BEYOND POLYESTER

100% bio-based synthetic fibers

MATERIAL INNOVATION INITIATIVE

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CONTENTS

INTRODUCTION TO THE MATERIAL INNOVATION INITIATIVE'S WHITE SPACES

About the Material Innovation Initiative (MII): Our mission is to accelerate the availability of high-quality, high-performance, animal-free, and environmentally preferred materials ("next-gen materials") with a focus on replacing silk, wool, down, fur, and leather and their synthetic alternatives.

In Q4 of 2021, MII, in collaboration with The Mills Fabrica, published a White Space Analysis Report outlining seven critical white spaces within the next-gen materials industry. Now, in a new white space mapping process we seek to look at the material landscape up and down the value chain with a new lens. We want to identify unmet and unarticulated needs. These are not only missed opportunities, but a lot of times also barriers to the growth and adoption of next-gen materials. We need to direct interests, attention, and resources to fill these gaps for the benefit of accelerating the entire next-gen materials industry. Whether you are a material startup looking for high growth opportunities, a scientist developing a new technology or material, a brand looking for the future trends and needs of sustainable products, or an investor thinking of strategically diversifying into next-gen materials, we are certain this report will inspire your next move.

In this Beyond Polyester report, you will learn about the white space opportunities in bio-based synthetic fibers and textiles. Ensure you sign up for our newsletter to be notified of other relevant publications.

New to MII's analyses? Start with our series of State of the Industry Reports for the annual deep-dive on the next-gen industry including the key players, investments, trends, and news within the industry.

Image Credit: H&M Foundation / Rubi Laboratories

DEFINITIONS

"Next-gen materials" are animal-free and more sustainable than incumbent (animal-based) and current-gen (petrochemical-based) materials. Next-gen materials use a variety of biomimicry approaches to replicate the aesthetics and performance of their conventional animal- and petrochemical-based counterparts.

"Current-gen materials" are those used to substitute for animal-derived materials by winning on price. Synthetic leather made from petrochemicals, for example, sells at wholesale at one-third the price of the animal leather equivalent. We generalize these petroleum-based alternatives (e.g., polyurethane (PU), polyvinyl chloride (PVC), acrylic fiber) as "current-gen materials," but their current applications in the market are far beyond animal-based material replacements. More clothing is made from polyester and nylon, both plastics, than from cotton. Examples of "current-gen" alternatives include PU for leather, polyester for silk, or acrylic for wool.

"Disruptive textile technology" refers to material innovations that do not directly replace animal-based materials, but that may become promising feedstocks or resources for next-gen material innovation. Sustainable innovation in synthetics such as bio-based, biodegradable, or recycled polyester or polyurethane, and in sustainable renewably sourced fibers such as cellulosics and natural fibers, could have broad impacts in the plastics and textiles industries as a whole, as well as in the next-gen materials space. MII hosts a disruptive textile technology database to provide next-gen material innovators an easy way to find potential collaborators or suppliers.

"Bio-based" refers to materials wholly or partly derived from biomass such as plants, trees or fungi (the biomass can have undergone physical, chemical or biological treatment).[1]

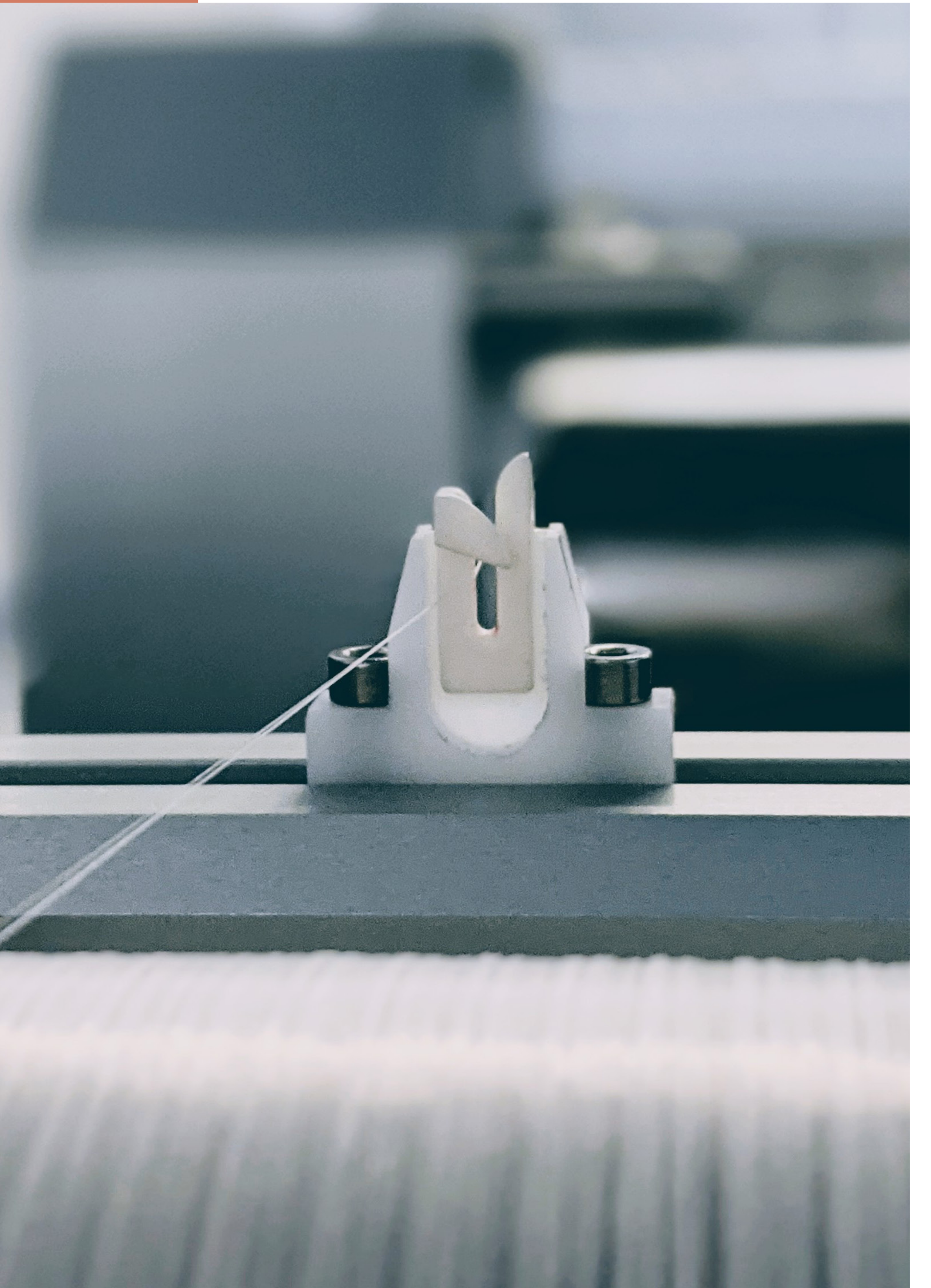


Image Credit: Kintra Fibers:
Kintra yarn processing at their Brooklyn, NY lab.

INTRODUCTION TO BEYOND POLYESTER

In the rapidly evolving landscape of next-gen materials, the quest for sustainable and ethical alternatives to traditional animal-based textiles is a pressing concern. Interest in next-gen materials is growing in all sectors. Despite global VC funding falling 42% and deal count falling 30% to reach a six-year low in 2023, funding for next-gen materials companies increased.[1] The next-gen materials industry enjoyed a 10% rise in investment funding in 2023, showing significantly higher investments than the general market.[2]

State of the next-gen material industry at a glance (2023)

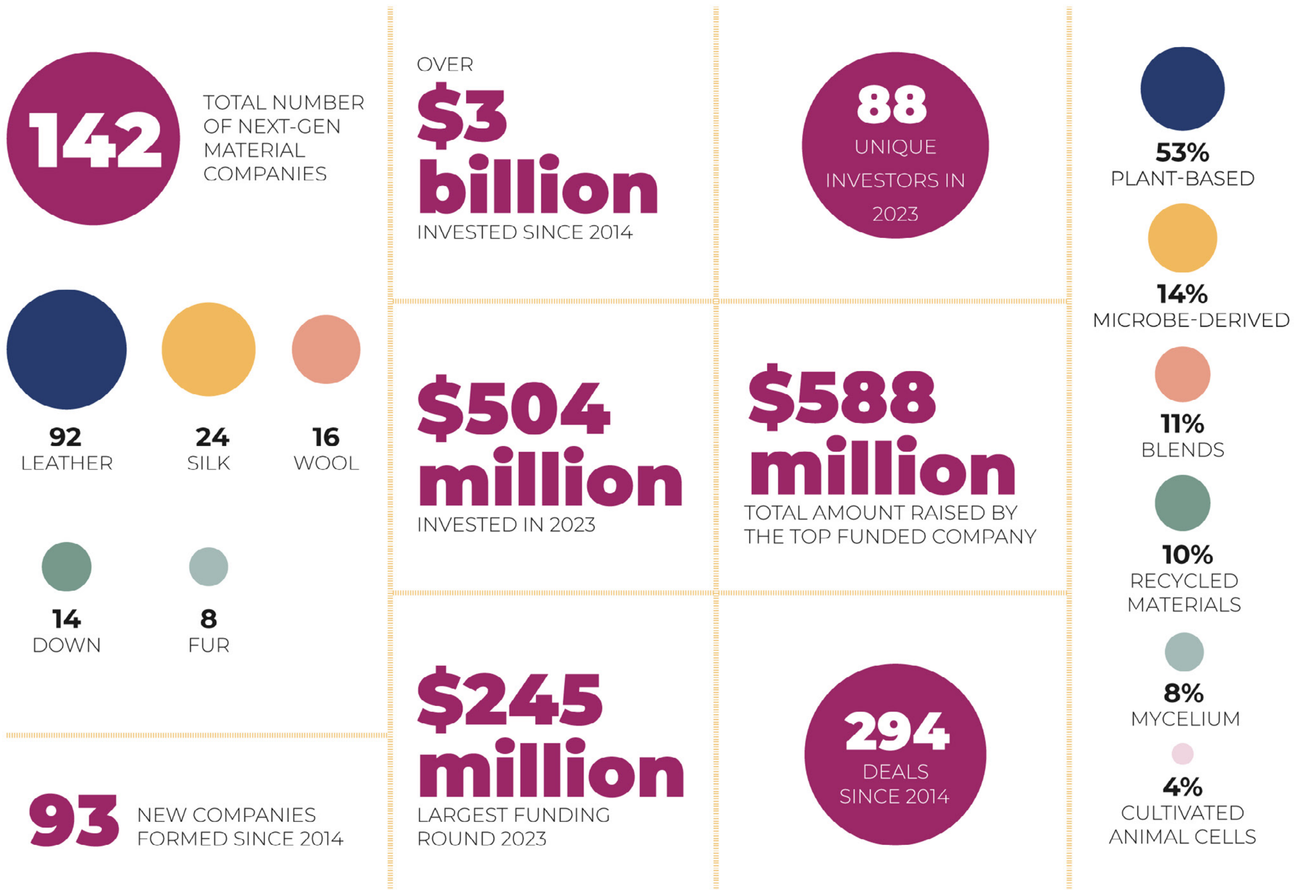


Figure 1. State of the next-gen materials industry 2023

Image Credit: Amit Dave / Reuters

Our report:

- Describes polyester's properties, including its performance and applications in textiles
- Details polyester's myriad environmental and ethical harms
- Highlights more sustainable and humane polyester alternatives
- Features innovators who are developing exciting next-gen alternatives to polyester

This white space report serves as a clarion call for entrepreneurs and investors to channel their resources into creating textiles that match polyester's performance and versatility while relying on bio-based, biodegradable, renewable, recycled, and humane alternatives. By doing so, they will not only fill a significant gap in the market but also contribute to a more sustainable and ethical future.

THE UBIQUITY OF POLYESTER AND OTHER SYNTHETIC FIBERS

Polyester accounts for approximately 54% of all textile raw materials produced annually, with over 63 million tons produced in 2022 alone.[1] Polyester is public enemy number one in the fashion industry's search for more sustainable materials and in the larger anti-plastic crusade of recent years.[2] Other synthetic and fossil-based fibers like nylon and spandex are also ripe for innovation. Therefore, sustainable alternatives to virgin, petroleum-derived polyester would make a huge impact in the textile industry, including in next-gen materials.

Polyester is a common "current-gen" (petrochemical-based) alternative to animal-derived materials.

Image Credit: Mood Fabrics

Polyester is often used as a replacement for silk, particularly in fast fashion applications.

Image Credit: Mood Fabrics

Polyester fleece is a common fabric in warm, fuzzy garments similar to wool or shearling.

Image Credit: Mood Fabrics

Some synthetic furs use virgin or recycled polyester fibers.

Image Credit: Vladimir Gudvin / Shutterstock

Nonwoven polyester fill is a common alternative to down insulation in apparel and bedding.

Image Credit: Mood Fabrics

Polyester fabrics are sometimes coated in polyurethane (PU) to make synthetic leather, and microfiber polyester is often used as a synthetic suede or nubuck.

Next-gen innovators who develop more sustainable and humane alternatives to silk, wool, down, fur, and leather will therefore also develop favorable replacements for polyester.

Like many other synthetics such as PU, performance and versatility have led to the widespread use of polyester in textiles. As a thermoplastic resin, polyester can be molded into shapes, extruded into fibers, and applied as a coating. It finds applications as reinforcement for automotive tires, nonwoven personal hygiene products, beverage bottles, food packaging, and of course, textiles for fashion, vehicles, and home goods.[3] Polyester's notable ability to be spun into fibers of varying diameter, cross-sectional shapes, and lengths allows it to produce everything from soft, velvet-like microfiber, smooth, shiny satin fabrics, and rugged outerwear. Additives incorporated into the resin formulation can also tune the color, luster, and environmental performance of polyester fibers and fabrics.

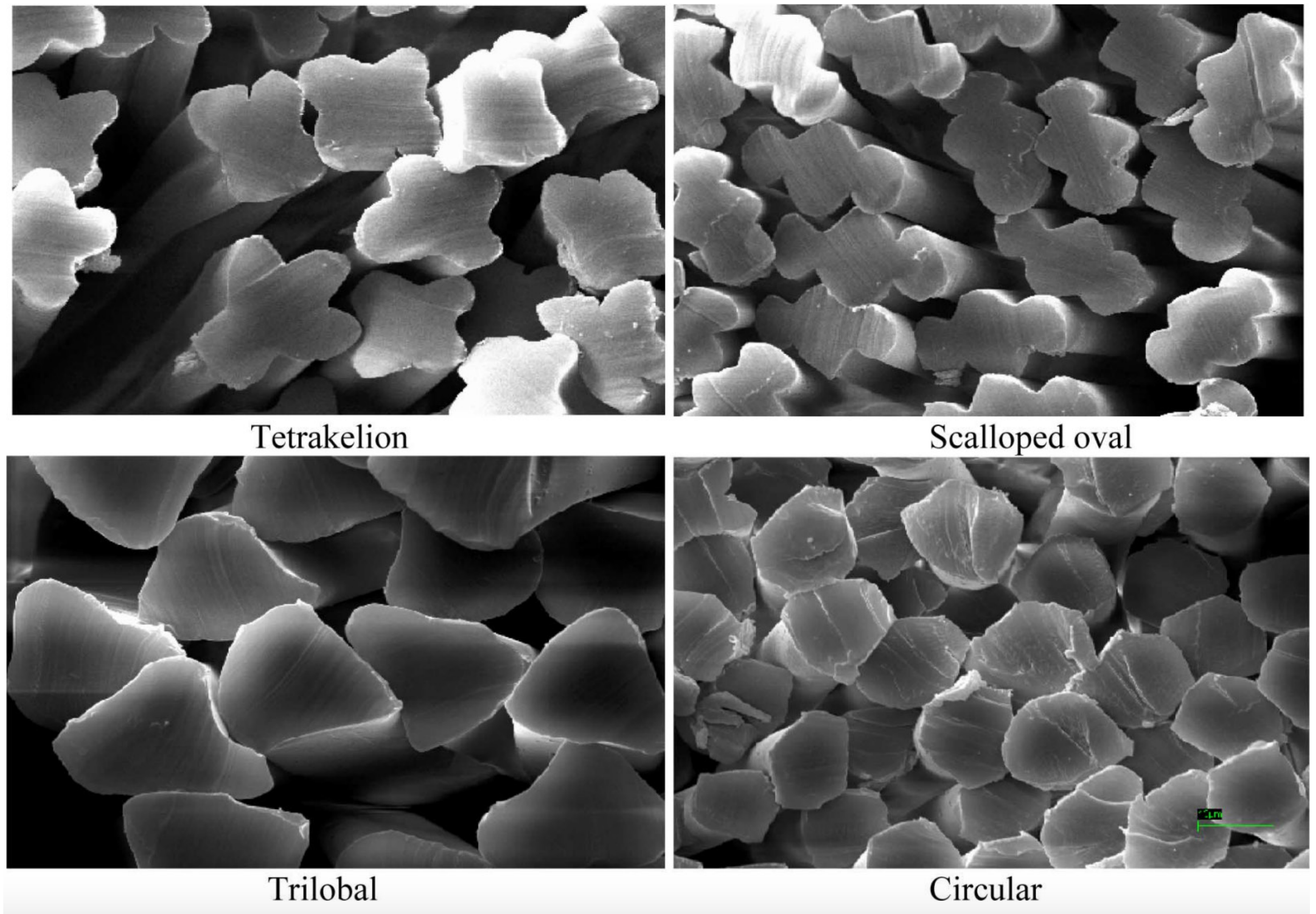


Image Credit: R.K. Varshney et al.

Figure 2. Scanning electron micrographs of a variety of polyester fiber cross-sections.

Originally, polyester fibers were only available in a tubular shape (giving the fabric its notorious shiny appearance). As a result of technological advancements, polyester can be formed in any number of shapes, allowing for manufacturers to emulate many natural fibers.

Image Credit: Masaya Yoshimura / Issey Miyake

Japanese designer Issey Miyake took advantage of the unique ability of polyester to permanently maintain folds, creating his iconic "Pleats Please" fabric.

Polyester refers to a class of polymers containing an ester bond, and thus encompasses a wide variety of materials. The most common form of polyester, and that most used in textiles, is polyethylene terephthalate (PET). This form of polyester has a good balance of properties including heat stability, strength, flexibility, elongation, and moisture wicking capabilities.[4] In addition, polyester is one of the most affordable yarns and fabrics available today. Polyester yarn costs around \$1/kg; in comparison, raw silk ranges from \$68–\$97/kg.[5][6]

Image Credit: PradeepGaurs / Shutterstock
A plastic recycling facility in India

Whether from recycled or virgin feedstock, however, polyester fibers are of growing concern for the release of microfibers into the environment. These microfibers (broadly labeled as 'microplastics') are associated with widespread effects on ecosystems, animals, and human health.[12]

Despite its advantages, polyester shares many of the same drawbacks as PU—namely, environmental concerns. Polyester is derived from fossil fuels and has an energy-intensive manufacturing process. Per ton of fiber, polyester spinning uses nearly 10 times more energy compared to the cultivation and spinning of organic cotton.[7, 8] Even though polyester is the most commonly recycled plastic and using recycled polyester can reduce the amount of energy required to make fibers, polyester textiles are still associated with abysmal recycling rates: **less than 1% of clothes, of all material mixes, are recycled.**[9, 10] This means that recycled polyester fabrics are typically made not from recycled textiles, but from recycled bottles. In addition, the traditional mechanical recycling process leads to a reduction in the quality of the polyester resin. Considering the demand for recycled polyester by the packaging industry, the fashion industry, and many more markets, there will not be enough high-quality recycled feedstock to serve all industries if recycling rates and processes do not improve.[11]

There will not be enough high-quality recycled feedstock to serve all industries if recycling rates and processes do not improve.

MICROPLASTICS FROM PETROLEUM-DERIVED TEXTILES CAUSE SIGNIFICANT HARM

- Fossil fuel-derived synthetic fibers such as polyester, which are nonrenewable and nonbiodegradable, currently comprise approximately 60% of materials[1] used by the fashion, automotive, and home goods industries and are projected to comprise approximately 70% of materials by 2030.[2]
- Synthetic materials contain microplastics, which accumulate and persist in ecosystems for hundreds of years, as well as toxins that poison ecosystems, harm animals, and fuel climate change.

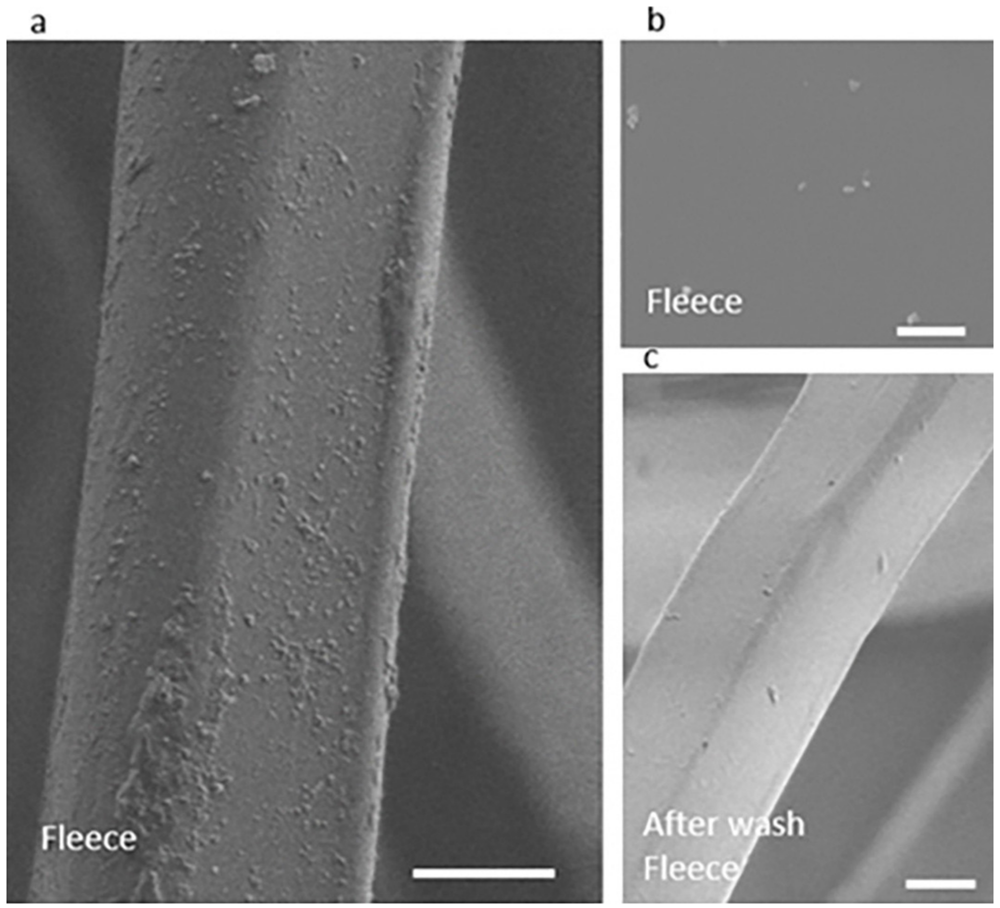
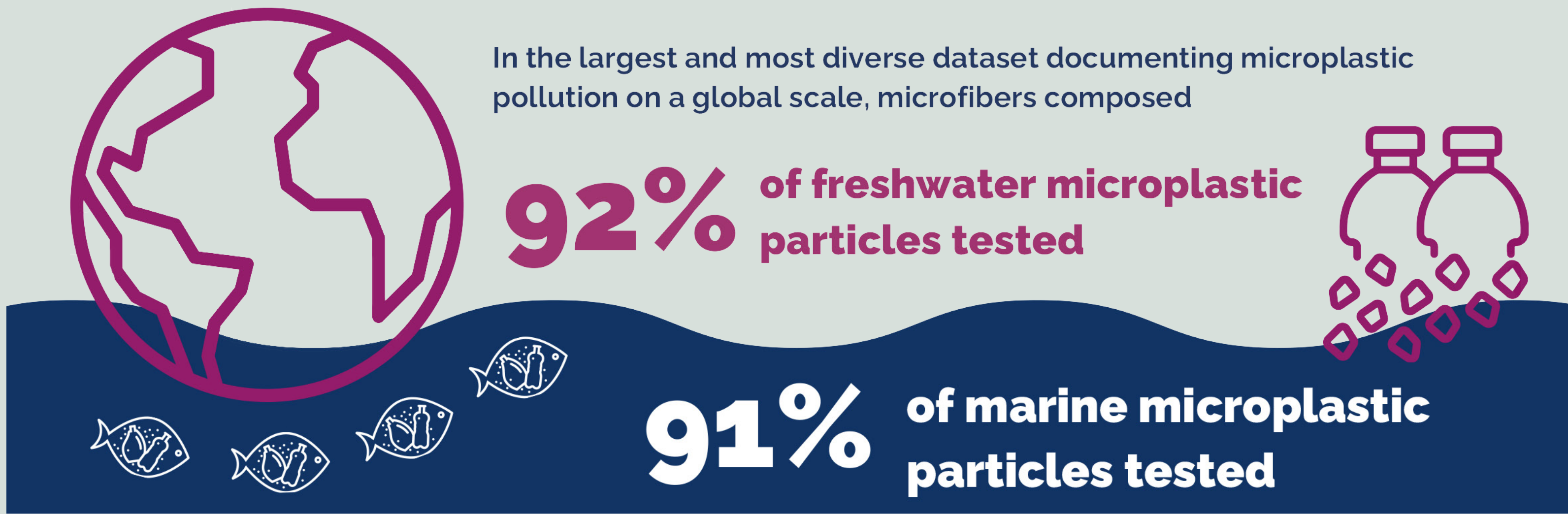


Image Credit: Empa

Figure 3. Microscopic view of polyester fleece before and after being washed, illustrating the amount of microparticle shedding after a wash cycle.

Image Credit: Desiree Martin / AFP Photo

- Microplastics have been found in nearly every environment tested for their presence, including the Amazon River and estuaries, deep sea trenches, remote lakes, Swiss Alps snow, Arctic ice, and all major oceanic basins.[3]
- In the largest and most diverse dataset documenting microplastic pollution on a global scale, the Global Microplastics Initiative found that microfibers from synthetic textiles comprised 91% of the marine microplastic particles and 92% of the freshwater microplastic particles it tested.[4]
- Microfibers from synthetic textiles break down into nanoplastics, which penetrate the air-blood barrier, blood-brain barrier, placental barrier, and nearly every organ. These plastics cause inflammation, hormonal imbalances, tissue damage, and cell death in humans.
- Microplastics harm trillions of animals who consume them by reducing their food intake, delaying their growth, altering their behaviors, decreasing their reproductive capabilities, causing inflammation and oxidative damage, poisoning them with toxins, inducing brain damage,[5] and leading to premature death.[6]



Microplastics: A Threat to Keystone Species

- Microplastics cause the most damage to ecosystems through harming keystone species[7] —including some species of zooplankton, crabs, and coral—all of whom serve critical functions for entire ecosystems.
    - Some species of zooplankton, which are primary consumers in marine ecosystems, have been proven to grow more slowly and lay fewer eggs as a result of consuming microplastics, thereby decreasing food available to entire ecosystems.[8]
    - Microplastics have an abundance of negative impacts on keystone coral species.[9]

Coral reefs are among the most biodiverse marine ecosystems on Earth and are vital for the survival of thousands of species. The impact their health has on entire ecosystems is profound.

Effects in Corals:

- Reduced growth
- Increased mortality among Symbiodiniaceae, the unique algae that live inside corals and supply them with vital nutrients
- Impairment of reproduction
- Coral bleaching
- Increase in diseases
- Tissue inflammation
- Decrease of detoxifying and immune enzymes
- Decreased calcification
- Impairment of feeding performance
- Decrease in food intake
- Necrosis
- Reduction of fitness
- Changes in photosynthetic performance
- Increased exposure to contaminants and diseases
- Metabolic alteration
- High production of mucus
- Lower fertilization success

Next-Gen Materials, Not Animal-Based Ones, Are the Solution to Microplastics

- Once microplastics enter ecosystems, they are impossible to adequately remove using current technologies.
- Without the availability of sustainable, cruelty-free alternatives, fashion brands and other companies replace polyester and other synthetic textiles with “natural” animal-derived materials that are sourced from the harming or killing of more than one trillion animals each year.
- For the health of our planet and future generations, it is critical that both synthetic and animal-derived materials are replaced with more sustainable and humane next-gen materials.

Image Credit: Shutterstock

BIO-BASED SYNTHETIC SOLUTIONS

How can we solve these issues with polyester's sustainability while reaping the benefits of its versatility? Like the case for PU, finding bio-based solutions to polyester would reduce the reliance on fossil fuels and could lower environmental footprints. One of the most notable commercial-scale solutions on this front is Covation Bio's Sorona polyester, which uses fermentation products to create a 37% bio-based polymer comparable to PET or nylon, with 63% fewer emissions than nylon 6.[1] Sorona has been employed by current next-gen fur innovators like Ecopel.

"There is no other product that offers the combination of performance and cost in a wide variety of applications that is offered by PET. So the first idea would be to make PET in a more environmentally friendly way, for example from plants rather than from fossil resources (biosynthetically). PET is made up of two molecules, ethylene glycol (EG) and terephthalic acid (TPA). The production of EG from bio-ethanol has been accomplished and the product is available at scale. The cost is typically ~15-30% higher than petro-EG which may be acceptable in many applications. Many companies have been chasing the bio-production of TPA for years. The molecule can be made from biomass using a variety of routes but the cost is typically estimated to be 2-5x higher than petro-TPA. So far this cost gap has not been acceptable to consumers and brands, so none of these processes are currently commercialized at scale. I believe it will be quite difficult to come up with a route to bio-TPA that will succeed based on its economics if the current cost position of petro-TPA remains the same.

Michael Saltzberg,
President M.A. Saltzberg Consulting
(former CEO Covation Bio)

Image Credit: Sci-Lume

“There are a wide variety of both natural and biosynthetic fibers that provide excellent performance and have been accepted by consumers. The reason the use of polyester continues to grow is again the combination of durability, performance and cost that it brings.

Consumer preference is driving brands to offer more non-polyester alternatives, but volume growth of these alternatives is slower than the world needs it to be primarily because of the huge price/cost gap between them and PET.

PET is at a huge scale, EG and TPA come from cheap raw materials and are relatively easy to make. Just as importantly, the companies that make these monomers and polymers do not have to pay the downstream environmental costs these products create, and there is no credit given to biosynthetic producers for the environmental advantages they create.

So if society wishes to reduce the use of PET and promote the use of biosynthetic or natural alternatives, governments will need to implement policies to recognize the environmental costs of petro-PET and similar products, e.g. a carbon tax or other fees on the petro-based molecules.

This will have the effect of leveling the playing field and promoting not just biosynthetics but also recycling and the sale of higher quality, longer-lasting apparel.”

Michael Saltzberg,
President M.A. Saltzberg Consulting
(former CEO Covation Bio)

RECYCLABLE, BUT NOT BIODEGRADABLE

On the end-of-life spectrum, many bio-based polyesters that rely on chemistries similar to PET may be recyclable, but not biodegradable. This includes Sorona, as well as bio-PET, which uses the same chemistry as fossil-derived PET but uses partial chemical inputs from the fermentation of sugars. To date, bio-PET has mostly been employed in packaging rather than textiles.

Image Credit: Kintra Fibers

PROMISING END-OF-LIFE OPTIONS FOR BIOSYNTHETICS: PLA AND BIO-PBS

Several biosynthetic options for textiles and materials offer multiple end-of-life pathways. For example, polylactic acid (PLA) is currently the most popular player in bio-based, degradable plastics. Typically used in food and beverage packaging applications, recent advancements in fiber spinning may enable 100% PLA garments.[2] Derived from fermented starches such as corn, PLA is 100% bio-based. It is also suitable for industrial composting, and for certain grades it is compostable at home or in anaerobic digestion. In some instances, PLA can also be recycled, but typically not in the average recycling facility where it can contaminate traditional plastic feed streams.[3] Unfortunately, PLA doesn't degrade easily in soil or the marine environment.[4] When PLA leaks into the environment, it can degrade much like traditional plastics and create macro- and microplastic pollution. Although PLA cannot access all end-of-life options, it was one of the first successful biosynthetics to take the stage.

Another biosynthetic worth noting for textile applications is bio-based polybutylene succinate (bio-PBS), derived from fermentation processes. Similar to PLA, bio-PBS may be recyclable in special instances. It biodegrades in industrial composting facilities, and there is some evidence of biodegradation in the soil or home composting.[5] Kintra Fibers is an innovator of bio-PBS fibers. Kintra's bio-based polyester alternative drew interest from H&M, Reformation, Inditex, and Bestseller and raised $8M in 2023.[6] While touted as a replacement for polyester, it is possible these novel fibers could be applied to next-gen silk, wool, down, or fur.

"What impresses us is that Kintra Fibers' technology leverages existing polyester production equipment for critical manufacturing processes, such as resin and yarn production."

Erik Lagerblad,
Head of H&M Group Ventures [7]

BIODEGRADATION CHALLENGES

Strategies exist to induce biodegradation in traditional fossil-based synthetics such as polyester. However, it is critical that these approaches do not fragment the plastic and increase microplastic pollution in the environment, and also do not break down the plastic into harmful byproducts.

Image Credit: Muntaka Chasant / Shutterstock

A July 2024 report by NGO Beyond Plastics titled "Demystifying Biodegradable and Compostable Plastics" states that "there are huge challenges to managing bioplastics at their end of life."[8] The report claims that the majority of "compostable" bioplastics are not home compostable, and many commercial and municipal composting facilities reject them over concerns of microplastic and chemical contamination, due to their biggest customers being strictly regulated organic farms. Globally there are weak federal standards for bioplastics and many take longer to break down than what industry claims suggest.

The Biomimicry Institute's report, authored by Libby Sommer (see quote below), "Biodegradation of Textile Fabrics" explains that biodegradation depends on a material's chemical structure, environmental conditions, and microbial activity, with natural fibers biodegrading more readily than synthetic fibers like polyester.[9]

"The replacement of fossil fuels with bio-based feedstocks may solve one problem, but it doesn't by default address the biodegradability of the material. To do that, new polymers for textiles need to be designed for biodegradability, of which there are some examples.
Correspondingly, waste infrastructure will be essential to ensure the practical biodegradation of these materials into useful products. In this case 'products' could be a range of things, such as sugars that can feed into fermentation systems, small molecules that can be used into chemical synthesis, or in the case of complete biodegradation, the conversion to carbon dioxide, water and biomass which is necessary to sustaining biological cycles."

Libby Sommer, Principal, Libby Sommer LLC

PHAS: A PROMISING SOLUTION

One of the most promising classes of bio-based, biodegradable synthetics derived from fermentation processes are polyhydroxyalkanoates (PHAs). As a thermoplastic material like PLA and bio-PBS, PHAs have the capability to be mechanically recycled, although only in special circumstances. However, PHAs are unique as the only class of synthetic polymers that has been shown to degrade in all major environments: industrial composting, home composting, anaerobic digestion, soil, or the marine environment.[10] In the past, PHAs were unable to compete with fossil-based plastics because of small volumes and high prices. With continued innovation and current sustainability demands, the time may be right for PHAs to succeed.[11]

PUTTING BIODEGRADATION INTO CONTEXT IN THE CIRCULAR ECONOMY

"Biodegradation is a critical waste management process, and an important part of creating a circular economy. Designing textiles to be biodegradable increases the likelihood of them breaking down once released into the environment. Since nearly all textiles are modified with mechanical and chemical finishes and treatments, better understanding of how these affect toxicity is important. At a minimum, removing hazardous substances from the textile production process is a good first step."

Libby Sommer, Libby Sommer LLC and Strategic Advisor to The Biomimicry Institute

Image Credit: H&M

In 2022, H&M designed a necklace, bracelet, and earrings featuring a heart pendant made from Newlight Technologies AirCarbon material.

Recent innovation from Mango Materials converts the greenhouse gas methane into PHA products via bacterial fermentation processes. These raw polymer pellets can then be spun into textile fibers. Employing a similar technique is Newlight Technologies, which creates carbon negative, biodegradable PHA.

The organization Fashion for Good collaborated with fashion brands, material innovators, and research institutes to launch the Renewable Carbon Textiles Project. Project members are committed to accelerating the development of bio-based, compostable PHA polymer fibers using renewable and/or carbon-based feedstocks such as landfill waste, methane gas, and captured CO_2.

In promoting the project, Fashion for Good's Managing Director Katrin Ley stated, "There is an urgent need to find replacements for the predominantly fossil-based fibres in the fashion industry through solutions such as biosynthetics from renewable sources. PHA polymers represent an exciting, yet challenging solution for reducing carbon emissions in the fashion industry, and this project aims to drive further innovation in this space to bring them to scale."

Continued R&D and scale up is required to discover if PHAs or other promising chemistries can meet the broad applications needed in the next-gen materials space. There is promise that these bioplastics can be drop-in solutions, capable of being manufactured with the same equipment and processes as fossil-based synthetics. To allow synthetics to be an ideal solution in the textile bioeconomy, continued R&D for 100% bio-based, 100% biodegradable synthetic fibers is needed.

"Often next generation materials involve some degree of compromise between scalability, properties, and—most importantly—cost. Which makes our job of moving beyond polyester extremely difficult. Sci-Lume Labs' Bylon® drops into the same manufacturing equipment used to make polyester and nylon, meaning it can scale quickly and compete at low price points; and it combines the capability and tunability of legacy synthetic fibers with the moisture properties and circularity of natural fibers. By delivering both circularity and commercial viability without compromise, Bylon enables the practical, large-scale adoption our industry needs to focus on."

Oliver Shafaat, founder Sci-Lume

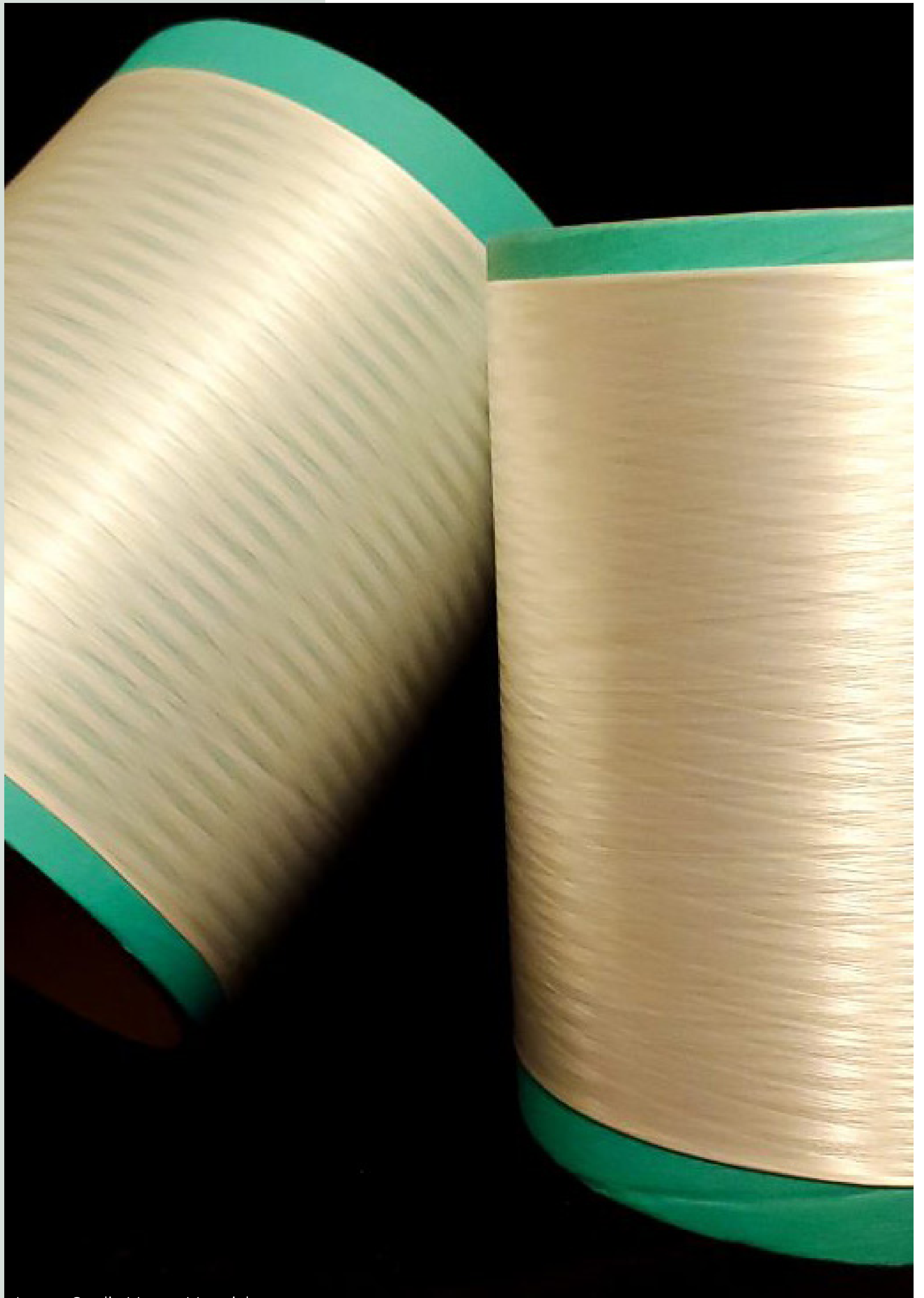
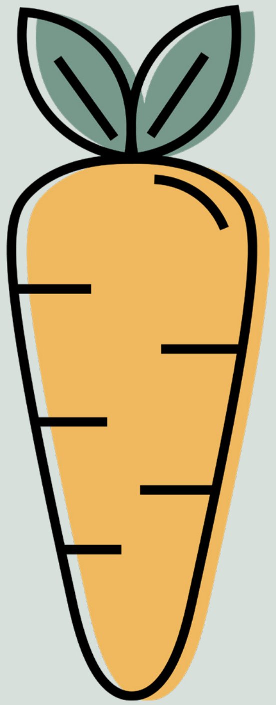


Image Credit: Mango Materials
Mango Materials' PHA fiber.

FOLLOW-UP READING AND RESOURCES ON THIS TOPIC

- **Material Innovation Initiative: Disruptive Textile Technology Resources.** Available at: https://www.materialinnovation.org/disruptive-textile-innovation-resources
- **Closed Loop Partners: Navigating Plastic Alternatives in a Circular Economy.** Available at: https://www.closedlooppartners.com/research/navigating-plastic-alternatives-in-a-circular-economy/
- **Planet Tracker: Textiles Resources.** Available at: https://planet-tracker.org/programmes/textiles/
- **Textile Exchange: Biosynthetics Resources.** Available at: https://textileexchange.org/knowledge-center/?_sft_kc-category=content+topic+materials+biosynthetics
- **Changing Markets Foundation: Fossil Fashion and Synthetics Anonymous Reports.** Available at: https://changingmarkets.org/portfolio/fossil-fashion/
- **The Micofibre Consortium: Resources for the Fashion and Textile Industries.** Available at: https://www.microfibreconsortium.com/resources-1

FOOD FOR THOUGHT



Using ingredients and molecules found in food to unlock new potential in biosynthetics? Recent scientific discoveries have found that common food components may hold promise for making bio-based materials with unique properties:

- **Vanilla** may unlock degradable plastics triggered by specific wavelengths of light.[12]
- **Cream of tartar** may make biodegradable plastics stronger.[13]
- The beta-carotene that makes **carrots** orange could make plastics that degrade in acidic environments.[14]
- Chemicals in **clove oil** have been found to form the building blocks for a variety of biobased polymers.[15]

NEWS AND UPDATES

Fairbrics, a polyester alternative that uses captured CO2 to create the building blocks for the polymer fiber, raised 22 million euros in 2023 to scale its technology.[16]

Humblebee Bio has developed a material solution inspired by the waterproof bioplastic produced by specific species of bees. Using a fermentation approach, they manufacture this same biosynthetic compound using genetically modified microbes for potential use across many applications. Perhaps as coatings or fibers for next-gen materials!

To learn about even more companies working on sustainable components for the next-gen materials industry, check out our Disruptive Textile Technology Resources list![17]

Image Credit: Veronica Harwood-Stevenson / Humble Bee Bio

Image Credit: SML

INNOVATOR PROFILES

Following is a sampling of innovators working in this space using a variety of technologies. This list is by no means exhaustive.

COVATION BIO

Materials: Sorona®, Susterra®,
Founders: formerly of DuPont's Biomaterials segment
Year Founded: 2022
HQ: USA
Market Focus: B2B
Stage: Commercially Available

Sorona® is a partially bio-based polymer that has been used in apparel, next-gen fur and carpeting.

Susterra® is 100% plant-based, high performance glycol with applications ranging from footwear to outdoor apparel, coatings, inks, and functional fluids. Performance polymers like bio-based adhesives rely on Susterra® propanediol for properties.

Applications are suitable for apparel and home.

Image Credit: Sorona

EASTMAN

Materials: Naia, Naia Renew
Founder: George Eastman
Year Founded: 1920
HQ: USA
Market Focus: B2B
Stage: Commercially Available

Eastman Naia uses cellulosic fibers to make filament yarn and staple fibers into sustainable textiles. They use sustainably sourced wood pulp and environmentally sound chemicals with low impact manufacturing processes. Their materials are biodegradable, compostable and compatible with molecular recycling.

Eastman holds FSC and PEFC Chain of Custody certifications and their material is produced in a closed-loop process where solvents are recycled back into the system for reuse. It is OEKO-TEX Standard 100 and is certified as having no hazardous chemicals by ZDHC. They use a third party reviewed LCA and received the TÜV AUSTRIA OK biodegradable certification for freshwater and soil environments and the 'OK compost' certification for industrial settings.

Its performance features include home laundering, no shrinkage, shape memory, odor reduction, easy stain removal, no pilling, and hypoallergenic properties. Naia is available in knits and wovens. Naia Renew is 60% cellulosic and 40% certified recycled waste materials. Applications are suitable for apparel and home textiles.

Image Credit: Mango

FAIRBRICS

Founders: Tawfiq Nasr Allah and Benoît Illy
Year Founded: 2019
HQ: France
Market Focus: B2B
Stage: R&D, Pilot Production

Fairbrics valorizes CO_2 from excesses emitted into the atmosphere and uses it as a feedstock for fiber and films. Using molecular chemistry they convert waste CO_2 first into pellets, which are then melted and spun into yarns. From there they can be woven to make ‘polyester’ fabric with the least possible environmental impact.

Direct carbon capture from factories is put through a fermentation process using clean energy and water resulting in recyclable next-gen synthetic materials and packaging options. Applications are suitable for apparel and packaging.


Image Credit: Fairbrics

FULGAR

Material: EVO
Founder: Marino Garosi
Year Founded: 2015
HQ: Italy
Market Focus: B2B
Stage: Commercially Available

EVO is a 100% bio-based yarn made from the castor plant and aged non-edible corn. Performance properties include: stretch, lightweight, quick dry, thermal properties, breathable, and odor free. Applications are suitable for athleisure, sportswear, swim, underwear, denim, ready-to-wear, and legwear.


Image Credit: Reformation

HEIQ

Material: HeiQ AeoniQ™
Founders: Carlo Centonze and Dr. Murray Height
Year Founded: 2005
HQ: Switzerland
Market Focus: B2B
Stage: Commercially Available


Image Credit: HeIQ

Using a proprietary manufacturing process, HeiQ AeoniQ™ is a cellulosic filament yarn that is biodegradable and "endlessly recyclable". Raw ingredients include: Circulose®, non-valorized agricultural waste and bacterial cellulose. End of life products are biodegradable and recyclable.
Apparel company Hugo Boss invested in HeiQ to help meet their sustainability goals which included product circularity and eliminating polyester and nylon from their collections.

HeiQ has since partnered with Italian textile mill BESTE to create a collection of HeiQ AeoniQ fabrics made in Italy.

Applications are suitable for apparel and performance wear.

KINTRA FIBERS

Founders: Billy McCall, Alissa Baier-Lentz
Year Founded: 2018
HQ: USA
Market Focus: B2B
Stage: R&D, Pilot Production

Kintra uses 100% bio-based inputs. They created a new polymer in the polyester category that is: 100% bio-based (from glucose via fermentation) by input, biodegradable, and compatible with standard polyester production equipment. In a preliminary cradle-to-gate LCA that compared their raw material and resin production processes to those of PET, they saw a 95% reduction in emissions. Kintra yarns pass the ASTM D6400 and ISO 14855-1 tests for industrial compost.

Their resin and yarns are tunable to make a wide range of knit and woven textiles ranging from silk-like wovens to various delicate knits. Kintra's brand and mill pilot partners are using Kintra yarns as an alternative to traditional synthetics such as PET polyester and nylon. Applications are suitable for performance wear to luxury apparel.


Image Credit: Kintra Fibers

MANGO MATERIALS

MANGO MATERIALS

Material: Sustainable YOPP PHA pellets
Founders: Anne Schauer-Gimenez, Allison Pieja and Molly Morse
Year Founded: 2012
HQ: USA
Market Focus: B2B
Stage: Injection molding grade is commercialized, fiber grade in development

Mango Materials produces fully biodegradable, readily compostable, and customizable PHA biopolymer pellets for injection molding and fibers via melt spinning. The pellets can be made from the fermentation of plant feedstocks or methane gas, where Mango Materials co-locates with methane producers. Applications are suitable for shoes, activewear, backpacks, rope, etc.

Image Credit: Mango Materials

NEWLIGHT

NEWLIGHT TECHNOLOGIES

Material: AirCarbon
Founders: Mark Herrema, Kenton Kimmel
Year Founded: 2007
HQ: USA
Market Focus: B2B
Stage: Commercially Available

Using decarbonization technology, Newlight makes a meltable PHB that can be used as a replacement for fiber, leather, and plastic. AirCarbon is a carbon storage material and is compostable. Newlight harnesses microorganisms found in nature to pull carbon out of greenhouse gases and convert into a resource. Applications are suitable for fashion, entertainment, hotel, food service, and automotive industries.

Image Credit: Newlight Technology

Image Credit: OceanSafe

OCEANSAFE

Material: naNea
Founder: Manuel Schweizer
Year Founded: 2019
HQ: Switzerland
Market Focus: B2B
Stage: Commercially Available

OceanSafe makes a proprietary novel synthetic fiber designed to replace conventional polyester called naNea. naNea performs like conventional PET, but its novel polymer structure renders biodegradability in the open environment. naNea does not emit microplastics, nor does it contain antimony or other harmful substances. naNea is Cradle to Cradle Certified® Gold and at end-of-life, it is recyclable. naNea biodegrades in seawater within 99 days by over 93% according to ASTM D6691.

naNea is available as fibers, yarns, and filament yarns. OceanSafe's materials are suitable for existing value chains. They qualify as drop-in technology and are, therefore, highly scalable. They match quality and price parity with existing materials.

Applications are suitable for apparel, trim, and home textiles.

RUBI LABORATORIES

Co-Founders: Neeka and Leila Mashou
Year Founded: 2021
Headquarters: USA
Market Focus: B2B
Stage: R&D

By engineering a unit to capture the CO_2 coming out of factory flues, Rubi Laboratories uses a cell-free enzymatic process to convert the CO_2 into pure cellulosic pulp. There is zero CO_2 waste in the process. The cellulosic pulp is spun into fibers via wetspinning. The resulting lyocell yarn is suitable for apparel. The fiber is silky and can be used in similar applications to animal-based silk and polyester. The fiber plugs into existing manufacturing equipment and has price parity with lyocell.
Rubi Labs has partnered with Walmart, Ganni, and H&M Group. Applications are suitable for apparel.


Image Credit: Ganni for Rubi Labs

SCI-LUME LABS

Material: Bylon™
Founder: Oliver Shafaat
Year Founded: 2021
HQ: USA
Market Focus: B2B
Stage: R&D

Using melt spinning, Sci-Lume has created a bio-based and biodegradable nylon alternative called Bylon™. Bylon™ uses agricultural waste as its renewable bio-based feedstock. It can be produced in existing manufacturing equipment that makes nylon and polyester. Applications are suitable for apparel.

Image Credits: Sci-Lume Labs

SUPPORT THE NEXT-GEN MOVEMENT

Credits:

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About MII

The Material Innovation Initiative is a nonprofit think tank that accelerates the development of high-performance, animal-free, and environmentally preferred materials with a focus on replacing silk, wool, down, fur, and leather and their synthetic alternatives. We advance the next-gen materials revolution by connecting science and big ideas. We focus on research, knowledge-sharing, and fostering connections to fast-track the development of environmentally preferable and animal-free materials.

We work to cultivate a global market for next-gen materials across the fashion, automotive, and home goods industries. We work for materials that can do more while requiring less of the planet, animals, and people involved at every stage.

We imagine a circular future where the default choice for your sweater, sneaker, or seat is humane and sustainable. A future where animals are allowed to live free and thrive, the planet is saved from pollution and degradation, and workers are treated fairly and with respect.

Image Credit: Jon Brown / Werewool

ENDNOTES

Definitions

1. In this report, we modify the European Committee for Standardization's definition of "bio-based products" so as not to include any animal-derived products. Institute for Sustainable Communities et al., "Spinning Future Threads: The Potential of Agricultural Residues as Textile Fibre Feedstock," June, 2021: p.22, https://laudes.h5mag.com/laudes/agri-waste_report_highlights/home/9656/agri_waste_report_2021_07_01.pdf

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