DESIGN DIRECTION

Biofabricated Futures

A revolutionary sustainability breakthrough, biofabrication is the engineering of biological products. This report explores its market evolution and future potential in transforming materials to drive commercial success.



Pitch Studios and Bérénice Golmann for Ganni, Global

Introduction

: The Climate Crucible - As the urgency of the climate crisis becomes increasingly undeniable, the stark contrast between our deteriorating environment and the relentless demand for consumer products becomes all the more apparent.

According to the World Economic Forum, global resource use has tripled since 1970 and could double again by 2050 if current trends persist. This is particularly concerning as Forbes **reports** that in 2023, consumers increased their total spending by 5.9%, with many of the factors driving this growth expected to continue into 2024.

This raises a critical question: How can businesses meet consumer demand without further damaging the environment?

: The Paradox of Sustainable Consumption - While **sustainable** materials may seem like the solution, consumers are not adopting these products fast enough to make a significant impact, despite professing to be climate-conscious. This phenomenon of '**contradiction** consumers' is notably prevalent among Generation Z, as underlined in our recent **Generations: Now and Next 2024–2025 report**, in which we highlight the demographic's addiction to fast fashion, despite their intention to shop sustainably.

Numerous theorists, including Dr Daniel Benkendorf of the Fashion Institute of Technology, have explored the reasons behind the discrepancy between people's values and their actions. LS:N Global's original **interview** with Dr Benkendorf revealed that a lack of tangible consequences and the inaccessibility of sustainable options, both in terms of price and availability, contribute to this disconnection. More recently, he **told** LS:N Global: 'There's a bimodal effect happening. The shift is in the right direction, and consumers are more aware than ever. But for the larger share of the worldwide population, even if they were interested in sustainability at some level, it isn't at the top of the list. Fashion companies and individuals concerned about these issues struggle to break through the noise and make it a priority.'



Above and right: The Shitthropocene is a mock anthropological view of humanity's consumption habits. David Byars for Patagonia, Global

Biofabricated Materials

Created using biological processes, often involving living organisms or their components like cells, proteins or DNA. Biofabrication techniques can range from fermentation of micro-organisms to grow materials that replicate leather or silk to genetic engineering to produce novel materials with specific properties.



: Rebranding Nature - Many early and accessible sustainable material explorations, such as Nike's **Air Hobbits**, Osmose's **rustic leather** and Boas Kristjánsson's **fish** skin collection, were characterised by organic, `raw and occasionally even grotesque aesthetics that signalled a close affinity with nature. While these were positive and potentially viable steps forward, they may have unintentionally made sustainability seem less appealing. This created a landscape where sustainability had to work harder than ever to attract consumers.

Today, businesses must strive to make sustainability more relatable and attractive to consumers. Some success has been observed in this area, such as the beauty sector's new era of synthesised branding, re-inventing the concept of sustainability and its visual representation – as explored in our recent **Design Direction**. Conservation and environmental organisations' efforts to **rebrand nature-driven** experiences to engage the next generation have also gained traction, but there is still a way to go with consumer products.

: Biofabricating Success - The emergence of biofabricated materials offers a promising opportunity for businesses in the material field. Produced, cultivated and crafted through biotechnology, these materials exhibit progressive regeneration, scalability and commercial viability.

This is combined with the capacity to emulate the aesthetics of our cherished everyday products while offering opportunities for enhancement in terms of aesthetic quality and performance. This approach brings sustainability to the consumer.

Framework

Our Biofabricated Futures framework demonstrates how businesses in the materials sector can navigate towards a sustainable future that aligns with both operational viability and consumer appeal.

Regeneration

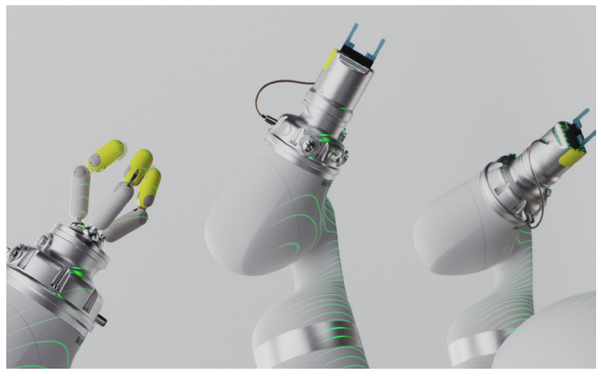
From Reclamation to Regrowth:
The commercial perspective on sustainability is evolving from a static focus on re-using and recycling to a dynamic approach embracing 'regrowing' nature. This uses technology to learn from and collaborate with nature to enhance material innovation, enabling businesses to flourish while minimising harm to the planet.



Pitch Studios and Bérénice Golmann for Ganni, Global

Scalability

From Bio-infancy to Bio-expansion:
Until recently, bio-innovations were in their infancy, hindered by scalability obstacles. But progress towards the Fourth Industrial Revolution, including increased research and investment, advancing technologies and radical collaboration – explored in **Elastic Brands** – is allowing new solutions to emerge, from experimental stages to fully scaled implementations.



N.bio by Phillip Peters, UK

Quality

From Dismissal to Desire:
With technology, brands can now control and enhance the quality of biomaterials – both in terms of performance and aesthetics – leading consumers to perceive these products as equal to or better than traditional materials.



Celium by Polybion, Mexico



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Regeneration

For some time, the focus has been on creating something new from something old, but what about creating something renewed?

Re-using and recycling approaches are sufficiently sustainable; they optimise existing resources. But a forward-looking perspective demands we explore ways to innovate for longevity without environmental compromise. Regrowth emerges as a promising strategy, not only encompassing the literal notion of regrowth – biofabricating or 'growing' materials through technology – but also offering businesses a pathway to sustainable growth, particularly in a landscape contemplating concepts like de-growth and **post-growth**.

In her 2020 **Ted Talk**, Suzanne Lee, director of The BioCouture Research Project and CEO at US-based biotechnology company **Modern Meadow**, discusses biofabrication in relation to the Fourth Industrial Revolution (4IR), an evolution characterised by the 'digitisation of the manufacturing sector', according to **McKinsey and Co**.

In relation to the materials field, this concept embraces tech-powered biomimicry – a practice that draws inspiration from nature's strategies. Lee suggests that: 'The very essence we've sought to marginalise, life, might indeed be our greatest collaborator.' She continues: 'I don't think we have a choice but to biofabricate our future.'

01 Pitch Studios and Bérénice Golmann for Ganni, Global; 02 Echoes of the Earth: Living Archive by Refik Anadol, Switzerland; 03 Designing Rainwater: Harvesting Regenerative Water Systems for Enhancement of Local Resources by MA Biodesign and LVMH, UK; 04 N.Bio by Phillip Peters, UK; 05 Keel Labs, photography by Ryan Duffin, US



NTN's Fall/Winter 2024 collection to be made from Spiber's Brewed Protein, Japan

Toolkit

- **Re-imagine Sustainable Strategies:** Instead of merely replacing, repairing or reclaiming materials, explore the innovative approach of 'regrowing' materials to transform your sustainability efforts
- **Engineer for Endurance:** Distinguish between sustainability and longevity. In the same way that advances in **healthcare extend human lifespans**, use biotechnology to enhance the durability and endurance of your products
- **Harness Nature's Advantage:** Take cues from nature and biology to inspire your designs. Explore biomimetic principles to identify nature's desirable properties and innovate ways to replicate and enhance them

Case Study 1: Spiber

Spiber, a Japanese biotechnology start-up, employs advanced synthetic biology, polymer science and material science to craft its innovative Brewed Protein™ materials from plant-based sugars via microbial fermentation technology. Inspired by spider silk, its fibre exhibits characteristics akin to cashmere and wool. The company tells LS:N Global that it has recently 'developed keystone technologies that replicate the process of protein evolution – which takes millions of years in nature – in the laboratory, where it can be accomplished in a matter of years or even months'

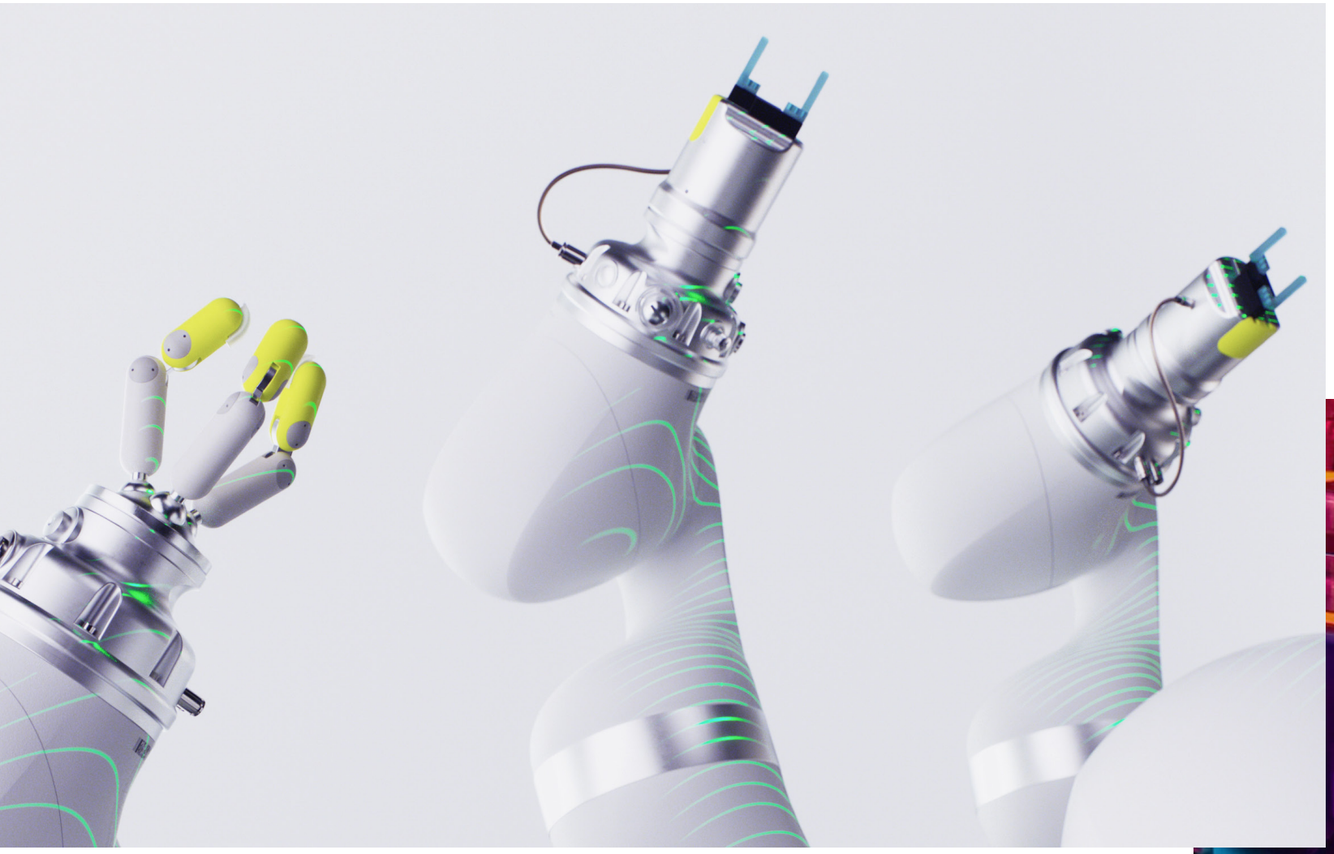
Case Study 2: Pneuma

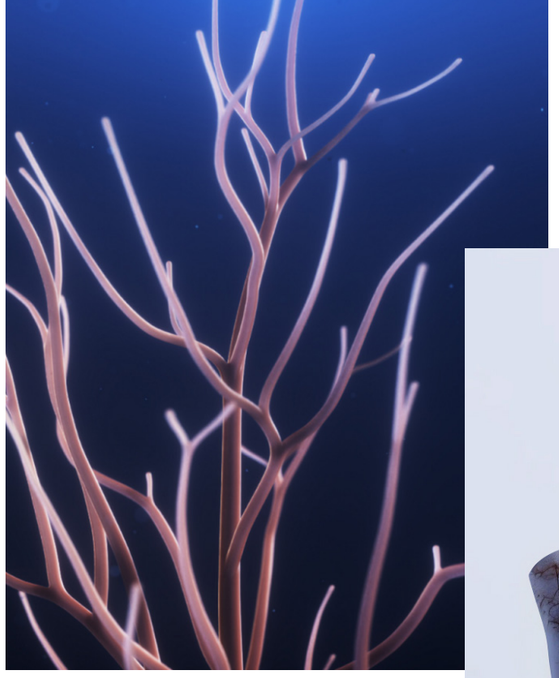
Certain biofabricated materials have unique properties reminiscent of those found exclusively in nature. Pioneering companies like Pneuma specialise in crafting materials infused with living cells that actively engage in photosynthesis, thereby enhancing air quality and mitigating carbon dioxide levels. **Pneuma's** ground-breaking product, OXYA I, represents the inaugural living and breathing textile fibre. The company's 'biomaterials are not just designed to co-exist with nature; they could play an active role in sustaining it', according to its website.

‘It takes time for brands to get familiar with innovation and really trust innovations’

Maurizio Montalti, co-founder, SQIM

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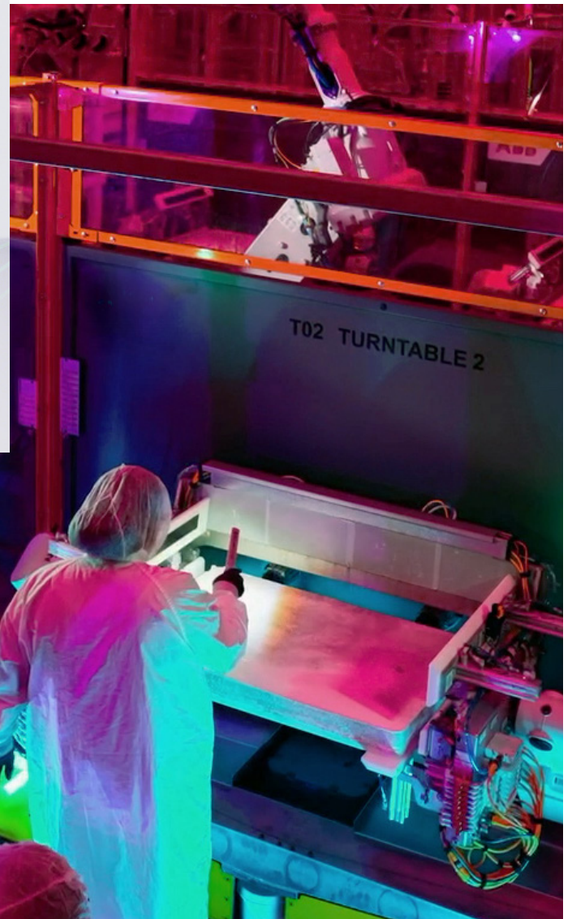


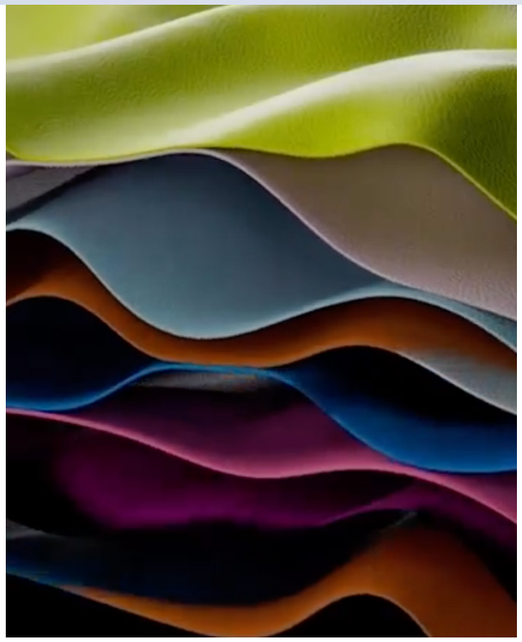


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Scalability

For a long time, bio-innovations were in their infancy. While promising ideas and technologies existed, it was often a struggle to implement them on a large scale or to reach widespread adoption or acceptance.

But, as highlighted at the 10th anniversary of the **Biofabricate Summit** in early 2024, biotech has finally reached a tipping point. The Fourth Industrial Revolution is bringing a new era of connectivity, advanced technologies, and most importantly, interest and acceptance from consumers, businesses and investors. This development is set not only to transform global business but also to contribute to the creation of a sustainable and viable planet for the long term.

01 N.bio by Phillip Peters, UK; 02 Fine Mycelium technology by MyCoWorks, US; 03 AI imagery by The Future Laboratory, UK; 04 Mycoworks, US; 05 Fine Mycelium technology by MycoWorks, US



Hermés partnership with MycoWorks, Global

Toolkit

: **Seize the Opportunity:** In a period marked by **accreditation**, expertise and scientific advances, investments in technologies that facilitate and drive these factors are increasing. Consider what opportunities this will present for your business, especially given the significant influence of the materials sector on the entire consumer product industry

: **Substance Over Spectacle:** Focus on creating a product that maintains its promised qualities over time, such as sustainability and desired properties, rather than solely seeking attention or hype in the short term

: **Consider Symbiosis Strategies:** This can involve sharing knowledge and resources with competitors, strategically seeking investors in high-performing sectors, and breaking down silos between different fields

Case Study 1: Mycoworks

MycoWorks, a California-based biotechnology firm, fabricates leather-like products using a technique involving Fine Mycelium. At the Biofabricate Summit 2024, CEO Matt Scullin detailed how he and his team dedicated years to perfecting an automated process for batch-producing Fine Mycelium. This substantially diminished the reliance on human labour, resulting in a material that is mass-producible and highly customisable. Its facility in South Carolina is the largest biomaterial plant ever established, producing millions of Fine Mycelium sheets annually via 50,000 trays. Scullin says scalability poses the greatest challenge among the three key pillars in making a biofabricated material commercially viable.

Case Study 2: SQIM

SQIM is a mycelium materials producer in Europe comprising Mogu, which specialises in mycelium-based materials for architecture and interior design, and Ephea, which offers a mycelium-based alternative to leather for luxury fashion, design and automotive applications. By pursuing scalability, SQIM has revolutionised the fabrication process, pushing the boundaries of innovation. Co-founder Maurizio Montalti acknowledges the necessity of substantial funding. By strategically targeting the luxury market initially, SQIM can command premium pricing and attract investment. Recent investment by Kering Group enabled SQIM to expand. Having solidified its presence in the luxury market, SQIM now aims to democratise access to its products.

Case study 3: Polybion™

Polybion™ produces high-performance biomaterials like Celium™, a premium cellulose derived from fruit waste. In 2022, Polybion™ launched FOAK I, the first bacterial cellulose production facility, designed to produce 1.1m square feet of Celium™ annually. Its scaling strategy emphasises volume, consistent quality and competitive pricing. Utilising minimal infrastructure and fruit waste, its process uses large-scale fermentation equipment, making it feasible and globally adoptable.

‘We have been living in a transitional time where we are forced to respond to the needs of the previous industry’

Maurizio Montalti, co-founder, SQIM

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Quality

The greatest potential in the future of biofabrication lies in the ability to enhance and control quality.

In the previous decade, sustainable solutions often lacked innovation and dynamism, resulting in rather rudimentary – and unappealing – outcomes, especially aesthetically. ‘We have been living in a transitional time where we are forced to respond to the needs of the previous industry,’ Montalti tells LS:N Global.

With recent developments, we are now entering an era of sophisticated, intelligent and uncompromised sustainable solutions. For resistant consumers, this signifies products that emulate familiar items while boasting elevated aesthetics, exceptional performance and greater relevance to their unique needs.



01 AI imagery by The Future Laboratory, UK; Photography by Ellie Burgin, UK; 03 Celium by Polybion, Mexico; 04 Fine Mycelium technology by MycoWorks, US; 05 Ligne Roset partnership with MycoWorks, photography by Pol Rebaque, US



Bio-VERA™ by Modern Meadow, US

Toolkit

- **Design with Intent:** Use consumer insights and data to develop materials that are purposeful and highly relevant to their aesthetic and performance needs
- **Innovate with Familiarity:** Use the rising interest in **nostalgia** and comfort by utilising these technologies to develop innovative products that evoke familiar items, blending the new with the beloved to resonate deeply with consumers
- **Identify Innovation Gaps in Existing Materials:** Determine what new functionalities and capabilities are needed that current materials have never provided before. See our **Material Far Futures** report to explore 10 paradigms that we believe will disrupt industry in the coming decades

Case Study 1: Modern Meadow

Transforming the luxury market presents one of the most significant and daunting challenges for innovators. Leather remains a cornerstone material in this area, its perceived quality seemingly irreplaceable. In his talk at the Biofabricate Summit 2024, MycoWorks' Matt Scullin echoed the sentiments of paralysed consumers: 'Should I sacrifice the amazing qualities of animal leather for values?'

Modern Meadow is a US-based biotechnology company that uses biofabrication to create sustainable materials. Its latest material, Bio-VERA™, is engineered using the company's Bio-Alloy™ technology, which blends plant-based proteins with bio-based polymers to impart the functionality of proteins. Bio-VERA is designed to deliver a more enhanced look and feel of leather, and is stronger and lighter with more than 90% sustainable content.

Case Study 2: Modern Synthesis

Modern Synthesis is uses the inherent capabilities of microbes alongside cutting-edge biological tools to fabricate a remarkably versatile natural fibre known as nanocellulose. At the heart of its process lies the use of agricultural sugars as a nutrient source for bacteria, which seamlessly transforms these sugars into nanocellulose fibres. Operating at the nanoscale, these fibres exhibit unparalleled strength, boasting a remarkable durability about eight times that of steel, along with innate binding properties. Modern Synthesis's patent-pending methodology uniquely enables the amalgamation of a biofilm with natural textiles, birthing a novel material category. This integrated approach not only fortifies the nanocellulose but also grants brands the flexibility 'to tune the material's look, feel and function'. photosynthesis, thereby enhancing air quality and mitigating carbon dioxide levels. **Pneuma's** ground-breaking product, OXYA I, represents the inaugural living and breathing textile fibre. The company's 'biomaterials are not just designed to co-exist with nature; they could play an active role in sustaining it', according to its website.

Applications

Apparel and accessories

● Ganni – In 2023, Ganni **partnered** with **Polybion** to create a bacterial cellulose-made blazer for the Global Fashion Summit and will launch a commercial line of products made with Celium™ in autumn 2024

● Balenciaga – Balenciaga's **collaboration** with **Gozen** introduced an innovative Maxi Bathrobe Coat made with its LUNAFORM material. LUNAFORM™ employs microbial fermentation of bacteria to yield a cellulosic leather-like sheet material that can be tanned and finished, offering a compelling avenue for sustainable luxury

● Aldanondo y Fdez – Barcelona-based **Aldanondo y Fdez** utilised MycoWorks' **Reishi™** for a new footwear **collection**. The partnership demonstrates the design possibilities of a luxurious new biomaterial for footwear, elevating hand-craftsmanship as well as quality and performance



LUNAFORM™ Maxi Bathrobe Coat by Balenciaga and Gozen, Paris Fashion Week 2023, France

Interiors and furnishings

● Ligne Roset – **Ligne Roset**, renowned for its high-end furniture like the iconic Togo, has revealed plans to secure a substantial share of the production capacity for the luxury biomaterial **Reishi™** from biotech leader MycoWorks' latest full-scale facility

● The North Face – This also extends to automotive interiors. Corde is a **concept** model of the Land Cruiser Prado designed by The North Face and Spiber, and is the world's first vehicle to feature Brewed Protein™ fibres in its interior. The project was exhibited at the Japan Mobility Show 2023

● BASF – Modern Meadow has **partnered** with BASF to revolutionise the material industry by combining its biofabrication expertise with BASF's Ultramid® Ccycled® material. This collaboration helped to create Bio-VERA™, a sustainable and luxurious material integrating post-consumer waste and bio-renewable technologies, powered by Modern Meadow's Bio-Alloy™ technology



Corde by The North Face and Spiber, Japanpiber, Japan

Applications

Construction and building Gets Phygital

● Laura Maria Gonzalez's Biocement – **Laura Maria Gonzalez's** Microbes Make Mountains exhibition highlights how microbial communities can be cultivated to produce biocement, a greener alternative to traditional concrete. Through a series of prototypes and interactive displays, Gonzalez demonstrates the aesthetic and structural possibilities of biocement, advocating its integration into future architectural and design practices

● Tower Bridge Court – FORE, a real estate firm in the UK and Europe, is developing the **Tower Bridge Court** project as a net zero carbon landmark in London, using biocement floor tiles from **BioMason** in collaboration with StoneCycling. BioMason's process involves growing tiles through hydroponics-like technology, where micro-organisms harden the tiles using an aqueous solution, eliminating the need for traditional firing by employing biologically controlled structural cement



Tower Bridge Court, London, UKon, UK

Packaging

At present, packaging accounts for over 40% of total plastic usage (source: **Plastic Oceans**). But Parley for the Oceans founder Cyrill Gutsch **argues** that plastics cannot support a circular economy as they can never be manufactured and recycled without harmful side effects.

Gutsch believes that future packaging should not rely on existing materials but instead be created from new biofabricated solutions.

Making the transition isn't straightforward, especially in low-value sectors. Jessie Wölke of German sustainable beauty brand No Planet B tells LS:N Global that 'all packaging costs have increased, making profitability difficult in the brutal mass market'. SQIM's Montalti adds that scaling mycelium packaging is nearly impossible due to competition with extremely cheap polystyrene.

The solution remains uncertain, but partnerships like those between global chemical company BASF and climate-tech pioneer Modern Meadow offer promise for a bio-revolution.

And for brands in slower-moving industries it could be worth considering that the answer might not lie solely in improving the material of packaging, but also in enhancing the function, and thus the value, of packaging itself. Would consumers pay more for **temperature-determining jars** or **products packaged specifically to optimise their contents**?



Bioplastic Skin by Valdís Steinarsdóttir, Icelandsdóttir, Iceland