

The
**Nature
of Fashion**

Design for Transformation

Case Study Report

The Germany Pilot by
Beneficial Design Institute



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Foreword

Fashion must become a regenerative force within planetary boundaries—not as a distant aspiration, but as an urgent ecological and economic imperative. The textile industry is in crisis: 92 million tons of waste annually, up to 60 billion unsold garments, and around 8% of global carbon emissions. A century of linear "take-make-waste" has exceeded Earth's biophysical limits. Transformation is no longer optional.

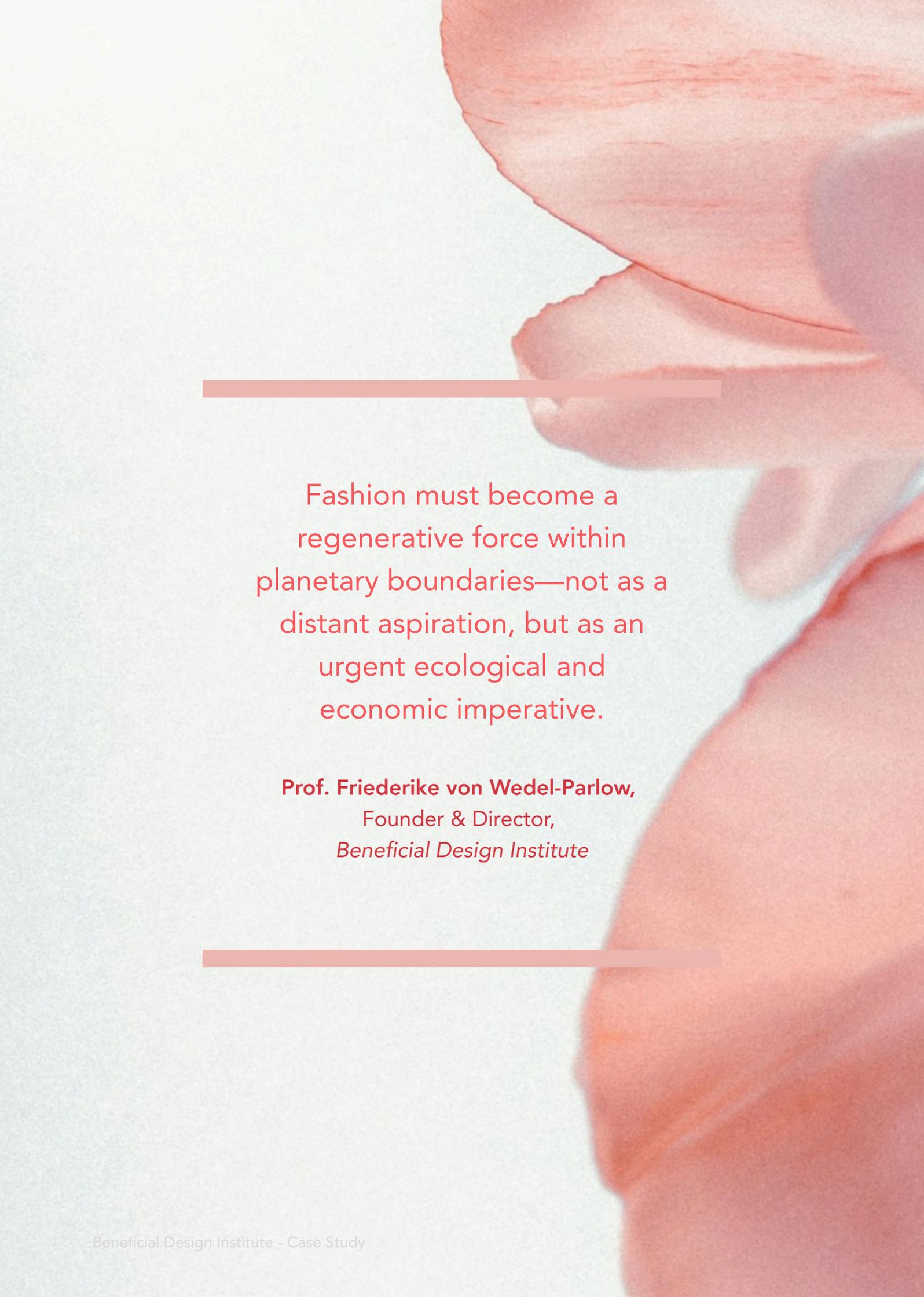
The "Nature of Fashion: Design for Transformation" initiative embodies the Beneficial Design Institute's vision of positive fashion—one that actively regenerates rather than merely reduces harm. By integrating Cradle to Cradle design, circular bioeconomy, biomimicry, and life-centered principles, the answer emerges from nature's own logic—transformation through breakdown and renewal.

Germany, Europe's largest fashion market with a 64% textile collection rate, provides ideal conditions for this transformation. Brandenburg's 250 biotechnology firms, deep circular economy expertise, and established textile infrastructure position the region uniquely to pioneer Europe's future. Research by the Beneficial Design Institute and Fraunhofer Institute demonstrates that textile waste becomes feedstock for medicine, agriculture, and packaging—creating employment while retaining regional value.

Yet technology alone cannot succeed. We need policy courage: funding for textile biorefineries, regulations mandating material safety, industrial commitment to need-based production. Most critically, cultural transformation—recognizing fashion's true purpose: creating beauty worthy of care, repair, and love. Garments that transcend seasons. Materials that nourish, not poison. A future where regeneration becomes fashion's narrative.



Prof. Friederike von Wedel-Parlow,
Founder and Director,
Beneficial Design Institute



Fashion must become a
regenerative force within
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Section 1
Introduction

Nature of Fashion: Design for Transformation

The *Nature of Fashion: Design for Transformation* initiative reimagines the global fashion and textile system through the lens of nature's wisdom. Recognizing that **the current take-make-waste model has exceeded planetary boundaries**, this program calls for a radical redesign of how we produce, use, and dispose of textiles. Drawing inspiration from nature's process of decomposition and regeneration, **the initiative advances a break-down-to-build-up paradigm, shifting circularity toward a truly regenerative system** that aims to align industrial activity with ecological cycles.

Launched by the **Biomimicry Institute** and funded by **Laudes Foundation**, the initiative builds upon years of applied research and early pilot projects that demonstrated both the potential and complexity of transforming mixed textile waste into new, biocompatible materials. These efforts combine technical innovation, systems thinking, and narrative transformation to illustrate that **waste should not be an endpoint but the beginning of renewal**.

Now in its second phase, *Nature of Fashion: Design for Transformation* operates across three pilot regions, **Germany, the Netherlands, and Ghana**, each testing locally adapted technologies and collaborative approaches to material transformation. Through these real-world projects, the initiative illustrates that circularity alone is not enough; **true transformation lies in designing fashion as part of life's continuous cycle**, where everything created can safely return to the Earth.

1. Germany and 2. the Netherlands (Northern Europe): Focusing on *value creation from waste* through biological and thermochemical processing of textile waste to produce materials that serve as feedstock for other industries, replacing disposal with material regeneration.

3. Ghana (Accra): Applying nature aligned principles to remediate environmental pollution in the Korle Lagoon, leveraging local microbial ecosystems to break down legacy textiles and waste accumulation.

At its core, this initiative integrates science, design, and storytelling to catalyze systemic change. It aims to establish recognition of **textile decomposition and sustainable waste transformation as a vital process missing from the broader circular economy framework**. By learning from organisms and ecological processes that safely transform matter into nutrients for new life, **the project envisions a fashion industry that restores ecosystems, regenerates resources, and fosters community well-being**.

Introduction to the Beneficial Design Institute Pilot

About the Partner

The Beneficial Design Institute (BD-I) is a design research institute specialising in eco-design and sustainability, based in the Berlin-Brandenburg metropolitan region. BD-I develops holistic innovation concepts and circular product solutions for the textile and fashion industry, and combines design, material and circular economy expertise with practical implementation – from research to market readiness. Its interdisciplinary work integrates science, art, technology with the aim to regeneratively transform the industry through biocompatible materials, new value creation paths and consistently nature-inspired design.

Focus of the Pilot

As an implementation partner in the Nature of Fashion: Design for Transformation initiative, BD-I leads the German pilot based in the **Berlin-Brandenburg** region. The institute is pioneering new models of **regional circular value creation infrastructure**, transforming **mixed, low-value textile waste** which is currently destined for incineration or export that ends up in landfill in the global south — into **high-value, biocompatible materials** for use in sectors such as agriculture and medicine. Rather than accepting incineration as inevitable, the pilot demonstrates how even the "lowest category" of textile waste can become the foundation for regenerative industries complementing reuse, repair and recycle strategies.

Innovation and Approach

This pilot integrates three areas of innovation: mapping post-consumer textile waste streams from B2B and B2C sources and their regional impacts, testing biotechnological transformation pathways, and identifying regional markets and value creation potentials. Working with key research and industry partners including **Fraunhofer IAP**, **Fraunhofer IGB** and **matterr GmbH**, two complementary biotechnological approaches are being developed. The first applies a two-step process of **hydrolysis** and **bacterial fermentation** to convert polyester-rich textile waste into **polyhydroxybutyrate (PHB)**, a biodegradable polymer with medical-grade potential. The second pathway utilizes CO₂ from syngas from textile gasification to cultivate microalgae, generating **beta-glucan** and other **bio-mass compounds** for agricultural and industrial applications. Together, these approaches demonstrate how diverse textile waste streams can be diverted from incineration and reintroduced as safe, regenerative materials.

Transformative Potential

The Berlin-Brandenburg pilot demonstrates the gap between technical feasibility and systemic constraints. While lab-scale results are promising, scaling is constrained by siloed funding structures that favor isolated technologies over integrated systems. Despite these barriers, BD-I's work shows how regional bioeconomies can transform waste into resources for regeneration through systems thinking and collaborative design with its ecosystem of partners.

The Team

The Partners



The Funders

Laudes ———
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Federal Ministry
for the Environment, Nature Conservation,
Nuclear Safety and Consumer Protection



Federal Ministry
for Economic Affairs
and Energy



Section 2

The Challenge

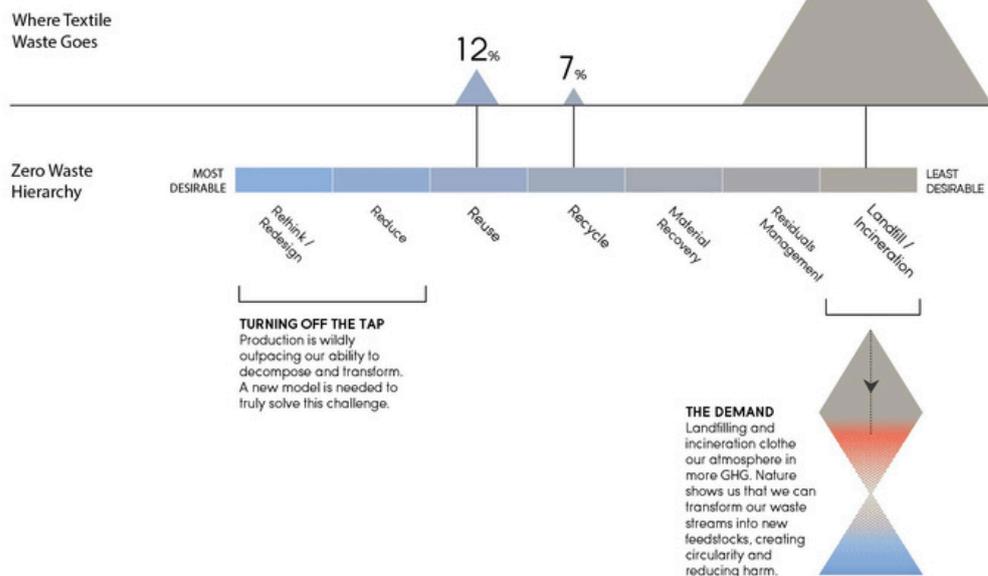
Germany's Textile Waste Dilemma:

Berlin sits at the heart of Germany's textile waste dilemma. Each year, approximately **1 million tons of textile waste (two-thirds of country's annual textile consumption)**⁴ is collected across the country, yet only a fraction finds a second life. Around **54,000 tons are incinerated annually** under the label of "energy recovery," while thousands more are exported, legally and illegally, to the Global South, where they flood local markets and pollute waterways and landfills.

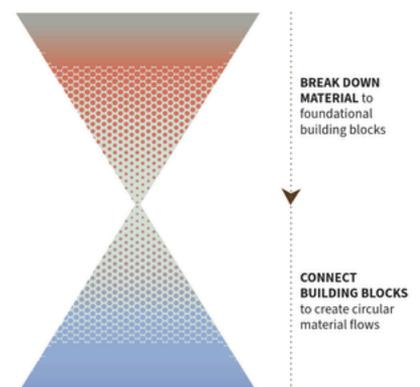
This is not a problem of scarcity, but of **system failure**. The textiles being burned or dumped are not inherently worthless, they are simply incompatible with existing recycling infrastructure. The dominant paradigm in circular textiles today is **fiber-to-fiber recycling**, which holds promise for homogeneous materials like pure cotton or polyester. Companies such as **Södra** in Sweden and **Lenzing's Refibra** in Austria have demonstrated the viability of converting textile waste back into new fibers.

But there's a catch: fiber-to-fiber recycling requires materials that are **at least 95% homogeneous**. In reality, the vast majority of textiles produced globally are **blends** of cotton-polyester, wool-acrylic, elastane-nylon combinations designed for performance, comfort, and cost efficiency, but are nightmares for immediate circularity. Currently, **less than 1% of global textile waste** is sent for fiber-to-fiber recycling. 85% becomes waste and ends up in landfills in the Global South, is lost and scattered in nature, or ends up in incineration.

Zero Waste Hierarchy VS. The Current Reality



Nature of Fashion: Break-Down-To-Build-Up



And then there's contamination. Even textiles that might technically qualify for recycling are often rendered useless by dirt, mold, dyes, finishes, contaminants and heavy chemicals used throughout the global textile supply chain. Fast fashion accelerates this problem: garments are produced cheaply, worn briefly, and discarded quickly, often after just a handful of wears. By the time they reach collection bins, many are already degraded beyond mechanical or chemical recovery.

This leaves a significant category of textiles at the **lowest level of the waste hierarchy**: unsuitable for rewear, reuse, redesign, or conventional recycling. These are the textiles BD-I calls the "**stubborn 10%**", the fraction that even the most optimistic circular models struggle to address. They are difficult to recover and require a variety of strategies to ensure they are recycled in a high-value manner.

Europe's policy landscape adds both urgency and complexity. The **EU Circular Economy Strategy** explicitly promotes circular processes in the textile sector, and **Germany's National Circular Economy Strategy (NKWS)** emphasizes resource efficiency, waste collection, high-quality recycling, and research support. These frameworks signal political will, but they do not yet provide the integrated funding or infrastructure necessary to transform the most difficult waste streams.

So the question becomes:

What do we do with textiles that the system has given up on?

For decades, the answer has been incineration or export. But what if the answer lies not in more efficient sorting or better fiber separation, but in **rethinking what waste can become**? What if, instead of trying to return polyester to polyester and cotton to cotton, we could transform these materials into something entirely new: something biocompatible, regenerative, and valuable across industries?

That is the challenge the Berlin-Brandenburg pilot was designed to address. Not by perfecting the circular loop, but by **learning from nature's decomposition processes** to ensure that textiles can safely return to the earth at the end of their useful life. The pilot takes inspiration from natural ecosystems, whose community members work together to breakdown discarded waste into valuable material building blocks that move in the system to create new opportunities. This principle serves as a lever for industry transformation by driving the use of biocompatible materials, new value creation pathways, and a focus on producing fewer, higher-quality textiles with designs inspired by nature.



Section 3

The Approach

Design for Transformation in Berlin-Brandenburg

At the core of the Berlin-Brandenburg pilot, the Beneficial Design Institute (BD-I) is pioneering a nature-inspired systems design to tackle what the circular textile economy currently overlooks: transforming mixed, contaminated, and blended textile waste into biocompatible materials that never become waste again.

Regional Textile Waste Landscaping

Through a regional textile waste landscaping conducted in Berlin-Brandenburg, the pilot team analyzed three major waste streams for their suitability in the (hydrolysis-based) transformation pathway: post-consumer textiles from households (B2C), medical workwear, and industrial cleaning cloths (B2B).



Left to right: Mixed fast fashion waste (SOEX), Medical Workwear (Sitex), Industrial Cleaning Cloths (Mewa) © Beneficial Design Institute GmbH

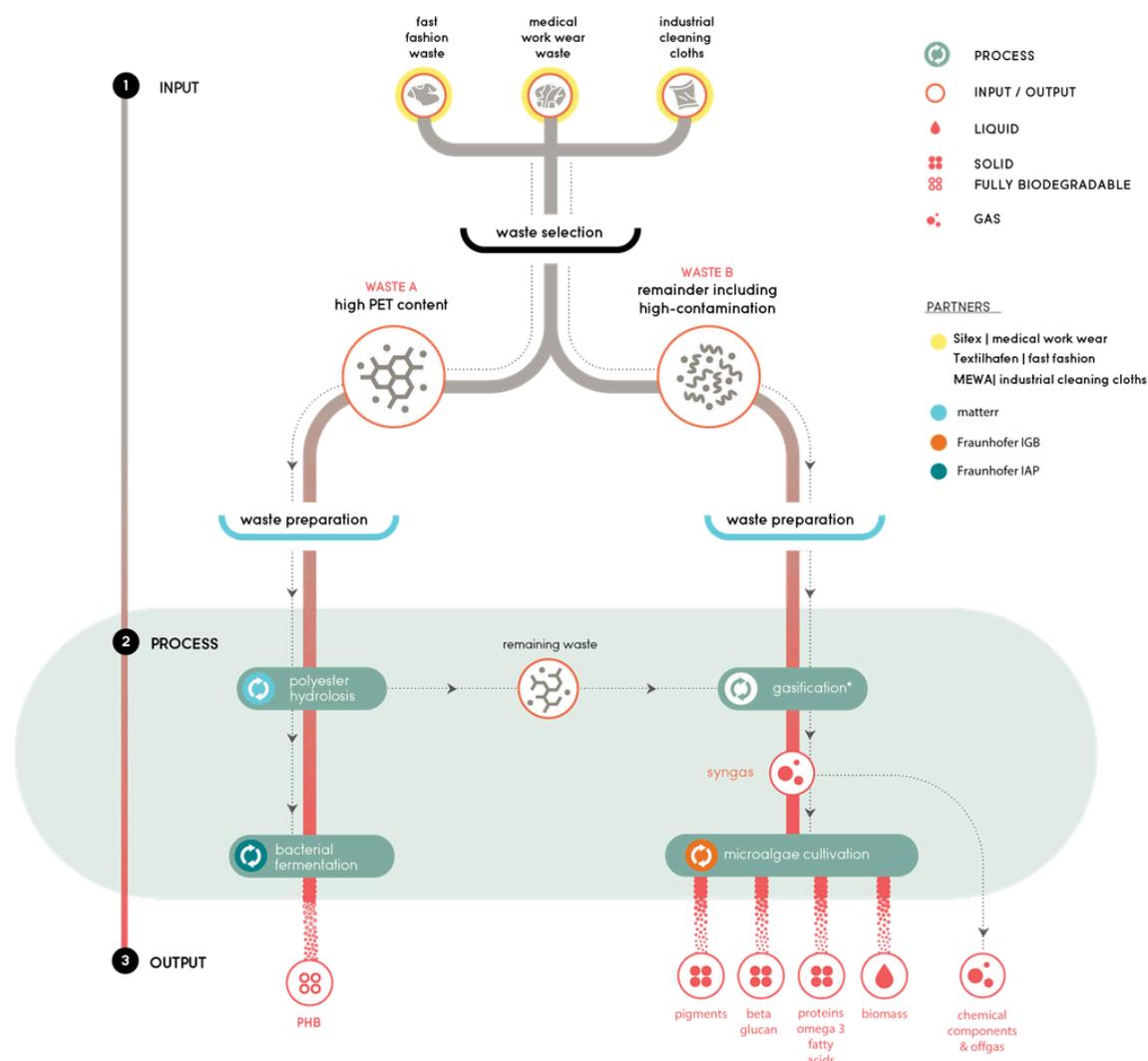
All three fractions possess conversion potential, but with varying scalability conditions. In particular, B2B textiles such as medical workwear demonstrated the highest immediate viability due to their homogeneity, defined material composition, and available logistical frameworks. In contrast, post-consumer household textiles - though abundant - remain highly heterogeneous and chemically less defined, requiring further research and improved data accessibility before efficient hydrolytic conversion becomes feasible.

Based on these findings, the pathway prioritizes industrial and workwear textiles for initial scale-up, with subsequent expansion toward more complex fractions like fast-fashion and mixed household waste as sorting and capture technologies evolve.

leading countries for post-consumer textile waste: Germany, and neighboring countries Poland and the Netherlands. Strengthening collaboration across these regions is essential for establishing an integrated transnational valorization cycle, enabling effective scale-up of circular textile solutions and cross-border pilots in Europe.

Instead of treating waste as an endpoint, the project redefines it as a starting point, as feedstock, applying two complementary technological pathways that mirror material transformation in nature. These pathways combine **polyester hydrolysis, bacterial fermentation, and microalgae cultivation**, with the aim of forming a system that decomposes polyester, elastane, and other textile waste into **safe, reusable biological building blocks** — in much the same way ecosystems cycle nutrients.

**Regional Transformation Pathway:
Bacterial Fermentation +
Microalgae Cultivation**



PATHWAY I:

Polyester Hydrolysis



Bacterial Fermentation

The first transformation pathway focuses on converting **polyester-based fractions** of mixed textile waste, such as post-consumer fast fashion, industrial workwear, and cleaning cloths, into **polyhydroxybutyrate (PHB)**, a fully biodegradable and thermoplastically processable biopolymer.

The first step includes the **sorting, collection and preparatory processing** of textile waste at the lowest level of the hierarchy. For the feasibility study, 18 different sample categories were selected from medical workwear, industrial cleaning cloths and fast fashion, all of which had a high PET content and had been sorted for incineration from partners such as **Soex, Textilhafen, Sitex, and Mewa**.



Left to right: Pathway 1 infographic ; Waste preparation PES © Beneficial Design Institute GmbH; Hydrolysis matterr technology © matterr; Bioreactor for Bacterial Fermentation Fraunhofer IAP © Fraunhofer IAP

Feasibility was tested on selected samples with varying degrees of soiling, different colours or elastane content, as well as printed products compared to unprinted and mixed and blended materials. These materials are shredded by **matterr** and subjected to the matterr technology at laboratory scale. Depolymerization through alkaline hydrolysis followed by purification steps leads to the polyester's monomers terephthalic acid (TPA) and monoethylene glycole (MEG).

The MEG is then introduced into a **bacterial fermentation process** developed in collaboration with the **Fraunhofer Institute for Applied Polymer Research (IAP)**. Here, bacteria such as *Cupriavidus necator* metabolize MEG to synthesize **polyhydroxybutyrate (PHB)** inside their cellular structures. The PHB can be extracted and serves as a biodegradable bioplastic that combines durability with environmental safety and is capable of replacing petroleum-based plastics in medical, agricultural, and consumer applications.

The feasibility study shows that PHB and its related copolymers belong to bioplastics that are completely biodegradable, compostable and biocompatible. Due to its melt properties, PHB is particularly suitable for processing techniques such as injection moulding and 3D printing. The feasibility of these technologies has been successfully demonstrated – all 18 types of textile waste tested could be depolymerised, and the conversion of MEG to PHB is feasible.

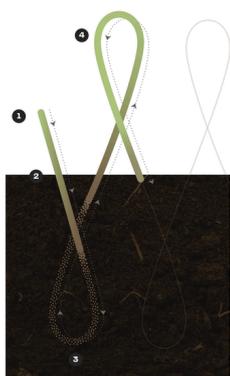
PHB-based Product Applications for Regional Value Creation

Beyond technological proof of concept, the project has actively pursued market analysis to identify product segments with the highest potential for biocompatible cross-industrial applications and assess proof of concept also from an economic lens. Early-stage findings highlight economic opportunities for the TexPHB material, positioning it as a competitive alternative to conventional bioplastics within selected regional markets. Especially in Berlin-Brandenburg and Germany, promising application fields emerge in agriculture, forestry, water protection, and medical technology - domains where products can safely remain in their environment - soil, water or within the human body, eliminating the need for complex take-back or recycling systems.

Notable product examples include biodegradable tree clippings and geotextiles for erosion control, artificial shore protection and breakwater structures, medical devices such as pill capsules, bone screws, and surgical instruments, as well as items for funeral services like urns and coffins. By prioritizing markets where biodegradability and environmental compatibility are paramount, the pathway not only demonstrates technological viability but also validates economic potential at an early stage, laying a foundation for future regional value creation.

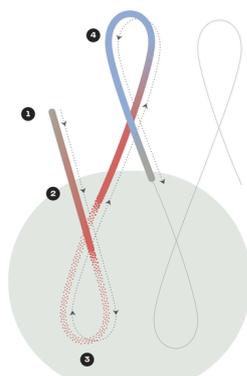
Image below: Decomposition model in nature and pilots
Image right: Industry use cases for material outputs

Design for Transformation: Nature's Model



In Nature

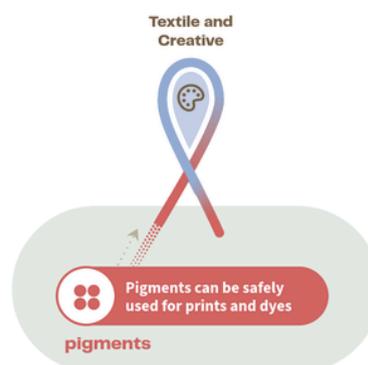
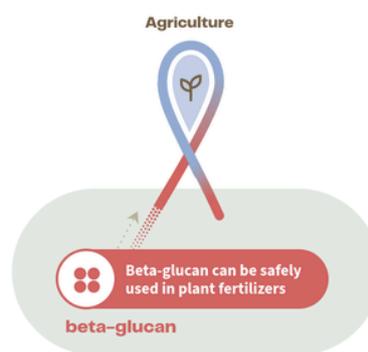
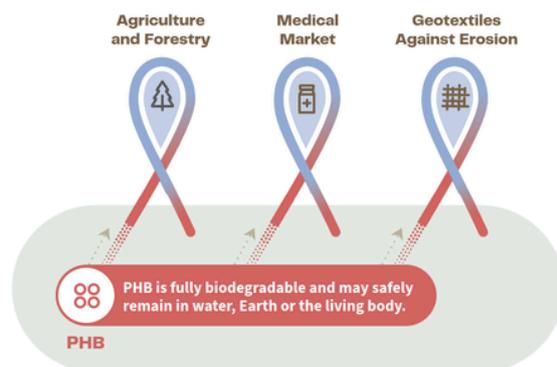
- 1 INPUT organic material
- 2 PROCESS decomposition
- 3 OUTPUT material building blocks
- 4 NEW INPUT new growth



Pilot Programs

- 1 INPUT textile waste
- 2 PROCESS decomposition
- 3 OUTPUT material building blocks
- 4 NEW INPUT renewed feedstocks

Industry Potential



PATHWAY II

Syngas



Microalgae Transformation

As part of its second approach, BD-I is researching the conversion of the remaining textile waste that is not transformed via polyester hydrolysis, or that falls out of the process as waste. These are, in particular, **critical, mixed and unsortable material fractions that are converted into biomass compounds using biotechnological and thermochemical coupling.** This feasibility study focuses on the question of how microalgae can handle circular CO₂ instead of technical or biogenic sources and the accompanying exhaust gas streams of the mixture. Is growth negatively affected? Can they even be part of the purification process for critical gases?

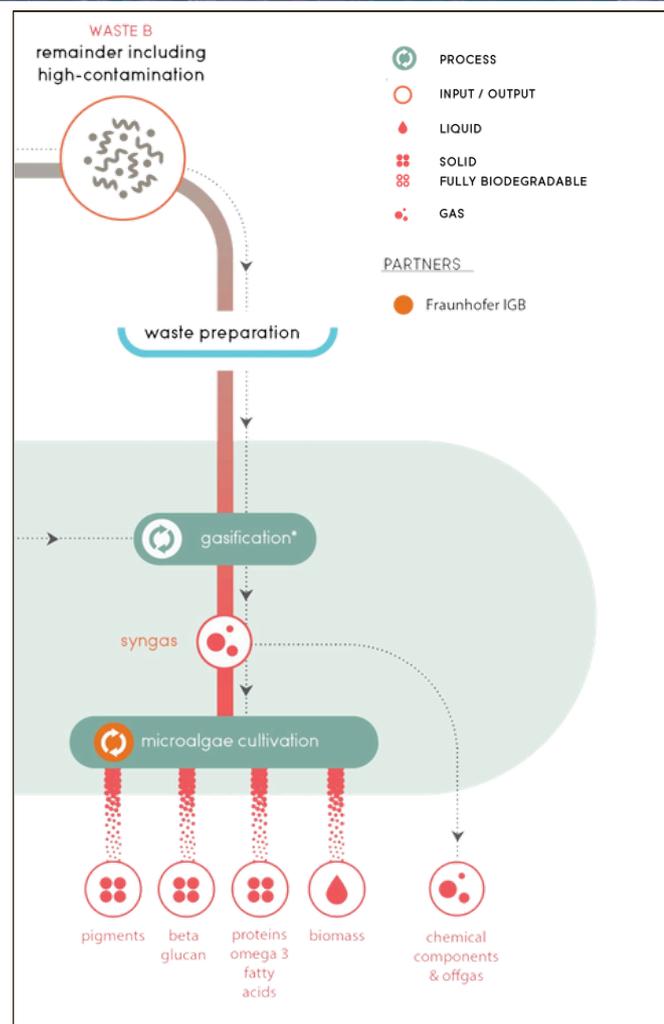


Image right:
Pathway 2- Syngas > Microalgae cultivation and outputs

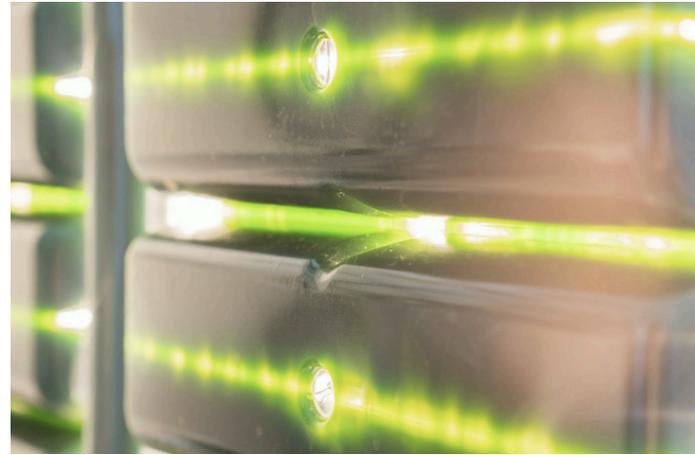
The investigations are also intended to provide insights into the properties and composition of the syngas obtained from the gasification process of textile waste, which can be modelled during the gasification process. BD-I was able to draw on findings from the Dutch pilot project led by Circle Economy, which had already carried out initial gasification tests with its cooperation partner, TNO, using textile waste. Through **TNO**, possible process optimisations and downstream potential could also be included in the investigation of the input stream.

The **Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB)** is leading the investigation of **microalgae cultivation** using **CO₂-rich syngas**, based on an extensive literature review. The ongoing tests aim to refine the tolerance ranges for pollutant concentrations from gasified textile waste and to optimize algae productivity in flat-plate airlift bioreactors.

Images right:
Microalgae cultivation in flat
panel bioreactor at Fraunhofer
IGP © Fraunhofer IGP



In this process, microalgae binds carbon through photosynthesis and converts it into biomass that contains various usable components: omega-3 fatty acids, colour pigments, beta-glucan and other ingredients that can be used in areas such as food, feed, agriculture, prtextiles and medical applications. The focus is particularly on **beta-glucan**, a polysaccharide with promising applications in **agriculture (biofertilisers, plant stimulants)** and **biomaterials**.



Based on **Regenerate Fashion's** initial market research, a comprehensive market analysis is also being carried out to explore further potential applications for the use of circular CO₂ obtained from textile waste, taking into account regular factors, costs, quantities and commercialisation potential, etc. Products obtained from biomass include pigments used in the food industry, for example, but which can also be used for textile printing and dyes.

Initial findings show that, on the one hand, the purity of the circular gas obtained from textile waste is crucial for the growth of algae. On the other hand, various scenarios for CO₂ extraction and downstream processes have emerged, which are also being evaluated for their feasibility and their ecological and economic impacts with the support of **epea GmbH**. The results of the project will be compiled in a report in Q1 2026.

Through this pathway, the project extends the concept of material transformation beyond the bacterial level, illustrating how biotechnological systems can be grouped together to metabolize waste streams that current industrial processes exclude. Once integrated, the polyester hydrolysis-fermentation line and the syngas-microalgae system are a good step to complete a regional transformation cycle where synthetic waste becomes organic input, and residual carbon is biologically reabsorbed into new, safe materials.

Integrated Design and System Synchronization

While each pathway has shown feasibility potential individually, the true innovation lies in **system integration**. BD-I's long-term vision is to synchronize these processes into a **continuous regional material cycle**. This "Design for Transformation" model enables multiple pathways that leverage chemical and biological specialties to interact as a unified ecosystem rather than as isolated technologies.

By establishing partnerships between research institutions and industry, manufacturer networks, and customers and users in various markets, BD-I is positioning the Berlin-Brandenburg region as a **textile transformation hub** and embedding biological manufacturing in local value chains. This development depends on three key areas: access to textile waste and the associated infrastructure and pre-processing, the biotechnological transformation processes themselves, and the appropriate markets and product innovations in which the material obtained is used.

Future scaling initiatives include expanding the processes to cotton hydrolysis as a raw material extension for glucose fermentation, as well as a market approach in the medical sector that focuses on converting medical workwear into absorbable biopolymers for medical purposes. In addition, gasification will be modelled and optimised for algae cultivation in further studies. Further research is needed to purify the other chemical components, residues and exhaust gases produced in the process and convert them as far as possible into biocompatible materials or market them as chemical components.

Together, these efforts point toward a regenerative regional bioeconomy where waste is continually transformed into resources.

Integration is one of the key innovation processes here: only when textile waste streams, biotechnological transformation and market applications are synchronized, can isolated pathways become a living, regenerative ecosystem.

Isabella Rhein,
Systems Design & Innovation Manager,
Beneficial Design Institute

A close-up photograph of a bird's feathers, showing a mix of vibrant red, orange, and white. The feathers are layered and have a soft, downy texture. The lighting is warm, highlighting the intricate details of the feather structure.

Section 4

What We Learned

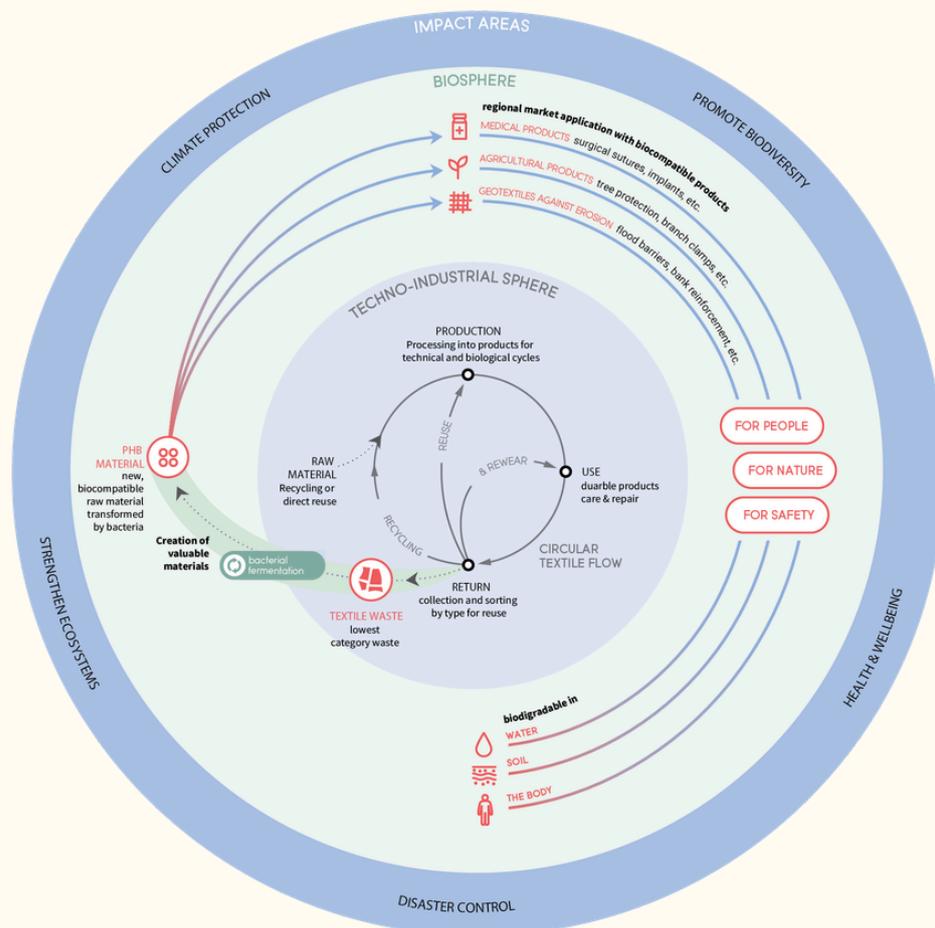
Key Findings and Strategic Insights from the Pilot

Technical Milestones and Results

The Berlin-Brandenburg pilot successfully demonstrated that even *the most challenging waste textiles, those considered unrecyclable, contaminated, or blended*, have potential to be transformed into **biocompatible outputs** with applications far beyond the textile sector.

Polyester Hydrolysis and Bacterial Fermentation:

- Laboratory-scale trials, led by **matterr GmbH** and the **Fraunhofer Institute for Applied Polymer Research (IAP)**, showed proof of concept that polyester-rich waste fractions from post-consumer fast fashion, industrial workwear, and cleaning cloths can be chemically depolymerized into **monoethylene glycol (MEG)** and **terephthalic acid (TPA)**. Eighteen different waste samples were processed, validating the adaptability of the matterr process across diverse low-value input streams. Utilizing monoethylene glycol raw material **Polyhydroxybutyrate (PHB)** can be extracted from the bacterial fermentation process. PHB shows promise as a biodegradable substitute for fossil-derived plastics in applications from flood protection, agriculture and forestry, right through to medical technology, as well as PHB geotextiles.



Microalgae Cultivation Using Circular CO₂ from Gasified Textile Waste:

- In collaboration with the **Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB)**, the use of CO₂ within the syngas derived from gasified textile waste (data supplied by the Dutch partner **TNO**), was analysed and tested for the cultivation of microalgae to produce **beta-glucan** and other biocompatible outputs from algae biomass, valuable for agriculture and material science. Early results confirm that CO₂-rich syngas derived from mixed waste can serve as a productive carbon source, though work continues to optimize contaminant thresholds and reactor performance.

Key Challenges and Insights

- 1 Textile recovery:**
 - Access to and recovery of textile waste in the lowest waste category including an infrastructure with digital data and process recording from manufacture and procurement onwards are being systematically created in a comprehensive platform as part of a regional textile hub.
- 2 Material Complexity:**
 - Hydrolysis efficiency and PHB yields were strongly dependent on input material properties. Workwear and industrial cleanliness proved easier to process than highly variable B2C fast fashion waste or heavy contaminated cleaning cloth.
- 3 Technical Yields:**
 - PHB production yield remains limited and requires further environmental performance optimization, such as the efficiency of PHB extraction and replacing harmful solvents. Mechanical and chemical characteristics (e.g. brittleness) must be enhanced to scale up to broader functional applications.
 - **Strategic Insight:** Process optimization and synchronization are central: all process steps — sorting, chemical and biological processing, product integration — must be aligned for commercial and environmental viability.
- 4 Funding and Integration:**
 - The German funding model still hinders system design of the pilot. Separate programs favor single-technology R&D, creating gaps in infrastructure and knowledge transfer needed for full systems demonstration.

- 5 Market Alignment:**
- Progress depends on aligning product outputs (e.g., medical-grade PHB, agricultural beta-glucan) with real-world end-user needs, securing demand, and validating performance; not just technical feasibility, in practice.
 - **Strategic Insight:** Stakeholder and market orientation matter as much as technical advancement; products must meet user needs and regulatory requirements from the outset.

- 6 Transnational Collaboration:**
- Without international partners, some pathways (particularly those requiring gasification infrastructure) would not have reached proof-of-concept potential. **Transnational partnerships and data-sharing are required until German or EU frameworks support holistic system pilots.**
 - **Strategic Insight:** Regional and cross-border collaboration isn't a bonus, but a necessity for scaling these approaches and achieving "design for transformation" at relevant scale.

Implementation Steps and Collaboration

Due to **fragmented funding landscapes in Germany**, each technological pathway was implemented as a distinct proof-of-concept project, rather than as a fully integrated system. As a result:

- The hydrolysis–fermentation process was funded and validated by partnerships including BD-I, matterr, Fraunhofer IAP, and textile collectors and services (SOEX, Textilhafen, Sitex, and Mewa), with backing from Brandenburg's Climate Protection Ministry.
- The syngas–microalgae pathway was extended through international collaboration, based on findings on syngas from the Dutch pilot partner to render the study at Fraunhofer IGB.
- Despite structural barriers, this approach enabled **practical cross-border learning (country-to-country), process adaptation, and groundwork for future systems integration** thereby prefiguring what a regional, ecosystem-based textile transformation hub could become.



Section 5

Impact & Potential

Environmental Feasibility and Economic Outlook

The Berlin-Brandenburg pilot demonstrates that transformation is not just technically possible, there are also signs that it is ecologically necessary and economically promising. By redirecting textile waste from incineration to regenerative material cycles, the project offers a tangible model for how regional circular bioeconomies can emerge from what the linear system discards.

Environmental Impact: From Waste to Safe, Regenerative Materials

By transforming these materials, that have no existing material cycling pathway, into **biocompatible outputs**, the project reduces dependence on waste-to-energy infrastructure, advances circular bioeconomy principles, and aligns with the **EU Circular Economy Strategy** and Germany's **National Circular Economy Strategy (NKWS)**.

Early **Life Cycle Assessment (LCA) of the PHB pathway** results show significant environmental advantages:

Key Environmental Advantages

1. **Carbon Reduction:** Compared to fossil-based ethylene glycol production, the polyester hydrolysis and fermentation pathway demonstrates **60–99% lower fossil resource depletion and CO₂ emissions**.
2. **Water Efficiency:** Water use is negligible, as the system operates within closed-loop processing cycles.
3. **Biodegradability and Safety:** PHB is fully biodegradable in soil and marine environments, non-toxic, and suitable for medical and food-contact applications. This positions it as a direct alternative to conventional plastics, reducing microplastic pollution and persistent chemical contaminants.

From an environmental-impact perspective, some process stages remain critical, especially the use of sodium hydroxide and solvents in hydrolysis and PHB extraction. Ongoing work on heat integration, chemical recycling, and solvent recovery can mitigate these impacts. Importantly, **regional valorization** via stable textile waste flows shortens supply chains, cuts logistics emissions, and supports local green jobs.

While a full-chain LCA is still pending at pilot scale, early findings indicate alignment with **EU circular economy goals**: avoiding incineration, reducing fossil dependence, enabling safe material loops, and turning waste into biocompatible resources.

Economic Feasibility: Building Regional Value Chains

The pilot's economic viability hinges on increasing **process optimization, product validation, and market alignment**. PHB production yields remain low at current lab scale, requiring further refinement in fermentation efficiency and extraction methods. However, the focus on **B2B textile waste as a starting point for scaling**, particularly medical workwear, provides a strategic advantage: these materials are more homogeneous, consistently available, and traceable, reducing variability and contamination compared to post-consumer fast fashion. This approach also enhances feedstock security by ensuring a consistent and high-quality supply of input materials.

The **Medical TexPHB** initiative represents the first scaling pathway. By transforming discarded medical workwear into **resorbable biopolymers** for medical applications such as sutures, implants, and surgical instruments, BD-I is an **extended open loop narrative** that resonates with institutional partners and funders. This approach leverages high-value markets to validate the technology before extending into "lower-performance" applications such as fashion and interior textiles.

Key economic opportunities include:

- **Regional Industrial Integration:** Partnerships are positioning this area as a hub for biomanufacturing and driving regional value creation by shortening supply chains and supporting green jobs. A new facility, that is being planned in the region, will provide industrial-scale fermentation capacity, enabling PHB production beyond laboratory proof-of-concept.
- **Market Diversification:** Beyond medical applications, PHB and beta-glucan offer pathways into agriculture (biostimulants, biofertilizers), forestry (biodegradable planting pots), and packaging (compostable films). This is on top of the medical circular model that transforms work wear into medical polymers.

Funding activities are being prepared to support scaling to **Technology Readiness Level (TRL) 7** over a 2–3 year horizon (Q4 2025 to Q4 2027, potentially extending to Q4 2028). These investments would enable pilot-scale testing, product validation, and regional ecosystem integration.

Transformative Potential: A Model for Regenerative Bioeconomies

The Berlin-Brandenburg pilot exemplifies the tension between **technical innovation and systemic constraint**. While proof-of-concept has been achieved, scaling depends on overcoming fragmented funding, building regional infrastructure, and aligning product outputs with market needs. Despite these challenges, the work offers a powerful vision: textile waste transformed into regenerative materials, local jobs created through biomanufacturing, and regional ecosystems strengthened by circular design.

By focusing on **stable B2B waste streams**, integrating **biotechnological and thermochemical processes**, and building **cross-sector partnerships**, BD-I is demonstrating how even the "stubborn 10%" of textile waste can become the foundation for a nature-inspired, regional cycle without waste — one that mirrors how forests, soils, and ecosystems continuously transform matter without producing harm.



The background is a soft, abstract watercolor wash in various shades of red, orange, and pink. The colors are blended together, creating a textured, painterly effect with some darker, more saturated areas and lighter, more delicate washes. The overall mood is warm and artistic.

Section 6

The Path Forward

Next Steps, Key Takeaways, and Vision for Transformation

The Berlin-Brandenburg pilot has proven that transformation is possible, even for textiles the system has discarded. It has shown that polyester blends, contaminated workwear, and mixed-material waste can be broken down biologically and thermochemically, then rebuilt into materials that are safe, regenerative, and valuable across industries. But proof-of-concept is not the same as systemic change. *The question now is:*

How do we move from laboratory validation to regional and industrial scale?

Next Steps: Advancing from Proof-of-Concept to Pilot-Scale Integration

The pilot is entering a critical transition phase, from **Technology Readiness Level (TRL) 3–5 (laboratory validation) to TRL 6–7 (pilot-scale demonstration and industrial validation)**. This shift requires coordinated investment, infrastructure development, and cross-sector alignment.

Immediate priorities include:

Scaling the TexPHB Pathway & Developing Products (2025–2028)

Working with **Fraunhofer IAP** and market partners, BD-I will advance the polyester hydrolysis and bacterial fermentation process and develop products for concrete cross-industry applications i.e. the medical field. The focus is on transforming **medical workwear into resorbable biopolymers** for surgical and clinical applications (as an example). By starting with high-value, traceable B2B waste streams, the pathway can validate technical performance and commercial viability before expanding into broader fashion and interior textile markets. Specifically, this pathway will prioritize workwear textiles as a consistent feedstock and develop high-performance PHB-based products for medical use.

Cooperating with a new Biomanufacturing Facility (2026 onward)

A new **bacterial fermentation facility is planned to be built and operationalized in the region of Brandenburg**. This industrial-scale infrastructure will enable PHB production beyond laboratory volumes, creating regional capacity for biopolymer manufacturing and positioning Brandenburg as a hub for circular biomanufacturing. Synchronizing this facility with upstream hydrolysis processes and downstream product development (including building partnerships with end users in medicine, agriculture, and forestry) will be essential for establishing a robust, integrated system.

Advancing the Syngas-to-Microalgae Pathway (2025–2027)

Following completion of proof-of-concept trials using syngas from the Dutch TNO gasification facility, Fraunhofer IGB will refine the microalgae cultivation process, focusing on **agricultural applications** for beta-glucan (biostimulants, biofertilizers). The next phase will explore opportunities to establish local or regional gasification partnerships within Germany to reduce dependency on international collaborators and to enable system integration at the regional level.

Building Data and Infrastructure for System Synchronization

To integrate pathways into a continuous, region-wide transformation cycle, BD-I will develop:

- Comprehensive **sorting and data systems** to assess textile waste streams, map material composition, and track feedstock availability across regional supply chains.
 - **Process optimization studies** to synchronize hydrolysis, fermentation, gasification, and algae cultivation, ensuring material and energy flows are complementary.
 - **End-user validation protocols** in collaboration with medical, agricultural, forestry, and packaging partners to confirm product performance and regulatory compliance.
-

Securing Systems-Level Funding (2025–2026)

BD-I is preparing funding applications to support pilot-scale testing, regional ecosystem integration, and product commercialization. These applications emphasize the need for **systems-level innovation funding** to support multiple pathways simultaneously, addressing the fragmentation that has slowed scaling to date.

Process Synchronization:

Assessing whether cotton hydrolysis solutions that at Fraunhofer IAP can generate glucose for fermentation in Brandenburg would broaden feedstock integration and enhance process flexibility

Policy Alignment and Systemic Barriers

The pilot operates within a supportive policy framework of the **EU Circular Economy Strategy** and Germany's **NKWS** both of which emphasize resource efficiency, high-quality recycling, and research support for circular business models. However, systemic barriers remain:

1

Fragmented Funding Structures:

German funding programs tend to support individual technologies rather than integrated transformation systems. This has forced BD-I to pursue pathways sequentially and to rely on transnational partnerships (e.g., with TNO in the Netherlands) to synchronize gasification and microalgae cultivation.

2

Infrastructure Gaps:

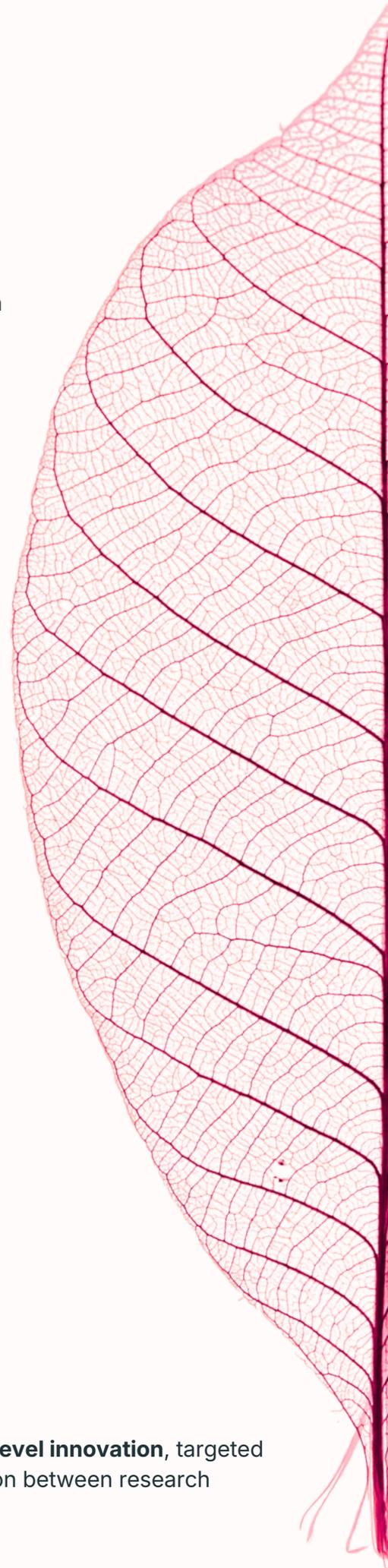
Access to gasification facilities, consistent sorting protocols, and industrial-scale fermentation capacity are still underdeveloped in the region, limiting the pace of scaling.

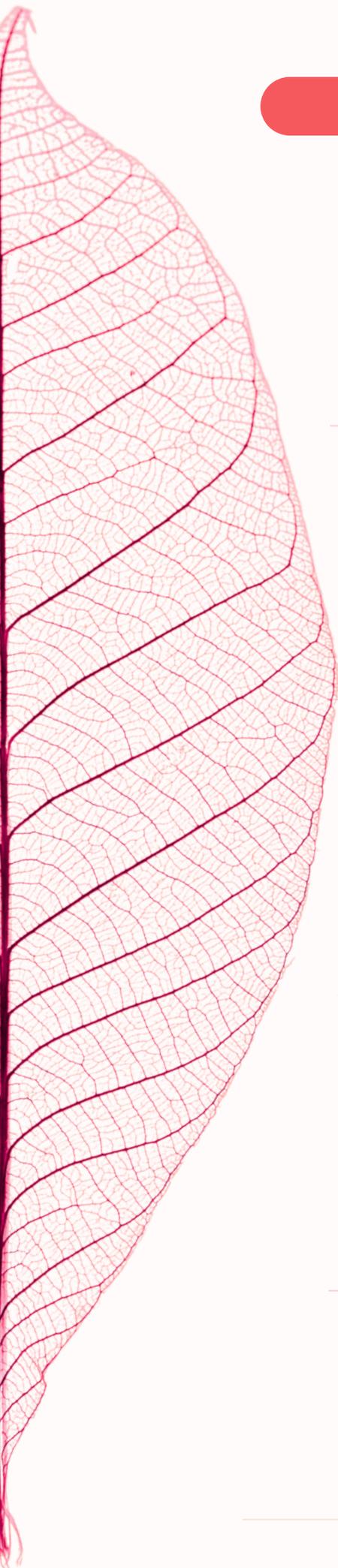
3

Market Readiness:

PHB's material properties, such as brittleness, require further refinement to meet performance standards in high-demand sectors like medicine and fashion.

Addressing these barriers will **require policy support for systems-level innovation**, targeted investment in regional circular infrastructure, and closer collaboration between research institutions, industry partners, and public agencies.





Key Takeaways: What This Pilot Demonstrates

- 1. Transformation Beyond Recycling:** Circularity — conventionally understood as fiber-to-fiber and product-to-product — cannot address the majority of textile waste. True transformation requires **new pathways** that directly address the realities of mixed fiber and contaminated textile waste, that are **inspired by nature's decomposition processes** where waste becomes input for innovative new material cycles. BD-I's work proves that even the "lowest category" of textiles can become safe, biocompatible, high-value materials.
- 2. Technical Feasibility Is Not Enough:** Proof-of-concept is essential, but scaling requires **systems integration, infrastructure investment, market alignment, and cross-sector collaboration**. Technical success alone cannot overcome fragmented funding structures, siloed research programs, or structurally weak regional ecosystems. Policy and investment must shift toward supporting integrated transformation systems, not just individual technologies.
- 3. Regional Circular Bioeconomies are Viable, and Require Coordination:** Brandenburg has the research capacity, industrial partnerships, and material flows to become a **textile transformation hub**. However, realizing this vision depends on synchronizing multiple actors—universities, research institutes, industrial partners, waste collectors, product developers, and public funders. Coordination mechanisms must be strengthened to enable knowledge sharing, infrastructure alignment, and strategic collaboration.
- 4. B2B Waste Streams Offer Strategic Advantage:** Medical workwear, service textiles such as industrial cleaning cloths, and uniforms **provide consistent, traceable, and homogeneous waste streams** that reduce variability and contamination. Starting with B2B models enables faster validation, clearer market narratives (e.g. "medical TexPHB"), and stronger partnerships with institutional end-users. These models can serve as proof points before extending into more complex B2C fast fashion waste.
- 5. Cross-Border Collaboration Is Essential:** Without the Dutch pilot's gasification infrastructure (TNO), BD-I's microalgae pathway would not have reached proof-of-concept. Inter-Pilot and international collaboration accelerates learning, reduces duplication, and enables pathways that individual pilots cannot pursue independently. Design for Transformation is inherently transnational, and its success depends on shared data, resources, and infrastructure.



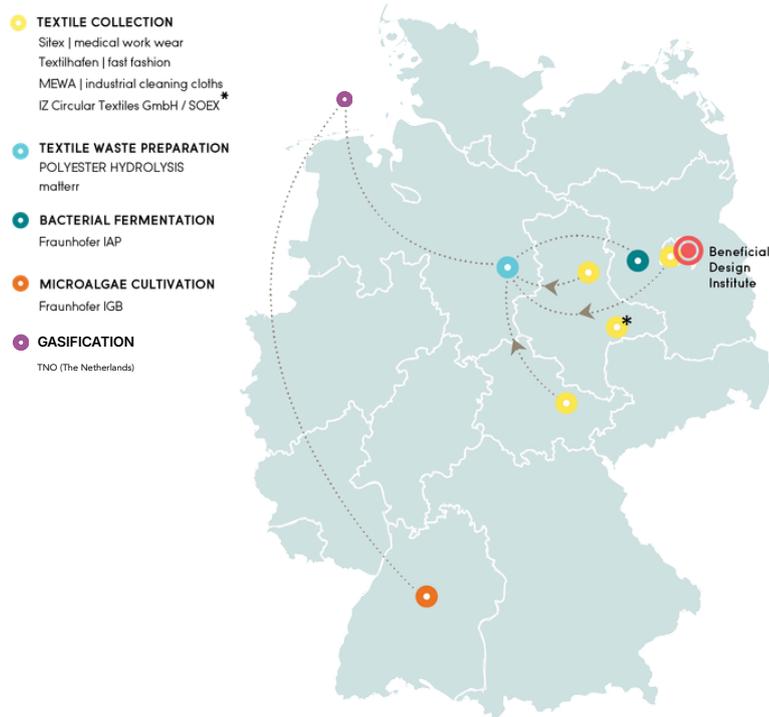
Design for Transformation is inherently transnational and its success depends on shared data, resources, and infrastructure.

Vision

From Waste to Regeneration, From Constraint to Possibility

The Berlin-Brandenburg pilot is more than a technical demonstration, it is a systems prototype for how regions can transform textile waste into regenerative prosperity. It shows that even within fragmented funding landscapes and incomplete infrastructure, innovation can advance when partners align around a shared vision: that waste is not an endpoint, but the beginning of something new.

Regional Transformation Pathway: Beneficial Design Institute



The vision for Brandenburg is clear: a regional textile transformation ecosystem where:

- Mixed, low-value textiles are collected, sorted, and processed locally.
- Polyester-rich fractions are hydrolyzed and fermented into biodegradable polymers for medicine and agriculture.
- Residual fractions are gasified, with syngas feeding microalgae cultivation to produce biomaterials for soil health and regenerative farming.
- Regionally localized biomanufacturing facilities transform these outputs into products that circulate safely within the economy, and eventually return safely to Earth.

This is not a utopian fantasy: **the technical pathway potentials have been validated**; the partnerships are in place; the regional infrastructure is emerging. **What remains is the political will, funding alignment, and systems-level coordination** needed to move from laboratory to landscape, from proof-of-concept to transformation at scale. The Berlin-Brandenburg pilot demonstrates that transformation is possible. The next chapter will determine whether it becomes inevitable.

Closing Reflection

In nature there is no concept of waste.

Every molecule, every fallen leaf, every organism is continuously transformed into new life and positive potential, such as nutrients, available energy, and structure. The fashion industry, by contrast, has built its success on waste: waste as strategy, waste as byproduct, waste as inevitability. The *Nature of Fashion* initiative rejects this paradigm.



Nature of Fashion asks:

What if we designed industrial systems like natural ecosystems, where nothing is discarded, only transformed?

The Berlin-Brandenburg pilot answers that question with evidence, partnership, and possibility. It proves that even the textiles deemed worthless by the linear economy can become the foundation for regeneration. It shows that regional economies can thrive when they learn from nature. And it reminds us that transformation is not about perfecting the circular loop, it's about **rethinking what cycles can be.**

Yet this journey also reveals how much the entire system must change, all the way from how we design, make, use, and return materials, to how we define value itself. It underscores the need for less and better: for textiles made in the right volumes, from biocompatible materials, and with lasting beauty and purpose.

The research demonstrates both the promise and the limits of this approach. There are still waste fractions to manage, residual toxins that could not be eliminated,, and complex processes that demand significant effort. These are learnings and calls for action for the industry to change use of chemicals in the production adapted to nature. But within these challenges lies proof that solutions exist, even at the end of the cycle. Collaboration with algae, bacteria, and the strategies of nature, whether in forests or in bioreactors, shows that transformation is possible when industry begins to think like an ecosystem. Transformation, ultimately, is not about perfecting the circular loop. It is about reimagining what cycles can be, and learning, again, to make for the planet.

Innovation Partners

Beneficial Design Institute

The Beneficial Design Institute GmbH is a design research institute focused on developing sustainable, circular products and systems in fashion and textiles. It researches, develops and tests comprehensive innovation concepts, offers consulting for companies and organizations, and works with a holistic closed-loop approach in the sense of Cradle to Cradle, eco-design and a circular bioeconomy. BD-I focuses on material-oriented product and systems innovation, as well as context- and culture-sensitive implementation strategies that can be applied regionally and globally, always aiming for positive impacts on human health and the environment.



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Systems Design &
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Julie Stamm
PHB Impact Evaluation



Esther Werring
Textile Flow Research



Iris Blackwood
PHB Market Research



Leonie Otto
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Research Assistant

Fraunhofer IAP – Bacterial Fermentation

The Fraunhofer Institute for Applied Polymer Research (IAP) specializes in the development and application of innovative polymers. It supports companies and partners in researching sustainable materials and processes. The focus is on the production and processing of environmentally friendly, economical polymers on a laboratory and pilot scale. Fraunhofer IAP has had the topic of biopolymers from textile waste on its agenda for a year and is aiming to establish a joint consortium for the recycling of cellulose from polycotton.



Jens Balko
Head Technical Center
Biopolymers



Marion Stage
Dipl.-Biochem. Polymer Research



Maren Wandrey
Project Manager
Bioprocess Development

matter GmbH – Polyester Hydrolysis

Matter GmbH (formerly RITTEC 8.0 Umwelttechnik GmbH) specializes in advanced polyester recycling using its innovative depolymerization technology for complex PET-rich waste streams - including mixed polyester textiles - to yield high-quality monomers terephthalic acid and monoethylene glycol. As part of the pilot project, Matter GmbH is contributing its state-of-the-art process expertise to support the conversion of polyester-rich textile waste into valuable monomers for new, biocompatible materials.



Tim Seedorf
Head of Research & Innovation



Mandy Paschetag
Head of the Sustainable Production Technologies Working Group at the Technical University of Braunschweig

Fraunhofer IGB – Microalgae Cultivation

The Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB) develops interdisciplinary solutions in the fields of biotechnology and process engineering. Its portfolio includes the cultivation of microorganisms and algae, process optimization, and resource-efficient bio-manufacturing. As part of the pilot project, Fraunhofer IGB is using synthesis gas from textile gasification to cultivate beta-glucan via microalgae systems, thereby opening up new possibilities for agricultural and bio-based applications.

The research at Fraunhofer IGB was performed by Konstantin Frick and Tobias Ebbing, who have since left the institute.



Dr. Susanne Zibek
Group Manager
Bioprocess Engineering

EPEA GmbH

EPEA GmbH, founded by Prof. Dr. Michael Braungart - co-creator of the Cradle to Cradle® design concept - is an international innovation partner for environmentally compatible products, processes, and systems. EPEA advances Cradle to Cradle® as a method for circular economy transformation across industries - from the molecular to the modular level, from material chemistry to urban development.



Prof. Michael Braungart
Cradle to Cradle Design
Philosophy

Regenerate Fashion

Regenerate Fashion LLC is a sustainability consultancy that works with fashion companies and textile producers as well as textile industry associations and international development agencies globally. We focus on advancing sustainable practices in the fashion industry. We provide strategic advisory, research analysis and capacity development on circular economy practices, alternative fibres, recycling technologies, sustainable product design and just transition



Larissa Roviezzo
Managing Director



Nadja Gegner
Research Recycling
Technologies & Markets

Textile Service & Collection Partners

As part of the project, we examined three different textile waste streams in the lowest waste category. Industry partners provided significant support for the feasibility and potential analysis with their expertise and the necessary used and sorted test materials:

MEWA Textil-Service SE & Co. Management OHG

Textile service company offering a full service for workwear and cleaning cloths on the European market.



Dr.-Ing. Diana Wolf
R&D Technology,
Association Work
BU Production & Logistics



Nicole Kiefer
Trendscout ecological
Sustainability

Sitex – Textile Dienstleistungen Simeonsbetriebe GmbH

Textile service company specialising in workwear and service textiles for use in medical facilities.



Moritz Schäpsmeier
Corporate Communications

Textilhafen part of Komm & Sieh gGmbH

A non-profit inclusion enterprise of the Berlin City Mission. Its work focuses on the clothing bank for homeless people and regional textile cycles in its own second-hand shops and at the Textilhafen, where around 8 tonnes of donations are sorted by hand every week to support the reuse of textiles and social projects.



Beatrix Landsbek
Head of Textilhafen

Project and Narrative Partner

Biomimicry Institute

The Biomimicry Institute is a nonprofit dedicated to making nature's solutions accessible to those working to solve our greatest design challenges. The Institute launched the *Nature of Fashion: Design for Transformation* initiative to apply nature's genius to one of the world's most resource-intensive industries, advancing decomposition as a vital and underutilized strategy for true circularity in fashion, textiles and waste management industry.



Asha Singhal
Director, *Nature of Fashion*



Jen Fredette
Communications Manager



Amanda Sturgeon
CEO, Biomimicry Institute



Miranda Berger
Head of Development and
Communications



Anna Konstantinova
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Andrew Meador
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Carla Delgado
Graphic Design by Page 33
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Conductor & Circularity
Strategist



Lauren Bright
Collaborative Projects
Architect & Technical Expert



Claudia Richardson
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Endnotes

1. 92 million tons of textile waste annually (global): Earth.Org. (2024). 10 concerning fast fashion waste statistics. <https://earth.org/statistics-about-fast-fashion-waste/>
2. The Guardian. (2024). 'It's the industry's dirty secret': Why fashion's oversupply problem is an environmental disaster. <https://www.theguardian.com/fashion/2024/jan/18/its-the-industrys-dirty-secret-why-fashions-oversupply-problem-is-an-environmental-disaster>
3. Carbon Responsible. (2025). *Redefining fashion's footprint: Impact in focus*. <https://carbonresponsible.com/fashion-report/>
4. Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection. (2025). Clothing and textiles. In National Circular Economy Strategy (NCES). <https://www.kreislaufwirtschaft-deutschland.de/en/the-national-circular-economy-strategy-nces/action-areas/clothing-and-textiles>
5. European Environment Agency. (2025). Share of textile waste sent to incineration or landfill in the EU. <https://www.eea.europa.eu/en/circularity/sectoral-modules/textiles/share-of-textile-waste-sent-to-incineration-or-landfill-in-the-eu>
6. Hwafune. (2025). Mono-material textiles in circular design and regulatory compliance. <https://www.hwafune.com/news/8/114>
7. Boston Consulting Group. (2025). Spinning textile waste into value. <https://www.bcg.com/publications/2025/spinning-textile-waste-into-value>
8. Circle Economy. (2024). Textiles. Circularity-Gap.world. <https://www.circularity-gap.world/textiles>

Glossary

B2B (Business-to-Business): Commercial transactions or waste streams originating from business operations rather than individual consumers. In this context, refers to textile waste such as medical workwear, industrial cleaning cloths, and uniforms that offer more consistency and traceability than post-consumer (B2C) fashion waste.

B2C (Business-to-Consumer): Transactions or waste streams originating from individual consumers, such as discarded fast fashion garments. B2C textile waste tends to be more variable, contaminated, and difficult to process than B2B waste.

Bacterial Fermentation: A biological process in which microorganisms (bacteria) metabolize organic substrates to produce desired compounds. In this pilot, bacteria such as *Cupriavidus necator* convert monoethylene glycol (MEG) into polyhydroxybutyrate (PHB).

Beta-Glucan: A polysaccharide (complex carbohydrate) produced by microalgae and other organisms. It has applications in agriculture (as a biostimulant or biofertilizer), food, cosmetics, and biomaterials due to its biocompatibility and functional properties.

Biocompatible Materials: Materials that are non-toxic and safe for biological systems, including humans and ecosystems. They can safely interact with living organisms and decompose without causing harm to the environment.

Bioeconomy: Knowledge-based production and use of biological resources—such as plants, animals, and microorganisms—to provide products, processes, and services across all sectors of a sustainable economic system. Applications include agriculture, forestry, energy, fisheries, aquaculture, chemistry, pharmaceuticals, food, biotechnology, paper, textiles, and environmental protection. The bioeconomy aims to address global challenges like food security, health, resource efficiency, and climate and environmental protection.

Biomimicry: A design approach that draws inspiration from nature's strategies, patterns, and processes to solve human challenges sustainably and in harmony with all life on earth. In this initiative, biomimicry informs how textile waste is broken down and transformed, mirroring natural decomposition cycles.

Bioreactor: A controlled vessel or system in which biological processes (such as bacterial fermentation or microalgae cultivation) occur. Bioreactors optimize conditions like temperature, pH, and nutrient supply to maximize microbial productivity.

Break-Down-to-Build-Up Paradigm: A circular economy model inspired by natural decomposition, where materials are broken down into their molecular components and then reassembled into new, safe, and valuable materials—rather than simply recycling them into the same product type.

Circular Economy: An economic system that aims to eliminate waste by keeping materials in use for as long as possible through reuse, repair, refurbishment, remanufacturing, and recycling. The goal is to create closed-loop systems that reduce resource extraction and environmental harm.

Circular Bioeconomy: An economic model that merges bioeconomy and circular economy principles by keeping biological resources and materials in closed loops - using renewable raw materials, cascading use, and recycling to maximize resource efficiency and reduce fossil dependence.

CO₂ (Carbon Dioxide): A greenhouse gas produced by combustion, respiration, and decomposition. In this pilot, CO₂-rich syngas from textile gasification is used as a carbon source for microalgae cultivation.

Contamination: The presence of unwanted materials, chemicals, dirt, or microorganisms in textile waste that make it unsuitable for conventional recycling processes. Common contaminants include dyes, finishes, oils, mold, and non-textile components like zippers or buttons.

Cotton-Polyester Blends: Textiles made from a mixture of natural (cotton) and synthetic (polyester) fibers. Blended fabrics are common in fashion but are difficult to recycle because current technologies struggle to separate and recover individual fiber types efficiently.

***Cupriavidus necator*:** A commercially available wild strain of bacteria capable of producing polyhydroxybutyrate (PHB) by metabolizing carbon sources such as monoethylene glycol (MEG). It is used in biotechnological applications for biopolymer production.

Enzymatic Hydrolysis: A chemical process that uses enzymes (biological catalysts) to break down complex molecules such as cellulose or polyester into simpler components like glucose or monomers. This process is more selective and environmentally friendly than traditional chemical hydrolysis.

EU Circular Economy Strategy: A European Union policy framework aimed at transforming the EU economy into a circular model, emphasizing resource efficiency, waste reduction, sustainable production, and product design for longevity and recyclability.

Fermentation: A metabolic process in which microorganisms convert organic substrates (e.g. sugars or glycols from textile or agricultural wastes) into products such as biopolymers, alcohols, or acids. In this pilot, fermentation is used to produce PHB from MEG.

Fiber-to-Fiber Recycling: A recycling approach that converts used textiles back into fibers for new textile production. This method requires relatively homogeneous (unmixed) materials and is currently limited to about 1% of global textile waste.

Fraunhofer IAP (Institute for Applied Polymer Research): A German research institute specializing in polymer chemistry, materials science, and biotechnology, focused on polymers (i.e. synthesis, processing, recycling). It is a key partner in developing bacterial fermentation processes for PHB production. Fraunhofer IAP is part of Fraunhofer Society, one of the world's leading organizations for applied research.

Fraunhofer IGB (Institute for Interfacial Engineering and Biotechnology): A German research institute focused on biotechnology, process engineering, and sustainable material systems. It leads the microalgae cultivation pathway using syngas from textile gasification. Fraunhofer IGB is part of Fraunhofer Society, one of the world's leading organizations for applied research.

Gasification: A thermochemical process that converts organic materials (such as textiles) into syngas [a mixture of hydrogen (H₂), carbon monoxide (CO), and carbon dioxide (CO₂)] by heating them in a controlled, low-oxygen environment. Syngas can be used as a chemical feedstock or energy source.

Incineration: A waste management process that completely burns materials to generate energy. While it reduces landfill volume, incineration releases greenhouse gases and destroys materials that could otherwise be recovered and reused.

LCA (Life Cycle Assessment): A methodology for evaluating the environmental impacts of a product, process, or service throughout its entire life cycle, from raw material extraction to production, use, and end-of-life disposal or recycling.

MEG (Monoethylene Glycol): A chemical compound (C₂H₆O₂) produced by hydrolyzing polyester. It is used as a feedstock for bacterial fermentation to produce polyhydroxybutyrate (PHB) and has applications in antifreeze, plastics, and textiles.

Microalgae: Microscopic photosynthetic organisms (algae) that convert carbon dioxide and light into biomass. In this pilot, microalgae are cultivated using CO₂-rich syngas to produce beta-glucan and other valuable compounds.

Mixed Textile Waste: Post-consumer or post-industrial textiles composed of multiple fiber types (e.g., cotton-polyester blends), contaminated materials, or items unsuitable for conventional recycling. This category represents the majority of textile waste globally.

NKWS (National Circular Economy Strategy): Germany's national policy framework for transitioning to a circular economy, emphasizing resource efficiency, waste prevention, high-quality recycling, sustainable production & consumption.

PHA (Polyhydroxyalkanoates): A family of biodegradable biopolymers produced by bacterial fermentation. PHAs are used as alternatives to petroleum-based plastics in packaging, agriculture, and medical applications due to their biocompatibility and environmental safety.

PHB (Polyhydroxybutyrate): A specific type of polyhydroxyalkanoate (PHA) biopolymer that is fully biodegradable, thermoplastically processable, and suitable for applications in medicine, agriculture, and packaging. It is produced by bacterial fermentation of substrates like MEG.

Polyester: A synthetic polymer commonly used in textiles, made primarily from petroleum-based chemicals such as terephthalic acid (TPA) and monoethylene glycol (MEG). Polyester is durable and inexpensive but not biodegradable and difficult to recycle in blended fabrics.

Polyester Hydrolysis: A chemical process that breaks down polyester polymers into their monomer building blocks, monoethylene glycol (MEG) and terephthalic acid (TPA), using heat, pressure, and alkaline or acidic solutions.

Proof-of-Concept: A demonstration that a technology, process, or approach is feasible and can achieve its intended objectives under controlled or laboratory conditions. It precedes pilot-scale and industrial-scale implementation.

Regenerative Design: A design philosophy that goes beyond sustainability (minimizing harm) to actively restore, renew, and revitalize ecosystems, communities, and resources. It aligns industrial systems with natural cycles of regeneration and decomposition.

Regenerative Bioeconomy: A regenerative bioeconomy takes the circular bioeconomy further by aiming to restore, renew, and enhance natural systems. It focuses on increasing ecosystem health, biodiversity, and resilience, generating positive environmental impacts while providing sustainable products and services. In comparison with the term circular bioeconomy, circularity is about efficiency

and waste reduction, while regeneration adds a crucial element of environmental restoration.

matterr technology: revolPET® Process: A proprietary polyester hydrolysis technology developed by matterr GmbH (formerly Rittec 8.0 Umwelttechnik GmbH) that chemically depolymerizes polyester textiles into MEG and TPA for reuse or further processing. See page 15 graphic for reference.

Syngas (Synthesis Gas): A mixture of hydrogen (H₂), carbon monoxide (CO), and carbon dioxide (CO₂) produced by gasification of organic materials. Syngas can be used as a chemical feedstock for producing fuels, chemicals, or biomaterials, or as an energy source.

TPA (Terephthalic Acid): An organic compound (C₈H₆O₄) used as a monomer in the production of polyester. It is recovered during polyester hydrolysis and can be reused in polymer production or other chemical processes.

Textile Waste Hierarchy: A framework for managing textile waste that prioritizes (from most to least preferred): prevention, reuse, repair, refurbishment, remanufacturing, recycling, energy recovery (incineration), and disposal (landfill). The "lowest hierarchy" refers to textiles unsuitable for higher-value recovery pathways.

Thermochemical Process: A category of chemical reactions that use heat to transform materials. Gasification is a thermochemical process that converts textiles into syngas at high temperatures in low-oxygen conditions.

TRL (Technology Readiness Level): A scale (typically 1–9) used to assess the maturity of a technology, from basic research (TRL 1) to full commercial deployment (TRL 9). TRL 4–5 represents laboratory validation, while TRL 6–7 indicates pilot-scale demonstration.

Waste-to-Energy (Incineration): A waste management process that burns materials to generate energy. While it reduces landfill volume, incineration releases greenhouse gases and destroys materials that could otherwise be recovered and reused.

The
Nature
of **Fashion**

Design for Transformation

Thank you for taking the time to read this report. If you have any questions or would like to discuss our findings further, please don't hesitate to reach out to us.

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Laudes ———
— Foundation