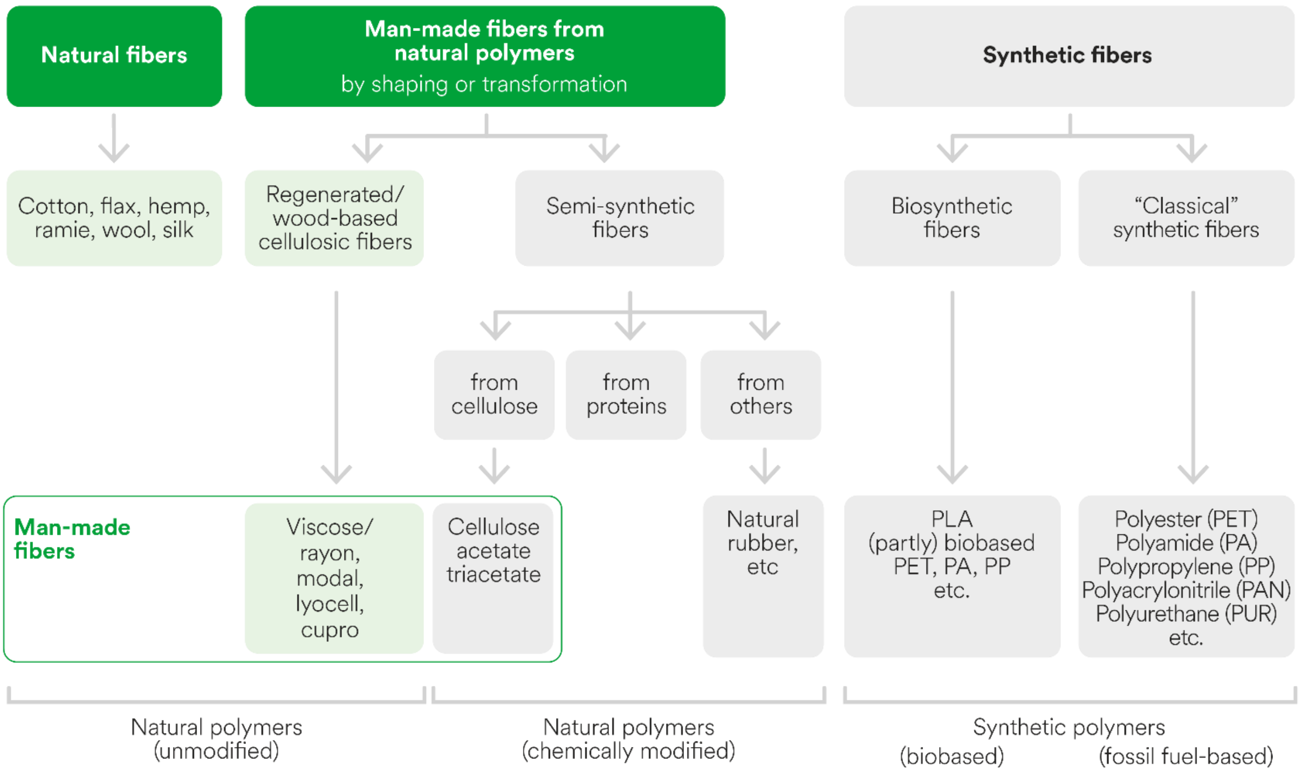

Figure 5: Fiber types on the world market

Lenzing's viscose and modal production process

Viscose fibers were the first regenerated cellulosic fibers produced on an industrial scale since the late 19th century and are produced in a multi-step process. In contrast to the Lyocell process, where cellulose is directly dissolved in a respective solvent (NMMO[2]), the cellulose in the viscose process needs to be derivatized by a chemical reaction (xanthation with carbon disulfide) prior to being dissolved in sodium hydroxide solution.

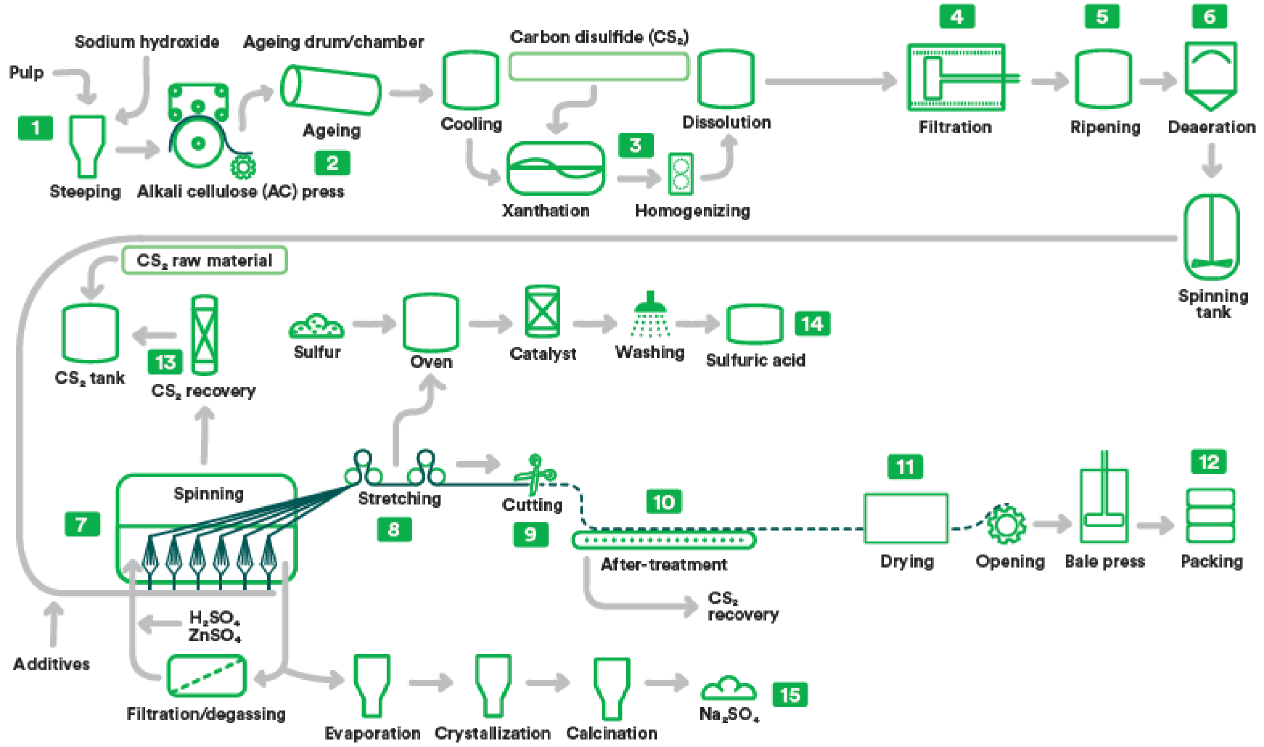

Figure 6: Lenzing's viscose and modal production process

Lenzing's modal fibers are exclusively produced in Lenzing (Austria) and Nanjing (China) in a modified viscose process. At the Lenzing (Austria) site an integrated production process is employed in which the raw material pulp is produced at the same site as the fiber itself.

In the first step, pulp is steeped in a sodium hydroxide solution and is converted to alkali cellulose (AC) after pressing out excess lye (1). The AC is then aged in a drum or chamber (2) prior to reacting with carbon disulfide (CS_2) in a reaction chamber (3). The resulting xanthate is then dissolved in lye prior to being filtered (4). The resulting deep orange and highly viscous cellulose solution (hence the name) is then ripened (5) and deaerated (6) before the viscose enters the spinning process. The cellulose solution is pressed through a number of orifices into an acidic spin bath where a plurality of single filament tows is formed (7). After stretching of the tow (8) it is cut into the desired staple fiber length (9). In the after-treatment (10) the staple fibers are desulfurized, repeatedly washed and bleached and finally a finish agent is applied. After drying (11) of the viscose fibers they are pressed into bales and finally packed (12).

[2] NMMO: N-Methylmorpholine N-oxide is an aqueous, biodegradable, organic solvent

CS_2 is recovered from different waste gas streams (13) and is fed back into the system. Sulfur compounds containing waste gas streams are also converted into sulfuric acid (H_2SO_4) in several process steps and are reused in the process (14). Zinc is precipitated and recovered from the waste water. Sodium sulfate, generated as a reaction product of sulfuric acid and sodium hydroxide in the spin bath, is isolated as a co-product in a multi-step process (15) and is sold to other industries.

Lenzing's responsible viscose criteria

1

Responsible wood and pulp sourcing
Wood and pulp used in the viscose production process come from sustainably managed forests and plantations.

Evidence 1

- FSC R (FSC-C041246) or PEFC™ (PEFC/06-33-92) certified and controlled sources
- CanopyStyle verification (by Preferred by Nature) of the entire wood and pulp supply.

LENZING™ ECOVERO™ and VEOCEL™ branded fibers fulfill Lenzing's criteria for responsible viscose and provide a solution to improve the sustainability of the industry. These fibers are available from the Lenzing (Austria), Purwarkata (Indonesia) and Nanjing (China) sites.

2

Responsible production and closing the loops
Viscose production requires chemicals that need to be handled safely and effectively to reduce impacts on human health and ecological systems. Proper recovery and emission treatment equipment is required to reduce air and water emissions to a minimum and close the loops in the viscose process. For further details, see closing the loop, page 15.

Evidence 2

- LENZING™ ECOVERO™ and VEOCEL™ branded fibers are certified with EU Ecolabel (page 23).
- Higg MSI scores of LENZING™ ECOVERO™ and LENZING™ Viscose fibers show substantially better performance than generic viscose.
- OEKO-TEX® STANDARD 100, Annex 6, product class I - aligned with Detox Campaign

3

Safety and health for workers and community
Management practices such as safety trainings, safety walks & talks, safety and environmental management systems are required to run the process effectively and to make continuous improvements. This avoids health risks for employees and the community.

Evidence 3

- ISO 14001:2015 at all viscose sites
- ISO 45001:2018 at all viscose and lyocell sites

4

Quality and product safety
Quality is a key pillar of sustainability and product responsibility. Without quality, no product is sustainable, since it will not satisfy the intended function. Products must be safe to use and meet the purity requirements for the respective application.

Evidence 4

- ISO9001:2015,
- OEKO-TEX® STANDARD 100, Annex 6, product class I

5

Transparency along the value chain
Customers and consumers can support sustainable products if they have information about how and where the products are made. Track- and traceability of raw materials in the final product ensure that they originate from responsible resources, thereby preventing counterfeiting by unscrupulous producers. In the long run, this will help improve the overall sustainability of the industry thanks to informed decision-making by all parties.

Evidence 5

- Fiber identification technology for e.g. LENZING™ ECOVERO™ Viscose, ECOVERO™ x REFIBRA™, TENCEL™ Modal, LENZING™ FR
- Downstream value chain track and traceability via blockchain technology
- Lenzing fiber certification scheme

6

Substantiated claims for sustainability communication
Communication is essential for improving transparency. Responsible producers take communication seriously and help their customers and final consumers to use sustainable products with substantiated claims.

Evidence 6

- Marketing/Branding support
- Disclosure of potential impacts via Higg MSI

Closing the loops in the viscose process: best practice

In the viscose process, CS_2 and caustic soda (NaOH) are used to dissolve cellulose pulp to form the spinning mass. During this process, some carbon disulfide is transformed into hydrogen sulfide (H_2S). When regenerating the dissolved pulp as fiber in an acid spin bath, carbon disulfide and hydrogen sulfide are released as exhaust gases at different locations along the production process. As shown in the figure below, the three recovery systems required to close loops and to safely handle these gas streams are:

1. Condensation unit
2. Wet Sulfuric Acid (WSA) plant and
3. Carbon disulfide Adsorption Plant (CAP)

CS_2 exhaust streams with low hydrogen sulfide content are treated in the condensation unit as well as in the carbon disulfide adsorption plant (CAP) to recover it. CS_2 exhaust gas streams with higher hydrogen sulfide content are preferably recycled as sulfuric acid (H_2SO_4) via catalytic oxidation in wet sulfuric acid (WSA) plants.

Without a WSA plant, H_2S rich gas cannot be handled safely, and would be a potential hazard to human health. The recovered carbon disulfide in the condensation process and CAP plant and the sulfuric acid produced in the

Air emissions target	To improve the Lenzing Group's specific sulfur emissions by 50 percent by 2023 (baseline 2014)	Measures implemented
Measure(s)	Lenzing implements a carbon disulfide adsorption plant (CAP) upgrade at the Purwakarta plant (Indonesia)	2023
Progress made in 2023	The carbon disulfide adsorption plant (CAP) in the Purwakarta plant (Indonesia) was succesfully implemented and started operating in July 2023. Viscose fibers from this plant are now EU Ecolabel certified. All measures have been implemented for this target, however to achieve the target, the measures need to operate for a whole year.	

WSA plant are directly reused in the viscose process. This closes the loop of sulfur compounds used in the viscose process. Both technologies, state-of-the-art CAP and WSA, are essential. Proper maintenance of these systems is key to avoiding any release of CS_2, H_2S, SO_2, or other sulfuric substances. By doing so, more than 90 percent of the carbon disulfide can be recovered safely and reused in the process.

Viscose production facilities without a WSA plant face the challenge of handling hydrogen sulfide emissions from the viscose process. In this case, hydrogen sulfide may be processed through energy generation boilers or by absorbing hydrogen sulfide in caustic soda to form sodium hydrosulfide hydrate. Both of these alternative H_2S control measures have the disadvantage of lower recycling rates of sulfur chemicals compared to the WSA option. In addition, burning hydrogen sulfide in energy generation boilers also results in higher SO_2 emissions, unless the SO_2 emissions are recovered as gypsum.

Another prerequisite of a safe viscose process is a plant design with sufficient capacity in equipment such as blowers to ensure safe extraction and transfer of carbon disulfide and hydrogen sulfide to the recovery equipment described above.

Closing the loops in viscose and modal production process in the Lenzing Group

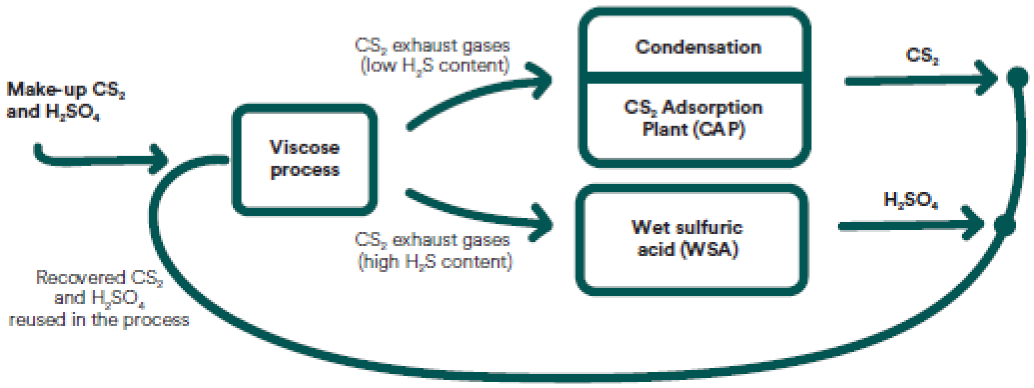

Figure 7: Closing the loop in viscose and modal production process

Lenzing's lyocell production process

Lyocell fibers are the latest generation of regenerated cellulosic fibers. They have been produced at a commercial scale for about 30 years. The generic fiber name is lyocell. The branded products from Lenzing are marketed as TENCEL™ Lyocell and VEOCEL™ Lyocell fibers.

The initial idea in developing the lyocell process was to derive cellulose fibers from pulp without relying on the chemically complex viscose process.

Best practice reporting

As there are many emission points along the viscose fiber production process, the Lenzing Group reports CS_2 and H_2S emissions, expressed as sulfur emissions, based on mass balance calculations, which reflect the reality much better than the single point measurements.

Similar to viscose fiber production, the raw material pulp is derived from renewable wood or to certain extend from alternative sources such as cotton scraps. In contrast to the traditional chemical viscose process, the lyocell process directly dissolves cellulose in the organic solvent N-Methylmorpholine-N-oxide (NMMO) without the need to derivatize the cellulose[3]. This means that, in contrast to the viscose process, no CS_2 is used and the overall production process for lyocell fibers is therefore simplified.

Waste generation in the production process is minimized thanks to closed loops and lower consumption as well as higher utilization of both chemicals and raw materials.

The lyocell production process starts by suspending pulp in water and NMMO in order to get a homogenous slurry (1). In the next process step, water is removed and cellulose is thereby dissolved to form a solution called dope (2). Prior to spinning, the cellulosic solution is filtered in order to remove undesired particles and undissolved material (3). The heart of the production is the spinning process (4) where the cellulosic solution is pressed through a number of very small orifices thereby forming cellulosic filament tows. These filament tows are cut into staple fibers of desired length and then enter the after-treatment zone where the fibers are washed and a finishing agent is applied (5). The wet staple fibers are then dried, opened, pressed into bales and finally packed to obtain the final product (6). The recovery rate of NMMO in the lyocell process is 99.8 percent. The recovery starts with filtration and pre-purification steps (7) of the spin bath before water is removed by evaporation (8) to obtain NMMO and the whole cycle can start again after minor solvent losses are compensated with make-up NMMO. Water that is obtained from the evaporation step is also fed back into the process (9) and only a small amount of water is sent to the wastewater treatment plant (10).

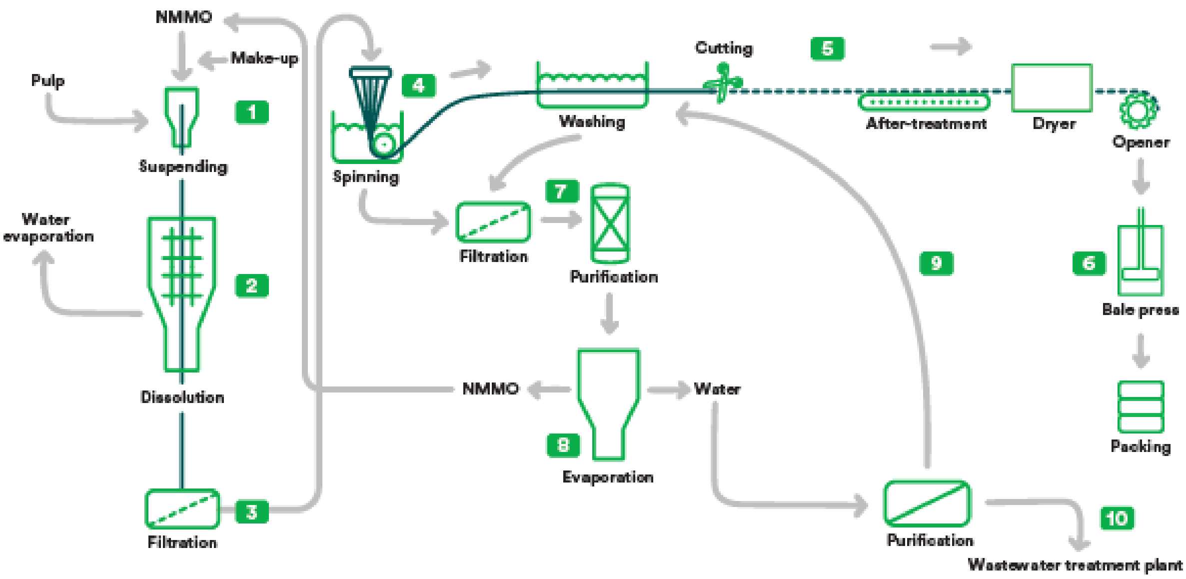

Figure 8: Lenzing's lyocell production process

3 For literature on the lyocell production process, see White 2001 and Ganster & Fink 2009

Lenzing has also developed technological measures to minimize the process energy required in lyocell production. The second-generation plant installed at the Lenzing site (Austria) includes new heat recovery systems to reduce energy consumption compared to the former plant design. In principle, due to the generally simple process requiring less effort to close the loops.
Use of lyocell fiber offers great advantages from an environmental perspective compared to other cellulosic fibers. Compared to the viscose process, the lyocell process is much less resource-intensive and leads to a significant reduction in chemical use due to conversion of pulp into fiber in a closed-loop process.

Lyocell fiber is the latest generation of regenerated cellulosic fibers. It has been produced at a commercial scale for 30 years. The generic fiber name is lyocell. The branded products from Lenzing are marketed as TENCEL™ and VEOCEL™ fibers.

Further technologies

Wastewater treatment plants

Effluents are discharged in a controlled manner, therefore avoiding groundwater contamination. Process water is treated by biological wastewater treatment plants (WWTPs). The Lenzing Group has wastewater treatment

„Waste water" target	**To improve Lenzing Group's specific wastewater emissions (chemical oxygen demand (COD)) by 20 percent by 2024 (baseline 2014)**	**2024 On track**
Measure(s)	Lenzing implements a wastewater treatment plant upgrade at Purwakarta site (Indonesia)	2023 Achieved
	Lenzing implements a new wastewater treatment plant at Grimsby (UK) site	**2024 On track**
Progress made in 2023	The building of the wastewater treatment in Purwakarta (Indonesia) took place in 2023, the start-up is planned for the beginning of 2024. The wasterwater treatment plant project in Grimsby (United Kingdom) is on track and will come into operation in 2024.	

plants at all its sites except Grimsby (United Kingdom). The Grimsby site complies with all local laws and regulations on wastewater as well as the EU Water Framework Directive. In order to meet the even more ambitious Lenzing Environmental Group Standards Lenzing is investing in a new WWTP. Site preparation has finished and as of 2023, construction is underway. The construction also entails a cooperation with the local government to apply new technology from an ongoing R&D project.

Lenzing's plant in Purwakarta (Indonesia) has made great progress in improving its environmental performance. The completed EUR 100 million plant upgrade includes an upgraded WWTP. Its construction concluded in 2023 and once it is fully operational, it will reduce wastewater emissions significantly.

In 2021, another WWTP upgrade project was approved for the site at Mobile, USA. The lyocell plant was one of the first of its kind and will undergo a modernization of the existing WWTP in order to meet the Group's sustainability strategy and target for COD emissions. This investment will not only help to fulfill future ZDHC requirements for lyocell production but will also allow potential enlargement of fiber production capacity. The project includes the refurbishment of existing structures and new modular elements for the most up-to-date wastewater treatment. The investment thereby extends the life cycle of the WWTP. Construction was completed in December 2023. Commissioning of the new systems has started and the operational transition is expected to take place during Q1/2024.

Textile recycling technology – contribution to circular economy

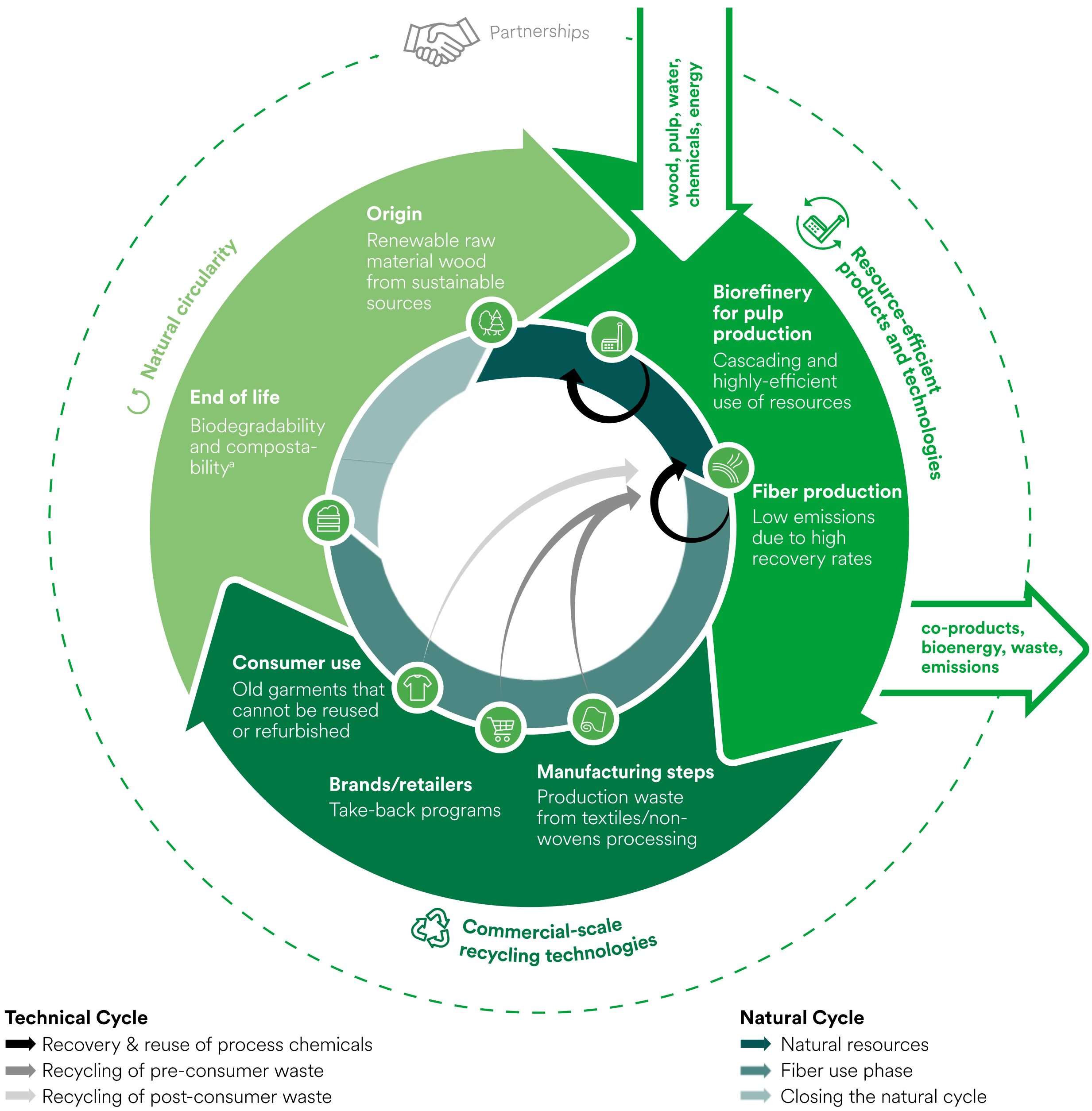

Figure 9: Lenzing's circular economy practices

In line with Lenzing's circular economy vision, "We give waste a new life". Every day, the current generation of innovative fibers, manufactured in a commercial large-scale, use pre-consumer cotton scraps, post-consumer garments, and wood from sustainably managed forests as a raw material. The cotton material is recycled into pulp which is blended (up to 30 percent) with dissolving wood pulp to produce high-quality lyocell fibers for textile and nonwovens applications. This technology diverts tons of cotton scraps and post-consumer garments from entering landfills or incineration. They are produced with high resource efficiency. By Lenzing's own calculations, Lenzing fibers with recycled content require 95 percent less water to produce and have a lower land use than conventional cotton.

Particularly in the development of circular flow models that enable economic growth without increasing the consumption of natural resources, close collaboration all along the value chain is essential for Lenzing. Accordingly, cooperation was sought and continues to take place with various partners – from raw material

„Textile recycling“ target	**To offer viscose, modal and lyocell staple fibers with up to 50 percent post-consumer recycled content on a commercial scale by 2025**	**2025 On track**
Measure(s)	All fibers with recycled content offered by Lenzing contain a share of post-consumer waste	**2022 Delayed**
	Lenzing increases the recycled content from 30 to 40 percent for fibers produced with REFIBRA™ technology for textiles	**2023 Delayed**
	Lenzing introduces its viscose and modal fibers with REFIBRA™ with a minimum of 30 percent recycled content	**2023 Delayed**
	Lenzing and Södra collaboration will recycle 25,000 t of textile waste per year at Södra's Mörrum site	**2025 Delayed**
Progress made in 2023	The joint efforts with Södra to develop a recycled pulp with a share of post-consumer waste on an industrial scale were again successfully continued and also honored by the ITMF-Award. Project plans have been updated to increase the intended volume of the new production line from 25 kt/a to 50 kt/a feedstock and start-up of this plant is forecasted for 2027. Overall, Lenzing continued with product and process development towards reaching the key target for 2025. One key milestone was the introduction of a viscose fiber with REFIBRA™ technology with 20 percent recycled pulp from post-consumer cotton textile waste, with the goal of further increasing this percentage in the near future. The biggest challenges remain to adapt the characteristic of recycled pulp for industrial fiber production and also to seek solutions to make recycled pulp processable on industrial scale.	

producers to fashion companies – in further development of the REFIBRA™ technology. Lenzing's R&D department is also actively engaging with the market, cooperating with interesting start-ups as well as guiding others in their approach. Lenzing also actively participates in cross-industry organizations (e.g. Ellen MacArthur Foundation, Sustainable Apparel Coalition's policy group) to further increase awareness and importance of the topic in the public and political sector.

Lenzing itself is further improving REFIBRA™ technology and showcasing its ecological benefits. On the technological side, this not only involves optimizing the processes, but also expanding the raw material base. Among others, it has been possible to increase the recycled content in these fibers to 30 percent, as well as enabling new applications in the textile sector by expanding the spectrum of available fiber types.

To drive transparency specifically in textile manufacturing, TENCEL™ Lyocell fibers with REFIBRA™ technology can be identified in the final product thanks to a special manufacturing system, even after long textile processing and conversion steps through the value chain. Furthermore, recycling options for nonwovens cut-waste and discarded textiles (post-consumer waste) are being assessed. This involves textiles and roll goods made from different fiber types, making it a very complex and challenging process.

Both TENCEL™ and ECOVERO™ fibers made with REFIBRA™ technology for textile applications and for nonwoven products are available with Recycled Claim Standard (RCS).

Recyled Claim Standard

The RCS is a chain of custody standard to track recycled raw materials through the supply chain.

The Recycled Claim Standard verifies the presence and amount of recycled material in a final product. This is achieved through input and chain-of-custody verification by a third party. It enables transparent, consistent, comprehensive independent evaluation and verification of recycled material content claims for products.

LENZING™ Nonwoven Technology

The LENZING™ Nonwoven Technology is a nonwoven web formation process that starts with dissolving wood pulp and produces a direct formed nonwoven fabric made of 100 percent continuous lyocell filament. The technology offers a unique self-bonding mechanism where substantially endless fibers bond into a fabric during the laydown process. This self-bonding mechanism allows for a much wider variety of basis weight, surface textures, drapeability and dimensional stability than other nonwoven technologies based on cellulose. The sustainable products are fully biodegradable in soil, fresh water and marine environments as well as compostable in home applications and industrial facilities and thus offer new opportunities for the future nonwoven market.

Eco Filament technology

With the launch of TENCEL™ Luxe branded filaments produced with Eco Filament technology in 2017, Lenzing has advanced the filament market and created a forward-looking innovation.

Fibers produces with Lenzing's Eco Filament technology avoid conventional yarn spinning, which is energy-intensive and predominantly based in regions with very high share of fossil-based electricity. For example, at industry level, spinning processes contribute to 28 percent of the total CO_2 emissions of the textile value chain (excluding use phase).

Shortcut fibers

The production of LENZING™ Lyocell Shortcut fibers is based on lyocell technology. Fiber cut lengths are between 2 and 12 millimeters, compared to the standard lengths of about 40 mm. Shortcut fibers blended with wood pulp are used in nonwoven applications, such as flushable moist toilet tissues, but can also be found in specialty paper applications such as filters and battery separators.

EU Ecolabel: Strict criteria have to be met in pulp and fiber production, both with regard to air and water emissions and with regard to the management of chemicals used

Trilobal fibers

The production of LENZING™ Viscostar fibers is based on the viscose technology. The fibers are produced using spinnerets with trilobal cross-section. LENZING™ Specialty Viscose with trilobal cross-section has a high liquid absorbency for use in tampons.

Incorporation of additives into the spinning mass

LENZING™ Viscose Color (ECOVERO™ Black) and LENZING™ Modal Color fibers are produced by incorporation of color pigments into the viscose or modal spinning mass for nonwoven and textile applications. This technology provides considerable ecological advantages by replacing the resource-intensive conventional dyeing process.

LENZING™ FR is a cellulosic fiber produced by incorporation of a flame-retardant additive into the spinning mass based on the modal process. These fibers are used in protective wear such as for firefighting, protection from metal splashes, protection from electric arc and motor sports.

Labels, certifications and standards

EU Ecolabel

The Lenzing Group Environmental Standard is based on the EU BAT associated emission limit values as proposed in the EU Best Available Techniques reference document (EU BREF), as well as prominent ecolabel requirements, such as the EU Ecolabel.

The European Commission established the EU Ecolabel in 1992. It is an environmental label awarded to products and services that have less impact on the environment and human health throughout their entire life in a certain product category. Products bearing the EU Ecolabel are therefore among the most environmentally friendly on the market.

Independent experts, scientists and NGOs devised the guidelines and criteria for awarding the EU Ecolabel in collaboration with the EU member states. The criteria are determined on a scientific basis and take into account the entire product life cycle. Regular revisions ensure that the criteria are adapted to new developments and that assessments remain current.

For the Lenzing Group this means that strict criteria have to be met in pulp and fiber production, both with regard to emissions released to air or water and with regard to the management of chemicals used. All Lenzing production sites fulfill the stringent criteria of the EU Ecolabel. The Lenzing Group can provide viscose, modal and lyocell fibers with EU Ecolabel certificate.[4]

Table 2: EU Ecolabel criteria

EU Ecolabel criteria

Man-made cellulose fibers criteria	**Limit**
Pulp: wood sourcing	Sustainable forestry: >25% e.g. FSC®, PEFC or equivalent schemes. Legal forestry: the rest
Pulp: bleaching agent	Elemental Cl free
Pulp: OX on finished fiber	⩽ 150 ppm
Pulp: sourcing	50% input from mills with energy or chemicals recovery
Staple fiber: sulfur emission to air	30 g/kg
Chemicals and processes criteria	
Restricted substance	Spin finishes: 90% of the component substances readily biodegradable
Substitution of hazardous substances	Should satisfy restrictions concerning certain hazard classifications

[4] Please note that LENZING™ fibers are certified with the EU Ecolabel Standard for textile products. Single use end products are NOT included in this Standard. Any labelling or marketing of single use end products made of LENZING™ fibers as EU Ecolabel certified must be checked independently and depends on the compliance with applicable EU Ecolabel Standards (such as e.g. EU Ecolabel Standard for PCPs and AHPs).

ZDHC

The ZDHC Roadmap to Zero Programme (ZDHC) is a collaboration of brands, value chain affiliates and associates committed to eliminating hazardous substances from the textile, apparel and footwear value chain. The ZDHC MMCF Guidelines V2.0 (published in 2023) addresses integrated expectations for discharged wastewater quality, emissions to air, and chemical recovery for manufacturing facilities producing man-made cellulosic fibres. The complete set includes:

- ZDHC MMCF Responsible Fibre Production Guidelines V2.0
- ZDHC MMCF Wastewater Guidelines V2.0
- ZDHC MMCF Air Emissions Guidelines V2.0

The guidelines lay down requirements with regards to laboratory testing ("ZDHC Approved Laboratories"), reporting practices (frequency, data format) and crucially "Parameters and Limit Values", that are target values for responsible fiber production (e.g. recovery rates for Na_2SO_4 or CS_2, raw material consumption: pulp, acetone, caustic soda) wastewater (e.g. COD to sea, BOD_5, Zn) or air emissions (e.g. carbon disulfide). According to the testing results and the corresponding ZDHC limit values the "foundational", "progressive" or "aspirational" levels can be reached. Reaching the target levels of the ZDHC guidelines is an important part of environmental management at Lenzing and (see ZDHC targets below).

ZDHC viscose	**To achieve 'aspirational' MMCF level for ZDHC wastewater and air emission guidelines at Lenzing viscose facilities by 2024**	**2026 On track**
Progress made in 2023	Lenzing viscose sites have continuously implemented the ZDHC MMCF guideline in its revised version 2.2. The implementation of the wastewater guideline continued in 2023. The implementation of the air emission guideline progressed according to planning, however, due to the delay of the official launch of the ZDHC Supplier Platform for man-made cellulosic fibers (MMCF), the reporting on the Platform will start in the first half of 2024. The target to achieve 'aspirational' level is now reassessed to 2026 due to supply chain disruptions stemmed from global issues and technical challenges.	

ZDHC lyocell	**To achieve 'aspirational' MMCF level for ZDHC wastewater and responsible production guidelines at Lenzing lyocell facilities by 2028**	**2028 On track**
Measure(s)	First ZDHC Gateway reporting of MMCF wastewater guideline v2 at all lyocell sites in 2023	**2023 On track**
	First supplier platform implementation and reporting of MMCF Guideline v2 – Responsible fiber production at all lyocell sites in 2023	**2023 Delayed**
	Lenzing lyocell sites achieves 'aspirational' level for wastewater and responsible production	**2025 On track**
	Lenzing site in Grimsby (UK) achieves 'foundational' level for wastewater and responsible production	**2025 On track**
	Lenzing site in Grimsby (UK) achieves 'aspirational' level for wastewater and responsible production	**2028 On track**
Progress made in 2023	The implementation is on track with all lyocell sites registered for reporting in 2023. However, due to the absence of ZDHC certified lab in USA and UK, the wastewater testing at these two sites could not be completed. The sites completed the reporting on the ZDHC gateway have all achieved aspirational level. Requirements according to the responsible fiber production guideline will be reported from 2024 onwards after the publication of the ZDHC supplier platform for MMCF in beginning of November 2023.	

Definitions/glossary

Best available techniques (EU BAT)
Best available techniques means the most effective and advanced stage in the development of activities and their methods of operations. The techniques should indicate the practical suitability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent, and, where this is not practicable, generally to reduce emissions and the impact on the environment as a whole.

Biobased
Biobased products are those that originate partially or completely from renewable resources. These products can be either biodegradable or non-biodegradable.

Biodegradable
Breakdown of polymers by **microorganisms** (bacteria & fungi) into H_2O, CO_2/CH_4, energy and new biomass.
Biodegradability: The ability of a material to be broken down by microorganisms (bacteria, fungi) into carbon dioxide, water, and new biomass, or compost, so that it can be consumed by the environment. Conditions must be defined to make the term relevant. Standardized test methods exist for most environments, describing the specific environment and the time permitted [Fehler! Textmarke nicht definiert.].

Bioenergy
Bioenergy is energy derived from biomass. The term refers to various forms of energy, including heat and electricity. Also the biomass that contains this energy can be referred to as bioenergy. The main sources of bioenergy are renewable resources.

Biorefinery
A biorefinery is a facility for sustainable processing of biomass into a spectrum of marketable biobased products and bioenergy.

Cellulose
Cellulose is a component of all plants and the most abundant natural polymer in the world. The cellulose content of wood is about 40 percent.

Co-products
Co-products products are by-products obtained during fiber production.

Dissolving wood pulp
A special kind of pulp with special characteristics used to manufacture viscose, modal and lyocell fibers and other cellulose-based products. This grade of pulp is characterized by higher alpha cellulose content and by a high degree of purity.

ECF
Elemental chlorine-free – a bleaching process that does not use elemental chlorine.

Finishing agent
Soap-like materials, applied in the final wash cycle. The adhesive properties of the fibers are adjusted in such a way that facilitates common types of processing for textile or nonwoven production. The effect is similar to using

a fabric softener when washing household laundry. A mixture of gliding agents, adhesive agents, and antistatic agents is used.

Higg Index
The Higg Index is the core driver of the Sustainable Apparel Coalition (SAC), an association of leading companies in the textile and chemical industry, non-profit organizations as well as research and educational experts aiming to create a more sustainable international textile industry. This suite of self-assessment tools empowers brands, retailers and facilities of all sizes to measure their environmental, social and labor impacts at every stage in their sustainability journey, and identify areas for improvement. The Higg Index provides a holistic overview of the sustainability performance of a product or company – a big-picture perspective that is essential for progress to be made.

MSI
The Materials Sustainability Index is the quantitative part of the Higg Index, scoring materials according to their environmental impacts in on global warming, eutrophication, water scarcity, and abiotic resource depletion (fossil fuels), and according to chemistry applied.

Regenerated cellulosic fiber
A fiber industrially produced from raw materials derived from cellulosic sources (wood, cotton, hemp, agricultural residues etc.), known in the industry as man-made cellulosic fiber or regenerated cellulosic fiber.

TCF
Totally chlorine-free (bleaching process).

Tow
Tow is a bundle of (several million) individual filaments.

References & suggestions for further reading

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