WORLD BIO MARKET INSIGHTS

THE BIOECONOMY IN 2025

A collection of over 50 feature-length insights exploring the global bioeconomy in 2025 - from feedstock to market and everything in between.

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How much is the US bioeconomy worth?

We investigate different estimates for its value and how much certain sub-sectors are predicted to grow over the coming years

We kick off the year by assessing how much the US bioeconomy is worth. We investigate different estimates for its value and how much certain sub-sectors are predicted to grow over the coming years. We also dive into why different agencies have put out different valuations of the sector.

How much is the US bioeconomy worth?

Biological materials have always been central to economic activity, whether in the form of food or goods. However, the private sector and governments around the world are increasingly looking to grow the higher-value, R&D-led segments of the bioeconomy as they search for renewable versions of petroleum-based materials.

The US is no exception to this. Market research agencies and government departments are unanimous in forecasting that its bioeconomy as a whole will grow over the next decade. However, estimates differ in how fast it will grow and how much it is worth today.

There are a couple of different estimates out there on the current value of the US bioeconomy. The reason they vary is because they measure different parts of the bioeconomy. As an example, we can look at two of the most recently calculated estimates for the value of the US bioeconomy.

5.1% of GDP, says the National Academies of Sciences

According to Safeguarding the Bioeconomy, a 2020 report from the National Academies of Sciences, Engineering, and Medicine, the US bioeconomy had a value of $959.2 billion in 2016 or 5.1 percent of the US GDP, and is set to steadily increase.

The report worked with an expansive definition of the bioeconomy, using the term to include any economic activity driven by research and innovation in the life sciences and biotechnology. This ranges from agriculture to pharmaceuticals. The study also accounted for investment into biobased research and commercial innovation in the US, stating that this is a vital component of assessing value in a sector that depends so closely on basic research into science and innovation.

Another important feature of the National Academies' methodology was to account for both the direct and indirect economic contributions of the bioeconomy. It concluded that of the $959.2 billion total value of the 2016 US bioeconomy, $402.5 billion came from direct means while the rest came from indirect and induced effects.
Indirect economic effects refer to how one unit produced in the biobased industries has an economic impact on activities in other industries due to interdependencies between them.

Indirect effects are an important part of assessing the bioeconomy's overall value because the sector is not associated with a single product. Rather, the bioeconomy spans a wide array of industries, associated more with the types of raw materials used in them (renewable, of biological origin) rather than what exactly the outputs are.

The USDA estimate

Next, we can look at the USDA's estimate of how much the US bioeconomy was worth in 2021. It said that $489 billion was generated by US biobased products and the biobased industries in that year. The report looks at agriculture and forestry, biobased chemicals, biobased plastics and packaging, biorefining, enzymes, forest products, and textiles.

The USDA figure is lower than the 2016 estimate from the National Academies of Sciences for two reasons. First, the year assessed by the USDA came in the middle of the COVID-19 pandemic when there was a major drop in economic activity.

Second, the National Academies' report included the value of investments into both tangible assets (sequencing machines) as well as intangible assets such as (genomic databases) associated with the sector. The USDA estimate, however, focused on value added to the US economy by biobased products.

These methodological differences become clear to anyone who reads the fine print but can be opaque to the general public. Standardised ways of talking about and measuring the bioeconomy would introduce more clarity into discussions and make it easier for policymakers to support and monitor the sector. The next step would be for countries to decide upon an international standard for bioeconomy valuations.

The value of bioeconomy sub-sectors

Elsewhere, we get more specific estimates for the value of sub-sectors within the bioeconomy. There has been great interest in estimating the value of the processing and industrial sectors of the bioeconomy, the higher-value segments of the bioeconomy also known as the industrial bioeconomy. What this segment excludes are agricultural activities involved in growing and harvesting feedstock for industry.

The industrial bioeconomy specifically adds $210.4 billion to the US economy, according to a report by TEConomy Partners, creating nearly 644, 00 jobs. The report was commissioned by a coalition of manufacturers and trade associations committed to expanding the US Bioeconomy.

The biggest output of the industrial bioeconomy is biofuels. Other products include chemicals used in industrial manufacturing. The term does not include anything destined for biopharma or the food and beverages sectors as these constitute other categories.

The National Institute of Standards and Technology has produced even more granular estimates, breaking the entire higher value industrial bioeconomy into two segments: general biomanufacturing and then the smaller advanced biomanufacturing sector. The latter is estimated at $94.6 billion while biomanufacturing in general is meant to be $438.6 billion.

Advanced biomanufacturing is any industry that produces things by growing biological molecules, or by altering biological materials not with machines but with chemical processes found inside mimic living processes. Precision fermentation is one example, a biomanufacturing method that broadly uses the metabolism of bacteria to cultivate chemicals. Biomanufacturing more broadly might include the production of natural textiles and conventional approaches to producing food ingredients that do not just any metabolic processes.

Forecasts for the US bioplastics market

We can also zoom in on the market value for specific classes of products. For example, we can look at the forecast value for biopolymers.

Biopolymers are a diverse category, ranging across anything from corn-based bioplastics to home-compostable algae cups. They cut

across the two categories studied in the National Institute of Standards and Technology's report since a biomaterial could be a bio-product made through advanced biomanufacturing processes or with more conventional, mechanical methods.

Grand View Research says that the US bioplastics market was worth $3.07 billion in 2023 and is expected to grow at a CAGR rate of 19.3% between then and 2030. This is compared to the much slower growth rate it forecasts for the US plastics market, at 3.5%.

While packaging holds the largest share of total US bioplastics revenue, the company forecasts that bioplastics destined for automotive and transport components are likely to exhibit the fastest revenue growth between 2024 and 2030.

The highest-value biobased materials of all are used to make biomedical implants. Although by volume a smaller market than the industrial biomaterials, Grand View Research expects the US market in medical biomaterials to grow at a CAGR rate of 14.8% from 2024 to 2030.

Algae bioplastics: an emerging niche

We can zoom in further to look at a biomaterial niche: the algae bioplastics market. Algae is a next-gen biomaterials feedstock and materials made from it are currently in the early stages of scaling.

Future Market Insights forecasts that the algae-based bioplastics market in the US will grow at a CAGR rate of 2.7% through to 2034. Yet if algal bioplastics are to grow, the entire algae supply chain will have to grow with it. This is because right now, there is still too little cheap cultivated seaweed in Western countries to feed entire industrial supply chains.

To stimulate investment into algae farms, there must be strong demand for the feedstock from multiple industries. Data Bridge Market Research believes that the whole microalgae market in North America would be over $721 million, a 6.60% CAGR increase from 2023. Meanwhile the company forecasts the entire algal products market – including food, supplement, and pharma applications – will grow 6.6% between 2022 and 2030.

Driving factors

Bullish forecasts for the US bioeconomy are partly based on actions by the Biden administration to invest in and expand the bioeconomy, from agricultural supply chains to higher-value industries.

One of these policy actions was the Bioeconomy Research and Development Act as part of the CHIPS and Science Act. There was also the 2022 Executive Order 14081, a whole-of-government approach to advancing biotech and biomanufacturing across agriculture and multiple industries.

China's efforts to become a world leader in industrial and medical biotech is likely to become another spur to the US bioeconomy over the coming decade. Chinese capacity in biobased fuels, chemicals, and plastics has grown while the country is also investing in novel proteins while China is quickly catching up with Europe and the US on biotech patents. These dynamics mean that industrial biomaterials is fast becoming yet another arena of competition between the two economic superpowers, promising sustained investment into US R&D and scaling.

JANUARY 15, 2025

Glowing textiles, fungi lamps: the world of biobased luxury

We look at the makers experimenting with natural materials for style-conscious markets that insist on aesthetic value along with sustainability and performance

Scaling is the name of the game in today's bioeconomy. Yet functionality and cost efficiency are not the only things biomaterials offer.

Renewable materials are also opening up new possibilities in luxury design. We look at the makers experimenting with natural materials for style-conscious markets that insist on aesthetic value along with sustainability and performance.

Nature Squared

The most innovative biomaterials producers enhance simple biological feedstocks using processing techniques that create something not-quite-natural but perfectly fit for function. This is the case with Nature Squared, the last word in the biobased luxury market.

Founded in 2000 by Paul Hoeve and Lay Koon Tan, the company has eclectic material tastes. Nature Squared's raw material portfolio is a raucous mix of shapes and textures ranging from the relatively familiar, such as rattan, to the exotic (at least for Western consumers), such as ostrich egg.

With a tagline of 'transforming waste into luxury', the company scours the world for renewable byproducts that might be used for luxury interior and craft applications. Many of the raw materials Nature Squared uses couples durability and renewability with beguiling colours and textures, including grasses, seeds, bark, shells, and feathers from all over the world.

Nature Squared's sales pitch is that it improves on both nature and traditional crafts, combining artisanal techniques with European technologies and tools. Turning natural raw materials, often waste, into high-quality bespoke interior items requires a large-scale technical effort and the company's R&D process happens across Barcelona, London, Hong Kong and Cebu, involving teams of artisans, engineers and chemists.

Building with eggshells

Nature Squared's riff on egg inlay, an East Asian craft, neatly embodies its waste-to-luxury ethic. Borrowing heavily from artisanal inlay work, Nature Squared developed a new process for turning waste shells into a multi-faceted design and construction material.

Turning waste eggshells into luxury material is a careful process. The materials are collected from businesses across Asia, such as bakeries. Nature Squared then meticulously cleans the shells, sorting them into sizes for use in different designs.

Once clean and prepared, there are two main routes for the eggshells. In one, the shells can be ground down to very specific sizes.Once mixed with other ingredients, the shells can be cast, for example, to form tiles. The second route turns the shells into a decorative embellishment. In one design, eggs can be shattered in precise ways to convincingly replicate the pattern of snakeskin.

Nature Squared says it is as committed to supply chain ethics as it is to sustainability. It is certified both to ISO 14001 and ISO 45001, the international standards for determining environmental impact and for occupational health and safety management systems.

Sustainable colour

Biobased luxury needs sustainable sources of colour. The development of biobased dyes is all the rage in the sustainable materials space and Bristol's Botanical Inks, founded by Babs Behan, is a well-established specialist.

In a world dominated by commodity production, the luxury sector hangs on its ability to offer products unique to a particular time and place. This aligns with founder Babs Behan's philosophy, which is that her dyes and inks should express its unique 'bio-region' in the South West of England.

What Behan's emphasis on bio-regionality means in practice is that the raw materials for her pigments are drawn predominantly from the local area, cutting down air miles and making for a product embedded in a unique soil and climate. Feedstock for the dyes are nearby plant materials grown without harmful synthetic chemicals. Organic garden produce and recycled food and farm waste also feature. The bio-regional ethos extends to the textiles that the company applies its dyes to, including wool from the Mendips and cashmere from a holistic Devon farm.

The company offers small and large-scale dying services for designers and brands. However, Botanical Inks' stringent 'soil-to-soil' approach means they are highly selective when it comes to choosing client projects. It only works with materials that use 100% natural fibres cultivated and processed without harmful synthetics, regardless of client preferences.

Any material it dyes also has to have been sourced as locally as possible, whether from Britain itself or from the continent. Alternatively, it is open to working with locally produced recycled fabrics. By imposing this strict set of criteria on client work, Botanical Inks is attempting to leverage change through the whole textile supply chain.

These exacting standards are not putting off clients, however, with many big names in British design having worked with Botanical Inks, including the Saatchi Gallery, the Tate, Jo Malone, V&A, and more.

"In a world dominated by commodity production, the luxury sector hangs on its ability to offer products unique to a particular time and place."

Colouring with nanostructures

Fashion is delving deep into the possibilities of natural materials to achieve entirely novel kinds of textile colour. Structural Colour Studio's paradigmatic idea that material nanostructures rather than pigments

can colour the clothes of the future could drive a sea-change in the way we approach luxury construction.

The brainchild of designer Noora Yau, fashion designer Anna Semi, and scientist Konrad Klockars, Structural Colour Studio has been developing what it calls 'Shimmering Wood Crystals', precision-printed wood crystals whose physical structure scatters light in particular ways that force the human eyes to see specific colours. This gets rid of the need to use toxic mineral pigments and even pigments altogether to achieve colour and sheen, opening new design avenues in biobased luxury.

Natural luxury

A growing part of the biobased luxury world specialises in turning hemp fibre into all manner of interior objects. Among them are Foersom & Hiort-Lorenzen, household names in the world of Scandinavian design.

In 2024, their collaboration with Danish furniture brand Normann Copenhagen launched a hemp-based chair range that takes classic modernist furnishing and upgrades it for a more environmentally conscious client.

Their 'Mat' chair range consists of a simple, curved seat crafted from a special composite made from hemp fibre and dried eelgrass composite. The biobased mix is made through a process of shredding, milling, and compression. According to Foersom & Hiort-Lorenzen, the material was 20 years in the making.

Then there is Materials Assemble, pioneering a semi-industrial process to make custom furniture from hemp. Their material is unique because it consists of 90% hemp bound with mycelium, the branched vegetative body of fungi. The resulting material is eminently pliable, meaning that it offers a strong alternative to oil-based furnishing materials such as EPS, EPP, or polyurethane foams.

Brands and designers are increasingly interested in mycelium and fungi for their binding ability: their ability to smother filler materials and solidify into any shape. Just like Materials Assemble, designer Sebastian Cox has discovered that mycelium is a high-performing 'medium' that can solidify around low value materials like wood waste and give them new life. In his MYCELIUM+TIMBER collection, he infused scrap willow wood with fungal strains, forming them into stools and lamp shades.

Similarly, fifth-generation luxury furniture maker Ligne Roset has also been exploring the uses of mycelium, incorporating fungal leather made by MycoWorks into their furniture design.

The most successful biobased luxury design companies, including in the mycelium space, are those leaning into the unique physical properties afforded by natural material and making a product that would be difficult to make using fossil inputs. The luxury fungi leather space today is dominated by the brand Ephea, which sells its soft mycelium leather replicas not as an animal leather replacement but 'a set of products setting a new standard' in material design.

Biobased embellishments

Decorative elements in fashion have a bad rep for sustainability. Sequin and glitter made from oil are a known environmental pollutant. Non-recyclable beads end up in landfills. Yet consumers and designers alike are still mesmerised by the colours and shimmering effects that oil-

based synthetics offer.

Now, biobased embellishments could give luxury fashion designers alternatives. Chief among them is Cellsense, a company set up by New York-based designer Aradhita Parasrampuria in 2022. It specialises in making beautiful objects from natural ingredients, primarily cellulose and algae.

The company's most remarkable product is its bioluminescent algae-cellulose bead that can be woven into textiles for outfits that quite literally light up a room. Cellsense's innovation is a masterclass in how natural materials can not just offer a less polluting product but can also expand creative choices in ways that fossil chemicals cannot.

Following Cellsense's lead, more luxury fashion designers could turn to the magic of synbio in order to push against design boundaries. This fusion between apparel and synbio is likelier today given the growing backlash against fossil-based fast fashion among certain markets.

Although historically one of the worst contributors to the climate crisis, the clothing sector could become an ideal incubator for new biomaterials. With a consumer base that thirsts for aesthetic novelty while increasingly baulking at the industry's impacts, the ideas being hatched today in the luxury sector could drive material innovations and cultural shifts that help lighten fashion's load.

JANUARY 22, 2025

The shape-shifting biomaterials that make buildings move

What if the materials we wore and built with could shape-shift? Responsive materials are already here thanks to new research and they could soon be hitting the market

What if the materials we wore and built with could shape-shift? Responsive materials are already here thanks to new research and they could soon be hitting the market.

Shape-shifting constructions

One of the amazing things about plants is their ability to change shape in response to environmental stimuli such as light and moisture, even without a brain or central nervous system.

Now, a new generation of biomaterials is similarly able to respond to environmental cues. Importantly, these materials are sensitive to changes happening around them because of their molecular structure alone, not aided by an external power source or a digitally programmed set of instructions.

Construction is a promising application for this type of biomaterial. German researchers published a paper last year on weather-responsive building shades that could keep the sun out or the heat in through subtle material shifts.

The research, which resulted from collaboration between the University of Freiburg and the University of Stuttgart, started off with cellulose – a material found in plants that changes size in line with humidity levels around it. They used a 3D printer to shape cellulose fibres until they closely resembled the structure of cellulose within living plants.

The result was an engineered biomaterial that unfurls under high humidity, creating an umbrella-like shading, then contracts in low humidity to let in heat and light. Some refer to this as 'passively responsive bioclimatic architecture': an architecture that responds to environmental cues of its own accord. The team has demonstrated the technology by installing it at a research building at the University of Freiburg.

In terms of borrowing from nature, this adaptive material ticks all the boxes. First, it is made from plant raw materials. Cellulose is an abundant natural material found in the cell walls of plants, fruits, leaves, and vegetables. Second, the cellulose is processed in ways that are inspired by the makeup of biological organisms. In short, it is both a biomaterial (made from biological stuff) and a bio-inspired material (designed based on biological mechanisms).

Building with weather-responsive biomaterials could be useful for adapting our built environment to the extreme impacts of climate change. However, materials like this can also help limit global warming if more widely adopted by the building industry.

Right now, major construction materials such as concrete or steel are huge contributors to global carbon emissions. Using responsive biomaterials in building work alongside carbon-intensive mineral-based materials would cut the impacts on the building industry, particularly as these materials can switch between multiple functions without needing any additional energy.

Sustainable simplicity

In general, the simplicity of biomaterials gives it an edge when it comes to building climate-responsive structures.

Conventional 'smart buildings' rely on complex networks of sensors and computer systems that allow them to become sensitive to the

environment. These technologically intensive projects present a number of practical issues since motor-controlled mechanical parts and intricate moving mechanisms can make for frequent technical failures and high maintenance costs.

Relying on the natural responsiveness of modified biomaterials is a potentially much lower-cost way to make buildings more climate-resilient, cutting down the number of moving parts involved. As Professor Achim Menges from the University of Stuttgart described it, "The biomaterial structure itself is the machine."

Guided curvature

Other researchers are leaning into low-tech routes for creating weather-responsive architectural biomaterials. University of Wellington researchers have developed a way to capitalise on the bending properties of commercially available plywood.

Unlike the Stuttgart team, this team did not make a responsive biomaterial by altering microscopic structures. They chose to work instead on the visible scale, cutting and shaping the wood in ways that would influence their movement and behaviour in an overall architectural structure.

The researchers iteratively developed plywood tiles, producing various shapes and sizes. These were in effect puzzle pieces that would eventually slot together to form a curved architectural structure.

Each wooden tile is laser-cut with very deliberate grooves. The combination of tile shape and tile groove patterns, the researchers surmised, would determine how the overall structure would be able to expand and contract in response to dryness or humidity.

They demonstrated their material on the beaches of Rio de Janeiro, using it to build an amphitheatre that drastically changed shape in response to temperature throughout the day. In the moisture, cooler mornings, the amphitheatre roof was tightly curled in, forming a closed canopy. Then, its tip would slowly stretch outwards to form an open shade as the beach became drier during the day.

"Relying on the natural responsiveness of modified biomaterials is a potentially much lower-cost way to make buildings more climate-resilient, cutting down the number of moving parts involved"

These contracting and expanding movements were guided by the specific ways that the shaped wooden tiles sat together as well as by the grooved shapes bored into their surfaces.

The advantage of this approach is its simplicity: using readily available tools and commercially abundant plywood, the researchers were able to mock up a structure that responded to environmental conditions in controlled and reversible ways.

Liquid crystal adaptations

Textiles are another application for these responsive materials. MIT scientists have developed FibeRobo, a fibre that contracts when hot and opens up when it's cold.

This type of material takes a cue from natural mechanisms. Scientists call this type of response in biology 'actuation' – an example would be the way a pine tree cone responds to surrounding humidity by opening its flaps to release seeds. The air humidity is swelling up layers within the cone.

Just as in architectural applications, the big plus of this responsive material is that there is no need for complicated sensors or hardware embedded into the material: in FiebRobo as in the pinecone, all the mechanisms are there within the fibres. This means that any textile manufacturer can work with a material, which is compatible with existing machinery and manufacturing processes. It is also a more appealing consumer package, eliminating the need for bulky gadgets woven into their clothing.

The fibre used here is an example of a liquid crystal elastomer whose properties change under different conditions. The LCE developed by the MIT team have molecules that become dislodged from their usually orderly crystal arrangements under higher temperatures, making the material contract to keep in heat.

The exact temperatures at which the material changes can be adjusted depending on how the LCE is synthesised. This property was crucial in allowing for its use in textile applications since some LCEs are only sensitive to extreme temperatures.

Biobased LCEs

Right now, the chemicals used to synthesise the LCE textile from MIT are not biobased, although these researchers eventually want to develop recyclable or biodegradable versions.

In Europe, however, a research programme called ALCEMIST will be dedicated to developing biobased liquid crystal elastomers from polysaccharides. Starting in 205, the European Research Council-funded project also prioritised industrial scalability. One of the applications they are exploring is autonomously adjusting 'kinetic buildings' like the ones envisaged by the Stuttgart researchers with their responsive building facades.

Another less obvious area of application for biobased LCEs is a reversible glue that is strong to hold while products are used but can easily be 'switched off' once it comes to end-of-life disassembly and recycling.

Enhancing wood

Wood is one of the most traditional biomaterials but today, companies

are looking to bring it into new applications, including as a substitute for silicate glass. What's more, certain kinds of engineered wood can take on new properties that are not found in nature, including responsiveness to heat and light.

The obstacle in the way of using wood for construction is its natural tendency to swell or degrade – also known as its hygroscopicity. To overcome these barriers, researchers have gone down a number of routes, including modifying wood surface behaviour using a polymer called PNIPAM (poly(N-isopropylacrylamide)).

When treated with PNIPAM, materials become able to reversibly change from hydrophilic to hydrophobic depending on the surrounding temperatures. This is important in preventing wood swelling, which happens when wood cells absorb moisture from the surrounding environment.

Researchers are also working on creating a low-cost, light-responsive and transparent wood that could replace silicate glass as window material. This is another climate-ready application of responsive biomaterials in building design: wood is more insulating than glass and so could reduce energy consumption in buildings.

In 2022, Chinese scientists published a way to modify wood with a substance called AG-80/DDM epoxy resin. When the wood is dipped in the substance, it begins to change colour in response to light. The resin imparts other properties to the wood too including pH-responsiveness, fluorescence, and weather resistance.

Responsive biomaterials can take on multiple functions and properties depending on different environmental conditions. Their ability to shift into new forms and back again can support sustainable design by cutting the need for carbon-intensive resources. Responsive architecture becomes possible without the use of metal, mineral, and energy-intensive computational hardware.

JANUARY 29, 2025

Trump's first week and its impact on the bioeconomy

The second Trump administration has burst onto the scene with a flurry of new policies

The second Trump administration has burst onto the scene with a flurry of new policies. We look at the first bioeconomy-related policies to emerge and how they may impact the biobased industries.

US exits Paris Agreement again

As expected, the Trump administration wasted no time in withdrawing the US from the Paris Agreement climate deal once again.

This doesn't affect the biobased industries directly, since belonging to the agreement did not oblige the US to hit emissions reduction goals.

However, the move does reinforce the basic policy priorities of the new administration: economic growth through fossil production, regardless of greenhouse gas emissions or other environmental factors.

Are biofuels subsidies at risk?

More directly consequential for the bioeconomy are possible changes to Biden's 2022 Inflation Reduction Act (IRA).

Trump and many Republicans have been heavily critical of the IRA's subsidies for clean energy. The Trump administration has already frozen IRA spending on the wind and EV industries. This week, Texas Republican representative Beth Van Duyne introduced a bill to repeal the biofuel-relevant sections of the act.

Biofuel producers will be watching Republican policies particularly closely over the coming months. They, much more than biochemicals or bioplastics producers, depend on government incentives, meaning they have more to lose from potential rule changes.

Biofuels and biomass suppliers were key beneficiaries of Biden's which supported biofuels expansion through two key provisions. One of these is section 45Q, which provides tax credits for biofuel producers that achieve carbon sequestration and carbon capture, utilisation, and storage deployment. For the last two years, industry players have planned their strategy and investments around this support.

45Z is the other IRA tax credit relevant to the biofuels industry. It promised a clean fuel tax credit for eligible producers starting in January 2025.

Cutbacks to either provision would lower biofuels' capacity growth outlook over the next few years compared to the scenario where they remain in place. The impacts would hit companies all along the supply chain, from farmers that provide the feedstock to the processors that create car and aviation fuels from the biomass.

Buffer factors: Republicans could ringfence biofuels

Despite the risks, biofuel tax credits could escape the worst of Republican clean energy cuts.

There are several factors that should buffer biofuels and biomass production against the most extreme policy moves to eliminate all Biden-era credits.

First, biofuels have also been less caught up in the US culture wars around environment and decarbonisation than other forms of renewable energy such as wind, solar and EVs.

Trump's political credibility certainly rests on removing what it calls

market-distorting subsidies to the EV and wind sectors, having made his hostility to the EVs and wind industries clear throughout his campaign.

Yet Trump's biofuels position is less clear and with biobased industries less visible in Republican rhetoric, there is less political pressure on the party to distance itself. Combined with the fact that significant portions of the Republican rural support base rely on the biofuels industry, it is feasible that his government leaves current subsidies largely untouched.

Second, there is a spectrum of views on clean fuel credits among Republicans: Representative Van Duyne may have moved against 45Z, but some of her party colleagues are not keen on eliminating it.

Representative Van Duyne is from oil-rich Texas. However, four of the top six fuel ethanol producers in the US are Republican strongholds: Iowa, Nebraska, Indiana, and South Dakota. Their representatives are likely to push back against any repeal.

Republicans from biofuel-producing states were already organising to retain the biofuel credit starting from November 2024, right after the election of Trump. Randy Feenstra, a Republican Iowa representative, led Republican colleagues to request stakeholder feedback on the IRA, arguing that Biden's law could be remade to fit the Republican agenda. The group is interested in how to edit the biofuel tax credits policy so it supports more domestic energy production and rural development.

Whether IRA biofuel benefits will remain in a state that can support investment and capacity growth will depend on how effectively the industry and producer states can lobby the new government. To achieve this, they will have to speak with one voice on how the sector can support key administration goals, such as energy security and economic competitiveness.

Why the bioeconomy could support Republican policy

The case of biofuels shows how there is nothing inherently contradictory between the bioeconomy and a Republican vision of a more industrially competitive, self-sufficient, and energy-secure US.

> "Building a bigger bioplastics sector would support the Republican goal of making US industry more globally competitive, especially in relation to China."

Aside from the energy security provided by homegrown biofuel feedstocks like corn, the expansion of biopolymer production would benefit US farming communities. Major biofuel feedstock producers in

the midwest are keen to exploit new higher-value industries for their crops.

In general, agricultural producers see selling into the higher-value biobased processing industries as a way to shore up their income and buffer against the volatility of prices for food commodities. Other farming sectors such as canola, soy, or sugar beets could also sell into new biobased markets.

Building a bigger bioplastics sector would also support the Republican goal of making US industry more globally competitive, especially in relation to China. China and other countries are pulling ahead of the US for biopolymer manufacturing as they diversify beyond petroleum products and strive to meet the growing demand for renewable goods.

Biotech becomes a security priority

Trump's embrace of fossil industry deregulation could slow demand growth for biomaterials geared toward sustainable consumer goods: renewable clothing, packaging, and bioplastics.

However, there is one part of the US economy that could sustain or even increase investments into the most advanced biomaterials through the Trump presidency: the military.

Under Trump, data-driven biotechnology could feasibly become an arena of competition between the US and geopolitical rival China. On January 15, in the very final days of the Biden administration, the Commerce Department proposed new export controls on certain types of advanced biotech research tools.

Biotechnology includes 'industrial biotech' such as biofuels, bioplastics, and biochemicals but also encompasses higher-value products like agricultural biotech, usually involving genetic modification of crops and livestock, and pharmaceutical biotech.

The proposed biotech export controls could clamp down on the export of analysis and measuring equipment used to generate large, detailed biological datasets relating to biological molecules, cells, and organisms. Data platforms for processing biological data are generally associated with higher-value biotech industries, for example, in speeding up the discovery and production of pharmaceuticals.

The measure aims to slow Chinese progress in the most advanced sectors of biological research, such as AI-aided analysis of biological data.

Advanced biomaterials and the data-driven research that underpins them would mesh more easily with Trump's focus on building the US' military edge than the consumer and sustainability-led biomaterials aimed at decarbonisation.

To some extent, the securitisation of biotech could keep R&D money flowing into the most advanced areas of biotech, afloat despite a slowdown in commercial demand for renewable goods.

The security and military interest in biotech could eventually have spillover effects for commercial biobased producers. Just like in pharma, biomaterials producers are looking to use genetic data analysis to speed up their discovery of new biomaterials or new, more cost-effective manufacturing routes, for example.

Continued investment in data-driven biotech driven by military and

economic competition with China could eventually bring down the costs of these tools, making them more widely available.

Tariff backlash would harm US bioplastics

Trump's favoured policy instrument for building up domestic industry is tariffs on imports, not just on China but on historic trade partners and allies like Canada, the EU, and Mexico.

Although he has not imposed any so far, new tariff hikes are expected to come into force soon. Trump himself has threatened a February 1 deadline.

Imports tariffs could harm the US bioeconomy by triggering a general trade war. Countries like Canada and Mexico will likely retaliate with their own tariffs on US goods, which will harm many sections of the bioeconomy. For example, the top buyers of bioplastic made by US manufacturers are Mexico, Canada, and China, all of whom are in Trump's crosshairs.

A narrowing of foreign markets would be a blow to US renewable materials producers. The importance of exports to the US bioplastics industry has been growing, with one estimate stating that 44.6% of industry revenue came from exports in 2022, up from 32.3% in 2017.

It is not just downstream biobased manufacturers that would be vulnerable to rising tensions between the US and traditional economic partners. US primary producers, those working in agriculture and forestry, would be affected by tit-for-tat tariff hikes too, given that US exports considerable biomass feedstock to China and other Asian countries.

It is clear that certain parts of the bioeconomy may face headwinds under a Trump presidency. Yet we should remember that the last explosion in climate tech investment, youth activism, and decarbonisation policy came right after the first Trump presidency.

Whatever the outcome of the next four years, it will be hard to turn back the clock on renewable materials. Once the pendulum swings back, demand and capacity in the US bioeconomy will almost certainly be bigger than they were in 2024.

FEBRUARY 5, 2025

The Danish bio-producer that made it in China

We look at how Novonesis broke into the Chinese market

As Western investments back away from China, Denmark's Novonesis is continuing to build on a three-decade presence there.

With a biochemicals portfolio that aligns with Chinese development priorities, the company's future in the local biotech ecosystem seems secure. We look at how Novonesis broke into the Chinese market.

The global face of Danish biotech

"The time for biosolutions is now," announces the Novonesis website. The Danish company specialises in enzymes, enjoying an almost 50 per cent global market share in this specialist commodity, as well as industrial microorganisms.

Enzymes may be a low-volume product compared to other biomaterials but it is found in almost every industry. Novonesis produces enzymes for use in edible proteins, food ingredients, household care, cleaning, medicine and health, and agricultural inputs.

The company's story began in the 1920s when the Pedersen brothers left their employer Nordisk to form a competitor firm Novo Terapeutisk Laboratorium. Nordisk and Novo merged in 1989 into the behemoth Novo Nordisk. In 1989 Novonesis, known as Novozymes until January 2024, split from the company.

As well as being one of the biggest European enzyme producers, Novonesis is a key example of a truly global company, with subsidiaries in countries across Asia, Europe, and the Americas.

Why China?

As one of the earliest Western biotech firms to set up in China, Novonesis' presence there is a major part of this success. The company currently holds about 2,200 patents and 800 trademarks in China's biotech sector and 1000 employees across six sites in the country. Novonesis opened its latest office in China just in October 2024 in Guangzhou, an exceptional mark of confidence in the market.

Novozymes, as it was then known, had a presence in Beijing since the early 1990s. It was only in 1997 that it finally established a Chinese subsidiary. From there, the company rode the coattails of the country's economic boom, one that reshaped global trade over the next decade.

Novozymes early on also saw China's potential as a booming consumer market for renewables products just as growth, urbanisation, and industrialisation were accelerating there.

"We have developed together with China's opening-up," said Graziela Chaluppe dos Santos Malucelli, a senior vice president at Novozymes in 2018.

The company also selected China for its large and under-utilised biomass resource pool.

Despite intensive urbanisation since then, China still has a huge agricultural and forestry sector and its byproducts from these sectors are among the biggest in the world.

In the late 2000s, Novonesis expanded its presence in the country by participating in collaborative projects with local firms.

Novonesis initially saw great potential in China's cellulosic biofuels market. In the late 2000s, it linked up with China Resources Alcohol

Corporation to collaborate on R&D.

This state-owned company offered Novonesis benefits such as its connections with research centres around the country. A key benefit of breaking into the Chinese biochemicals ecosystem was access to a strong pool of highly trained scientists at a lower cost than in Europe.

Partnering with local firms remains part of the company's strategic blueprint for other emerging markets along the biofuels and biochemicals supply chain such as Brazil and India.

> "The biochemicals producer is shaping up to play a key role within the Chinese government's new economic development strategy centering around 'high quality industry'"

Meeting China's needs

Novonesis basic business mission in China remains effectively the same as it did when it started there: to develop ways of turning low-value local agricultural waste into high value materials using proprietary processes.

Novoensis' strategy in China from the start has been to finely tune its product range to local market needs – in short, this means serving the development priorities of the Chinese government.

An overarching preoccupation in the Chinese Communist Party almost since its founding has been resource security and reducing import dependence for key goods. Novonesis slots neatly into the Chinese government's continued push to maximise domestic resources. A large biochemicals industry can mop up huge amounts of agricultural byproduct, displacing the need for costly imports in oil or other raw materials.

The biochemicals producer is shaping up to play a key role within the Chinese government's new economic development strategy centering around 'high quality industry'. If China made its name as the factory of the world for cheap goods in the 2000s, it now wants to build out more advanced manufacturing capabilities focused on higher-value industries: among them, biotech and biomanufacturing.

Apart from China's ambition to dominate in emerging industries such as biotech, Novonesis products are also attractive for a state now aiming to ease its dependence on food imports.

Novonesis launched its feed enzymes range Ronozyme in China in

2021, showcasing it at the China International Import Expo. China's livestock sector is currently looking for ways to cut imports in soybeans for animal feed. If company claims for the product are to be believed, Ronozymes could cut feed demand by improving metabolic efficiency in livestock.

The growth of the biobased industry could also meet another policy concern in China – industrial pollution. China's momentous growth over the last two decades has taken a toll on the environment. Waste is now posing huge concerns for public health.

Novonesis has already offered microbial wastewater treatment solutions in factories in Ningxia, Shanxi, Xinjiang and Inner Mongolia to meet both wastewater compliance laws and increasing water availability in the region.

First mover advantage

Novonesis' longstanding presence in China gives it an advantage now as the business world navigates new geopolitical tensions and competitive rivalries.

After the pandemic, some European chemicals companies have started investing in modern plants in China as rising production costs in their home region push them out. With a solid presence over three decades and its now-close ties to the Chinese government, Novonesis has an advantage over these newcomers.

Yet for certain Western chemicals producers, Novonesis' experience in Chinese industry could give them a leg-up in the new market. Novonesis produces PET-recycling enzymes for Carbios, a French biochemicals company. Their partnership could facilitate a possible tie-up between Carbios and Zhink Group to roll out a biobased recycling plant for PET waste in China.

Over the decades, Novonesis has cultivated an effective working relationship with the Chinese government. This relationship has mutual benefits, with Novonesis now a poster-child for the Chinese government as it attempts to show the world it offers a level playing field for foreign businesses that choose to operate there.

In 2017, China's Supreme People's Court ruled in favour of Novonesis and against Chinese rivals accused of infringing one of its enzyme patents. As well as being a landmark ruling for the firm it was a win for the Chinese government too, keen to show its intellectual property laws are upheld impartially, even for the Western innovators.

Nonetheless, compared to the US and Europe, Chinese law still has weaker protection for some biotech patents. Intellectual property is an area Novonesis has tactfully prodded the central government to improve, stating recently that it remains 'optimistic' its protection standards will fall in line with other major markets.

Novonesis has taken a diplomatic approach to the Chinese government on IP as it pushes to become a leading partner in delivering 'high-quality industry' for the state. For a Western firm, this approach has given it a position of relative influence within the country. In 2024 CEO Ester Baiget said that the company was collaborating with the Chinese Communist Party (CCP) to eliminate regulatory bottlenecks to achieve growth in domestic green transition industries.

Today

Novonesis' early expansion in China was reflective of the early 2000s global moment: China had opened its doors to growth, investment, and trade. Western governments and companies were keen to seize the opportunities.

Back in 2023, Novonesis president Michael Christensen emphasised the importance of pursuing ties between the business and political communities, urging EU-Chinese cooperation on biofuels.

Now, with geopolitical tensions between China and the West rising, Christensen's messaging sounds like one from a bygone era. Companies are moving supply chains out of the country to avoid regulatory backlash from the EU and US.

Yet for Novonesis, a changed global landscape only presents new opportunities. In China, Novonesis is cooperating with the government on resource security, growth through high-value industries, and environmental clean-up. Over in Europe, meanwhile, it is presenting biobased production as a way of derisking from China. Its CEO recently made her case to Brussels:

'For every job you're creating in biosolutions, four more jobs are created in the value chain.

And those are local jobs. It's jobs in agriculture, in production. They are jobs that allow you to deleverage. You won't need chips from China. It's biofermentation and feedstocks produced and used locally.'

With a firm foothold in both European and Chinese markets, Novonesis is confidently tailoring its business pitches to the policy ambitions of two rival regions, a sign of its skill in navigating a more fractured world.

FEBRUARY 12, 2025

The power of biobased solvents in paint, electronics, and more

Here are the areas where these green chemicals are making a mark

Solvents are small but mighty. These industrial chemicals are everywhere in industry, with total annual use estimated at 20 million tonnes annually.

Biobased solvents can lower the environmental footprints of industries as wide-ranging as mining and nutraceuticals and as novel as printed electronics. Here are the areas where these green chemicals are making a mark.

Phasing out toxic petrochemicals

A solvent is any substance that dissolves a material without changing anything chemically about it. Water is the classic example, capable of dissolving more substances than any other liquid.

Pharmaceuticals, printing, engineering and construction all need various solvents to manufacture their wares. Yet most are still made from crude oil, resulting in chemicals with damaging health effects.

Today, many industrial solvents are volatile, flammable, and explosive, as well as toxic to human health and the environment. Shockingly, they have even found their way into the food and ingredients industries – petroleum-derived chloroform or dichloromethane are commonly used to extract amino acids, flavonoids, proteins, and phenolic compounds from plants.

There is increasing demand for 'greener' biobased solvents that are lower impact, lower cost, biodegradable, and easily obtained from renewable sources. Many of the major solvent-using industries are starting to adopt them.

Paints and inks

The paint and coatings industry makes up the biggest slice of solvent demand at around 46% with the most common chemicals being ethyl acetate, butyl acetate and methyl ethyl ketone.

Paints rely on liquid solvents to suspend pigments and render them mixable and spreadable. They can also influence the paint drying process, the paint's thickness and flow. After they are applied, solvents are meant to evaporate into the air.

Some paints can go fully solvent-free and many of those on the market today are water-based. However, some kind of solvent is still essential in certain applications, for example, protective paints that guard the layer underneath.

Biobased solvents that can be used in coatings are n-butanol, acetone and propylene glycol. While plant-based solvents can be just as toxic when released into nature – they are after all, powerful chemicals – they are considered to release fewer air pollutants than their petrochemical versions.

Chicago-based Vertec is a major biobased solvent supplier that offers a range of solvents for coatings and paints made from corn, soybeans, citrus and other plant feedstocks.

Larger players in the chemicals and biobased spaces usually have their own offerings. European industrial giant Umicore supplies biobased solvents such as its Valires RD derived from soybean. Agribusiness corporation Cargills also produces a biosolvent named 'Agri-Pure', a vegetable derived substance with multiple uses including fro dissolving

inks and paints.

Valorising winery waste

Thanks to their ability to selectively draw out target compounds from different kinds of waste streams, biobased solvents can bridge between different segments of the bioeconomy, creating circular pockets within it.

One example of this is how biobased solvents could forge stronger supply chains between the viticulture and organic healthcare industries. Researchers found a way of drawing out bioactive compounds like phenolic compounds from winery waste using biobased 2-MeTHF – molecules with antioxidant and antimicrobial properties that are commonly used as a functional ingredient.

2-MeTHF has gained traction as a substitute for hexane, a solvent made from crude oil which is used to extract edible oils from plants and in cleaning agents. The substance is also a renewable alternative for dichloromethane, used in paint removal, adhesives, cleaning fluids, chemical processing and foam manufacturing.

Conventional oil-based hexane has been classified as neurotoxic or environmentally unsafe with inhalation leading to dizziness, nausea and headaches. 2-MeTHF still holds chemical hazards – it is highly flammable – yet exhibits far fewer health concerns and can be made from corncobs or even waste ingredients such as bagasse. This green chemical is generally quite abundant – suppliers are concentrated in China, with the US in second place followed by Germany in the United Kingdom.

A solvent for printed electronics

Green solvents are also finding uses in electronics. While the sector may seem distant from the chemical industries we normally associate with solvent use, emerging tech for printable devices is poised to fuel demand for sustainable inks.

Cyrene is one of the best known recent examples of a truly innovative biobased solvent for electronics. Originally developed in the Green Chemistry labs at the University of York, it was awarded a ‘Bio-based Innovation of the Year’ prize in 2017 for its wide-ranging potential uses and its potential to underpin more sustainable low-cost printed electronics.

> “There is increasing demand for ‘greener’ biobased solvents that are lower impact, lower cost, biodegradable, and easily obtained from renewable sources.”

Made from plant cellulose, the solvent was able to replace traditional solvents in graphene ink – the kind used in inkjet printers, where graphene flakes are dispersed in solvents.

The development of Cyrene was important from a commercial perspective because the product could lower the health impacts of printed electronics, a potentially high-growth industry.

A 2018 Nature article showed that biobased Cyrene solvent even performed when used to screen-print a graphene antenna – a high frequency antenna used in enhancing radio communications.

The paper confirmed that inks made using Cyrene can be used to print other kinds of devices too. Cyrene's performance in printed electronics owes to how the biobased solvent does not interfere with the conductive properties of the graphene.

Extracting from trees

Biobased solvents can support sustainable scaling in the bioeconomy at large. As well as dissolving and suspending materials evenly, some can selectively extract chemical compounds from another material – something critical for processing raw materials.

The extractive power of certain solvents can be used to transform formerly value-less waste byproducts into feedstock, all without the need for environmentally harmful chemicals. Wood is a key example.

The lignin inside woody material is in high demand as a biomaterial input as it can form the basis of a huge variety of materials, chemicals, and fuels. Yet despite its abundance, lignin is relatively costly to extract and process. Since all wood contains lignin, a sustainable and cheap biobased solvent could unlock vast volumes of as-yet uneconomic waste wood from the forestry industry.

Today, lignin is extracted using solvents that are harmful for the body and the environment. These include sulfuric acid and sodium hydroxide. Many researchers have recently converged on biobased chemicals known as deep eutectic solvents (DES) as a replacement for these. DESs are milder than the chemicals generally used in industry and require far lower temperatures to be effective, further saving on environmental impacts.

Among those investigating DESs for lignin extraction are scientists at the Wageningen University in the Netherlands. A group at its Food and Biobased research centre have pioneered an early investigation into a partly biobased lignin solvent based on lactic acid and choline chloride.

This biobased solvent is designed to boost lignin's industrial applications by making the extraction process still efficient while avoiding some of the environmental impacts of conventional chemicals. The lignin which results from the DES developed by the team is of higher quality than that of conventional solvents.

Extracting with trees

One of the many applications of lignin is as a solvent. Some types can even be used to extract metals. The organisation Swedish Mining Innovation is researching whether current fossil-based 'flotation reagents' could be partially or totally replaced with lignin particles. Flotation reagents are a key metals processing technology, used to

separate target metals from other materials but many are toxic to ecosystems.

In a pre-study, researchers at Swedish Mining Innovation found that lignin particles could selectively pick up on copper and other minerals, a process now protected under a Swedish patent.

In semi-pilot plant trials, the LIGNOFLOT researchers found that just very small concentrations of the lignin particles were necessary to improve flotation performance. Thanks to the biobased material, the use of petrochemical xanthate in the flotation process could be reduced by 75%, cutting the hazards associated with the process.

Biobased solvents are also being tried in lithium ion batteries for EVs. A team of Italian and German chemists reported a 'novel bio-solvent' lactic acid could be used as the electrolyte within the batteries.

The electrolyte component constitutes the 'in-between' of a lithium ion battery, a space where the ions move between the cathode and anode on either side. Once combined with conducting salts, the biobased material showed hgh electrochemical performance in a lab-scale battery demonstration.

This experimentation with biobased solvents in advanced industrial applications shows how mature the field has become. Attention to green solvents appears to only be increasing because the use of crude oil chemicals have become toxic in a PR sense.

Growing awareness of the problem has already led large players in the pharma industry such as Pfizer and GSK to throw resources at the problem. In the 2000s, Both companies have produced guides and classifications intended to inform industry best practices on sustainable solvent selection, highlighting the most toxic chemicals in usen today alongside their potential replacements, often biobased.

Biobased solvents must hit a large number of additional criteria that oil-based solvents do not have to: as well as performing well, it must be obtained from renewable feedstock such as plants, available widely and potentially cost-competitive, as well as being biodegradable without producing toxins. Although biobased solvents must do more than petrochemicals in order to compete, it is an area set to grow thanks to industry demand and considerable research attention.

FEBRUARY 19, 2025

The biodegradable microbeads that scrub out plastic pollution

For companies seeking biodegradable replacements, circular and plant-based options abound, waiting to be scaled

Major consumer markets have imposed microbead bans in recent years to tackle marine pollution. For companies seeking biodegradable replacements, circular and plant-based options abound, waiting to be scaled.

The bead backlash

Plastic microbeads are among the most notorious pollutants from the cosmetics and personal care industries. These tiny grains of PE or PP plastics found inside face scrubs, body soaps, and toothpaste measure less than 5 mm in diameter but have had a huge impact on ocean environments.

According to the Plastic Soup Foundation in 2022, 87% of the products of the ten best-selling cosmetic brands in Europe contained microplastics. Small yet buoyant, they escape through most sewage treatment filters. Like other synthetic polymers, these beads are not built to biodegrade. Once eaten by fish in the open ocean, the plastics can find their way into the human food chain.

Awareness of their ecological impacts prompted a huge legal and consumer backlash around the mid-2010s. Microbeads concentrated a lot of consumer activism at the time and how companies dealt with the issue became seen as a barometer of their ethics among the buying public.

Many big brands withdrew plastic microbeads at the time: P&G and J&J announced they would remove plastic microbeads in face scrubs and in toothpaste in 2015 in order to pre-empt any legal bans. L'Oréal got rid of them from their exfoliant products in January 2017.

As well as reputational damage, a barrage of regulations in key markets over the last ten years mean that cosmetics companies will need to opt for biodegradable alternatives in future.

In 2015, the US prohibited the manufacturing, packaging and distribution of rinse-off cosmetics containing plastic microbeads. The UK implemented similar legislation in 2018 while in October of 2023, a much more comprehensive EU legislation banning microbeads and a whole host of other microplastics came into effect. China too has banned microplastics in rinse-off cosmetics.

In the coming years, it is likely that wider bans on microbeads beyond cosmetics will come into force around the world.

Perfectly plant-based spheres

Microplastics are popular because they enhance the cleaning properties and skin-feel of the liquid formula in which they were mixed. Luckily, alternative biobased materials are well up to the task of replacing them.

The UK's Naturbeads is one of the best-known startups producing biobased alternatives to plastic microbeads. Naturbead's spherical microbeads are biodegradable because they are derived from the plant material cellulose, which can be worked into a huge range of materials.

So far, its business model has focused on licensing, selling IP and a production process more than a particular product: its customers can take on and use Naturbeads' patented equipment, software, and processes to create biodegradable microbeads in different colours and sizes.

Recently however the company began to construct its first full-scale production plant in Puglia, Italy after receiving its seventh funding round of £7.8 million in 2024. The company is now focused on scaleup and getting its plant-based material to price parity with oil-based versions – something that it says will be possible once it hits 500 tonnes per year of production.

Beyond beauty: microbeads in paint and biotech

For plant-based alternatives to become widely adopted, and to maximise revenue, biobased producers must understand the full range of microbead applications in industry today, creating a product that is just as versatile.

Naturbeads is keen to develop replacements for microbeads across the full spectrum of industries where plastic versions are used. Microbeads are best known as exfoliants in cosmetics and personal care. Yet they also have other somewhat surprising applications. As a cheap additive for certain paints and coatings, they can enhance pigment opacity, durability, and flow.

Paints and adhesives are in general a lower-value, higher-volume application for microplastics than personal care and cosmetics. However, removing oil-based microbeads from paint is just as important if we are to reduce the damaging impacts of plastic waste on wildlife and human health. Waste consultant Eunomia has estimated that far more plastic from building or road paint ends up in oceans than from cosmetics.

After reporting that it has successfully tested products for use in paints, and fillers in adhesives, Naturbeads now ambitions to produce microbeads for even more high-value uses: as carriers for enzymes in biocatalysis and cell scaffolding for laboratory meat. Since 2021 Natubeads has been working with Cellular Agriculture on developing new edible cellulose ‘microcarriers’ that can be used to make cultured meat.

Producing microbeads for the biotech industry presents its own set of R&D problems, as cultured meat scaffolds serve several functions at once. Three-dimensional scaffolds are anchoring structures for cells to attach, mature, and replicate. They give cultured meat density and texture. Given the right material and shape, scaffolds can make a huge difference in increasing cell growth rates, potentially contributing towards scaling cultured meat.

A sustainable plastic microbead?

Cellulose is not the only suitable replacement for plastic microbeads. Polymers made from plants rather than oil also have potential. Polyhydroxyalkanoate (PHA) is a natural polymer that can be produced by microbial biosynthesis from sugars and vegetable oils. It has excellent biodegradability, including in the deep ocean, with results comparable to that of plant cellulose materials.

Researchers at the University of Georgia New Materials Institute found microbeads made from the material degraded in 15 weeks in laboratory conditions, and 13 weeks in field conditions, resulting in no minute plastic particles.

Aside from biodegradability, the team investigated another crucial aspect of microbead sustainability: whether the compounds that PHA breaks down into are toxic to wildlife.

This was an important facet of the research since some biodegradable materials can still be toxic, turning into harmful compounds once environmental microbes consume and metabolise them. This can have impacts that ripple up the food chain. The researchers behind the study said that this was not the case with their PHA.

“Numerous and diverse types of invertebrates and microfauna were observed inhabiting the microbead environment, suggesting the PHA microbeads supported healthy microbial biomass production as organisms consumed the microbeads,” said Evan White, first author on the study and director of the New Materials Institute. “Most of the carbon from the microbead metabolized to CO2, and some was converted into the bodies of organisms in this vibrant ecosystem which can be seen in supporting microscopy videos.”

Research from elsewhere confirms the biodegradable properties of PHA. A recent paper in Nature by Japanese researchers confirmed the rapid biodegradability of PHA microbeads in natural habitats by leaving a sample on the seafloor of a Japanese port bay.

The team said that PHA microbeads are most likely to break down in products that end up in sewage wastewater since this is the environment that is richest in the microbes best capable of digesting the material.

PHA microbeads would need global PHA production to grow – currently production is no more than 40, 000 to 50, 000, according to a 2022 estimate, which amounts to less than 2% of the bioplastics market.

Despite this, one company that already offers PHA-based microbeads, known as Minerv PHA Bio Cosmetics, suitable for cosmetics use is Italy’s Bio-On.

Circular options for new biodegradable microbeads are also being explored. Last year, Canadian researchers showed that brewer’s spent grain, the main byproduct of brewing, can be used as a personal care exfoliant. The manufacturing process consisted of taking pulp from the grain, making it soluble, then dropping a solution of the grain into an acid bath to form solid beads.

Fortifying food without a trace

Beyond cosmetics, paints, adhesives, and cultured meat, biodegradable microbeads might have even more functions in the future, such as for storing and delivering drugs or nutritional compounds. Scientists have developed a new type of microbead material with special properties that make it useful for food fortification.

Food fortification, where common foods are loaded with beneficial nutrients and vitamins, play an essential role in public health, particularly in the developing world. Scientists found that biodegradable microbeads made from poly(beta amino esters) could be used to enclose and protect vitamins, allowing them to be safely placed inside food. The microbeads were found to be heat-resistant so they could be cooked without compromising their nutritional content.

With all their current and possible applications, microbeads show how even relatively simple biobased and circular materials can cut the ecological damage of various food and chemical industries. Innovation from startups like Naturbeads shows how biobased materials can often compete on performance with oil-based counterparts, including in high-precision applications like biotech and cultured meat.

FEBRUARY 26, 2025

Circular fertilisers set for growth after new EU Russia sanctions

We look at why the EU is prioritising circular fertilisers now, the geostrategic context for Hansen's call to action, and key producers that may benefit

Circular and biobased solutions stood front and centre in the EU's security agenda this week after agriculture commissioner EU Christophe Hansen called on the bloc to increase its use of manure-based fertilisers.

This championing of circular fertiliser is part of EU efforts to reduce dependence on Russian agricultural inputs after rolling out new sanctions on them. We look at why the EU is prioritising circular fertilisers now, the geostrategic context for Hansen's call to action, and key producers that may benefit.

The EU's fertiliser problem

The EU put import tariffs on nitrogen-based fertilisers from Russia for the first time this week in its 16th round of sanctions on the country.

The move came after years of concern in the bloc about how much its food security depends on Russian nitrogen and how this would narrow its strategic freedom in any geopolitical conflagration. By the end of 2024, the EU was getting a quarter of its extra-EU fertiliser imports from Russia.

These concerns became a reality after the start of the Ukraine conflict in 2022. Russia was no longer producing as much fertiliser as it used to while farmers in Europe panic-bought supplies. In November, the situation was urgent enough for the European Commission to release a communication for farmers on how to cut back and optimise their use while still securing normal yields. By 2023 Europe announced that the fertiliser market had reached a 'critical level' where farmers are facing 'unprecedented challenges due to record prices'.

EU finally sanctions Russian fertiliser

Because of its dependence, the EU had avoided targeting Russian fertiliser as part of its sanctions war until now, continuing to buy these critical products even while sanctioning other imports like oil.

The EU's decision to finally restrict Russian fertiliser imports was prompted by the unintended consequences of its earlier sanctions. After the EU restricted its purchases of Russian gas in 2024, Russia simply diverted the fuel to produce more fertiliser, shipping it into the EU where its cheap products found a ready market. The EU now seeks to close off this revenue source to the Kremlin.

The EU fertiliser sanctions will mainly affect two inputs: urea and ammonia. Russian urea, which makes up a third of European supply, is used widely as a nitrogen fertiliser, which increases crop yields. Ammonia is a feedstock for producing nitrogen-based fertilisers like urea as well as being an emerging fuel source.

In the absence of cheap Russian fertiliser alternative sources will have to be found alongside demand optimisation. Russian fertiliser imports would have to be partly replaced with domestic fertiliser made from easily-sourced sources like manure. The EU simply does not have the cheap natural gas it would need to produce its own synthetic nitrogen fertiliser on the scale Russia does.

A history of plant nutrient R&D

The decision to impose tariffs on Russian fertiliser could herald new waves of policy support for EU biobased and circular industries.

Europe has a strong track record on R&D in recovering plant nutrients

from manure, spending considerable sums on waste-to-fertiliser pathways since the 2010s onwards. Fertimnaure is an EU funded project that ended last year, focused on developing and testing mineral recovery from animal manure. Its final outcome was to demonstrate its waste-to-manure processing methods and tech at a Dutch pilot farm.

Manurerefinery, an ongoing EU project that will last until 2028, is developing modular small-scale and decentralised biorefineries that can convert manure into biobased feed and fertiliser in rural areas. The new sanctions could now provide some impetus for translating these R&D projects into wide scale capacity.

Europe's organic fertiliser producers

The latest sanctions will almost certainly benefit existing organic fertiliser producers in Europe. Many are smaller, producing a wide range of fertilisers that blend organic and mineral materials together. These include FRAYSSINET (France), Ilsa Spa (Italy), Culterra (Holland), and Angibaud (France). Organic fertiliser is diverse and manure is not the only feedstock for making it. Ilsa Spa for example specialises in extracting nutrients from plant or animal matter using enzymes.

Then there are nutrient recovery companies that specialise in recovering highly concentrated nutrients from waste streams. These include Amfer of the Netherlands, which claims to recover between half and 80% of the ammonia from the manure and slurry it treats. Since 2021, it has operated three full-scale plants: two in the Netherlands treating up to 30, 000 tonnes per year of digestate (a processed version of manure) and one in the UK treating up to 170, 000 tonnes per year.

EasyMining is another company that recovers agricultural inputs from waste. Their Aqua2™ treatment process removes ammonium nitrogen from wastewater using chemicals. THen, the ammonium nitrogen is converted into ammonium salt. The process has a reduced climate impact compared to traditional fertiliser production, which contributes significantly to the food system's environmental footprint.

There are also startups pioneering the niche of nutrient recovery from human waste. Finland's NPHarvest is one of them. It deploys a membrane system it calls the 'nutrient catcher' to retrieve plant nutrients from wastewater – an innovation it claims cuts operating costs by removing the need to use heating or high-pressure conditions to treat the waste. The membrane system is designed to plug-into biogas plants, agricultural operations, or municipal wastewater plants.

The biggest producers of organic fertilisers in Europe however are Yara (Norway) and K+S Aktiengesellschaft (Germany), both among the top fertiliser manufacturers in the world. K+S makes organic fertiliser alongside its traditional line of mined plant nutrients. They currently sell 25 organic farming-certified products.

Yara is Europe's largest fertiliser producer and market, including specifically for the nitrogen fertilisers that will be hit by sanctions. The company produces fertiliser products made up of both organic and mineral material.

Expanding its organic production capacity has been part of the company strategy since at least 2021, when Yara acquired the Finnish organic-based fertiliser producer Ecolan. In 2023, it acquired another organic fertiliser producer, this time in Italy, Agribios Italiana.

Cleaning up livestock pollution

Apart from security, biobased and circular fertiliser can reduce the environmental impacts of farming.

For some in the EU, market demand for manure cannot grow quickly enough. There are parts of Europe where animal waste has piled up to unsustainable levels, especially in the Netherlands and in Belgium which has some of the most intensive agricultural systems in the region.

Like synthetic fertilisers, the nutrients in livestock manure can clog rural environments with pollution, unbalancing aquatic ecosystems by encouraging algal blooms that suffocate other lifeforms. Untreated manure also releases various greenhouse gases, contributing to global emissions. Bigger demand for organic fertiliser could be the most effective way to stop this waste backlog.

The EU agriculture sector contributed 15.2% of total global agricultural emissions in 2021. Over the long-term the only way that Europe would meet its production needs while reducing the substantial planetary impact of agricultural production is to shift towards greater use of organic fertiliser. In this way the fertiliser supply chain impacts of the Ukraine war only sped up policy initiatives already in motion in Europe agriculture's environmental impacts.

Manure needs scaling to offer a real alternatives

In moving away from Russian fertiliser supply, the EU now faces a delicate balancing act. On the one hand, it wants to inflict damage on the Russian economy through its sanctions. Yet discouraging European farmers from purchasing cheap Russian fertiliser and encouraging them to buy more expensive domestic fertiliser will be politically contentious.

Relations between the farming sector and the EU are currently fraught. With margins squeezed by war and inflation, farmers groups across Europe have emerged as a potent political force campaigning against green regulations and for more support to enact sustainability regulations. To offer a real alternative that is affordable for the region's farmers and consumers, manure-based fertiliser will still need to scale substantially.

Long-term support for circular fertiliser scale-up and other aspects of the agricultural sustainability transition will be needed from the EU if the bloc is to earn the political backing of farmers, a key constituent in the fight for a sustainable and food secure future.

The bloc also needs a comprehensive strategy melding agricultural and envrionmental targets – the science of fertilisers shows how critically entwined these areas are, given that soil health is fundamental in determining the efficacy of organic plant nutrients.

The EU will have to back its sanctions strategy with resources and clear policy for the framing and fertiliser sectors, supporting the former in making transition to circular inputs while helping the biobased production deliver renewable, domestically produced goods at lower prices.

MARCH 5, 2025

Enzymes and metal unlock plant feedstock in Solugen's Bioforge

Solugen's major innovation is a manufacturing tool named Bioforge that blends metal catalysts with enzymes to produce industrial chemicals from plants. We profile the company from its beginnings

Last year, Solugen received one of the biggest Biden-era loans to biomanufacturing to pursue its mission of replacing oil and natural gas in chemical manufacturing.

Solugen's major innovation is a manufacturing tool named Bioforge that blends metal catalysts with enzymes to produce industrial chemicals from plants. We profile the company from its beginnings.

Minerals and biology meet

Since 2016, Texas-headquartered Solugen has been in the business of sustainable biochemicals, specialising in hydrogen peroxide and its byproducts glucaric acid and gluconic acid.

Although obscure to most consumers, hydrogen peroxide is produced in huge quantities globally. As a 'chemical intermediate', it's a substance that recurs across disparate industries and diverse materials – from textile, paper and food to chemicals, plastics and pharmaceuticals. One estimate says the market will reach $6.3 billion by 2026.

Yet more than any particular molecule it makes, it is Solugen's proprietary manufacturing platform that has garnered attention from investors. Solugen offers a new biobased manufacturing process which allows hydrogen peroxide production from plants rather than petroleum or natural gas.

Under Solugen's process, engineered biobased enzymes and then metal catalysts are used to treat feedstock derived from plants. The final result is indistinguishable from the product that comes out of the conventional manufacturing process.

A new way of making chemicals

Solugen's approach to producing hydrogen peroxide is said to be less energy-intensive than conventional manufacturing routes, according to the company, because it unlocks plant-based feedstocks.

Right now, most hydrogen peroxide is made from methane or natural gas (providing the hydrogen), which is then reacted with oxygen under high heat. The company also says its process is safer and less toxic.

The renewable feedstocks unlocked by Solugen's metal-enzyme treatment process are not the only factor in lowering the environmental impacts of the new process. The fact that Solugen's process converts plant feedstock directly into the target chemicals also matters.

This direct route eliminates the many waste products that come out of the chemical manufacturing process today. Solugen also claims its metal-enzyme treatment process also results in yields of target chemicals that are considerably higher than competitors that draw on petroleum.

Apart from environmental advantages, Solugen's manufacturing process opens the door to scale. Under the conventional process, large plants are needed to cope with the safety pressures of working with high heat and flammable inputs.

Solugen's process works with water and at room temperature, which can cut operating costs and space requirements and pave the way to lower prices for green chemicals. Smaller plants also mean modular facilities that their customers can fit out right next to their operations. Decentralised chemical production becomes possible.

The power of biology

Solugen's metal-enzyme chemical production tool relies on advances in biotech and gene editing. Rapid progress in these fields, as well as falling costs, allow producers to fine-tune the chemical behaivours of biological materials to meet precise manufacturing needs.

Solugen designs its enzymes, which they enhance using genetic engineering. This way, these biological compounds can be made highly optimised for specific chemical tasks.

The process of generating highly efficient enzymes for specific chemical tasks is made easier by using AI-filtered libraries that help screen different enzyme variants. The company then contracts out the actual production of these enzymes to specialist companies.

> "Solugen's process works with water and at room temperature, which can cut operating costs and space requirements and pave the way to lower prices for green chemicals."

Beginnings

The commercial idea of blending metals and enzymes in one biomanufacturing pathway came directly out of the graduate research that Solugen co-founders Sean Hunt and Gaurub Chakrabarti were doing back in the early 2010s.

Hunt's PhD research at MIT focused on the synthesis of peroxide with metal catalysts.

It was during his studies that he met his eventual co-founder Gaurab Chakrabarti. Chakrabarti was studying enzymology and cancer biology and discovered an enzyme system that could make hydrogen peroxide during his graduate research.

Eventually, the pair began to explore whether combining their interests could result in a more efficient hydrogen peroxide pathway than the one that already existed.

Looking back on their early meetings, Hunt has described how at first, he was sceptical about the industrial usefulness of the biological enzymes that Chakrabarti was interested in.

Hunt knew about the power of enzymes in chemical reactions but assumed they were too complex, finicky, and costly to work with at a commercial scale.

Hunt's initial wariness of working with biomaterials is perhaps shared by many industrialists and consumers who still assume that biobased replacements for fossil-based processes do not perform as well Solugen's industrial successes since that time prove that this is far from

the case.

Sensory deprivation kept Solugen afloat

Hunt quickly came around to the idea that custom-engineered enzymes can be powerful and scaleable solutions to production biobased chemicals. Still, the company had to prove itself commercially and secure its first orders.

After its founding, one of the first customers that Solugen sold its hydrogen peroxide to were US float spas. These are therapeutic spas where people can go to be suspended in the warm waters of sensory deprivation chambers.

Industrial chemicals may seem out of place in a spa setting but the chemical is an easy way to keep the flotation tanks clean. A stream of initial orders came in from the small and close-knit US float spa industry, showing the company that they might have a chance at staying afloat financially.

At this time, Solugen was just a startup on a shoestring. The founders recount how they had to keep up production to meet hydrogen peroxide orders from spas, they had to sleep on the floor next to their DIY reactor through the night.

2017 was a critical year for the company. In March, it secured the $4 million in seed funding needed to continue.

Major revenue growth came through multiple contracts with the oil and gas industry. Solugen turns byproducts of making hydrogen peroxide – glucaric and gluconic acid – into products that extract iron contaminants from oil. These organic acids also treat wastewater, increase crop fertiliser uptake, and control cement curing, allowing Solugen to enter a range of industries.

Bioforge Minnesota

By 2024, Solugen had broken ground on its latest new facility in Minnesota, which it says will have a production capacity of 120 kilotonnes per annum, estimated to create 50 manufacturing jobs once it hits full production.

Solugen's Bioforge facility in Marshall is located right next to a facility owned by ADM, one of the world's biggest agribusiness entities and food commodities traders. The co-location is no accident. Solugen has a partnership with ADM and will source dextrose from the company's corn processing complex next door. The dextrose will be the key feedstock in Solugen's manufacturing process.

Solugen has also taken advantage of its location in Minnesota, which has for years been developing biobased industries to increase the value of its agricultural sector. Indicating how Minnesota has become a prime location for the biobased industries, the state was home to half of the 160 projects that bagged funds from the US Department of Agriculture in August 2024, part of Biden's support for clean energy projects.

Riding the onshoring wave

Solugen is a bioproducer that has taken full advantage of the push to restore US manufacturing. In 2024, the US Department of Energy granted a $213.6 million loan to the firm. It was a big win for the company, marking the largest government biomanufacturing loan since Joe Biden brought in an executive order to expand the US bioeconomy

in 2022. The next biggest biomanufacturing loan recipient after Solugen had been one for $25 million, for Liberation Labs.

Solugen's 2050 vision is ambitious, envisaging a Bioforge in 'every city'. In one animated mock-up online, a roving X-ray vision spotlight moves through a futuristic cityscape, revealing an underground network of tubes and tunnels. These, Solugen explains, are transporting vital industrial chemicals made through its manufacturing methods throughout the entire city as and when they are needed.

Solugen believes this is possible because of the power of enzymes to convert cheap, abundant, and renewable inputs into just about every valuable product we like. Yet before anything like these futuristic visions could become reality, Solugen will have to convince the new US administration that green chemicals can become a centrepiece in the US industrial revival that Trump says he wants to achieve.

The political landscape has shifted dramatically since Solugen received its loan from the DOE in 2024, when Biden's Democrats were in power. However, the company remains hopeful. The company believes its goals are bipartisan and that there are no reasons that it cannot continue to expand – a generator of US jobs and manufacturing capacity that is a priority of the new administration as much as the old one.

MARCH 12, 2025

Green gems: making jewellery from plants and waste

We look at the creative possibilities offered by plant-based materials and how waste could gain a second life as shiny adornments

Jewellery made from plants or waste are appearing at all price points. We look at the creative possibilities offered by plant-based materials and how waste could be gain a second life as shiny adornments.

Gems from potatoes

New York bioplastic jewellery brand Mo.Na Gems is winning over the youth market to renewable design with their colourful earrings and keyrings.

Their creations are irresistible for their gummy bear translucence, a surface that mimics the plastic resin that dominates the lower-cost end of the jewellery market. Despite their appearance, Mo.Na Gems' luminous little 'gemstones' are made not from oil plastic but entirely from a compostable formula that uses potato starch. The material was formulated in 2021 by co-founders Mia Dunn and Mecca McDonald in their Johns Hopkins dorm kitchens.

Anticipating criticisms about non-biodegradable bioplastics, the brand proudly showcases the nature-friendly credentials of their starchy gems. Photos on Mo.Na's website show their precious bio-gems disintegrating after several weeks in the backyard compost.

Recent media commentary on the demise of ESG ring hollow when it comes to Mo.Na's consumer base. The brand regales their fans with Instagram posts aimed at an ecologically and socially conscious younger generation, reflecting on the ties between fashion and economic inequality, capitalism and sustainability.

Now a cult hit brand with a growing following, the company showcases the possibilities of biomaterials within mass-produced fashion goods.

By conquering the fashion-conscious youth market for affordable jewels, Mo.Na Gems is promoting the cause of bioplastics more broadly. Its self-professed mission is to make 'bioplastics look sexy' among its Gen Z cohort. Their marketing strategies for doing so are as fun as their poppy pieces, like their 'Galentine' make-your-own charm event in Brooklyn this past February.

Finnish bio-jewellery

Mo.Na is one of the most innovative new biobased jewellery makers on the scene. More than simply greening the market for kitsch consumables, they are loading a relatively unfamiliar material with rich cultural meanings – something that is essential if renewable fashion materials are to capture the public's imagination.

While Mo.Na targets the affordable fashion segment, circular and biobased options are catching on within every market. We see this in the work of Kalevala Koru, a Finnish company that designs, makes and markets jewellery. Recently, they released the Nolla collection of biobased earrings that chief designer Taru Harmaala Chaloff says was inspired by the endangered meadow flowers of her native country.

While Mo.Na's jewels resemble pick 'n' mix, Kalevala Koru are distinctly more understated. The delicately minimalist designers of the Nolla collection earrings consist of two interlocking disks, each made from a new, Finnish-made bioplastic that uses hemp, sugarcane, and fava bean. Brightplus is the company behind the new material. The dyes that colour the disks are also minimally processed, made from woad blue, soot black, and green from metal oxide. The silver parts are made entirely of recycled silver.

Conscious consumption

More than ever, jewellery buyers are basing purchasing choices based on what they know about the social and environmental impacts of supply chain. Mining, extraction, and smelting precious metals often come with huge costs for the environment and local communities and more buyers are attuned to this.

Yet precious metal and gemstone supply chains are also often opaque, crossing continents and legal jurisdictions in ways that make them difficult to track and regulate. This leaves consumers with little choice but to trust certification agencies that some have argued remain closely entwined with the jewellery industry.

Mined gems are not the only jewellery components that can be environmentally damaging, with plastic being another common culprit that raises the negative impacts of the fashion jewellery segment.

Finally, there are traditional biobased materials that humans have worn since the very beginnings. Many of the oldest jewels derived from animals, yet designers today are keen to look beyond traditional sources of biobased adornments. When a few types of material become coveted as luxury items, demand can feed damaging practices such as artificial pearl farming causing ecosystem imbalances or the illegal ivory trade. The ability to draw on a wider array of renewables is the key to building a more sustainable industry.

For these reasons, creators are turning to the possibilities of unexpected biomaterials for jewellery, especially those that are locally sourced. A recent study in Nature discusses how, over its entire life-cycle, biomaterials-based jewellery can emit lower levels of carbon and use up much less water than their mined counterparts. This is partly because the renewable materials need less heat (and therefore energy) in their processing.

There is evidence that these life-cycle stats matter for consumers. A global survey of 8,400 people across seven key consumer markets for diamonds found sustainability was a key deciding factor in purchases, with 60 percent of consumers and more than 80 per cent of opinion leaders who influence decisions of friends and family having chosen a product made in a more environmentally or socially responsible way. We are also seeing surging interest in upcycled and circular options.

Pineapple trumps plastics

Bioplastics are an obvious candidate to replicate the sheen, shine, and vibrant colour of cut gemstones in jewellery. Yet fibrous plants also have a role in creating wearable pieces.

Pressed fibre from pineapple leaves, for example, can create durable bangles that replace plastic ones. Other fibrous plants – sansevieria, ramie, abaca – are similar in their structural properties, ideal for being worked into biobased filigree, which is a type of metalwork that features flowy and intricate shapes. Malta's Bartoart is one jewellery designer experimenting with the possibilities of these, inlaying copper with the intricate, lace-like structures found inside the prickly pear cactus.

Nature abounds in fibrous plants that offer new design possibilities for jewellery. Some of these are well-suited for the mechanical components of jewellery: latches, bands, hooks. There are bamboo charcoal-infused polymers that could be durable elements in jewellery components.

Agricultural residues can both be worked into diverse materials with an array of aesthetic and mechanical properties.

London's circular luxury

London-based Oushaba makes luxury jewellery from e-waste. The results are spectacular reminders of the creative potential locked up in waste materials destined to leach toxic chemicals in a landfill. Oushaba's 'Constellation' necklace is a fine example of this, a sumptuous gold pendant made from a totem-like piece of circuit board.

At £14, 500, the 'Constellation' necklace is out of reach for most. Yet more affordable circular pieces are available from another sustainable jewellery brand based in London. Charlotte Padgham's circular metals are her main material, working cast-off silver and gold into earrings and rings that flow in sculptural, lava-like belts. Her SKINS collection, all the precious stones have been damaged and discarded cast-offs from the industry or from accidental breakage.

Padgham's commitment to circularity and sustainability go beyond her gems and metals work: she also uses sustainably sourced biodegradable materials in her packaging, including cellophane envelopes made from corn-starch, recycled card backing, and filler material hand-shredded from deliveries to her studio. There is a biobased consistency through her brand that suggests how a growing industry in sustainable jewellery could simultaneously bolster demand for other areas of the bioeconomy, including packaging, adhesives, and inks.

New materials, new designs

Jewelry made from minerals is still highly prized in many cultures. Yet it's also clear that biobased and renewable materials have been at the centre of fashion for millennia: think pearls, coral, and ivory. The future of sustainable design will depend on makers willing to experiment with new kinds of renewable materials, working them so that they can replicate the intricacy and allure of traditional jewellery.

To tap a wider range of renewable and sustainable materials, the jewellery industry will have to learn more about the mechanical properties of different biomaterials over the long term. As with most new materials, trial and error is often the surest route to product development. Mo.Na's founders recall a time when they had to refund a whole batch of orders after heatwave temperatures melted the early bioplastics gems they sold.

It's possible that computer-aided design could help here. Coupled with biomaterials, these digital tools could help the jewellery industry cut the waste inherent to trial-and-error designing. Computer modelling could screen for the best candidate materials more efficiently while simulating jewellery shapes, which can reduce the number of physical mock-ups needed. 3D printing could help producers cut the amount of byproduct that comes out of their process.

With renewable materials and digital efficiencies, the jewellery industry could become an unexpected engine for valorising all kinds of industry waste.

MARCH 19, 2025

The new bio-polymers taking green chemistry by storm

What makes biobased vitrimers so special and how could they become commercialised?

The last five years have seen an explosion of research interest in biobased polymers, which exhibit recyclability, shape memory, self-healing, and stimuli responsiveness in ways that no other type of plastic does.

Biobased vitrimers can be made from a variety of renewable feedstocks, making them a strong candidate for petroleum plastic replacement in industries as wide ranging as biomedics and automotive manufacturing.

The EU is researching how to incorporate the material into wind turbines for less wasteful energy generation while US researchers have used it to develop a new type of recyclable circuitboard.

What makes biobased vitrimers so special and how could they become commercialised?

The best of both

Biobased vitrimers are a relatively new class of materials pioneered by French researchers in the early 2010s. Their work created a new field in polymer science that has gained mounting attention from chemists since 2020.

What makes biobased vitrimers so special? The answer is that they solve a major problem in materials science and industry – how to make a material strong but also capable of being recycled several times.

Biobased vitrimers are able to do this by bringing together the best feature of two polymer groups with very different characteristics: thermoset versus thermoplastics. Thermosetting polymers are known for their high mechanical strength, heat resistance, and dimensional stability. These properties trace back to what is called its crosslinked molecular structure. Their properties mean they are found everywhere in the aircraft industry, tissue engineering, electronic devices, and automobile manufacturing.

Thermoplastics, by contrast, have a non-crosslinked structure. This is what makes this class of polymers so easy to recycle without compromising their structural properties. Yet they also have their downsides: they are mechanically weaker than thermosetting plastics at high temperatures.

Now, scientists say that vitrimers present us with a new type of thermoset which also has the recyclability of thermoplastics strengths. They can be made to have shape memory, to self-heal, to be welded or be reprocessed, all without compromising their structural properties.

At normal temperatures, biobased vitrimers behave like the strong, heat-resistant thermosetting plastics. At higher temperatures they start to flow and become processable, just like thermoplastics.

In fact, vitrimers behave somewhat like glass under high temperatures: once melted into a liquid state, their molecular networks do not lose integrity, meaning they can be cooled to form shapes over and over again, each time like they are a virgin material.

The unusual combination of strength and recyclability in the biobased vitrimers owes to its dynamic covalent bonds. These are very different from the crosslinked structure of the thermosetting polymers since dynamic covalent bonds are reversible chemical bonds: they allow the fundamental molecular matrix of the polymer to be re-arranged.

This ability for its molecular structures to rearrange is not just a boon for recycling. This type of structural feature can allow the material to alter slightly in response to temperature and pressure changes. This means biobased vitrimers can behave differently in different environmental circumstances, without the need for drastic alterations in the polymer's overall chemical composition.

Sustainability

One of the reasons why scientists and researchers are excited about biobased vitrimers is because the material meets many green chemistry principles, a set of rules that help researchers and producers assess how sustainable a material is.

Their ability to unite high strength with recyclability can allow industry to cut back on toxic waste entering the environment and support circular economy principles of re-use. Depending on the formulation, biobased vitrimers can even be biodegradable or compostable. The renewable feedstock can also reduce the chemical industry's dependence on fossil fuels and lower its carbon footprint.

Feedstocks for biobased vitrimers

Scientists have identified different feedstocks and manufacturing routes to produce biobased vitrimers and are still experimenting with different ingredients and processing methods for different applications.

One of the most studied biobased vitrimer feedstocks has been epoxidized soybean oil, found to be an ideal candidate.

Researchers have also used natural peach gum to make epoxy vitrimers, mixing it with itaconic acid. Peach gum is a kind of natural plant gum, secreted from the fruit and trunk of peach tree, opening a way for peach-growing regions to valorise an agricultural waste-stream.

The resulting chemical has the potential to replace petroleum-derived epoxy resins applied in anti-corrosive coatings, adhesives, electronics, transportation, construction, aerospace and high-performance composites. The peach gum-based formula was notable for overcoming a problem in using biobased vitrimers in transport, construction and aerospace: its low tensile strength. The peach gum based biobased epoxy vitrimer in fact had a strength comparable to commercial epoxy resin made from petroleum.

The next green adhesive?

The research into applications for biobased vitrimers ave focused on sustainable adhesives, self-healing coatings, and easily recyclable packaging.

Many high level adhesives currently in use throughout industry consist of epoxy thermosets – a type of thermoset plastic that is usually made from petroleum. The substance makes up around 70% of the global market for thermoset polymers and is found in furniture, floors, windows, and shoes.

Today, it is almost impossible to economically recover and recycle the adhesives inside products at the end of their lives because it is permanently bonded onto the surfaces of its application. With millions of tonnes of this adhesive each year crushed and burned, these non-recyclable epoxy thermosets pose a major environmental hazard. Greener adhesive materials are needed that have the functionality of petroleum epoxy resin but are capable of being recovered and

recycled.

One research paper has reported a biobased virtimer adhesive that can be made using the biobased compound vanillin and an epoxy resin made from linseed oil. The material was shown to be recyclable.

Another study led by researchers at the Chinese Academy of Sciences reported a biobased vitrimer with adhesive properties made from castor oil and vanillin. The material performed with 'excellent mechanical properties, thermal stability, solvent resistance, outstanding cycle processability, re-weldability and good shape memory behavior.' In addition, it showed rapid degradability under mild conditions and 'high performance antibacterial activity'.

Apart from combining strength and recyclability, a notable feature of biobased vitrimers are its so-called self-healing properties. This has been demonstrated in many studies, including one by another Chinese team that made a fully biobased, high-performing vitrimer adhesives using castor oil, cysteamine, and vanillin. The adhesion was exceptional but it also showed self-healing features.

Vitrimer composites in clean energy

The EU-funded R&D project EOLIAN is one of the early research projects that is trying to bring biobased virtimers into real world applications. It seeks to develop >60% bio-based vitrimer that can be used in onshore and offshore wind turbine blades.

Incorporating vitrimers into wind turbine design is meant to tackle the lack of recyclability right now in the industry. The aim is to make wind turbines circular, minimising its end-of-life waste, something that will become vital in reducing the environmental impacts of renewable power as capacity scales.

A vitrimer composite wind blade can be heated and turned into a new component for the wind turbine, or else can be separated out from other materials in order to manufacture parts for different applications altogether.

In wind turbines, the self-healing properties of biobased vitrimers come into their own. This makes it much easier to repair minor blade damage than ordinary, non-responsive materials. When the material gets heated, the molecular bonds in vitrimers break and rearrange themselves to 'heal' or fill-in scratches and microcracks.

New sustainable vitrimer composites – repairable, reprocessable, and easily recyclable – will provide a step change in how wind turbine blades are maintained, reused and recycled in a circular economy. This means that it is easier to repair small fractures from afar simply by building a heating system into the blade itself – something that can have other benefits too, like ice removal.

The project has its focus on using vanillin and epoxidised vegetable oils as their sustainable feedstocks.

Circuitboards

Moving from the large-scale of the wind turbine to the small scale of the digital world, the biobased vitrimer has even more surprising applications as a new type of circuitboard material.

Scientists from the University of Washington have found a way to replace the resin in circuitboard fiberglass with vitrimers. The resin material in circuitboards function as the flat surface on which chips, resistors, and transformers are printed. They are currently difficult to recycle because its constituent ingredients are difficult to separate out in a way that can be economically viable.

A “vPCB” (vitrimer printed circuit board) on the other hand can be recycled by being immersed in an organic solvent with a relatively low boiling point. Once the vitrimer is treated in this way it swells and forms a jelly-like material that can be re-used. This recycling method also leaves the circuitboard’s electronic components undamaged.

The biobased vitrimer circuit board is one of the earliest attempts to show the real commercial applications of this new polymer class. The research emphasised that these new biobased circuit boards could be made at existing electronics plants and can be recycled multiple times, reducing the carbon footprint and carcinogenic emissions of circuitboard manufacturing.

Towards commercialisation

Biobased vitrimers are such a new type of material that more research needs to be done on ways that its strength and re-processability can be maximised, as well as on how to best enhance particular properties or particular applications.

R&D is not the only thing that will get these materials to market. To commercialise, biobased chemicals either need to have staunch regulatory backing or far out-perform legacy materials across diverse applications to justify the costs of producing them.

Biobased vitrimer’s self-healing capability is one unique selling point of the material.

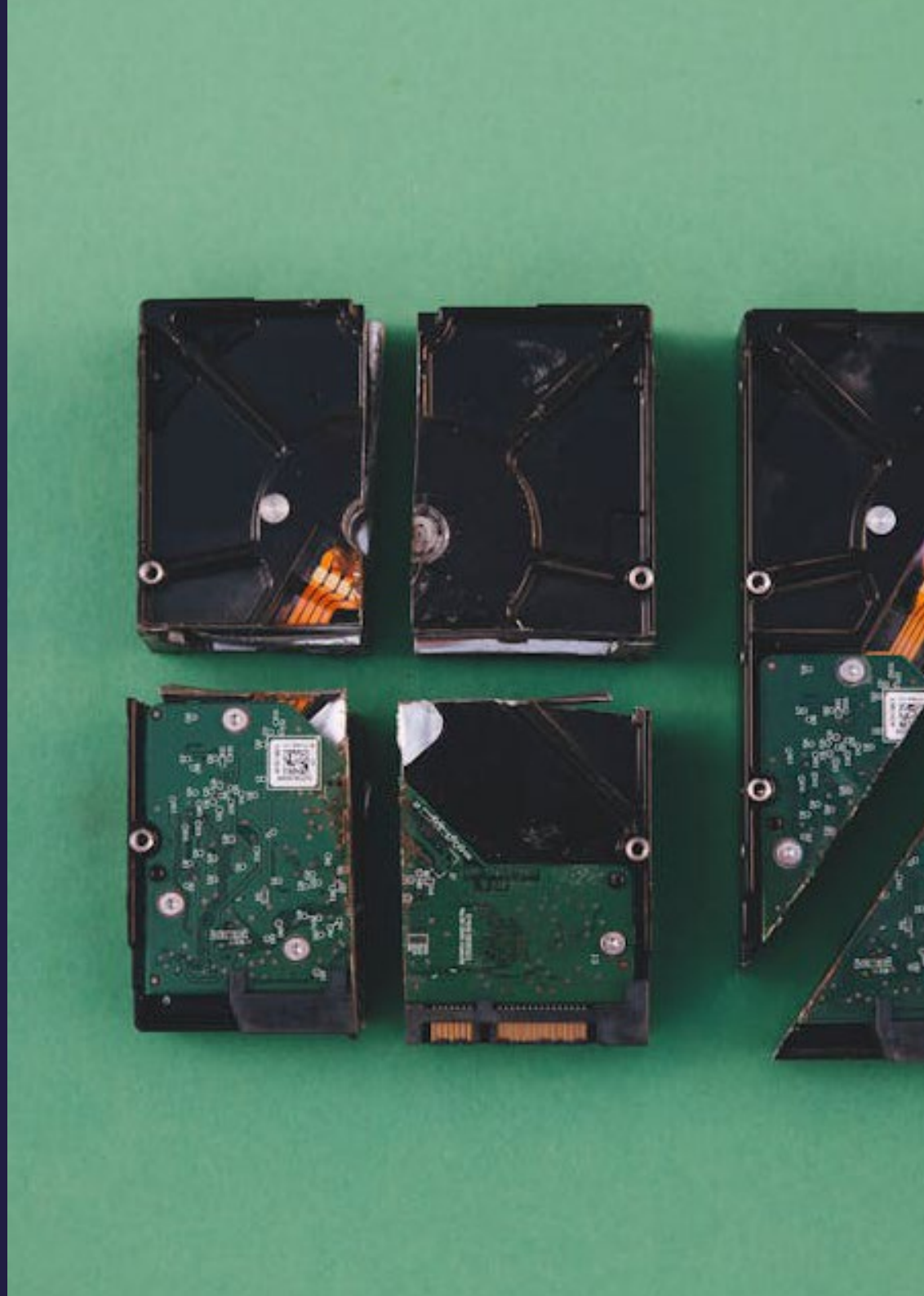
For certain vitrimers, however, we still need more research into maximising their mechanical strength relative to petroleum alternatives.

Another way to find a bigger market share is to fully lean into the operating cost-lowering aspects of green chemistry. One advantage of green chemicals is that biobased compounds in general do not require the very high temperatures needed to make ordinary synthetic chemicals. Finding biobased solvents and catalysts that can make the vitrimer manufacturing process more cost-effective (and, in general, less toxic) than petroleum polymers will be crucial in achieving a market edge.

MARCH 26, 2025

Why Europe should scale urban biomining

Urban biomining can unlock valuable metals in post-consumer waste, aligning with EU targets for critical minerals, economic revitalisation, and security



EU critical minerals supply chains are currently highly vulnerable to disruption. Biobased e-waste mining could open up new domestic sources sustainably while meeting the EU's new needs in defense planning.

We look at the multiple advantages offered by this emerging biotechnology, which uses living organisms to recover valuable and strategic resources.

The EU's mineral dilemma

The advent of new sectors like EVs and EV batteries presents the EU with a resource problem. Electrification and renewables require certain kinds of metals previously classed as 'minor', having limited industrial uses.

The elements we need to build the renewable age are referred to as 'critical minerals'. Most major economies have varying definitions of what constitutes a critical mineral. Still, there are certain elements that different governments consistently agree are vital to their strategic interests, including lithium, cobalt, manganese, and various rare earths.

The concern is that demand for critical minerals may grow quicker than supply over the next decade, especially in the West, which has so far lagged behind geopolitical adversary China on securing supply lines.

Chinese companies already operate a large portion of the world's critical minerals mines at incredibly low costs making it difficult for regions like the EU to catch up at scale – particularly in a manner that would be environmentally sustainable.

Moreover, the EU has limited reserves at home. To shore up its mineral supply would mean entering trade deals with mineral-rich regions, like South America or Africa.

An alternative to imports

While imports will always be vital to the EU's resource security, boosting domestic supply of strategic minerals as far as possible is still a key concern for the bloc. Relying on external suppliers runs the risk of supply disruptions from political instability. Weaker regulatory landscapes can also mean environmentally more harmful materials.

Urban mining could offer an alternative way to boost critical minerals supply in a sustainable way. Unlike ordinary mining, it does not draw on virgin materials from natural deposits made up of rock or brine. It involves extracting valuable metals and minerals from post-consumer waste and re-using them.

A greener way to mine

The EU produces about 5 million tonnes per year of e-waste: used and discarded phones, laptops, computers, and printed circuit boards. Although they are a treasure trove of high value resources, it is still uneconomic to take apart and recycle them, partly thanks to the costs of sorting. Until urban mining capacity scales, these piles of waste will go to landfill, posing a toxic threat to ecosystems.

Urban mining can be done in several ways. Today, non-biobased hydrometallurgy and pyro-metallurgy dominate.

However, these conventional methods for extracting metals from waste are extremely toxic and energy intensive. First, they require huge

volumes of acidic and basic solvents. Like many industrial processes involving synthetic chemicals, they both need very high temperatures to work, making it energy intensive and costly to operate. Third, these processes generate dust particles, toxic gases, and acid leachates that can poison waterways.

Biobased urban mining, which uses living organisms to selectively recover metals from waste – avoids many of the environmental problems that come with hydrometallurgical and pyro-metallurgical approaches. These methods are renowned among scientific researchers for their sustainability profile, requiring lower temperatures to be effective and smaller carbon footprints.

The scientific literature is full of bacteria and fungi that have been proven capable of leaching particular metals from waste. The EU has also funded several projects in the area, such as BIORECOVER and RAMINA, RUBICON, and BIOCriticalMetals. Now, years of research into urban biomining may be about to enter a new wave of commercialisation as regional independence in critical minerals looms larger than ever in EU policymaking.

The European firms driving biomining

An important recent urban biomining partnership was announced in February 2025 when Brain Biotech, a leading German biomanufacturing company, announced it was working with PX Group to develop a proof of concept for recovering gold from e-waste using biological means.

One of Brain Biotech's previous projects was to develop a mobile pilot plant for bioleaching gold from waste using microbes. The unit, called BioXtractor, was developed and tested with the help of PX Group a few years back. Their latest partnership with PX Group will test the performance of the mobile bio-mining unit at a larger scale.

There are several types of biomining and bioleaching is currently the most common in the commercial space. This is the type that Brain Biotech deploys. Bioleaching uses living microbes to extract metals from e-waste. Specifically, it relies on the chemical compounds excreted by these microbes as they metabolise to dissolve the metals and make them easier to recover.

Europe has a couple of other companies offering biobased urban mining tools. BiotaTec based in Estonia, founded in 2007, offers biomining tech for making critical raw materials more available in industrial waste, including e-waste. In the UK, N2s offers services in recovering metals from e-waste using bioleaching.

Further afield, New Zealand's Mint Innovation is another biobased urban mining startup focused on recovering both precious metals like gold and critical minerals.

Apart from microbes, scientists have long investigated fungi as a potential tool for metal recovery. However, fungal biomining tools are even less scaled than microbial pathways thanks to the slow growth rates of candidate species and the high costs of growth media.

Meeting mineral targets sustainably

Urban mining is still in its early stages and biobased methods in particular are still an emerging technology. Yet a changing geopolitical landscape is now, more than ever, providing impetus for more EU investment and policies targeted at scaling this low-impact mining

technology.

Brain Biotech and PX Group's biomining project was announced just before the 2025 Munich Security Conference, where EU and world leaders meet annually to discuss international security challenges.

Critical minerals were top of the agenda and there were sustained references to recycling as a crucial way for resource-poor Europe to secure them. During the conference, the European Commissioner for Environment Jessika Roswall stated that less than 1% of the critical raw materials in use comes from recycling. She urged the EU to close the mineral loop and keep valuable materials in circulation.

Roswell promised the Munich Security Conference that she would prioritise a competitive circular economy for critical minerals under the recently implemented Clean Industrial Deal.

Recycling metals from waste meets a key EU economic and foreign policy aim of the post-COVID years: diversification. Diversification means expanding the range of critical raw materials suppliers that the EU sources from. This aims to prevent import dependencies, especially on geopolitical rivals like China and Russia. Biobased methods speak directly to this need, offering the most environmentally sound way of scaling a European urban mining industry that reduces the bloc's reliance on third countries to access the materials it needs.

Recycling in general is already important in existing EU policy on achieving resource independence. The bloc's 2023 Critical Raw Material Act, written to wean the EU off China and other external suppliers, set a bloc-wide target that a quarter of the EU's annual consumption in critical minerals should come from recycling by 2030.

The EU's Critical Raw Materials Act was followed up by the 2025 Clean Industrial Act, which places similar emphasis on recycling key raw materials to, as far as possible, onshore the production of minerals and metals.

The defence dimension

Biotech for urban mining meets many of the EU's current policy priorities. It is one of the only ways that the EU can boost its domestic production of critical minerals in a way that is environmentally sustainable. There are also clear economic benefits to deploying biobased methods for urban mining.

It also serves a relatively new policy priority: building out its regional defence capacity. The 2025 Munich Security Conference was a historic moment for Europe as US Vice President JD Vance told delegates that the EU could no longer rely on his country for security guarantees.

In response, Germany and France are now calling for EU cooperation in increasing its own defence production. With many critical minerals having both renewable and defence applications, the push to build Europe's military capacity will no doubt give a boost to urban mining projects.

Yet the industry will still need clear backing from the EU to make the leap from small-scale production. Consistent policy is needed in the form of targets backed by financial incentives for companies to procure and produce recycled and low-carbon critical minerals.

APRIL 8, 2025

What does ‘biodegradable’ packaging really mean?

We explain the term and how it differs from ‘compostability’

Biodegradable packaging can help tackle toxic plastic pollution. But what does it really mean when a product is labelled as biodegradable? We explain the term and how it differs from 'compostability'.

The problem

Plastic pollution is choking the planet. 99% of all plastics today are made from petrochemicals that stay in the environment for hundreds of years, breaking down into hazardous microscopic pieces. These particles become small enough to leak into the human food system via soil, plants, and livestock.

All life on earth has become unwilling guinea pigs in the microplastics experiment: scientists are not clear on how damaging the long-term health effects of exposure will be. Urgent solutions are needed and biodegradable materials offer one way out.

Eliminating plastics outright where possible should be the priority. However, certain single-use products need plastic or plastic-like packaging for hygiene purposes. Plastics are also hard to replace in many industrial applications.

What industry needs are materials that mimic oil-based plastics but behave like biological materials at the end of their product life.

This is where biodegradable plastics come in.

The ideal sustainable packaging

By 2040, packaging is forecast to account for roughly 40 percent of plastic waste generation worldwide, according to one estimate.

Single use plastic packaging that serve a hygiene purpose can be difficult to eliminate. This is an obvious area where biodegradable alternatives could be useful.

The ideal sustainable packaging material for single use would decompose if left in the natural environment, just like a piece of wood on a forest floor.

An ideal sustainable packaging material would also decompose without toxic byproducts and only release harmless substances found everywhere in nature.

There is one caveat here, which is that no material – even completely natural ones – is entirely 'traceless'. This is obvious in the sense that matter never really disappears.

In a less obvious sense, no material is universally biodegradable in every environment on earth. This is because the temperature, light, and the microbe species present in any particular ecosystem will determine how fast any material will degrade and whether they do so safely. Every ecosystem is different so there is no guaranteeing that a material will behave the same way in all of them.

That being said, unprocessed natural materials (think bark, fur, food waste) and certain processed ones (plastics made from plant matter) tend to break down more safely, quickly, and in far more diverse environments, than materials made using petrochemicals.

Taking these constraints into account, a truly sustainable packaging material would be one that breaks down into harmless compounds over a reasonable time span in many different natural environments,

especially those where plastic waste tends to build up: soil and the sea.

This ideal sustainable packaging will most likely be a biomaterial or bioplastic, since they tend to be easier to break down into environmentally harmless compounds.

Bioplastics are a specific type of biomaterial. Many are suitable for packaging because they can closely resemble oil-based plastics.

The diversity of bioplastics we have at our disposal today is matched by the diversity of behaviours they exhibit once discarded. Which ones biodegrade? And what does that mean?

What biodegradable really means

Today, we can fashion many kinds of plastics using a range of raw biological materials. To sort through the choice on offer, eco-aware consumers seeking sustainable packaging will often look out for keywords like 'biodegradable'. However, this marketing term does not necessarily mean that the product is better for the planet.

In general use, a biodegradable material is one that breaks down under certain conditions. However, it says nothing about precisely what conditions the material needs to break down safely, nor the amount of time that it will take to break down.

When you see the term 'biodegradable' on a product in the supermarket, it tends to mean something a bit more specific: that the material breaks down only if collected and treated in a specialised composting plant. These facilities offer a finely-tuned environment designed to break apart the bonds of these materials.

Unable to break down safely in marine or soil environments, materials labelled biodegradable need to be taken to a properly equipped industrial composting facility in order for them to meaningfully tackle plastic pollution.

Biobased and biodegradable plastics like PLA and PP do not break down safely or quickly in a natural environment or even a home compost heap. The need for industrial facilities is not widely known among consumers, many of whom try (and fail) to compost these materials in their garden.

What we are seeing here is consumers mistake biodegradable products for home-compostable ones. The latter, which include potato starch bioplastics and certain algal bioplastics, can easily break down in a garden compost heap.

The problem with 'biodegradable' materials

The problem with biodegradable materials does not end at a lack of consumer awareness around their end-of-life treatment procedures. There is also a global infrastructural bottleneck.

Biodegradable plastics confront the same problem as recyclable plastics since there is nowhere near enough industrial capacity to break down the amount that is manufactured each year.

In theory, both biodegradable bioplastics and plastic recycling are strong solutions to the plastic pollution problem. Yet in practice, margins have remained too low for recyclers and composting firms alike to invest in enough capacity.

Without the capacity to treat them, a lot of biodegradable bioplastics are dumped into the environment, where these biobased materials can be just as dangerous to human health and wildlife as ordinary synthetic plastics.

More infrastructure for collecting and composting biodegradable plastics is needed to prevent them from contaminating natural environments. This is especially because we cannot use compostable materials in every applications.

There is often a trade-off between long-lasting material performance and compostability. Home-compostable materials are ideal substitutes for single use petroleum plastics packaging. However, they are less suitable for replacing other more durable applications such as industrial equipment or automotives.

As biodegradable plastics often have properties that are not easy to achieve with materials that break down so readily, they will remain an important part of the sustainable materials toolkit.

Standards and regulations

For the 'biodegradable' label to better support sustainable consumption, however, we need more laws governing when and how companies can use the term on their product.

This includes the UK, where companies are not regulated in their use of biodegradability claims, leaving the door open to greenwashing and consumer mistrust.

In the EU, there is a harmonised standard that lays out the criteria that a product has to meet to be classed as industrially compostable. There is another standard laying out the definition of biodegradable mulch films used for agriculture. However, there is no general standard defining what it means for a material to be 'marine biodegradable'.

Standards are one thing but imposing regulations that govern how companies talk about their products is a much more difficult step. There is some movement on this in the EU parliament. In 2024, it finally adopted a directive that would force companies to submit evidence if they are to use marketing claims like "biodegradable".

"Without the capacity to treat them, a lot of biodegradable bioplastics are dumped into the environment, where these biobased materials can be just as dangerous to human health and wildlife as ordinary synthetic plastics."

The science of biodegradation

Formulating regulations around biodegradability claims can be complicated but not impossible. There are many rigorous standards and assessment frameworks that have been developed by international and national bodies on the question.

Scientists already deploy precise ways of assessing biodegradability. Mostly this revolves around measuring how much of a material degrades in a given time frame in a given environment.

For example, a UCL study into materials labelled 'home-compostable' reported that 45% of materials they tested had either completely disintegrated or broken down to less than 2mm.

Robust labeling laws would force companies to label their products in line with the material science of biodegradability, taking the guesswork out of sustainable purchasing. Marketing language would be tied to laboratory, simulation, and field tests that show how rapidly materials break down in synthetic, industrial, and natural environments.

Industry & consumers need clear labels

Biodegradable bioplastics could play a vital role in the fight against plastics pollution. However, regulations are hampering industry growth.

Regulation is an under-appreciated factor in scaling the biobased industries. Today, a biobased company could develop a low-cost, high-performance biopolymer that easily biodegrades in diverse natural environments. Yet without the backing of regulatory authorities, it will have no easy way of proving these claims to the consumer.

Verified labelling would help sustainable materials companies find and expand markets more efficiently.

Consumers equally have a lot to gain from scientifically-grounded and tightly regulated labelling tiers indicating the degradability of packaging. It would leave them much less vulnerable to paying a green premium for products that do not necessarily live up to its sustainability claims.

In the rush for renewable alternatives, consumers and producers must not overlook the nuances of how materials behave when they reach natural environments. Further growth in the biomanufacturing industries will depend on clear labelling regulations that give producers and consumers alike much-needed clarity.

APRIL 16, 2025

Cracking form: eggshell innovations tackle plastic and pollution

Here are some of the most innovative eggshell-based materials on the market or in development today

Eggs are a symbol of springtime renewal. But did you know they can also support renewability?

Companies have been developing new materials using eggshell – a renewable, circular feedstock with applications as diverse as car tyres and skincare.

As a sustainable material, eggshell ticks all the right boxes. Annually, the world produces around 7.2 million tonnes of this biodegradable debris, making it an abundant and cheap feedstock.

Biomaterials made from waste eggshell are also circular, meaning they come from waste that has been cycled back into the economy as higher value goods.

Here are some of the most innovative eggshell-based materials on the market or in development today.

Stellantis – egg filler for sustainable tyres

With its reputation for fragility, perhaps carmaker Stellantis has developed one of the most surprising eggshell bio-innovations.

Stellantis is one of the biggest carmakers in the world and has recently developed a way of turning eggs into a calcium carbonate tyre ingredient.

It filed a patent for the innovation in February 2025 and claims it could make tyres more sustainable.

The eggshell-derived calcium carbonate would replace traditional, dirtier tyre material fillers like carbon black – a fine black powder made from burning hydrocarbons that makes tyres more durable.

The innovation showcases the impressive range of physical properties and applications that eggshells can offer once processed.

The company claims the technology could lower rolling resistance by 20 percent as well as improve fuel efficiency.

Rania Elakalla – egg 'marble' for homeware and design

Rania Elakalla is a Berlin-based designer who has pushed the limits of eggshell as a material for interior design elements.

By combining waste eggshell with nutshell, she has achieved a translucent, mineral-like material that resembles marble. Its name is Shell Homage.

Eggshell makes for a perfect circular input in construction because despite its biological origins, it counts as a mineral.

Eggshells are composed mostly of calcium carbonate, a substance which they share in common with almost every building you enter since it is an ingredient in cement.

One of the most stunning natural forms that calcium carbonate comes in is marble. Unlike real marble, however, Elakalla's material is made from two common waste byproducts of the food industry, avoiding the ecological impacts that come with mined rock.

The eggshell material takes on an astonishing rainbow of coloured

dyes and can be machined, sanded, or laser cut, forming anything from elastic sheets to hard surfaces depending on the production method.

The material is also 100% biobased as the bonding materials Ellakalla uses in them is made from renewable materials.

Its beauty and versatility mean that Shell Homage has the potential to replace more resource-intensive materials in homeware and design like plastics.

Ecoshell – biobased additive for plastics

US company Ecoshell has patented an eggshell filler for plastics.

Once eggshells are powdered and made into pellets, they can be dropped into virgin plastics and served up to the consumer without any loss in performance.

The end result is a material that is between 30 percent and 50 percent egg-based, cutting back on the need for virgin plastics and reducing the carbon dioxide impact of the material.

Composite materials like this which mix biobased and petrochemical substances can be a useful compromise for consumers and industry that want to lower their carbon footprints.

Composites that contain some low carbon circular and renewable materials lower the environmental impacts of a production line without having to re-fit equipment and supply chains for a switch to 100% biobased manufacturing.

In this case, Ecoshell reported that mixing in their eggshell-based pellets into plastic cuts 70 percent of the carbon emissions associated with the end product.

EGGXPERT – eggshell in skincare and 3D printing

EGGXPERT is a Dutch company working with waste eggshell to create many different materials across industries. Their work highlights the real versatility of the chemicals contained inside the humble waste food.

90 percent of eggshell waste consists of the mineral shell. However, EGGXPERT specialises in using up the thin membrane tucked inside of it.

Using the membrane the company has developed a circular peptide that can be used in the skincare and beauty industry as an ingredient.

Peptides are the building blocks of skin. It is a popular ingredient for the skincare and beauty industry because it is responsible for building all the components of skin that make it look young and healthy, like collagen and elastin.

The peptides in our skin are produced naturally by our bodies. However, when manufactured artificially for skincare products, these compounds can cause a lot of environmental harm.

The skincare industry generally uses peptides from petroleum feedstock and synthetic chemicals. Compared to these, egg membranes offer a gentler, circular input.

EGGXPERT's renewable peptides tap a growing market for sustainable cosmetics. The renewable ingredient fits the bill for an industry that often brands itself as using natural ingredients that support environmental health while being gentle on the skin.

Skincare is only one of the areas that EGGXPERT are working in. The company has also devised a very different material from eggshell, one it hopes will make the the 3D printing industry more sustainable.

EGGXPERT offers refined eggshell powders that can combine with biodegradable bioplastics to form more sustainable materials that can be used in 3D printers.

The product opens a pathway to reduce the use of oil-based, non-biodegradable plastics by the 3D printing industry.

University of Saskatchewan – eggshell bioplastic to combat pollution

A new eggshell-based plastic could clean up environmental pollution while securing strategic commodities in the process.

In 2024, Dr. Lee Wilson from the University of Saskatchewan in Western Canada, published a paper on a new eggshell-based bioplastic that could tackle fertiliser pollution in rivers.

The bioplastic material he developed contains chitosan – another biobased mineral, which is found in the shells of marine life – as well as eggshells and wheat straw.

The material is designed to tackle phosphate pollution, a huge environmental problem worldwide.

Phosphate is used to fertilise agricultural soils. However, excess amounts applied to fields are highly environmentally damaging.

When farmers overapply the mineral, the surplus washes off from the soil into rivers and lakes. When the material builds up in waterways, it can kill wildlife.

The second ecologically damaging aspect of phosphates is that it has to be mined from rock. This can be a carbon-intensive process that can harm habitats and wildlife.

Wilson's eggshell bioplastics try to address both of these problems. The material is designed to suck up excess phosphates from polluted water.

Once saturated with phosphates, farmers can apply the biodegradable eggshell bioplastics to the soil. Here, it will break down to release its mineral load and fertilise the soil.

The bioplastic therefore doubles as an environmental clean-up tech and a tool for reducing agricultural demand for mined phosphates.

This biobased innovation might have come at an opportune time. Global trade links are fraying, leading some regions to strengthen domestic supply chains in key goods like phosphate.

Circular solutions like Dr. Wilson's eggshell bioplastic could attract growing interest in the EU – a big agricultural producer heavily dependent on fertiliser from abroad.

UCL – healing egg membranes

Then there are the biomedical uses of eggshell membrane.

In terms of volume, the membrane forms a tiny portion of the eggshell. However, this natural wonder material punches above its weight when it comes to repairing damaged tissue.

Studies have shown that modified eggshell membrane can help in wound healing because it is so rich in molecules that aid tissue repair, including collagen and cysteine.

Following on from this, a research team at UCL have developed and validated a method for extracting the eggshell membrane intact and without changing its chemical properties.

The team have also developed a protocol for modifying the eggshell to improve on its natural properties for wound healing.

The team notes that its manual for extracting and treating eggshell membrane could be useful beyond biomedical applications.

The team points out that once extracted and treated in this way, the material could act as a biodegradable packaging that can replace oil-based plastics in certain applications.

Some examples of packaging applications where modified eggshell could work are wrapping, cling film, doggy poo bags, disposable wet wipes, and teabags.

Egg membrane is well-suited to biomedical and food packaging applications because it is highly biocompatible. This means that our immune systems are unlikely to reject it.

These emerging applications show that eggshells and their membranes have all the hallmarks of a super circular material.

While they may be a niche feedstock today, ecological and geopolitical pressures could soon favour faster adoption.

With climate change and new global trade patterns forcing more countries to reevaluate where their raw materials are coming from, widely available byproducts like eggshell could become far more common industrial input.

APRIL 23, 2025

Why insect protein is creating a buzz in Brazil

Brazil's entry into insect protein is only just beginning but with scaling, it could help drive greener global food systems

Insects are a future source of sustainable livestock feed and Brazil is an emerging site of investment.

Brazil's entry into insect protein is only just beginning but with scaling, it could help drive greener global food systems.

A boost to Brazil's insect sector

Brazil's bioeconomy is best known for its conventional agricultural exports like coffee or beef as well as biofuels production.

However, insect proteins could be a new biobased growth sector for the agribusiness giant. The most promising indication of this came in January 2024, when Japan's Sumitomo Corporation announced a joint investment into Brazilian insect protein producer Cyns.

Based in Brazil's capital Sao Paulo, Cyns has 15 years of experience cultivating protein-rich insects designed for use in animal feed. The 2024 funding round from Sumitomo was the first step towards scaling, with plans to establish a new rearing facility. They aim for Series A funding by 2026.

The hunt for climate-friendly protein

Sumitomo is a Fortune 500 company and one of the world's largest trading companies. Its Cyns investment was significant because it involved a major foreign investor betting on sustainable food production as a long-term trend in Brazil and its export markets.

This is because Cyns and other insect protein producers could meet a vital need in the climate tech space: a new, abundant, and sustainable source of proteins for livestock animals.

So much of the climate and ecological crisis stems from the way we eat and how we produce it. Animal products are a major culprit, accounting for 16% of global annual greenhouse gas emissions.

One reason that livestock farming today is so unsustainable is that animals need to eat lots of protein. The protein we feed to livestock generally comes from crops like sunflower seed, soybean, or rapeseed.

Huge demand for livestock feed worldwide means lots of the crops under cultivation today are actually for animal rather than human consumption.

The problem is that there is only a limited amount of fertile land available. This creates competition over land between food for direct human consumption versus animal feed consumption.

On top of this, eating livestock meat is an inherently wasteful way to get protein. This is because at each stage in the food system – from plants to livestock, livestock to humans – energy and nutrients get lost as heat or in materials that cannot be digested.

Cattle are particularly bad converters of feed into meat. Just 1.9 percent of the protein in their feed, for example, get converted into an animal product ready for consumption.

This means that lots of precious land, fertiliser, water, and other resources used to grow protein-rich crops are going to waste.

The future of livestock farming

Scientists are clear that the world must cut back on overall meat

consumption to meet climate and nature targets.

At the same time, some livestock farming is likely to continue. Some modelled scenarios where we meet climate change targets do allow for limited meat consumption.

Yet the future of livestock will be very different to the way it is today. One area crying out for change is animal feed. The industry must source new kinds of proteins for their animals. These future feeds must keep resource use and wastage to a minimum.

This is where Cyns comes in. The company has found a way to grow commercial quantities of the fly species Hermetia illucens, better known as the Black Soldier Fly. They then processes their larvae into a rich flour meant for the animal nutrition market.

The company claims that livestock feed made using a flour obtained from its larvae can cut the inefficiencies associated with using soybean, rapeseed, or sunflower seeds to feed livestock.

Scrumptious larvae

Cyns processes their flies when they hit their larval stage. This is when the insect is wingless and wormlike, waiting to change into their final winged form.

Larvae tend to be rich in easily digestible proteins. Black Soldier Fly's larvae are particularly nutritious. Protein content ranges from between 30 grams to 53 grams out of every 100 grams of dry matter. Cyns claims their larvae offer gross protein of above 50 percent.

Cyns stands out for having been the first company to obtain regulatory approval to make and sell Black Soldier Fly-based animal feed ingredients.

Livestock is not the only end market: Brazil's dog and cat food market are also ripe for sustainable inputs. Its pet food market is increasing 5.6% in terms of volume annually. Brazil's is also the world's fastest growing pet food industry.

Pet food is generally not as big a contributor to climate change and habitat destruction as the livestock feed industry. However, with the global pet population increasing, the industry's impacts are also growing, quickening demand for sustainable feed options here too.

> "Often, the nutrients and compounds locked up in organic food or farming waste is so diluted that it can be hard even for human industries to extract and use them at cost."

Natural upcyclers

Critters like the Black Soldier Fly are workhorses of the future proteins industry because they are natural upcyclers. This means they can eat and make use of low-energy, low-nutrient materials that other species struggle to exploit.

Often, the nutrients and compounds locked up in organic food or farming waste is so diluted that it can be hard even for human industries to extract and use them at cost.

The insect metabolism is different: evolution has equipped them with a biological system that can convert low value waste into high value compounds. It means they can concentrate nutrients diluted across high volumes or low quality waste into their bodies.

Cyns takes advantage of this upcycling ability. The larvae of Black Soldier Flies are plump reservoirs of high-quality proteins that can be easily processed into feed-grade flour. The end product is very far from the low-energy byproducts that the insects were fed on.

Insects against deforestation

For a nation built on cattle ranching, food tech like insect proteins is still an emerging industry in Brazil. So why is Japan's premier trading firm investing in it?

What Sumimoto likely saw in Cyns is a way to profit from mounting demand within Brazil's huge agribusiness sectors for sustainable farming inputs.

Brazil's feed market size was estimated to be $22.91 billion in 2022. A CAGR growth rate is forecast at 5.67 percent between 2023 and 2029 – unsurprising for the world's biggest beef exporter at a time when global meat consumption is growing.

Yet Brazil's agribusiness sector is in need of serious sustainability reforms. Right now, it contributes a fifth of its overall greenhouse gas emissions.

One of the biggest obstacles to reducing its agricultural impacts are soybeans – one of its biggest exports. Soybeans are used to make 70% of the world's livestock feed. Brazil tops the global rankings for share of exports.

Brazilian soybean is increasingly a toxic brand. Brazilian producers have destroyed highly biodiverse natural habitats to clear space for fields of this lucrative export crop.

A major driver of more sustainable bio-industries in Brazil will be regulatory shifts in big export markets like the EU, which is due to ban imports of soy linked to forest destruction.

Over coming years, increasing demand for sustainably produced food and feed from export partners could make insect protein-based livestock feed more appealing to Brazilian producers.

Brazil diversifies

Insect proteins could be one way for Brazil to diversify its bioeconomy and help the world to move away from habitat-destroying soybean cultivation.

Progress on scaling sustainable agricultural inputs in Brazil would have ripple effects across global supply chains. Not only is it a huge agricultural producer and a top agricultural exporter, it is also one of the most biodiverse countries on the planet.

Shifting Brazil's economy away from mass soybean production would support global conservation targets, helping protect habitats like the Amazon.

Scaled sustainable insect feed would also help food supply chains around the world reduce their ecological impacts. So much soybean comes from Brazil that many meat value chains around the world are intimately bound up with Amazonian deforestation. Scaling insect protein and exporting it could help make food systems elsewhere less destructive.

The insect protein value chain is still only just emerging in Brazil. Costs are not competitive compared to conventional protein sources. Some of this is down to the fact that insect feed production remains artisanal. More automation would lower costs.

On the plus side, demand for insect protein-based feed outstrips supply meaning plenty of room for capacity investments.

By leveraging its advantages, the country could construct a new export industry that finally breaks the link between livestock and Amazonian deforestation.

APRIL 30, 2025

Sonic sustainability: fungi and silk in musical instruments

Silk violins and Stradivarius-mimicking fungi open pathways for musical sustainability

Wood is at the heart of traditional instrument making. Yet climate change and deforestation is depleting the most sought-after varieties.

Biobased innovations now offer alternatives, including spider silk violins and fungal biotech. But can they compete with the traditional material on sound quality?

The spider silk violin

"The world's first silk violin" is what designer Luca Alessandrini has called his composite instrument, which replaces wood with a mix of biobased silk fibres.

This hyper-modern violin is pale and translucent. Despite its milky glow, Alessandrini's instrument behaves a lot like its traditional wooden counterparts.

His violin is made from silkworm silk, resin and spider's silk. The latter has resonating properties – the crucial ability of a material to respond to string vibrations in a way that amplifies their sound.

Alessandrini's design is a striking example of biomimicry, a field that borrows mechanisms evolved by living beings and applies them to solve human engineering problems.

Spider's silk is resonant because spiders use their webs to communicate. Using their silken structures, they transmit sounds that are below the range of human hearing.

Yet replacing wood in musical instruments is a formidable design challenge. Even aside from the cultural attachment to traditional materials, it is also very difficult to replace the rich tonal qualities inherent to certain wood species.

Different wood species interact with sound in very different ways, meaning that just a few choice species are coveted for violin making.

Alessandrini's material aims to replicate this complex variability of natural wood. Manufacturers can customise the amount of silkworm silk and resin. Changing this ratio can make the instrument sound very different when played.

His biotech violin already has a stamp of approval from Peter Sheppard Skaerved, a Grammy nominated violinist who says the new material comes much closer to the "organic subtitles of wood" than carbon fibre – today's standard substitute for wood.

Scaled biobased substitutes to carbon fibre could tap a valuable and growing market for non-wood instruments. Carbon fibre instruments are estimated to hit 1.73 billion in global value by 2033, representing a CAGR of 15.6% from 2024.

Music and sustainability

If wood comes ready-made with special sonic qualities, why the need for new instrument materials at all?

Right now, the instrument manufacturing industry is implicated in the global problem of habitat destruction. Each year, the world loses a Portugal-sized area of forest, mostly in tropical zones.

With illegal logging accounting for 15 – 30% of global timber

production in 2019, it is almost inevitable that some of the industry is sourcing from the black market, whether knowingly or not.

The industry is problematic from a biodiversity standpoint. Certain woods are highly sought after in instrument-making. Known as 'tonewoods', they are usually old and rare trees located in the tropics, home to hyper-diverse forest habitats and among the most vulnerable to logging.

Demand for the tonewoods has already led to the destruction of forests and the overexploitation of certain species, such as the rare Brazilian rosewood.

> "Right now, the instrument manufacturing industry is implicated in the global problem of habitat destruction. Each year, the world loses a Portugal-sized area of forest, mostly in tropical zones. "

Its ties to deforestation are not just an ethical concern. The music industry is also aware that overexploitation will deprive them of their tonewood raw materials altogether.

At the consumer end, musicians are becoming more aware about the sustainability impact of their instruments, knowing that the materials that went into making them may have come from a vulnerable habitat.

A new generation is demanding fresh approaches to instrument production that doesn't come in tension with biodiversity.

A warmer, less musical world

The hunt for sustainable materials that convincingly replicate the sonic properties of tonewoods is driven by aesthetics too.

The golden age of violin making was back in the 17th and 18th century. Well-preserved antique violins from back then now fetch millions.

The reason is not just their age. These instruments have sonic qualities that are rare and mysterious, surpassing contemporary factory-made equivalents for their richness.

What makes these baroque-era instruments so special? Scientists have proposed that the answer is climate.

A slight dip in global average temperature during those centuries meant that European spruce, used to form the bodies of these instruments, grew in a more uniform pattern.

It is no accident that the famous violin maker Stradivari used alpine

spruce from higher up in the Italian alps. Cool climates are better for instrumental wood because it encourages regular growth patterns. This produces a fuller, more consistent sound.

Today, the reverse is happening. A rapidly warming climate is reducing the amount of high-quality tonewood available in the world. Changing weather patterns are degrading the resonant properties of wood, even in colder habitats.

Violin-eating fungi

Not all biobased instruments involve replacing wood with exotic new materials. Some designers have found a way of using fungi to make ordinary wood fit for high-quality instrument making,

In 2008, researchers Francis W. M. R. Schwarze, Spycher, and Fink revealed a new violin material they called Mycowood. Using living microorganisms, Schwarze and his colleagues managed to recreate the effect of a much cooler growing climate on low quality contemporary wood.

Mycowood starts off as ordinary wood but the fungi are used to pare down contemporary wood to mimic 17th and 18th century alpine wood – the gold standard in violin manufacturing.

For their pioneering research paper, the researchers applied two wood-eating fungi to contemporary European spruce and sycamore maple, which made up the top and bottom plates of a violin respectively. The fungal species were Physisporinus vitreus and Xylaria longipes.

These fungi decompose thin, targeted layers of the wood known as 'latewood'. The best violin woods contain very little latewood growth as their thick secondary walls dampen overall resonance. Warmer climates encourage more latewood growth, resulting in lower-quality violins. Removing some of it creates a more acoustically pleasing material.

Audience favourite

In their blind test, the researchers got British violinist Matthew Trusler to play five different violins in front of a general audience of 113 participants.

One of the violins was a $2 million Stradivarus made in 1711. The other four were Mycowood violins, all made from a single tree of Norway spruce and sycamore maple but treated with the unique fungal thinning method laid out in Schwarze's paper.

Amazingly, the biotech violin passed with flying colours. Only 39 out of the 113 participants identified the Stradivarius while a significant majority favoured one of the other biotech violins for the sound they produced.

In the years that followed the publication of the paper, the researchers screened 20 different species of fungi for optimal results. They found two organisms: the best results for top and bottom plates of the violin respectively: the P. vitreus and the S. commune. Their strains have now been deposited at the Westerdijk Fungal Biodiversity Institute, Utrecht, The Netherlands.

The originators of this fungal manufacturing method claim that with the proper backing, they could manufacture superior instruments at a fraction of the cost it does today. They believe that their fungal biotech

can replace the dwindling stocks of high-quality tonewoods brought on by climate change.

As with all biotech innovation, this one raises ethical concerns. Will traditional makers be able to compete? For now, at least, the price tag for a mass-produced Mycowood violin is forecast to reach up to $30, 000 – similar for a premium-quality modern violin.

Fungal guitars

Guitars are another string instrument that could benefit from a fungal revamp.

Luthier and designer Rachel Rosenkrantz of Rhode Island have been using biomaterials to make sustainable instruments in keeping with her ethical values – no plastics, no rare woods.

Her 'Mycocaster' guitar for example features a body created from fungal fibre networks (or mycelia) embedded inside a more solid matrix made of filler materials like dried corn husk.

Like spider's silk, mycelium works so well as a musical material because the fibres are hollow, allowing it to amplify sound.

The production process is relatively straightforward: the filler material and living fungal fibres are both placed in a mould. For a few days, the fungi is allowed to grow and entwine its delicate networks around the filler material. The result is a blocky, styrofoam-like material.

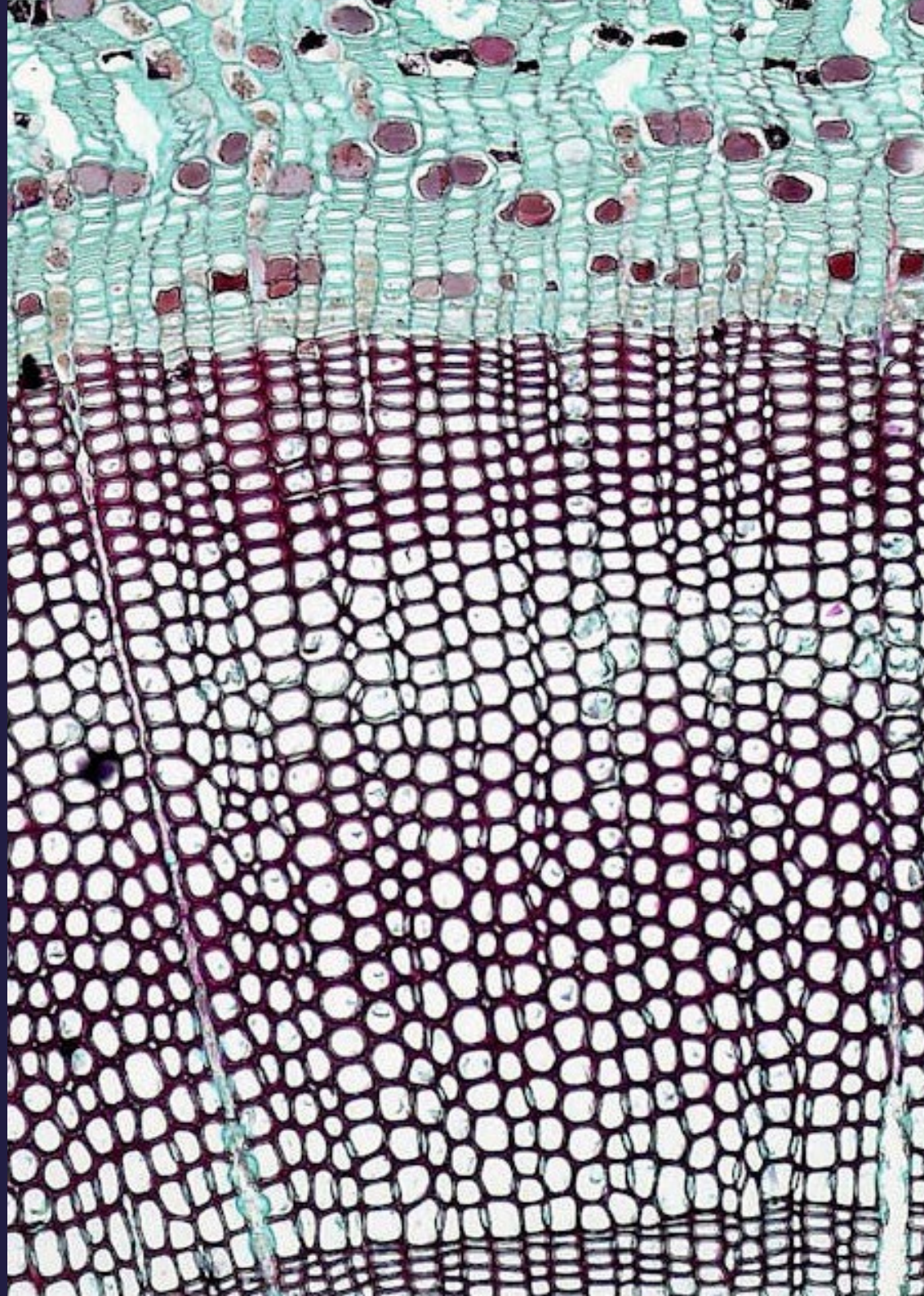
Once removed, the body is dried in an oven. It is then placed in a rosewood outline to protect the spongy material when the instrument is being played. Even though rosewood is deployed, the fungal design cuts back considerably on the need for wood.

The new musical biomaterials show that tonal richness is not just confined to rare, overexploited wood species. Other organic materials are ripe for experimentation, offering an opportunity for the music industry to shift towards more sustainable raw materials.

MAY 7, 2025

Biomaterials are back on the green investment agenda

Biomaterials companies received $392 million in funds in the first three months of 2025 alone



Biomaterials companies received $392 million in funds in the first three months of 2025 alone, according to Net Zero Insights, signalling that investors are returning to the sector.

Like other clean tech segments, biomaterials saw huge influxes of capital in 2022 followed by a corrective dip in 2023. Funding fell from a record $1.7 billion in 2022 to $583 million in 2024.

Now, funding flows could stabilise. If we see a similar performance over the next three quarters, 2025 could end on a near-record $1.5 billion in total sector investment.

Three companies bagged the lion's share of Q1 2025's biomaterials investments: Bloom Biorenewables ($15 million round), Tidal Vision ($140 million), and Pulpex ($80 million).

Who are these companies? And how have they managed to lure back capital after the green investment lull?

Tidal Vision: shell-based clean tech

US biomaterials company Tidal Vision is all about chitosan, the abundant organic material made from a substance found in the shells of crustaceans.

Investors are excited about chitosan for good reason. Chitosan is one of the most versatile sustainable materials, long celebrated by researchers for properties that make it ideal to replace many petroleum chemicals in industrial uses.

Chitosan is also a circular material, a byproduct of living creatures that does not need additional land and resources to create.

Many creatures that build chitin are ones we eat as seafood. The company sources it from discarded crab shells. Naturally, the company's co-founder and CEO formerly worked as a fishing boat captain in Alaska.

Tidal Vision creates custom-formulated chitosan materials for vastly different industries and applications.

One application area where Tidal Vision is working is wastewater treatment. Some chitosan compounds are highly reactive, meaning that it attracts a range of pollutant particles. The company's chitosan-based clean tech can treat water polluted with metals, phenols, antibiotics, and pesticides.

One factor bolstering chitosan's demand potential is that the applications it can be used in are currently dominated by toxic, unsustainable chemicals. Cost-friendly, eco-friendly alternatives are needed to replace many hidden industrial chemicals that pass under the consumer's radar.

For example, Tidal Vision has a chitosan-based replacement for flame retardant finishes, where high-performing biobased alternatives are still hard to come by. Most options on the market today are based on toxic halogen, phosphorus, and phosphorus-nitrogen. All come with high environmental and health risks.

The chitosan biomaterials industry is still in the early stages of scaling and Tidal Vision looks on track to becoming one of the leading Western producers. The US biotech tech company will use its $140 million Series

B funds from early 2025 to expand production capacity. It is currently setting up new facilities in Europe, Texas, and Ohio.

Pulpex

This Scottish renewable packaging firm has a plant-based material that could replace plastic and glass bottles.

Its packaging material comes from wood pulp and the company currently works out of a R&D and pilot facility in Cambridge, England.

According to one Life Cycle Assessment cited by the National Wealth Fund, the Pulpex bottles have between 40-70% lower emissions than 33CL plastic bottles.

Notably, Pulpex gained the backing of two state-owned funds in its February 2025 Series D.

£43.5 million of Puplex's February £62m Series D investment came from the National Wealth Fund, a private fund owned by the Treasury and which aims to drive growth in the UK economy.

Another £10 came from the Scottish Investment Bank, which is a Scottish state-owned investment and national development bank based in Edinburgh.

Interest in Pulpex from state-adjacent investment funds signal that governments see sustainable biomaterials as an pathway to a more robust economy despite the much-vaunted shift away from ESG in the private sector over the last three years.

The company itself is a collaboration between huge corporate players like Diageo, Unilever, PepsiCo, Estée Lauder and Kraft Heinz to find lower carbon alternatives to glass or plastic packaging.

The Series D capital will go towards building its first commercial bottle production facility near Glasgow, Scotland.

Bloom Biorenewables

Switzerland's Bloom Biorenewables raised $15 million in April 2025. Like the other two major Q1 investment recipients, Bloom's product portfolio does not just target one application.

The company specialises in modifying natural biological materials into a substitute for petroleum called lignin. Just like petroleum, this basic chemical holds a huge number of industrial uses. Lignin is a highly abundant substance found in the woody structures of plants, including tree bark. It's what makes plants stand upright, gives tree bark it's 'woody' feel, and gives vegetables their crunch.

Bloom currently markets three lignin-based materials – DPX, cellulose, and lignin. All three are potential biobased building blocks that can perform different functions in diverse industries and replace fossil-based chemicals.

Its DPX, short for dipropylxylose, is an industrial solvent useful for pharmaceuticals, paints and coatings, plastics and rubber and resins.

Solvents are any substance that can dissolve other chemicals to form mixes, called solutions. For many chemicals, water is a very effective solvent. For others, water is not very effective, which means other kinds

of solvents are required.

In pharma, solvents are used for helping along chemical reactions, extraction, and purification of ingredients. In paint, the solvent 'carries' the pigment and gives it the right consistency for application.

Industrial solvents today are overwhelmingly made from oil, gas and other fossil sources. Bloom's lignin solvents are a way of weaning production off of fossil derivatives and bringing down its carbon footprint.

Its lignin-based cellulose, meanwhile, is another industrial allrounder. Cellulose is the most abundant renewable biopolymer on earth and has a vast array of potential uses. Bloom is targeting its cellulose at the cosmetics (as a biobased thickening agent or emulsifier in creamy products) and nutraceutical markets (as a source of insoluble fibre)

Why investors are returning to biomaterials

European regulation

One reason that investors are returning to biobased cleantech is that European regulations around industrial chemicals are tightening up. This is expected to drive up demand for less toxic and biodegradable alternatives.

For example, the EU is formulating new regulations to restrict so-called forever chemicals. This is a class of around 10, 000 non-biodegradable chemicals used throughout industry and which have been linked to cancer and ecological degradation.

> "Forever chemicals are used in almost every industry, meaning high demand for substitutes if more regulation comes into force banning certain compounds. Biobased chemicals offer genuine alternatives."

The current effort to clamp down on these toxic chemicals began in January 2023 when Germany, the Netherlands, Denmark, Sweden, and Norway submitted a proposal to the European Chemicals Agency.

The countries called on the EU to restrict the manufacture, use and marketing of all PFAS under its regulation.

Following a scientific and technical consultation period, the EU is in the process of assessing what restrictions it may impose on an industry by industry basis. The European Commission is expected to issue a final opinion this year.

Forever chemicals are used in almost every industry, meaning high demand for substitutes if more regulation comes into force banning certain compounds. Biobased chemicals offer genuine alternatives. Cellulose-based materials, for example, could replace certain forever chemicals used in textiles and packaging.

Big corporations take the leap

Big names are adopting biomaterials, which can encourage smaller companies to do the same.

For example, Hyosung – the world's biggest spandex producer – invested $1 billion in a biobased spandex production site last year in Vietnam.

Last November, couture house Dior announced it would be incorporating a biobased polymer by Avantium in its packaging.

When assessing the health of the biomaterials market, the focus tends to fall on the big consumer-facing fashion and beauty brands. However, biobased options are also filtering through to the less visible world of essential commodities.

Biocarbon producer Vow Green Metals signed a supply agreement earlier this year with Outokumpu, the largest producer of stainless steel in Europe and the second largest in the Americas.

Better technology, clearer vision

Biomaterials saw record capital flows at the peak of the COVID pandemic. On the one hand, this helped to push sustainable technologies into the limelight. Yet now that the dust of market exuberance has settled, investors are left with a more focused pool of tech and talent.

Over the last three years, producers have had the time to refine and refocus their products. The tech around today is simply better and more likely to scale.

Investors have had time to assess the market too, in order to identify technologies that will best maximise returns through high-volume orders from multiple sectors.

What all three of the big biomaterial investments of Q1 2025 share is the versatility of their technologies. The applications for Bloom's biobased chemicals or Tidal Vision's custom chitosan materials are not confined to just one industry. This kind of adaptability will appeal to investors as it is likely to maximise demand.

The biomaterial funding uptick shows that in spite of any short-term investment trends, the global shift away from fossil inputs will be an enduring theme in coming years.

MAY 14, 2025

How plant-based chemicals trap carbon in rocks

Biobased chemicals offer a plant-based pathway to carbon storage

Biobased chemicals can help lock up carbon dioxide inside rock, a technology we need to reach net zero.

Here's how plant-based formulations could boost the carbon storage sector.

A plant-based pathway to net zero

In November 2024, researchers led by Jiajie Wang at Tohoku University, Japan published a paper outlining an exciting new application for biobased chemicals: geological carbon storage.

Biobased chemicals could make rocks better at absorbing and storing carbon dioxide, a key technology in mitigating climate change.

In a vital breakthrough, the researchers also say these chemicals can allow the carbon storage sector to draw on seawater instead of scarcer freshwater – something that has been a barrier to scaling the sector.

Removing carbon from the atmosphere

Carbon storage is any method of slowing climate change by drawing carbon from the air and locking it up in a more stable form.

Many policy pathway models indicate that we need to install a lot more carbon storage than we have in operation today to meet net zero targets.

The technique will likely play a vital role in reducing the climate impacts of industries that are difficult to switch from fossil to renewable energy, such as in cement or certain chemical sectors.

The International Energy Agency estimates that around 107 Gt of carbon dioxide must be permanently locked up through some form of carbon storage mechanism by 2060 in order to meet global climate goals.

If we do not scale carbon storage, the agency said, the energy transition is still possible. However, it will end up costing much more overall. Without it, we would have to make carbon emissions cuts using more expensive and less developed technologies.

The Royal Society agrees on the need for carbon storage expansion, noting that between 300 and 400 new carbon wells connected to underground storage systems would be required by 2050.

Long-term storage is key

In carbon storage, permanence is key. The longer it can prevent greenhouse gases from entering the atmosphere, the more likely it will help us limit climate change.

To be effective, carbon storage needs to keep gases out of the atmosphere for at least several centuries. This is because human activity is already on track to keep heating the planet for another century or longer.

One promising carbon storage method is the geological route. This involves carbon dioxide gas, dissolved in water, into rock. Over time, the carbon gas mineralises. With mineralisation, the storage process is complete: in its solid form, carbon cannot easily break free and re-enter the atmosphere.

Geological carbon storage is described as a 'permanent' method of carbon dioxide storage. Although nothing is truly permanent when it comes to geology, it is seen as the most surefire way of keeping carbon out of the atmosphere on the longest possible timescales.

Rock and salt stand in the way of scale-up

There are several methods of achieving geological carbon storage. One of them is to inject carbon-rich fluids into rocks that are naturally reactive with carbon.

The approach is viable in theory and there have been two large-scale pilots showing that it is possible in practice. Yet several things stand in the way of scaling.

Right now, there is not enough economically viable capacity. One reason is that only certain kinds of rocks have the right properties.

Basaltic rocks are particularly well-suited as carbon storage but often even they lack the interconnected pores and permeability to allow large amounts of carbon to be easily pumped in.

Ease of injection is vital to reducing costs and increasing predictability out in the field – non-negotiables for companies seeking return on investment into this nascent tech.

To be suitable for carbon storage, rocks must have a high level of permeability and porosity. This means there are only a limited number of sites in the world where geological carbon storage can be safely and economically carried out.

There have been other resource constraints on geological carbon storage. Injecting carbon dioxide into rocks requires large amounts of water. Yet freshwater is precious on a warming planet and is only set to become scarcer.

Seawater is an abundant alternative but there are major problems with using it in carbon storage applications. Seawater contains a lot of salts and sulfates that can dramatically change the chemical reactions that define the carbon storage process.

The biggest problem is that when dissolved in seawater, carbon can mineralise much quicker than when it is dissolved in freshwater. If the carbon mineralises too quickly it will clog pipes and make injection inefficient.

> "In a 2024 study, scientists revealed how an acidic and alkaline version of a single biobased chemical – known as chelating agents -could make geological storage more practical."

A two-step biobased solution

To scale carbon storage using seawater, we need a way to ensure that the carbon gas remains a gas while it is being injected into the rock.

Another way is to find a way of altering suboptimal rocks to make them more suitable as carbon stores. By enhancing the physical properties of rock, we could expand the number of sites around the world that would be economical to use as carbon storage.

The Japanese researchers at Tohoku have found a biobased chemical that they say can do both of these things. In their 2024 study, the scientists revealed how an acidic and alkaline version of a single biobased chemical – known as chelating agents -could make geological storage more practical.

The acid and alkaline versions of the chelating agent are meant to be used at different steps in the carbon storage process.

The acidic formulation has a preparatory function – applying it to rocks makes them more suitable for carbon storage. It increases rock porosity and permeability, in other words, makes sure that the rock has enough air pockets inside it to maximise the amount of carbon gas that can get injected inside.

The alkaline chemical, meanwhile, is used in the actual injection step. When added to the carbon-seawater solution being injected into rock, it prevents the premature mineralisation of the carbon.

The alkaline chemical has a dual function. Later on, once the carbon-seawater solution is inside the rock, the alkaline chemical contains ions that encourage the carbon gas to finally mineralise into rock. This mineralisation step ensures that the carbon dioxide cannot leach out into the atmosphere.

Depending on how the alkaline agent is made, producers can fine-tune exactly when the carbon will turn into rock.

Why biobased is better

Synthetic chelating agents exist so why are the biobased ones supposedly better for carbon storage?

The chelating agent that the researchers used in their study is a biobased, biodegradable chemical known as N,N-Bis(carboxymethyl)-L-glutamic acid (GLDA). GLDA can be made acidic or alkaline.

This biobased GLDA has unique features that combine technical performance with sustainability.

First and most importantly, GLDA allows the carbon storage process to draw on seawater instead of freshwater to perform the injection.

This is because GDLA has chemical properties that prevent the technical issues with using seawater in this application

GLDA initially stops the carbon from turning into rock too quickly. This reduces the risk of blocked pipes during injection.

Yet GLDA is also biodegradable in seawater. Over time, the metals and microbes in seawater naturally break down the GLDA until it is no longer able to limit carbon mineralisation.

Once the GLDA is broken down, the carbonin the seawater turns into rock, completing the carbon storage process.

Finally, there is the sustainability advantage of using biobased chemicals. The biobased GLDA the researchers demonstrated is itself a form of carbon storage.

This is because the raw materials used to make it are plants, which lock up carbon from the atmosphere in their cells through photosynthesis. This maximises the sustainability impact of carbon storage tech, since the carbon used to perform the injection process will end up mineralised in rock too.

Another way that biobased GLDA reduces the environmental impact of carbon storage processes is its biodegradability in seawater. This will limit its ecological impacts if it leaks into the environment.

The urgency of scale-up

Carbon storage via injection into basalt is an emergent technology. The earliest large-scale field trial came in 2013 in the Wallula experiment, where carbon was injected into the Columbia River basalts of the US Pacific Northwest.

Seawater-based carbon injection is an even newer innovation. Only one project has managed to inject carbon into basalt using seawater – a pilot project in Iceland conducted by the company Carbfix in 2023.

Yet the sector looks set to balloon in coming decades. There will be growing demand for carbon storage technology as the urgency of cutting greenhouse gases mounts.

The attractiveness of carbon clean-up technologies will only grow if policy to cut emissions at their source continues to lag behind global targets.

Estimates cited by the Royal Society say that there will be a need for between 7 to 8 gigatonnes of storage for carbon dioxide a year by 2050 and cumulative storage of 350-1200 gigatonnes by 2100 to keep temperatures below 1.5 degrees.

The Tohoku University research findings marks the latest milestone in developing basalt-based geological storage, one that shows that biobased materials could have a vital role in expanding the industry.

MAY 21, 2025

The rise of UK alternative protein companies

Which UK companies are in the running to capture this growth market? Here are some British alternative protein startups to watch

Alternative proteins are no longer the preserve of Silicon Valley startups. Homegrown UK companies are now competing in a market that could be worth $20.5 billion by 2029.

Policy support for the sector is growing more than ever. Earlier this year, the UK government launched a research programme that could pave the way for product approvals. Public R&D funds are also increasing.

Which UK companies are in the running to capture this growth market? Here are some British alternative protein startups to watch.

Oceanium – Oban, Scotland

Low-input, fast-growing marine algae could become an important source of sustainable protein that needs less land, less fertiliser, and less freshwater to produce.

Scotland-based Oceanium is one of the companies leading the way, turning seaweed into plant-based meat. It has been working to scale its biorefinery since 2023 with a series of investment rounds.

Founded in 2018, the company isolates protein and protein products from kelps and green seaweeds. The end result is not just one product but a whole range of ingredients for food and beverages.

This business model is known as a 'cascade biorefinery', a biomass processing plant that produces several chemicals from a single feedstock at the same time. The advantage of this is that it squeezes out maximum value from the starting raw material – in this case, seaweed – minimising waste materials.

The model allows Oceanium to target several markets at once, including nutraceuticals. Selling higher value algae proteins into the health and wellness industry can support margins enough to continue producing for lower-value markets like food.

Cascade biorefineries make economic sense in a nascent industry that needs to cut costs and maximise returns as much as possible to compete against heavily subsidised livestock products.

Naylor Nutrition – Lincolnshire

Cabbage is an unusual choice of alternative protein feedstock. Nonetheless, Naylor Nutrition of Lincolnshire are busy promoting it as a sustainable source of future protein.

In 2023, Naylor Farms began constructing what it calls the world's first dedicated brassica protein plant. It will produce four products made from the humble winter veg: a protein gel egg alternative, a nutrient-rich protein powder for the wellness market, a high-protein cabbage fibre, and an umami syrup that injects flavour into cooking.

Cabbage has certain advantages over better-known protein crops like soy and peas, such as its resilience, suitability to diverse climates and soils, and high biomass yields per acre.

Quorn – North Yorkshire

No overview of the British alternative protein industry could overlook the original alt-meat producer: Quorn.

Based in Billingham, Stokeley, and Thetford, the company is the leading face of alternative protein, stocked by almost all supermarkets in Britain

today. It has around 40 per cent market share for UK alternative meats.

Quorn's products are based on the fermentation of filamentous fungi species Fusarium venenatum.

Quorn's business history contains a key lesson for investors in the alt-protein space today – the company's commercial success was a long time coming.

Despite being approved for sale in the UK in 1983, it was the BSE epidemic of the mid-1990s that shifted consumer preference away from livestock beef towards plant-based options.

From there, major British supermarkets Sainsbury's and Tesco carried the brand to prominence, giving its products more shelf space and collaborating on product development.

Today, Quorn's annual sales remain far higher than all its alternative protein peers apart from Beyond Meat.

Myconeos – Nottingham

Plant-based cheese still can't match the real thing on taste. Myconeos is trying to change that using fungi.

Myconeos is one of the boldest food biotech firms in the UK. A 2018 spin-off from Nottingham University, its basic innovation is a new way to make certain fungi species sexually reproduce in the lab – something that is very difficult to achieve.

Unlike asexual reproduction, the survival strategy favoured by most fungi, sexual reproduction combines and shuffles genetic traits. Sexual reproduction has a key advantage when it comes to food tech, though – it introduces diversity: in flavour, growing habits, and colours. This gives Myconeos' scientists more choice when it comes to selecting new strains that they could cultivate into tasty cheese replicas.

The technology could be repurposed to enhance other kinds of plant-based proteins and create fermented meat products.

One of the more intriguing applications for Myconeos' fungal technology is its ability to save heritage cheese varieties from extinction. French cheesemakers have enlisted the help of Myconeos after it appeared that the camembert strain was struggling to sexually reproduce after decades of producers simply cloning the bacteria asexually.

The company is still starting in its commercialisation journey with just one seed funding round in December 2021.

This™ – London

This™ is fast-becoming Britain's most recognisable plant-based protein brand. Its products stock most high-street supermarket shelves with offerings that have extended beyond patties and mince into an elaborate ready-to-eat range.

The company suffered heavy losses in the last couple of years after rapid growth in the pandemic-era surge in sustainable eating. Now, it is targeting profitability by this year as it focuses on improving margins.

This pattern of growth followed by financial consolidation is a familiar

trajectory in the sustainable food space, which saw a stunning boom in 2022 followed by a slump. This fared better than most of its competitors in 2023 and continues to consolidate its gains with an investment round last year, with a Series C equity funding round of £20 million.

Nova Farina – Norwich

Nova Farina is an alt-protein producer trying to leverage the agricultural wealth of its local region to create sustainable foods.

The company specialises in creating new plant-based ingredients for food manufacturers using British crops. Its focus is on pea protein – a classic in the plant-based protein space – but it is also interested in other feedstocks, including fava beans.

Its home base in the region of East Anglia is one of the best places to explore the protein potential of native arable crops, with a favourable climate and highly diverse cropping plants already being grown there.

Companies like Nova Farina that sell to other businesses are set to benefit from ongoing growth in plant protein demand from major supermarkets for own-brand vegan offerings.

By building new markets for processed legumes. Nova Farina and others like it are crucial for supporting climate-driven transitions in British agriculture. As southern England warms, we are likely to see farmers shift towards planting higher protein legumes that the company works with.

CellRev – Newcastle

UK alt-protein startups are dominated by plant-based options, but CellRev specialises in creating enzyme inputs for fermented proteins.

Fermented proteins involve growing proteins in the lab from the cells upwards, rather than extracting protein products from plants. This type of alternative protein has higher entry costs but can deliver highly customisable ingredients that replicate conventional meat and dairy.

Another feature that marks CellRev out from an investor perspective is that it has been developing a type of cell production technique called continuous cell harvesting.

As we explained in a previous feature, continuous cell harvesting is considered to be the most economical way of cultivating meat in the lab compared to the more common batch method.

Companies that manage to crack continuous harvesting on an industrial scale will gain a significant advantage in the alternative protein market. Right now, one of the biggest barriers to consumer acceptance is that alternative proteins are still generally more expensive than livestock proteins.

Building alt-protein while supporting farmers

The UK has many advantages when it comes to nurturing a vibrant alt-protein sector. First is a solid university-to-industry pipeline in the life sciences, with rich potential for R&D collaborations between the two.

The government has given over £75 million in alternative protein innovation since 2021, which has boosted its standing relative to

European peers.

Most importantly, alternative protein may soon go from novelty to policy necessity due to climate pressures. The UK's reliance on imported food makes it highly vulnerable to supply shortfalls as volatile weather ravages foreign producers.

Just last month, UK food industry insiders published a whistleblowing memo pointing to serious risks of shortages in their sector thanks to climate change.

With the UK likely to face climate-driven food insecurity much faster than comparable economies, the alternative protein sector could turn out to be an important pillar in domestic food security.

To allow it to meet the challenge, alt-protein producers in the UK still needs more policy support. Although it has stepped up recently, government investment lags behind leaders like Canada and Denmark. While there is an abundance of plant-based protein startups, there are relatively few cultivated meat outfits in the UK compared to in the US or Israel.

To help the industry succeed, the government also needs a policy that supports legacy livestock farmers in making the sustainability transition.

Pushback against sustainable food reform is less likely when there is serious financial support and educational opportunities for those who may lose out, including UK livestock farmers that face economic threats from growth in the alt protein industry.

In addition to favourable regulation and investment for alt protein, then, we need more social-scientific research into the challenges novel proteins will pose to some traditional sectors.

MAY 28, 2025

The power of sustainable jelly

Gelatin can replace plastic in fashion and cool buildings sustainably

Gelatin is best known as the main ingredient in jellies. Yet this humble store-cupboard staple has many applications in consumer goods and industry.

Research has found that gelatin works as a powerful biodegradable alternative to plastic in textiles, fashion, and electronic wearables. It could also play a part in climate change adaptation as a biobased method of cooling buildings sustainably.

Spun jelly

Gelatin is a water-soluble protein that falls under the category of soft biopolymers. Biology is built on these soft materials: DNA, protein, and tissue are all examples of this group in action.

Soft, edible gelatin may not seem like it has the durability to function as an input in consumer goods but research is showing that it could rival plastic or cotton in apparel manufacturing.

Gelatin could be the foundation of sustainable new fashion textiles, according to researchers at the University of Colorado Boulder. Led by Eldy Lázaro Vásquez, the team developed a DIY machine that turns gelatin into textile materials that can replace resource-intensive cotton or plastic.

The production process starts with a liquid gelatin mixture. The researchers built a custom machine that draws out the gelatin into long fibres suitable for spinning. The fibres are dyeable at this stage. A fruit extract called genipin is added to make the fibres stronger.

The fibres of this material dissolve in hot water in minutes. Despite this, producers can customise the physical properties of the gelatin fibre so that it is resilient enough to withstand cold water and rainfall while it is being used.

Gelatin for high-tech apparel

The researchers who came up with the gelatin clothing textile are targeting the wearable tech market. Wearable tech refers to clothing that contain sensors and circuit boards, making the material sensitive and adaptive to environmental and bodily changes.

It is difficult to make wearable tech circular because of the economics of recycling. Companies still cannot easily disentangle electronic material from clothing fibre at low enough cost to make profit. Gelatin solves this because it can easily dissolve in water, leaving just electronic material behind for re-use.

Jelly ephemera

Gelatin textiles could also provide biodegradable, sustainable alternatives to plastic in single use applications.

Events and hospitality are areas where this biodegradable feedstock could find its niche. Tablecloths, food packaging, and branded apparel are all part and parcel of festivals and conferences. These products have a short lifespan and often end up as littler in the open environment.

Make-your-own

Beyond its versatility, gelatin is a special feedstock from a socio-economic perspective since it lends itself easily to decentralised, DIY

production of sustainable goods.

Unlike seaweed-based alginate, for example, gelatin is on sale in just about every supermarket. The material is easy to process, mould, and customise, even without high-tech industrial facilities.

This makes the input ideal for small producers around the world working with low-tech tools.

The University of Colorado Boulder researchers showcased the DIY ethic that comes with gelatin feedstock.

> "Waste gelatin is an inherently sustainable feedstock. Using up the byproducts of industries like agriculture, fisheries, and food processing to create useful products avoids the energy use required to cultivate brand new resources geared specifically for consumer goods."

For about $650, they say, people can download open-source blueprints from this website and build the gelatin textile-making machine themselves. Their innovation cuts out intermediaries: with a small budget and some technical know-how, people can make their own biodegradable fibres.

Fast (sustainable) fashion

Gelatin-based textiles can be thrown away without toxic after-effects. Using gelatin, the fashion industry could craft apparel that comes with far less environmental harm than the plastic-based fibres that dominate today.

Biodegradability was the driving idea behind the gelatin fabric recipe developed by Sanskriti Gupta, product consultant and fashion manufacturer.

Gupta came up with a method to create a gelatin material that can be used to make biodegradable bags or other textile products.

She says her product takes seriously the idea that one third of our plastics end up in the ecosystem. Designers must anticipate the flaws in global recycling systems and create products that can break down in nature without harming it.

Her material combines gelatin powder, glycerine, and plant-based starch. These three main ingredients are mixed and heated for 10 – 20 minutes, then left to cure in a mould for up to five days, then sewn together into its final form. The material is endlessly customisable using natural dyes – for example, turmeric powder or tea bags.

The recipe for Gupta's gelatin material is simple, allowing anyone to produce the sustainable material without capital intensive equipment or ingredients. It is available online so that the public can copy and build on the formula.

Circular sources

Waste gelatin is an inherently sustainable feedstock. Using up the byproducts of industries like agriculture, fisheries, and food processing to create useful products avoids the energy use required to cultivate brand new resources geared specifically for consumer goods.

There are lots of places to source waste gelatine for startups and producers looking to work with gelatin. One is the apparel industry. Approximately half the gelatin-rich skins used in leather making are discarded during the process of manufacturing, leaving a huge pool of potential inputs.

Gelatin from leather waste does not meet the hygiene standards required of human food products. However, researchers at Shaanxi University of Science and Technology in 2022 found another application as a circular, biodegradable non-food packaging film.

The researchers point out that hoovering up leather industry waste in this way prevents pollutants from apparel making from entering and contaminating the environment. Reducing industry waste by valorising it is an economic way to prevent byproducts from pooling in large, dangerous concentrations.

Circular gelatin-based materials could help make the food industry more sustainable too by mopping up their byproducts. Gelatin is a protein usually derived from the bones and hooves of animals. Commonly, producers will landfill any gelatin that is not suitable for food or cosmetics. Livestock waste offers another abundant and cheap circular resource pool that can pose environmental hazards if it is not upcycled.

Another large generator of waste gelatin is the seafood industry. Currently, 75 percent of total fish weight are scales, skins, heads, viscera, and bones that cannot be eaten. Shrimp shells are another rich source of the compound.

Finding industrial uses for seafood waste is vital to make the most of precious marine resources. Gelatin from marine sources are also halal, overcoming religious objections to material sourced from pigs or cattle.

Currently, gelatin cannot be made using plants. Yet laboratory fermentation is an emerging source of vegan gelatin that avoids animal slaughter. US startup Geltor brews gelatin inside microbes, which are genetically programmed to churn out exact replicas of animal-derived gelatins. This new way of producing gelatin breaks the link between biomaterials and polluting livestock industries.

Smart jelly

Scientists intrigued by its gel-forming ability have also been exploring gelatin's potential for use as a smart packaging material. This refers to packaging that can detect and respond to changes in its environment, alerting consumers to food spoilage or other contaminants.

Studies have found ways of making gelatin packaging that changes visually when the food it has packed is past its best. Various studies

have explored embedded natural dyes in gelatin films that change colour as the acidity levels of foods change, one proxy for spoilage.

Gelatin is a good base material for these pH sensitive dyes because it is naturally film-forming. It is also biodegradable, cutting the forever-waste associated with petroleum plastics.

More research still needs to be done to make sensitive gelatin films stronger and moisture resistant. This will be essential if gelatin films are going to find wider uses in the food industry since the material will have to withstand long periods of transport and storage.

Cooler construction

The most intriguing application for gelatin in recent years came out of China last year, when scientists demonstrated that the material could be used in a sunlight cooling material for buildings.

Researchers from Sichuan University showed that an aerogel sheet made from gelatin and salmon DNA could lower a building's temperature by around 6 degrees celsius in clouds and 16 degrees in direct sun.

The aerogel is meant to act as a passive layer around the house that reflects more light than it receives. In effect, it forms a giant mirror that bounces visible light away from the building rather than allowing it to penetrate it and turn into heat.

The finding demonstrates the power of gelatin as an ingredient in biobased climate adaptation technologies. The major advantage of using a biomaterial coolant over air conditioning is that it uses far less energy to manufacture and run.

Demand for low-energy cooling materials is set to increase as heatwaves become more frequent and intense under climate change. These technologies could prove particularly vital in cooling urban areas of energy-insecure developing countries that experience the most extreme effects of the climate crisis.

The key challenge for both these technologies lies in scale-up and manufacturing. However, this kind of boundary-pushing research showcases the range of applications that gelatin offers beyond its traditional role as a food ingredient.

JUNE 4, 2025

Cooling biomaterials in a warming world

A new generation of biomaterials can keep houses, food, and medicine cool without air con

As global temperatures rise, the need to scale climate adaptation technologies is becoming increasingly urgent.

Net temperature-related deaths could increase by 50 percent by the end of this century. Materials that cool our homes without damaging the environment are increasingly sought after as record-breaking temperatures become more frequent.

Although cutting emissions to prevent further global heating is our biggest priority, we also need to change the way we cope with volatile weather.

Certain biomaterials can form the basis of sustainable passive cooling systems. Unlike air conditioning, passive cooling is a lower-energy way of combating extreme heat. Biobased passive cooling tech does one better by safely biodegrading at the end of their product life.

Researchers are developing new biomaterials for climate-ready building design that protects inhabitants and cuts down energy use.

Elephants and fungi for cooler buildings

How do animals that live in the heat cool down? And how can humans borrow from them to improve their built environment? These were the questions driving research conducted by scientists from Nanyang Technology University in Singapore, who have developed cooling biobased tiles based on the texture of elephant skin.

The tile material itself is made from mycelium, the root systems of fungi. A network of fibrous, thin roots holds together bamboo shavings and other organic waste, creating blocks of firm material that can be cut to size easily.

The biomaterial's cooling properties come from two components. First are the mycelium roots themselves. Mycelium composite materials are already renowned for their insulating properties.

The bumpy texture of the material is another component of the tile's cooling capacities. The surface of the fungal tiles takes inspiration from the evolutionary adaptations of elephant skin, which scientists know help them live in scorching environments.

The cracks and wrinkles on an elephant skin's surface help to cool down the animal. They increase skin surface area which means that more moisture is always evaporating from their bodies.

The test results showed promise. The elephant skin-inspired tiles showed a 25% greater cooling rate than flat ones.

The advantage grew to 70% when exposed to simulated rain. Just like in living elephant skin, the folds in the textures trap lots of rainwater, increasing the volume of water that evaporates and therefore cools the surface.

Already, scientists are moving towards commercialisation by working with Singapore start-up Mykilio to scale their idea and test it in the real world.

Traditional architecture, but biobased

Elsewhere too, researchers are exploiting mycelium as a biodegradable construction material for a warmer world.

In 2023, a study led by Kumar Biswajt Debath at the University of Technology Sydney developed a perforated screen made of mycelium designed to reduce indoor temperature and energy demand during extreme heat events.

The team called their device a 'bio-jaali'. A jaali is an ornamental lattice common in Indo-Islamic and Indian architecture. The traditional jaali lattice was made from sandstone. Its many openings were designed to cool the air coming into a building.

The team aimed to redesign this functional architectural feature with biobased materials instead.

> "Cooling functions account for nearly a fifth of all building electricity. It is the fastest growing use of building energy globally and is set to triple by 2050."

Their bio-jaali is made from mycelium roots grown around sawdust, wheat, or rice straw. In fact, any agricultural product can function as the filler material inside mycelium construction blocks, including agricultural byproducts.

An ideal candidate for local and circular filler material would be the agricultural 'stubble' left in fields after harvest.

This leftover material is a huge pollution hazard in India, where farmers burn the residue, a practice that causes severe air pollution during harvest time. Uses for the material in construction could make it pay for farmers to pick and sell the material rather than burn it.

Turning down the air con

These mycelium materials are examples of biobased 'passive cooling', a term that refers to design choices that reduce heat gain and increase heat loss without relying on energy-intensive 'active cooling systems' like air conditioning.

Examples of simple passive cooling in buildings are adding shade with trees, adding ventilation, and incorporating highly insulating elements to design.

Passive cooling systems are an important tool for both adapting to climate change and mitigating it. Active cooling systems such as air conditioning and electric fans are extremely energy intensive and contribute a lot to global warming.

Reducing their use as much as possible is key to moving towards more sustainable economies. Globally, the cooling industry accounts for 10

percent of emissions – more than aviation and shipping combined.

Cooling functions account for nearly a fifth of all building electricity. It is the fastest growing use of building energy globally and is set to triple by 2050.

Demand growth is especially skyrocketing in hotter developing countries as incomes and living standards rise, allowing citizens to more easily afford expensive goods like electronic cooling tech.

The extra energy demand required to fuel air conditioning makes it difficult for countries to move away from fossil fuel.

To cut electricity demand for space cooling, the International Energy Agency recommends government policy that mandates building designs that help maintain a comfortable temperature. Biomaterials could be a vital part of the push to design cooling properties into buildings from the get go.

Camel-inspired food packaging

Like air con, refrigeration is one of the most consequential modern technologies. It has radically reshaped the global food system, supply chains, and our eating habits.

Yet similar to air con, refrigeration tech has a huge environmental impact. Packaging materials that keep its contents cold for longer can help reduce demand for energy-hungry cooling processes.

Scientists at MIT have taken inspiration from camel hair to produce an insulating material that can cool its contents without a power source. It offers a low-energy way to transport temperature-sensitive goods like pharmaceuticals, for example.

Camel hair keeps animals cool in desert environments by allowing just enough sweat to evaporate to keep the skin cool while minimising moisture loss from the body.

The MIT material takes this lesson and recreates it using two layers of soft biomaterials. First, a hydrogel bottom layer holds a reservoir of water. Above, a layer of aerogel acts like camel fur, allowing some of the water beneath to evaporate and cool but trapping most of it and reserving it for later.

The system could be used to package food and medicine to prevent spoilage and loss through essential supply chains. While storage and transport trucks for these goods are refrigerated, the time taken up by loading and unloading can lead to spikes in temperature that affect product durability.

It could also preserve food for longer in a way that does not require an active power system – something that could help farmers and food distributors in hot countries.

The aerogel the researchers developed was made from silica. However, the two gel layers could be made from biological materials.

Nano-scale cooling films

Films and coatings that can be applied over large surfaces are an efficient way to make a building less prone to overheating – useful in retrofitting structures that were not initially built with heat protection in

mind.

A biobased building can have many cooling elements. Using various biological feedstocks and biomaterials, we can increase its resistance to overheating one element at a time.

Windows are an important point of intervention for a passive cooling system. They are where light and heat most easily enters the building.

At Finnish R&S research and development organisation VTT, a team has developed a passive cooling nanomaterial from a very abundant biological material called cellulose.

Their new biobased nanomaterial adapts to environmental change, cooling when the temperature rises and trapping heat when it drops.

The material is a film made of plant-based nanocellulose for windows doped with particles whose optical properties shift with the environmental temperature.

In addition, it applies a thin reflective coating on one side of the film so it acts as a mirror that reflects bright sunlight in hot weather, preventing the room within from heating up as quickly as it would without the film application.

The team claims that in lab tests, their nano-coating achieved cooling by around 5 degrees celsius.

Many researchers are now trying to develop scalable layers that can be applied all over the buildings to cut energy demand for cooling quickly.

Biobased materials are most desirable from a sustainability perspective – most coating materials today are made from synthetic materials that are environmentally toxic and do not break down in nature safely.

Work done by material scientists at Stockholm University on biobased nanoparticles indicate that powerful heat-regulating materials do not need to rely on synthetic chemicals to work.

Their fully biobased coatings are partly made of lignin, a material found throughout the plant world. Lignin nanoparticles are embedded in chitosan, another highly abundant material found in shells of sea creatures, to form a material that blocks UV light.

Work like this shows how powerful renewable materials can be against heat, particularly when exploited at a nano-metre scale. Under their simulation, the coating led to a 58 percent reduction in temperature increase compared with uncoated glass.

The biggest human challenge of this century will be climate adaptation. Biobased cooling materials show the role that biological feedstocks will have in adapting to a warming world.

JUNE 11, 2025

Sun, sea, sustainability: biobased swaps for greener holidays

Heading off on your summer holiday doesn't mean you have to leave your sustainable conscience behind

Most of the items you need for lounging on a beach or campsite have biobased or circular substitutes that are more eco-friendly than conventional products.

We show you how to holiday with a lighter impact by incorporating renewable and upcycled products into your summer packing.

Biobased beach toys for greener play

Spades and buckets are a must for curious young beachcombers. This summer, you can help keep their exploration instincts more sustainable with petroleum-free beach toys.

Bigjigs makes a bioplastic toy spade from agricultural waste, namely wheat fibre. Products made from waste materials in general will have a smaller carbon footprint than those from petroleum oil, which go into the vast majority of children's toys on the market.

Green Toys has a more elaborate range of sustainable beach toys for budding sand architects. A dumper truck made of 100% recycled milk jugs has all the colour and character a child's toy needs but comes with a lighter environmental load than new plastic.

The company's recycled amphibious aircraft toys – the Seacopter or Seaplane – will be another beach play hit, with buoyant stabilisers for hours of fun.

For the classic beach toy kit, Green Toys' Sand Play set combines a bucket, sand castle mould, a spade and rake made from 100 percent recycled materials.

Some toys support beach clean-up. For adults, Bureo's frisbee is made in California from recycled fishing nets – a huge source of marine plastic pollution globally that both releases microplastics and ensnares wildlife.

Remember that buying anything second hand will almost always trump new purchases in the sustainability stakes. There will be a stunning range of pre-loved beach toys online that will save you money, cut resource demand, and reduce pollution.

Eco-friendly bikinis

Outdoor swimming is a spectacular way to wile away a summer's day. However, the bikinis and trunks you are used to are likely contributing to toxic microplastics pollution.

Swimwear is notorious for its reliance on oil-based plastic fibres: polyester and nylon are the major ingredients. Whenever you wear swimming gear made from these, they release a stream of microscopic plastic particles into the water around you.

Microplastics are one of the most serious environmental and health hazards of our time. They have contaminated everywhere from beaches to the deep ocean, disrupting the biology of living organisms right up through the food chain – from fish to humans.

Unfortunately, a recent study found no difference in the amount of microplastics shed by recycled and non-recycled activewear materials.

Further, bioplastics and oil-based plastics alike shed damaging particles, meaning you need other, non-plastic biomaterials for a

greener swim.

Cotton is one of the better options as its organic fibres harmlessly break down in the water. Organic cotton is even better from an ecological perspective since it demands fewer pesticides compared to conventional cotton. Other sustainable swimwear materials are hemp and bamboo, both plants that can form weavable fibres.

MovesGood makes a 90% bamboo textile and 10% elastane bikini set. BeachCandy offers swimwear ranges with a mix of hemp and organic cotton. For Children, Pure Earth Collection sells swimming costumes made from 98% organic cotton, 2% lycra, and non-toxic yet bright dyes.

Most hemp or bamboo swimwear contains a small portion of conventional plastic in the mix to achieve the right elasticity and fit. On the whole, however, these non-plastic fibres will cut the polluting potential of your swimming gear compared to conventional options.

Eco-picnicking

Plastic is the ideal picnic material – easy to clean, less prone to shatter, and light. Yet a petrochemical dinner set seems at odds with the idea of picnicking in nature.

Nowadays, you can dispense with petrochemicals altogether in your outdoor lunch. One option is Skaza's sugarcane bioplastic picnic set for four. It contains portable plates, cutlery, and more. The carrier strap is made from cotton.

Skanza's sugar cane picnic set is as light as an ordinary plastic but it is made of 81% sugarcane. In general, circular bioplastics like this emit far less carbon during manufacture than ordinary plastics, making for a more sustainable option than oil-based plastic sets.

Sugarcane is renewable, unlike the petroleum that goes into ordinary plastics. Importantly, it is also a circular raw material – a byproduct of sugar manufacturing that is usually discarded.

Finally, a picnic wouldn't be a picnic without a blanket. Unfortunately, many on the market are made with cheap plastic fibres that come from petroleum and are not biodegradable. Often, the waterproofed lining relies on synthetic chemicals and plastic too.

Sustainable producers will opt for all-natural materials, especially materials that are waste byproducts of other industries. One example is the UK manufacturer Tweedmill, which has eliminated plastics from its 'random recycled' picnic rug product.

This thick picnic blanket is made from wool weaving byproducts, making it circular and less resource-intensive than blankets which use virgin wool. To lighten its environmental load even more, the rug is backed with waxed cotton instead of plastic lining for water resistance.

Again, second-hand options are usually far more sustainable than any manufactured product. The longer you use an item, too, the more sustainable it becomes because it avoids adding to fresh demand for raw materials and the energy needed to process them.

Old fridges become cool bags

Cooler bags are an essential piece of kit for campers and beach-goers in summer. Today, oil-based plastics are the go-to material for its

powerful insulating properties.

Recycled versions are more environmentally friendly. One innovative brand on the market is Retulp's Fridgebag, marketed as the world's first cool bag made from recycled fridges.

Fridges are full of plastic: thin handles, shelves, doors, and shelves. As demand for refrigeration grows globally, we need scaled and sustainable solutions for end of life options.

Products like Fridgebag normalise a circular approach to used fridges. Turning potential landfill waste into new and high-value consumer goods can prevent this material from being dumped in landfill sites.

The sustainability impact of upcycling can be significant. Each upcycled plastic appliance cuts some demand for virgin petrochemicals.

Eco-friendly snorkelling

What's a trip to the beach without the magic of snorkeling? The wonder of seeing underwate worlds is undeniable. Yet most of the gear involved is full of petroleum plastic.

With 5.2 trillion pieces of plastic waste estimated to be in the oceans, plastic dependence puts a dampener on a sport that should be helping care for marine ecosystems.

Today, more manufacturers are developing sustainable gear. Fourth Element is among the best known, using natural rubber for a more sustainable surface suit in its Surface suit.

Most often, wetsuits are made from neoprene. This non-biodegradable material takes a lot of energy to manufacture. The natural material offers a lighter alternative.

Fourth Element's natural rubber suit also uses ocean-friendly glues and inks while the inner and outer lining are made from recycled plastic bottles.

If you're packing goggle defogger, don't forget to use Stream2Sea's reef-safe, biodegradable formulation.

Ghost-gear kayaks clean up coastlines

Kayaking is an exciting way to see coastlines and waterways. Yet this is another holiday sport that relies heavily on petrochemical plastics.

British startup Odyssey Innovation is doing important work making kayaks out of discarded plastic fishing equipment – also known as ghost gear.

Discarded or 'ghost' fishing gear is a huge problem globally. Unfortunately, there is no shortage of this material on the beaches of England.

The company sources waste feedstock from local anglers as well as the anti-litter group 'Keep Britain Tidy'. This waste-to-kayak pipeline is helping fishers in Cornwall, England recycle up to 60 percent more of their used gear.

This company has pioneered an innovative, conservation-centric business model too. Founder Rob Thompson says he makes 10 percent

profit on the cost of his recycled kayaks, a portion of which funds further beach clean-up activities.

Natural sandals

Sandals are a must for beach holidays. By choosing more sustainable materials, you can quite literally make a greener footprint this summer.

Second-hand sandals are abundant but if you are going for a new purchase, natural materials are the best bet.

Natural rubber is a plastic alternative that can compost naturally at the end of its life. Sea Sense makes functional, colourful options from 100 perfect natural rubber and has eliminated plastic from the design altogether.

Cork is another light-weight footwear material that naturally biodegrades. These Corker flip flops from Gumbies are made with a comfortable cork footbed with recycled rubber outsoles. Even the cotton canvas toe posts and straps are recycled.

Take a raincheck

Summer storms needn't make your holiday travels a misery. Stock up on slick sustainable raincoats and you can brave the downpours in eco-friendly style.

Outdoor wear like waterproof coats are usually awash in polluting plastics fibres like polyester and nylon but there are better options out there.

Waxed cotton jackets are one of the best choices you can make for sustainable rain gear. Not only is the cotton base material natural and biodegradable, the water resistant wax treatment is not toxic for the environment.

It is important to look at what coating material your raincoat uses. Most manufacturers use highly eco-toxic, non-biodegradable synthetic chemicals to create the rain-proof layer. Others use synthetic waxes based on petroleum.

However, high-performing biobased finishes achieve the same waterproofing effect without the eco-toxicity.

Patagonia, the leading name in sustainable outdoor wear, uses a 100 percent plant-based wax finish on its cotton outerwear. Waste olive oil, sunflower oil, and castor bean oil from the food industry go into making it.

It took a decade for Patagonia to formulate a plant-based coat wax that worked as well petroleum paraffin wax. The end result shows the functional power of plants to ease our dependence on petrochemicals.

JUNE 18, 2025

Are biomaterials healthier for us?

We look at how biomaterials affect our health compared to petrochemicals

Almost all of our consumer goods contain petrochemicals. We know about the environmental damage these cause. Less appreciated is how these products are also harming our health.

Biobased materials can be more sustainable, but are they any healthier?

We look at how biomaterials interact with our bodies in a range of applications, from cosmetics right the way through to architecture.

How petrochemicals harm our health

In 2024 the health impacts of petrochemicals went TikTok viral. The online outcry centered on a study reporting the toxicity of flame retardants inside black plastic cooking spatulas, whipping up fears about the dangers lurking in everyday materials.

The study turned out to contain a simple arithmetic error, which had exaggerated the health risks.

However, the media uproar did highlight an unsettling fact about our consumer landscape: the human health risks of modern industrial materials.

Throughout our lives, petrochemicals damage our bodies as we use and interact with them.

Often, the most toxic parts of plastic are the petroleum-based additives that manufacturers use during processing. They use these additives to improve the material's physical properties.

One is a group of chemicals called plasticisers. Phthalates are an example, a chemical which can cause hormonal disruption, metabolic disorders, and can damage reproduction. Others are bisphenol, which affects hormone release and function in the human body, and phthalic ester.

Additives like this are generally more damaging to human health than the petrochemical plastics that it is embedded in.

However, plastic itself poses a health hazard once it breaks down into smaller and smaller particles.

Microplastics is where we see most clearly how environmental and bodily health are sometimes difficult to disentangle.

Microplastic pollution works its way up the food chain into the human bloodstream. They are known to cause cancer, change our metabolism, and poison our neurological system.

The health harms of microplastics do not end there. These microscopic pieces tend to attract and concentrate any herbicides, pesticides, and other synthetic chemicals found in the environment.

Once concentrated, these harmful chemicals become even more potent. Once eaten by wildlife, they eventually enter the human food chain.

Finally, microplastics are disease transmitters: they attract microbes and pathogens, carrying them to new places where the organisms may not have resistance – including human beings.

Is biobased better?

Biobased materials are made from renewable, biological sources rather than fossil minerals.

Some biomaterials can be kinder to our bodies than conventional oil-based ones. The health benefits of these biomaterials are usually tied to how easily they biodegrade in the natural environment.

Many biomaterials are also compostable. This means materials that break down relatively rapidly (just like organic matter) and do not release environmental toxins when it does.

Compostable biomaterials break down like natural materials into water, carbon dioxide, and biomass. Left in the environment, they get absorbed by hungry animals, plants, and microbes.

Healthwise, compostable biomaterials tend to be among the most benign. This is because their chemical structure is pretty much in line with the materials commonly found in nature.

Increasingly, skincare and beauty brands are reaching for these natural materials in their formulations.

Safer skincare

Shockingly, petrochemicals are found inside most cosmetics and skincare products on the market.

The skin is a porous barrier meaning that it will absorb at least some of the substances that we put on this.

> "Generally, plants can do everything that synthetic chemicals can. New biobased products are coming onto the market all the time."

This can lead to allergies and skin irritability to more serious internal problems – parabens and phthalates inside makeup, moisturisers, hair and shaving products, can cause hormonal disruption.

Consumers are becoming more aware of the health and environmental damage caused by the petrochemicals industry and are demanding renewable alternatives with less impact.

Biobased skincare ingredients are leading this shift in market demand for effective yet safer alternatives.

Generally, plants can do everything that synthetic chemicals can. New biobased products are coming onto the market all the time. Biobased beauty brands like Ursa Major and Ofnature are drawing on plant-based antimicrobial extracts, essential oils, and natural antioxidants to extend shelf-life. Plant-based compounds also provide healing or UV

protection.

Consumer demand for more natural ingredients has encouraged new marketing narratives that evokes ancient wisdom and simpler times.

Typifying this trend are British brands like Ffern, which makes limited edition perfumes with seasonal ingredients, sustaining their commitment to planet and people with yearly endowments to traditional English crafts.

Health-conscious packaging

Packaging is everywhere in the modern economy: the food we eat and the products we order online come coated in protective plastic layers, most of which are still made from petrochemicals.

Consumers want to know these materials are not releasing harmful compounds into food or liquid, especially when stored for long periods of time.

This consumer concern is understandable, with a staggering 10, 259 chemicals relating to plastic packaging materials today, according to one estimate. This includes all the chemicals used in manufacturing or in the final packaging material including additives.

We already know the damaging health impacts of many of these. Polystyrene-based polymers (expanded foam included) emit the compound styrene into the environment. Disposable oil-based plastics release microplastics and other harmful substances in hot water.

Natural biomaterials made of vegetable or plant fibre like wheat, wood, bamboo, or palm leaf can be good, low-impact alternatives to plastics generally safe for human health.

One experiment that studied particle migration between wheat pulp and wood packaging and three liquids showed that the materials were well below the migration limits set by EU legislation.

Biobased plastics, meanwhile, are not entirely free of concern when it comes to prolonged food storage solutions. Certainly, bioplastics are not more dangerous than petroleum plastics. Further, bioplastics can be vital in reducing the environmental impacts of certain technologies and industries.

Yet like all plastics, biobased PLA and PHA release nanoparticles into food that have potentially harmful effects. A lot of this is down to the additives that producers have to use to achieve certain functional properties.

The alternatives are new non-plastic biomaterials that strike a balance between the simplicity of organic matter like plant fibres and the functionality of synthetic materials.

For example, plant-based nanocellulose is a promising candidate for non-plastic, non-toxic food packaging.

Although it must be processed to become a useful packaging product, nanocellulose-based materials are not as heavily processed as plastics, providing an alternative that is more ‘biocompatible’ – in other words, les likely to produce adverse reactions in the body.

Healthy buildings, healthy bodies

We tend to separate environmental health from individual health. However, a healthy environment is essential for human physical well-being.

Buildings are one area where environmental and bodily health merge in very obvious ways: the materials we build with and live with each day have an immense impact on our physical state.

Modern buildings contain a plethora of synthetic chemicals. A dangerous side effect of these are volatile organic compounds or VOCs, particles released by chemicals and materials when they degrade.

VOCs contribute to poor indoor air pollution – their presence is linked to poor human health, allergies, irritation, nose and throat issues, and tiredness.

Two major VOC sources inside buildings are petrochemical paints and coatings, including epoxy resins, alkyd paints, and polyurethane.

Biobased paints and coatings can achieve lower VOC release and create a healthier indoor environment. Plants and natural resins are used as raw materials substitutes for the traditional petroleum.

In addition to low-VOC coatings, some manufacturers are formulating zero-VOC options that are made without any measurable pollutants, according to regulatory guidelines.

The low and zero-VOC paint and coating market is growing in the EU, which has been imposing stricter regulations on the industry for health and sustainability.

A better choice

An important thing to bear in mind is that all materials – including biobased ones – release chemical byproducts when exposed to light, air, heat, and moisture.

However, we can cut the number and volume of health-damaging substances we are exposed to by opting for biobased materials and manufacturing ingredients. In many cases, biobased materials present the healthier choice for consumers looking to reduce their exposure to harmful pollutants.

Yet R&D into healthier biomaterials is still ongoing. A key takeaway is that the health impact of a material comes from the hidden additives it contains.

Right now, there is a particularly urgent need for the biobased industry to develop non-toxic alternatives to relatively overlooked chemicals like adhesives and plasticisers. These are used in small amounts relative to major materials like plastics but they have outsized effects on health and environment.

JUNE 25, 2025

Living detectors: how biosensors protect wildlife

Biosensors are helping scientists monitor, understand, and protect nature

Biosensors are devices that exploit biological materials or living microorganisms to detect particular chemicals in their surroundings.

These biotech devices are becoming essential tools of the trade in wildlife conservation and ecological science.

They deliver quick, accurate, and detailed data vital in keeping wildlife safe from a myriad of threats, including illegal hunting, climate change, and other environmental threats.

The concept of a biosensor is familiar to all of us. Some are already in major use, with pregnancy and COVID-19 tests as well-known examples.

In conservation and ecology, biosensors are used to detect certain ions (to identify heavy metal pollution, for example), pathogens, enzymes, microplastics, or algal toxins.

Ecologists and conservators are already using biosensors to monitor pollution, animal pathogens, and even whether there are specific kinds of animals present in a particular habitat. New biosensors are constantly being developed for fresh applications.

Here's how they help scientists monitor, understand, and ultimately help protect natural habitats.

The race to save coral

Coral reefs are one of the most spectacular natural artefacts. These mineral architectures harbour a huge density of marine wildlife, often found nowhere else.

They also support human life, harbouring new drugs (azidothymidine for HIV was discovered in a sponge in a Caribbean reef) or supporting local economies through tourism or fisheries.

Yet these shimmering incubators are fast disappearing. Human activity and climate change have driven a 14 percent decline in global reefs between 2009 and 2018. The loss in speeding up.

Scientific understanding and accurate measurement is essential to save the remaining reefs. Biomaterials are helping advance this by enabling real-time data collection on underwater threats.

Fighting coral bleaching

Biosensors help scientists understand the chemical composition of seawater in more detail than other methods.

One biosensor with potential in coral reef monitoring uses a mix of selected microalgae and microbes as sensing organisms. Scientists have demonstrated this device can detect petroleum hydrocarbons and heavy metals underwater.

There are even more exotic forms of biosensors that could be useful in marine monitoring. One of them exploits the sensitivity of protein nucleic acid phages. These can detect pathogens, herbicides, and disease markers – useful in reef research as these habitats are highly sensitive to a range of pollutants, including agricultural runoff into the sea.

Scientists are already using biosensors to study coral resilience during bleaching events. This happens when the seawater gets too warm,

prompting coral to expel life-giving algae from their tissues. This puts the coral at risk of starvation and disease. It can take between 9 and 12 years for a recovery.

Coral probiotics are important to understand when it comes to safeguarding coral reefs from warming sea temperatures. These are microorganisms that support coral health, bolstering its defences against potentially lethal bleaching events.

Researchers at the Guangxi Laboratory in China recently developed a brand new type of biosensor to detect the coral probiotic species C. marina in order to learn more about the protection these organisms offer coral reefs.

To do this, they built a biosensor that exploits the sensitive properties of a biological substance called oligonucleotides. These are short DNA or RNA molecules and are already used in genetic testing and forensics. The researchers reported that their new biosensor had 'excellent performance', detecting the C. marina DNA even at very dilute concentrations.

Chinese universities have become a hotbed of research into biosensors for coral reef monitoring. Yet the country is also a major driver in the destruction of reefs as it vyes for territorial claims to low-lying reefs and islets in the South China Sea with the Philippines, Malaysia, Brunei, Taiwan, and Vietnam.

Rooting out poison-fishing in the Philippines

Biosensors can be highly sensitive, rapid, and accurate. This makes them ideal in helping authorities protect coral reefs by tracking down illegal fishers.

Sodium cyanide is a substance illegal fishers use in the water to stun fish while still keeping them alive. In the Philippines, some use this method of illegal fishing to collect tropical sea fish for the aquarium trade.

The process is gruesome: fishermen squirt bottles laced with sodium cyanide pellets into coral reef crevices where the fish of interest live.

Once stunned, the fish are easily collected and placed into seawater back on the boat. It is estimated that over 1 million kilos of the stuff have been used in Philippine reefs since the 1960s.

Needless to say, sodium cyanide is highly toxic to the fragile reef system. The cyanide disrupts the symbiotic algae that live inside the coral and which allows the coral to 'eat'. Without them, the coral lacks the means to consume nutrients from the seawater around. Eventually, the coral reef starves.

Biosensors are now being used to combat cyanide fishing. Their rapidity is what gives them the advantage in this application: these light, portable devices can quickly and accurately detect the compound in the water without the need for lengthy analysis back in the laboratory, as with older methods of detection.

Speedy cyanide detection is paramount in this work: any fish poisoned by sodium cyanide can quickly recover thanks to their efficient detoxification mechanisms.

Living cyanide detectors

How can biosensors alert trackers to the presence of cyanide? There are several ways that living microorganisms are used to detect the poison. All depend on the specific ways these creatures respond to the chemical.

Some bacterial species can biodegrade cyanide. These bacteria are placed in the sensor. If the poison is present, the bacteria convert the cyanide into cyanate-consuming oxygen. This means any decrease in dissolved oxygen in the biosensor indicates the presence of cyanide.

Some cyanide biosensors exploit the way that cyanide restricts microbial respiration. The decrease in oxygen consumption by the microbe therefore acts as a reliable signal that the poison has been detected.

Other cyanide biosensing methods rely on how the cyanide disrupts enzyme production by the microbes.

Tracking invaders and diseases

Biosensors are also being used to monitor underwater ecological threats not from humans but from certain kinds of wildlife.

When invasive fish move into a new area, they can quickly upset the ecological balance of the habitat. Stronger species can quickly outcompete or consume existing fish, creating a less diverse habitat.

Yet monitoring invasive fish in real-time is incredibly difficult. It is impractical and expansive to install in-situ monitoring systems in fast and deep rivers and lakes.

> "Biosensors are as diverse as the capabilities of the bacteria or biomaterials inside them, meaning they can be custom-made to pick up on environmental signals that other forms of analysis cannot."

Zebra mussels are a common invasive species around the world. They can cause widespread economic damage for humans by clinging to the insides of pipes. They also reduce the amount of food available for other aquatic species.

To detect populations quickly and accurately, Portuguese researchers have developed an enzyme-based biosensor that signals the presence of zebra mussel DNA in water.

The next frontier for biosensor applications in the field could be in wildlife disease detection. The US Geological Survey has pioneered in this area, developing a biosensor for a disease that has killed more than

five million bats in North America since 2006.

White-nose syndrome is an infectious disease that afflicts bats while hibernating over winter. In some North American bat colonies, up to 99 percent have died from the ailment.

The new biosensor works to detect the DNA of the fungal agent that causes the disease through skin swabs or dropping samples of bats.

The biosensor could now aid early treatment, which depends on accurately detecting the bacteria and estimating how far the fungus has travelled.

The advantages of biosensors

Biosensors are now an integral part of monitoring environments and detecting threats to wildlife and habitats. Biomaterials can do things that other materials cannot when it comes to monitoring natural environments consistently and systematically.

Conventional methods rely on samples that need sending back to the lab – something that takes time and can lead to samples degrading in transit.

By contrast, biosensors offer simplicity, rapidity, portability, and affordability. Light and quick enough to work in-situ, scientists can take quick readings in the field. This property can make a crucial difference in applications where time is of the essence, such as detecting the signs of illegal hunting.

Conventional monitoring methods for coral reefs (for example, using satellite imagery of the water) are comparatively limited in that they tend to deliver on a basic set of information such as salinity, dissolved oxygen, and temperature.

For conservation relevance, scientists often need more detailed data, such as the presence of enzymes and pollutants or agriculture pesticides.

Biosensors are as diverse as the capabilities of the bacteria or biomaterials inside them, meaning they can be custom-made to pick up on environmental signals that other forms of analysis cannot.

This versatility is useful to ecologists and conservationists, who want a complete picture of the coral reef's environmental condition. They offer a potent example of how biotech can widen the lens that science has on threatened habitats.

JULY 2, 2025

Analysing Asia's latest biochemicals deals

We analyse major Asian biochemicals deals from the past year and what they mean for the countries involved

Asian government funding support for the biotech ecosystem grew 140% between 2021 and 2024, driven by India and China.

Meanwhile, new anti-plastics legislation in the region is starting to boost demand for renewable materials.

In response to this growth, Asian companies are partnering up to expand capacity in biochemicals.

Some of the biggest Asian biomanufacturing collaborations announced over the last year have involved companies from China, Malaysia, Thailand, Singapore, and Japan.

Often, they are already major players in petrochemicals, now expanding into biochemicals. Many are cooperating with European chemicals companies.

We analyse major Asian biochemicals deals from the past year and what they mean for the countries involved.

Braskem Siam (Brazil/Thailand) – Toyo Engineering (Japan), October 2024

What's the product?
Bio-based polyethylene (bio-PE)

Who's buying?
Regional and global markets

Braskem Siam has chosen Toyo Engineering Corporation to work on engineering design for the latter's 200, 000 tonne capacity biobased polyethylene (bio-PE) plant in Thailand.

Braskem Siam's planned bio-PE plant, expected to come online by 2027, will be the first plant to manufacture this material in Asia. Sugarcane will be the main feedstock.

Bio-PE is used across industries in food packaging, personal care, and toys. Ethylene is normally made from fossil fuels.

Braskem Siam is a petrochemicals company that has branched off into the biomaterials market. It is a joint venture between Brazil's Braskem (the largest petrochemical company in Latin America) and Thai-based petrochemical company SCG Chemicals.

The deal will be welcomed by the Thai government, which is actively trying to grow into a biotech powerhouse to upgrade its economy.

Thailand's green ambitions
Thailand's 2021 "Bio-circular-green economy' strategy aims to turn the country into a biobased hub with emphasis on biomaterials manufacturing capacity.

This is a 20-year National Strategy that aims to stimulate investment and enhance the business environment. It will also see Thailand cooperating with Japan on designing a new circular economy for Thailand.

For Thailand, a thriving bioeconomy is a pathway towards greater economic prosperity and reducing inequality. It is already a major agricultural exporter but its ability to process higher value goods would

mean more revenue and less reliance on a fluctuating agricultural commodities market.

Brazil's Asian ventures
The Braskem-Toyo deal also reflects growing interest by foreign chemicals companies in tapping Asian biobased demand. The plant would be Braskem's first industrial park in Asia, set to almost double existing production of Braskem's global bio-PE production.

Braskem is not the only Brazilian producer trying to enter the Asian bioanufacturing sector. In January 2024 Brazilian paper and pulp producer Suzano signed an agreement with Japan's Mitsui & Co to develop biobased businesses. The deal aims to tap Suzano's Brazilian eucalyptus farms as well as pulp byproducts.

Kemira (Finland) – Shanghai Bluepha Microbiology Technology (China), June 2025

What's the product?
Bio-based packaging coating

Who's buying?
The Asia-Pacific market

Chinese biotech company Shanghai Bluepha agreed to collaborate for three years on commercialising a biobased coating for packaging in the Asia Pacific region.

The biobased coating is meant to eliminate the toxic chemicals usually used to finish packaging.

These include the thin plastic lining found in many food and beverage packaging (usually polyethylene) otherwise made of compostable paper materials.

Food packaging lining can also contain chemicals known as PFAS. This class of substances is linked to cancer and environmental toxicity.

The biobased version that Kemira and Bluepha will promote instead uses PHA material developed by Bluepha to be degradable in sea water.

Shanghai Bluepha is a green industrial biotech company founded in 2016 by scientists from Tsinghua and Peking University.

Asia-EU trade
The primary goal of the collaboration is for the Finnish company to sell into the Asian packaging supply chain and capture market demand there for sustainable alternatives.

However, Bluepha also has its eye on the EU market, where green chemicals demand is being driven up by EU regulation.

Bluepha's PHA has already cleared the main regulatory hurdle to selling in Europe. Its product met the EU food contact material test, meaning it can be used for good packaging through the region.

Chinese biotech policies pay off
Bluepha is testament to the success of the Chinese government's biotech policies over the last two decades.

Since 2009, it classed biotech as a strategic energy industry that got preferential tax treatment, subsidies, and government procurement.

The result is a booming industry that is now competitive with European and US firms on innovation and manufacturing costs.

Neste (Finland) – PCS (Singapore), November 2024

What's the product?
Bioplastics

What's the deal?
Neste to supply feedstock to PCS

Who's buying?
Mitsubishi, Toray Plastics, Synthomer

Another Finnish-Asian collaboration. This time, Finland's Neste will be supplying Singapore-based chemicals company PCS with renewable feedstock for bioplastics.

The renewable material Neste will be providing is based on waste products like used cooking oil or the byproducts of vegetable oil processing.

Neste already has a renewable materials refinery in Singapore.

PCS will use Neste feedstock to make different chemical precursors for plastics: ethylene, propylene, and butadiene.

One customer will be Japanese multinational Mitsubishi, which will be receiving biobased butadiene from the firm.

Mitsubishi had already committed to entering the renewable materials supply chain, having agreed on a strategic partnership with Neste to develop value chains for renewable chemicals in 2024.

The companies Toray Plastics in Malaysia and UK-registered Synthomer will also receive the PCS-Neste butadiene, ready to be formed into products across various industries.

In January 2025, Synthomer announced that its supply agreement with PCS and Neste would be used to create its range of 20 percent biobased rubber latex gloves.

The company says this would represent one of the first Asian butadiene value chains that conforms to the USCC certification – a sustainability certification system for sustainable feedstocks.

PCS Singapore started as a joint venture between the Government of Singapore, The Development Bank of Singapore Limited, and the Japan-Singapore Petrochemicals Company Limited.

The company mainly produces industrial chemicals based on fossil sources. Yet as this supply deal shows, even fossil companies are moving into the growing Asian market for green alternatives.

MojiaBio (Singapore) – A*Star (Singapore) – March 2025

What happened?
A Singaporean collaboration announcement

What's the product?
Biomanufacturing platform

Who's involved?
A company and a public agency

Singapore is hoping to put itself on the map for biobased manufacturing capabilities with this syn-bio platform, known as the Sustainable Bio-manufacturing Technology Platform.

The partnership is a public-private collaboration between two Singaporean entities: MojiaBio, a startup in green chemistry, and the government's Agency for Science, Technology, and Research (A*STAR).

MojiaBio has developed a platform to convert low-cost renewable materials into advanced biobased molecules for different industries.

The platform engineers enzymes and microbial strains so they can serve specific applications. For speedier and more accurate bio-engineering, the platform uses the National University Of Singapore's computational modelling expertise.

The government agency's role in the partnership is to help the company commercialise the product.

Synbio for economic development
For two decades the Singaporean government has focused on building up its biopharma industry.

Now, synbio is Singapore's latest target of economic development. The new MojiaBio collaboration is a breakthrough for the Singapore government's Green Plan 2030, which now aims to build its biobased chemicals sector.

Government agency A*STAR is crucial in this development scheme, as its role is to bridge between academia and industry.

The centre of Singapore's biobased research efforts is the National University of Singapore, now working on a number of projects that fit the green synbio mould including a programme developing a blue-green algae biomanufacturing platform.

Petroliam Nasional Berhad (Malaysia) – Enilive (Italy) – Euglena (Japan), July 2024

What's the product?
Biofuels

Who's buying?
Markets around the world for renewable transportation fuels

Another Europe-Asia collaboration, this time on biofuels, between Petroliam Nasional Berhad, Enilive and Euglena.

The three companies reached a final agreement last summer to develop a biorefinery in Malaysia. The plant will have capabilities in sustainable aviation fuel (SAF), bio-naphtha, and hydrotreated vegetable oil.

When finished, the biorefinery will have the capacity to process about 650, 000 tonnes of raw materials per year.

The feedstock will come from waste: used vegetable oils and the byproducts of vegetable oil processing.

In December 2024, the companies announced that Samsung would serve as the main contractor for the joint venture, providing engineering procurement, construction, and commissioning.

As a whole, Southeast Asian SAF capacity is growing rapidly as a means of achieving industrial development with Malaysia and Singapore leading the way.

Malaysia's feedstock advantage

One of Malaysia's big advantages when it comes to building a cost-effective SAF industry is that it has a large pool of palm oil refining waste, which is an attractive circular biofuel feedstock.

Right now Malaysia mainly exports their palm oil effluent to China for biodiesel production. Yet the expansion of domestic SAF capacity could mean this feedstock is diverted into a home industry, allowing the country to capture more of the value locked up in the agro-waste it generates.

By building up its sustainable fuel capacity, Malaysia is aiming to take advantage of growing regulation-led demand in Europe and South Korea.

The EU will require that at least 2 percent of sustainable aviation fuel be available at all its airports. South Korea plans to introduce mandatory blending requirements from 2027.

JULY 9, 2025

Startups take on Europe's untapped feedstocks

Unconventional feedstocks offer Europe sustainability and supply security

The EU needs to start tapping unconventional biomass to grow its bioeconomy.

This is according to a new report that took stock of the EU's bioeconomy potential.

Opportunities for Innovation in the Bioeconomy by the European Environment Agency, released July 2025, states the EU economy needs to increase its flow of biological raw materials to support a domestic renewable materials industry.

One way to do this without falling back on imports is by drawing on unconventional feedstocks:

- Fishery discard
- Agricultural waste
- Forestry waste
- Processed food waste
- Marine algae

Already, there are many European startups dedicated to each of these feedstock categories.

These innovators offer the EU a firm foundation for scaling novel biomass processing capacity.

But first, why are European agencies interested in increasing its domestic biomass rather than simply importing its raw material requirements?

The EU's raw material worries

Securing industrial raw materials supply has become top priority for the EU ever since the start of the COVID pandemic and resulting trade disruptions. Raw materials for the bioeconomy has been no exception.

The goal is to reduce dependence on foreign suppliers so that in the event of conflict or disruption, the EU can sustain critical industries.

More supply without more land

The EU's ecosystems can provide only half the capacity needed to sustain current resource use in the region.

One thing that the EU cannot do, however, is to simply grow more crops for industrial use.

Bringing new areas of land under cultivation competes with wildlife and habitat conservation. If the EU wants to meet its biodiversity targets, it will have to look at other ways to boost its domestic biomass supply.

The report highlighted several unconventional feedstocks, each with applications across different industries.

Agricultural waste: compostable polymers, packaging fillers, microbial growth medium

Each year the EU generates around 700 million tonnes of agricultural waste – more than the annual EU wheat harvest, which comes in around 130 million tonnes.

This hefty store of biomass could find uses in the sustainable packaging

industry. One company that has taken up this niche is Proservation, founded 2022.

Proservation uses grain husks to create an alternative to styrofoam. The company specifically sources spelt husks from the Ländle region, which the company says produces around one tonne of the stuff per day, per mill.

Proservation calls its grain residue material an 'ecological cushion', describing it as an alternative to polystyrene packaging filler.

Traceless, founded in 2020, is another German company using up agricultural waste to create higher value goods.

Traceless is a little more developed in its commercial journey. Rather than focusing on a single material from a single feedstock as Provservation does, their offering is a broad-based platform that extracts materials from different kinds of agricultural residues.

These natural materials are home compostable, meaning that they will readily break down in a home compost pile and do not need special processing to be made safe for the environment.

Agricultural waste also has biotech applications. Zymofix is a category-defying circular startup that rears functional microorganisms on agricultural waste.

The company first harvests agricultural waste and converts the material into a high quality substrate for beneficial organisms. These organisms are then fed back into the food system, sold onto farmers that apply them to the soil.

Forestry residue: personal care ingredients

The Nordic countries are the centre of wood waste biomaterials innovations. This is because of the huge forestry industry that exists across this part of northern Europe.

Finland's Montinutra is taking wood sugar and turning it into luxurious personal care products. The sugar, derived from trees, contains antioxidants and holds uses in skin care and hair care.

The company doesn't take the sap from living trees, however. Its feedstock comes as a byproduct from sawmilling – a huge industry in Finland where there are over 12 million cubic meters of wood sawn annually.

The basic material can be altered for use as industrial binders and barrier coatings too.

Estonia's Fibenol creates biochemicals from hardwood chips. These foundational chemicals can then be turned into all manner of goods, including biofuels, cosmetics, and alternative sugars. The process it uses minimises waste – over 90 percent of the biomass inputs will become marketable materials, indicating a very efficient process.

Processed food waste: cosmetics, drinks, biodegradable packaging

This feedstock category starts a little down the food chain – the uneaten byproducts of grocers, food factories, supermarkets and restaurant dining.

In Warsaw, Poland, startup Rebread is turning unsold bread into a

number of consumer products.

Rebread turns the unsold bread into a clean, standardised raw material. This can be used as a base material in the food industry but also for biotech (as a medium for bacterial cultivation) and in packaging or cosmetics.

Huge amounts of bread go to waste each year thanks to a short-shelf life and rampant overproduction.

This poses an ecological problem since all the agricultural resources that go into cultivating and processing the grain become effectively wasted, enlarging the environmental footprint of the food system.

Fishery discards: alternative protein, biogas, fishscale leather

Fishery discard may seem like a waste product with few higher value uses. However, these cast-offs are feeding into one of Finland's most innovative biotech startups – Hailia.

"We take the whole fish, grind it, and recreate the structure...it's not gritty. It has the mouthfeel of cooked fish," according to Michaela Lindström

Hailia's approach to using up the whole fish resonates in the context of a crisis in global fisheries.

3.1 billion rely on fish for 20 percent of their daily protein intake. 800 million relying on these animals for food and income. Yet with a growing global population, the gap between sustainable protein and human need will grow.

Finding innovative ways of making more of the caught fish palatable to consumers could ease pressure on wild populations.

Fish waste has uses beyond food. Company Green Gas AS uses it, alongside other organic matter, as a feedstock for energy through its biogas plants.

Fish discards could soon be hitting the runway thanks to LVMH-backed Ictyos, which turns waste fish skin into sustainable leather.

The startup was founded by three chemical engineers that saw valuable fish skin going to waste in restaurants around their native France. Even the tannins they use to treat the fish skins are biobased rather than minerals, as in traditional leather production.

Fish waste leather is less harmful to the environment than traditional leather from livestock. It is also a good way of cleaning up the fishery industry.

Creating luxury goods soaks up discarded scales, solving the unseemly problem of decomposing fish waste which generates carbon dioxide and can poison the environment.

Marine algae: biopolymers, cosmetics ingredients

Marine algae may not be waste but it is a highly sustainable source of biomass. It can be processed into many of the biochemicals and biomaterials needed in industry with just a fraction of the inputs that land-based agriculture needs.

Northwestern France has a rich history of seaweed harvesting. Today, startups in the region are creating high value chemicals from them.

Algaia from Brittany, France uses algae to produce biopolymers that go into stabilising cosmetic gels. Using biobased chemicals like these can avoid the need for many petrochemical ingredients so common in modern makeup.

Another Brittanny-based algal startup is Algopack, which makes packaging material from the plant.

The problem with waste

Drawing on unconventional biomass sources is not without its technical challenges.

Certain kinds of biomass are not economically viable to process. Emerging methods may be needed to fully exploit these alternative sources of raw materials at a commercial level. Compared to crops grown specifically for industrial purposes, agro-waste is of uneven quality and hard to sort. They can be tough to transform into a consistently high-quality product in a way that is cost effective.

Microbes to the rescue

The answer lies in new processing methods. Microbial biorefineries (or conversion plants) are an emerging and cost-effective way to turn waste into new goods.

Certain microbes produce high value compounds either by metabolising waste feedstock into the target chemical or by releasing enzymes that alters it chemically.

Microbes are nature's biotech platforms. They are so effective at performing complex chemical conversions that they can significantly bring down the costs of working with even poor quality waste materials.

In Europe, some microbial biorefinery capacity has been in commercial operation for some time. However, since 2020, a new generation of companies have sprung up, selling microorganisms that can make light work of a wider variety of waste products.

Emerging European microbial conversion startups include AmphiStar from Ghent, founded in 2021. It uses microbes to turn waste into biosurfactants, a substance in cleaning fluids and soaps.

Switzerland's Albatros meanwhile uses AI to identify the best microorganisms to digest different agro-waste byproducts and turn them into human food. These microbes concentrate the nutrients dispersed through agro-waste. The results are ingredients and additives that maximise protein and nutrition.

Another waste-to-food startup is ÄIO, founded 2022, which is using microbes to turn agricultural and wood byproducts into edible, animal-free fats.

JULY 16, 2025

Decadent vegan ice cream? It's all about the fat

Vegan ice creams are more moreish than ever thanks to new non-dairy fats

A new generation of sustainable producers is upending consumer perceptions of non-dairy ice cream.

Historically, vegan ice creams have struggled to replicate the creaminess of dairy versions. Now, advances in food tech are making non-dairy decadence cheaper, meaning that vegan scoops can be just as indulgent as traditional brands.

Whether dairy or not, the flavour and texture of ice cream ultimately boils down to the fats used to make it. Today, producers have a wide range of plant-based options to choose from, with coconut fats leading the way.

Meanwhile, food tech breakthroughs are promising to make the non-dairy ice creams of the future even tastier. The alternative ingredients sector has developed precision fermented milk fats without the cows, opening even more exciting possibilities for sustainable summer treats.

What makes an ice cream taste good?

Fats are fundamental to the luxuriousness of ice cream. Non-dairy ice cream is no exception.

The secret of ice cream is in how fats are combined with air.

When milk is whipped and frozen, some fat sticks together forming random clumps. These clumps cluster around and secure tiny air bubbles, creating a network of fat throughout the ice cream. This results in the dreamy mouthfeel of ice cream we know and love.

Usually, dairy ice cream gets fat from cow's milk. Premium ice creams contain the highest fat percentage while regular ice cream contains a bit less. In the US, the FDA stipulates that ice cream must contain at least 10 percent milkfat to be marketed as such.

Plant-based fats

To achieve the beloved textures and flavours of conventional ice cream, vegan offerings must replace fat from livestock with fat from other sources.

Vegan ice creams are possible because fats are also found in plants. Today, most of the vegan ice creams on the market will use coconut fat, which is rich in the saturated fats that makes the sweet treat so satisfying.

Magnum, which reported a 95 percent jump in growth for its vegan range between 2024 and 2025, is one of the biggest companies leading the non-dairy charge in supermarkets. Its range of vegan ice creams draws on coconut fat with a base of soy protein.

At the other end of the corporate scale, Greek startup Plan(e)t Foods (founded 2021) makes their vegan ice cream with Greek oats and coconut fat as a source of added fat. In June 2025, the vegan food producer raised €1.05 million.

Booja Booja, a stalwart of the vegan ice cream sector, uses fat from cashew nuts plus coconut syrup for a perfectly creamy bite. The combination works for a brand that pitches itself as a maker of luxury desserts that just happen to be plant-based.

Small companies, big flavours

Industry heavyweights like Magnum and Ben and Jerry's are mainstreaming non-dairy in supermarket aisles everywhere.

Yet when it comes to the most exciting vegan tasting experiences, it is sometimes the smaller, more specialist startups pulling the weight.

Kind Kones may not be a household name (yet) but their ice cream innovations showcase the gastronomic potential of non-dairy desserts.

The Singaporean vegan ice cream wants to eliminate not just animal products in ice cream but also artificial ingredients. While some plant based options are stacked wtih preservatives, Kind Kones' ingredient lists stand out for their natural simplicity.

Kind Kones puts to rest the notion that vegan desserts can't get experimental with flavour. So far, it has put out around 150 flavour combinations on the market.

Some cater to the Southeast Asian palette like its Pandan Gula Melaka, inspired by the shredded coconut buns popular in the region.

In the US, black-owned Cajou Creamery has made cashew cream-based ice creams that are a veritable tasting menu of South American flavours: their horchata tub evokes the flavours of the vanilla and cinnamon drink popular in Mexico while Cortadito mixes the coffee and sweet steamed milk to conjure up the Cuban espresso.

Chewing the fat

Further advances in vegan ice creams will rely on breakthroughs in the alternative food tech sector.

For years, the alternative ingredients sector has been busy developing vegan versions of basic ingredients used across food production, including fats.

Ice cream companies are a key target market for vegan fat producers.

Ice cream makers need high quality fats to replicate the melt, texture, and creaminess of dairy ice cream for a customer base that demands moreish luxury from their products.

Coconut oil has been the go-to non-dairy ice cream fat yet some are keen to find alternatives.

Coconut fat works in some vegan ice cream formulations but not in others. The coconut flavour can become noticeable in milder flavouring combinations.

> "One advantage of these microbe-produced fats is the freedom they offer to food producers. These fats are, in theory, endlessly customisable."

Developing the perfect non-dairy fat with a neutral taste has been a particular obsession for the food tech industry. Now, many believe the hope for the creamiest, most convincing non-dairy ice cream fats lies with the biomanufacturing technique called precision fermentation.

Precision fermented fats are fats produced in the bodies of microbes rather than taken from either animals or plants.

One advantage of these microbe-produced fats is the freedom they offer to food producers. These fats are, in theory, endlessly customisable. Simply by altering the microbes, producers can achieve different kinds of fats with different properties.

These fermented fats mimic the crucial chemical properties that impart that moreish 'ice-cream'-ness to the entire ice cream, by clinging onto the flavour and slowly releasing it in a deliciously rich medium.

Animal-free fats from the lab

Yali Bio is one company pioneering in fermented fats, collaborating with Givaudan, Ingredion, and AAK.

The food tech company recently demonstrated its fermented fat at a Food Tech event in San Francisco. The ice cream they used to showcase the ingredient reportedly ran out in an hour.

Ice cream is the most obvious application for Yali Bio's fermented fat. However, it could also be a game-changer for non-dairy baked goods. This is because the melting point of Yali Bio's fat can be fine-tuned to meet the needs of different products.

Fermented fats of the kind that Yali Bio and others are developing could be the tipping point that the industry needs to convince a much larger market to adopt vegan offerings, not just for ice cream but savoury products too.

Often, the reason that non-dairy baked goods like pastries and cakes fall short are the way the fats they contain react with sugar, eggs, flour, and other elements.

It is difficult to use plant-based oils and butters in ways that impart richness, flavour, and moisture in as many different products as animal butter.

Apart from their convincing chemical qualities, companies like Yali Bio argue its precision fermented fats are even more planet friendly than even some of the plant-based ingredients like coconut oil.

This is because microbes need drastically fewer resource inputs to make ice cream-friendly fats than cultivated coconuts and cashews, including water and land area. Using fewer cows products would also mean cutting the greenhouse gas emissions associated with livestock agriculture.

Eliminating palm oil with microbes

Greenhouse gas reductions are only one of the environmental benefits that precision fermented fats offer.

They could also reduce the damage to wildlife that certain plant-based ingredients can cause.

One area where fermented fats could support a more ethical food supply chain is by displacing palm oil, a relatively common ingredient in non-dairy ice creams.

Some vegan producers opt for palm oil fat as an additive in their non-dairy ice cream to raise the melting point so the product holds its shape in high summer temperatures for longer.

However, palm oil plantations have destroyed tropical forests across Asia, Latin America and West Africa. 90 percent of global supply is now grown on a few islands in the highly biodiverse countries of Malaysia and Indonesia.

Dutch startup NoPalm is turning precision fermentation to the task of eliminating palm oil from non-dairy ice creams and other products.

The company specifically produces tailor-made oils and fats grown inside microbes to replace the habitat-wrecking ingredient in all kinds of vegan foods.

Non-dairy ice creams of tomorrow

Precision fermentation of complex biological structures like dairy proteins is still not cost-effective. However, startups like France's Verley are already producing some precision fermented dairy proteins and trying to scale.

With these lab-made fats and dairy proteins coming to the fore, the vegan ice creams of the future could be new sites of bold flavour experimentation.

What makes precision fermentation such a powerful biomanufacturing tool is that it can copy any biological material in large volumes without needing to slaughter any animals.

Everything that animal creams and fats do in non-dairy desserts today could be replicated in the vegan ice creams of the future – without the ecological and carbon footprint of livestock dairy.

Fermented fats and proteins could also open the door to ice creams healthier and more accessible.

Fermented ingredients are customisable on a precise molecular level, paving the way for dairy proteins without lactose allergens or ice creams that use healthier fats while still offering the creamy density of dairy options.

With the power of precision fermentation, the future of non-dairy ice cream looks delicious.

JULY 23, 2025

Solar goes biobased

Biomaterials could minimise the environmental impacts of solar panels

Solar is the future of the global energy mix. More solar capacity was added to the US grid in 2024 than from any other single energy source in the past two decades.

Over in China, the world's leading consumer of solar, installed capacity rose 45.2 per cent year-on-year.

Yet the rise of this renewable energy has its own environmental costs. They are critical components of a greener economy, but as the industry grows, we must make sure that solar manufacturing itself sticks to sustainable principles.

The main sustainability issue with solar is that the panels need many energy-intensive minerals and chemicals.

Each panel contains a panoply of mined elements, pushing up the ecological footprint of renewable energy: tellurium, silver, zinc, and silicon. The panels also contain petrochemicals.

Renewable biobased resources can underpin a new generation of solar panels that balance energy efficiency, cost, and environment.

Power-hungry silicon

To see how biomaterials can improve the sustainability of the new energy landscape, we have to understand the components and materials inside a typical solar panel.

Solar cells are an important component of the solar module. When they are exposed to light, they absorb energy.

The solar cells turn this energy into negatively charged particles, which make up the electric current that enters the grid and power your homes.

More than 98 per cent of solar panels on the market today contain solar cells made from crystalline polysilicon. This silicon-based solar tech is so popular because it is highly efficient at turning light into energy.

However, the silicon solar cell has major downsides in terms of sustainability. Environmental impact assessments of solar power typically show that the cells of a panel are among its most energy-hungry components.

This is largely down to how energy-intensive the mining, processing, and purifying of silicon is. Coal power is prominent in the global polysilicon manufacturing industry, which is overwhelmingly dominated by China.

Silicon alternatives: organic solar cells

Concerns about the ecological footprint of silicon are driving researchers to develop a new generation of solar cells.

Cue organic solar cells, which dispense with silicon and use carbon-based materials instead.

Organic solar cells appeal for different reasons. One is a reduced environmental footprint from the absence of silicon.

Another is that carbon-based materials are much cheaper raw materials than silicon.

These materials also have unique physical properties. Silicon leans towards heavy, rigid, and bulky products. Carbon-based materials can be rendered into flexible, thin sheets.

This means organic solar cells could form the basis of new types of panels, ones that are easily transported, and fitted onto various surfaces, including windows and even apparel.

Biobased organic solar cells

The word 'organic' conjures associations with natural and renewable materials. This is not the case for organic solar cells. Despite the name, they are made today from oil-based plastics (plastics are carbon-based, just like biological materials are).

Biobased components of organic solar cells are however coming into development.

Researchers at Sweden's Linköping University and KTH Royal Institute of Technology have now shown that wood can be used to enhance performance in ordinary organic solar cells.

The wood-based material the researchers have come up with goes into the middle of the solar cell, the part that is sandwiched between two electrodes. This is known as the electron transport layer.

The material they have used is known as kraft lignin which is made from ordinary wood pulp.

The role of kraft lignin in the solar cell is to make the device more stable – in other words, its ability to perform reliably over time – something that can make organic cells more commercially viable.

Organic solar cells may not match dominant silicon cells for efficiency in energy conversion. However, the marginal difference in efficiency between the types doesn't matter in many applications.

Lower efficiencies are good enough for solar panels integrated into textiles, vehicles and buildings – lower-energy applications where ramping up efficiency at the cost of the environment is difficult to justify.

Red onions trump petrochemicals

Apart from energy-intensive minerals, there are also fossil-based plastics found inside typical solar cells – both in organic and polysilicon solar technologies.

Within a typical solar panel, solar cells are sandwiched between two layers called 'encapsulants'. These are two protective layers that keep pollution, moisture, and dirt out of the energy-generating cells.

Unfortunately, these protective layers often rely on fossil polymers, like polyolefin or ethylene-vinyl acetate (EVA).

Researchers at the University of Turku, Finland found that cheap biobased materials can be used to replace these oil-based coatings.

The researchers applied red onion dye to a biomaterial called nanocellulose. Nanocellulose is a broken-down version of cellulose, which is found everywhere in the biological world, particularly in plants. Astonishingly, the biobased dye outperformed a commercial PET-

based UV filter.

Circular waste coatings

Solar cell coatings made from circular materials could be on the horizon thanks to new research.

Scientists from Saudi Arabian, Indian, and Ethiopian universities published in Nature last year on new bio-waste solar cell coatings.

NanoBioCelluSynth (NBCS), and EcoPolyBlend were the names of the two materials they formulated and tested. These are both biobased polymers.

The first, NBCS, is made by breaking down cellulose-rich anaerobic biomass digestate into nanoscale cellulose particles.

Digestate is a huge and largely untapped feedstock. It is a waste byproduct of the biogas industry, which turns biological feedstock into gas energy. Europe alone produces between 118 and 138 million tonnes of the stuff per year.

80 per cent of the NBCS material developed and tested in the study was made from digestate-derived cellulose, a material found in plant cell walls.

Other ingredients in the mix were natural additives (10 per cent), with the remaining share made up of agents, stabilisers, and fillers.

The EPCB material on the other hand is 60 per cent composed of biopolymers and 20 per cent from plant-based cellulose, starch or lignin, all of which are abundant natural materials.

For testing, these materials were applied to the solar cell's surface. After this, the panel was subject to solar simulators that mimic sunlight as well as 'outdoor' weather conditions in an indoor chamber.

The study showed these bio-waste solar coatings are high performing while offering a lower impact – up to a 30 per cent carbon footprint reduction compared to conventional materials.

Environmental multi-tasking

Circular and biobased solar cell coatings can benefit the environment in multiple ways.

Apart from potentially reducing demand for petrochemical coatings from the solar industry, it can also clean up waste created by the anaerobic digestion sector.

Digestate may be biobased but in large quantities in nature, it can cause soil and water pollution.

The problem is that it is expensive for digestate operators to process the digestate to render it harmless.

Upcycling the waste could become more viable if new sources of demand arise from the solar panel industry.

Power from plant pigments

Another emerging type of non-silicon-based solar cell are dye-sensitised solar cells. This uses dyes to convert light into electrical

energy.

Like organic solar cells, the dye sensitised cell is a 'third-gen' solar technology, which is just starting to get commercialised.

Usually, the dyes used here are synthetic and ruthenium-based. Ruthenium – a metal – has been popular for its efficiency at absorbing light and facilitating charge transfer.

However, ruthenium is relatively scarce and its compounds can be highly toxic. These issue are sparking research into possible alternatives that use more common and natural materials.

The plant world is an obvious place to look. Fruits, plants, and flowers are full of colourful and natural pigments that have the kind of light-absorbing properties developers need for dye-sensitised solar cells.

Many are investigating anthocyanins, a class of natural pigments that are responsible for some of the boldest colours in the plant kingdom.

Scientists have been experimenting with a range of anthocyanins extracted from black rice, red cabbage, mulberries and blueberries for the purpose. Chlorophyll is another natural pigment that scientists believe could be an efficiency-enhancing yet sustainable input for dye sensitised cells.

Biobased supports solar recycling

Recycling is a major roadblock in making solar panels sustainable. Despite solar panels containing highly valuable elements, recovering them is still to costly to be done at scale.

One solution could be to fabricate solar panels with more biobased materials.

The reasoning is that recovering precious metals from solar panels could become more profitable if more of the device could be incinerated at the end of its life.

A panel made from plant-based materials, particularly the substrate layer on which other components are mounted, could be burned to leave only precious metals behind.

This straightforward incineration recovery gets rid of the need for costlier and more complex chemical processes to selectively pick out valuable elements for re-use.

Cutting edge research into biobased additions and enhancements in solar reflect changes in perceptions around clean energy technology.

For years, the focus of renewables policy and the solar industry was simply to maximise solar cell efficiency, drive capacity roll-out, and replace fossil fuels as quickly as possible.

Yet as the industry matures and the environmental impacts of renewables become clearer, attention is now turning to the sustainability aspects of the energy transition itself.

Biobased materials can help keep the ecological impacts of the clean energy transition to a minimum while striking a balance between cost, performance, durability, and environment.

JULY 30, 2025

Korea perfects biobased beauty

Korean beauty brands have become leading innovators in biobased ingredients

Mirror skin, PDRN treatment, spicules and sleeping masks are just some of the more esoteric beauty trends of 2025. All owe their popularity to the rise and rise of the Korean beauty industry.

The Korean beauty industry is estimated to be worth $11.2 billion in 2025 and demand for its products continues to grow rapidly.

The industry is also affecting a culture shift in global beauty consumption. Korean brands like Beauty of Joseon, Klairs, and Purito are overturning the idea that synthetic formulations perform better when it comes to skin and beauty.

Many Korean beauty products have a glowing reputation worldwide for minimally processed, often plant-based, ingredients that get luminous results.

This emphasis on natural skincare means that Korean brands are a growing source of demand for high-value biobased chemicals. Big Korean beauty producers are not just buyers of biobased ingredients – they are also key innovators responsible for developing and commercialising new biochemicals for use in skin and hair.

We explore how key Korean manufacturers and brands are drawing on advanced biological materials to replace (and surpass) synthetic chemicals in cosmetics and skincare.

More natural ingredients

Looming tariffs have US cosmetics consumers and influencers worried. Many are scrambling to get their hands on cherished Korean beauty imports they have been loyal to for years.

The rush to stockpile Korean beauty goods in the US is a brilliant example of how cosmetics have become one of the country's most powerful exports.

Fans of Korean beauty products have become enamoured with toners, moisturisers, and cleansers that use gentler, natural ingredients to achieve results – often at a lower price point compared to Western equivalents.

Silicon alternatives: organic solar cells

Cosmetics company Kolmar Korea is building on its biobased range, led by the growth in global demand for Korean products.

The company announced this year that it would be developing a skincare range containing natural Korean ingredients, with products aimed squarely at the international market.

The company's new business strategy will foreground biobased ingredients associated with traditional skincare practices in Korea.

Kolmar is leaning into the mystique that has built up around Korean skincare on platforms TikTok and Instagram, where influencers post daily skincare routines incorporating their favourite brands.

Products coming out of the country are strongly associated with natural ingredients that are minimally processed.

This emphasis on natural ingredients dovetails nicely with growing consumer concern for eco-friendly products. Biobased ingredients tend to be less environmentally toxic as well as less irritating to the skin.

> "Fermentation is not just a convenient method for mass-producing biochemicals. It also allows cosmetics manufacturers to enhance the skincare benefits of plants while keeping synthetic chemicals in the production process to a minimum."

Another key selling point of Korean beauty is how biobased ingredient use goes hand in hand with product innovation.

At Kolmar, a third of its workforce is dedicated to research while around 6 percent of annual sales is invested back into R&D.

One beauty problem that Kolmar is currently trying to tackle is how to add fragrances to products without synthetic chemicals that damage sensitive skin. Here, native plants like Rose of Sharon and lotus are proving useful.

Korean botanicals are a burgeoning area of biotech research.

CoSeedBioPharm is an important player here, providing functional ingredients derived from biodiversity hotspot Jeju, while Smile Company sources herbs from the Mediterranean for cosmetics compounds.

Western firms snap up Korean ceramides

The Korean beauty industry is scaling the use of precision fermentation to create biobased ingredients. This is where microbes reproduce complex molecules at scale.

Western companies have taken note. British speciality chemicals company Croda purchased Korea's Solus Advanced Materials in 2023 for their ceramide fermentation technology.

Solus had developed a way to ferment ceramides for lotions, cosmetics, and hair care. It already had a supply agreement with L'Oréal for its ceramides.

Ceramides are a fundamental beauty ingredient. They are the fats that are naturally found in skill cells, making up 30-40% of the outer layer.

Fermented ceramides was at the heart of another deal in 2024 when specialist Korean cosmetics ingredients supplier Jin Young Bio was snapped up by Belgium's Solvay spin-off Syensqo in 2024. Again, Jin Young Bio company specialises in creating ceramides through a fermentation process that uses genetically engineered yeast. The acquisition aligned with Syensqo's push to expand their renewable materials portfolio.

Fermentation is not just a convenient method for mass-producing

biochemicals. It also allows cosmetics manufacturers to enhance the skincare benefits of plants while keeping synthetic chemicals in the production process to a minimum.

Labio is a Korean beauty company that has been pushing the performance limits of all-natural ingredients using fermentation. Their range includes chemicals derived from fermenting blueberries designed to strengthen overall skin resilience and a fermented antioxidant carotenoid for wrinkle reduction.

Mushroom biocosmetics

Korean companies are leading the way in developing mushroom cosmetics, a relatively new biobased beauty trend.

Fungi is everywhere these days in new renewable materials and chemicals, including those used for cosmetics and skincare. Nowhere in the world is this trend more pronounced than in Korea.

Luxury Korean cosmetics brand Amorepacific – owner of trendy Korean brands Laneige and Innisfree – have peppered their products with mushrooms that hold skin-rejuvenating properties.

Its luxury label Sienu for example features anti-ageing skin care products with lingzhi mushroom, among other high-end ingredients like diamond and gold.

Korean skincare brand Mary and May have incorporated another species, the Tremella fuciformis – or the snow mushroom – into a serum designed to 'brighten, hydrate, and revitalize' skin.

This mushroom has been used in traditional Chinese medicine as a bodily tonic. Modern scientific studies have supported the idea that the species can help skin antiaging and UV protection.

Clearer skin with biobased ingredients

Two powerful Korean companies agreed to join forces in 2024, in a deal to capitalise on the natural beauty trend.

Korean cosmetics manufacturer Daebong LS and chemicals giant LG Chem agreed to develop and commercialise cosmetics with LG Chem's 100% biobased 3HP (3-hydroxypropionic acid).

Biobased 3HP an active ingredient that can be used in various skincare products. A major selling point is that it can replace the popular salicylic acid in cosmetics and skincare.

Salicylic acid is a staple ingredient in Western skincare. The chemical exfoliates dead cells, unclogs pores, and helps prevent acne. However, the chemical is harsh and can remove too much of the skin's natural oils, causing irritation and dryness.

3HP is attractive to cosmetics manufacturers seeking natural ingredients with the same functionality as salicylic acid but with fewer drawbacks.

LG Chem is one of the world's most recognisable industrial chemicals companies. Yet it has a lot to gain from the collaboration with Daebong thanks to the latter's intensive expertise in cosmetics.

Daebong is one of the companies that has made Korea a world class

innovator when it comes to beauty biotech. It operates facilities right the way through the value chain, from material development to production, and sales. It also enjoys partnerships with approximately 1000 cosmetics companies around the world.

Daebong's capabilities and contacts should allow LG Chem's biobased 3HP to reach consumers more efficiently.

Biobased preservatives

One of the biggest technical hurdles to all-natural skincare is formulating cost-effective biobased preservatives.

Cosmetics use fossil-based preservative chemicals to extend the shelf-life of a product by combating mould, bacteria, and oxidation. The majority of preservatives in cosmetics are still made from fossil chemicals.

One company tackling the problem is GS Caltex whose chemical GreenDiol is antibacterial, antiseptic, and made from cassava and sugar cane. The multifunctional green chemical also adds moisture to the skin and can be used to extract active ingredients from plants.

GS Caltex is the only company to be mass producing the chemical using a 100 percent biobased process, one that does not involve harmful chemical additives.

This Korean manufacturer signed an MoU with L'Oréal Group in 2023 to develop biobased cosmetics ingredients. GS Caltex exemplifies the biobased innovations drawing the European beauty giant to expand into Asia Pacific.

The surge in demand for Korean skincare throughout Asia, Europe, and the US reflects a simple fact: consumers are reacting against the petrochemicals and non-biodegradable ingredients found in most cosmetics.

Mainstream cosmetics still contain compounds that are harmful to the environment, our bodies, or both. Korean beauty offers an alternative, replacing these with potent functional ingredients found in nature.

AUGUST 6, 2025

Biomaterials on demand with 3D-printing

Is 3D printing the future of industrial biomaterials?

Manufacturers are increasingly seeking high-performance renewable materials to replace carbon-intensive inputs in energy, pharmaceuticals, biotech, and packaging.

Biobased industrial inputs may be more sustainable than their fossil counterparts. Yet to appeal to manufacturers, biomaterials must match or outperform fossil chemicals at a reasonable cost.

3D printing is rising to the challenge, making specialist industrial biomaterials easier to manufacture anywhere, any time, and in small, targeted batches.

We look at how 3D printing can help drive biomaterials adoption in highly specialised industrial niches.

AI in 3D biobased printing

The ability to manufacture highly specialised biomaterials rapidly and cheaply is fundamental to building a more sustainable industrial sector.

3D printing – the printing of 3D objects based on digital instructions – could help make this happen, especially when twinned with artificial intelligence software.

This intersection of AI, biomaterials, 3D printing, and manufacturing is getting attention in the EU currently through a project known as ORGANIC. The industry-partnered research programme aims to develop a platform that deploys AI to print large industrial biobased parts.

Over the next four years, ORGANIC will focus on developing a platform that can print a biobased middle layer for turbine blades. A biobased component like this would make turbines much easier to recycle than they are currently.

Although the project centres around wind turbine components, the ultimate aim is to develop a digital printing platform that can help any sector develop custom low-carbon biomaterials for its own needs.

An end-to-end AI-led biomaterials design and printing platform is still an emerging concept so the project must design its system from the ground up.

One of the most interesting elements of the projects will involve prototyping printing heads fitted with sensors. Coupling the sensors with AI software will allow the printer to self-correct while producing components.

In working at the intersection of 3D printing and biomaterials, the EU is preparing for growth in industrial biomaterials demand.

3D printing facilitates an on-demand, made-to-order business model that delivers niche biomaterials in small batch quantities.

This means that rather than choosing from a limited and generic range on the mass market, clients will be able to order renewable materials to exacting standards.

This emphasis on made-to-order innovation could encourage wider biomaterials adoption in manufacturing sectors, which have exacting performance criteria for their inputs.

AI-led design

The ORGANIC project plans to use AI not just at the manufacturing stage but also at the design phase.

AI can make it cost effective to develop and print products in brand new, niche materials. This is because developers are faced with potentially thousands of industrially useful biomaterials and composites – the R&D needed to identify cost-effective, high-performing, and sustainable options for specific use cases can be capital intensive and time-consuming.

Designing highly specialised and sustainable biomaterials for industry is one area where AI could have immense social value. This project will be a testing ground for whether it can work in practice.

The use of AI to semi-automate the material discovery process should help cut the costs of developing new industrial biomaterials. This is important since certain niche industrial materials will never be in high enough demand that producers will be incentivised to mass produce them.

AI programmes can rapidly explore large numbers of sustainable materials in the digital realm, eliminating the need for costly experiments using physical materials.

The tech promises to make the R&D and testing for biomaterials (and the market price of the finished product) as cost-effective as possible, making innovation less capital intensive for companies.

Printed biobased resins

Similar to the EU's ORGANIC is Project Nexus, a UK-based industry-academia collaboration to develop 3D printed biobased industrial parts.

Unlike ORGANIC, Project Nexus is working on developing manufacturing equipment for the bioprocessing industries.

Bioprocessing is a manufacturing method where living cells are cultivated to produce chemicals, usually inside vats called bioreactors. Bioreactors are essential equipment for bioprocessing, vessels that house the cells and biological reactions needed to manufacture target chemicals.

Bioreactor components like sensors are almost always built with fossil plastics: polyethylene, polypropylene, polycarbonate, and polyvinyl chloride.

Unfortunately, these plastics bioreactors and their parts are designed to be single use only. This gives a profit advantage in advanced bioprocessing industries, where the purity of the final product is all important – any cross-contamination between batches of microorganisms or enzymes can spell huge losses for the producer.

Bioprocessing is commonly used for biopharmaceutical drugs but also some industrial biomaterials. Globally, the single use bioprocessing market has been valued at $32.52 billion in 2024.

These disposable bioreactors are a disaster from an environmental and waste management perspective, producing a stream of waste plastic that will never biodegrade safely.

This is the problem that Project Nexus is attempting to solve. Industry partners include Photocentric and Sartorius, both industrial 3D printing companies, the biopharma solutions company Metamorphic, and CPI, a manufacturing tech company. On the academic side are Imperial College and the University of Sheffield.

For the next two years, these collaborators will develop and test biobased versions of bioreactors and their components, such as the sensors which continuously monitor what is going on inside the vessels during manufacturing.

The bioreactors that will be developed by the project will be made from biobased resin. These will be tested for use in pharmaceutical R&D and manufacturing.

The project has circular ambitions for its biobased resin bioreactors too. Once they have been used in pharma manufacturing, they can be upcycled for use in the biobased industrial chemicals industry. Pristine chemical purity is not as high a priority in the sector as in pharmaceuticals, allowing for component re-use.

Custom bio-foams

3D printers are usually associated with solid parts but they can also be adapted to work with liquids.

Founded in 2022, Dutch company FoamPrint3D is tapping the possibilities of liquid biobased 3D printing by turning vegetable oil into polymer foams for a wide sweep of industrial applications.

Polymer foams are everywhere in the economy. Most of us encounter them in the form of packaging. Crucial to the global shipping and e-commerce industry, these plastics offer soft, cheap cushioning for fragile goods. Another application is in headphone cushioning.

There are more specialised niches too. As lightweight, pliable materials, they have found uses in aeroplanes or as the spongy interiors of podiatry shoes.

The ubiquity of foam polymers in industry is a huge environmental problem. Most foam on the market today does not biodegrade safely. This means the material risks ending up as microplastics pollution in the soil and water. Recycling is possible but rarely done because it is simply not profitable enough.

To mitigate the foam pollution problem, FoamPrint3D offers clients made-to-order renewable foams that it says are biodegradable and free from harmful additives.

Filling the niche

Biomaterials made from plants or organic waste can have a dramatically lower environmental footprint than fossil plastics.

This is why meeting Net Zero targets will depend on adopting renewable materials in carbon-intensive sectors like construction and packaging.

Yet for these industrial applications, sustainability on its own will not be enough – biomaterials also need to meet a set of exacting performance standards.

FoamPrint3D shows how 3D printing can support industrial shifts to renewables without a loss in performance.

A foam that ends up in sound-proofing will need a very different internal makeup to one destined for ergonomic furniture. Its printing process can precisely control the structure of the foams they produce, meaning clients can demand products with highly specific properties.

Services like FoamPrint3D's can make it easier for different industries to switch over from ordinary fossil plastics to renewable by bringing down the costs of hyper-customisation.

Driving sustainable choice

Traditionally, 3D printing has been associated with fossil plastics, yet the EU's ORGANIC, the UK's Project Nexus, and the Netherlands's FoamPrint3D show how well it can be easily adapted for use with biomaterials.

Right now, 3D biobased printing is finding a techno-economic niche in supplying specialist industries with custom sustainable materials that will help them meet compliance targets.

The customisable and limited-run nature of 3D printed products is what makes them so unique.

Renewable materials that go into packaging, energy infrastructure, and construction must have precise properties that producers cannot always find in mass-marketed products.

Developing and producing custom materials is an option but it can be a costly process for manufacturers, raising the barrier further for sustainable materials to enter high-performance niches.

3D printing can help speciality biomaterials compete with heavily subsidised fossil chemicals in the exacting segment of industrial materials. This does this because it lends itself to low-volume, specialist production.

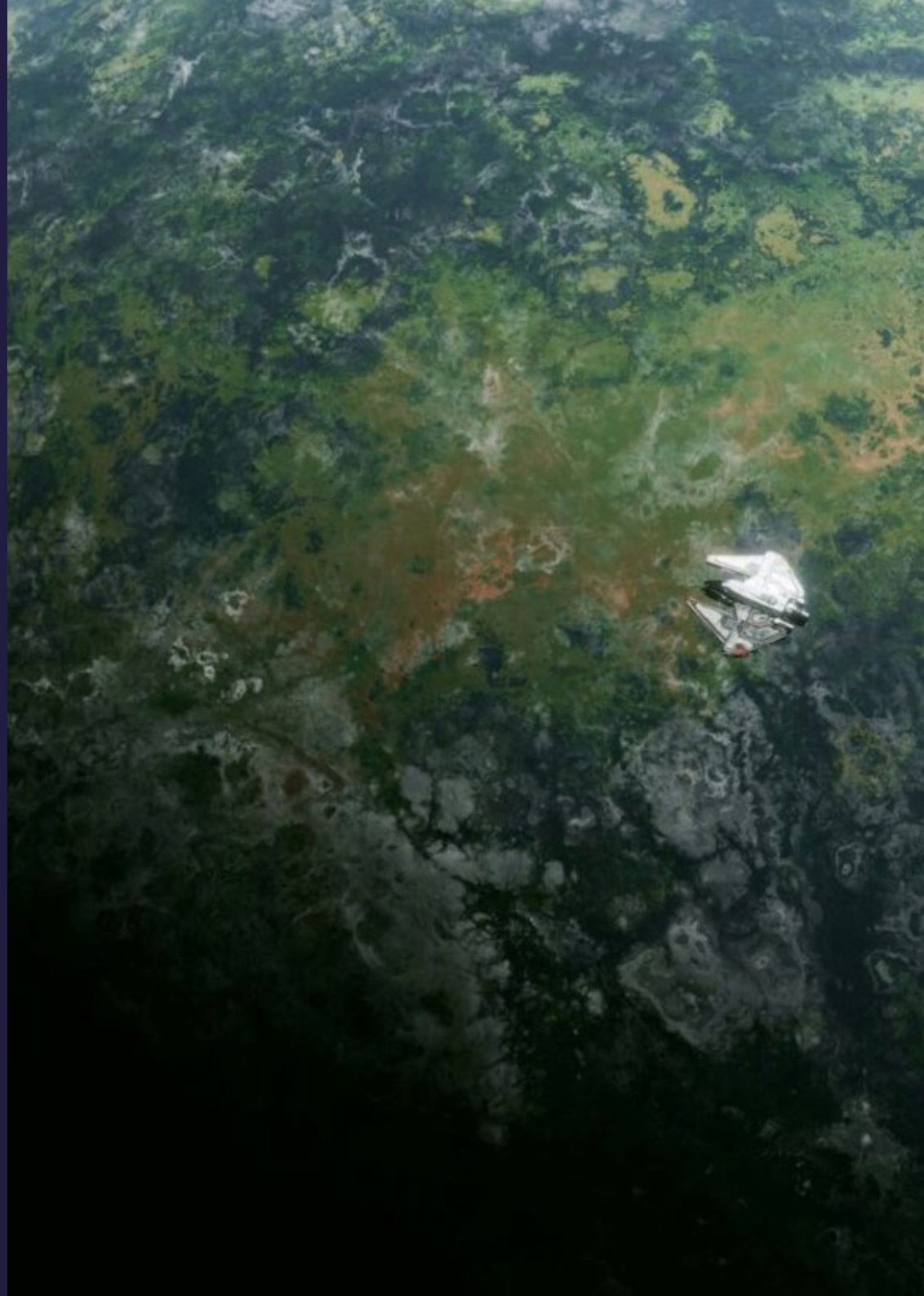
Capable of meeting small batch, specialist orders, 3D printing makes the development and marketing of custom biomaterials less risky compared to a manufacturing platform that relies on high market demand to lower per-unit production costs.

Certain industrial biomaterials are so specialist that they will never have mass market demand to bring down production costs. 3D printing fills the gap, offering finely tuned biobased components through a highly nimble mode of manufacturing.

AUGUST 13, 2025

Biomaterials enter the space age

Biomaterials could support safer and more sustainable space travel



What could vegetables offer space exploration? According to the European Space Agency, a lot.

Last year, the agency unveiled the results of a collaboration with the Côte D'Azur University: a new, fully biobased epoxy resin composite.

The project shows how biomaterials can offer powerful functionalities in space travel with fewer health and environmental risks than petrochemicals.

Here is how biobased materials could support safer, more sustainable space travel.

Orbiting orange peels

The space-ready biobased resin developed by ESA and Côte D'Azur University was made from sawdust, fruit and vegetable peel, and brown algae. The project turned these into building block molecules that can form ultra-strong materials.

The team behind the Côte D'Azur-European Space Agency partnership believe that biobased materials like this could one day replace many petroleum-based materials in spacecraft.

Projects like this reflect growing concerns around the sustainability of the aerospace industry. The amount of space debris in orbit is increasing, with more than 25, 000 particles larger than 10 cm circulating around Earth alone, according to NASA.

There are also calls for space research to deliver innovations that solve problems back on Earth, such as pollution and climate change.

As well as meeting the challenges of space travel, the new biomaterials coming out of aerospace research could eventually help other industries decarbonise.

Circular, not just biobased

To maximise sustainability in spacecraft, using biological raw materials is not enough. Materials must also meet two more criteria: that they come from waste raw materials and they are recyclable.

The European Space Agency has followed both of these principles in designing its biobased resin. It has used waste matter, not crops, for building its space composites.

Waste feedstock cuts a biomaterial's environmental impacts. Unlike crops grown for the purpose of building industrial materials, ordinary waste is already abundant and does not require water, land, and fertiliser to grow.

The European Space Agency has also formulated its biobased resin to be recyclable using non-toxic chemicals.

Recyclability is also a key consideration in cutting the environmental impacts embedded in space materials. Whether a biobased material is more sustainable overall than a petrochemical product can hinge on whether it can be broken down and used in new ways.

Sustainability is not the only driving force behind this research. Human health is another factor.

Most epoxy resins and thermosets are still made from petroleum. These

contain hormone-disrupting bisphenol A and epichlorohydrin. Much of the motivation around developing the biobased resin came from the aim of reducing dangerous chemicals in spacecraft.

The biobased resin has gone through testing at the European Space Agency's Research and Technology Centre in the Netherlands, where a 2, 500-strong technical workforce subject new technologies to the simulated rigours of space.

So far, production has only amounted to a few kilos of the biobased resin. The next step for the team is to scale and commercialise.

Taking the heat

Materials made from renewable feedstock can often offer functionalities for aerospace applications that are difficult to achieve using purely synthetic substances.

In the US, this is being proved through the long-term collaboration between private company Cambium and the US naval Air Warfare Centre.

The partners have developed a biomaterial that meets the need for less toxic fire-resistant materials in air and spacecraft.

Safe space travel relies on reliable fire resistance built into the construction of the craft. Fires are impossible in the outer vacuum of space but combustion inside the vehicle remains a risk. This is due to the presence of electrical systems and a lack of natural ventilation.

In 2020, the partners unveiled a composite biomaterial. It included molecules obtainable from plants and other biological sources, or produced from sugar via fermentation processes.

Health concerns drove the R&D. Many fire-resistant coatings in space and aircraft are based on halogen. These release highly toxic smoke while they burn. Cambium embarked on a search to find less toxic materials for the exterior and interior that still offer the same level of fire resistance.

Bamboo-aided spaceflight

The biomaterial developed by the European Space Agency is a polymer – a type of material composed of long molecular chains. Plastics are a kind of polymer, with most made from petroleum.

Biobased polymers are a convenient way to incorporate renewable materials into design, since industry is already familiar with oil-based polymers and their range of useful properties.

Yet space applications can draw on a much wider range of biomaterials than just polymers. Bamboo wood is one of them.

The wood of the bamboo has a strength-to-weight ratio that is approximately six times greater than that of steel. This means that it is both incredibly light and incredibly strong.

The unique combination of lightness, strength, and sustainability have already sparked research around the world into bamboo composites for a myriad industry applications.

In the aerospace industry, bamboo-based biomaterials could replace

or supplement fiberglass, a material popular in making the bodies of aircraft and spacecraft.

Manufacturing fibreglass can release a lot of greenhouse gases because high temperature furnaces are needed in the process. Cutting the amount of fibreglass required with bamboo composites could lower the emissions associated with aerospace construction.

Bamboo's combination of lightness and strength is attractive in aerospace because the weight of the craft is a huge determinant of project costs. Heavier crafts rip through fuel faster during take-off, racking up the price of launch.

Bamboo's strength comes from its microscopic structure. The wood is composed of many tiny tubular bundles surrounded by supporting fibres. Within these supporting fibres are microfibres arranged in a highly ordered pattern. These structural arrangements make the overall material capable of absorbing large amounts of energy.

From a sustainability perspective, bamboo is difficult to beat. Compared to fibreglass the material takes far less carbon dioxide to manufacture. It is also biodegradable.

Bamboo biomaterials are not just one thing – the wood can be processed in many ways.

This could mean mixing bamboo fibres with other materials to form a bamboo-based composite. Graphene nanomaterials could be incorporated for added strength, for example. Infusing the cell walls of the wood with resin is another way of refining the natural material for specific applications.

Silken space spools

Another material found in nature that can surpass steel on strength and lightness is spider silk. The material is also elastic, capable of forming structures that stretch without breaking.

These properties make spider silk ideal for building more sustainable and less polluting spacecraft, as an additive in composite materials for on-board equipment or structural elements of the craft, as a sustainable and lightweight storage and packaging material, and for parachutes or ropes. Its elasticity also makes it ideal for patching up damaged equipment.

Sider silk in aerospace is still an emerging area of research. However, there are promising indicators that the material can be incorporated into spacecraft in different ways.

In 2022, a journal article published in Acta Astronautica revealed scientists reported on how a spider silk aircraft windowpane performed just as well as the current industry standard despite being lighter.

NASA is going a step further, looking into the possibility of spider silk production during actual space missions.

In 2019, the space agency announced research into equipping spacecraft with fermentation equipment. These would allow astronauts to manufacture spider silk compounds using specially engineered microbes. Astronauts could process these compounds into useful silk-based materials, like surgical sutures or fabrics, once landed.

Biomanufacturing equipment like this can extend the length of

a voyage and cut costs by reducing unnecessary supplies on the outgoing flight.

Bio-inspired hygiene

On-board hygiene is another area where biomaterials can serve safer space travel.

In space, crew members travel light, dispensing with amenities we take for granted like water and detergent for laundry.

Without running water and cleaning supplies, maintaining hygiene is harder. Certain biomaterials with inbuilt microbial resistance could help.

Traditionally, anti-bacterial minerals like selenium, silver, and quaternary ammonium compounds have been applied as disinfectants on board spacecraft.

However, mineral-based anti-microbials like this pose a toxicity risk. There can be a thin line between the amount that kills bacteria and the amount that can harm human cells. In the closed confines of a spacecraft, the risk of these substances accumulating into harmful levels is higher.

Once again, the European Space Agency is leading research into incorporating biobased anti-bacterial coatings for space, investigating chitosan and lignin for their potential.

Chitosan is a compound found in crustacea while lignin is a natural polymer found inside most plant

Working with the Luxembourg Institute of Science and Technology, the agency found that lignin was a particularly effective additive for anti-bacterial solvents.

Another area that the agency is investigating is ‘nano-patterning’. Cicadas and dragonfly wings come naturally armed with tiny structures that physically kill bacteria that land on them. Man-made materials that imitate this using densely packed nano-sized ‘teeth’ can mechanically kill bacteria that come into contact with the surface.

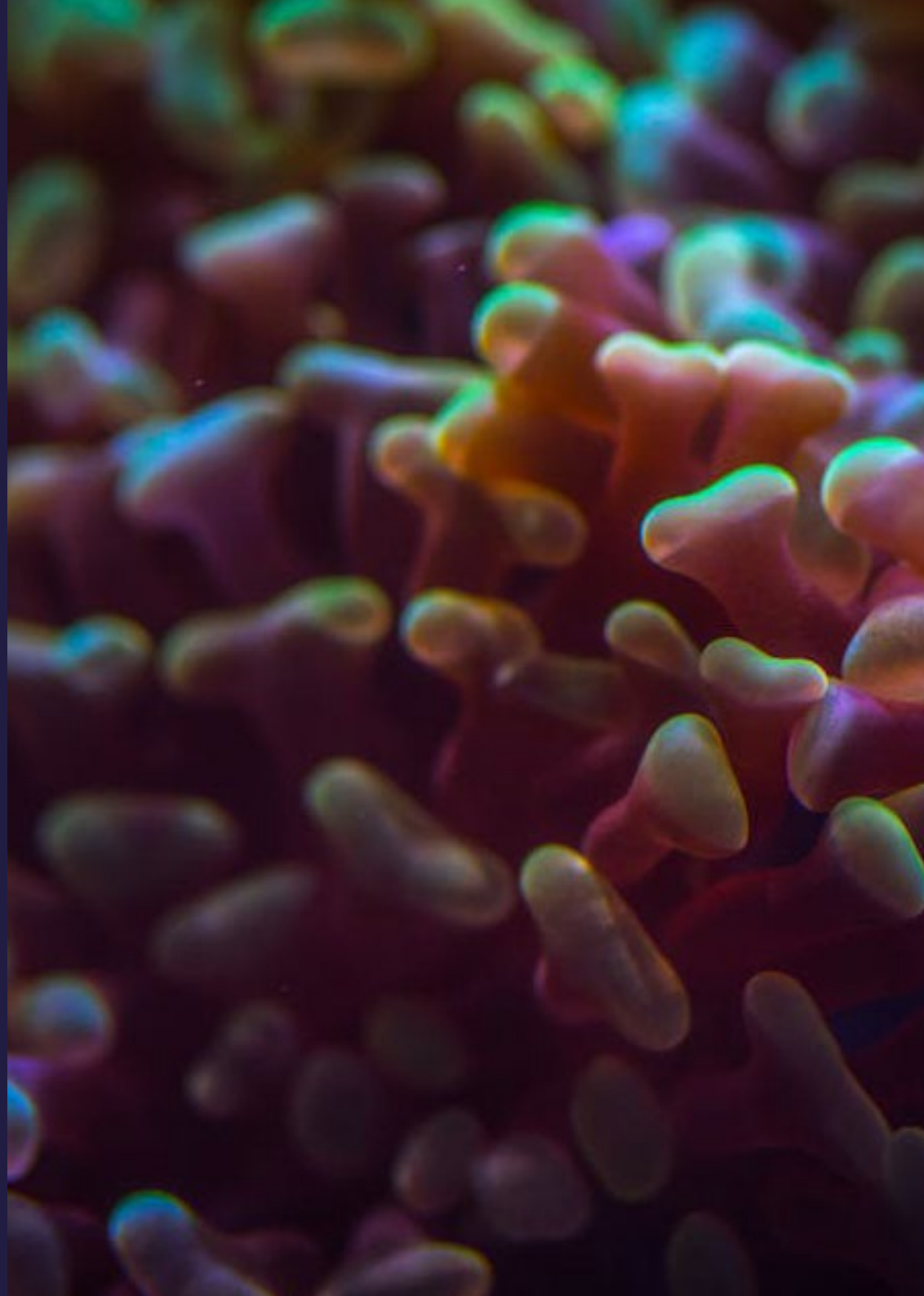
These anti-bacterial nano-structures could be applied to textiles used for clothing, as well as for making anti-bacterial dressings.

The biomaterial innovations coming out of the aerospace industry prove how renewable, sustainable materials can excel in high performance applications while supporting human health and sustainability. For advanced biomaterials, the sky is the limit.

AUGUST 20, 2025

The latest in biomaterials research

The best in new biomaterials research from the last year



The science of biomaterials is advancing rapidly. New renewable materials are being developed all the time that could replace carbon-intensive materials in industry.

Keeping up with new material innovations can be difficult, so we've made it easier: we review seven exciting studies that have come out of the biomaterials space over the past year.

1. Moss that mops up oils

Researchers in China have modified sphagnum moss into a biobased adsorbent that removes oil from water.

The new moss material reportedly improved on existing biobased options for oil-cleanup.

Previously, scientists have experimented with biobased oil adsorbents made from other biological feedstock, including wheat bran, corncobs, pomelo peels, cotton, orange peel and lemon grass.

Yet these natural materials fell short on a number of crucial criteria. The moss material in this study reportedly offers higher adsorption capacity than previous innovations, plus reusability. The researchers claimed their tests show that the material maintains over 90 percent of its starting capacity, even after it is used through 10 cycles.

Both of these features make the material potentially much more cost-effective – less of it is needed to clean the oil out while the initial cost is spread out over multiple uses.

Unlike many previously developed biomaterials, the moss material showed a higher water-repellence, meaning it rejects water effectively. This overcomes a major problem with biobased oil adsorbents: usually, plant materials attract water, an unhelpful property when the aim is to soak up oil and leave behind clean water.

Biomaterials can be a sustainable way of removing contaminants from the environment. As they tend to be made from biodegradable compounds, using them in natural environments does not come with a risk of causing further environmental harm, unlike certain chemical treatment methods.

2. Bacteria make circular clothing

Making the clothing industry more sustainable is essential to meeting climate and ecological goals. Most fabrics contain fibres based on petrochemicals and only 0.3% of global textiles are circular, leaving tens of millions of tonnes of toxic clothing waste in landfills each year.

In January 2025, UK researchers published a new way to make some common textiles more circular. Known as man-made cellulosic fibres, these are the third most produced textile fibres on the planet: viscose, Lyocell, cupro, and modal.

Today, most of the cellulose used in making these fabrics are taken from wood pulp. This may sound like they are good for the environment. However, 30 percent of the wood pulp used to make cellulosic fibres come from ancient and endangered forests, making the sector highly destructive to biodiversity and natural carbon stores.

> "Scientists from Korea showcased a 100 percent biobased adhesive based on starch nano-particles. The material is reportedly comparable to petrochemical products in terms of adhesion strength."

Viscose production is also problematic for the solvents it uses to transform the wood pulp into textiles. Toxic chemicals are often required.

The study presented a way to use enzymes and bacteria to convert mixed waste into a biobased feedstock for textile production. They call it bacterial cellulose.

Published in the Journal of Cleaner Production, the study details the upcycling process. It starts with textiles, agricultural residues, and municipal solid waste. All of these materials contain cellulose but at too diffuse a concentration to be useful without some cost-effective process for extraction and purification.

Enzymes digest the cellulose in the waste textiles, turning it into glucose. Bacteria then get to work converting the glucose, converting it into virgin-quality bacterial cellulose.

By cutting out virgin wood and toxic chemicals from the fibre production process, we are left with a material that has a much lower environmental footprint.

Importantly, the study verified the sustainability credentials of its method, using a life cycle assessment that compared their new approach to mainstream cellulose fibre manufacturing. It found that their material did better on several sustainability metrics: land use was only 10 percent of the conventional method while it also cut back on freshwater pollution.

3. Rice-based adhesive

Adhesive fills our consumer and industrial landscape – few consumer products do not use them. Unfortunately, the vast majority are derived from petrochemicals.

Developing high-performing adhesives without any petroleum has proven to be a tricky task for scientists, but biobased researchers continue to improve on prototypes.

One advance in biobased adhesives was published in Chemical Engineering journal last year. Scientists from Korea showcased a 100 percent biobased adhesive based on starch nano-particles. The material is reportedly comparable to petrochemical products in terms

of adhesion strength.

The basic raw material for the nanostarch was protein from rice powder, with additional materials sorbitol and glycerol.

This rice-based adhesive is meant for ordinary applications where we make things stick with just a little pressure application – think plasters – showing the power of biobased innovations that make everyday objects greener.

4. Does sustainability pay?

Recently, a literature review on sustainability certification schemes for biobased products was published in the Journal of Cleaner Production. It asked whether sustainability labels on biobased products have a positive or negative impact on the biomaterials industry.

It found that the economic impacts of certification are largely positive for biobased producers. On the whole, the costs that companies face in getting sustainability claims authorised by regulatory authorities are outweighed by the revenue increases that follow.

This is because sustainability labels tend to increase consumer appetite for biobased products. In some cases, it even encourages them to pay a price premium over ordinary, more polluting options.

The social sciences are often overlooked when it comes to building a biobased economy. But insights from these disciplines are essential to scaling renewable materials. Delving into the economics of biobased production and understanding consumer behaviour can help identify industry challenges and how to overcome them.

5. Self-healing bio-roads

This biobased innovation could be the solution to road potholes.

UK researchers have incorporated tiny biobased ‘encapsulents’ smaller than a strand of human hair into an asphalt mix, creating a road material that can heal its own cracks as they form.

The encapsulant, taken from the species Lycopodium clavatum, is filled with a biobased oil taken from pine bark. The oil releases into the road once the asphalt begins to crack. Microcracks on the surface heal in less than an hour.

The technology was designed with the aid of artificial intelligence, helping the researchers understand how both asphalt binders and biobased oils behave at a molecular level and interact with one another.

These biobased road spores offer up a brilliant example of how seemingly arcane biotech capabilities can fix ordinary problems. In the UK, potholes are estimated to cost £143.5 million a year in the damage they cause.

6. Plastic-absorbing squid bone

Microplastics pollution is one of the most urgent public health issues of our time. Decades of plastic production have filled our soil, water, and oceans with an estimated 4.6 billion metric tonnes of these toxic particles. Their long term health effects are still unknown.

Tackling microplastics must target the root cause: this means dramatically reducing petrochemicals production. Yet we also need tech that can mitigate the damage already done.

A group of researchers led by Wuhan University's Hongbing Deng have been trying to tackle microplastics clean up, developing a new biomaterial just for that purpose.

The material is a new biobased foam that absorbs almost 100 % of microplastics in water on its first use.

The material, a reusable and biodegradable biopolymer, was tested in still water as well as samples from lakes, the coast, and agricultural irrigation pools. The raw materials used to make the plastic-absorbing polymer are among the most common materials found in nature: chitin and cellulose. The material tested in the study used chitin taken from squid bone and cellulose taken from cotton.

The researchers said they hoped for pilot production followed up by large-scaled commercial production if testing went well.

7. Biomaterials and their environmental impact

Biomaterials are an essential to building a sustainable economy. The Intergovernmental Panel on Climate Change (IPCC) specifically mentions wider biomaterials adoption as a key part of mitigating climate change. This is because biomaterials often surpass their petrochemical equivalents on many measures of sustainability including lower carbon emissions.

Yet as with any industrial activity, biobased materials can have some negative impacts on the environment.

Recent research has shown that certain biobased fibres can harm earthworms, an essential part of sustaining soil health.

Another study released last year showed that microplastics from bioplastics harm water fleas – a key part of aquatic food systems.

The impact of bioplastics on wildlife still needs more research, as well as industry and policy focus.

We must fully understand the impact that renewable materials have on the environment to properly mitigate risk and develop safer materials that live up to their sustainability promises.

AUGUST 27, 2025

Oyster wool for sweater season

Sustainable clothing needs alternatives to sheep wool

Autumn is just around the corner for many of us and winter wardrobes are waiting in the wings. But have you ever considered the environmental impacts of layering up?

Wool is an essential winter staple: insulating, soft, breathable. However, it emits more carbon than plastic fibres like polyester, acrylic, and polyurethane.

Here are some animal wool alternatives that can keep us toasty without warming the planet.

The impact of wool

Wool is one of the oldest textiles. Archaeological finds indicate that it's been in use since 10, 000 BCE.

Like many material products of evolution, wool is hard to beat when it comes to protecting us against the elements. The fine structure traps air pockets to prevent heat from escaping. It is also easy to fine-tune, offering fibres that vary for different degrees of texture and warmth.

In a world where oil plastics dominate clothing textiles, wool also stands out for its biodegradability. This is a plus for the environment, since any discarded wool that ends up outside poses far less of a toxicity threat to wildlife than polyester, acrylic, or other plastic materials.

However, the material is also incredibly resource intensive to make. Shockingly, the carbon dioxide produced per kilogram of wool is double that of polyester, which is based on fossil plastics. Wool also emits higher carbon than acrylic and polyurethane – in fact, it usually tops the list when it comes to carbon-emitting textiles.

This makes sense when we consider how livestock is a significant contributor to global warming, accounting for more than half of total global agricultural emissions. Wool is no exception. The carbon emissions of wool production come from the burps and farts of sheep.

Around 1 million tonnes of wool is made each year. Replacing some of this with more environmentally friendly options is now easier, with a diverse range of wool alternatives made from less impactful feedstock.

Coconut and hemp wool from Colombia

The fashion industry needs more planet-friendly winter warmers. In Colombia, a group of university students have heeded the call, developing a coconut-hemp wool alternative that won the PETA prize for animal-free wool in 2018.

The material goes by the name Woocoa and can be knitted just like sheep's wool.

The material is sustainable on many different levels. Not only could it displace the need for carbon-intensive livestock fibre, it is made from waste rather than crops specifically for textile manufacturing – medical marijuana waste, to be precise. This keeps the impacts of the material down, especially when it comes to agricultural fertiliser pollution and water usage.

The material results from a sophisticated biomanufacturing process that gets rid of harmful processing chemicals – it is produced using enzymes from oyster mushrooms.

The material has some of the properties of wool that are difficult for synthetic fibres to fully mimic. For example it is naturally antimicrobial and wicks away humidity.

Clothing is just one application for the wool alternative. These strong fibres can also be used in water filtration equipment or as biodegradable packaging.

Wool from the sea

Taiwanese startup Creative Tech Textile found inspiration for a sheep-free wool in farmed oysters.

Using discarded oyster shells from the aquaculture industry, as well as recycled plastic waste, the developer has come up with a circular fabric to create a soft, wool-like fabric known as 'Seawool'.

Just like sheep's wool, the fabric comes with a naturally low heat conductivity. This means it does not draw heat away from your body while wearing it, ensuring you stay warm.

One reason why the material is able to mimic the heat-insulating properties of sheep wool is the structure of its surface – marked with tiny scales that come from powdered oyster shell. The rough micro-textures distinguish it from synthetic polyester, a common wool substitute in the clothing industry.

Since 2022, the company has used up 100 tonnes of oyster shells as well as 20 million PET bottles in its wool production. Every time the company reaches for this waste feedstock, it means that much less need to draw on damaging virgin materials like sheep's wool or new plastic fibres.

The material is already a hit with knitwear producers. English clothing brand Albert and Maurice has adopted Seawool and turned it into autumn/winter menswear jumpers. Josephine and Co have a womenswear collection that uses the material.

The company has also developed Smawarm, a highly insulating material designed for gloves, down jackets, bedding, and sleeping bags. This shows how these circular wool alternatives serve outdoor applications that demand the highest levels of insulation.

Scottish mussel beard fibres

Britain may soon be getting its own line of wool sourced from the sea. Scottish startup Seastex is turning to mussels to create multi-functional fibres that could be used in anything from construction to design.

Seastex's feedstock are the 'beards' of the mussel. These are the inedible bunches of thread-like fibres that allow mussels to truss themselves to surfaces like rocks. Mussel farmers cut and discard the material off while harvesting.

The team is already securing access to around three metric tonnes of the stuff every week and has built a prototype and production line. For now, the target market is construction and interiors where the bulky fibres could fill a niche in sustainable upholstery and soundproofing.

Like Taiwan's Seawool, this Scottish mussel fibre wool does not put pressure on human food sources, since the feedstocks are all byproducts of the food industry rather than crops that could have gone

on to be eaten. This enhances the sustainability of the final product.

A plant-based wool from India

Back on land, plants can also offer feedstock for warm wool-like substitutes.

Indian fashion entrepreneur Gowri Shankar has a poetic story about how he got the idea behind his plant-based wool brand Weganool, which takes material from the wild flowering shrub Calotropis.

One day, he was staring outside the window one afternoon when he noticed birds plucking fibres around a Calotropis bush for a soft, yarn-like material they used in their nests. It sparked the idea that he could use the plant to make clothing textiles.

Weganool's vegan wool uses 30% Calotropis fibre and 70% organic cotton. The plant is suited to substitute for animal wool because its fibres are hollow inside, making it capable of trapping heat.

Calotropis, commonly known as milkweed, is a hardy plant that moves quickly into areas of barren soil that other plants cannot thrive in. Like the oyster shells and mussel fibres that go into Seastex and Creative Tech Textile's products, this hardiness makes milkweed a sustainable material – it does not put pressure on human food supply because it can be grown on poor soils that would not support food crops. It also requires few inputs like pesticides and watering.

> "In a process that is similar to fermenting beer or cheese, chemicals with specific properties can be produced at scale, consistently."

Brewed wool from Japan

One emerging manufacturing tech that promises to take the sheep wool substitutes to another level is precision fermentation. This technique uses industrially reared, custom-engineered to produce any biological chemicals – whether food ingredients, medicines, or the kinds of proteins found in animal fibres.

In a process that is similar to fermenting beer or cheese, chemicals with specific properties can be produced at scale, consistently.

Japanese company Spiber is the leader in precision fermented textile fibres. It produces what's called Brewed Protein from sugarcane, a fibre that can be refined into many different kinds of textiles. Spiber's Brewed Protein remains the only precision fermented protein fibres available on an industrial scale.

Technically, Spiber's Brewed Protein is synthetic in the sense that it

is created in a laboratory. Yet it mimics the protein-rich fibres we find in fur and hair through the animal kingdom, making them eminently biodegradable.

In 2022, Spiber conducted a study into how sustainable its Brewed Protein actually was. It did this by analysing the environmental impact of its fibre against typical cashmere and wool production. The analysis found that Brewed Protein had lower impacts than on greenhouse gas emissions, water scarcity, and eutrophication (nutrient pollution of waterways from agriculture).

Spiber is trying to draw out the full spectrum of its material's properties through collaborations with industry. In the field of warm clothing and knitwear, the brand has been working in particular with luxury Italian textile mills.

In 2025, Spiber announced a strategic partnership with Manifattura Sesia to create a new yarn line that mixes 30 percent Brewed Protein and superfine merino wool. The advantage of blending natural wool with the protein fibre is that it produces a yarn that is soft and more lightweight than pure wool. Alongside the comfort factor, it also cuts back on the environmental impacts that come with material taken from livestock.

In 2024 came a collaboration with Baruffa Lane Borgosesia, an Italian wool mill. The partners have been experimenting with spinning techniques that blend Brewed Protein (30%) with merino wool (70%).

Spiber's Brewed Protein is also holding its own as a complete wool substitute without blending. The Italian wool mill Botto Giuseppe sells a range of 100% Brewed Protein worsted yarn in diverse colour options. Spiber's work with industry would finally pull the R&D limelight onto sustainable wool. In fashion, wool fibre has received less attention than leather when it comes to developing vegan manufacturing pathways.

Wool fibre is an incredible natural material. Now, we can mimic its warmth and flexibility with diverse sustainable feedstocks. The high-tech luxury of Spiber's brewed yarns are just starting to hit high-end fashion while circular options that tackle seafood waste show us how we can do more with less. Sweater season now comes with a sustainable conscience.

SEPTEMBER 3, 2025

What consumers really think of biomaterials

When and why do people buy bio?

Consumer appetite for sustainable products is rising. Understanding shopper preferences and what shapes them is key to unlocking new markets.

We review research insights into consumer behaviour around biomaterials, including when and why people buy bio.

Sustainable materials in demand

Packaging is a huge niche where biomaterials can offer strong value for customers.

It is one of the biggest applications for plastics globally, accounting for 26% of total production. The oil-based plastics that dominate today are key drivers of pollution and global warming, fuelling government and consumer desire for alternatives.

Yet biobased packaging is a relatively new concept. The first step towards wider acceptance is to build consumer understanding of what they are and their environmental benefits.

Generally, consumers are receptive to the idea of sustainable packaging in general, including biomaterials. In 2022, a UK survey of 1100 respondents found that 80% preferred environmentally friendly materials.

We see this demand for sustainable packaging in a range of markets. In a survey of 781 Chinese consumers, 77% showed awareness of the harms of traditional packaging while 67.2% had some understanding of the benefits of sustainable packaging.

One study found that globally, 72% of consumers are willing to pay more for sustainable products.

Price is king

While these are positive signs, we need to acknowledge the difference between consumer awareness and actual purchasing decisions.

In most cases, price is the biggest factor in deciding whether a consumer aware about the benefits of bio will act on this by actually buying more sustainable options.

When the more sustainable option is more costly, some consumers will forego the purchase, believing that the responsibility for absorbing these higher costs lies with big producers and the government rather than themselves.

According to a recent McKinsey survey, the consumer emphasis on price in making packaging decisions has only become more pronounced over recent years as inflation drives up the cost-of-living.

Environmental concerns tend to rank lower although there are exceptions, particularly in European countries like France or Italy.

Biobased versus biodegradable?

The McKinsey survey seems to show that consumers have lost interest in environmental issues. However, this is not quite the case.

Cost has become a growing concern for consumers over the years but, on the whole, people do not care about the environment any less than they did before.

Given that consumers still believe in the importance of environmental factors, what criteria are they using to make purchasing choices that are more sustainable?

Many studies on consumer attitudes towards biomaterials show that knowledge is a powerful influence on purchasing decisions.

Often, a basic understanding of how materials impact the environment and the subtle differences between biomaterials can make a huge difference in what consumers look for.

We see this clearly when it comes to biobased versus biodegradable products. Most people assume that a material made from biological feedstock will biodegrade safely in the environment. However, this is not the case: some plant-based materials can biodegrade in nature, others will biodegrade in specially-equipped industrial plants, and others are not degradable at all.

Whether consumers are aware of this can change how they shop for biomaterials dramatically.

Consumer knowledge matters

A 2023 study published in the Journal of Cleaner Production showed how education on sustainable materials can influence purchasing choices.

It conducted a choice experiment that involved 12,000 Japanese consumers divided into two groups: one was taught the difference between biobased products and biodegradable ones. The other group was not.

The study found that the group that had been educated on the difference between biobased and biodegradable would prefer products that were biodegradable over just biobased. This group had learned that biodegradability is a special property that has to be specifically built into the design of the material – not something that comes automatically.

Informed marketing

Findings like this are vital for the biomaterials industry. It indicates that with better information and education, consumers are more likely to choose biobased products over competitors.

This is especially important for newer startups in the biomaterials industry that have developed materials focused on end-of-life sustainability.

In general, any kind of biomaterial tends to do better than oil plastics when it comes to carbon emissions reduction. However, some plant-based biomaterials can be just as harmful as oil plastics if discarded in the environment.

Many newer biobased startups today are trying to tackle this issue. California's Cruz Foam have developed a compostable biobased foam that degrades more rapidly and safely than traditional plastic in nature. Companies that use seaweed feedstock tend to fall into this category, including the UK's Imperial College spinoff FlexSea and London-based NotPla.

However, without consumer awareness around the importance and relative scarcity of biodegradable products on the market today, it is

harder for these more sustainable options to find a foothold.

More consumer education on the importance of biodegradability is needed to boost market uptake for newer generations of biomaterials that are less harmful to biodiversity.

Culture matters

Cultural context also matters when it comes to convincing people that biobased is better.

The same study found a strong preference among the Japanese consumers for biobased products that use local feedstock as raw material over imported feedstock. Some of this might be a perception that local safety standards are higher.

Whatever the reason, it means that marketing sustainable goods in Japan demands different approaches to marketing in other parts of the world. Emphasising local feedstock origin more than environmental qualities could be a more effective strategy in a country that is highly import-dependent. In these contexts, the decentralised nature of biological feedstock compared to petroleum and mined minerals can be a huge advantage.

What's "sustainable"?

Culture also shapes what consumers believe makes a biomaterial sustainable in the first place.

In Germany, consumers looking for sustainable packaging options tend to prioritise reusability first and foremost, regardless of what the materials used are. This means consumers there put an emphasis on materials that are highly durable. After reusability, German consumers rank recyclability and then degradability as their second and third priorities when it comes to assessing sustainable options.

In France, preferences are slightly different: consumers looking for sustainable options rank recyclability as the top attribute, followed by reusability and degradability.

Cultural differences like this can inform R&D and product marketing for biomaterials producers. Fully recyclable biobased options are likely to do well in France while consumers might have a harder time accepting a biomaterial that can degrade in natural environments but cannot easily be recovered and re-used as a new product.

Labels that convince

Research shows that consumers tend to look for a single attribute when making sustainable choices. This varies between individuals and also between cultures: in Germany, it tends to be reusability. In France, it is recyclability.

The belief that a single property always makes a material greener can be detrimental for the biomaterials industry. In reality, it's often hard to make generalised claims about what makes materials more sustainable: feedstock sourcing, applications, market alternatives, and many other variables matter.

These nuanced elements of sustainability can make it harder for biomaterials producers to succinctly communicate why their products are better than their competitors.

The only accurate way to judge product sustainability is to look for a life-cycle assessment – this is a careful analysis of a product's impacts at every stage of its existence: its manufacturing, processing, use, and end-of-life.

This is where regulation comes in. The EU's Ecolabel system is one of the most sophisticated product labelling schemes for sustainable goods. Based on life cycle assessments, it communicates quickly to consumers which are the best-performing sustainable products on the market today.

The EU Ecolabel is only allowed on products that perform within the best 10-20 percent of products available on the European market in terms of environmental performance. Here, 'performance' means impacts on health, safety, social and ethical aspects through the entire product life cycle. It also assesses durability, reusability, recyclability and recycled content.

The nuances of what makes a material sustainable can often be unclear. Well-regulated labelling schemes are one of the best ways of boosting consumer awareness of and confidence in the materials they are buying. According to Euromonitor, 28% of consumers identify unclear labelling as their main barrier to sustainable purchases.

Room for growth

On the whole, the biomaterials industry has much to celebrate. There is a long-term trend among consumers demanding more sustainable choices. Awareness around the damage caused by petrochemicals grows each year, particularly among younger generations.

However, cost and quality remain the most important factors in purchases. Over the last couple of years, cost has only become more important as consumers grapple with inflation.

Despite this, demand for sustainable materials has immense potential for growth. Educating the consumer can go a long way here.. Information on what precisely a particular product or material does better than potentially cheaper competitors is crucial to maximising sales. Understanding cultural contexts and adapting marketing narratives is also key.

There is huge room for regulatory intervention here. Robust sustainability labelling is one of the most effective ways to communicate with consumers and instil trust that the products they buy are contributing towards a healthier planet.

SEPTEMBER 10, 2025

The stars of sustainable beauty packaging

The brands proving sustainable beauty is possible

Consumers are often frustrated by how much disposable packaging comes with beauty products. Given the industry's environmental impacts, they're right to be.

Typically, a bottle of mascara lasts eight months. Yet the plastic it is made from won't break down for hundreds of years in the environment.

Recycling is one option but it only works a limited number of times before the material degrades. Landfill is the ultimate destination for almost all plastics.

Yet some brands are showing that it's possible to reduce impacts using biobased and circular materials. These alternatives often offer a contemporary, high-impact aesthetic that makes products stand out visually.

We look at the makeup companies that have made sustainable packaging a key focus of their brand.

Axiology: playful with paper

US vegan make up brand Axiology is one of a tiny minority in the industry that has ditched plastic altogether, not just in its shipping materials but in its product packaging too.

Instead, the company has turned to one of the most overlooked, yet also most reliable, biobased materials of all: paper.

All of Axiology's make-up packaging is made by a women's cooperative in Bali that upcycles outdoor paper pollution. The resulting packaging packs a punch, reminding us how strong and multi-functional this everyday material can be.

The brand's Reishi mushroom-infused foundation sticks come in an irresistibly chunky round pot. Their 'Balmie Super Fan Pack' presents 12 lip-eye-and-cheek stains as a palette of children's crayons, slotted neatly into a bright red rectangular box.

Axiology's packaging delights in the playfulness and tactile delights of card, demonstrating how much creativity biobased materials allow for.

One of the biggest barriers to going plastic-free is the functionality and strength that allegedly only plastic provides. Yet Axiology's shift to paper lipsticks, compacts, and boxes reminds us that plastic use is more often a habit than a necessity: why does foundation need to be pumped out of plastic tubes when it could be rolled onto skin from a purse-friendly pot?

Lush leads the way

One of the world's leading innovators in sustainable cosmetics is Lush. The British high street brand has been advancing sustainable packaging for years, making it the centrepiece of their branding aesthetic.

Lush has proven that aesthetic appeal can go hand in hand with lower environmental impacts. The brand stands out for a unique look that is tightly connected to its green and low-waste packaging policies. Resourcefulness is the watchword here, with the company eliminating unnecessary materials while presenting their wares in a way that is totally distinctive to the brand.

Many of its products, such as their famous bath bombs, come with

no packaging whatsoever. Yet the company hasn't missed out on any visual branding opportunities: the intricate, eye-catching moulds its bath products are set in make them look good enough to eat.

Biomaterials also feature in their product range. Liquid products like body mists come in chunky, utilitarian spray bottles made from 'zero waste' and 'circular' sugar cane bioplastics. The company has also released statements that it vets its plastic supply chains, including how the feedstock is obtained.

At Lush, shipping packaging gets the eco-treatment too. In 2007, Lush made the bold switch from plastic filler material to edible popcorn – a shift entirely in keeping with the brand's zany persona and bare-essentials approach to sustainability.

Yet the company soon changed to using a more processed biobased alternative to popcorn filler, one that actually performed better on product protection and energy reduction.

Eco Flo, a packaging foam nugget made from cornstarch, is now the company's filler of choice. Not only is it biodegradable in water and soil, its manufacturing uses up less heat and energy compared to popcorn!

BYBI Beauty: glass, metal, and sugarcane

BYBI Beauty is another brand that has made eliminating oil plastics the forefront of its sustainability mission.

All the makeup containers that come out of this female-owned brand is made from either biodegradable sugar cane or glass.

> "Sugarcane-based plastic behaves like oil PET but it has far lower emissions. Its physical similarity to fossil plastic means sugarcane plastic can be processed by existing recycling plants."

Glass can be a useful aid in eliminating packaging plastic in makeup. Like plastic, it is infinitely malleable but unlike it, it can be recycled infinitely without any loss in the quality.

However, glass doesn't have all the properties required for every packaging application. This is where bioplastics can take over.

The sugarcane bioplastic used by the brand is a more sustainable alternative to PET plastic made from oil. Sugarcane is sustainable because it is a waste byproduct of making sugar, meaning that using it for packaging does not take away from the human food supply.

Sugarcane-based plastic behaves like oil PET but it has far lower emissions. Its physical similarity to fossil plastic means sugarcane

plastic can be processed by existing recycling plants. This removes the problem that afflicts certain types of bioplastics, which is the lack of specialised recycling plants needed to process them.

BYBI Beauty acknowledges that its sustainable packaging is a work in progress. Despite its recyclable nature, recycling rates for PET remain relatively low. The company says that it is constantly scouting for new sustainable packaging technologies and is in touch with suppliers to adopt solutions as they become available.

Sugarcane in men's skincare

The other big sugarcane packaging advocate in cosmetics is Bulldog, which seven years ago adopted the biobased material for its men's face wash and moisturiser range.

The tube and cap of their bottles are made from sugarcane-based PE and PP, types of plastics that can be recycled together.

Bulldog makes its tubes from over 50 percent sugarcane plastic. 100 percent sugarcane plastic would not have the right functionality for the caps. However, like BYBI, Bulldog says it's always on the hunt for new packaging materials that can improve its sustainability profile.

In 2025, Bulldog's supplier Amcor cut the impacts of its sugarcane packaging further with a 16% reduction in the plastic material needed for its tubes. Reducing the environmental impact of packaging is often a multi-pronged effort, where material choice works hand in hand with eliminating unnecessary bulk.

Tropic: all-round sustainability

Tropic is leading the charge on all-round sustainable packaging with recyclable and biodegradable, marine-safe containers.

Some of their bestselling makeup containers are refillable. This means customers never have to buy another makeup palette again, having the option to buy refill pans that slot easily in. Tropic claims its refill makeup containers have eliminated 12.5 tonnes of packaging already.

Biobased solutions come into play in their shipping materials. Products are sent to customers in recycled cardboard. The biodegradable air packs for cushioning shocks in-transit are made from potato and cornstarch.

All elements of their parcels are entirely compostable, meaning it will easily break down in an ordinary home compost heap. This applies right down to the tape, which uses vegetable glue rather than conventional adhesives that use fossil chemicals.

Bamboo simplicity from Zao and Elate

Natural wood grain is not a texture you see often in the cosmetics packaging world, where the sleek exteriors of resin and oil plastics are much more common.

Zao is breaking the mould with its bare and bold cosmetics design. Its mascara bottles, eyeshadow palettes, blush sticks and more come in casing made entirely from bamboo. The visual branding move announces the company's environmental commitments at first sight.

Bamboo is one of the most popular biobased options for cosmetics on

the market today.

North America's Elate is another brand making makeup containers and applicators out of visible bamboo, along with aluminium and glass, two materials that are highly recyclable.

Its bamboo containers and palettes are refillable and endlessly customisable, cutting the plastic waste out of experimenting with colours and products.

Fungal packaging on the rise

Fungal packaging is an emerging trend in cosmetics packaging that we are set to see more of in the coming years. Early adopters include Wildsmith, Lush, Seedlip, Haeckels, and Selfridges, who use the material to protect products during shipping.

These packaging containers start off with mycelium, the thread-like roots of a mushroom. They can be combined with organic waste, like wood chips, and then moulded into custom shapes and sizes. Growing mycelium packaging requires very little in the way of resources like land and water, making it lighter on the environment than even sustainable forms of forestry. The material is also home compostable, meaning they are able to break down in ordinary garden compost heaps – no sorting and collection required.

The fungi packaging supplier that has made major inroads in the cosmetics space over the last several years is Magical Mushroom. It has already partnered with the UK's Lush as well as Swedish makeup brand LOWD Cosmetics.

Magical Mushroom is the exclusive EU and UK licensed distributor for fungi material developer and manufacturer Ecovative Design, a major name in the mycelium biotech and biomaterials space.

For companies that want maximally sustainable packaging, options are multiplying every year. Brands are trialling and testing alternatives, augmenting the industry's knowledge overall about what works for which applications. Making the switch from fossil materials to biobased is getting easier than ever and these brands are showing us how.

SEPTEMBER 17, 2025

Surviving the Valley of Death: a guide for bio-startups

What can biobased entrepreneurs do to give their startups the best start in life?

The early years are the most dangerous for a startup. Known colloquially as the 'Valley of Death', this is when great ideas can falter on regulatory issues, lack of funding, or a lack of expertise.

Why does this happen? And what can biobased entrepreneurs do to give their startups the best start in life?

Why the Valley of Death?

Here are some of the biggest challenges that startups can face in the critical period between verifying an idea in the lab and scaling production.

1. Demonstration plants are costly, but vital
Startups often struggle to gather enough investment for the all-important industrial demonstration, an essential part of commercialising biobased products. This is where startups prove to potential investors their manufacturing process can be done cost-effectively at large, commercial capacities, not just in the lab or at smaller, pre-commercial scales.

The gap between lab-based and industrial production is huge. In the laboratory, researchers have the luxury of working with pure and expensive feedstock that fit their technical needs perfectly. They are also able to supervise every part of the process. These ideal conditions fall away at the industrial scale, where processes involve tens of thousands of liters.

Yet industrial demos are expensive, far exceeding the costs of doing very early-stage research and development. The cost gap is starkest when the R&D took place in academia, where material costs may be covered by a research institution. This expense can be particularly challenging for startups that are not yet generating revenue, let alone profit.

There is a major funding gap in the EU and in the US when it comes to helping projects move from pilot to industrial demonstration scales. At this stage, therefore, biobased startups are highly dependent on private investors to ensure they can remain on the road to commercialisation. Yet the early startup faces additional obstacles when it comes to convincing VCs to back them.

2. Investor caution
Compounding the problem of costly demos, there can be low investor confidence in new biobased technologies at their earliest stages.

The biobased industry comes with high risks from the investor perspective. Biomanufacturing sometimes features processes unproven at scale – for example, processes that use some new microorganism strain. Biological processes and organisms are notoriously difficult to standardise.

Frustratingly, this low investor confidence tends to present as a chicken-and-egg problem: investor scepticism leads to a lack of demo projects. Lack of demo projects leads to investor scepticism. Breaking the cycle is vital for getting biobased technologies out of the lab and onto the market.

The fact that VC firms want to see high returns quickly is another reason that biobased products can lose out at the early stages – even where they are clearly pitched towards growing markets for sustainable tech. Regulatory approvals for new products can take years. Getting

good ideas to market often means putting profit expectations to one side in the short term.

3. Lack of local biomass availability
A startup has to prove that they have a reliable, local source of feedstock to attract investment. In addition to being abundant, the feedstock must be high enough quality for the manufacturing process without being too costly to hamper profitability.

Feedstock supply is a consideration that is often overlooked in the R&D phase. In the lab, only small volumes are needed and researchers can afford higher quality materials than would be viable at industrial scale to showcase technological possibilities.

However, an under-developed supply chain will heighten risk perception among investors. For VC firm At One Ventures, which has backed California startup Cruz Foam, supply chain security is a key criteria in how they evaluate candidates.

Proving feedstock and supply chain reliability can be a challenge for certain materials in the biobased space. This is especially compared to petrochemicals supply chains, which have simply been around for longer and enjoy high public subsidies.

4. Lack of expertise
If a startup wants to prove their idea works at the industrial scale, they need experts capable of evaluating demo results and suggesting adjustments to make the manufacturing process as efficient as possible.

Lab and industrial expertise don't always overlap: the researchers responsible for an exciting innovation in the lab may not be the same ones able to evaluate industrial processes.

An understanding of biobased production is a niche specialty that startups must ensure they have access to from the start. Startups must also have a handle on where their expertise in business administration will be coming from when they embark on their commercialisation journey.

"Feedstock supply is a consideration that is often overlooked in the R&D phase. In the lab, only small volumes are needed and researchers can afford higher quality materials than would be viable at industrial scale to showcase technological possibilities."

Overcoming the Valley of Death

The Valley of Death may seem insurmountable but there are clear ways of improving commercialisation rates for early startups and their innovations.

1. Collaboration between industry, academia, and policy
The surest way to avoid the Valley of Death is for industry to work closer with academic institutions and researchers.

Targeted collaborations between industry and research at an early stage can make it easier for startups to access experts capable of evaluating and improving industrial processes or handling the business day-to-day, such as marketing.

These academia-industry collaborations are most likely to succeed when their R&D aligns with existing or incoming environmental policy.

Developers focused squarely on solving particular problems and meeting particular policy goals will tend to have a clearer idea of the kind of resources they will need to successfully market.

This alignment between academic, industry, and policy is especially crucial for sustainability tech, such as biomaterials and biobased products – growth industries that remain high-risk and where environmental regulation remains a critical driver of demand growth.

2. Government support
Although there is a growing number of specialist VCs working with biobased innovations, this sector is still perceived as high risk for many investors.

Compared to VC firms, public finance entities are more willing to wait for a high-impact idea to reach market maturity.

All emerging industries depend on heavy public support to grow and biomaterials are no exceptions. Once they reach a state of maturity, risk is lower, natural momentum gathers and private investment is happy to crowd in: equity investments become more common as major offtakes agreements lock in guaranteed demand.

Public support for biobased industries is rising around the world. China and India are backing their biotech sectors with local government policies, resulting in biotech startups in the Asia-Pacific increasing their investment by 140% in the three years to 2024. The EU is also looking at ways to improve public financing instruments to give more support to worthy but cash-strapped biotech ventures.

3. Reflection and research
Policy plays a huge role in supporting biobased tech out of the lab and onto the market. Yet there are important things that startups themselves can do to maximise opportunities.

Early startups must engage in continual self-reflection to survive the post-lab phase. This involves evaluating both the state of the business and the state of the market that they are entering.

Developers must ask themselves regularly what problem their tech solves, its applications areas, the possible products that could come out of their fundamental tech, the skills they need to market, and what the role of each team member should be.

Reflecting honestly on these components of the business should lead

to sharper focus, a more efficient allocation of cost and time resources, and greater teamwork.

4. Open-access demo facilities
Open access demo facilities are another way that governments can make it easier for biobased startups to prove scalability for potential investors at cheaper cost.

The Scottish Government has recently announced an £847,000 investment to support the purchase and installation of a 300-litre fermenter at the Industrial Biotechnology Innovation Centre's (IBioIC) FlexBio scale-up facility based at Heriot-Watt University in Edinburgh.

However, a facility of this size is more suited for the earlier proof of concept stage than industrial scalability demos.

Between 20,000 and 100,000 litres capacity is needed to really prove large-scale production feasibility. Capex for such facilities can be between $5 to $50 million and build-time can range between 3 to 12 months.

The EU is mounting a bigger effort in open access demo facilities. Bio Base Europe Pilot Plant is a non-profit dedicated to making demo facilities more cost effective for the region's biobased startups.
In November 2024 the project finished constructing its first 75, 000 litre demo fermenter in Ghent, Belgium where developers can validate their industrial fermentation processes. Half the building and facility cost came from competitive public funding.

Working together

Overcoming the Valley of Death is about fostering a whole regulatory and funding environment where good ideas meet less unnecessary resistance on their way to commercialisation. It is also about encouraging startups to plan carefully for the pitfalls that can arise outside the laboratory.

In short, avoiding the Valley of Death requires a collective effort: alignment between startups, regulators, policymakers, and venture capital firms to scale vital technologies that demand high capital expenditure in the short-term.

SEPTEMBER 24, 2025

Beer goes green

The surprising links between beer and sustainability, from Oktoberfest to circular leathers

Oktoberfest season is here. Starting 25 September, 7 million visitors will flock to the Munich festival for a pint-fuelled mix of music, beer, food, and revelry.

Beer is the focal point of the event, but its organisers are also showing how the beverage industry is driving sustainable change.

For years, Oktoberfest Munich has tried to reduce its waste and environmental impacts – a sign of how the beer industry as a whole is moving with the times.

Elsewhere, beer producers big and small are also feeding into a sustainable economy as they supply feedstock for beer-based biomaterials that reduce emissions.

Here are the surprising links between beer and sustainability.

Oktoberfest cleans up

Beer may be the focal point of Oktoberfest, but the German drinking festival is also known for its long-term initiatives to cut waste and limit environmental impacts.

The local government banned disposable crockery in 1999 at large-scale events, leading to a 90 percent reduction in festival waste.

Renewable electricity makes up a large portion of the festival's energy needs. Lately, it has been re-using water used to clean beer mugs for its sanitary facilities.

Wurst gets a biotech makeover

Oktoberfest food has been getting the green treatment too, with the festival proving a valuable testing ground for emerging vegan meat brands.

Traditionally, Oktoberfest is associated with Bavaria's meat-heavy regional cuisine. Dishes like Hendel (roast chicken) and the all-famous wurst (sausage) are part of its drinking culture.

Yet classic cuisine is getting a biotech makeover in response to consumer demand for less environmentally harmful vegan alternatives.

The festival is increasing its vegan food options each year, reaching out to alternative protein companies to expand its vendor offerings.

In 2022, the festival joined forces with Munich-based alt-protein startup Greenforce to offer a vegan Weißwurst (white sausage) for the first time. One of those who invested in Greenforce in 2021 was Michael Käfer, a businessman who heads one of the Oktoberfest's most exclusive drinking taverns, the Käfer Wiesnschänke.

Oktoberfest supply deals are a huge boost for any vegan supplier. Approval at a German beer fest where carnivorous tastes reign supreme is a marketing coup for any company seeking mainstream market acceptance.

Purists may argue that a beer festival is no place for meatless proteins. Yet the biomanufacturing process used to make many alt-proteins today is not so dissimilar to the way beer has been produced for thousands of years.

Precision fermented vegan proteins are manufactured using the same basic principles as those deployed in beer brewing, highlighting the biotechnological kinship between beer and the most innovative vegan meats.

Putting beer in our buildings

Oktoberfest's sustainability efforts are only the tip of the iceberg when it comes to how the beer industry is finding niches in a greener economy.

Around the world, startups are linking up with beer producers to turn ordinary brewery waste into extraordinary natural materials that can replace plastics and other everyday carbon-intensive materials.

The push to use beer waste for sustainable manufacturing is happening in the hometown of Oktoberbest itself, in Munich.

Here, university students at the Technical University have proposed a way to re-use beer production waste. Their university spinoff startup HopfON has found a way of using up the biomass discarded at the hop harvesting stage.

Hop harvesting comes right at the start of the beer supply chain. Currently, the practice is highly wasteful. Only the flower of the hop plant is used to make beer. This means that from the total plant matter harvested, just 20 percent goes into the final product. The remaining 80% normally get thrown away.

Right now, waste hop material has little value. But with a little processing, it could become raw material for other industries.

HopfON has figured out a process to take hop waste and manufacture acoustic panels, thermal insulation and building boards used in construction. The waste it uses comes from hop farms in Germany's Hallertau region.

Using hop discards to make architectural elements unlocks an innovative way of meeting national emissions reduction targets.

Hop-based biomaterials can displace high-carbon materials like plastics from our buildings.

This could be a huge win for climate policy globally and in the EU: around half of the world's resource extraction is used on buildings and construction. The sector contributes 36% of the EU's total greenhouse gas emissions. A lot of this is down to the non-renewable materials that are commonly used in buildings, like insulation.

Beer-based bio-leather

The beer industry has massive potential to contribute towards a circular economy. This is a type of economy where waste materials from one industry gets transformed into raw materials for another. Circular economies tend to be more sustainable because using waste reduces the amount of raw materials we need to freshly cultivate or extract.

Beer has an important part to play in a circular system because it is a global industry whose supply chain generates large amounts of organic waste.

Importantly, this low-cost waste contains large amounts of valuable materials: nutrients that could serve as agricultural fertilisers, food

supplements, and fibres for strong building materials.

Apart from harvesting, the other major waste generator in the supply chain is the brewing itself. Brewing creates a byproduct known as brewer's spent grain, a brown, solid mush, a mixture of leftover hops, yeast, barley and water.

Brewer's spent grain accounts for 85 percent of brewery by-products. Estimates say the EU alone produces around 3.4 million tonnes each year and every 100 litres of beer creates around 20 kg of the stuff.

One of the most established beer waste biomaterial startups, the UK's Arda Biomaterials, is pushing beer post-brewery waste to its limits.

Arda has found a way to turn the spent grain into sustainable leathers, a process that takes advantage of the plant-based protein found inside it.

Arda's vegan beer-based leathers are pitched towards growing demand from the fashion and automotive industries for more sustainable, ethical alternatives to animal leather.

Arda is known for eye-catching collaborations with cosmopolitan brands. The company paired up with London craft beer producer Beavertown Brewery for a collection of beer-based leather fashion accessories released in 2024. In 2024 it also unveiled a convincing mock-snakeskin handbag with the fashion label Been, using waste materials sourced from London's "Beer Mile'.

Beer bags from UnPlastic and Empa

The reputation of beer waste as a biomaterial feedstock is rising because it is so easy to turn it into all-rounder materials that can be useful across many applications.

Swiss researchers at the Empa institute have developed a way to turn brewer's waste into nanocellulose, which can be made into biodegradable food packaging.

The process starts with freeze-drying the spent grain, which turns the brown, flaky substance into a translucent white gel that can be worked into thin, flexible packaging. Their innovation is particularly useful for packaging heat-sensitive foods like meat.

Beer waste has great potential as a feedstock for making plastic-free packaging. Just this year, EU-funded project BIOSUPPACK announced it has developed a compostable packaging for food, cosmetics, and household cleaning. The material is a polymer known as PHB.

The ultimate aim of the project, which runs to 2026, is to make a highly sustainable, cost-effective packaging. Beer waste could one day furnish us with genuinely affordable biobased alternatives to petrochemical materials.

Brewed food

Big brewing companies are also trying to tap into their brewing waste. Carlsberg Sweden is now part of a project called Brewed and Renewed, investigating how spent brewery grains can become human food.

The brown mush that comes out of the brewing process may look

unappetising as a snack, but its basic components are not far from bread or breakfast cereals – rich in fibre, antioxidants, minerals and protein.

There's certainly no shortage of feedstock to experiment with: Sweden alone generates 80, 000 tonnes of brewer's spent grain per year. Yet as with any industrial scaling project, there will be technical hurdles to overcome along the way.

Beer waste-based ingredients would tackle at least two sustainability issues at the same time, ensuring that the fertiliser and water that went into cultivating beer do not go to waste while also reducing the resource demands of the human food system.

Making food from spent grain is not a new idea. Switzerland's UpGrain has already been using the byproduct to produce nutritious barley-based ingredients for the food industry. Dutch retailer Albert Heijn has been stocking bread varieties made from UpGrain's barley ingredient and these contain up to 120% more protein and 900% more fibre than conventional products.

One practical problem with using a brewer's spent grain is how to store large amounts of it safely. The substance is moist and nutrient-rich, which can encourage rapid microbial growth. Generally, spent grain startups have solved the problem by drying it as soon as possible and grinding it to a powder.

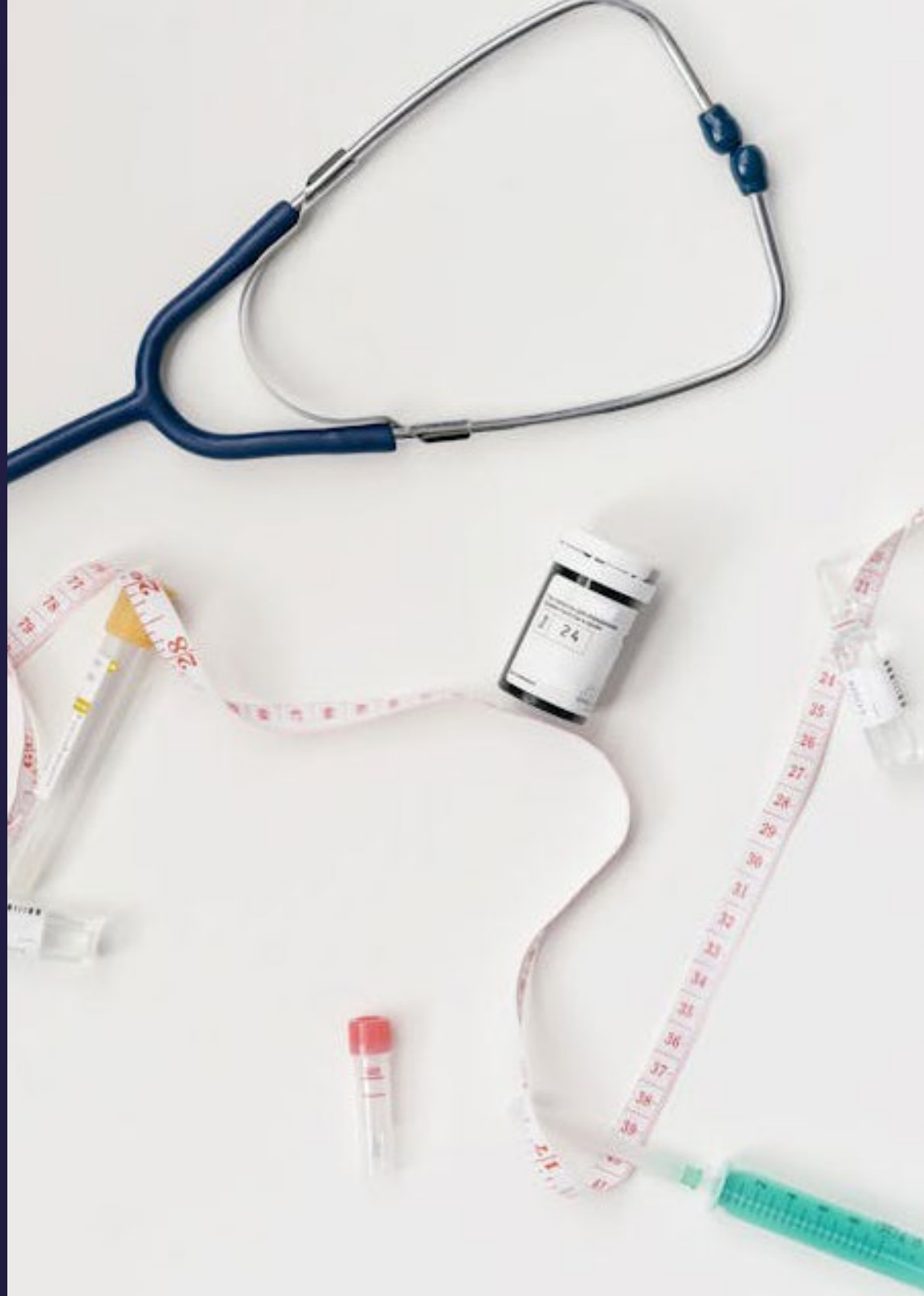
Brewed and Renewed will run between 2025 and 2025. Alongside Carlsberg Sweden, food companies like Bageri Gruppen as well as the sustainability non-profit Axfood are participating.

Projects like Brewed and Renewed show there is industry appetite for circular initiatives that turn around beer waste feedstock. With Oktoberfest season in full swing, now is the perfect time to support this green beer transition and its circular efforts.

OCTOBER 1, 2025

Healthcare has a plastic problem – biomaterials can help

Biomaterials can lower healthcare emissions and simplify waste management



Europe's healthcare system produced more than 900, 000 tonnes of single-use plastic in 2023.

This plastic dependence is bitterly ironic. Plastic is incredibly harmful to our bodies and the food, water, and air we consume, undermining the health system's mission to preserve our wellbeing.

Yet single-use plastics are hard to simply eliminate in healthcare. Throwaway containers, bags, and instruments maintain hygiene and prevent infection.

There is a solution: making disposable equipment biobased and biodegradable.

The plastics in our health system

In Europe, estimates say 36 percent of healthcare waste is plastic. 42% of this is incinerated.

The bulk of plastic use in healthcare happens in seven applications:

- fluid bags and tubing
- gloves
- rigid devices (like syringes)
- device packaging
- personal protective equipment
- wipes
- pharmaceutical packaging

These are dominated by oil-based plastics like polyethylene terephthalate (PET), polypropylene (PP), and polyvinyl chloride (PVC and polyurethane dominate these life-saving applications. None are biodegradable.

More often than not, single-use plastics from the healthcare sector end up in landfill.

Once in the soil, the single-use plastics that fill hospital environments will not break down for thousands of years. When they do disintegrate, they release harmful chemicals that inevitably enter the human food system.

When biomaterials help

One way to reduce plastic waste is to eliminate as many single-use products as possible.

Unfortunately, this is not an option in many medical applications. Single use products support hygiene and prevent infection.

Increasing recycling is another avenue to reduce waste. Hospitals do not recycle single-use petroleum plastics as much as they could for practical reasons, like the burdens of sorting and storage.

Finally, we can replace certain single-use petroleum plastics with single-use biomaterials instead.

Biomaterials are a general term for any material made using biological (and therefore renewable) rather than mined raw materials.

Plants, crustacean shells, and wood can be processed into thousands of different biomaterials with all kinds of properties, some of which match

petroleum plastics on their safety and performance features.

Low-emissions, anti-landfill

Some biomaterials offer advantages in single-use applications that petroleum-based plastics cannot, such as a lower carbon footprint.

For biomaterials to maximise the sustainability of single-use healthcare items, however, they must be biodegradable or compostable. This means they can decompose safely and quickly once they are used.

There are already examples of biodegradable and biobased single use equipment on the market. The “biogown” by TerraLoam uses corn starch and biodegradable polymers to create gowns that degrade in open landfill over 12 to 18 months. Irish company HaPPE Earth specialises in biobased medical aprons made from maize that ‘disappears’ in around 8 weeks.

These are both examples of compostable personal protective equipment, meaning the biomaterials they are made from need no special facilities to decompose safely.

By contrast, biodegradable biomaterials must be sent to specially equipped industrial plants which offer the right heat and microbial conditions to turn the materials into water, carbon dioxide, mineral salts, and biomass.

In 2024, University of Maine researchers developed a biodegradable, biobased isolation gown using materials already made at a relatively large scale: paper and a biobased coating chemical known as VerdeCoat. Isolation gowns are worn by health workers attending patients under isolation and are often made from petroleum plastic polypropylene.

The researchers wanted biodegradable, biobased gown specifically designed to be sent to special industrial composting plants.

The advantage of industrially composting single-use items is that composting plants can systematically extract and recover valuable compounds from the material that can be re-used. This is something that could not happen if the apron was simply made to decompose out in nature.

What hospital products can go biobased?

There are immense opportunities for biobased swaps in our health systems. A recent report by the biobased industry association BB-REG-NEET on Britain’s public health system the NHS stated that at least 670 NHS contracts and 407 agreements for goods where biobased alternatives could serve just as well as conventional plastics.

Changing the materials in use across an entire sector like health is a challenging project, but pilot projects around the world are showing that it is possible.

University Hospitals Birmingham implemented biodegradable materials for certain pharma product packaging and food service containers. It reduced hospital waste sent to landfill by over 20%.

Finland has been looking to its forestry industry to bring down the plastic impact of its healthcare system.

Central Finland Central Hospital in Jyväskylä became a testing ground for wood-based healthcare materials under the Sami&Samu project, which ran from 2018 to 2021.

The trial did not limit itself to solid wood-based materials. It also tested antimicrobial and bioactive compounds taken from Finnish trees.

Surfaces of any kind – clothing, curtains, floors, and tables – can become incubators and carriers of disease when bacteria survive on them. In one test, a biobased antimicrobial coating was sprayed onto hospital privacy curtains. In addition, the hospital trialled fabric patient bags made from wood material, as well as wood-based coffee cups and salad plates in the canteen.

Karolinska University Hospital in Sweden has mounted a sustainable pilot project that proves how far sustainable alternatives can be integrated into healthcare. It has replaced many single-use medical devices with biodegradable alternatives. Surgical drapes are now made from biodegradable plastics, as well as certain medical packaging. Patient wristbands from plant-based materials have also been trialled.

An EU project has recently identified which hospital disposables could most easily be replaced with biobased alternatives.

The project found some 'low-hanging fruit' when it came to potential biobased switches. These were catering supplies, containers used at the bedside (for example, to collect urine samples), and some surgical single-use equipment like protective clothing and masks.

Pharmaceutical packaging is another area where biodegradable biomaterials have the potential to reduce environmental impact.

Public health systems are large-volume consumers that need reliable stock over the long term, making them ideal offtake customers that can lock in demand for biobased companies looking to scale. In this sense, healthcare and the biobased industries could work hand in hand as they build practical, sustainable materials that keep toxic waste out of landfill.

Advanced applications

However, more sensitive medical equipment, like syringes and blood bags, pose a bigger challenge for biobased swaps since they have stringent safety requirements.

Changing the materials used in highly regulated medical equipment can pose a huge administrative hurdle for hospitals. Yet options do exist, with a number of companies manufacturing biomaterials for medical uses.

Arkema Group for instance makes biopolymers that meet ISO 10993 regulations on medical devices that come into contact with the human body.

Arkema's patented biopolymer, polyamide 11, is made from the castor bean. The company manufactures the basic polymer, which it sells onto companies that transform them into medical devices and other products.

The company says that its bean supply is grown on the poorest soil in India and does not compete with human food or contribute to deforestation.

Polyamide 11 can be made into single-use medical devices to replace surgical steel and petroleum-based plastics: tubing, IV bags, and balloon catheters (used to enlarge narrow openings in the body), are all end applications for the material.

The afterlife of medical disposables

All kinds of material – whether biobased or petroleum-based – can contaminate the environment if left in landfill. Ensuring a plan for end-of-life processing is therefore essential to reducing the environmental impacts of healthcare equipment.

For example, Arkema's Polyamide 11 is not biodegradable but is recyclable. Arkema has acquired a recycling plant in Italy to recycle their customer's waste into lower-spec, non-medical applications.

Like recyclable plastics, biodegradable bioplastics encounter gaps in end-of-life processing capacity. Sorting is time-consuming while collection and specialist end-of-life treatment facilities really depend on the state of local services. Bioplastic composting capacity remains patchy across the world.

However, modular composting systems can overcome the absence of centralised composting infrastructure for bioplastics. Dutch company Pharmafilter offers a small on-site anaerobic digestion system that takes in hospital waste and uses specialised microbes to decompose them. It is currently installed at five hospitals in the Netherlands, including its leading university medical centre.

Pharmafilter's small-scale, on-site composting facilities demonstrate another advantage of using bioplastics and biomaterials: as well as breaking down bioplastics, they can also process a diverse range of materials including food waste, hazardous material like used bandages and syringes,and wastewater.

Using biobased alternatives in conjunction with an all-purpose industrial composting facility can therefore simplify hospital waste management procedures.

Changing the materials we use in the healthcare sector can seem a daunting task. However, we have already seen rapid changes in the material make-up of our healthcare systems.

Traditionally, glass, metals, ceramics, wood, and stone dominated medical equipment before widespread plastic adoption in the mid 20th century. With plastic pollution in the 21st century at crisis point, another material turning point for healthcare could be on the horizon.

OCTOBER 8, 2025

Safe as houses: bio-insulation in EU energy security

Biobased insulation shows how EU energy security and climate policy can go hand in hand

Proper insulation can lower heating bills. Yet biobased insulation offers a whole host of other benefits as well.

Today, startups are turning plants into building materials that keep homes warm. Biobased insulation comes with fewer environmental impacts than the mineral wool and polyurethane common in buildings today.

Biobased insulation is especially poised for success in the EU, where it can support multiple regional policy priorities: energy security, economic security, and decarbonisation. Here's how.

Europe backs Finnish biofoam

In Europe, the fortunes of biobased construction companies are rising. Finland's Fiberwood secured a $3.1 million EU grant in June 2025 to scale its circular insulation foam. Made from recyclable and plastic-free wood fibre that would otherwise be landfilled or burnt, its biofoam is circular and biodegradable.

Using this EU funding, Fiberwood will focus on optimising production, testing new sources of used wood feedstocks, and improving its technical performance.

Fiberwood's ultimate goal is to lay the foundations for a full commercial factory. With mass production, prices can come down and drive wider market adoption.

Decarbonising construction

Fiberwood's low-carbon insulation material is special because it can replace petrochemical materials all too common in the construction sector.

Biobased insulation materials – particularly when made from waste – have a far smaller carbon footprint compared to traditional mineral wool or petroleum-based versions.

Overhauling the materials we build with is a vital part of fighting climate change. The construction industry contributes 42% of global greenhouse gases. Yet it is one of the hardest to decarbonise.

The construction sector's carbon footprint mainly comes from the materials it uses to build with, not the type of energy it uses to power itself.

This means decarbonising construction is not just a matter of electrification. We must also find renewable, circular alternatives to replace the mined, fossil-based materials that make up our buildings. Low-carbon insulation will be part of this equation.

Bio-insulation meets EU policy

The EU's decision to finance a biobased insulation startup speaks volumes about the region's priorities today.

ING and Oxford Economics are both forecasting that demand in Europe for building renovations will grow over coming years, particularly for renovations designed to cut energy consumption.

Oxford Economics predicts a surge in European renovation. Coupled with new building sustainability regulations, this marks a huge opportunity for biobased companies

Demand for insulation materials is likely to ride this new wave of construction work. Around 64% of final European household energy use goes on heating. Insulation can cut this significantly, making it a vital part of energy efficiency upgrades.

Europe's newfound appetite for energy renovations is driven by a regional push to reduce energy consumption as much as possible. Economic and security factors are behind this.

European businesses and consumers have faced rising energy costs since the pandemic. Russia's war in Ukraine also prompted the EU to switch from cheaper piped Russian gas to more expensive liquefied natural gas.

As the EU's ties with Russia continue to deteriorate, Europe's economic motives to lower energy consumption have merged with security priorities. The bloc wants to become more self-sufficient in critical resources like energy to avoid the supply shocks it has been experiencing since 2022. Some of this can be achieved by lowering overall demand for import-intensive commodities like gas.

Sustainable energy security

This impetus to increase energy efficiency in building stock is also coming from climate policy.

The EU's Renovation Wave strategy, part of the European Green Deal, aims to improve energy efficiency in buildings across the region. It plans to renovate 35 million buildings across the public and private sector by 2030. This represents double the expected renovation rate in the region – a huge fillip for the construction industry.

The renovation policy is already having an impact on markets and national laws. Europe dominated the market for insulation material in 2024 thanks to this new demand driver. Already, some countries are anticipating the incoming EU regulations: France has banned the rental of energy inefficient buildings from January 2025.

These building renovations will have to meet strict regulations on energy efficiency and greenhouse gas emissions laid out by the EU's separate Energy Performance of Buildings Directive, adopted by the Parliament in 2024.

The EU's Energy Performance of Buildings Directive does not just aim to reduce emissions from heating and lighting. It also encourages new builds to reduce emissions locked up in their building materials. This will be a boost to biobased and circular construction companies in Europe developing the low carbon materials the sector needs to hit these targets.

Nordea estimates that the Renovation Wave will require a total of €1.2 trillion between 2024 and 2030. The project is set to mobilise a whole set of private and public funds to achieve its goals.

Fire-safe biofoam

The EU renovation overhaul will not face a lack of choice when it comes to sustainable insulation materials. Yet some consumers will still need convincing on safety aspects such as fire resistance.

The EU-funded SAFE-PUR project is addressing fire safety concerns around biobased insulation materials. The project has patented a new firesafe insulation material made from C5 cellulosic sugars and

> "The ability to scale high-performance, fire-safe insulation made from such an abundant form of waste as straw would be a gamechanger for the circular economy."

materials from soy, castor, and rapeseed oil. It is meant to replace widely-used polyurethane or polyisocyanurate foams, which are highly flammable and produce extremely toxic fumes when burnt.

The biobased material developed by the EU project was found to reduce flammability by around 30 percent compared to polyurethane foams. It was also less toxic when on fire, reducing smoke emission and toxicity levels by around 80 percent.

The material improves on fire safety because it does not contain the same chemical additives normally used in manufacturing insulation materials, like foaming agents and stabilisers.

Straw and grass support circular security

Since the pandemic, the EU has wanted to reduce its import dependence on critical materials and energy.

For biobased insulation to support these priorities, it must be made from abundant and easily accessible local feedstock.

Feedstock doesn't come more accessible than grass clippings, the material of choice for sustainable construction company Ecological Building Systems. The company's 'Gramitherm' insulation material is made from cutting taken from public grass verges mixed with recycled jute fibres and a binder made from recycled polyester. It claims that their material is carbon negative.

The product has also achieved A+ ratings in tests for emissions of volatile organic compounds. It also meets European criteria E for fire resistance, meaning the material won't transmit fire to other parts of the building.

Agricultural waste straw has lots of potential as insulation feedstock. In April this year, Chinese researchers published a fully biobased wheat straw insulation material that uses biobased additives as binders and fire-retardants.

Italy's Prespaglia is one of the premier EU construction materials companies already working with straw as insulation. Their pressed blocks of cereal straw, clay, and hydraulic lime are purposely made for construction.

The ability to scale high-performance, fire-safe insulation made from

such an abundant form of waste as straw would be a gamechanger for the circular economy.

The insulating capabilities of straw vary with species, which display minute differences in microstructure. A 2018 study found that wheat straw had the highest insulating performance and barley the lowest. The way that straw stems are arranged as well as the density of straw all impacts on final performance too.

These natural variables suggest that with more research and experimentation, industry could uncover more straw-based insulation materials with even higher performance specs.

Climate and security

The EU has faced a more uncertain energy landscape after 2022. Energy security concerns now permeate every aspect of its policy.

Climate goals risk being sidelined as security gets greater emphasis. However, biobased insulation is a good example of how the EU can address resource security and climate at the same time.

In its drive to upgrade energy efficiency in buildings, the EU can help scale sustainable insulation materials that help boost low carbon manufacturing while lowering costs for consumers.

Low carbon manufacturing can also support regional self-sufficiency. This is because waste feedstock can be easily sourced from local industries, easing reliance on imports.

Finally, waste-based biofoams are a key tool for decarbonising the building sector, a major priority in the fight against climate change. Apart from lower carbon impacts, renewable material also biodegrades safely in nature, building a leave-no-trace ethos into construction.

The EU push to strengthen energy security is also a decarbonisation opportunity. With biobased construction companies proliferating in the EU, the low carbon technology it needs is already there for scaling.

OCTOBER 15, 2025

Seaweed solutions for the hardest plastics to recycle

Biobased versions of thin film plastics are safer for health and the planet

Bags, pouches, labels, liners, lids. Thin film (or 'soft') plastics are everywhere we look. Yet they are among the most harmful for human health and the environment.

In many ways, thin films are the ultimate problem plastic. Usually, they are used only once before being thrown away. They are rarely recycled, meaning a lot of them end up in our soil and oceans.

Three major seaweed plastic startups have the IP we need to stem the tide of thin film waste.

Their biobased, biodegradable films are designed to melt away naturally in the environment, solving one of the biggest barriers to more sustainable packaging.

What are film plastics for?

Thin film plastics are flexible, sheet-like plastics used across multiple industries, like food, agriculture, and fashion. Usually, they are made from the fossil plastic polyethylene.

These films are used to extend the product life of food (the clear wrap around supermarket vegetable trays) and make packaging more user-friendly (yoghurt pot lids, see-through windows on sandwich boxes). Dry cleaners and fashion brands use it as garment bags to protect clothing during transport.

In agriculture, huge spools of thin films are used to wrap hay bales or cover soil to trap nutrients and moisture.

What's the problem with thin film plastics?

These thin, see-through materials look innocuous. However, they are one of the most dangerous household waste products in terms of health and environmental impacts.

Often, thin films are the only components of food packaging that you can't put in your home recycling bin. This is because it gets caught in sorting machinery at facilities, causing jams. Usually, they end up either burned or in landfill, releasing toxic byproducts in the process.

Sometimes, local supermarkets offer recycling services specifically for these plastics: consumers drop them off and the shop supposedly takes them to specialist recycling sites.

Shockingly, however, a UK tracking project found the material collected by supermarkets actually ends up burnt – a practice that releases extremely toxic air particles.

Clearly, we need better solutions to thin film plastic waste.

Of course, the most sustainable practice would be to eliminate packaging altogether. However, thin films play a vital role in parts of the food system, such as preserving foods and growing crops in agriculture.

In applications where thin films support food security and sustainability, opting for new, more sustainable materials becomes necessary.

The seaweed startup trio

Many startups have turned to seaweed in order to make more sustainable versions of thin film. These startups include the three most

recognisable names in compostable bioplastics: Sway, NotPla, and Zerocircle.

The attractions of seaweed for biomaterials companies are clear. Their natural components like agar, carrageenan, and alginate have gelling and film-forming properties. They also contain biopolymers like cellulose and starch, ideal for bioplastics production.

It is also easy to make materials from seaweed that are compostable or biodegradable, even edible. Unlike petroleum, seaweed is a renewable source. Unlike land plants, they lack the tough woody parts that make terrestrial species so costly to process.

One of the big three startups creating seaweed-based thin films is Sway, whose material is almost indistinguishable from ordinary soft plastic wrapping. In contrast to the conventional material, it decomposes safely and quickly in soil as well as on the home compost heap.

The company's key technology offering is a seaweed resin, which it has branded TPSe, made from a blend of seaweed and land plants.

India's Zerocircles takes locally cultivated seaweed and makes it into materials specifically designed to dissolve in ocean water.

An important feature of their plastic pellets is that they can be 'dropped in', meaning they can be fed into conventional plastic film-making machinery that usually only works with petroleum plastic pellets. This makes it easier for conventional plastic producers to switch to the material, supporting the scalability of their material.

"The attractions of seaweed for biomaterials companies are clear. Their natural components like agar, carrageenan, and alginate have gelling and film-forming properties. They also contain biopolymers like cellulose and starch, ideal for bioplastics production."

NotPla, a London startup, is famous for their clear and compostable seaweed-based products designed to replace single-use petroleum plastics in a myriad of packaging applications, from grease-proof lining to plastic bottles and clear sandwich windows.

Seaweed startups accelerate

In 2023, Sway, Zerocircle, and NotPla won first, second, and third respectively in the Tom Ford Plastic Innovation Prize.

The prize was just the first phase of Unwrap the Future, a multi-stage accelerator programme aimed at scaling replacements for non-biodegradable thin film plastics.

The three companies then entered the second phase of the programme in 2024, working with brands like J. Crew, Tom Ford Beauty, and Stella McCartney to test the seaweed packaging for their products.

J. Crew has used Sway's biopolymer packaging through its distribution centre on products ranging from denim to shoes.

Snowboard company Burton has been testing Sway and Zerocircle's materials to see whether they can replace the shrink film they currently use and whether they can withstand the temperature and humidity fluctuations that occur as they move through the supply chain.

Meanwhile, designer label Stella Macartney trailed NotPla film with its poly bag supplier.

Thin films in agriculture

One of the biggest end uses for plastic film use is agriculture. The strong, thin and flexible material is ideal for mulching, where farmers trap soil moisture, temperature, and nutrients in the soil by physically covering it.

Agricultural film plastics are generally made from fossil-based polyethylene. They are particularly harmful to human health because mulch on cropland is a major source of soil microplastics. From here, they enter crops and eventually, the human body.

Agricultural films are also very difficult to recycle economically – especially when they are extremely thin.

A safe, compostable agricultural plastic would need to break down in reasonable time into simpler compounds safe for the environment – water, carbon dioxide, methane, and other basic elements.

The hunt for sustainable mulching material

Some bioplastics physically behave much like the organic matter they are made from. This means that once they are used, farmers can crush and bury the material in soil, where natural microorganisms break it down just as they would any other biological material.

Regulation in the EU has been driving up adoption of biodegradable mulch material. In 2018, the European Standard for biodegradable mulch films in agriculture and horticulture was released. In 2024, the EU formally recognised that certain soil biodegradable mulch plastics could be classed as fertilisers and therefore beneficial for the soil.

However, there remain several barriers limiting adoption among farmers. Among them are a lack of knowledge about compostable mulch options. Predictably, cost matters too. Biodegradable mulch is more expensive than petroleum-based plastic films.

To sell biobased mulch material to the agricultural industry, producers will have to focus relentlessly on the cost factor. Already, there can be cost advantages to using compostable mulch. Foremost, they get rid of the need to remove compostable plastic at the end of the growth season, since they are simply buried in the ground. This could lower transport and labour costs.

The innovation gap

Soil-biodegradable mulch films have been in use for more than 20 years, mainly made from polylactic acid (PLA). They are a crucial pathway to more sustainable agriculture and many are tested to strict standards governing soil biodegradability.

However, we still need more research investigating the long-term effects of compostable mulch on the environment. This is because biobased materials can behave in very different ways under realistic field conditions compared to the standardised test conditions normally used for certification.

Research into how biodegradable mulch behaves in soil long term is critical because this material does generate microplastics while they are in the process of decomposing completely.

Microplastics from biodegradable, biobased mulch are unlikely to be anywhere near as permanent as those generated by conventional plastic. However, they can have their own environmental impacts. Another open research question is how the microplastics behave once rainwater or irrigation washes them into waterways. This is because biodegradable mulch does not necessarily break down at the same rate or in the same way in water as they do in soil.

In general, an innovation gap in thin film plastic for agriculture remains. The industry urgently needs materials proven to break down safely and quickly in a wide range of climates and soil types, with minimal impact on wildlife and soil. At the same time, they will need to offer the cost benefits of conventional plastics.

That's a wrap

Material innovations in agricultural mulch may be a work in progress. Yet the thin films used in packaging already have technological solutions ready to scale.

Between them, NotPla, Sway, and ZeroCircle have the IP to fully replace fossil-based films in applications where they are necessary to keep products safe, dry, and user-friendly.

Recycling remains an important way to make the packaging industry more sustainable. On its own, however, it cannot solve the issue of plastic waste. Low market prices for these plastics rarely justify the high costs of recycling them.

Thin film plastics are a key area where new biomaterials and recycling can go hand in hand to make the packaging industry greener and safer.

OCTOBER 22, 2025

Why bad land makes for good feedstock

Crops grown on marginal land can make industry more sustainable

In July, an EU project began that aims to transform poor-quality land into the basis of new biobased supply chains.

The RUNFASTER4EU project wants to demonstrate that crops grown on marginal land can become sustainable energy and materials products at an industrial scale.

Marginal land is getting more attention from biobased entrepreneurs and policymakers as a sustainable raw material source.

But what is marginal land? And how do crops from them make the biobased industries more sustainable?

How marginal land benefits biobased industry

Marginal land refers to agricultural sites that are not economically viable to cultivate for human food or animal feed. This could be agricultural land that has been abandoned, land degraded through ground pollution, or has soils that struggle to retain moisture and nutrients.

One estimate has placed marginal land at 38-53.5 million hectares in the EU and the United Kingdom. Climate change is set to increase this amount in certain regions.

Marginal lands may not support food crops, but they can support industrial crops for energy and renewable materials.

Sourcing feedstock from marginal land tackles a major objection to certain biobased energy and material products: that expanding industrial cropland can reduce land for growing human food or for biodiversity conservation.

Environmental arguments intersect with economic ones here. Increasing the pool of low-cost biomass feedstock is key to lowering the prices of biobased goods. Using crops from marginal land can achieve this without adding unnecessary burdens on the environment.

This is because almost by definition, crops that can thrive in marginal land generally demand less of the energy-intensive soil conditioners, fertilisers, and water resources that other crops would need. The minimal resource demands of these plants means that they can become the foundations of maximally low-carbon industrial supply chains.

In some contexts, planting the right species on the right kinds of marginal land can boost biodiversity.

Switchgrass: biofuel substitute

US renewable supply chains are developing at a steady clip, driving up demand for quality biomass feedstock. The country has an estimated 11% of the contiguous landmass considered marginal land. In these areas, only a few commercially profitable species could thrive. One of them is Switchgrass, a high-yielding source of biofuel.

Switchgrass is one of the most well-known feedstock crops. The deep-rooted grass is native to the Central North American Plains and so well-suited to poorer soils.

Corn is the main biofuel feedstock in the US but on certain marginal lands, switchgrass can make more economic sense. The exact profitability of cultivating Switchgrass depends on which varieties

you plant where, as well as the price for biofuels at a given time. Field research shows input costs vary for different cultivars in different soils across the US Midwest.

Apart from providing lower-carbon fuels, these grasses can also improve soil carbon storage where they grow. Researchers found that when switchgrass was planted in highly eroded, sandy loam soils in Oklahoma's Dust Bowl-remnant fields, soil carbon levels quickly rose there.

Similar results were found by a team at the University of Colognia, which planted a large switchgrass field site at the university experimental farm back in 2007. After 13 years, there was a significant increase in soil carbon.

Switchgrass has different carbon impacts depending on soil type and location, so careful site-by-site monitoring is essential. Where the crop can raise the net carbon retention of soil, it can provide a low-cost way to reduce planet-warming gases in the atmosphere.

There is also a lot of research that indicates that when planted on previously degraded or unused sites, switchgrass has more positive biodiversity impacts than corn biofuel crops, particularly on pollinator insects and birds.

Miscanthus: a marginal all-rounder

Miscanthus (or elephant grass) is another plant that grows happily on marginal land.

So far, the plant has found more diverse applications than Switchgrass, including in packaging, construction, and even equestrian sports.

In the equestrian industry, ArenaMend has developed Miscanthus fibres that can be used to fill out the sandy surfaces inside riding arenas. These fibers are meant to replace toxic synthetic materials commonly found in arena surfaces, such as tiny plastic granules or shredded carpet.

In Dorset, England, the company Agrikinetics is investigating how to turn local Miscanthus plants into pulp for packaging. Packaging made from the plant could have a far lower environmental impact than using virgin wood pulp, which is relatively slower-growing and can come from unsustainable forestry sites.

The company's Miscanthus-promoting activities do not end there. The UK firm is solely dedicated to Miscanthus product development. It says the crop is especially suited to rural revitalisation, as it lends itself to decentralised, small-scale production by producers located in the countryside.

Indeed, Miscanthus grows well in almost any setting, including urban and semi-urban sites we would not normally associate with agriculture.

One unlikely haven for Miscanthus is on land near aviation runways. In the Netherlands, this humble grass has been planted around the country's Schiphol airport, where it serves a dual function: it offers a natural way to ward off birds while providing local bio-businesses with a sustainable feedstock source.

Geese are naturally afraid of the tall and dense Miscanthus plants. When planted around airports, the birds are less likely to disembark

near the runway, reducing the likelihood of deadly collisions with aircraft.

Some of the Miscanthus grown around the airport has gone to local biobased business BioBound, which has made concrete paving stones with the grass. These paving stones were recently installed at the airport.

The outdoor benches in front of the terminal are also made from Miscanthus-based bio-concrete. The material is circular because at the end of their lives they can be broken up and used again as insulation material.

The Midas touch

Switchgrass and Miscanthus are only the most well-known industrial crop species suited to marginal land. Soon, we could have our pick of new plant varieties that can withstand unfavourable soils.

The EU's MIDAS project is developing new, non-edible plant varieties that can grow in marginal soils mapped around the region.

Their objective is to selectively breed crops that can provide reliable industrial feedstock, including under a warming climate, while also restoring biodiversity in certain parts of Europe.

The crop species they are working with include safflower, crambe, cardoon, castor bean, and poplar – all species naturally predisposed to arid conditions.

Some of the industrial products that can be made from these plants can nourish soil elsewhere: technologies: biochar, bioherbicides, biostimulants, and mulching film made from marginal crops could improve land efficiency in dry Mediterranean areas.

Certain crop species that grow in marginal areas can provide a host of benefits for wildlife, particularly for the insects vital for pollinating our food crops. MIDAS is aiming for plant varieties that can expand feedstock supply for biobased products and give back to the soil and ecosystems where they grow.

Marginal isn't always unproductive

Converting every single piece of unused land to feedstock growing is not the point either.

Some uncultivated land may appear unproductive. On closer inspection, they can actually be vital for sustaining livelihoods that turn around foraging, subsistence farming, and pasturage for indigenous peoples, pastoralists and the rural poor around the world.

This signals a wider point about building sustainable economies. As well as industrial decarbonisation, sustainability must include social aspects, like preserving traditional cultural and economic practices that already respect the physical limits of our planet.

Traditional uses of marginal land can provide countries with irreplaceable public and ecological benefits just as they stand today. The search for industrial sustainability therefore cannot ignore these existing uses: In some cases, marginal lands may better serve overall environmental goals if left to communities that engage in low-intensity farming and foraging.

> "From the innovations already on the market, it is clear that almost every industry could benefit from feedstock grown in marginal sites."

Converting unused marginal land into sources of industrial feedstock must be done in a strategic manner that can expand biomass supply without negative social impacts. To achieve this, policymakers must set out clear criteria for deciding when a piece of marginal land is best used for industrial feedstock rather than any other uses, including for subsistence.

Certification schemes that evaluate the ethical impacts of supply chains must have a way for assessing whether the biomass supply displaced traditional resource use.

Even given these constraints, the world still has a lot of marginal lands to offer that are ideal for industrial crop production. Crops grown on these demand few resources and can keep land competition for food and wildlife to a minimum.

From the innovations already on the market, it is clear that almost every industry could benefit from feedstock grown in marginal sites.

Feedstock crops that can grow on marginal land do not just provide a sustainable resource for today but a source of economic security for tomorrow. Plants that can offer food, fuel, and materials even under unfavourable conditions will become increasingly important as climate change makes growing conditions more volatile. The biobased industry's increasing interest in marginal crops is therefore crowding R&D and investment into a vital area.

OCTOBER 29, 2025

Biomaterials that go bump in the night

Spiders, hagfish, semi-alive robots, and the blackest blacks: here are the spookiest biomaterials around

As the nights draw in and the days get colder, our thoughts naturally turn towards the otherworldly.

Even in the eminently scientific realm of biomaterials, we get unexpected glimpses of the uncanny if we peer closely.

From the gruesome hagfish to the blackest of blacks, this feature looks at the world's spookiest biomaterials, paying homage to the wondrousness of nature on which biomanufacturing depends.

These bio-horror tales are best read next to the fire, mug in hand, and one ear out for any bumps in the night.

Hagfish slime

Slithery, slimy, and ancient: hagfish are one of the most reviled creatures of the deep. These predator-scavengers live in every ocean except the polar ones and have been around for at least 300 million years. Yet their bottom-dwelling habits mean that most people, at least in the West, have not encountered them.

Spineless and jawless, their snake-like bodies are eerie enough. But their secret weapon is slime – their primary defence mechanism.

When Hagfish feel threatened, they release a milky mucus-and-thread mixture from their bodies. Once the concoction mixes with seawater, the ingredients form the incredibly strong, stretchy, and transparent substance – a substance so thick that it clogs the gills of any fish that tries to eat them, suffocating the predator-turned-victim.

The power of this saline goo came to public notoriety in 2017 thanks to a road accident in Oregon, US. A truck containing 3,400 kg of Hagfish overturned while transporting them to Korean culinary markets. The road was instantly slathered in a stretchy coating of Hagfish slime, resembling layers and layers of thickened clingfilm.

Yet Hagfish slime is not simply a grotesque curiosity. Material scientists have been fascinated by its properties for years because it holds immense industrial applications. Specifically, scientists are interested in the thin protein fibres that make up the slime. These become silk-like when dried and could form the basis of sustainable textiles, especially for high-performance applications.

Despite their industrial potential, we still lack a precise working model of how the slime is structured and why it behaves the way it does. This has made it difficult for scientists to artificially re-create the slime and its critical constituents inside labs.

The reason we still lack a full explanation for the slime's physical properties is that Hagfish slime is a highly complex substance. 90 milligrams of the Hagfish's mucus-thread secretion can create more than a litre of slime once combined with seawater. The mysterious thing here is that the final slime substance is mostly composed of "just" seawater – in fact, Hagfish slime is 1000 times more dilute than typical mammal mucus. Yet with a smattering of mucus and silk-like proteins, it can do things that ordinary mucus could not.

Hagfish slime is an example of just why biology is vital in the search for new, more sustainable industrial materials. Though its constituents appear relatively simple and few in number, its properties are more than the sum of its parts. In other words, natural evolution has created something more elegantly complex than humans could have thought

up on their own. Science continues to unpick the sticky intricacies of this future bio-textile.

Spider's web fibres

Spiders are the stuff of occult lore: silent weavers of the darkest crevices, spinning esoteric patterns in silvery thread. Now, their webs have become the stuff of modern biomanufacturing and the way they get made is nothing short of magic too.

Spider silk has become a raw material in cutting-edge low-carbon clothing textiles. It is easy to see why, given that it strikes that elusive balance between strength and flexibility. Made of protein, it is also biodegradable, unlike the fossil plastic fibres that make up most of the world's textiles.

Yet industry producers do not simply harvest its threads from unsuspecting arachnids. Japanese startup Spiber, a heavyweight in spider silk textiles, carefully grows synthetic spider silk inside custom-engineered, patented microbes. From there, the silk protein is extracted, purified and processed into fibres.

Spiber's so-called 'Brewed Protein' is chemically similar to the constituents of natural spider's silk in crucial ways. However, it is modified to better fit its end applications. For example, natural spider silk shrinks in water – not ideal for clothing.

To fix this, the company identified the amino acids associated with shrinkage and altered it to make a material more stable in water. Similar methods can be used to adjust the sensory properties of Brewed Protein. The end result may resemble cashmere, lamb's wool, or silk.

Evolution has been creating highly-adapted materials in a similar way over millions of years. Spiber is recreating some of this magic in the lab, using the tools of modern genetics to conjure up dreamily soft yet rigorously functional fibres without any exact analogue in nature.

The natural mysteries of the spider's web have not all been unravelled. There are probably thousands of natural proteins out there with special properties that could serve as the basis of other new materials. Spiber released its Spider Silkome Database in 2022 that lists all protein gene sequences that make up spider silk, enabling other developers to potentially construct and explore whole new webs of functional materials.

"The natural mysteries of the spider's web have not all been unravelled. There are probably thousands of natural proteins out there with special properties that could serve as the basis of other new materials."

Blackest black

What's the blackest black you've ever seen? Think the inkiest of nights, the dimmest of forests, the abyssal depths of a laptop screen that has run out of charge.

Chances are, you still haven't come close to seeing true black: nature contains few surfaces that absorb almost all light that hits it.

For most of modern history, the darkest of industrial dyes have come from fossil fuels. Coal is one of the few natural materials to give a solid and immersive black, the kind that envelops you like a winter's evening.

From the 17th century to the 20th, a whole dye industry grew up around the Bideford coal deposits found in North Devon, UK. The coal seams here yield a particularly rich dark mineral pigment. 'Bideford Black', as it is known, supplied the paints, paper, cement, textiles and cosmetics industries. Today, this naturally occurring black still sold to artists in the form of ink.

Outshining (out-darkening, even) Bideford Black are the 'super-black' synthetic coatings of modern times. The company Surrey NanoSystem sells one known as 'Vantablack', which for a long time claimed the world record for the darkest man-made substance. MIT researchers in 2019 came up with an even darker material they say is 10 times blacker than anything that came before.

Such intense blacks are only useful in high-spec applications, for example in aerospace and defence. Today, most of the black dye in consumer goods and textiles is the humbler Carbon Black, created by burning heavy oil or natural gas to create a sooty pigment.

Carbon Black is one of the most produced chemicals on the planet, favoured for its relatively cheap cost and its resistance to fading under UV exposure. Its presence inside so many commercial goods only adds to the environmental problems posed by plastics and other non-renewables.

Yet deep, durable blacks need not come from the murky depths of the oil industry. Biobased versions of black dye are now on the market, offering companies a way of honing their product aesthetic without relying on fossil chemicals.

US startup Nature Coatings has produced a wood waste-based black pigment meant to replace almost any instance of petroleum-based carbon black. Recently, it entered the cosmetics market where it is vying to replace Carbon Black and Black 2 – common in mascaras, eyeliners, and nail polish – with its own sustainable pigments.

Algae is another rapidly growing source of biobased black dye, underlining the prodigious versatility of this wonder-feedstock. Denver Colorado's Living Ink is one of the companies at the forefront of algal black dyes, working specifically with algal waste to achieve an even more sustainable manufacutring process. It has partnered with companies that want to remove petrochemicals from their product range, including Stella McCartney. The British designer featured Living Ink's Algae Black in their Spring 2024 Collection.

The xenobots are coming

With the rise of commercial AI, all eyes are now on the autonomous robots industry, which could be the next tech sector to blow up.

Amidst all the excitement, we forget that biotech may yet have a leading role in future robotics. The most sophisticated robots we may yet create might not be from plastic or metal but rather the stuff of life: cells.

In around 2020, scientists at the the University of Vermont, Tufts University, and the Wyss Institute for Biologically Inspired Engineering at Harvard University created autonomous organisms almost from scratch, assembling ordinary, unmodified stem cells from the African clawed frog Xenopus laevis on a petri dish.

The inert cells soon began to self-assemble, transforming into motile, life-like bots that could move around and perform very specific tasks. The researchers' aim had been to build tiny, organic robots to perform intricate tasks at the microscopic scale – collecting microplastics from the ocean, for example, or perform medical work inside the human body.

Half-organism, half-computer, this kind of entity is known as a xenobot: synthetic lifeforms built on biological hardware to perform pre-set activities.

In 2021, the researchers observed something surprising about their cellular creations: they were managing to self-replicate spontaneously. The researchers had initially nudged their xenobots to perform the simple task of collecting together tiny unattached cells and organising them into piles. Yet they found that these simple piles were eventually morphing into brand new, fully-functional xenobot replicas.

Xenobots move and replicate somewhat like a living creature but there are key differences between them and natural organisms – for example, they lack a brain or a digestive system. Arranged by humans but made entirely from natural cells, xenobots inhabit that dusky twilight zone between machine and organism, nature and artefact, life and death.

NOVEMBER 5, 2025

EU, French laws to boost circular fashion demand

European laws will boost circular demand by making sustainable production more competitive

For fashion companies today, industry competitiveness often means engaging in practices that impose damaging costs on people and the planet.

Things are set to change in the EU, however, where new regulations that favour circularity and sustainability are coming into force.

In October 2025, the EU passed a sweeping law that puts the costs of clothing waste on unsustainable producers.

France has been the fastest to implement these rules nationally, but other EU countries are poised to bring in similar legislation soon.

We explain Europe's anti-waste law, how France has chosen to go about implementing it in its national laws, and why these changes could boost biobased and circular businesses.

Europe takes action

Landfilling, eco-toxic chemicals, a rising carbon footprint, and endless consumption. The modern clothing industry imposes a huge burden on the planet.

To correct skewed industry incentives that fuel over-production and disposability, the EU is taking action. In early October 2025, a new law came into force that makes it more costly for producers to sell unsustainable clothing in European markets.

The law says all EU member states must establish producer responsibility schemes for textiles and footwear. In concrete terms, this means all EU countries will need to establish some system for ensuring clothing producers pay a fee according to the environmental impacts of their products.

> "The driving aim of the EU's new law is to shift responsibility for sustainably managing textile waste away from the consumer and towards the producer. This principle is known as Extended Producer Responsibility ("EPR")."

Product sustainability will be judged according to an eco-score ranking system. This score measures whether a product is repairable and recyclable as well as how its manufacturing impacts the environment.

Hence, the EU law aims to cut not just end-of-life waste but all kinds of sustainability impacts through the entire supply chain. Member states have 30 months after the law comes into force to establish such schemes.

The money collected from the sustainability tax will fund the collection, sorting, and preparation of used textiles for recycling or re-use.

Producer pays, not the consumer

The driving aim of the EU's new law is to shift responsibility for sustainably managing textile waste away from the consumer and towards the producer. This principle is known as Extended Producer Responsibility ("EPR").

Putting the costs of managing clothing waste on the industry rather than the consumer is something that experts have long recommended to clamp down on the immense environmental damage associated with fashion.

Under the law, companies with more sustainable products will be exempt from or face lower fees, giving firms a clear incentive to make more sustainable products and handing greener producers a better chance at competing on the market.
The law also actively supports the build-out of alternatives. The fee collected from producers will fund information campaigns educating consumers on sustainable textiles and footwear. It will also go towards product design R&D into greener manufacturing.

The laws should have far-reaching ripple effects through the supply chain. Producers selling on the European market will now reach for lower-carbon materials in order to keep their EPR taxes low. This means a wave of new demand for all kinds of biobased goods, from circular fibre to low-carbon dyes. It will also provide a boost for recycling firms that specialise in turning used textiles into new products.

France to tax fast fashion

France has been the quickest to embed the EU anti-waste law into national laws through its 'anti-fast fashion' bill.

Under the bill – formally known as the Proposition de loi visant à réduire l'impact environnemental de l'industrie textile, AN, N° 1557, 17e législature – every item sold by so-called "ultra-fast" fashion brands in France will incur a €5 tax (roughly US$5.80), increasing to €10 (roughly US$11.60) by 2030. The surcharge will be capped at 50% of the item's retail price to maintain affordability.

How much producers pay will depend on their products' eco-scores, which will be based on an existing calculation tool used for the voluntary environmental scoring of textile products.

The fines collected from ultra-fast fashion companies will be spent on supporting French sustainable fashion producers. The law is now being revised to comply with EU law and could be implemented early next year.

Fashion protectionism

In a country wracked with political fissures, the anti-fast fashion bill has attracted striking consensus: the new bill passed with just one vote against.

On closer inspection, France has just the right conditions in place for an anti-fast fashion backlash. Despite its reputation for crafted luxury, low-cost and mass-produced clothing has swamped the French market. Between 2010 and 2023, the value of advertised products in the fast fashion sector in France grew from 2.3 billion euros to 3.2 billion euros.

While this is a huge ecological problem, the popularity of the anti-fast fashion laws in France does not simply reflect a commitment to environmental clean-up. Economic and political factors also explain

> "Many companies in the business of clothes recycling are pointing out that they need more support from the EU if they are to build enough infrastructure required to reach circular policy goals."

why the country has stepped up in regulating the industry.

Fashion is a major contributor to GDP in France. This includes domestic high street brands as well as the renowned luxury fashion houses, which still sustains a relatively large artisanal workforce.

Lower-cost foreign competitors are a threat to this domestic industry. This is why the issue has been championed not just by the ecological left and the centre but by the French right-wing, which now dominates the Senate.

"Ultra-fast" fashion faces extra burden

When the right-leaning French Senate revised the anti-fast fashion bill this year, it made the law as much an instrument of market protectionism as an environmental regulation.

Under its current wording, some of the bill's rules would only apply to Chinese brands such as Shein or Temu but not French and European fast-fashion companies.

All clothing producers will be subject to product taxes based on their eco-scores. However, ultra-fast fashion platforms Shein and Temu will additionally face a ban on advertising, including the influencer-led advertising that drives so much of their revenue.

This two-tier application of the law results from a distinction in the bill between "classical" and "ultra-fast" fashion. What counts as "ultra-fast" producers remains imprecise but a final legal definition will likely set the bar so high that only Chinese companies with massive economies of scale will qualify. European fast fashion brands, which lag their Chinese rivals for sheer scale, will likely be exempt from some rules as they will fall short of this threshold.

Many see this as a way of protecting domestic producers from Chinese firms, including domestic French brands like Naf Naf, Kookaï, and Jennyfer or bigger European firms like H&M and Zara.

A boost for circular firms

Despite the selective nature of France's legislation, it is still a significant step that will provide a welcome boost for circular firms around the world.

Some of the startups to benefit will be close to home. For example, Reju is a French-owned textile recycling startup that recently

announced plans to build their first industrial-scale plants in France. The changing laws will also benefit US firms like Circ, which is building a commercial plant in France.

Yet many companies in the business of clothes recycling are pointing out that they need more support from the EU if they are to build enough infrastructure required to reach circular policy goals.

This is the message from the European Circular Textile Coalition established in response to the EU law. It is led by materials regeneration company Reju. It includes Resortecs, Coleo, Les Tissage de Charlieu, Synergies TLC, Nouvelles Fibres Textiles, Sympany, European Spinning Group, Ariadne Innovation, Erdotex, Utexbel, and Noyfil.

They argue that the EU must support companies like them, with the tech and know-how to carry out recycling and help the region get the most out of its discarded textiles.

The group wants government support for textile recyclers but also more overlooked parts of the circular fashion supply chain, like sorting and collection, or companies that specialise re-introducing recycled textiles back onto the market.

The EU is also being called on to address the impacts which its new law will have on developing countries, which play a huge role in upcycling, repairing, and re-selling discarded textiles originating from northern markets.

Non-profits representing secondhand textile markets on the African continent are calling for EU countries to send a portion of their producer fees to the countries responsible for sorting and re-selling unwanted textiles. This would be to fund better recycling infrastructure in these countries, acknowledging the continuing role that they will play until the EU builds domestic capacity.

The EU and France are leading the way in incentivising companies to produce more sustainably and more durably. The next part of the puzzle for Europe will be expanding regional recycling capacity so it can turn its growing supply of low-quality, used textiles into high-quality goods at industrial scale.

NOVEMBER 12, 2025

The sweet taste of circular treats

How food waste can satisfy our sweet tooth, sustainably

Circular cakes, desserts, and other confections are now on the table thanks to the rise of upcycling startups.

Food manufacturers can now reach for cocoa from cacao pulp, flour from brewer's spent grain, and sweeteners from fruit peel – all products made by waste ingredient specialists like Upcycled Food Inc, Agrain, and Fooditive Engine.

Ingredients like this could be the future of food, strengthening supply security, reducing environmental impacts, and offering decadence and nutrition in one.

Waste not, want not

Waste-based French chocolate maker Green Spot Technologies was in the news this week after raising €5M ($5.8M) for its range of fermented cooking ingredients.

The spotlight was firmly on its waste-based, chocolate-flavoured powders that replace cocoa in baking. With climate change driving volatility in cocoa harvests, many investors believe these circular swaps are the future of confectionery.

Brazil has its own version of waste-based chocolate thanks to Cellva Ingredients. In March, the company unveiled its CoffeeCoa "chocolate" ingredient made from coffee waste instead of cocoa beans.

It's not just chocolate, however, getting the waste treatment. Slowly but surely, a circular supply chain for flour and sweetener is building as commercial customers demand sustainable treats, at scale.

Guilty treats

Waste-based desserts sound like an unlikely sell – after all, is there anything less decadent than thrift? Yet food from cast-offs could become one of the most important food trends in coming decades.

Today, our cakes and desserts are stuffed with resource-intensive ingredients that contribute to deforestation, biodiversity loss, and climate change. Chocolate is among the most carbon-intensive foods in the world, while butter and milk come with the high greenhouse gas footprint associated with industrial livestock rearing.

Then, there's the problem of food waste. Around a third of all food produced in the world ends up being discarded each year. This amounts to around 8-10 percent of annual greenhouse gas emissions – nearly five times the total from aviation.

In a warming world where food security will dominate the economic agenda, the future of sweet treats is circular. This means confectionery, cakes, and desserts that require minimal land and resources – in other words, cooking with waste we already produce.

Consumers are already showing a growing appetite for upcycled food, with BCC research predicting the global market will grow at a CAGR of 5.6% to $74.8 billion by the end of 2029.

Beer to baked goods

The global economy produces around 1 billion tonnes of food waste annually and there is no shortage of ideas on how to transform these mountainous scraps into sweet indulgences.

Leading the way in building a waste-to-confectionary pipeline is Upcycled Foods Inc., whose products include upcycled flour (made from brewer's spent grain) and cocoa powder (from the usually-discarded pulp of cacao fruit).

Like many big names in the confectionary ingredients sector, Upcycled Foods Inc focuses sharply on business-to-business sales. The startup offers a one-stop-shop for commercial customers wanting custom circular ingredients to incorporate into their own products.

Satisfying industry demand for sustainable sweets starts with flour, a near-universal ingredient when it comes to baked goods, snacks, and desserts. Accordingly, Upcycled Food's flagship product is ReGrained SuperGrain, a flour made from spent grain – the main byproduct of the beer brewing industry.

Upcycled Foods Inc. often forges a link between health and circular sustainability: its "protein crisps" for example are sold as a healthier alternative to carbohydrate-heavy crunch mixes found in bars and cereals.

This emphasis on health and nutrients represents a wider tendency in the waste ingredients industry. By offering clients the ability to embed flavour and nutritional value into basic ingredients, upcyclers are trying to maximise markets: if demand for sustainable products lags, the health pitch remains.

In 2022, bakery ingredient specialist Puratos collaborated with the company to supply upcycled materials to commercial bakers. Another collaboration came in 2023, when Upcycled created a 'super grains' English muffin with Boston-based baked goods company Stone & Skillet.

Beer to flour, via AI

In Denmark, Agrain is another company offering circular flour from spent grain at commercial scale. After starting out in direct-to-consumer offerings, the company has now focused its strategy on business-to-business marketing instead, where wholesale orders and long-term contracts promise faster expansion.

Currently, the company produces three flour products for bread, cakes, pizza, pasta, and other starchy delights. Each offers a distinctive aroma and flavour profile, created by blending different types of spent grain.

Agrain, like other circular firms, must reckon with the unpredictability that comes with waste feedstock. Supply can be uneven, something Agrain solves by sourcing from multiple breweries so that there is a consistent flow of feedstock year-round.

The properties of the feedstock they source can vary too. The kinds of waste that upcycling companies have to work with can change dramatically over time and unevenness of stock is a given.

Spent grain is no exception. The material comes in different malt types with varying chemical properties: Agrain says its eight partner breweries supply more than 200 unique malt and grain types. This translates into different sensory properties, like aroma colour and taste, which is a problem if the consumer expects consistent food products.

Not being picky about feedstocks is a key competitive advantage in the circular baking ingredients sector: turning low-cost feedstock into high

quality foods that meet strict quality and safety standards is the whole purpose of the industry.

Agrain is managing the problem of uneven feedstock using an AI-assisted "blending algorithm" and by selling three types of flour products rather than a single one.

AI is a key part of its business model and production process because it allows the company to deal efficiently with natural differences in its spent grain feedstock. The algorithm helps formulate "recipes" to make Agrain's three flour products, given what spent grain is available at any time. It makes suggestions about which spent grain malt types to pair in which ratios to obtain the distinctive flavour profile of each of the three flour 'flavours' it sells.

Agrain has turned the unevenness of its waste feedstock into a branding opportunity: its three flavour-range offers customers choice while allowing the company to valorise a range of spent grain types. This shows how it is possible to find creative ways around the typical problems that come with working with food waste.

Molecular upcycling

Agrain shows how digital technology is central to managing costs in upcycling confectionary ingredients.

Biotechnologies like precision fermentation are also playing an important role in turning waste into new confectionary ingredients. Fooditive is perhaps the most biotech-heavy food upcycling company. The Dutch startup does not just sell a particular product line or work with a particular feedstock. Instead, what they offer is a service: the ability to custom-develop innovative sustainable ingredients.

> "Not being picky about feedstocks is a key competitive advantage in the circular baking ingredients sector: turning low-cost feedstock into high quality foods that meet strict quality and safety standards is the whole purpose of the industry."

Fooditive's ability to develop custom ingredients, including from waste feedstock, rests with its "Fooditive Engine", a platform that offers both precision fermentation and bioconversion to create new foodstuffs from unexpected sources.

The company's precision-fermented casein, for example, offers a key food industry ingredient without the greenhouse gas footprint of animal casein.

Fooditive's pitch is that their technology produces ingredients that are not just more sustainable but also healthier compared to conventional foodstuffs.

Its Fructosyl Oxidase enzyme modifies pear and apple waste in a way that turns them into a novel sweetener. Currently, the product is undergoing US FDA review. The company says its product is a healthier alternative to sugar in baking, chocolate, fruit fillings, and beverages.

Many products in the development pipeline at Fooditive are attempts to revamp problematic food industry staples. These include emulsifiers and preservatives, two broad families of food ingredients coming under increasing scrutiny for their health impacts.

The case for waste

Like many circular innovations, circular sweets solve several problems at once.

Upcycling discarded food prevents greenhouse gas emissions associated with food overproduction. It also strengthens supply chains, as valorising local waste can reduce the risks to food security posed by import disruptions and climate-driven harvest volatility.

There's the health case too: upcyclers are forced to develop basic ingredients from scratch, allowing nutrition to be built into food products from the start.

The world of circular baked and sweet goods also shows how sustainability doesn't have to be austere: with policy, logistics, innovation, experimentation, and marketing, decadent food with a smaller environmental footprint becomes possible. "Waste" is really a misnomer when it comes to upcycled sweets, given how so much of what we throw away can become mouth-watering confections.

NOVEMBER 19, 2025

MENA governments back circularity and biomanufacturing

MENA governments bank on circularity and biomanufacturing for growth

Governments in the Middle East and North Africa (MENA) are increasingly backing the biobased and circular industries through policy, roadmaps, and regulation.

In recent years, Morocco, Egypt, and Saudi Arabia have all mounted major initiatives to reduce plastic waste, build waste management infrastructure, and encourage investment into sustainable materials.

Beyond the employment and economic development benefits of these sectors, regional governments want circular and biobased supply chains to mitigate supply security and climate concerns.

The region has an arid climate and faces increasingly severe droughts under climate change. Getting the most out of local biomass and waste can make the economy as a whole more resilient, whether to trade shocks or volatile agricultural yields.

Morocco centralises waste management

In May 2025, Morocco's government announced it was going to pursue green procurement – making public spending decisions that support sustainability. The announcement fit with Morocco's widening emphasis on building a sustainable economy.

In April, Morocco had begun to prepare its National Circular Economy Roadmap, surveying existing circular practices within the domestic economy and comparing Morocco's sustainable industries against international benchmarks.

In August 2025, with the roadmap still in progress, the government mounted the National Household Waste Recovery Plan (2024-2025).

The plan's broad objective is to improve national household waste recovery and management, targeting 100% professional collection and cleaning rate for household waste.

The plan also aims to achieve a 10% waste recovery rate, where recovered waste gets converted into energy. In addition, there are plans to eliminate 60% of construction and demolition waste, a huge source of emissions.

To achieve these targets, the country will need to grow domestic capacity for processing waste. In support of this, the plan lays out targets for new waste infrastructure, promising to build 50 provincial waste disposal and recovery centres.

Updating and replacing national waste infrastructure is key to building circular economies from the ground up. A well-functioning public waste management system is crucial for circular firms, which need a large and reliable supply of feedstock.

Morocco has a diverse range of potential feedstocks aside from waste. Already in rural areas, the carob value chain is part of forest restoration projects. Elsewhere, interest is growing in gum, honey, and miswak, reflecting the diverse potential of biological resources across the region.

Egypt's landfill-to-energy strategy

Egypt has been formulating national policies to grow its bioeconomy and circular industries too. Again, the centrepiece of circular policy is waste – its collection, management, and treatment, and in particular, its conversion into energy.

A key piece of legislation stimulating circular economy buildout is the 2020 Law on Waste Management. The 2020 legislation has encouraged fresh private investment into circular services by establishing the Waste Management Regulatory Authority (WMRA), an entity that allows private investors to provide waste management services like collection, sorting, transport, and treatment.

In all, there are now around 36 private contracts spread throughout Egypt's recycling value chain, compared to two in 2018. The private contracts include waste-to-energy projects – a key plank in the government's push for circularity.

Waste-to-energy conversion is now in place at the Al-Salam and El-Hammam landfills, which turn the greenhouse gases emitted by these landfills into electricity. At Cairo's Abu Rawash's treatment plant, wastewater is being converted to agriculture and industrial products.

The government appears keen to expand waste-to-energy capacity. In June 2025, it approved feed-in tariffs (above-market rates) for electricity generated from biogas, where that biogas comes from sanitary landfills or sewage plants. The feed-in tariff should encourage private companies to set up more capacity in the sector. The tariff will be subject to review after three years or once total installed capacity reaches 80 megawatts – whichever comes first.

Plastic waste reduction is another major area of concern for Egypt. The country is by far the largest source of plastic waste that pollutes the Mediterranean Sea, accounting for 43% of the total, according to the WWF.

The government is currently involved in a project to reduce single-use plastic waste. The anti-plastic initiative, funded by the Japanese government, centres around producing sustainable alternatives to plastic material and building recycling capacity for waste.

"In all, there are now around 36 private contracts spread throughout Egypt's recycling value chain, compared to two in 2018. The private contracts include waste-to-energy projects – a key plank in the government's push for circularity."

The project also has regulatory objectives – a key consideration in building sustainable industries. So far, it has issued five new national standards for alternative plastic bags. Regulations like this are essential in reducing plastic waste. They are designed to give clear criteria for verifying whether alternative materials offer sustainability improvements compared to plastic. The project has also initiated a

survey of local labs to assess how much technical capacity the country has to analyse materials and confirm they meet sustainability standards.

In conjunction with Nile University, the project has embarked on a market study to assess raw material availability and industrial readiness for local production of plastic alternatives. The ultimate goal is to establish factories for plastic alternatives across the region, particularly in coastal and tourist areas.

In the realm of biomanufacturing, the Egyptian government launched its National Bio-based Economy Strategy in 2021 laying out how the country could use biological resources to produce energy, materials, and chemicals more sustainably.

In terms of biological feedstock, Egypt has plenty. The country produces around 30-35 million tonnes a year of agricultural wastes. Of this, only 4 million tones are being used as organic manure and 7 million as animal feed. This leaves circular producers with a huge pool of untapped local resources.

Another factor driving Egypt towards circular energy generation is the desire to remain competitive in Europe, a major export market for the country. New EU laws will impose carbon taxes on certain imports, pressuring seller countries like Egypt to decarbonise their industries in order to avoid these tariffs.

Saudi Arabia builds its non-oil economy

Saudi Arabia's oil wealth has made it the economic heavyweight in MENA. However, the country is now trying to diversify its sources of income by developing other economic sectors.

In January 2024, the Kingdom launched its National Biotechnology Strategy, a plan that focuses heavily on building medical biomanufacturing capacity in the country as well as crop optimisation for food self-sufficiency.

Food tech has benefited from the recent policy pivot towards biomanufacturing. US company Liberation Labs struck a deal with the kingdom's NEOM Investment Fund in 2025 to build a precision fermentation facility in the country, a move designed to reduce Saudi Arabia's high food import dependence.

The government's Vision 2030 programme is a blueprint for Saudi Arabia's transformation from an oil state into a more diversified economic player. The plan emphasises the need for the Saudi Kingdom to maximise its domestic resources – something that circular practices align well with.

Just as in Egypt, the focus of Saudi circular legislation so far has been on waste management.

Vision 2030 itself lays out national targets to divert 100% of solid waste, 60% of construction waste, and 60% of hazardous waste from landfilling. The Saudi Green Initiative, a government project to encourage sustainable development, is running an initiative to divert 94% of all municipal solid waste in Riyadh from landfill by 2035. It aims to do this via recycling, composting, waste-to-energy conversion, and other means.

New infrastructure is in the works to sustain these ambitions – 1, 329 new Saudi recycling and waste processing facilities are anticipated by 2035. The investment required for this is estimated to be around $22

billion and Saudi Arabia is actively trying to bring foreign investors on board. One of MWAN's tasks is to attack private investors interested in working with government agencies on the issue of waste management.

In 2019, Saudi Arabia established the National Centre for Waste Management (MWAN). The agency's role is to build a national system for dealing with waste sustainably. One area MWAN is trying to develop currently is the waste-to-energy sector, whereby greenhouse gas emissions from open disposal sites are turned into energy.

Ongoing urbanisation and population growth, coupled with poor recycling rates, explains Saudi Arabia's focus on waste management as opposed to upcycling and valorisation. Around 94% of Saudi waste still ends up in landfill because the country lacks sorting and collecting capacity – the basic infrastructure needed for more downstream circular industries to take hold.

Like in Egypt, Saudi Arabia is placing great emphasis on circular construction materials and waste. The Saudi Investment Recycling Company is currently completing its first recycling facility for construction and demolition waste in Riyadh, a facility that may one day also be able to recycle fertiliser, paper, plastics, and metals.

What is striking about circular and biobased policies across MENA is how governments are using them to serve wider development goals, such as bolstering food and resource security or attracting foreign investment.

Morocco, Egypt, and Saudi Arabia also show that circular policies offer practical solutions to the problems that accompany rapid economic development, such as the build-up of toxic waste around urban areas and industrial sites.

Going forwards, circular and biomanufacturing capacity will continue to expand in the region insofar as they serve national development agendas.

NOVEMBER 26, 2025

What's ZymoChem getting right?

Cost-cutting and product selectiveness have powered this biochemical startup to success

2025 has been a stellar year for ZymoChem. In February, the California-based biochemicals company announced a successful commercial-scale demo for its biodegradable super-absorbent polymer.

The following month came a partnership with Lululemon, arguably the world's best-known athleisure brand.

By the fourth quarter, it had been named startup of the year by the International Textile Manufacturers Federation.

We take stock of ZymoChem's achievements and the strategic factors driving its success.

Lululemon lends scale-up support

Moisture-wicking, fast-drying, light, and stretchy: plastic fibres combine properties that sportswear demands and which no other scaled materials deliver. Yet manufacturing them releases huge amounts of greenhouse gases, presenting an industry-wide problem: how to eliminate synthetics without compromising function.

The Lululemon-ZymoChem tie-up of March 2025 aims to find a way out of the impasse. Lululemon is looking to do this by helping ZymoChem scale its biobased adipic acid.

Adipic acid is a key ingredient in manufacturing nylon 6,6, a type of nylon popular among sportswear manufacturers for its durability. Making conventional adipic acid from petroleum releases a greenhouse gas called nitrous oxide. This is a gas that warms the planet far more quickly than carbon dioxide if released into the atmosphere.

ZymoChem's biobased adipic acid, meanwhile, has far lower 'global warming potential', meaning the amount of heat trapped by greenhouse gases from product manufacture.

With Lululemon's support, ZymoChem should be able to expand production for its biobased adipic acid. In turn, Lululemon will gain access to a steady supply of the biobased acid to work into its products.

This is not the first time that Lululemon and ZymoChem have crossed paths: the athleisure-wear brand invested in the startup's series A funding round in January 2024.

This most recent partnership promises to be a lucrative collaboration – Lululemon has reported that 30% of the material it uses in its products is nylon. Take-offs with global brands like these are often the surest route to kickstarting major expansion for biobased producers.

Picking the right products

The Lululemon tie-up also tells us a lot about ZymoChem's winning strategy: a combination of its laser focus on strategic markets and foundational problems within sustainable manufacturing.

The company has been highly selective about the products and markets it works in, targeting widely-used yet environmentally damaging chemicals where there are no viable scaled alternatives.

Few materials fit this profile better than nylon, a fossil-based plastic fibre that made up 5% of the global fibre market in 2023 (amounting to 6.7 million tonnes). Despite the high emissions associated with

manufacturing, nylon remains a widely used material due to its low cost and high performance.

Biobased alternatives will be an important way to ease this fossil reliance: recycled nylon makes up just 2% of the global market thanks to the high costs of collection, sorting and processing. ZymoChem is looking to fill the gap.

Fermented nappies

ZymoChem is now moving beyond the textiles market. In February 2025, the company made a major product announcement – it had reached commercial scale production for its biodegradable Super Absorbent Polymer (SAP), brand-name BAYSE.

SAPs are some of the hidden base chemicals of the modern economy – these substances can absorb thousands of times their weight in water, a function that makes them indispensable across sectors. Though mostly found in nappies and sanitary pads, they are also useful in certain construction and agriculture applications.

The company says it has achieved multi-metric tonne production levels with its precision fermented version. It also claims to have maintained the same productive efficiency it achieved at the lab level – an impressive feat given the difference in scale between lab and commercial production.

Yet even while striking out, the company is still sticking to its same product selection criteria.

Synthetic, fossil-based SAPs are in wide use but have huge negative side effects for both health and environment.

This is because most are made from petrochemical derivatives, making them emissions intensive. They also do not biodegrade safely, if at all, thanks to their chemical structure.

Finally, they are also a potential trigger for allergic reactions. SAPs are now facing increasing scrutiny from health experts, regulators, environmentalists, and industry want alternatives.

All this marks out a product with a lucrative market for sustainable replacements, just like with nylon precursors.

Precision fermentation on a shoestring

ZymoChem's big sell is its technical capabilities in precision fermentation. This is a manufacturing process where genetically programmed bacteria consume and metabolise ordinary inputs like plant matter and turn them into complex chemicals – in this case, highly absorbent biopolymer. No petroleum is needed.

Precision fermentation is why ZymoChem's products can claim minimal environmental impacts. However, sustainability can only ever be one part of the equation for a company intent on scaling.

The other factor has to be cost: few industry clients will buy materials based on their environmental credentials alone, particularly in a global business environment wracked by uncertainty.

Yet bringing down costs in the field of sustainable chemicals is no easy task. In our current economic setup, cost-effectiveness and

environmental soundness rarely, if ever, coincide. Fossil fuels and derivative chemicals have already achieved vast economies of scale, not to mention government subsidies and locked-in processing infrastructure.

The cost advantages enjoyed by legacy chemicals are especially clear in the case of synthetic precursors (like conventional adipic acid), which are already cheap to manufacture because they are usually the byproducts of petroleum refining.

This means that if biobased producers are to compete with fossil incumbents, they must be ruthless in managing operating costs. One route to lower-cost precision manufacturing is optimising strains. This means genetically programming workhorse microbes to ramp up their productivity, in other words, capable of producing more target chemicals using the same amount of inputs.

ZymoChem has been busy in its microbe optimisation, designing its organisms to conserve carbon where others would lose it into the air as waste. This, says the company, allows for 50 per cent higher yields compared to current best-in-class biomanufacturing.

Apart from fine-tuning the microbes, producing chemicals in larger facilities can bring down costs dramatically. So can managing electricity demand. Agitators, chillers, and air compressors suck up around 70% of total energy demand in precision fermentation facilities.

In all likelihood, ZymoChem will bring down costs further through a combination of tools: expanding into bigger facilities – something dependent on securing offtakes – making energy demand efficiencies, and tweaking the genetic code of their industrial microbes.

Government as angel investor

ZymoChem's 2025 achievements all build on a decade's worth of R&D, demos, and fundraising.

Industry observers could be forgiven for assuming that the seed financing round is where commercialisation begins. However, this is far from the case for biotech firms. The pre-seed is the time they must demonstrate a viable manufacturing process for investors. This demands lots of capital – a tall order for most early startups.

Seed funding often comes after years of graft and ZymoChem was no exception: its first investor round came late in 2021, 6 years after formally incorporating.

Luckily, ZymoChem in its earlier years had the backing of a major investor that counts among the most risk-tolerant in the world: the US Department of Energy. Unlike many private entities, government agencies have the luxury of time. Being under no pressure to make immediate returns on their investment, government backers have the resources and freedom to bring promising startups to maturity over a longer timespan.

The agency backed the company at almost every step. In 2015, just two years after it was founded, the startup received $250, 000 from the government body, as well as an additional $100, 000 from the US Department of Agriculture. In 2020, after a period of robust growth, the company received a $1.1 million grant from the Department and then another $4.2 million in 2021.

This funding was essential for ZymoChem in its early years before

private investment flows filled in for public funding, underlining the importance of policy in nurturing biobased winners.

Winning strategies

Of course, all the public funding in the world would be meaningless without a clear strategy. ZymoChem's has revolved around achieving cost competitiveness and specialising in just a few choice products.

What unites ZymoChem's products is that they are all biobased alternatives to popular synthetic substances used across multiple industries. Practically, this is a safer way for a biobased startup to maintain revenue through cyclical downturns. Their focus on foundational chemicals also makes them better placed to snap up the big brand deals that can build scaling momentum.

In addition to selecting products with the widest reach, a relentless focus on cost has characterised ZymoChem's strategy. This will only become more important as its biobased products make inroads into more fossil-dominated sectors.

Right now, few in the precision fermented space can match ZymoChem's laser focus on scaling and cost-cutting. This puts the company on a secure footing longer term. As the sustainable investment boom of the pandemic years recedes and economic uncertainty persists, cost will become an even bigger factor in how industry buyers and end-consumers weigh up products.

DECEMBER 3, 2025

EU centres competitiveness in new bioeconomy strategy

The EU wants biobased and circular scaleup to boost regional competitiveness

"The bioeconomy represents a strategic opportunity of the 21st century". So opens the EU's new bioeconomy strategy document, its first since 2022.

The new strategy document lays out how the EU will focus on scaling biobased technologies, targeting those with the greatest commercial potential.

We review how it promises to push the EU bioeconomy to its fullest potential.

Competitiveness wins out

The 2025 EU bioeconomy strategy distinguishes itself from its 2022 predecessor in its emphasis on competitiveness.

This reflects how the region is a very different place to where it was just three years ago. The region is struggling to compete with the US and China, which were able to invest in post-pandemic recovery in ways that the politically fragmented EU could not.

The 2022 Ukraine war led the EU to dramatically reduce dependence on Russian gas. However, the region is now more reliant on US liquefied natural gas as well as Chinese-made renewables.

The latest bioeconomy strategy speaks strongly to this context. At a time of economic uncertainty, the EU sees its biobased sector as the least environmentally damaging route to economic independence and supply stability.

Lead markets in focus

To maximise the economic benefits of the bioeconomy, the EU plans to funnel support towards a select group of biobased technologies. These will be products that a) offer the highest added-value and are b) ready to be sold or have achieved industrial maturity.

The strategy identifies the following biobased sectors as the most promising in terms of value-add and industrial maturity:

- Bioplastics, biopolymers, and biobased fibre packaging
- Biobased textiles
- Biobased chemicals
- Biobased construction products
- Biobased fertiliser and plant protection products

Barriers to scale-up

According to the strategy, the barriers to faster scaling of these sectors are exactly those preventing the region from competing more generally with China and the US.

These barriers are:

- regulatory burdens on business,
- insufficient funding for startups and scale-ups.

Here are the strategy's proposed solutions.

Tackling regulatory complexity

Unlike its economic competitors, the EU is a bloc of sovereign countries

with their own political systems and policy priorities. This fragmented policy landscape works against the kind of unified stimulus needed to get a region-wide bioeconomy off the ground.

The lack of coherent governance has been a recurring issue through the last several EU bioeconomy strategies. To unify bioeconomy policies across the bloc, the Commission says it is working with member states to align investment priorities. This is happening under the Important Projects of Common European Interest (IPCEI) framework, which aims to help states collaborate on large-scale projects that benefit the EU as a whole.

Fragmentation afflicts not just policy but also product regulations. As the strategy acknowledges, when national rules and interpretations of laws diverge from one another, it makes it more costly to do business – especially for small and medium-sized businesses.

The strategy's main solution is the EU Biotech Acts. These acts seek to simplify regulatory requirements and accelerate product authorisations, for example, with fast-tracked authorisation for microbial solutions in industry and streamlined permitting for biomanufacturing. The Commission also promises to better coordinate national and EU product approvals so that companies are able to hear final decisions more quickly.

Robust regulations also help drive up demand. Consumers are more likely to opt for biobased goods if there is a trusted, scientifically-grounded system for labelling environmental performance. Yet there is still a lack of EU-wide regulation on how to systematically evaluate sustainability. The current strategy says that efforts to rectify this are happening through the ongoing review of Product Environment Footprint methods.

Tackling the funding gap

Funding is still insufficient to scale the EU bioeconomy, according to the strategy, particularly for scaling biomanufacturing, advanced biobased materials, and circular bioeconomy infrastructure.

Lack of funding is a major reason why so many biobased companies fail. Most often, startups fold at two critical points in their journey: between prototyping and commercial production or just after the product hits the market. These treacherous points of the startup lifecycle are known as 'Valleys of Death'.

More funding for biomanufacturing infrastructure could reduce the failure rate. The strategy acknowledges the need for more pilot and demo plants where startups can test their manufacturing processes. Startups usually struggle to access these capital-intensive facilities, leading them to miss out on investment.

The EU has several measures planned to address this lack of funding and support. Most importantly, it proposes widening access to both early- and late-stage venture finance at both the EU and national level. It promises increased bioeconomy funding in the next Multiannual Financial Framework of 2028 to 2034 via the European Competitiveness Fund (ECF) and the Horizon Europe Framework Programme policy.

Until the next MFF, the plan is to develop a bioeconomy booster programme through the Circular Bio-Based Europe Joint Undertaking (CBE-JU) as well as improve access to finance and other services for

startups via the Scale-up Europe Fund and other European Innovation Council instruments.

Securing demand

Biomanufacturing facilities are capital-intensive. Often, they are also geared towards selling into relatively new markets. These factors mark out the sector as high-risk for private investors, who want to know there is secure market demand before parting with cash.

To boost private sector demand for biobased goods, the EU Commission proposes a pilot project known as Bioeconomy under the Competitiveness Coordination Tool (CCT). Under this project, it plans to establish a voluntary alliance of EU corporations known as "bio-based Europe Alliance" (BEA). The alliance will be designed to "ensure a reliable and predictable demand for biobased materials and products.

It estimates that the group will collectively buy biobased products worth €10 billion by 2030. This should convince investors to finance demo facilities for startups.

The strategy also acknowledges the public sector can be a large source of early demand for the bioeconomy. The Commission says it will support public buyers wishing to purchase biobased solutions, something that will be supported by the forthcoming revision of the Public Procurement Directive.

Better markets for circular feedstock

Circularity remains a major theme in the 2025 strategy as it was in previous bioeconomy documents. Biobased production based on waste feedstock maximises resource efficiency, in keeping with the EU's emphasis on resource self-sufficiency since the pandemic and Ukraine war.

"The strategy also acknowledges the public sector can be a large source of early demand for the bioeconomy. The Commission says it will support public buyers wishing to purchase biobased solutions, something that will be supported by the forthcoming revision of the Public Procurement Directive."

According to the strategy, one of the major barriers to growing circular production is that there is no single EU market for secondary biomass. Circular producers are instead having to purchase feedstock from fragmented suppliers, raising the costs of sustainable production.

The strategy says that the Circular Economy Act, scheduled for adoption by 2026, will help build a more efficient single market for waste. The Act will provide an EU-wide end-of-waste criteria, a checklist that determines when a material has been transformed from waste into a high-quality potential manufacturing input. The act also provides new intra-EU waste shipment rules that will make transactions between exporters and importers of waste easier.

Sustainability

Biomass is finite and even making renewable products can have negative environmental impacts if not properly managed.

To ensure the sustainability of the bioeconomy, previous EU strategies heavily promoted the cascading principle, a method of keeping biomass carbon locked away from the atmosphere and within products for as long as possible.

According to the principle, biomass should be used for the most resource efficient, highest-value applications possible – usually sustainable materials and chemicals. These should be recycled as many times as possible. Only then should biomass be burned for bioenergy or biofuels.

The 2025 strategy has shifted on this. Although it states that where feasible, biomass should be used for materials and chemicals, the language is now more favourable to turning biomass straight into fuel, especially waste biomass.

The strategy justifies this by stating that “biofuels will continue to play a role in the decarbonisation of the transport sector” and other applications where it is not feasible to switch to renewable electricity.

Now more than ever, the EU frames biofuels and bioenergy as one route to greater energy self-sufficiency. This re-centering of biofuels is consistent with a bigger EU policy shift. With regional industries still hurting from elevated energy prices, the EU’s reasoning is that it simply cannot afford to overlook a domestic source of power like biofuels.

EU policy is now dominated by the desire for resource self-sufficiency, particularly in energy. The new agenda is also re-shaping the region’s approach to the bioeconomy. Yet one key message has remained consistent: that circular and biobased manufacturing can support long-term economic resilience.

DECEMBER 10, 2025

China’s chemical giants invest in biomanufacturing

China’s bioeconomy moves from startup to scaleup

Major chemical companies in China are entering biomanufacturing, driving down the costs of sustainable materials.

We profile three Chinese companies that show how the country's bioeconomy is rapidly shifting from startups to scale-up.

A history of scale

China has mastered industrial scaling in key sectors over the last 40 years, led by the goal of becoming a globally competitive export economy.

In 2015, China's government shifted strategy, vowing to move away from the low-tech industry that dominated the country's economy. The new national policy was to master more sophisticated manufacturing processes in sectors like computing, renewables, advanced materials, and specialty chemicals.

Ten years on, its industrial policy has paid dividends. In 2022, the country represented 44% of global chemical production and 46% of capital investment, making it the biggest global player in the space. Specialty chemicals in particular have boomed.

The last 5 years have seen particularly intense expansion, with Chinese chemical production now so large it could meet a significant slice of global demand.

Chinese biochemicals are no exception to this growth trend. China already produces more of the bioplastic PLA than it can consume, with major producers like Kingfa still expanding. China is also the leading global producer and exporter of PBAT, which makes up 30% of the global biodegradable plastic produced in the world in 2021.

The Yangtze River Delta (YRD), with hubs like Shanghai, Jiangsu, Zhejiang, and Anhui, concentrates China's leading synthetic biology and biomanufacturing industries.

The Chinese biomanufacturing sector is also about to get a lot bigger. According to CEC Capital Group's projections, China's bio-manufacturing market is expected to reach 2 trillion yuan (279 billion U.S. dollars) by 2033, a 16.6.% compound annual growth rate.

A lot of this growth will come from major investments by existing chemical companies that have already achieved scale in petrochemicals. Having cut their teeth in the legacy chemicals sector, they are now transferring capital and know-how to renewable materials.

Kingfa

Kingfa is a typical Chinese biomanufacturing heavyweight. Founded in 1993, its niche has been in specialty materials: engineering plastics, carbon fibre, composite materials, hydrogen energy, and high performance resins, as well as polymers for medical applications. It also recycles plastics.

On top of synthetic chemicals, Kingfa is growing its biobased offering. It is already among the world's biggest bioplastic producers, making 274, 000 tonnes of biobased plastics in 2024.

At the start of 2025, it completed its 10, 000 tonne annual capacity bio-based 1,4-butanediol (succinic acid) plant in Liaoning province, China. The plant makes the chemical using a bio-fermentation process,

a departure from traditional methods that use petroleum-based ingredients.

As with the other Chinese green chemical giants, R&D is an important component of its work. In 2024 it signed a "Green Biomanufacturing Strategic Cooperation" with Beijing University of Chemical Technology in 2024, saying the partnership aims to reduce emissions through green manufacturing and by transforming the petrochemical industries.

Kingfa is now expanding to new markets to sustain its growth. This year, it began construction on its largest European facility to date in western Poland. The site in Poland will have productive capacity but also an R&D section to develop EU-compliant technologies in biodegradable materials and chemical recycling.

2025 was also the year that Kingfa broke ground on its new plant in Mexico. It already has a European facility in Wiesbaden, Germany. Its European and South American sites come in addition to a long-term presence in India.

Wanhua

Wanhua is one of the largest chemical producers in the world, known for its dominance in the Methylene diphenyl diisocyanate market. The chemical is a precursor for rigid polyurethane. It also develops and manufactures petrochemicals and performance chemicals.

Though most of Wanhua's revenue still derives from synthetic chemicals, the company is now investing in biochemicals and biomaterials – what the company calls 'emerging materials'. It set up a new biobased innovation R&D platform to develop these renewable alternatives.

In 2022, the company announced it had developed a bio-based thermoplastic polyurethane (TPU) product, building on its success in the fossil polyurethane supply chain. Its TPU has a biological content of up to 98%, with ingredients such as corn straw, and additives such as rice bran wax, as well as non-food corn and sesame.

TPU has applications in automotives, wires, cables, sports equipment, and in textile coatings, making it just the sort of multi-functional, multi-sectoral material that chemical producers target to maximise returns.

Wanhua Chemical also makes the biodegradable biomaterials PBAT, PLA, and PBS resin under the brand name Waneco. The range includes Waneco®T18 for agricultural mulch, designed to be buried after use, just like ordinary organic waste.

Wanhua's ten production sites are based mostly in China but also in Hungary and the Czech Republic. R&D sites also extend across China, as well as Spain and Hungary. These international expansions are key to company strategy. The Spanish site opens doors to researchers and markets in both Europe and North Africa. At the same time, Spain's cultural ties with South America marks a path towards another key growth market.

Sinopec

State-owned Sinopec has developed the most diverse range of biobased chemicals of the companies profiled here. Its product range extends from bioenergy (biojet fuel, biomethane) to biomaterials, including film for covering agricultural land and packaging materials

such as biobased polypropylene.

Sinopec's independently-developed PBST Biodegradable film targets microplastic pollution in farming. Plastic sheets used in agriculture are a huge source of pollution globally. China is the world's biggest user of the material and suffers most from the problem.

This year, Sinopec tested its PBST mulch plastic in a pilot test in Wusu, Xinjiang. It achieved a cotton yield equal to that of fields where traditional plastic mulch was used, suggesting no loss in performance between the fossil plastic and Sinopec's biobased material.

The company is active in bioenergy too. Germany's BASF recently signed an agreement to get biomethane from Sinopec subsidiary Sinopec Tianranqi Company for BASF's Nanjing chemical site. The partnership is designed to lower the carbon footprint of the products made there, ready for compliance with foreign markets.

Sinopec remains heavily embedded in the upstream of the fossil supply chain, being the largest oil and petrochemical products supplier in China. It is involved in petroleum and natural gas exploration and production. At the same time, it is investing in renewables, including in solar, wind, and biomass. It is aiming to become China's biggest hydrogen producer.

Beijing supports scale

The government has signalled it is about to ramp up support for scaling biomaterials and biochemicals. While traditionally China's biotech policy has focused on healthcare and genomics, policy emphasis on biomanufacturing and industrial green chemicals has been growing since 2022.

> "In 2023, China's largest investment holding company, the State Development and Investment Corporation (SDIC), was tasked to lead public investment into biomanufacturing."

In November 2025, Beijing announced it would build scaling infrastructure for biopharma, food additives, enzymes, and cosmetics. The government has not yet specified how many test facilities it will build as part of the programmes. It has however published a list of 43 companies it has selected to build the test facilities, with the largest share from the food additives industry, followed by biopharma and biomanufacturing.

In 2023, China's largest investment holding company, the State Development and Investment Corporation (SDIC), was tasked to lead public investment into biomanufacturing. The SDIC launched the

Biomanufacturing Innovation Academy in Tianjin in December 2024. The institution has RMB 6 billion ($848 million) to commercialise enzymes, amino acids, food additives, and functional sugars.

Scale is not the only distinguishing mark of the Chinese chemical industry. Increasingly, the country is challenging the US on innovation too. In 2023, China was the top country for most-cited papers in synthetic biology (61% of global share) and biological manufacturing (29 %). The country has poured an estimated minimum of CNY 20 billion (EUR 2.6 billion) into public research in that year alone.

Analysts expect the government will soon formally back the biomanufacturing sector as a major new source of economic growth. The country has already conquered EVs, batteries, and nuclear power, in some cases to the extent of saturating global markets. Now, Beijing wants to achieve the same clout in chemicals and biopharmaceuticals, sectors where Chinese companies are globally competitive but not yet dominant.

Competitive advantages

The Chinese companies now throwing their weight behind biomanufacturing share certain features.

All began in specialty synthetic chemicals, achieving market dominance in key industrial molecules. Although they maintain their presence in synthetics, they are rapidly diversifying into green chemicals as global demand grows.

As established industrial producers, they have the requisite capital and talent to develop, test, scale, and market new materials.

Further, their size gives them the ability to vertically integrate operations: many have in-house R&D units, including in renewable materials, and the facilities to pull their own innovations out from the lab and into the market. This self-sufficient structure cuts costs and helps keep product prices down.

An opportunity for the world

With Chinese biomanufacturers expanding production facilities abroad, other regions could now profit from their advances.

With the right tech transfer deals, countries where Chinese companies are expanding could ensure access to the latest production methods and manufacturing processes they are bringing.

Such deals could become an important way for the rest of the world to build their own manufacturing industries using Chinese IP for producing sustainable materials at scale.

DECEMBER 17, 2025

The Australian startups shaping the future of food

Australia's biomanufacturing potential starts with its foodtech startups

Australia has become an incubator for the world's most innovative foodtech startups.

Some are developing biochemicals for soil and livestock that cut emissions and waste. Others are fermenting animal-free proteins that move away from traditional farming altogether. All draw on synthetic biology for their IP.

We look at how their success leans on Australia's institutional excellence in biotech research, why they indicate broader potential for biomanufacturing growth in the country, and the bottlenecks to scaling these industries.

Food system innovations

Number 8 Bio is typical of a new generation of Australian biotech startups. Its product BetterFeed is an animal supplement that reduces methane emissions from livestock – one of the biggest drivers of climate change.

So far, cost-effective tech solutions have been elusive. This is despite livestock methane contributing 30% of global warming since pre-industrial times.

Number 8 Bio, however, claims its supplement has economics on its side. Unlike competing supplements, the company claims BetterFeed actually enhances herd productivity. "Our solution redirects energy, otherwise lost to methane, towards [animal] growth", says its website. The argument is that farmers will want to adopt the product to see these economic benefits, something that will drive uptake enough to meaningfully dent emissions.

Economics is a key consideration on the supply side too. The company outsources chemical manufacturing to large external producers to keep costs to a minimum. Number 8 profits by retaining the intellectual property on using the chemical in ruminants and the precise ingredient combination.

Tech meets policy

Number 8 Bio's climate-tech chimes with the times. Methane is a huge problem for the Australian agriculture industry, responsible for a little over 50 percent of the country's methane emissions.

Livestock emissions are a big hurdle standing in the way of Australia's climate pledge to reduce its emissions by 43% below 2005 levels by 2030. In its search for climate solutions, the government has been backing the methane-tech sector.

By 2025, it had invested $29 million into a competitive grants program designed to drive R&D in the field. Large-scale trials for promising technologies are currently underway, due for completion over the next two years.

Synbio specialist

Functional feed supplements are precisely the kind of specialised, high-value innovations that play to Australia's research strengths in synthetic biology.

Synthetic biology provides the foundational tech for making renewable molecules that can compete with synthetic chemicals on cost and performance. It is the basic science that underpins bioeconomy development. Australia ranks 7th and 12th globally for its share of

highly cited synbio publications and total publications in the field respectively.

Number 8 Bio's feed supplement is a direct product of this research ecosystem. Co-founders Dr Alex Carpenter and Dr Tom William were both synthetic biologists at Macquarie, the country's leading university in the field. William was previously the chief scientific officer at the institution's Austrian Genome Foundry and supervised Carpenter during his PhD.

Sustainable food tech

Methane-reducing supplements are the tip of the iceberg within Australia's foodtech sector, which is also gaining a reputation for alternative proteins.

The promise of alternative proteins lies in both sustainability and abundance: their aim is to manufacture nutritious food in labs rather than the soil, cutting the land use, emissions and biodiversity loss that accompanies intensive farming.

This is precisely what Australia's All G says it offers with its lactoferrin – a key baby formula ingredient. Making the substance is usually highly resource-intensive: it can take 10, 000 litres of cow milk to get 1 kg of the stuff. However, All G's industrial microbes can recreate lactoferrin in the lab without cows, saving on water, land, and emissions.

In its search for sustainable food systems, Australian startups have not forgotten traditional agriculture. At the other end of the food supply chain, Loam Bio is developing custom microbes that boost crop yields and health by improving soil. Startup ThinkBio is also in the business of making biobased products that allow farms to cut synthetic fertilisers while maintaining their crop yields.

Infrastructural bottlenecks

Despite the innovations coming out of startups, infrastructural gaps are hampering more rapid scale-up. As in the EU and North America, one of the biggest bottlenecks for Australian biomanufacturing is a lack of facilities to pilot and demo new products, let alone produce them at industrial scale.

Commercial fermenting facilities are capital-intensive pieces of infrastructure – not the kind that small, innovative startups are capable of founding on their own. All G had to look to Europe for protein manufacturing facilities, for example.

Another Australian company may become part of the solution. Cauldron builds biomanufacturing facilities and has already set up a fermentation demo plant in Orange, New South Wales. It is in the process of building a bio-fab in Mackay with support from the Queensland Government. In 2024, it received $4.3 million from a government Industry Growth Programme to build fully-automated fermentation tech.

Cauldron's expertise is also in demand internationally. In 2024, the US Department of Defense awarded the company $1.76M to plan a commercial-scale plant in the US. This indicates the potential for Australian companies to play a bigger role in building cross-border biobased supply chains across Western countries.

Regional governments get involved

While national biomanufacturing capacity still needs development, bioenergy is already an indelible part of the Australian economy at a regional level.

Australia's biomanufacturing industry is currently dominated by bioenergy, with New South Wales holding most capacity. The provincial government has even listed biofuels as one of their six key industries.

The scaling success that biofuels have seen in New South Wales holds lessons for the other biomanufacturing sectors. It points to the crucial need for local government policy if biobased chemicals and materials are to become a bigger share of the national economy.

Queensland already leads the way on biomanufacturing initiatives, with its Biofutures strategy and roadmap since 2016. This plan includes but is not limited to biofuels. It has so far supported biomanufacturing projects and businesses, while also completing the essential task of mapping biomass feedstock supply, sites, and infrastructural gaps.

Untapped sugar waste

Australia also holds great potential for circular biomanufacturing industries.

If the push to build circular manufacturing comes from any legacy sector in Australia, it will likely be the sugar manufacturers. Australia is among the leading global exporters of sugar, producing 30 million tonnes of sugarcane in 2023. Much of the country's domestic waste comes from the industry.

"The scaling success that biofuels have seen in New South Wales holds lessons for the other biomanufacturing sectors. It points to the crucial need for local government policy if biobased chemicals and materials are to become a bigger share of the national economy."

In 2022, the industry published a collective vision of transforming their waste into high-value products using synthetic biology tools. Biofuels, bioplastics, and alternative proteins were some of the end products the industry envisaged.

Harvesting and processing sugar yields large amounts of inedible byproducts, many of which can be processed into industrial chemicals

and materials. These products can often replace fossil-based chemicals in industry and consumer materials.

Australia's sugar waste-to-chemicals pipeline is gaining some momentum already. The MacKay biomanufacturing facility being built by Cauldron sits in the heart of Australia's sugar-growing territory. This co-location could spark a regional supply chain by reducing transport and input costs.

Applying synthetic biology to upcycle their own waste is an attractive revenue-earner for Australia sugar producers. Many are facing financial pressure from falling global sugar prices and natural disasters that have damaged crops. From this point of view, circular biomanufacturing has the potential to buffer Australian industry from external stressors like these.

Growing demand is key

To build large supply chains, research capabilities are not enough. Government policies are also needed to support young biobased startups and boost demand for their products.

The Australian government has established some policies favourable to scaling biomanufacturing. Biotech featured in the 2022/23 government List of Critical Technologies, including synbio and biological manufacturing. This recognition should drive more federal funding into the sector.

Yet there are also limits to current federal policy. The flagship industrial policy of the Australian government – Future Made in Australia – emphasises liquid biobased fuels but not higher-value products of the kind flourishing among domestic startups. Boosting demand for non-biofuel biochemicals thus remains the biggest task for federal policymakers.

The surest way to grow biobased demand would be to place biomanufacturing at the centre of national economic security policies. Incentivising consumers and industry to buy biobased products should sit in a broader drive to secure Australia's supplies of food, fertiliser, and medicine over the long term.

This national self-interest could prove the biggest and most reliable spur to biobased scale-up in coming years: methane-reducing additives, cost-effective proteins, and synthesised nutrients can all serve as pillars of food security on a resource-constrained planet.

Australia is particularly vulnerable to climate-driven resource insecurity, with the country's agriculture hit by acute heatwaves in recent years. An orderly, planned transition to biomanufactured supply chains could become one of its best chances of weathering the century of climate change.

DECEMBER 24, 2025

Why Thailand became Asia's rising biobased star

Policy and raw materials supply are propelling biobased growth in Thailand

Thailand's government has made bioeconomy growth a centrepiece of its development strategy since 2021.

With tax incentives for biobased investors, efficient costs, and abundant feedstock, the nation is emerging as Asia's rising biobased star in foodtech, industrial biotech, and beyond.

We look at why biomanufacturing has flourished in Thailand and the investments that have put the Southeast Asian nation on the map.

Investors pile in

Thailand is primed to become a precision fermentation food hub in Asia Pacific, according to research consultancy Hawkwood Biotech. The company ranked Thailand top-of-class in 5 out of 7 categories that make for biomanufacturing success, including labour, utility, and capital costs.

Companies have been quick to notice these advantages, including homegrown startups. Regene Bio, the first precision fermentation startup founded by Thai entrepreneurs, secured undisclosed financing earlier this year for its plant-based milk protein. Its microbe-manufactured compounds mimic cow's milk in taste and nutrition, the result of combining synbio with Thailand's abundant agricultural feedstock.

Thailand's Advanced Greenfarm is another domestic foodtech company. It is turning fast-growing pondweed – an uncommon foodtech feedstock – into nutritionally-rich powders and proteins. From its hydroponic farms in Nakhon Pathom, the company now supplies almost 200 shops around Thailand with its products.

Domestic companies may be on the rise but it is foreign (often Asian) investors that are helping Thailand build its industrial capacity. Singapore-registered Full Circle Biotech announced a 7000-tonne capacity factory for insect protein in Thailand earlier this year. Already, its entire future supply has been snapped up in offtake deals with Thai aquaculture farmers wanting a feed alternative.

The country is also making headway in industrial biotech capacity. German industrial giant BASF recently announced a new plant for APG – a biobased surfactant – in Thailand. Their only other AGPG plant in Asia is located in China.

Such a diverse range of investments only indicates one thing: Thailand ticks the right boxes for global competitiveness, from government policy to infrastructure, feedstock availability, and costs.

Boosted by policy

Policy has been the all-important factor explaining the build-out of high-value biobased capacity in Thailand over the last seven years.

The government's 2017 Bio-Circular-Green (BCG) Strategy is key to understanding the policy landscape in Thailand. It represented the government doubling down on historical efforts to stimulate biobased production, circular manufacturing, and green industry more generally.

Although biofuels were the target of government bioeconomy initiatives in the early 2000s, the policy focus now switched to more technologically sophisticated sectors such as biomaterials and, in particular, bioplastics.

The 2017 strategy has, on the whole, paid off. In the years that followed, Thailand grew its biobased supply chain considerably, particularly in bioplastics.

In 2019, the country became the world's second-largest producer of PLA (polylactic acid, the most common bioplastic). This was despite producing none of the material in 2016, a year before its policy statement on growing the bio-sector.

In 2021, Thailand reached 23.6% of the global production capacity for PBS (Polybutylene succinate, another common bioplastic). From 2019 to 2021, its bioplastic exports doubled, both in volume and value.

More bioplastics manufacturing is in the works for Thailand. Major US producer NatureWorks is currently constructing a 75, 000 tonnes annual capacity PLA plant in Nakhon Sawan province.

A bio-based development strategy

The vision of a vibrant bioeconomy in Thailand became more urgent in 2021 as the Covid pandemic rolled on. In that year, the Thai government made the biobased, circular, and green sectors central to its post-pandemic recovery strategy.

A national BCG working group was formed to oversee the whole process, from R&D to regulatory frameworks and creating new industrial sectors.

The 2021-2026 BCG strategic plan aimed to increase Thai GDP by THB 5 trillion. This target highlighted the main purpose of Thailand's biomanufacturing ambitions all along: to boost growth, employment, and lift itself out of middle-income status. In this, Thailand joins many other middle-income countries that are nurturing green growth to bolster their economies as a whole.

> "Thailand's bioeconomy strategy is echoed by its national industrial strategy, Thailand 4.0 policy advocates for bioeconomy development, identifying biofuels and biochemicals as Thailand's major growth engines."

Biomanufactured products hold so much promise for the Thai economy due to the dominance of agriculture, which makes up around 10.5% of the country's GDP. Biomanufacturing offers the opportunity to squeeze more revenue out of the raw materials that the country already makes, representing a natural path to growth.

Thailand's bioeconomy strategy is echoed by its national industrial strategy, Thailand 4.0 policy advocates for bioeconomy development,

identifying biofuels and biochemicals as Thailand's major growth engines.

Attracting high-value investors

Ensuring that biomanufacturing growth serve the country's development goals means attracting the right kind of foreign investment.

The Thai government currently offers tax exemptions on corporate income for up to eight years. To maximise the development value of these foreign biobased investments, the government links the size of tax breaks to the sophistication of the tech that companies are bringing to the table.

This is designed to attract the most advanced biobased sectors to Thailand, meaning those biobased processes and technologies that maximise value-add, GDP, and competitiveness.

To make the country as attractive as possible to these investors, companies willing to invest can also benefit from import duty exemption on machinery and raw materials needed in production.

With measures like these, the Thai government has tried to eliminate any possible barrier to advanced biomanufacturers setting up in the country.

Food giants rally around Thai startups

Major food corporations, both foreign and domestic, are also helping startups in Thailand thrive.

Space-F is an incubator set up by food suppliers NIA, Thai Union Group, Thai Verage, and Nestle. At the same time, Japan's Ajinomoto is offering a support programme for fermentation and alternative proteins in the country. These are all signs that global food players are keen to capitalise on Thailand's biomanufacturing advantages and tap into higher-value products.

Private sector involvement in the Thai bioeconomy was baked into the national strategy from the start. The 2017 BCG government strategy was launched in overt collaboration with industry: it began with a memorandum of understanding signed by major pirate corporations, research centres, and public institutions.

Feedstocks abound

Aside from tax breaks, Thailand's bioeconomy sector would not be where it is today without the immense store of raw materials from its agricultural industry.

The country is one of the world's top producers and exporters of sugarcane, cassava, and palm oil, amounting to 25, 21.5, and 12.2 million tonnes in annual production respectively.

When Dutch company Corbion invested in a bioplastics plant in eastern Thailand, it said that the country's excellent raw material sources were a major reason for setting up there. Bioethanol biorefineries cluster in the northeast of the country, where cultivation is concentrated.

Yet as climate change buffets these sectors, Thailand's industrial feedstock composition may have to change. Shifting from food-based feedstocks to the inedible wastes left behind from cultivation may

be the only way for Thailand to maintain its food supply while also reserving enough raw material for industry.

Regulatory progress

The Thai economy has all the components to grow its global position as a biomanufacturing producer.

Yet while Thailand has attracted a lot of investment into biotech R&D, there is still an imbalance between supply and demand-based policies.

The food approval process in the country remains stringent, slow, and precautionary – in other words, out of sync with the growing number of foodtech alternatives now available and the government's desire to encourage growth in value-adding sectors.

Despite its rising reputation as a novel protein tech hub, the country has not approved a single fermentation-derived product for sale in the country. It is still in the process of developing regulations for cultivated meat.

With no products approved for the domestic market, fermentation companies in Thailand will have to export to other countries where more mature foodtech markets are to be found.

This export focus means that Thailand will have to rapidly upgrade its workforce and regulations to bring supply chains up to international standards. Thailand is already a well-developed export economy yet upskilling its workforce will be vital if the country is to expand the synbio-rich sectors that the government is keen to cultivate.

The government has taken steps in the right direction here. In November 2025, it released $153 million for advanced industries like biotech, including training programmes to upskill workers. It is the first direct sum given to the biobased industry, as opposed to more indirect measures like tax incentives.

Despite these barriers, there is reason to believe Thailand's policy environment will only become more favourable. The bioeconomy enjoys solid political backing there, with successive Thai governments having shown commitment to using it as an engine of development.

Political will, combined with an immense local raw materials supply, means Thailand's rise as a biobased producer is in no danger of slowing.

JANUARY 1, 2026

The 2025 bioeconomy review

The year’s biggest trends in biobased innovation, regulation, & investment

2025 was a dynamic year for the biobased sector, with important developments across regulation, innovation, and investment.

Overall, scaling momentum continues to grow, particularly in Asia, while biotech investment also showed signs of recovery.

We review the biggest themes from the year, starting with innovation.

Innovation

New biopolymers

Biopolymer innovation was a major theme this year, with both brands and labs unveiling new renewable materials.

The LYCRA company announced its new corn-based fibre in April, a 70% renewables-based alternative to conventional Lycra. The company says it may reduce the carbon footprint of the material by up to 44 percent.

Another biopolymer launch came from Covation Biomaterials. Its bioPTMEG replaces an ingredient usually made from petroleum that goes into manufacturing spandex, polyurethanes, and thermoplastic elastomers.

Fashion was not the only target for new plant-based swaps. Planet Smart came out with its biobased super-absorbent polymer, meant to replace petroleum-based absorbers in menstrual pads and diapers.

Lab innovations were full of industry potential. Researchers at the Max Planck Institute reported on an enhanced bacterial strain that produces renewable materials more efficiently. The bacteria increased biomass production rate by 15-20% in the lab, the sort of bio-engineering that could support cost-effective biomanufacturing.

Recyclable bioplastics have been a major theme in research output this year. Purdue University researchers focused intensively on developing recyclable corn-based bioplastics made using enzymes. At Northeast Forestry University in China, researchers reported on a bamboo plastic that fully biodegrades in soil within 50 days. They also say the material can be recycled with 90 percent of its original strength maintained.

Fashion demands better

2025 saw an uptick in fashion brands reaching for renewable materials, particularly in categories like sports, where sustainable alternatives have been hard to develop.

Under Armour and UNLESS launched an entirely plant-based line of athletic apparel – a technical feat in a segment where fossil-based polymers dominate for their light-weight functionality.

Stella McCartney is now using Balena's new industrially compostable BioCir material in the soles of its S-Wave trainers. Soles are one of the most environmentally impactful elements of footwear, a problem that Fashion for Good is trying to tackle in its new R&D project on biobased polymers.

Meanwhile, Hugo Boss introduced its own recycled polyester yarn made from textile waste this year. The company is exploring licensing options that may eventually allow other companies to use the material as well.

In the lab, too, biomaterials for sportswear got mounting attention. Donghua University developed a biobased and PFAS-free waterproof

fabric. This is the holy grail of sustainable outdoor apparel design, which currently relies on harmful chemicals to make waterproof gear.

Still, high prices are inhibiting wider uptake of renewable materials in fashion. To mitigate the problem, Fashion for Good launched a pricing process this year that aims to keep novel textiles competitive with legacy materials – the Price Parity Toolkit.

According to this method, end-retailers and brands pay a fee upfront to fabric producers right at the start of the supply chain. This enables the fabric producer to sell to the next company at a lower price, meaning a less rapid mark-up as the material moves further down the supply chain.

Regulation & policy

Trump's overhaul

One policy story dominated in early 2025: the return of a Trump-led administration to the White House.

The administration quickly revoked Executive Order 14081 issued by the previous administration to advance the US bioeconomy. This meant far more uncertainty for US biomanufacturers this year than in 2024. Yet some US lawmakers pushed back, proposing new laws to sustain biomanufacturing growth.

Senators Amy Klobuchar (Democrat, Minnesota), and Jerry Moran (Republican, Kansas) introduced the Agricultural Biorefinery Innovation and Opportunity (Ag BIO) Act in March. It seeks to improve support for advanced biofuels, renewable chemicals, and biobased products, including competitive grants.

The National Biotechnology Initiative Act, introduced in April, could bring back some of the coordinating functions provided by the revoked Executive Order. It aims to bring biotech-relevant agencies and policies, covering every sector from agriculture to defence, under a single national strategy.

Other proposed laws aim to offer sustained support to US foodtech innovation. Senator Adam Schiff (Democrat, California) recently introduced a bill in the US Senate to directly fund research, manufacturing, and training in novel proteins.

Some policies from the new government have benefited certain bio-producers. In June, the Trump administration proposed to raise the amount of US biofuels that petroleum refiners must blend into the domestic fuel supply over the next few years.

A new EU bioeconomy strategy

The EU's Bio-based Industry Consortium responded to White House policy shifts by calling on US companies to move to Europe, a sign that biomanufacturing remains high on the agenda in the region.

Nonetheless, the role of the EU bioeconomy is changing. During the 2020s, climate and sustainable food production were key drivers of biobased policy. Now, with the EU's manufacturing sector facing high energy prices, US tariffs, and reduced demand from China, biomanufacturing is seen as a pathway to economic competitiveness.

The economic potential of biomanufacturing was at the fore in the EU's updated bioeconomy strategy released in November.

The strategy promised to harmonise regulations and tackle the funding

gap for biomanufacturing. It said it would also target support at high value-add, market-ready segments, such as bioplastics, biobased textiles, biochemicals, construction, and biobased plant products.

Foodtech matures

Foodtech funding was down almost 60% year-on-year. Yet as established players mature, the industry faces new challenges, such as securing regulatory approvals.

More companies than ever before are re-shaping the future of food production, forcing countries to catch up with their legislative processes. This is the case in the UK, whose small but growing insect bioconversion industry is finally getting serious regulatory attention.

In May, Innovate UK got £326,610 to develop new safety evaluation procedures for the UK insect industry. As elsewhere, the UK must develop systemic measures of risk, safety, and regulatory compliance of insect-derived feed, food, and oils before they can go on the market. This is especially where insects are fed on waste.

Other foodtech products already enjoy a much more certain regulatory environment. Early in the year, Onego Bio, Finnish-US food ingredient company, submitted a notification to the US Food and Drug Administration for its non-animal egg protein.

Biobased farming inputs continue to gain confidence from regulatory bodies. Biotalys got the go ahead from the US Environmental Protection Agency for its protein-based biofungicide in December. In June, ProGro BIO announced plans to seek EPA approval for biocontrol products that target crop pathogens and insects with all-natural ingredients.

"Positive indicators abounded this year. In the first quarter of 2025, there were some indications that the worst of the funding drought could be over when Net Zero Insights reported a surge in biomaterials investment during the period."

Investment

The pandemic 'sugar rush' in sustainable biotech investment came back down to earth with a bump in 2023. Ever since, industry players have been watching for signs of a rebound

Positive indicators abounded this year. In the first quarter of 2025, there were some indications that the worst of the funding drought could be over when Net Zero Insights reported a surge in biomaterials investment during the period.

Over the year, the iShares Biotech Exchange Traded Fund (ETF) jumped in share price nearly 29%. There was a 37% jump for the SPDR S&P Biotech ETF. Overall, funding activity in biotech finally exceeded 2019 levels after the post-pandemic slump.

Patterns of investment have changed from the pandemic peak, however. Fewer biotech companies were getting larger amounts of capital this year. This suggests investors are placing safer bets on more established companies with proven processes.

Western biotech funding may have bottomed out but the major growth prospects now lie in Asia Pacific. Here, juggernauts like China and India, as well as emerging players like Thailand and Vietnam, are building domestic biobased industries to lock in future growth.

Despite the disruptions of a trade war with the US, Chinese biotech deals in 2025 increased slightly to 2024, indicating the sector's resilience to external shocks. Other Asian governments are investing into biobased infrastructure in a bid to attract private investment.

In Asia, bioeconomy policies are embedded into national growth strategies. Indonesia, for example, is trying to strengthen national energy self-sufficiency by expanding its domestic biofuels production.

Thailand has tied biomanufacturing to its national development strategy for years, resulting in a stream of major capacity investments. Foreign investments into Thailand's biobased sector continued in 2025. BASF announced an expansion there in December while Braskem entered a joint venture for a bio-ethylene plant with SCG Chemicals in August.

Singapore is a hotbed of innovation in the biobased sectors, supported by government investment. The bioeconomy is set to see a significant portion of the new 5-year $37 billion package for research, innovation, and enterprise.

With major public investments, local raw materials, and competitive costs, Asia is shaping up to become the site of the next phase in biobased scaling.

TOGETHER, LET'S MAKE BIO THE NEW NORMAL

Our mission is to contribute to the global adoption of industrial biomanufacturing, and enable bio-based solutions to achieve price parity with fossil-derived incumbents.

Our focus is on connecting commercialized bio producers with customers, and improving the success rates of startups and scaleups.

We'll achieve our mission through continuing to embed ourselves within the sector, arrange targeted commercial meetings and curate world-class discussion and debate.

Thank you for joining us on our mission to make bio the new normal.

BIO INNOVATIONS APAC
4 - 5 MARCH 2026 | SINGAPORE

BIO INNOVATIONS EUROPE
10 - 11 JUNE 2026 | THE HAGUE, THE NETHERLANDS

BIO INNOVATIONS NORTH AMERICA
9 - 10 SEPTEMBER 2026 | OMAHA, USA

WORLD BIO MARKET INSIGHTS
NEWS & INSPIRATION FOR THE BIOECONOMY

WE WOULD LOVE TO HEAR FROM YOU

We love to talk to people and build happy and healthy relationships. Contact one of the team to explore how to get involved as we accelerate the transition towards a bio based economy.

PAUL MACDONALD
Co-Founder & MD
paul@worldbiomarkets.com

FELICITY MACDONALD
International Account Manager
felicity@worldbiomarkets.com

MAX FOWLER
International Account Executive
max@worldbiomarkets.com

ELLIS OWEN
International Account Manager
ellis@worldbiomarkets.com