2026



Concepts Biobased

The Complete Guide

The biobased approaches, innovators and products set to disrupt the future of the textile industry.

Unmatched insight and analysis into the innovations shaping the global textile value chain.

WTiN

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Executive summary

Following on from last year's Concepts 2030, we've honed this edition to flow alongside Performance Days' thematic choice for October's Munich show – biobased innovation.

The topic has ebbed and flowed against the context of the wider material and chemistry transition in recent years, which has encouraged a pivot from conventional, fossil-fuel-based products. Such strategies are increasingly prevalent against the backdrop of enacted and incoming regulatory and legislative moves in key markets – eco-modulated Extended Producer Responsibility (EPR), Ecodesign and tightening restrictions around per- and polyfluoroalkyl substance (PFAS) usage are all prime examples.

The narrowing of our long-term fibre, material and chemistry toolkit has therefore created an opening for novel solutions promising both performance and sustainability. In the face of these demands, innovators are turning to our natural world as a valid resource stream and influence source.

As such, much akin to textile-to-textile recycling, the biobased textile technology space has seen huge growth in interest and investment over the last decade. The sector has industry-wide relevance, with biobased innovation finding applications across fibres, materials, coatings, dyeing, product fabrication and more. Here, we explore a few of the most exciting and dynamic focal points.

First, ***Regenerative & agricultural feedstocks*** – the leveraging of biobased waste streams and agricultural ingredients. The potential here is huge, with innovators tapping underutilised industrial byproducts, locally abundant bio feedstocks and strategically selected DNA to develop next-generation textile solutions.

As well as the extraction of biobased ingredients and inputs, innovators are also replicating evolutionary engineering from our natural world – replicating structures, mechanisms and systems found in flora and fauna for textiles' gain. ***Bioinspired materials science*** covers all forms of biomimetic innovation, from synthesised silk protein fibres to animal-free furs and nature-inspired coating technologies.

Elsewhere, biobased innovations' association with renewable and regenerative systems offer synergy with the industry's increasing pursuit of circularity. ***Circularity bio processes*** tracks emerging and market-ready solutions across domains such as biobased traceability, end-of-life product design and textile-to-textile recycling.

Lastly, ***Microbial & biological engineering*** delves into advanced biobased and bioinspired technologies cultivating colour and structure from natural inputs. Here, biological systems are paramount, with processes such as sugar-based fermentation being deployed to propagate ingredients at scale. Said solutions have the potential to disrupt not only the colourants and materials we use – spanning dyes, inks, foams and more – but how our supply chains develop and manufacture textile goods moving forward.

Yet despite these promising areas, biobased innovation is hindered by unique challenges: not least commercial-scale technical and economic viability. The industry must also address a current gap in expertise bridging both textiles and design with biology, chemistry and computation. The geography of our industry also plays a part; we must ask if there are discrepancies between strong industrial textile hubs and biotechnology growth, expertise and investment. Could this ultimately vex technical assimilation with existing supply chain systems and slow adoption?

Within the same vein, we may need to reflect on the current constraints placed upon us by business as usual. We are increasingly incentivised – through regulation and self-imposed transition targets – to pivot to non-petrochemical constituents, fibres and chemistries. However, our industrial system is a product of these very products. Therefore, a transition to next-generation technologies will ultimately be very difficult to enact without matching the same levels of transformation, investment and ecosystem support granted to fossil-fuels before it.



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With special thanks to:
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Understanding the Commercial Readiness Scale

WTiN's Commercial Readiness Scale gives an indication of what stage of commercialisation a product is at. It ranges from Emerging: a research stage development; Scaling: the product is being produced on a small but growing scale, and Commercially ready: the product is well-established and ready to purchase.



Emerging



Scaling



Commercially ready



Regenerative & agricultural feedstocks



Regenerative agricultural feedstocks are raw biological materials, such as corn, soybeans and crop residues. They are grown using conservation practices that rebuild soil health and lower carbon usage. These materials feed into growing markets including textiles and are being used in fibres, materials and dyes. These crop byproducts and biobased ingredients can be valorised to reduce reliance on fossil-based synthetics.

Jen Vanderhoven has over two decades of experience across scientific research, commercial leadership, innovation and policy and is a Fellow of the Royal Society of Chemistry (FRSC). At BBIA, she works to accelerate the adoption of biobased materials, engineering biology and sustainable biomanufacturing. She works closely with policymakers and industry leaders to develop the regulatory and investment landscape to grow the UK's bioeconomy.

Throughout this section we touch upon waste-stream fibres, biosynthetics and agri-waste dyes, pigments and inks and analyse innovations worldwide at different points in their journey. Vanderhoven speaks about the changing nature of regenerative agricultural feedstocks and how they can be best utilised to create a profitable bioeconomy.

Discussion with **Dr Jen Vanderhoven** FRSC, CEO of Biobased and Biodegradable Industries Association (BBIA), where she leads the UK's voice for the industrial bioeconomy.



WTiN: What factors or focuses do you see being critical to regenerative and agricultural feedstocks over the next five years?

Dr Jen Vanderhoven (JV): Over the next five years, the critical focus must be on moving from a linear fossil-based economy towards a circular, renewable carbon bioeconomy. This means not only replacing fossil resources but ensuring that the feedstocks we use deliver wider environmental, economic and social benefits.

A key priority will be the sustainable mobilisation of diverse biomass resources. Agricultural residues, forestry byproducts, food waste streams and other underutilised biological resources represent a significant opportunity to create new value chains without increasing pressure on land use. We need to move beyond the idea that biomass means growing more crops solely for industrial purposes; instead, we should focus on cascading the use of existing resources and maximising the value extracted from every biological resource.

Developing robust supply chains will also be critical. Many innovative materials exist at laboratory or pilot scale, but scaling requires reliable access to sustainable feedstocks, investment in processing infrastructure and stronger links between farmers, manufacturers, technology developers and end markets.

We also need improved sustainability assessment. Not all biobased materials are automatically sustainable – the benefits depend on feedstock choices, land management practices, processing methods and end-of-life pathways. A science-based approach, supported by transparent lifecycle assessment,

"Not all biobased materials are automatically sustainable – the benefits depend on feedstock choices, land management practices, processing methods and end-of-life pathways."



Regenerative agricultural feedstocks are raw biological materials which are finding increasing use in fibres, materials and dyes. Source: Adobe.com

will be essential to build confidence and avoid unintended consequences.

WTiN: Since the UN's implementation of its 2030 agenda in 2015, how has the conversation and aims changed surrounding biobased, biodegradable and compostable chemicals and materials?

JV: Initially, the focus was largely on replacing fossil-based plastics and reducing visible pollution, particularly plastic waste. Today, the ambition is much broader: these materials are increasingly recognised as essential to building a circular, low-carbon and regenerative bioeconomy across multiple sectors, including textiles.

In the textile industry, the conversation has shifted from simply replacing synthetic fibres with biobased alternatives to rethinking the entire value chain – from renewable feedstocks and biological dyes to low-impact manufacturing processes and improved end-of-life solutions. There is growing recognition that the industry must reduce its dependence on fossil-derived fibres and chemicals while designing products that remain in use for longer and can be safely recycled, biodegraded or composted where appropriate.

There is also a much greater appreciation that biobased, biodegradable and compostable materials each have distinct roles to play. Biobased fibres and chemicals reduce reliance on fossil carbon, while biodegradable and compostable materials can offer environmental benefits in specific applications where textile products or components are difficult to recover or recycle. Rather than seeking a single 'silver bullet', the focus has shifted towards selecting the right material for the right application.

Perhaps the biggest change has been the move from focusing on individual products to transforming entire systems. Achieving the Sustainable Development Goals requires changes across feedstock production, manufacturing, supply chains, policy, standards, waste infrastructure and consumer behaviour.

For textiles, this means creating circular value chains that combine renewable carbon, sustainable production and responsible end-of-life management. The question is no longer simply "How do we replace synthetic fibres?" but "How do we redesign the textile industry to eliminate its dependence on fossil carbon while delivering the performance, affordability and sustainability consumers expect?"

"Agricultural residues, forestry byproducts, food waste streams and other underutilised biological resources represent a significant opportunity to create new value chains without increasing pressure on land use."

WTiN: What do you feel the industry's priorities should be for achieving a successful bioeconomy? And what would this look like?

JV: A successful bioeconomy would be one where renewable biological resources are used to create sustainable products, strengthen domestic manufacturing, support rural economies and reduce reliance on imported fossil resources.

The industry's priorities should include:

1. **Building scale:** Many biobased technologies have proven technical feasibility, but the challenge is moving from innovation to commercial deployment. Investment is needed in scale-up capabilities, demonstration facilities and manufacturing infrastructure.
2. **Creating fair markets:** Today, fossil-based materials benefit from more than a century of infrastructure investment and often do not reflect their environmental costs. Biobased solutions frequently face higher costs because they are competing against an established fossil system. Policy frameworks must remove these structural disadvantages.
3. **Developing sustainable supply chains:** Collaboration between agriculture, forestry, technology and manufacturing sectors will be essential to ensure feedstocks are produced and used responsibly.
4. **Improving consumer and market confidence:** Clear standards, credible sustainability claims and better communication are needed to help businesses and consumers understand the benefits and limitations of different materials.

Ultimately, the bioeconomy should deliver economic growth alongside environmental improvement – creating high-value jobs, revitalising manufacturing communities and driving sustainable industrial innovation.

WTiN: What are the top strategies for developing and scaling crop and farm byproducts into commercially viable fibres, materials and dyes?

JV: The priority must be creating integrated value chains that connect feedstock producers with technology developers, manufacturers and end users.

Several strategies will be important:

Firstly, maximise the value of waste and byproducts. Agricultural residues and food processing waste represent significant untapped resources. Technologies that can extract fibres, chemicals, pigments and other valuable components from these streams can create additional revenue streams for farmers while reducing waste.

Secondly, design for scalability from the beginning. Many innovations fail to reach commercial markets because they are developed without considering feedstock availability, processing

costs, manufacturing compatibility or end-of-life considerations. Early collaboration with industry partners is essential.

Thirdly, invest in processing infrastructure. The UK needs more access to pilot and demonstration facilities that allow companies to bridge the 'missing middle' between laboratory development and commercial manufacturing.

Finally, develop markets through procurement and partnerships. Large buyers, including retailers, brands and public sector organisations, can play a critical role in creating demand and reducing investment risk for emerging technologies.



Forms of algae, such as seaweed, have seen immense industrial interest within the textile sector and beyond, spurred by its versatility and environmental benefits. However, further investment is needed for greater industrialisation. Source: Adobe.com

WTiN: Are there any bottlenecks you see hampering progress within this space?

JV: The biggest challenge is moving from innovation to scale. The UK and Europe have world-leading research and many promising technologies, but commercialisation remains difficult.

Key bottlenecks include:

1.Feedstock supply chains: Sustainable biomass is often dispersed, seasonal and variable, creating challenges around collection, processing and logistics.

2.Access to scale-up infrastructure: Companies often struggle to access the pilot and demonstration facilities needed to prove technologies commercially.

3.Cost competitiveness: Biobased alternatives are often competing against fossil-derived materials that benefit from mature infrastructure and historic investment. For example, in some cases, biobased chemicals can currently cost two to seven times more than fossil equivalents.

4.Regulatory uncertainty: Inconsistent approaches to sustainability assessment, waste regulation and product standards can slow investment and market adoption.

5.Lack of coordinated market signals: Businesses need confidence that there will be demand for sustainable products before investing in new manufacturing capacity.

Addressing these barriers requires collaboration between industry, government, investors, researchers and the agricultural sector.

WTiN: Are there any technologies you feel are overhyped in this space? Or are there any key ones we are ignoring?

JV: Rather than focusing on individual technologies being overhyped, we should be cautious of the idea that there is a single solution to replacing fossil-based materials. The transition requires a portfolio of approaches, because different applications have different technical requirements and environmental considerations.

Some areas receive significant attention, while others may be under-recognised. For example, agricultural residues, lignin, cellulose, hemicellulose, algae, seaweed and other underutilised biomass streams have enormous potential but often require greater investment and infrastructure development.

We also need to recognise the importance of 'behind-the-scenes' technologies. Advances in biotechnology, fermentation, enzyme engineering, separation processes and sustainable chemistry may not always attract public attention, but they are essential enablers of the bioeconomy.

"Many biobased technologies have proven technical feasibility, but the challenge is moving from innovation to commercial deployment."

One area that deserves more focus is the integration of technologies into industrial systems. Producing a sustainable material is only one part of the challenge. Ensuring it can be manufactured at scale, compete economically, integrate into existing supply chains and achieve genuine environmental benefits is where the greatest impact will be delivered.

The future bioeconomy will not be built by one breakthrough technology, but by connecting many innovations into a functioning industrial ecosystem.

Waste-stream fibres

Utilising waste agricultural products or derivatives, such as orange peel, pineapple and banana leaves to create fibres and fabrics.



Opportunities

1. Byproducts mitigate impact

While not a direct replacement, these fibres have a lower environmental impact than conventional cotton, reducing resource use, chemical inputs and carbon footprint. This is an advantage for the textile and apparel industry, as environmental targets and compliance are increasingly implemented. The EU Waste Framework Directive would see agricultural byproducts converted into fibres fall under waste-to-recovery principles, while final biobased textiles will be subject to the Extended Producer Responsibility (EPR) rules.

2. End-of-life potential

Not only do plant-based fibres have the ability to biodegrade but they can enhance soil quality. Although more research is needed, it is a promising characteristic and presents an opportunity for resource recovery and reuse.

Threats

1. Supply chain stability

Availability and quality of crops are inconsistent. Crops grow at specific times of the year, meaning it can be difficult to establish a consistent feedstock supply. This is also hampered by weather, soil and regional changes, which can affect the composition and performance of the final product. To overcome this, companies may face high costs as they could be forced to gather waste from different sources or compete with existing byproduct supply chains.

2. Process adaptations

There are also processing and technological barriers to overcome when introducing new fibres and fabrics into the market. Plants need to be broken down into soft textile pulp, commonly via chemical or mechanical technologies. The agricultural fibres themselves can be rough or weak compared with cotton or polyester and as such, they are often blended to make the clothes wearable. This lowers their recyclability and end-of-life viability.

The fashion and textile industry relies heavily on materials such as cotton and polyester, which come under scrutiny for their impact on the environment and humans. Cotton has been criticised for the vast amounts of water needed in its production, while polyester is created from fossil-fuel materials that emit CO_2 into the atmosphere.

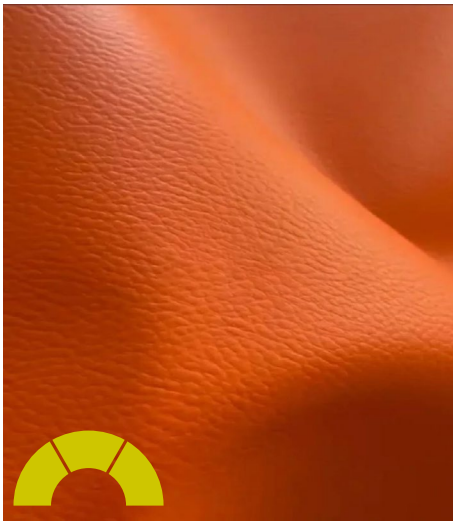
Cellulose-based textile materials have received much attention and research in recent years. Previously mainly created from wood, studies from the likes of Chalmers University of Technology, in Sweden, have uncovered the potential from other waste streams such as wheat and oat. These require fewer chemicals than manufacturing forest-based cellulose and have the potential to enhance the value of waste products from agriculture.

In March 2022, the EU Strategy for Sustainable and Circular Textiles was introduced to transform the textile industry by 2030, focusing on enhancing the durability, repairability and recyclability of textile products. The strategy emphasises the need to increase the use of biobased fibres, reducing reliance on synthetic materials.

Global testing, certification and inspection company, SGS, considers this compliance requirement and promotes the use of renewable feedstocks in biobased materials. It says they are less toxic to the environment, require fewer hazardous chemicals, less water and less energy to produce than synthetic alternatives. Using the example of hemp, SGS says it is a highly sustainable crop that grows with minimal water, thrives in poor soil and does not require pesticides, making it ideal for eco-friendly farming.

In the past, agricultural residues have been burned because of their low economic value, contributing to environmental harm and climate change. Meanwhile, the apparel and textile industry's reliance on resource-heavy fibres like cotton has exacerbated water and pesticide usage, as well as greenhouse gas emissions.

Laudes Foundation commissioned the report Spinning Future Threads to highlight the potential of various agri-residues, such as banana, hemp and pineapple, for producing cellulosic natural fibres. However, it is essential to remember that these fibre streams are still in their infancy and many need to be blended to be viable commercially. WTiN recently spoke to Dixie Carter, president of US-based industrial hemp processor Panda Biotech, about the potential for building an integrated hemp fibre-to-yarn supply chain in India. Carter says the company is still working on "optimising blend ratios and identifying best practices for processing."



WTiN's Textile Innovation Podcast spoke with Stefano Mazzetti, co-founder and CEO at Ohoskin, in November 2025. Source: Ohoskin



Grouse Fibres is developing protein-based fibres and bioproducts from protein side-streams. Source: Grouse Fibres



Arda transforms spent grain from beer and whiskey production into durable and plastic-free textiles. Source: Arda Biomaterials

Ohoskin

Sicily, Italy

Commercially ready

Ohoskin is an Italian company that has created patented fabrics derived from orange and cactus byproducts in Sicily. Through a circular economy process, Ohoskin transforms waste into a durable material for luxury brands seeking a high-quality, biological and sustainable alternative to animal leather. In November 2025, WTiN's Textile Innovation Podcast spoke with Stefano Mazzetti, co-founder and CEO at Ohoskin, about how the company is valorising these agricultural byproducts, turning them into a recyclable premium material. The company has already created several products for the automotive and fashion and textile industries, incorporated by brands including Ganni, Cheetah Stories and Lamarr.

Grouse Fibre

Stretton-on-Fosse, UK

Emerging

As a materials science startup, Grouse Fibre is developing protein-based fibres and bioproducts from protein side-streams. Using protein chemistry and wet-spinning, the company converts non-food grade proteins into biodegradable materials. Grouse Fibres specialises in the creation of casein fibres, also known as milk fibre – a protein-based textile derived from casein, the main protein in milk. It has been around since the 1930s, when it was created as a substitute for wool and silk; it has similar properties to wool such as softness, warmth and dye absorption. Currently, Grouse Fibre is designing fibres primarily for technical applications, such as horticulture, defence, industrial and biomedical uses. However, consumer apparel is an area the startup is looking to explore as a longer-term opportunity, with plans to spin a yarn from its fibres later this year (2026). Currently the company is making its casein fibres available for testing to academia, research and industry. It says it understands "the need for innovation in research" and is "ready to collaborate on custom setups for certain research initiatives."

Arda Biomaterials

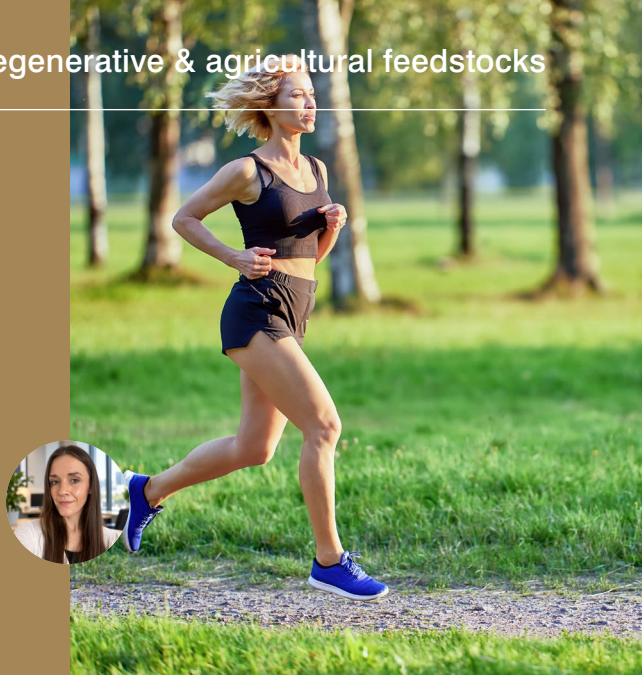
London, UK

Scaling

Arda transforms spent grain from beer and whiskey production into durable and plastic-free textiles that replace animal and synthetic leather. Using supramolecular chemistry, Arda extracts and reconfigures grain proteins. The company says it is compatible with continuous, high-volume manufacturing. In 2025, Arda closed an oversubscribed US$5.25m (GB£4.05m) round led by Germany's Oyster Bay Venture Capital. The funding is being used to make advancements to its first innovation – New Grain – and begin commercialisation. Arda says it partners with brands and manufacturers to develop products, scale production and unlock drop-in materials that compete on price. To date, the company has publicly launched a showpiece handbag with BEEN London and converted Heineken-owned Beavertown Brewery spent grain into branded cardholders.

Biosynthetics

Biosynthetics are a drop-in synthetic substitute material for fossil-based materials. They can be wholly or partly derived from natural, renewable sources such as corn, sugar beet, sugarcane, wheat and more. They are more environmentally friendly than their fossil-based counterparts, used in the production of bio-nylon and polylactic acid (PLA), for example.



Opportunities

1. Drop-in compatibility

A big opportunity of biosynthetics lies in the fact they are designed as a drop-in solution and are chemically identical to petroleum-based plastics. This means existing manufacturing plants and recycling streams can be used, saving the industry the cost of new machinery, equipment and training. There is a chance of performance continuity as they match their synthetic counterpart in terms of stretch and durability, which are difficult for other materials to achieve.

2. Lower impact potential

Biosynthetics offer the textile industry environmental benefits, as they are derived from biobased sources absorbing carbon dioxide during growth, reducing overall greenhouse gas (GHG) emissions and toxicity: fewer hazardous chemicals and less energy are needed to produce them. With the industry focused on reducing its environmental impact, this offers a viable route forward.

Threats

1. Biodegradability isn't guaranteed

According to Textile Exchange, biobased materials are made from renewable feedstock rather than fossil-based, non-renewable resources, yet this doesn't automatically mean the material is biodegradable. Additionally, there are concerns around their impact on microfibre shedding. Like conventional polyester or nylon, they can shed plastic fragments into water systems during washing.

2. Uncompetitive costs

High costs are associated with biosynthetic materials. They frequently fall victim to the 'green premium' and cost significantly more than their fossil-based equivalents. This is driven by smaller production scales, expensive raw feedstocks, high energy inputs and complex downstream purification and separation processes. This increases brands' reluctance to invest in these materials, as they are not only expensive, but have yet to prove themselves on a commercial scale.

In WTiN's *Concepts 2030* report we looked at biosynthetic drop-ins. Here we found that, despite widespread calls and pledges to transition away from virgin forms, uptake of both recycled and biobased materials remained low; the latter is particularly challenged, with the Nova-Institute estimating a 0.01% share of total 2024 polyester production, as cited in Textile Exchange's 2025 Materials Market Report.

However, biosynthetics represent a key step in decoupling textile production from fossil resources without overhauling existing infrastructure. In 2026, Performance Days outlined three factors driving the adoption of biosynthetics: limited fossil resources, as renewable carbon secures future material supply; regulatory pressure, driven by climate policies shifting the industry away from fossil-based feedstocks; and performance without compromise, as brands and consumers desire lower fossil dependence but the same high performance.

There is much opportunity for this category of textiles in the future as brands and manufacturers are being increasingly pushed towards adopting greener production methods and materials. There is growing consumer demand for these products and compliance will further research and adoption in this sector. While investment is still needed to reach cost parity and reliable feedstocks need to be optimised, there is promise in this space.

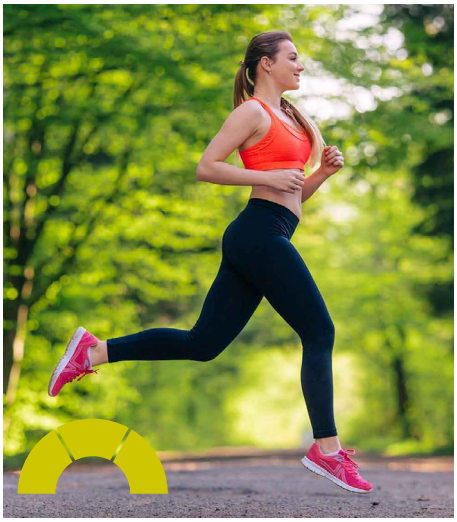
> **"While investment is still needed to reach cost parity and reliable feedstocks need to be optimised, there is promise in this space."**



Uluu produces a fermented plastic alternative from farmed seaweed and sea water. Source: Uluu



OzoneBio has developed OzoPure – a next-gen, biobased adipic acid prime for nylon 6,6 production. Source: OzoneBio



LDZ is dedicated to manufacturing and creating products sustainably. Source: Adobe.com

Uluu
Perth, Australia
Emerging

Australian start-up Uluu produces a fermented plastic alternative from farmed seaweed and sea water. Its materials are natural polyhydroxyalkanoates (PHAs), with claims they are non-toxic, microplastic-free, home compostable and marine biodegradable. Uluu hydrolyses seaweed using enzymes that break it into fermentable sugars, before separating the sugary liquid from the remaining seaweed material. It then feeds the seaweed liquid to microbes capable of growing PHAs inside them, before extracting them in freshwater to burst the cells open and extract the PHAs. The PHAs are dried into a powder and turned into pellets ready for manufacturing. At commercial scale, Uluu states its production process has scope to capture and store up to five kg of CO_2 for every one kg of material produced. The technology also has the potential to reduce global CO_2 emissions by more than two gigatonnes per year.

OzoneBio
Calgary, Canada
Scaling

OzoneBio develops biobased adipic acid, a key building block for Nylon 6,6, using renewable wood-waste feedstocks. The company says its process leverages a 'green chemistry' approach enabling it to convert complex biomass into high-value products while minimising greenhouse gas emissions. For every kilogram of bio-adipic acid produced, approximately 100 kg of nut shells or wood waste are upcycled. Currently, OzoneBio is scaling production and supporting academic research by partnering with universities to validate the performance and environmental impact of its product. It hopes to expand into new applications including bio-nylon fibres, biodegradable plastics and vanillin alternatives.

LDZ New Aoshen Spandex Company (LDZ)
Jiangsu, China
Commercially ready

LDZ is a Sino-foreign joint venture controlled by Lianyungang Industrial Investment Group. The company, based in Jiangsu, China, was named winner of the International Textile Manufacturers Federation (ITMF) Sustainability & Innovation Award 2025, for its project exploring industrial-scale biobased elastane. To create its biobased elastane, LDZ uses non-food crops as raw materials to achieve a biochar (organic material) content of up to 75%. The company's biobased elastane has been adopted by brands including Fila, Youkeshu, Only, Regina Miracle and Ubras.

Agri-waste dyes, pigments & inks

Biobased colourants that have been extracted from agricultural byproducts, crop residues or food-processing waste. The presence of dyes and colourants in effluents is a concern because of the adverse effects they can have on various forms of life and the environment. As such, innovators have turned to the natural world to create sustainable, non-toxic solutions.



Opportunities

1. Diverse toolbox of possibilities

Agricultural byproducts are abundant renewable resources with little to no economic value and can be difficult to dispose of. There is an opportunity to valorise these byproducts by converting them into pigments, inks and dyes, addressing end-of-life challenges presented by these waste streams.

2. Bypassing petrochemical constituents

These products go some way to eradicating the use of petroleum-based dyes, pigments and inks, which are commonly used in the textile industry. Synthetic dyes can contain over 70 harmful chemicals that are non-biodegradable. They are estimated to contribute to roughly 20% of global water pollution, making dyeing one of the most polluting aspects of textile production. Agri-waste offers a sustainable, biodegradable alternative that contributes to a circular economy.

Threats

1. Performance concerns

Agri-waste dyes, pigments and inks tend to be restricted to an earth-toned colour palette and struggle to achieve the same light-, wash- and rubfastness as their synthetic counterparts. This is due to several factors, such as natural chromophores breaking down under UV exposure and pigments bleeding in laundering due to weak physical absorption. Colour range is also limited as most waste streams produce only yellow, brown, beige and rust hues, with blues and greens the most difficult colours to replicate with viable performance.

2. Scalability challenges

Agri-waste streams vary with weather, soil quality and seasons, leading to inconsistent colour profiles. Additionally, the availability of some dye plants is limited by land scarcity, which poses a challenge in scaling up dye production. Various environmental factors, such as climate change, drought and floods also affect agricultural production and, thus, the supply of raw materials.

Interest in natural dyes has increased as an eco-friendly alternative to synthetic colourants within the textile industry. The industry faces increasing pressure to adopt sustainable practices due to the environmental impact of conventional dyeing processes.

Traditional synthetic dyes often involve hazardous chemicals and generate substantial wastewater, posing considerable ecological challenges. The European Parliament has estimated synthetic dyes are responsible for 20% of global wastewater. They are derived from carbon-intensive petroleum and coal tar, relying on non-biodegradable chemicals that are toxic, mutagenic, carcinogenic and highly polluting.

This coupled with growing regulatory pressure on synthetic pigments, rising environmental, social and governance (ESG) commitments and increased demand for sustainable alternatives has created an opening for natural colourants.

Utilising agricultural waste has multiple benefits for the textile & apparel industry, in that it is biodegradable, sustainable and consumes byproducts that would otherwise be sent to landfill or burnt. With rules surrounding the management and handling of this waste, these biobased colourants could offer a safe and viable alternative to conventional chemistry.

However, agri-waste colourants are limited in colours and in their properties. There is much research and innovation happening in this space to improve fastness and palettes, but it is important to remember that this remains a challenge at present.

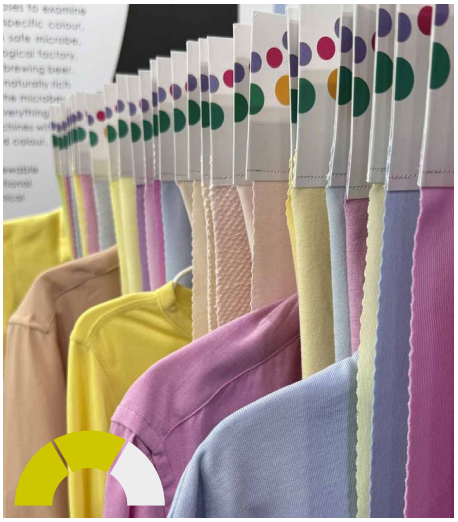
> **“The industry faces increasing pressure to adopt sustainable practices due to the environmental impact of conventional dyeing processes.”**



Sages London's collection of natural dyes from food waste. Source: Sages London

Sages London
London, UK
Scaling

Sages London produces natural dyes from food waste. The company's proprietary bio-chemical process isolates phytochemicals to extract industry-ready powders from sources such as avocado pits, blueberries, red cabbages and onion skins.
With over 12 colours produced, the company claims the dyes are a like-for-like replacement for synthetic dyes and have been successfully integrated into a range of industrial processes. Additionally, it has achieved industry standards on fastness tests.
The company's core range has been developed for use within commercial dye houses, having already partnered with brands including Osmose Studio – a company that specialises in biodesign and mycelium materials. Sages is also developing a limited batch of new colours designed specifically for use in small vat dyeing processes or standard kitchen equipment to support smaller brands and students. The company has been selected for the 2026 cohort of the EarthScale programme, which will support it in raising Series A funding.



Colorifix grows bacteria on a commercial scale using sustainable feedstocks such as soil and deep-sea sediments. Source: Colorifix

Colorifix
Norwich, UK
Scaling

Founded in 2016, Colorifix grows bacteria on a commercial scale using sustainable feedstocks such as soil and deep-sea sediments. The company says this allows colours to be produced without damaging chemicals and with less water and lower CO_2 emissions. The bacteria can also be used to deposit pigments onto textiles.
The company has collaborated with H&M on a colour story collection and with Pangaia on a range of hoodies, using pigments found in silk cocoons and the Midway Geyser Basin in Yellowstone National Park. It has also worked with Vollebak on its DNA T-shirt, using DNA from the indigo plant.
Furthermore, in 2025, Colorifix closed US$18m in funding led by Inter IKEA Group, with H&M Group Ventures continuing as an investor. Licences are now being granted for customer onboarding in India and Sri Lanka, with Southeast Asia expansion active.

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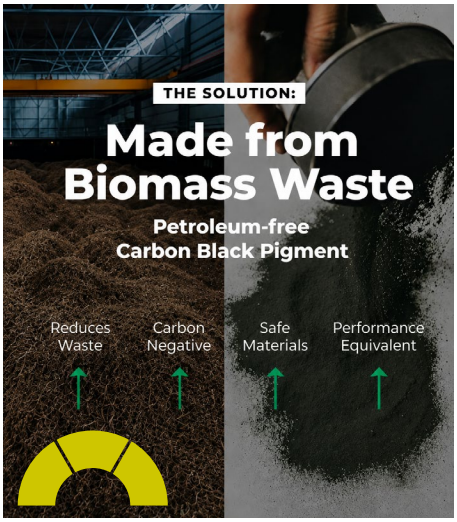


Living Ink transforms green agricultural waste into carbon-negative pigments and biobased inks to replace carbon black. Source: Living Ink

Living Ink Technologies
Berthoud, US
Commercially ready

Living Ink transforms green agricultural waste into carbon-negative pigments and biobased inks to replace carbon black. The company claims its product lines, Algae Black pigments and Algae Ink printing inks, offer safer and lower-impact alternative colour solutions for industries spanning footwear, textiles and cosmetics, to name a few.
Living Ink specifically uses algae waste as its feedstock, sourced from farms, which the company positions as a responsible waste disposal route for partners in wastewater treatment and dietary supplement production.
The black pigment meets the textile industry's specifications of traditional carbon black in its intensity and resistance to UV light degradation. Already, Living Ink has collaborated with brands including Nike, Patagonia and Vollebak.



Bioinspired material science



Transcending all industrial sectors, biomimicry is a design and development approach drawing its influence directly from our natural world. The depth and breadth of inspiration is great, with proponents extracting material, chemical, structural and systems inspiration from an array of biological life – arthropods, plants and microorganisms being among the most prominent.

There is ample potential for textiles here, with emerging innovators proposing new fibres, coatings and dyeing solutions, among others. However, innovation scouts will do well to keep close observations on adjacent industry sectors, such as automotive, marine and medicine. Biomimetic design principles are equally fielding interesting new developments in these areas, with many innovators refining a function over a market-specific application. As such, there is great potential for knowledge and technology transfer into the textile domain, should said function align with a specific need.

Discussing biomimicry's broad industrial value, WTiN sits down with two names of the US-based Biomimicry Institute – Asha Singhal, director of Nature of Fashion, and Sarah McInerney, director of innovation.

The Biomimicry Institute is a non-profit organisation dedicated to the pursuit of biomimetic innovation across industry, education and culture. As part of its operations, it runs the annual Ray of Hope Accelerator, geared towards supporting emergent and scaling startups through non-dilutive funding, resources and support. Previous textile-centric alumni include Amphico, Ecotune and Sparxell. Additionally, its Nature of Fashion initiative supports and pilots projects geared towards effective textile waste management, for a more circular future.

Discussion with **Asha Singhal**, director of Nature of Fashion, and **Sarah McInerney**, director of innovation, at The Biomimicry Institute (BI).



WTiN: Textile & apparel appears ripe for biomimetic innovation, but what are the biggest hurdles to commercialising at scale? How does cost sensitivity, manufacturing and supply chain rigidity, production scalability and weak commercial adoption come into play?

Asha Singhal (AS): It is ripe. The science has been proven and the sector is moving towards proving the route to market. All four of the things you name are real and they behave less like separate hurdles than like three moments where an innovation can lose momentum: where it enters the system, who carries the cost of scaling it and whether the people who would buy it can find it.

Achieving industrial acceptance

Supply chain rigidity is the first, and it is better treated as a design constraint to accept early on than a barrier to push against. Brands do not own mills, so an innovation that runs on machinery already installed can move quickly, while one needing new equipment waits for a capital cycle it does not control. Some of the most encouraging progress comes from innovators who made that choice deliberately, including companies scaling microbial pigment production specifically because it works on existing dyehouse equipment.

Assuring economic viability

Cost and scalability meet at the second moment, where biology scales differently from the sectors most investors are used to and a first commercial plant needs capital of a size and patience only now becoming understood. Underneath the cost question sits something structural and, in its way, quite hopeful, which is that the price a new material is measured against carries none of the cost of what happens to that material afterwards. That is an accounting choice rather than a verdict on bioinspired materials and it is what regulation is beginning to correct.

Designing for function over application

On adoption, the word weak is worth gently reframing, because interest has been abundant and it is contracted demand that has taken longer to build.

One real advantage the field has here is that biomimicry begins with



the function needed rather than with a material category, which widens considerably what counts as a candidate solution. AskNature, our open database, is built around functions in addition to industries for that reason. Scouts who search that way can surface applications from medicine, water treatment or marine technology that a solely materials-led search won't return.

Sarah McInerney (SM): From the perspective of the Ray of Hope Accelerator (RoHA), the primary binding constraint is key product market selection and capital matching. The appeal of mass-market apparel brand partnerships is flashy and exciting but entering into such partnerships at the early stage can be capital intensive and resource draining for sustainable technology and product development. This is exacerbated by the fact that these types of apparel procurement cycles are incredibly slow, work on tight margins and are sensitive to minor fluctuations in unit pricing.

A more successful route through the lab to pilot or to plant is choosing strategic beachhead markets: targeting high-value, highly regulated or performance-driven sectors that provide the necessary profit margins to absorb the initial certification and low-volume production costs.

This approach correlates with the biomimetic functional design pathway, as startups are working towards functional need over consumer application. For example, Seprify [a RoHA startup from its 2021 Cohort] spun out of the University of Cambridge, creates cellulose-based white pigments inspired by the Cyphochilus beetle. This uses a disordered nanostructure to generate brilliant whiteness without pigments. Rather than competing on price against cheap synthetic dyes in mass-market apparel, Seprify targets high-value functional coatings, cosmetics and food-grade packaging. These sectors command high margins and are under heavy regulatory pressure to replace toxic titanium dioxide (TiO_2), allowing Seprify to absorb initial certification costs before bringing its white structural finishes to apparel.

Diversifying finance strategies

However, you must also consider the challenges startups face when transitioning from that initial working pilot to commercial scale. This is where the capital method needs to be intentional and resilient – blended financing is one such approach. I am seeing success where non-dilutive grant funding, regional industrial infrastructure and corporate capital are bridging this gap.

For example, Sparxell [2023 RoHA Cohort] develops plant-cellulose structural pigments to replace toxic dyes. It has successfully blended public non-dilutive funding with impact and corporate-linked venture capital – leveraging a EU€1.9m [US$2.2m] non-dilutive grant from the European Innovation Council (EIC), alongside university seed backing (Cambridge Enterprise) and ocean-focused impact capital (SWEN's Blue Ocean fund). This public-private funding stack de-risked their technology, allowing them to transition from pilot scale to launching a commercial-scale facility capable of producing plant-based textile inks and pigments by the ton.

WTiN: How should manufacturers, brands and biotech innovators alike safeguard against these challenges? What kind of investment or partnership models do you see working best to drive results and sustainably ramp up industrial adoption?

Simplify industrial adoption

AS: A few patterns have been encouraging to watch. One is designing into the system that already exists, since the innovations moving fastest tend to fit the machinery and working practices already in place.

Manufacturers have a great deal to offer here. Where a mill has been part of the thinking from the beginning rather than from sampling onwards, the difference in how quickly something reaches production can be considerable.

Leading with the function

Another is entering through a market where the material's defining property is what makes the product work. Our German Nature of Fashion pilot partner takes discarded medical workwear, breaks it down and rebuilds it into a biodegradable polymer called PHB. The first intended use is not clothing but medical devices such as dissolvable sutures and bone screws, where a material that safely breaks down inside the body removes the need for a second operation. Biodegradability is the function a surgeon is paying for, and medical margins can absorb the testing and certification that apparel margins cannot. Once proven in that setting, the material could move into interiors and eventually textiles with a validation history already behind it.

SM: This pattern for success is also evident across the medical innovations within the Ray of Hope Accelerator Portfolio. These unique technologies – from textiles to adhesives and devices – all target high-margin medical procedures with a clear functional need that absorbs the steep costs of FDA (Food and Drug Administration) testing, clinical trials and high per-unit manufacturing costs.

Regional partnerships

AS: On partnership models, regional industrial ecosystems have been working noticeably well. In the Netherlands, our Nature of Fashion pilot partner is coordinating several technology collaborators at different stages of maturity, with regional government, port authorities and innovation agencies providing the convening infrastructure.

In Berlin-Brandenburg, the surrounding density of biotechnology firms and research institutes has been a real asset to the work. Cross-border collaboration has been similarly productive, and gasification data from a partner in a neighbouring country helped one of our pathways reach proof of concept.

What these have in common is that they give an innovator access to research capacity, industrial partners and material flows together rather than one at a time, which is difficult for a single grant or a single brand relationship to replicate.

SM: To build upon my previous answer of strategic beachhead markets and blended cap table, the critical word is patience. Scaling hardware-heavy or biotech ventures requires patient capital and risk-tolerant investors who truly understand deep-tech development cycles.

The software boom, and now the artificial intelligence (AI) rush, has warped venture expectations around return timelines and speed to impact. This disconnect is a major friction point for early-stage startups, where adapting, iterating and pivoting production models takes physical time and infrastructure. The RoHA's model of supporting startups across global cohorts with non-dilutive funding, mentorship and corporate networking, is critical in helping founders de-risk their core IP without diluting equity before hitting industrial scale.

The double-edged sword of reaching pilot scale and capacity is what I'm seeing more and more as "pilot fatigue", or what I recently heard a founder call "death by pilot." This is where a startup produces a limited sample run for a specific pilot in exchange for brand alignment, recognition – some limited runway, likely only enough to execute said pilot, that then never transitions into a commercial deal or purchase order.

So, in the end, the startup has morphed their tech to fit a potential customer, probably worked themselves into the ground to accomplish it and have little more than a potential line offering on their website.

[The Biomimicry Institute's] Biomimicry Co-Labs solve this by creating 12-month, multi-partner industrial collaborations that brings together manufacturers, anchor points across the supply chain and multiple brand partners. This type of structure aggregates demand, identifies a shared goal to address and enables the distribution of operational cost.

WTiN: In your view, has fashion and textile's shifting regulatory landscape – prioritising sustainable materials, greener chemistries and traceability – bolstered or hindered the commercialisation of biotech and biomimetic innovation? Do you feel it's put greater validation and certification demands on early-stage innovators?

AS: Bolstered, on the whole, because regulation has given this field firm dates to work towards. For a long time, these materials were sold on the basis that a buyer might want them, which is something a procurement team can always decline. A requirement with a date attached changes how the business case gets written.

The Ecodesign for Sustainable Products Regulation (ESPR) came into force in 2024 with textiles high on its priority list. Large enterprises can no longer destroy unsold textiles and footwear in the EU as of July 2026. The ESPR textile delegated act and Digital Product Passport (DPP) requirements are expected around 2027 and Extended Producer Responsibility (EPR) schemes are live in several member states.

Restrictions on fluorinated chemistry are creating similar momentum around finishes. Encouraging work is emerging in response, including Amphico in our accelerator portfolio, which has developed a PFAS-free waterproof breathable membrane drawing on repellent nanostructures found in biological surfaces.

Where the frameworks are still catching up is on capacity, with Dutch collection rates under Extended Producer Responsibility running behind the 2030 target so far. That reads to us less as a shortcoming of the policy than as a fairly precise indication of where infrastructure investment would do the most good next.



BI co-founder, Janine Benyus, leads a biomimicry excursion in Seeley Lake, Montana, US. Source: The Biomimicry Institute

Validation pressures on emergent innovators

On validation, the demands have certainly grown and the cost of chemical registration and testing weighs more heavily on a small team than on an established supplier. Meeting a high bar early can also become an asset, though. Our German pilot partner is entering medical applications deliberately, and there the certification requirement is exactly what gives a buyer confidence in the material.

The one thing we would encourage care about is assessing a material in isolation, because a laboratory test cannot represent the full range of conditions a textile ends up in. A cotton fibre left in frozen tundra stays intact for a very long time while the same fibre in a warm compost pile breaks down. This is a reminder that breakdown depends on the system a material meets rather than on the material alone. That has a bearing on how definitions get drafted too.

Framing recycled content narrowly as fibre returning to fibre would leave out biological and thermochemical pathways that handle precisely the mixed and blended material fibre-to-fibre recycling cannot reach. There is a real opportunity in writing them broadly enough to recognise decomposition alongside recycling.

WTiN: Textiles are one of many application areas The Biomimicry Institute covers. Do you feel there is crossover potential from other industrial focuses that textiles' innovation scouts should be watchful of?

AS: Yes, and it runs in both directions. Biomimicry is organised around function rather than industry, and that is the practical heart of the method.

It begins with the function needed, whether that is water repellency, selective filtration, thermal regulation or colour without pigment, and then looks at how living systems achieve it, wherever that happens to appear.

AskNature, our open database, is built that way for the same reason. The useful consequence for anyone scouting is that a search by material category returns what is already classified as a textile material, while a search by function can surface the medical coating, the marine treatment or the water technology that solves the same problem in a different sector.

Several companies in our accelerator portfolio sit in those spaces, such as:

- Mycocycle, working on fungal bioconversion of industrial waste
- Xatoms, creating photocatalysts that break down persistent water contaminants
- DisperseBio, supporting biofilm dispersion for maritime use
- Scientian Bio, enabling biological sensing of chemical compounds

None were developed with apparel in mind and each has potential to be applied in the textile sector.

The second direction concerns material crossover between industries and it is less widely recognised. Sectors largely operate in silos, with textiles expected to return to textiles, yet the outputs of breaking a garment down are not garments. In our pilots, the biodegradable polymer recovered from polyester-rich waste could go into geotextiles and erosion control, or into medical devices such as pill capsules and bone screws.

What these markets share is that a material safely remaining in soil, water or the body is a specification rather than a claim, and they carry margins able to absorb the cost of validation. That makes them a realistic first home for materials, which may later find their way back into textiles, arriving with a validation history already behind them.

SM: From the perspective of the RoHA – and I'm sure many other programmes that share a diverse portfolio – the variety of sectors, technologies and countries supported within our portfolio provides a unique type of co-lab opportunity for global collective action.

For example, beyond the foundational textile innovators like Amphico (PFAS-free membranes) and Spintex (low-energy gel spinning) targeting high-performance materials, the likes of Sparxell (structural colour) and Ecotune (waste-to-polymer conversion) target fashion, interiors and automotive markets. This portfolio also leverages crossover technologies from adjacent industries to address broader textile challenges:

- **Natural fibre processing & upcycling:** Renaissance Fibers applies clean degumming to hemp to produce high-grade textile fibres, while Fiberly transforms agricultural waste into drop-in textile feedstocks.
- **Waste management:** Mycocycle and Novobiom utilise fungal bioconversion and mycoremediation to transform industrial waste streams and contaminated substrates into usable raw materials. Sudoc employs bioinspired catalyst chemistry to break down persistent toxic chemicals in water



Bioinspired founders and startup teams venture to Yosemite, US, for their Nature Retreat – a mandatory, multi-day component of their RoHA programme. Source: The Biomimicry Institute

systems, offering massive potential for sustainable dyehouse wastewater treatment.

The potential of our Co-Lab structure is that is offers a vehicle for cross-sector pollination by organising multi-stakeholder cohorts around specific functional goals, such as non-toxic water repellency or biological waste breakdown. Co-Labs allow innovation scouts from textiles, medical and industrial chemistry to co-invest in shared technological solutions rather than duplicating effort in industry silos.

Similarly, are there any biomimetic properties or functions you think are still relatively underexplored with potential in textiles? Things nature does that are nascent in our understanding, or we haven't quite figured a commercial angle for yet?

AS: A good many, and what is striking is that most commercial work so far has looked at static structure, while response and process remain comparatively open.

Smart materials

Hygronastic movement is one of the most interesting. Pinecones, wheat awns and legume pods open and close in response to moisture through differential swelling between two adjacent tissues, with no motor, sensor or power source involved.

Work by Veronika Kapsali and Julian Vincent, published in 2020, applied that principle to produce a textile which increases its permeability to airflow by 25 to 30% when damp – the opposite of how cotton, wool and rayon behave. The yarn acts as both sensor and actuator, yet the approach has yet to find a commercial home.

Structure over chemistry

Structure replacing chemistry is another. The nanopillar arrays on cicada and dragonfly wings disrupt bacteria physically rather than chemically, and this has been demonstrated repeatedly on flat films. The remaining challenge is transferring that geometry onto cylindrical fibres within a knitted structure, which is an engineering problem rather than a biological one.

Passive thermoregulation sits in similar territory, with the triangular hairs of the Saharan silver ant both reflecting solar radiation and releasing heat efficiently, and the disordered chitin network of the *Cyphochilus* beetle producing brilliant whiteness with no pigment at all. Much of that has been shown on films and coatings and rather less on textiles at scale.

Nature-inspired processes

Process is the other area with room in it. Living systems build their toughest materials in water, at ambient temperature and pressure, without solvents, and a spider produces a remarkable fibre from a liquid gel at room temperature. Spintex, in our accelerator portfolio, has built a spinning process on that principle and the same question could be asked of a good deal of wet processing.

The largest gap, and the one Nature of Fashion [a BI initiative] exists to work on, is how living systems take materials apart rather than how they make them.

In ecosystems, breakdown and build-up are inseparable and the output of one becomes the input to the other. The clothes moth digests keratin, which most digestive enzymes cannot touch. It uses alkaline chambers in its gut alongside a wide range of proteolytic enzymes under nearly anaerobic conditions, and ruminants and termites solve comparably difficult problems. What recurs in each case is that the capability belongs to a community rather than to a single organism, which suggests that bioreactors designed around microbial diversity rather than single-strain optimisation could prove far more robust with the variable feedstock textile waste always presents.

WTiN: Looking five-ten years out, where do you expect bioinspired innovation to have made the biggest impact? Will they be cost-restricted to luxury lines or could they have broken through into mass market applications?

AS: Coatings and finishes look likely to move first, largely because restrictions on fluorinated chemistry give them a date to work towards – anything replacing a substance the law is removing has a buyer waiting.

Colouration is probably where change will be most visible. Structural colour from cellulose, microbial pigment production that runs on existing dyehouse machinery and algae-derived inks are at or near commercial readiness. Additionally, colour is often a process substitution rather than a system rebuild, which is a large part of why it can move quickly.

Fibres might take longer, being the most capital-intensive and the most exposed to direct comparison on cost per kilogram, so meaningful volume in specific applications seems a more realistic expectation than broad substitution.

The change with the largest reach may well be the least visible, which is feedstock chemistry. A core set of industrial building blocks underpins most of what the sector makes, and a number of them occur naturally in biology, so substituting waste-derived and biobased versions into existing manufacturing asks nothing of the consumer and nothing of the mill.

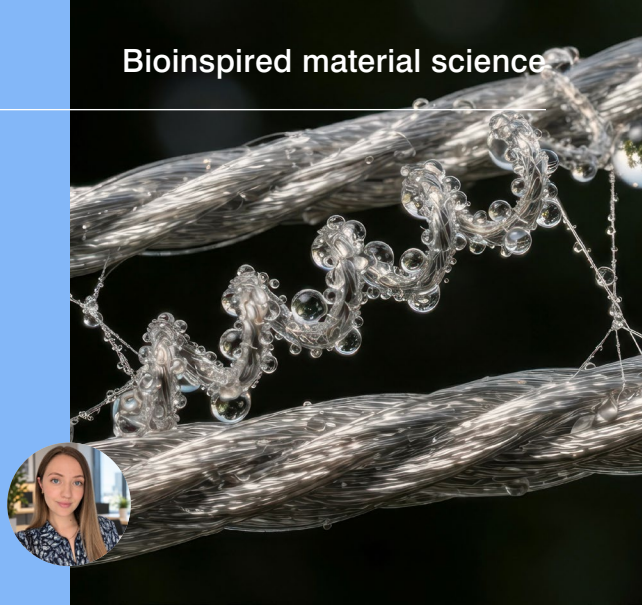
On luxury and mass market, it is worth treating this as a sequence rather than a destination – and with some care. Luxury demonstrates that a material is desirable, which is valuable, though luxury volumes are small and a plant is financed on volume. What tends to reach broad adoption is the category where the bioinspired route becomes the more practical option commercially or where regulation has made the incumbent unavailable.

Timescales are worth being realistic about too. Our German pilot is moving from laboratory validation towards pilot-scale demonstration across 2025 to 2028, roughly, which is a two-to-three-year step for one pathway in one region, and it is going well. Extrapolated sensibly, 10 years points towards early industrial scale in a number of well-supported regions rather than saturation.

The wider picture is that bioinspired materials sit within a network of strategies alongside reduction, reuse, repair, recycling and restoration; the most useful shift available to the industry over the next decade may be to build the system that can handle what it already makes rather than searching for a single material that solves it.

Artificial spider silk

Derived from proteins, these biomimetic fibres attempt to replicate the characteristics of one of nature's most sought-after materials. Artificial silks can involve a host of processes, including recombinant protein production – via bacteria, yeast or other host organisms – molecular design and spinning optimisation to deliver enhanced fibre performance.



Opportunities

1. High versatility and tuneability

Structural proteins – such as those found in spider silk – offer malleable building blocks for innovators, enabling precise tweaks at the molecular level to meet the needs of varied markets and clients. Applicability to a wide range of industrial sectors can help diversify investment, validate the technology, scale and drive down pricing.

2. Innate sustainability qualities

Manmade spider silk proteins negate the petrochemical compositions of other high performance, synthetic fibres. Many academic and commercial developments in the space claim non-toxic formulations and lower comparative energy consumption during production, as well as biodegradability and recyclability traits. There is also compatibility with solution dyeing with some innovations, enabling lower impact colouration.

Threats

1. Technical shortfalls

Currently, the credentials of many artificial spider silks struggle to match those of their natural counterparts. There are many practical hinderances: conventional spinning technologies can fail to exhort the same chemical and mechanical conditions on the finished fibre, or complex spider proteins sequences can be difficult to replicate through bacterial fermentation. Innovators are working to alleviate these challenges, however knowledge gaps and technical barriers persist.

2. Industry acceptance

Even if these materials are successfully validated and commercialised, they may still experience industry resistance on the ground, jarring market adoption. Where possible, novel materials should be conscious of common production setups and conventional supply chains to avoid unnecessary costs and operational downtime. However, if bespoke solutions are needed – such as specialist spinning setups – this is likely to cause disconnect between stakeholders.

Prized for its strength-to-weight properties and elasticity, spider silk has long been seen as a material worthy of industrial interest. However, unlike the silkworm – which has a storied farming history – spiders are ill-suited for commercial silk harvesting, not least due to their cannibalistic tendencies. As such, despite vast technical challenges and costs, there is an appetite to replicate the unique evolutionary talent of the spider without need of the organism.

The crux of the problem is the complex biological, chemical and mechanical dynamics at play during natural spider silk production. It is a multifaceted challenge: innovators are working to replicate the distinctive chemical profile of spider silk, including its precise protein sequence and molecular weight, as well as the fibre's physical architecture and properties. The latter is partially achieved through the spider's distinctive spinning mechanism – a novelty difficult to simulate with conventional fibre spinning technology.

In addition to these challenges, high-quality spider silk proteins, despite improvements, can still be difficult and expensive to cultivate within bacterial or yeast fermentation setups.

The diversity and technical parameters of these challenges do not come cheap. R&D here is intensive and expensive. Several prominent innovators in the space have raised significant funds to support their industrialisation, however, their use within the fashion sector remains constrained to high-fashion or limited capsule runs.

In the meantime, the survival of these promising fibre technologies rests on investor patience and industrial support. Fortunately, the high-performance potential of artificial silk captures interest from outside fashion's fast-moving ecosystem, drawing investment and support from industrial, automotive and aeronautical players alike.



Link Silk can be manufactured either through bacterial fermentation, which creates Link Proteins, or via gene-edited silkworms. Source: Link Spider

Link Spider
Shenzhen, China
Scaling

Avid synthetic biology proponent, Link Spider, leverages tools such as microbial fermentation and protein engineering to create numerous fibres, colourants and materials prime for the textile sector and beyond. Among its offerings are spider silk protein fibres, Link Silk, of which there are two current production methodologies. The first involves industrial microbial fermentation, using microbes to cultivate the spider silk proteins at scale, while the second employs use of genetically edited silkworms. The latter tunes the silkworms to produce spider silk, reportedly negating some of the sequence length issues incurred with microbial approaches – a hinderance which can impede final fibre performance. As such, gene-edited Link Silk is claimed to exhibit particularly competitive strength, resilience and elasticity, akin to Kevlar and nylon.

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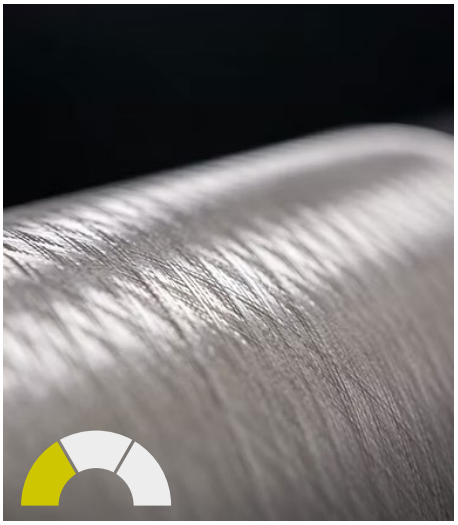
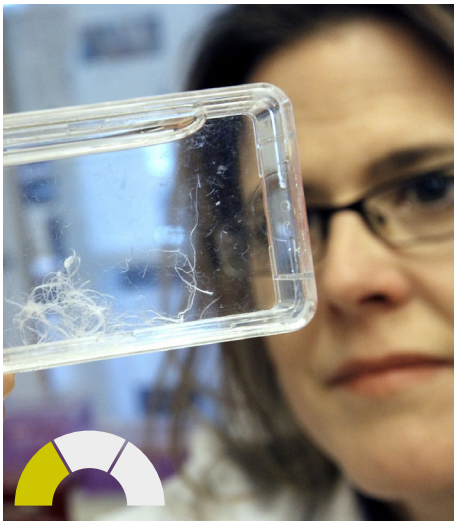


Spintex is currently engaging with the aerospace sector to incubate and validate its technology. Source: Spintex

Spintex
Oxford, UK
Emerging

Spintex's offering centres on emulating a spider's spinnerets for artificial silk production. Having developed both a synergetic fibre dope and spinning methodology, these components work together to enhance the final product's performance. Akin to a spider's silk, Spintex's fibres start as a shear-sensitive, liquid protein gel. This solution is then pulled through the startup's biomimetic spinning apparatus. This process expels the aqueous component of the solution, encouraging the proteins to align through shear flow – turning the liquid solution into a continuous solid fibre. Spintex claims its proprietary pultrusion process can be done at room temperature, without use of harsh chemistries and creating only water as a byproduct. As with other technical textile startups, the company is diversifying its sector interests to derisk and scale; in 2026, Spintex joined the Airbus Launchpad in the UK, co-funded by the UK Space Agency – a move which will enable it to validate its technology in the technically demanding aerospace sector.



As 2026 H&M Global Change Award winners, Artsilk hopes it will soon be ready to officially spin-off, find investors and begin industrial collaborations. Source: Artsilk, Hans E Ericsson

Artsilk
Uppsala, Sweden
Emerging

Artsilk is an early-stage academic endeavour and H&M Global Change Award winner also inspired by the spider's natural spinning mechanism. The team has devised a way to create water-soluble spider silk proteins – currently at kilogram scale – and spin them with no harsh chemistry or high temperature inputs. Rather, the pH of the spinning solution is adjusted to trigger the polymerisation process, enabling the production of reportedly high-performance fibres through a multifilament extrusion process. Further, the fibres' configurable proteins enable the team to experiment with novel properties, such as electronic conductivity or magnetism – traits which may have applicability in future technical and industrial applications. However, high-performance textiles, protective kit and sporting equipment are Artsilk's current target markets. Next steps for the team include optimising washing and stretching phases to make a viable yarn prototype, which may lay the foundations for an official spinout company.

Biomimetic functionality

Coatings, finishes and modifications leveraging mechanisms and surface structures lifted directly from nature to bestow functional textile properties. Through bioinspired approaches, these technologies seek high performance while avoiding use of per- and polyfluoroalkyl substances (PFAS).



Opportunities

1. Regulatory tailwinds

Global restrictions on PFAS is prevalent, particularly within US and EU markets: consumer products, such as sports and outdoorwear, having few exemptions. As such, new means of augmenting textile surfaces sans PFAS and with promising functional capabilities hold immense potential for brands and mills currently struggling to balance performance and sustainability.

2. Multi-sector applicability

Many of these bioinspired technologies are spun out from institutions and founding teams grounded in scientific and industrial understanding. This often means technologies emerge with no one applicational bias and are targeting multiple use cases, sectors and industries at once: common focuses include advanced materials, packaging and consumer textiles. This spreads risk and diversifies investment interest.

Threats

1. Nascency & competition

While startups offer promising solutions to the industry's performance qualms, they must compete against more established players working to the same end. Adopters must weigh investing in higher risk emergent innovators against possible market-ready breakthroughs from trusted names. Balancing this risk-reward will be key to ensuring that there is a diversity of compliant textile solutions on the market in the face of tightening regulations.

2. Real-world performance

Emergent innovations appear promising on paper, but real-world testing differs from laboratory results. Non-PFAS technologies have long struggled to uphold the durability and performance levels of their counterparts – oleophobicity being particularly difficult to replicate. Other factors such as washability and UV resistance will prove key should biomimetic functional technologies be serviceable in areas such as outdoor and workwear.

With global pressures to transition entirely from PFAS-based chemistries – multiple bans taking place this year (2026) – academia and industry are seeking alternative strategies for high textile functionality.

Restricted on the chemicals front, many are turning to the natural world in search of inspiration – a source rich in millions of years of evolutionary R&D.

Muses can be found from across the biological kingdoms, drawing influence from animals, plants and fungi. Startups Amphico and Sparxell have been respectively inspired by the unique water-repellent properties of arthropods and structural colour of iridescent fruits and insects. The superhydrophobic qualities of the lotus leaf have long been an influence for many studies and products – not least for Cellulotech and the Wyss Institute teams, featured within this section.

Nevertheless, translating these bioinspired mechanisms and technologies into commercially viable textile solutions is no small feat. Startups must scale their novel innovations while conscious of existing industrial norms, costing sensitivities and holistic performance expectations within the textile supply chain. Simultaneously, established textile players are heavily incentivised to devise their own remedies to the PFAS restrictions, creating a competitive and fast-moving ecosystem for both innovators and industry adopters alike.

However, the need for solutions – from whichever source – is fuelling interest in biomimetic developments, which can span drop-in coating solutions, advanced grafting and laser technologies and surface texture engineering.

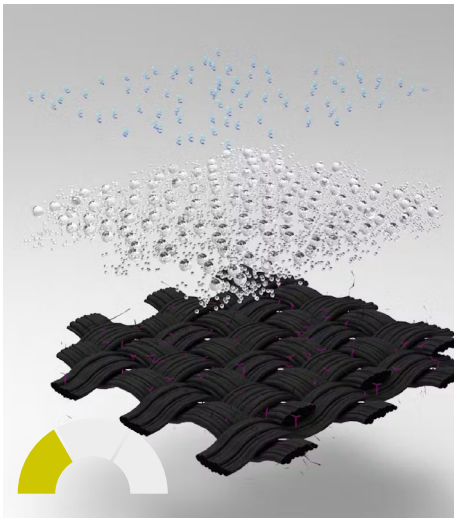
In many instances, these innovations are versatile by design, enabling the innovator to pivot the tech to various industrial sectors. So, while textiles are a primary focus for our featured startups, good awareness of cross-market developments may enable brands and mills to snag relevant, transferable technologies prior to competitors.



Cellulotech's grafting technology claims to elicit a greater, more consistent functional coverage on surfaces such as fibres than coatings, with less attributed material use and CO_2 production. Source: Cellulotech



Demeter Bio is scaling a biobased, PFAS-free coating technology claiming durable, high levels of water, oil and alcohol resistance. Source: Demeter Bio



Two different sized silica nanoparticles are irreversibly attached to the fabric substrate, which assumes a similar bumpy structure to that found on the surface of the lotus leaf. Source: Wyss Institute, Harvard University

Cellulotech
Victoria, Canada
Scaling

Inspired by the innate repellency of the lotus leaf, Cellulotech aim to commercialise a patent-protected grafting technology prime for cellulosic materials. At its crux, the startup covalently grafts fatty acid molecules – derived from a biobased source – onto cellulose fibres and other hydroxylated materials. The process reports to negate use of solvents and catalysts, requiring only hot air, while claiming vast CO_2 reductions over conventional coating processes. It's positioned as pertinent to a number of applications, such as packaging, nonwovens, workwear and outdoorwear. Superhydrophobicity is marketed as one of the technology's key functionalities across all use cases, reportedly achieving contact angles of up to 150°. It also claims no impact on breathability, recyclability and compostability, with good wash-resistance even without use of robust PFAS chemistry. The startup hopes to push its commercialisation via a trifecta of affordability, scalability and performance, aided by a dedicated French R&D subsidiary handling industrial piloting.

Demeter Bio
London, UK
Emerging

Inspired by biomimicry and biological systems, Demeter Bio has used biopolymers to create two initial solutions negating PFAS ingredients in consumer products. MelioShield is a polymer technology augmented for the cosmetics industry while the team's other debut product, Fibrepel (formerly known as AguaShield), is engineered as an alternative to fluorinated durable water repellents (DWR). The latter's industrial aims are packaging, performance materials and textiles. While non-PFAS DWRs have become a market norm in consumer segments such as outdoorwear, performance and durability remain a challenge – namely regarding oil and alcohol repellency. However, the team is confident that such demanding levels of repellency can be achieved with its biobased technology, which this year was validated with a Royal Society of Chemistry Emerging Technology prize. It follows Demeter Bio's success in securing a place on the UK government-backed DeepTech Catalyst Biotech Incubator earlier in 2026 – unlocking access to research funding, specialist facilities and business mentoring key to its next stage of commercialisation.

Wyss Institute (Nixe)
Boston, US
Emerging

Harvard University's (US) Wyss Institute is geared towards the research and development of novel technologies leveraging bioinspired and biomimetic innovation. Sustainable materials are one of the Institute's multiple focuses in this pursuit, with other dedicated branches in areas such as therapeutics, molecular robotics and synthetic biology. Borne of its materials segment is Nixe – a collaboration between teams based at Harvard and North Carolina State Universities (US). Nixe is a reportedly PFAS-free, nanostructured silica-based coating technology, prime for use on and within textile structures. It achieves its repellency performance by employing use of two different sized silica nanoparticles: simulating the bumped surface morphology of the famously repellent lotus leaf. The achieved surface chemistry of the fabric claims to create a breathable, water-repellent effect created within a low-cost, closed-loop, water- and PFAS-free process. With the Institute carrying an ethos of industry-academic collaboration, it is seeking partners and licensees to help scale the technology.

Animal-free texture

Materials developed with vegan inputs that replicate or reinterpret the appearance, handle, structure or performance of animal-derived materials, including leather, fur, down, wool and silk. Biological building blocks and material-engineering approaches are used to create alternatives to said conventional materials.



Opportunities

1. Regulatory pressure could strengthen commercial demand

Global textile waste and extended producer responsibility (EPR) measures are encouraging brands to rethink material sourcing and end-of-life strategies, potentially creating opportunities for biobased and compostable alternatives to conventional faux fur and leather.

2. Feedstock diversity

Banana stems, agricultural residues and other biological resources are being explored as inputs, reducing reliance on individual feedstocks while giving developers more options to balance cost, performance and material characteristics.

Threats

1. Increasing market competition

The growing number of alternative-material developers makes it harder for brands to distinguish technologies with proven performance and scalability from those still at an early stage, potentially weakening confidence in the wider category.

2. Greater scrutiny of material claims

Tighter requirements for substantiating biobased content, composability and environmental performance could increase verification costs and expose gaps between marketed and actual material composition. Some animal-free materials still rely on synthetic binders, coatings or adhesives, making it harder to substantiate fully fossil-free claims.

The development of vegan materials is shifting beyond simply replacing animal-derived inputs. Increasingly, companies are seeking biobased alternatives that also reduce reliance on fossil-derived synthetic materials, while replicating the texture, feel and performance of leather, fur and other animal-derived materials.

A key challenge is therefore performance replication at commercial scale. Developers need to balance hand feel, appearance, durability, colour and texture consistency with compatibility with existing textile and footwear manufacturing processes.

Drop-in compatibility could help accelerate adoption; Rheom Materials highlights this approach, with its Shorai resin pellets designed to run on standard plastic extrusion equipment. Its partnership with Econock also demonstrates how small-batch manufacturing can help emerging materials reach finished products and potential brand customers.

There are still technical and commercial challenges requiring collaboration between scientists, material developers and skilled manufacturers, particularly in maintaining consistent colouration, texture and performance as materials move towards commercial production. Kym Canter, founder and creative director of Biofur, echoes this sentiment: “The challenges are technical and commercial: matching exact hand feel, pile density, colour, price, lead times, testing requirements and performance standards for each product category.”

Durability and end-of-life performance present another trade-off. Coatings, binders and other treatments can improve flexibility, abrasion resistance and water resistance, but may complicate biodegradability or end-of-life processing. Meanwhile, greater scrutiny of claims such as biobased, renewable, compostable and ‘free from harmful substances’ is increasing the importance of testing and certification.

All three following pioneers have recognised certifications or independent validation. Banofi and Biofur hold USDA Certified Biobased Product certification, while Banofi also has PETA-Approved Vegan status and PLNTmatter has third-party validated life cycle assessments. Together, these reflect a broader push towards independently verified claims. As more animal-free texture materials scale, substantiating these claims may prove as important to adoption as technical performance itself.



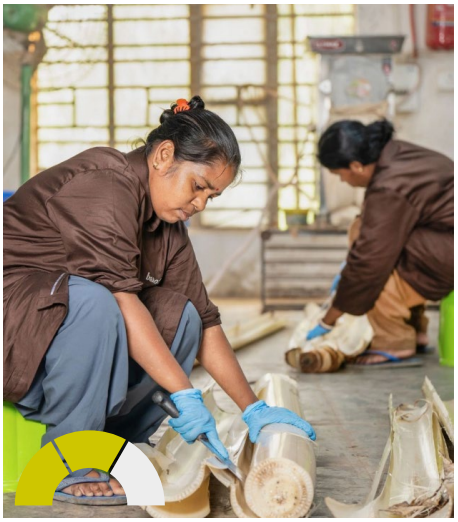
Regenerative bamboo – PLNTmatter's foundational material for biomimetic processing. Source: PLNTmatter

PLNTmatter
Los Angeles, US
Scaling

Founded in 2025, PLNTmatter is Ettitude's materials innovation division, formerly known as Ettitude Materials. While Ettitude applies its materials to consumer home textiles, PLNTmatter develops and commercialises plant-based fibres and textile technologies for fashion brands and supply-chain partners. Its CleanBamboo technology converts bamboo into fibre through a closed-loop, lyocell-like process. PLNTmatter states that the process uses non-toxic chemicals and recycles the solvent, while the resulting fibres offer properties including natural softness, odour resistance and hypoallergenic performance. PLNTmatter offers plant-based fibres and textiles positioned as alternatives to silk, cashmere, wool, linen and elastane. Its range spans knits and wovens, with textures from shiny to matte and draped to structured.
In September 2026, PLNTmatter presented a CleanBamboo fabric capsule developed with Casa da Malha at Première Vision Paris. It also joined the Denim Deal community to explore CleanBamboo as a blending fibre for circular denim applications.

PERFORMANCEDAYS
FUNCTIONAL FABRIC FAIR
MUNICH

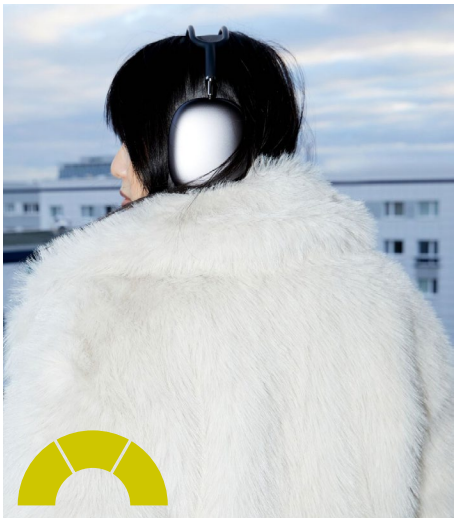
Exhibiting at Performance Days:
Booth IN30



Banana crop waste for leather alternative materials. Source: Banofi

Banofi
Kolkata, India
Scaling

Founded in 2022 by Jinali Mody, Banofi is a material innovation company developing plant-based leather alternatives from banana crop waste. The company works with around 100 smallholder farmers, sourcing discarded banana biomass and converting fibres into pulp. The pulp is combined with a biobased binder and natural rubber, followed by protective and colour coatings. The resulting material comprises a protective topcoat, composite material layer, biobased adhesive and backing. Banofi offers multiple colours, textures and finishes, with applications such as wallets, watch cases and passport holders.
In its 2024 MIT Solve application, the company reported achieving pilot scale, generating around US$30k in monthly materials sales and receiving orders from more than 40 global brands. The company is still investing in factory expansion to advance towards large-scale production.



Biofur's next-generation biobased fur, Biofur NXT. Source: Biofur

Biofur
New York, USA
Commercially ready

Kym Canter founded House of Fluff in 2017 to create animal-free alternatives to conventional fur. The company later evolved into Biofur, a material innovation business developing 'nature to nature' solutions for petroleum-based textiles such as synthetic fur, sherpa and fleece textiles. Its first-generation PLA (polylactic acid) materials began with Biosherpa, its first biobased sherpa, which Biofur states is USDA BioPreferred certified. Biofur converts renewable feedstocks into sugars, which are fermented into lactic acid and polymerised into PLA. The polymer is then pelletised, extruded and spun into yarn for biobased pile textiles.
In September 2026, Biofur introduced Biofur NXT as a new biopolymer and the next generation of its textiles. According to the innovator, Biofur NXT is made from agricultural waste and offers improved colourfastness, durability and softness, alongside greater flexibility in production.



Circularity bio processes



Circularity bio processes can be defined by the use of biobased concepts or technologies to support and develop circular processes across the textile lifecycle. The field spans biological recycling, enzymatic treatments, biodegradation, biobased feedstocks and microbial processes, with the aim of keeping materials and their constituents in productive use or safely returning them to biological cycles.

The opportunity is significant: EU member states, for example, generated 6.94 million tonnes of textile waste in 2022, equivalent to 16kg per person, according to the European Environment Agency. But only around 1% of clothing material is recycled into new clothing, according to the European Commission.

Research is increasingly investigating enzymes and microorganisms capable of selectively breaking down fibres, separating blends or converting textile waste into new materials and useful biological outputs. Drivers include waste reduction, pressure on virgin resources, regulation and demand for lower-impact recycling routes.

Yet biological processes face risks around scalability, cost, feedstock contamination, process control and whether claimed environmental benefits withstand full life cycle assessment (LCA). The emerging opportunity is therefore not to simply make textiles biodegradable, but to use biology to create controlled, recoverable and regenerative material cycles.

Introducing the topic and exploring its potential is Dr Mark Taylor, member of the Leeds Institute of Textiles and Colour (LITAC) Academic Network and research fellow in fashion technology and sustainability at the School of Design, University of Leeds, UK. LITAC's leading of the Back to Baselines in Circular Fashion and Textiles Network – a multi-million-pound research initiative that aimed to build a clear, data-driven baseline of the UK fashion sector's sustainability status to help the industry reach net-zero and circular economy goals – means the Network is one of the industry's leading voices and drivers of circularity.

Discussion with **Dr Mark Taylor**, member of the Leeds Institute of Textiles and Colour (LITAC) Academic Network and research fellow in fashion technology and sustainability at the School of Design, University of Leeds, UK.



WTiN: Regulation is increasingly pushing businesses to consider the impact of a product's entire lifecycle. How do you see emerging policy influencing investment and innovation in biobased, circular systems over the next five years?

Dr Mark Taylor (MT): Emerging policy has the potential to make biobased and circular systems a core compliance requirement rather than a voluntary sustainability choice. Over the next five years, instruments such as the EU Strategy for Sustainable and Circular Textiles, the Ecodesign for Sustainable Products Regulation (ESPR) and mandatory Extended Producer Responsibility (EPR) will embed durability, recyclability, recycled content and traceability into market access. This shifts investment towards materials and processes that can demonstrate performance across the full lifecycle.

EPR fee modulation will financially penalise multi-material products that are hard to recycle (monstrous hybrids) and reward design for disassembly, monomateriality and fibre-to-fibre recycling pathways. As a result, investment should increasingly flow to biobased fibres and chemistries that are compatible with circularity, eg low toxicity, recyclable and supported by robust data on origin, impacts and end-of-life. Policy clarity also strengthens the business case for scaling advanced sorting, chemical recycling and digital product passports that carry verified lifecycle information.

At the brand level, regulations targeting waste, unsold stock and product destruction should (will) accelerate reuse, repair, rental and product-as-a-service models. This could create demand for biobased textiles engineered for multiple lifecycles, refurbishment and eventual recycling.

Finally, due diligence, corporate reporting and anti-greenwashing rules will raise the evidentiary bar. Innovation will favour biobased concepts backed by credible life cycle analysis (LCA) and end-of-life scenarios rather than headline 'biobased' claims. In effect, policy has the possibility of steering both investment priorities and innovation towards data rich, lifecycle aligned, genuinely circular biobased systems.

WTiN: Textile & apparel industry technologists have made meaningful progress within circularity and end-of-life management innovation – yet bottlenecks to widespread adoption and integration remain. From your perspective, at what stage is the industry today on this journey, and what role do biobased approaches have to play in overcoming those challenges?

MT: The textile and apparel industry is no longer at the 'pilot' stage of circularity, but it is still far from fully circular. Meaningful progress has been made in garment-to-fibre recycling, repair and resale models.



LITAC contains from numerous research initiatives and centres such as the 3D Weaving Centre and the Future Fashion Factory which work towards more productive, digitalised and sustainable textile solutions. Source: LITAC, University of Leeds

Brands are making early preparation for digital product passports (DPPs). Yet the industry remains stuck in a transitional phase where innovation outpaces infrastructure, standards and commercial incentives.

The biggest bottlenecks are structural, such as inconsistent material flows, limited high-quality feedstock, immature sorting and recycling capacity, and a lack of harmonised design standards that allow products to move through circular systems at scale. Many biobased materials also enter the market without clear end-of-life pathways, creating uncertainty for recyclers and brands.

Biobased approaches can help unlock these constraints but only when designed for circularity rather than simply for fossil replacement. Biobased fibres and chemistries that have low toxicity, are monomaterial and compatible with mechanical or chemical recycling can reduce contamination and improve yield. They can also support the development of more predictable feedstock streams, which is essential for scaling garment-to-fibre recycling.

Equally important is the role of biobased innovation in reducing dependency on complex blends and hazardous chemistries that currently block circular flows. Biobased coatings, adhesives and auxiliaries that enable disassembly or clean recycling can remove key friction points in end-of-life processing.

Overall, the industry is in a consolidation phase: early breakthroughs exist, but widespread adoption requires materials, processes and business models that are intentionally engineered for circular systems. Biobased innovation is a critical part of that shift provided it is lifecycle aligned, not just bio-labelled (which would be greenwashing).

WTiN: From 2024, LITAC led the Back to Baselines in Circular Fashion and Textiles Network – a multi-million-pound research initiative – that aimed to build a clear, data-driven baseline of the UK fashion sector's sustainability status. Its aim is to help the industry reach net-zero and circular economy goals. What does Back to Baselines mean in practice, how does it integrate biobased approaches and what other fundamental principles do you think the industry must pay attention to in its pursuit of circularity?

MT*:* The broader principles [that] the industry must pay attention to mirror the B2B project's findings [are below]:

1. **Evidence over claims:** Circularity requires measurable performance, not narrative sustainability.
2. **Material simplicity and compatibility:** Products must be designed to flow through existing and emerging recycling systems.
3. **Durability as a prerequisite:** Without long life, circularity becomes waste management rather than value retention.
4. **System alignment:** Design, materials, business models and infrastructure must be calibrated to the same baseline expectations.

Ultimately, Back to Baselines reframes circularity as a performance challenge, not a branding exercise. Biobased innovation contributes meaningfully when it meets those baseline conditions and strengthens the technical foundations of circular systems.

WTiN: In academia, are there any particular advancements or developments within biobased textile and apparel technology that are underexplored? Things that have yet to crossover into commercial viability, but hold potential for the future of circularity?

MT: Across academia, several promising biobased textile and apparel innovations remain underexplored and have not yet made it into commercial viability, largely because they require new infrastructure, standards or investment models to scale.

Work on polyhydroxyalkanoate (PHA) fibres is particularly early stage but notable. Although PHA is well studied in biomedical and packaging contexts, fibre development is still experimental. Academic studies show that PHA can be melt spun into fibres with tuneable biodegradation rates and mechanical properties controlled through copolymer selection. Its compatibility with enzymatic depolymerisation offers potential circular end-of-life routes distinct from both polyethylene terephthalate (PET) and polylactic acid (PLA), but challenges around cost, thermal stability and consistent fibre performance currently limit commercialisation.

One area with significant potential is biobased polymer regeneration, where researchers are developing routes to depolymerise and repolymerise biobased fibres (eg, PLA, PHA, cellulose derivatives) with lower energy and chemical intensity than conventional recycling. These pathways could create closed loop systems for biobased materials that currently lack viable end-of-life options.

"Success for biobased circularity will not be defined by the volume of biobased materials on the market, but by their integration into functioning circular systems."

Another underdeveloped frontier is biobased functional chemistries [such as] adhesives, coatings, membranes and performance finishes derived from lignin, chitin, alginate or mycelium. Many of these show promise for replacing persistent synthetic chemistries, reducing toxicity and improving recyclability, but they remain at lab scale due to stability and processing challenges.

Academia is also advancing bioengineered fibres that are designed for circularity from the outset: protein-based fibres with tuneable mechanical properties, microbial cellulose with controlled crystallinity and hybrid biosynthetic

composites that can be disassembled or recycled more easily than current blends. These materials could reduce reliance on complex fibre combinations that currently block circular flows.

WTiN: Looking ahead, what do you think success will look like for biobased circularity in textiles, and what should brands, manufacturers and innovators be doing now to help make that future a reality?

MT: Success for biobased circularity will not be defined by the volume of biobased materials on the market, but by their integration into functioning circular systems. In practice, success will look like materials that are designed for multiple lifecycles, supported by compatible chemistries, and able to move predictably through sorting, recycling and regeneration infrastructure. It also means biobased innovation that demonstrably reduces system friction, lower toxicity, simpler material architectures and clearer end of life pathways, rather than adding new complexity.

A mature biobased circularity landscape would include stable feedstock streams, harmonised design standards and recycling technologies calibrated to the behaviour of both biobased and conventional fibres. DPPs and verified LCA data would underpin claims, enabling brands and recyclers to make evidence-based decisions. Crucially, success also means commercial models that capture value across multiple use cycles, not just at point of sale.

To make [a mature biobased circularity landscape] happen, brands, manufacturers and innovators should act now in three areas:

1.Design to baseline criteria
Durability, monomateriality, low toxicity chemistries and recycling compatibility must be treated as non-negotiable.

2.Invest in infrastructure alignment
Collaborating with recyclers, chemical suppliers and technology developers to ensure new biobased materials can be processed at scale.

3.Commit to data integrity
Robust LCA, transparent supply chains and credible end-of-life modelling are essential for both compliance and trust.

Ultimately, success will be measured by how well biobased materials strengthen circular systems – not by how 'bio' they are, but by how effectively they enable long life, low impact, regenerative textile flows.



Biobased traceability

The use of biological tracers to validate, verify and authenticate products within the supply chain to counter malpractice, misinformation and counterfeiting while supporting circular regulation, or the use of biobased materials for physical tagging.



Opportunities

1. Strengthen regulatory compliance and data credibility

Biological tracers can verify the accuracy of data stored in digital product passports (DPPs) and other digital transparency systems. DNA markers and other identifiers provide physical proof of origin and authenticity, reducing the risk of material substitution, fraud and counterfeiting.

2. Enable more effective circularity and end-of-life processing

Verified information on fibre composition and product constituents supports more accurate sorting, recycling and end-of-life management, improving the efficiency of circular textile systems.

Threats

1. High implementation costs and challenges

It may be difficult to quantify the indirect return-on-investment (ROI) of adoption – such as stronger compliance, improved brand trust and reduced counterfeiting – and therefore justify the high initial cost of adoption. Additionally, biological verification is only viable if the applicable DPP platform allows integration.

2. Immature technology landscape

Beyond established DNA markers, other biobased traceability technologies remain in nascent stages and therefore have limited scalability. This immaturity also means there are currently no universally accepted standards for biological markers.

The application of biobased technologies to traceability efforts remains emerging but is increasingly rising in prominence. This is because biobased traceability technologies can support compliance with regulatory efforts that push the responsibility of providing authenticated information within the value chain. For example, as digital transparency systems become a prerequisite in the EU – under the EU's digital product passport (DPP) legislation – information is at risk of distortion and misrepresentation by supply chain actors who wish to frame their products as sustainable. Therefore, it is paramount that these digital systems provide verified information to counter potential misinformation – as Swiss technology company Haelixa puts it, the "DPP regime requires [transparency] to be based on validated data inputs."

By applying a biological tracer to a garment's constituents, actors along the supply chain can confirm a product is authentic and has come from the correct place. Additionally, counterfeiting and malpractice along the supply chain can be countered by these traceability technologies.

The most commercially mature application of biobased technologies in traceability comes in the form of DNA and biological markers. However, researchers are also exploring whether microbial communities and biochemical signatures can help to identify fibre origins, while enzymatic authentication of fibre composition, blends and content is also on the periphery.

Importantly, legislation such as DPPs – and other related regulations that stipulate the availability of information – aim towards circularity. End-of-life management is reliant on information on product constituents and components to support how a product is processed and potentially recycled; as such, the addition of biological tracers to digital transparency systems that verify this information is arguably quintessential. Technology provider TextileGenesis, for example, asserts it is a 'competitive imperative'. Meanwhile, on the periphery, some companies are utilising biobased materials themselves to comprise physical tags for garments.

> **“The addition of biological tracers to digital transparency systems that verify information is quintessential to end-of-life management and therefore circularity.”**



Oritain proves the origin of products and raw materials, such as cotton. Source: Adobe.com



Haelixa provides scientific proof of material origin at every step of the supply chain. Source: Haelixa, Adrian Ehrbar Photography



PulpaTronics offers recyclable RFID tags made from cellulose. Source: PulpaTronics

Oritain
London, UK
Commercially ready

Oritain uses high-precision forensic science and data to prove the origin of products and raw materials, building ‘transparency and trust’ in global supply chains across fashion and cotton, coffee, horticulture, red meat, dairy and more. It does so by using a product’s unique chemical fingerprint to assure its origin – reportedly with high precision. By tracing products and raw materials back to their source, the company says it help organisations worldwide to achieve regulatory compliance, reduce reputational risk, protect product integrity and support ESG commitments.

Haelixa
Zurich, Switzerland
Commercially ready

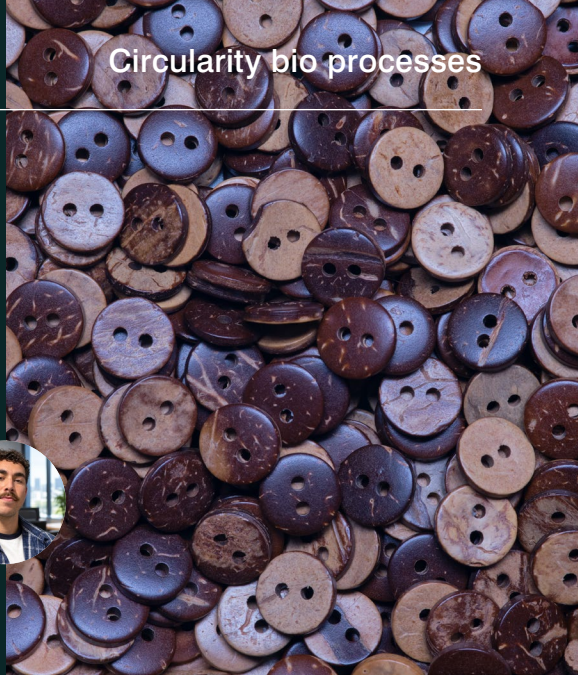
Haelixa is a Swiss technology company, spun off from ETH Zürich, that provides a DNA-based traceability solution for industries including textiles. Specifically, the company applies a unique, plant-based DNA sequence to fibres – ideally at the earliest viable point in the supply chain – through a sprayable, water-based formulation. Haelixa claims the applied DNA remains affixed to the fibres, even though harsh dyeing and finishing steps. The traceable technology enables brands to verify material origins and claims to enhance supply chain transparency.

PulpaTronics
London, UK
Emerging

PulpaTronics offers RFID tags made from paper (cellulose) – “revolutionary, metal-free and chipless RFID tags made to preserve our natural resources”, the company website states. Where a traditional tag requires chemical etching and various levels of heat pressing to join the components together, the UK-based company instead optimises paper to “create the perfect microstructure” and “yield the highest level of conductivity”.

Biodegradable components

The use of biobased, degradable components – such as buttons, trims or adhesives – to increase the natural degradability of a product in support of sustainable or circular end-of-life management.



Opportunities

1. Design for end-of-life from the outset

Adopting biodegradable components enacts a design-for-disassembly or design-for-degradation approach, ensuring end-of-life considerations are embedded during product development rather than addressed retrospectively.

2. Improve whole-garment biodegradability

Conventional garments often contain plastic trims or buttons that prevent an otherwise natural fibre product from biodegrading. Replacing these with biodegradable alternatives enables more complete biological decomposition, without needing consumers and waste managers to remove components at the end-of-life.

Threats

1. Potentially incompatible end-of-life infrastructure

Many regions lack the industrial composting or biological recycling infrastructure needed to process biodegradable textiles and components at scale. For example, current textile sorting systems are generally not designed to distinguish between biodegradable components and conventional ones, making it difficult to route products to the correct end-of-life pathway. As a result, many of these adopted components may contaminate recycling streams, or still end up in landfill or incinerated, limiting the intended environmental benefit and possibly proving to be a waste of investment.

2. Performance and verification trade-offs

Some biodegradable components may offer lower durability, moisture resistance, heat stability or wash performance than conventional alternatives. Additionally, demonstrating that a component is biodegradable requires recognised testing standards. Without robust evidence, sustainability claims may be challenged.

Traditionally, the components of garments – such as buttons, trims and adhesives, among others – are not designed with biodegradability in mind, meaning a large part of a garment (or often the entire garment) ends up in landfills or incinerated as part of its disposal.

Biodegradability can play a valuable role in establishing circularity by designing products to safely return to biological systems after use – ensuring that industry tackles its gargantuan waste issue. Doubly, by designing components with biodegradability in mind, a full garment's sustainability metrics can be improved while ensuring sustainable modularity of a product.

In today's industry, fibres are receiving a larger share of the industry's investment and funding efforts, but trims, buttons and other components are just as vital to determining whether a garment is actually recyclable, compostable, biodegradable or compatible with next-gen circular systems.

To this day, biodegradable trims remain a relatively niche category, but several fringe suppliers and innovators are developing solutions from natural polymers, agricultural waste, plant-based materials and compostable biocomposites.



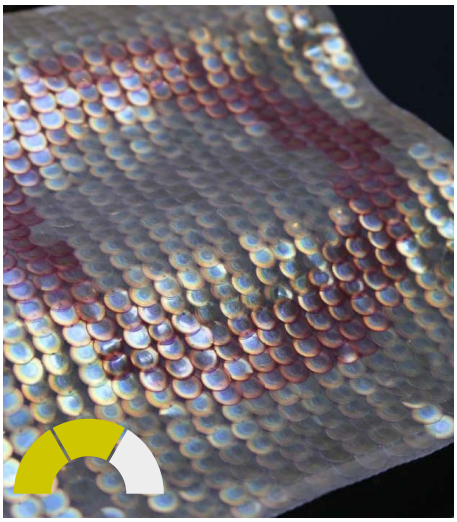
Pro-Stretch sources biodegradable materials such as NAIA Renew Yarn and Sorona corn fibre, as well as trims such as coconut buttons. Source: Pro-Stretch

Pro-Stretch
Congleton, UK
Commercially ready

Pro-Stretch creates innovative trims and garment accessories using new sustainable materials. The company supplies a wide range of sustainable, recycled and biodegradable garment trims and tapes, including mechanical stretch tapes, waistband elastics, sports bra elastics, knitted mesh, webbings, labels, drawcords and more. It sources plant-based biodegradable materials such as NAIA Renew Yarn, Sorona corn fibre, bamboo and coconut.

PERFORMANCEDAYS FUNCTIONAL FABRIC FAIR MUNICH

Exhibiting at Performance Days Munich:
Booth N22



Radiant Matter develops plastic-free, biodegradable sequins for the fashion industry. Source: Radiant Matter

Radiant Matter
London, UK
Scaling

Radiant Matter develops BioSequin – plastic-free, biodegradable sequins made from cellulose nanocrystals. The sequins are designed as an alternative to conventional PET sequins, which can shed microplastics and are difficult to recycle.



Duraflex leverages Azolyx – a trademarked biomass acetal (POM) material – within its trim offerings. Source: Duraflex

Duraflex
Tsuen Wan, Hong Kong
Commercially ready

Duraflex offers a broad range of trims and fastening components aimed at outdoor, sportswear, bags and performance apparel. Comprised of Azolyx – a trademarked biomass acetal (POM) material capable of biodegrading under anaerobic conditions while providing strength, stability and water resistance – Duraflex's products span buckles, strap fasteners, buttons, eyelets, hooks, zipper pulls, shoelace keepers and more, with the aim to "significantly reduce waste destined for landfills and potentially eliminate it entirely."

PERFORMANCEDAYS FUNCTIONAL FABRIC FAIR MUNICH

Exhibiting at Performance Days Munich:
Booth P06-07

Biological textile-to-textile recycling



The use of biological processes and agents – such as enzymes, fungi or bacteria – to recycle textiles into new, usable ingredients and materials.

Opportunities

1. Achieve higher-quality fibre recovery

Biological processes can break down fibres into reusable building blocks, potentially producing higher-quality recycled materials than traditional recycling methods, such as mechanical means.

2. Recycle complex textiles

Enzymes and microorganisms can be engineered to target specific fibres, coatings or components, creating opportunities to process textiles that are difficult to recycle mechanically.

Threats

1. Cost and process control

Enzymes, microorganisms and controlled processing conditions can add cost and complexity, particularly where large volumes of variable textile waste must be handled. Further, biological recycling remains relatively immature; while a select few innovators have achieved a level of industrial growth, processes have yet to comprehensively demonstrate consistent performance, throughput and economic viability at industrial scale.

2. Feedstock complexity

As with other approaches, biological recycling is hindered by contamination tolerances and economic viability. Blended, dyed and chemically finished textiles can contain multiple materials that make biological separation more difficult and can reduce process efficiency.

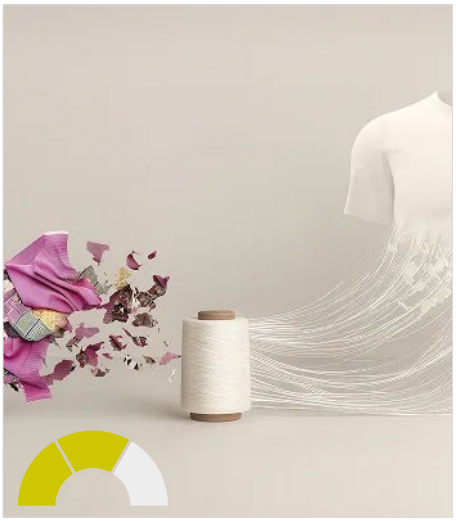
Biological textile-to-textile (T2T) recycling uses enzymes, microorganisms or other biological processes to break textiles down into their basic components. These components can then be recovered and used to produce new textile fibres, creating a biological route to fibre-to-fibre or textile-to-textile recycling.

Unlike conventional mechanical methods, biological processes can selectively target specific materials, enabling potentially more efficient recovery from complex or blended textiles. The technology's ability to target specific fibres, coatings or components within a blended garment or textile means industry does not have to rely on monomaterials as the only feedstock for textile-to-textile recycling, opening the gate to better manage a variety and mix of materials.

However, still in a nascent stage of industrialisation, biological T2T recycling comes at a cost; enzymes, microorganisms and controlled processing conditions require high investment costs and wider recycling ecosystem growth, particularly where large volumes of variable textile waste are concerned.

Aside from the financial cost, there remains limited scalability. Relatively immature processes have yet to comprehensively demonstrate consistent performance, throughput and economic viability at industrial scale. Meanwhile, blended, dyed and chemically finished textiles can contain multiple materials that make biological separation more difficult and can reduce process efficiency in the short-term.

“Biological textile-to-textile recycling uses enzymes, microorganisms or other biological processes to break textiles down into their basic components. These components can then be recovered and used to produce new textile fibres, creating a biological route to fibre-to-fibre or T2T recycling.”



Carbios seeks to ‘close the loop’ of plastic and textiles circularity through enzymes. Source: Carbios

Carbios
Clermont-Ferrand, France
Scaling

Carbios is a biotech company that develops enzyme-based technologies to break down and recycle PET plastics and textiles into virgin-quality building blocks. Its engineered enzyme depolymerises PET, separating its components into monomers that can be used to make new, virgin-quality PET and polyester, enabling a fibre-to-fibre recycling loop rather than downcycling the material.



Reo Eco is ‘leading recycling and production solutions’ for a smarter textile industry, having recently collaborated with Nigerian American designer, Kelechi Mpamaugo. Source: Reo Eco

Reo Eco
Huai’an, China
Scaling

Reo Eco’s BioCulus technology is an enzymatic, biological textile-to-textile recycling solution. BioCulus works by treating polyester textile waste to depolymerise it into momomers that are then purified and re-polymerised into PET. This PET can be converted into recycled polyester chips and filament yarn.

PERFORMANCEDAYS
FUNCTIONAL FABRIC FAIR
MUNICH

Exhibiting at Performance Days Munich:
Booth IN23



Cellulose Renaissance seeks to reduce waste from fast fashion. Source: Cellulose Renaissance

Cellulose Renaissance
York, UK
Scaling

Cellulose Renaissance touts itself as ‘one of the first biobased textile-to-textile recycling systems.’ This ‘bold new approach’ leverages enzymes and fermentation to recycle discarded textiles into high-quality virgin materials. The process breaks cellulose fibres down into sugars, then uses bacterial fermentation to convert those sugars into new cellulose. This bacterial cellulose is then processed into material that can be spun into new yarns.

Recode 2050

重製未來

FUNCTION IN FABRIC

BIOBASED MATERIAL DEVELOPMENT

Plant Origins. Textile Possibilities.

Taiwan's textile manufacturers are expanding the possibilities of biobased materials by combining fibre development, yarn engineering, fabric construction and finishing. Pineapple leaves and cacao pod husks show how agricultural by-products can enter new textile value chains.

Pineapple leaf fibres can be extracted, processed into yarn and blended with other fibres to create fabrics with distinctive texture and structure. Bringing them into clothing requires coordinated expertise across the supply chain, from fibre preparation and blending to weaving, dyeing and finishing.

In Recode 2050, UUIN gives these capabilities a fashion context, working with pineapple-fibre blends, recycled PET polyester, TPU-laminated cotton, antibacterial fabrics and LIBOLON's ReEcoya® solution-dyeing technology.

The resulting collection shows how Taiwanese materials can support expressive silhouettes while retaining a clear functional purpose.

GrandeTex's SECAO® represents another route. According to the company, cacao pod husks undergo fermentation and hydrolysis before the resulting extracts are incorporated into polymer masterbatches and spun into yarn.

Together, these developments demonstrate how Taiwan's textile industry can translate alternative material origins into practical fabric solutions for international brands. The ability to connect material research with scalable textile processes strengthens Taiwan's value as a sourcing partner for performance-driven collections.

TAIWAN TEXTILE SELECT

Taiwanese textiles. New possibilities.



Collection previews: UUIN / ALLENKO3 / PCES

FUNCTIONAL TEXTILES IN FASHION

Taiwan’s Textile Expertise

Taiwan's textile expertise extends from fibres and yarns to fabrics, membranes, lamination and specialist finishing. Taiwan Textile Select: Recode 2050 brings together 31 textile companies and six fashion labels, making this breadth of capability visible through finished garments.

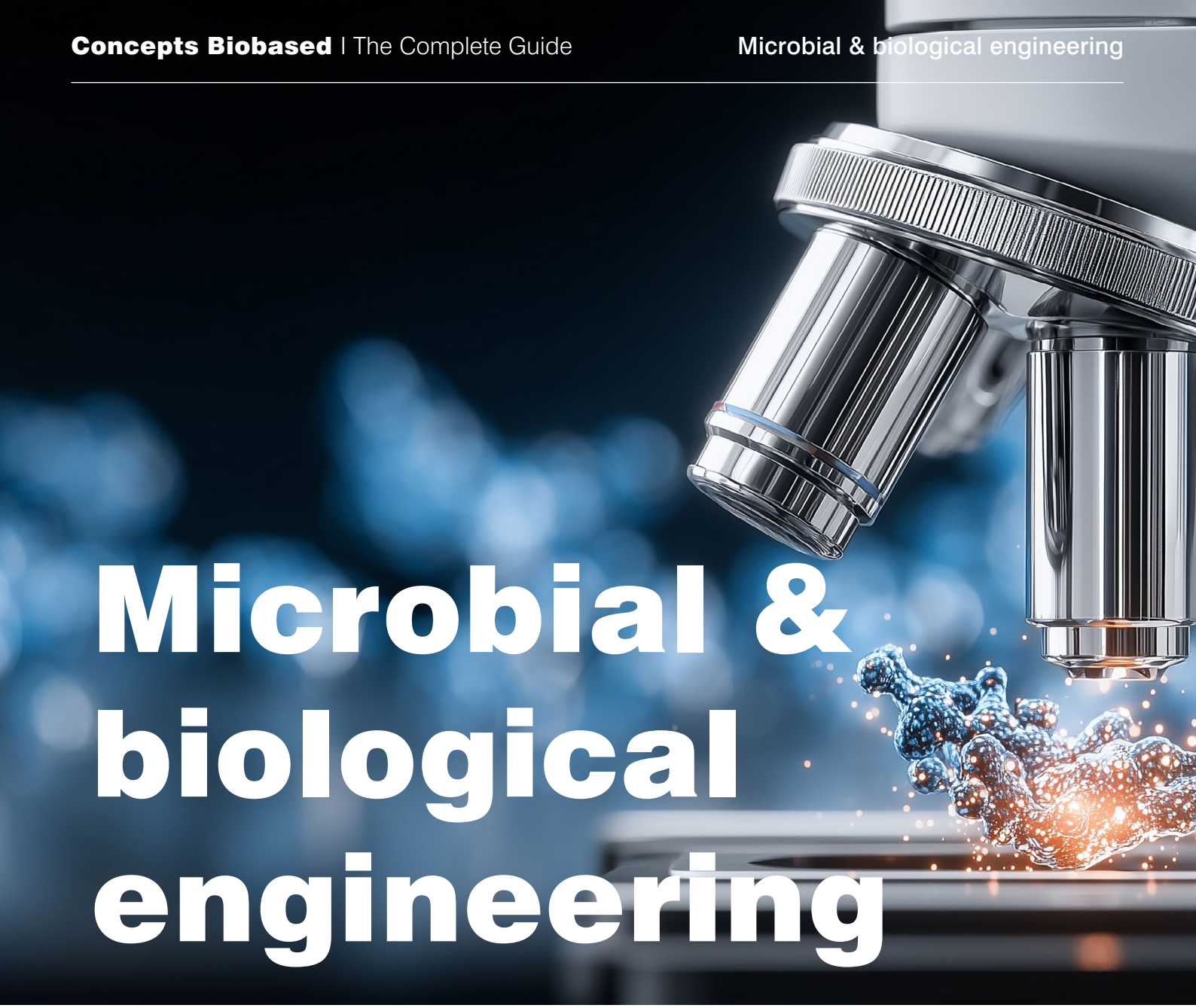
The three labels shown here interpret that supplier expertise in different ways. ALLENKO3 uses lightweight, flexible performance fabrics to create sharply tailored yet relaxed clothing designed to move between commuting, work and exercise.

PCES combines performance textiles with partner-supplied deadstock and zero-waste patterning. Draping, layering and sculptural construction give existing resources new expression, demonstrating how material efficiency can become part of a collection's design language.

UUIN connects biobased and recycled inputs with translucent layers and structured forms, illustrating how technical materials can contribute to both visual identity and wearability.

Across the wider 48-look presentation, Taiwanese suppliers contribute comfort, protection, waterproof and abrasion-resistant structures, cooling and sensing functions, recycled inputs and advanced processing. Their role extends beyond supplying fabric to supporting product development through material knowledge, process integration and application expertise.

For international sourcing and product-development teams, Recode 2050 presents an industry capable of translating material concepts into fabrics with defined performance, distinctive aesthetics and practical applications.



Microbial & biological engineering



Among the many fields of emergent textile innovation, microbial & biological engineering stands out for is relevance and capabilities in many of the inputs and processes that go into our clothing.

The space has enormous potential to reshape how textiles, colourants and finishes are made – shifting production from extraction or synthesis towards biological systems like fermentation, microbial cultivation and enzymatic processing. Two areas illustrate this shift in particular: biocolourants and bacterial cellulose.

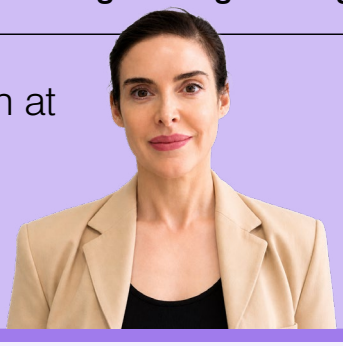
Biocolourants use microorganisms, algae and biological feedstocks to produce dyes and pigments, offering an alternative to conventional natural or synthetic colouration routes. Many technologies claim optimised water and resource usage, alongside the transition from petrochemical colourants. This could prove a boon in reducing the associated impacts of a historically intensive dyeing sector, should adaptations be made to integrate biological solutions at scale.

Elsewhere, advances in bacterial cellulose – produced by specific bacteria through fermentation – hold great potential in the fabrication of novel fibres, material sheets and foams, among other forms. This is also unlocking new methods of fabrication and production.

However, while there are great gains to be made in the pursuit of performance, novelty, localisation and sustainability, there are equally many pitfalls to consider. Biological systems are fluid, dynamic and at times fallible. This adds pressures to scalability, economics and repeatability. Additionally, biological origin alone doesn't guarantee sustainability – claims still need backing from independent and validated evidence. There also exists a bridge to gap in the textile industry's knowledge, understanding and acceptance of biological systems – requiring sector-wide upskilling to optimise on the potential.

WTiN discusses these concepts and concerns with Nancy Diniz, course leader of MA Biodesign at Central Saint Martins, University of the Arts London (UK): a cross-disciplinary course leveraging biology, chemistry, computation and design to explore biobased and bioinspired solutions.

Discussion with **Nancy Diniz**, course leader of MA Biodesign at Central Saint Martins, University of the Arts London, UK.



WTiN: Where in the textile value chain – fibre production, wet processing & dyeing and garment manufacture, etc – is microbial and biological engineering currently concentrated?

Nancy Diniz (ND): At present, I see much of the activity concentrated at the material production and wet-processing stages: developing biobased fibres and materials, microbial pigments and dyes, bacterial cellulose, mycelium-based materials, and biological alternatives to conventional chemical processing.

Biological colour is particularly active because microorganisms such as bacteria and microalgae can potentially produce pigments through fermentation or cultivation rather than relying exclusively on petrochemical synthesis or resource-intensive agricultural crops.

Mycelium-based leather and bacterial cellulose is also interesting because it challenges the conventional distinction between growing a raw material and manufacturing a textile. Instead of extracting a fibre and subsequently spinning, weaving and finishing it, the material itself can be cultivated into sheets or potentially grown towards particular geometries and properties.

WTiN: Alternatively, which stage or application do you think is being underexplored relative to its potential impact on the industry?

ND: What I think remains unclear or maybe underexplored is systems-level integration. There are many compelling material prototypes but fewer projects asking how biological production changes the entire textile value chain: where materials are grown, how they are processed, how much water and energy they require, how they interact with existing machinery, and what happens at end of life.

In the way I teach biodesign, I am particularly interested in how we move from material substitution to systems transformation. Replacing a synthetic pigment with a biological pigment is valuable but the greater opportunity is to ask whether biological processes can enable more local, distributed and circular forms of textile production.

WTiN: How compatible are novel biological colour, coatings and materials solutions with existing dyehouse and mill infrastructure? Where, if any, do you think brands or manufacturers will need to make the biggest capital or process changes to meaningfully adopt them?

ND: Compatibility varies enormously depending on the organism you are using. Some living-based pigments are already commercially available and these can potentially operate as drop-in alternatives – particularly when the biological process produces a pigment molecule that can subsequently enter relatively conventional dyeing or printing processes. Others require completely different conditions because the organism itself, or a biologically active process, is



MA Biodesign students have access to a PhD-staffed science laboratory to aid their exploration of biobased, bioinspired and biomimetic innovation. Source: Ana Blumenkron, Central St Martins (UAL)

involved in producing or applying the colour.

This distinction is important. There is a major difference between using biology to manufacture a colourant and using a living biological process as part of textile production.

In the latter case, manufacturers may need fermentation bioreactors or a specific cultivation infrastructure, sterile or semi-controlled environments, monitoring systems, different water-management protocols and expertise in microbiology. Temperature, pH, nutrients, contamination and time become production parameters alongside the familiar parameters of textile manufacturing.

I therefore do not think adoption necessarily means replacing entire mills. A more realistic near-term scenario may be hybrid manufacturing environments, where biological production is introduced upstream and integrated with existing textile finishing, printing or manufacturing infrastructure.

The largest investment may ultimately be less about individual machines and more about creating the technical knowledge, quality-control systems and biological processing infrastructure necessary to make these processes reliable at industrial scale.

WTiN: Biobased innovation can draw on a range of feedstocks and integrate with varied supply chains. Does this give the sector real flexibility to localise near key partners and existing textile manufacturing hubs, or does it face its own geographic constraints (for example, concentrated technical expertise, feedstock availability, energy demands or uneven government incentives)?

ND: I think both. One of the most exciting characteristics of biological production is that it can potentially work with locally available biological resources and waste streams.

Agricultural residues, food-processing waste, seaweed, forestry residues and other regional resources can become feedstocks for fermentation, cultivation or biofabrication. This creates opportunities to establish production systems around local material ecologies rather than transporting raw materials across very long global supply chains.

But biology does not automatically mean localisation. Biological manufacturing creates its own dependencies: access to strains and biological resources, fermentation infrastructure, specialist knowledge, controlled environments, water, energy, laboratory facilities and appropriate regulatory frameworks. A process may use a local feedstock but still depend on highly specialised equipment or expertise located elsewhere.

Seaweed and algae are good examples as their potential is strongly influenced by geography, climate, water conditions, cultivation infrastructure and local ecological regulation.

The more interesting question is therefore not simply "Can this material be produced locally?" but "What biological and industrial ecosystem needs to exist around it?"

This is where I see considerable potential for textile manufacturing regions. Existing textile hubs already contain knowledge, infrastructure and skilled labour. Biological technologies could potentially be layered onto these capabilities rather than creating entirely separate industries.

WTiN: Cost is one criticism often levied against early-stage biobased innovation; is this justified? If so, is this vulnerability being addressed to help innovators in the sector? Could costs become more competitive with any near-term technological breakthroughs?

ND: Yes, it is justified to some extent. Many emerging biological processes remain expensive compared with highly optimised petrochemical and conventional textile supply chains that have benefited from decades of investment, enormous production volumes and established infrastructure.

However, the comparison can also be misleading because the market price of conventional materials does not necessarily reflect their full environmental costs – water pollution, carbon emissions, resource extraction, toxicity or end-of-life impacts.

For startups, one of the biggest challenges is moving through the difficult middle ground between a successful laboratory prototype and reliable industrial production. Scaling biological systems is particularly challenging because biology is not stable, it has a high degree of variability. A process that works extremely well at one litre does not necessarily behave identically at thousands of litres.

Near-term advances in fermentation, bioreactor design, automation, AI-assisted process optimisation, strain engineering and the use of inexpensive waste-derived feedstocks could significantly reduce costs.

But I would resist framing success solely as reaching price parity with the cheapest conventional material. We should also be asking what environmental performance, functionality, circularity or local economic value the biological process provides.

WTiN: Factors such as biosafety, novel organism approval, GMO use and biobased labelling claims could slow real-world adoption against the rate of scientific progress. Do you see regulation, certification and consumer-trust issues hampering the commercialisation of these technologies?

ND: Yes, I do. Regulation is always a hurdle in material innovation but more so for biobased solutions and it will become increasingly important as these technologies move from experimental materials into mainstream products.

There are several different issues that are sometimes grouped together under 'biobased'. A pigment extracted from algae, a colourant produced through microbial fermentation, a genetically engineered microorganism producing a molecule and a textile containing living organisms raise very different regulatory and biosafety questions.

The greatest vulnerabilities are likely to arise where novel organisms, genetic engineering, biological containment and consumer-facing environmental claims intersect.

WTiN: Are there any other risks the industry should be wary of as they explore adopting these novel solutions?

ND: One caution I would emphasise across this entire area is that



The university keeps a stock of novel and innovative materials influenced by industry trends as an on-site research resource. Source: Ana Blumenkron, Central St Martins (UAL)

biobased should not automatically be equated with sustainable.

The exciting potential of microbial and biological engineering lies not simply in replacing petroleum-derived dyes, fibres or coatings with biologically derived equivalents. If we reproduce the same extractive, centralised and disposable production model using biological feedstocks, the transformation will be relatively limited.

The greater opportunity is to rethink manufacturing around biological principles: renewability, circular flows, adaptation, local resource availability and interdependence.

At the same time, biological production introduces something designers are not traditionally accustomed to: living organisms have their own behaviours and temporalities. They grow, mutate, respond and sometimes fail.

From my own work with mycelium, algae, microorganisms and bio-digital fabrication, I have found that this uncertainty is not simply a technical problem to eliminate. It can fundamentally change the designer's role – from imposing predetermined outcomes towards creating conditions in which materials and living processes can develop.

For textiles, that shift could ultimately prove more consequential than any single new fibre, pigment or material.

WTiN: If you imagine microbial & biological engineering realising its potential in textiles, what does that look like in practice for a mainstream apparel brand or consumer? What academic, industrial or commercial milestones do we need to surpass to get there?

ND: For the consumer, perhaps surprisingly, it may not initially look very different. You might buy a garment whose colour was produced through microbial fermentation, whose coating was derived from algae or whose fibres incorporated biologically manufactured components without the garment appearing radically unfamiliar.

The profound transformation could happen behind the product, in how materials are grown, coloured, processed and circulated.

For a mainstream apparel company, I imagine a future supply chain combining conventional textile expertise with fermentation, cultivation and biological manufacturing. Biological colourants might be produced closer to dyeing facilities and regional waste streams could become feedstocks. Digital monitoring could optimise biological production and materials could increasingly be designed with their biological end-of-life pathways considered from the beginning.

To reach this point, several milestones are necessary: reliable scale-up; reproducible colour and material performance; appropriate fastness and durability; credible life-cycle assessment; regulatory clarity; better biological manufacturing infrastructure; and much stronger collaboration between microbiologists, material scientists, textile engineers, designers and manufacturers.

Education is very important. In the MA Biodesign at Central Saint Martins, one of the things we teach is biological literacy and lab skills for designers. Designers do not need to become microbiologists, but they need enough understanding of lab experimental protocols in order to be able to 'biofabricate' concepts and materials. They also need this to collaborate responsibly with scientists and engineers and to question the ecological implications of the systems they propose.

The milestone I would most like to see is therefore conceptual as well as technological: a shift from asking "What new material can biology give us?" to "What new relationships between materials, production, organisms and ecosystems can biological design enable?"

Biological colour

Colourants produced or obtained through biological systems or processes for textile colouration, including fermentation, biosynthesis and enzymatic processes. Common sources include microorganisms such as bacteria, fungi and microalgae, as well as biological feedstocks such as seaweed and plants.



Opportunities

1. Diversifying through scalable biological production

Biological colour offers diverse routes to textile colouration using microbial, algal and other renewable biological feedstocks, potentially reducing dependence on petrochemical raw materials. Further, fermentation and controlled cultivation can provide more predictable production conditions than relying on naturally occurring colour sources. This has the potential to improve supply consistency and scalability.

2. Drop-in compatibility lowers adoption barriers

Colourants designed to work with existing dyeing equipment and workflows could reduce the need for new infrastructure and make adoption easier for established textile manufacturers.

Threats

1. Performance, cost and consistency at scale

Biological colourants must compete with established synthetic dyes on cost while achieving sufficient production volumes and reliable supply. Scaling fermentation, cultivation and downstream processing can require substantial investment. Additionally, biological colourants still need to consistently meet textile requirements for shade and colourfastness, fixation and processing efficiency. Variability can become more challenging as production moves from pilot to industrial scale.

2. Environmental claims still need verification

Biological origin does not automatically demonstrate lower environmental impact. Claims on carbon, water or energy savings should be supported by a life cycle assessment (LCA), independent testing or recognised standards, rather than company marketing alone.

Biological colour is evolving from the use of naturally extracted colourants towards controlled biological production. Microorganisms, algae, fermentation providing new routes to generate textile dyes and pigments.

WTiN's coverage on biobased colourants reflects Tintte's development of microbial pigments being developed for textile dyeing and screen printing. While commercialisation remains at different stages of each production route, recent developments suggest that biotechnology is beginning to move biological colour beyond niche natural dye applications towards scalable textile colouration. As Pili CEO Jérémie Blache describes it, the sector is working towards a "new standard that is reliable," with traceability, innovation and regulation increasingly shaping its development.

However, biological origin does not automatically demonstrate greater sustainability. Production can still require energy, water, chemicals and resource-intensive downstream processing, while environmental impacts vary according to the feedstock and production method. The biological route also differs: some colourants are produced through microbial fermentation, while others are derived from cultivated microalgae before being processed into textile dyes or pigments. These differences affect production efficiency, scalability and environmental performance.

As biological colour moves towards commercialisation, evidence will become increasingly important. Claims around reduced water use, lower emissions, non-toxicity or improved sustainability should be supported by credible evidence rather than biological origin alone. LCAs, independent testing, recognised chemical-safety standards and industrial performance data can help substantiate such claims.

Ultimately, adoption will depend not only on whether colour can be produced biologically, but whether technologies can demonstrate consistent textile performance, competitive production and measurable environmental benefits at scale. This will determine which approaches progress from promising pilots to wider commercial adoption.



Tintte creates sustainable living colours as a replacement for petrochemical dyes that eliminates toxic chemicals. Source: Tintte



Kimono dyed with Mounid's algae-based dye. Source: Locality and Mounid



Biobased colourants from Pili, produced through fermentation and chemical synthesis, as alternatives to petrochemical colourants. Source: Pili

Tintte
Miami, US
Emerging

Tintte, a biotechnology company founded in 2023, is developing biocolourants and biocompounds using microbiology, synthetic biology, green chemistry and AI. Its biocolourants are produced by cultivating naturally pigment-producing microorganisms through controlled fermentation, without reliance on petrochemical feedstocks. The colourants are designed to integrate into existing textile dyeing workflows, with lower water and energy use than conventional dyeing processes. The company is currently scaling towards pre-industrial production, with conducting industrial trials underway in Argentina and manufacturing trials with partners in Europe and Asia.

Mounid
Göteborg, Sweden
Emerging

Mounid, founded in 2019, develops algae-based textile dyes by transforming microalgae and algae into textile colourants. The company has developed processes for extracting and processing algae-derived pigments for textile colouration that it says can eliminate hazardous auxiliary chemicals, providing a potential alternative to fossil-based dyes. It has been progressing the technology through industry-backed pilot projects and research programmes since 2020. In July 2025, Mounid introduced its first algae-based blue dye, OCEANiD, which was demonstrated through a 50-metre fabric dyeing pilot at the Swedish School of Textiles at Science Park Borås. Further testing through the Locality project at the University of Borås has explored dye performance on cellulosic fabrics, with ongoing optimisation of colourfastness, fixation, drying and process efficiency to support industrial scale-up.

Pili
Toulouse, France
Commercially ready

Pili, founded in 2015, is a biotechnology company specialising in bioproduction, biomaterials and biobased chemicals, with applications including dyes and pigments. The company develops colourants through microbial fermentation and began industrial-scale production of its first biobased dye, Eco-Indigo, in 2024. The dye reached the market in early 2025; Eco-Indigo was applied at industrial scale to denim through collaborations with Orta Anadolu in Türkiye (Turkey) and US premium denim brand, Citizens of Humanity. Eco-Indigo is REACH-registered and commercially available, with Pili reporting comparable shade and colourfastness to synthetic indigo. In 2026, Eco-Indigo received the ANDAM Special Prize, recognising its development as a biobased alternative to petroleum-derived indigo. To date, Pili has invested more than €35m (~US$40-41m) in developing and scaling its technologies.

"We are creating a new standard that is reliable. Traceability, innovation and responsibility are driving this change and soon, regulation will too."

Jérémie Blache, CEO, Pili

Cultivated bacterial cellulose



Cellulose produced by certain bacteria through controlled cultivation or fermentation, using carbon-containing feedstocks to support microbial growth and cellulose production. The resulting cellulose can be processed or engineered into different material forms, including fibres, sheets, foams and other structures, for textile and related applications.

Opportunities

1. Alternative feedstock pathways

Cultivated bacterial cellulose can be produced using different carbon-containing feedstocks, including agricultural and industrial food waste streams. This could reduce reliance on conventional cellulose sources while also creating value from low-value biological waste.

2. A versatile material platform

Bacterial cellulose can be developed into diverse material forms, such as from regenerated fibres to foams. This opens potential applications beyond conventional textiles, including footwear, interior decorations and other material sectors.

Threats

1. Scale-up and production cost

Moving from laboratory or pilot production to commercially viable volumes remain challenging. Fermentation, processing and drying requires large investment in infrastructure, while innovators are pressured to achieve competitive production costs.

2. Feedstock dependency

The environmental and economic benefits of cultivated bacterial cellulose depend partly on the feedstock used and how efficiently it can be converted into cellulose. Reliance on refined inputs or variable waste streams could affect both the sustainability case and production costs.

Bacterial cellulose was first identified in the late 19th century, but interest in its use as a textile and fashion material grew from the late 2000s and early 2010s. Since then, research has expanded from fibres and sheet-like materials into composites, textile finishing and other formats, alongside efforts to improve cultivation and processing.

Unlike plant-derived cellulose, bacterial cellulose is produced through microbial fermentation, forming a highly pure cellulose network with distinctive properties. Its strength, flexibility and moisture retention have supported exploration across different formats, including films and sheets for leather alternatives, fibres and filaments for textiles, and porous foams for footwear and other materials. This versatility could allow bacterial cellulose to complement rather than simply replace conventional cellulose materials.

The EU Deforestation Regulation (EUDR), applying from 30 December 2026, requires covered products including cattle and wood to be deforestation-free when placed on, sold within or exported from the EU. Fabulose's development of bacterial cellulose-based leather alternatives provides a relevant response to this wider supply-chain challenge, using industrial CO_2 and waste streams to develop animal-free materials designed to reduce reliance on resource-intensive supply chains.

Factors such as this mean bacterial cellulose is gaining momentum, with companies such as Polybion and research organisations including HKRITA exploring bacterial cellulose-based leather-like films. As highlighted in last year's Concept 2030 Unlocking cellulose feature, moving these innovations beyond experimental applications will require investment in production infrastructure and R&D to improve scalability, consistency and cost competitiveness.



Nullarbor: microbial cellulose, spun into tree-free lyocell. Source: Nanollose



Foamlab's bio-nanocellulose foam for diverse applications. Source: Foamlab



Bacterial cellulose film. Source: Fabulose

Nanollose
Perth, Australia
Scaling

Founded in 2014, Nanollose is a biotechnology company developing technologies for the production, processing and application of microbial cellulose to create new and improved fibres and other materials sustainably. In 2017, Nanollose claimed to be the first company to successfully convert plant-free cellulose into rayon fibre. The company subsequently developed a process to convert microbial cellulose from a range of fermentable waste streams into viscose dope, which was spun into plant-free rayon fibres, branded Nullarbor. In 2018, this followed demonstrations of Nullarbor fabric. In the following years, Nanollose worked on technology improvements, formulation development and broader opportunities to commercialise Nullarbor fibre at industry scale. In its June 2026 quarterly report, Nanollose announced the completion of its fourth pilot production run with Birla Cellulose, with the material passing dissolution and spinnability trials. The pilot produced 580kg of Nullarbor fibre, its largest single production run to date. Following the pilot, Nanollose identified an approximately 80% improvement in pulp-preparation efficiency at laboratory scale, alongside the elimination of a production step.

Foamlab
Delft, Netherland
Scaling

Spun off from Delft University of Technology and founded in 2024, Foamlab is a biotechnology company developing biobased foams with engineered, tunable properties to replace fossil-based plastics. Foamlab uses bacterial cellulose as a highly pure cellulose feedstock, grown through microbial fermentation, giving it greater control over the design and performance of its materials than conventional plant-derived cellulose. The cellulose is engineered into porous bacterial nanocellulose (BNC) foam structures, where three-dimensional nanofibre networks can trap air. By controlling the foam's structure and density, Foamlab can tune properties ranging from ultra-lightweight and flexible to denser, more impact-resistant materials. These properties enable thermal insulation, cushioning and structural support, with potential applications in fashion and textiles, construction and packaging. Foamlab also positions BNC foam as a circular material, stating that its foams are fully compostable and can break down into nutrients that return to the ecosystem. In April 2026, Foamlab announced EU€3m (approx. US$3.5m) in funding to support its commercialisation, including the construction of a pilot plant and production scale-up.

Fabulose project
Cross-Europe initiative
Emerging

Fabulose is a 42-month, almost EU€3.5m (approx. US$4.1m) project launched in June 2025, bringing together 10 partners from six countries. It aims to develop a biobased leather alternative made from bacterial cellulose and cyanophycin, combining dyed textile backing with functional coatings and surface finishing. To produce these materials, industrial CO_2 and food and agrifood side streams are transformed into bacterial cellulose, cyanophycin and bacterial pigments. Patented HighPerCell spinning technology, developed by the German Institute of Textile and Fibre Research (DITF), enables the production of continuous cellulose fibres from various biobased materials. Fabulose is developing roll-to-roll production to support future scale-up and aims to advance lab-proven technologies from TRL 2–3 to pilot-scale production at TRL 5 by 2028. Initial prototypes are being developed for handbags, small leather goods and shoes, alongside potential applications in furniture, automotive interiors, apparel and home decor.



Innovator index

Bioinspired material science

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Wujiang District, Suzhou City,
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Address - **Factory**
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Regenerative & agricultural feedstocks

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Colorifix

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Website - www.colorifix.com

Grouse Fiber

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Living Ink Technologies

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Ohoskin

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