Bio-Beauty:

The Future of Engineering Biology in UK Cosmetics

BBIA

COSMETICS CLUSTER UK

Contents

1. Executive Summary

The UK's Modern Industrial Strategy envisions the nation as one of the world's top three hubs for technology driven innovation by 2035, anchored by the ambition to create the UK's first trillion-dollar tech company.

Engineering Biology — the cornerstone of this new industrial era and one of the Industrial Strategy's 8 growth-driving sectors — drives the sustainable design and manufacture of fuels, chemicals, materials, food, and medicines. Globally valued at over £30 trillion by 2050, the bioeconomy represents a transformative opportunity for the UK. The government has already committed £2 billion over the next decade, including £380 million for research, development, and infrastructure to scale bio-based products.

The global beauty and personal care industry is undergoing a structural transformation, driven by rising consumer demand for sustainability, advances in biotechnology, and increasing regulatory and economic pressures. Valued at over £550 billion in 2023 and projected to approach £1 trillion by 2030, the sector presents a major growth opportunity—particularly for countries able to lead in innovation and sustainable production.

The UK is well positioned to capitalise on this shift. With a strong foundation in engineering biology, world-class research institutions, and an established cosmetics market, the UK has the potential to become a global leader in bio-based beauty. Domestic market growth, alongside increasing demand for "clean," ethical, and high-performance products, is accelerating the transition toward sustainable alternatives.

However, the environmental footprint of the cosmetics industry remains significant. Heavy reliance on fossil-derived ingredients, high carbon emissions, extensive water use, and persistent plastic waste highlight the urgent need for systemic change. Transitioning from fossil carbon to renewable, bio-based inputs offers a pathway to reduce emissions, improve resource efficiency, and build more resilient supply chains.

Engineering biology is central to this transformation. Technologies such as precision fermentation, enzymatic biosynthesis, and AI-driven molecular design enable the sustainable production of high-performance cosmetic ingredients. These innovations not only reduce environmental impact but also improve product consistency, functionality, and scalability, supporting a shift toward a more circular and regenerative industry model.

Despite this potential, several barriers are constraining progress in the UK. Bio-based alternatives often face higher costs compared to petrochemical incumbents, while limited domestic feedstock capacity reduces supply chain resilience. Most critically, regulatory complexity—particularly within UK REACH and related frameworks—creates significant delays, duplication, and cost burdens, disproportionately affecting innovative bio-based products (45% slower and twice as expensive). In practice, these barriers slow commercialisation, deter investment, and risk the UK falling behind global competitors.

At the same time, significant opportunities are emerging. Circular feedstocks, waste-derived inputs, and carbon capture technologies can reduce reliance on virgin resources. Advances in bio-based materials and packaging offer solutions to plastic pollution, while embedding Life Cycle Assessment (LCA) into product design enables sustainability to be engineered from the outset.

To unlock this opportunity, targeted regulatory reform is essential. Establishing a clear, proportionate, and innovation-friendly framework—supported by streamlined approval processes, sustainability-aligned incentives, and international harmonisation—would accelerate market adoption and investment.

To support this transition in 2024 the BBIA, in collaboration with the Cosmetics Cluster UK (CCUK), established the "Beauty and the Bioeconomy" Taskforce. This initiative focuses on three key areas: the development of sustainable ingredients to replace petrochemical inputs with biodegradable, plant-derived alternatives; the advancement of green biotechnology, including engineered biology and fermentation-based production; and the design of eco-friendly packaging solutions that minimise waste and promote recyclability or compostability.

Building on previous BBIA and CCUK, and BB-REG-NET research, there is a clear need for regulatory reform to unlock the full potential of the UK bio-based chemicals and materials sector.

To address this, five priority actions are recommended:

1. **Establish a UK Bio-Based Materials Regulatory Roadmap (2026–2030)**

Develop a coordinated, cross-sector framework with:

- Clear approval timelines and service-level agreements
- A single-window submission portal
- Alignment across Defra, DBT, DSIT, and relevant regulators

2. **Create a Green Innovation Pathway**

Introduce fast-track approval mechanisms for low-risk, sustainable bio-based materials - such as the AI-designed suncare actives from Twig Bio or the waste-derived oils from Clean Food Group - within UK REACH and OPSS frameworks, incorporating lifecycle and circularity considerations.

3. **Enable Data Equivalence and Read-Across**

Reduce duplication and cost by recognising comparable safety data across bio-based analogues - for example, by leveraging existing safety profiles for fermentation-derived sophorolipids like Holiferm's HoliSurf - and harmonising non-animal testing approaches across agencies.

4. **Integrate Sustainability into Regulatory Decision-Making**

Embed environmental metrics—such as carbon intensity, recyclability, and circularity—into regulatory assessments and procurement frameworks. Substantial climate benefits, such as the 90% reduction in greenhouse gas emissions achieved by microbial oil fermentation, should be weighted as key factors in preferential regulatory treatment.

5. **Strengthen International Alignment**

Enhance global competitiveness by aligning with OECD and WTO standards, harmonising definitions, and ensuring mutual recognition of data and testing approaches.

2. Economic and Environmental Potential for Engineering Biology in UK Cosmetics

2.1 Economic Potential

The global beauty and personal care market is a high-growth consumer sector, driven by rising disposable incomes, evolving beauty standards, increased digital engagement, and continuous innovation in product formulations. According to industry research, the market was valued at approximately USD 557.2 billion in 2023 and is projected to reach around USD 937.1 billion by 2030, representing a compound annual growth rate (CAGR) of about 7.7% over the period[1]. This expansion is fuelled by strong demand for skincare, clean beauty, and multifunctional products, alongside broader consumer trends toward health, wellness, and personalised beauty experiences. The growing influence of e-commerce and social media continues to play a central role in shaping purchasing behaviour and accelerating market growth.

In the United Kingdom, the beauty and personal care market reflects this global momentum, with sustained growth expected across multiple segments. The UK cosmetics and personal care market reached USD 14.3 billion in 2025 and is forecast to expand to USD 24.0 billion by 2034 at an estimated CAGR of around 5.75%[2]. Growth is being driven by increasing demand for natural and sustainable products, alongside the continued rise of digital retail channels. Broader estimates indicate that the UK beauty and wellness market—including services and professional sectors—is already worth tens of billions and is expected to continue expanding as consumer preferences shift toward science-backed and ethically positioned formulations[3].

The global bio-beauty segment is projected to grow at a CAGR of around 7–8% over the next decade[4], presenting a significant opportunity for early movers. The UK is particularly well positioned to capitalise on this growth due to its strong engineering biology ecosystem, including leading universities, biotech clusters, and advances in synthetic biology and sustainable biomaterials. By leveraging the Regulatory Innovation Office (RIO), the UK has the potential to establish streamlined, forward-looking regulatory frameworks for bio-beauty products, providing clarity and confidence for innovators and investors. Early leadership in this area would enable the UK to help shape global regulatory standards, accelerate product commercialisation, and maximise return on investment, while reinforcing its position as a hub for sustainable, science-driven beauty innovation.

The UK beauty and personal care sector is already one of Europe's most mature and high-value markets. In 2024, it was valued at over $13.4 billion and is projected to reach approximately $23.2 billion by 2033, growing at a CAGR of 6.24%[5]. Within this, the cosmetics segment is expected to reach $3.35 billion in 2026, up from $3.20 billion in 2025[6]. Taking a broader view, the UK beauty and wellness market was valued at $57.70 billion in 2025 and

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[1] Beauty and Personal Care Products Market Report, 2030
[2] IMARC Group, 2026
[3] IMARC Group, 2026
[4] Organic Personal Care Market Size & Share Report, 2030
[5] IMARC Group, 2026
[6] Mordor Intelligence, 2026

is forecast to expand to $73.56 billion by 2034[7], highlighting the scale and diversity of the wider ecosystem.

Consumer demand continues to shape both category dynamics and retail structures. Skincare remains the dominant segment, accounting for approximately 33% of total spending, driven by premiumisation, the growing use of active ingredients, and the adoption of multi-step routines influenced by Korean beauty trends[8,9]. Retail is evolving in parallel: specialist beauty retailers such as Boots, Superdrug, Space NK, and Sephora accounted for 37.40% of UK beauty retail sales in 2025[10], reflecting demand for curated product ranges and expert advice. Meanwhile, online sales are growing at a CAGR of 6.65%, supported by direct-to-consumer models, subscription services, and the increasing influence of digital content and social media[11].

Sustainability is becoming a defining factor in purchasing decisions. Around 30% of UK consumers are willing to pay up to 10% more for products with strong environmental or ethical credentials, accelerating demand for refillable packaging, clean formulations, and cruelty-free certification[12][13]. This aligns with wider global trends toward natural and organic ingredients, which are increasingly recognised as key drivers of market growth.

The UK remains one of Europe's largest and most dynamic beauty markets. According to industry estimates, the total market reached £10.3 billion in 2024, up +8.4% year-on-year, supported by strong demand for skincare, haircare, and more environmentally sustainable personal care products[14] Sector share by product category is shown in Table 1, with a relatively balanced distribution across core segments. Toiletries account for the largest share at 26.7%, reflecting steady demand in everyday categories such as bath and shower. Skincare follows closely at 26.2%, driven by premiumisation, active ingredient adoption, and continued K-beauty influence. Fragrance represents 21.1%, supported by strong luxury positioning, though it remains sensitive to fluctuations in travel retail. Haircare contributes 14.2%, with growth concentrated in premium products and increasing interest in scalp health. Colour cosmetics account for 11.8%, a segment strongly shaped by social media dynamics and influencer-led trends.

Table 1. 2024 sector share by product category

Category	Share	Notes
Toiletries	26.7%	Bath/shower segment; steady demand
Skincare	26.2%	Driven by premium, active ingredients, K-beauty trends, clinical hybrids
Fragrance	21.1%	Luxury positioning, travel retail sensitive
Haircare	14.2%	Growth in premium ranges, scalp-health products
Colour cosmetics	11.8%	Social media & influencer-led trends

[7] IMARC Group, 2026
[8] IMARC Group, 2026
[9] Mordor Intelligence, 2026
[10] Mordor Intelligence, 2026
[11] Mordor Intelligence, 2026
[12] Grand View Research, 2026
[13] Mintel, 2026
[14] https://www.statista.com/topics/5760/cosmetics-market-in-the-united-kingdom-uk

Figure 1 and Appendix Table 1 provide a deeper dive into SIC code 2042 'Manufacture of perfumes and toilet preparations' and shows that in 2024, 47.8% of UK total manufacturing activity in this sector is heavily concentrated in England. Across England, there are 755 businesses employing 12,485 people, generating a total turnover of approximately £1.13 billion. Average turnover per business stands at just under £1.5 million, indicating a sector that is substantial in scale but composed largely of small to medium-sized enterprises.

London accounts for the largest share of businesses within England, with 230 enterprises employing 1,169 people and generating £223.8 million in turnover. This equates to an average turnover per business of approximately £973,000 and turnover per employee of £191,412. While London has the highest concentration of firms, its turnover per business is below the England average, suggesting a higher prevalence of smaller operations.

Greater Manchester stands out for its high productivity and scale of output relative to the number of firms. With 30 businesses employing 559 people, the area generates £315.8 million in turnover. This results in an exceptionally high average turnover per business of approximately £10.5 million and turnover per employee of £564,970, significantly exceeding both London and national averages. This suggests the presence of larger or more capital-intensive operations within the region.

Scotland, with 45 businesses, generates £99.8 million in turnover, equating to an average turnover per business of approximately £2.2 million. Although employment data is suppressed, the turnover figures indicate relatively strong performance compared with many English local authorities.

At the local authority level, activity is more limited. Birmingham reports 10 businesses generating £3.8 million in turnover, while Bristol also has 10 businesses with £2.3 million in turnover. Bradford records five businesses with £2.0 million in turnover, and Cardiff has 10 businesses generating £1.03 million. In several other areas, including Liverpool, Leicester, Leeds, Northern Ireland and parts of Wales, data is suppressed or unavailable, likely for confidentiality reasons or due to very small numbers of businesses.

Overall, the manufacture of perfumes and toilet preparations in the UK is concentrated geographically, with England dominating in scale, London hosting the largest number of firms, and Greater Manchester demonstrating particularly high turnover and productivity levels.

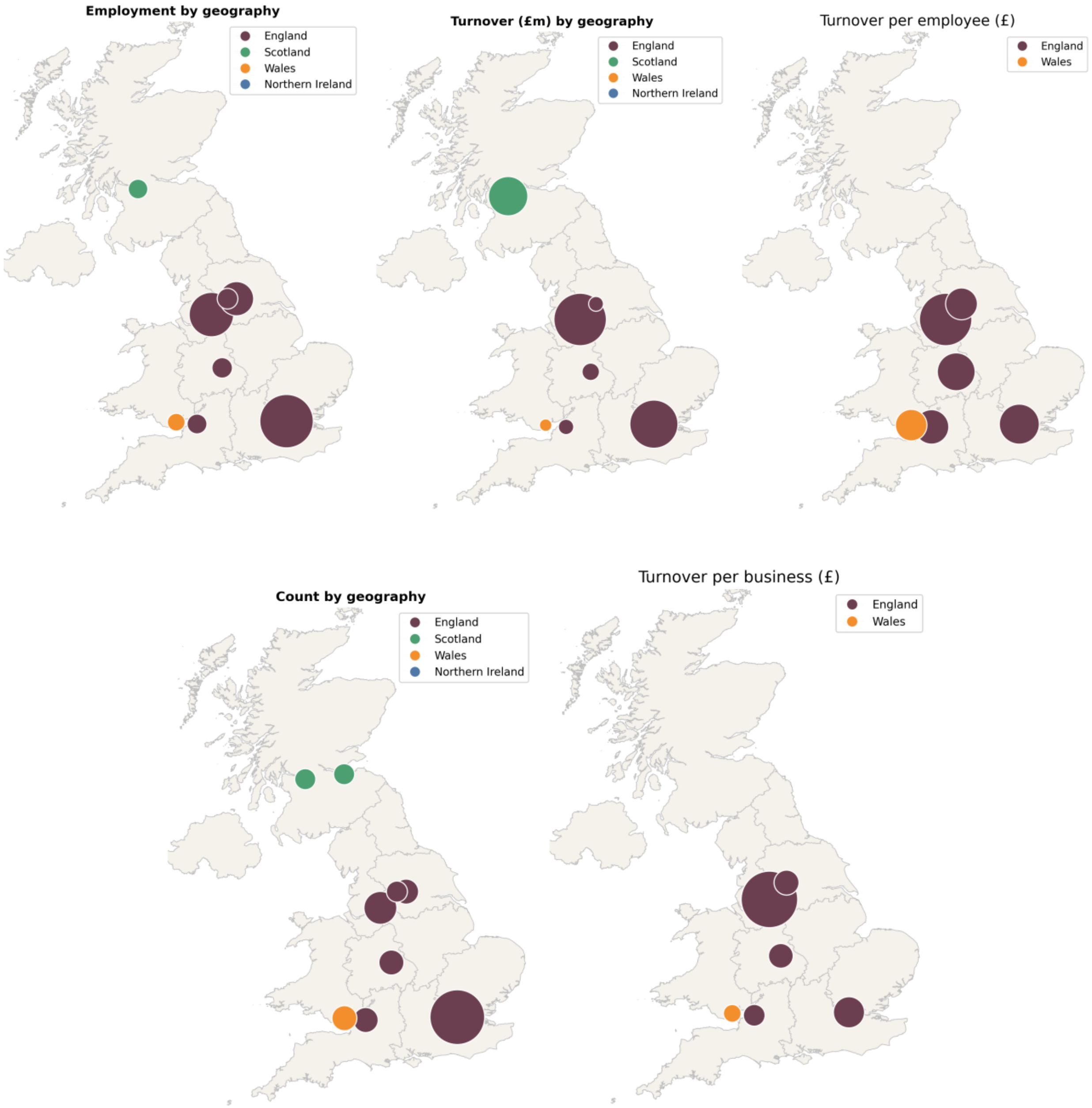

Figure 1. UK Analysis of SIC code 2042 'Manufacture of perfumes and toilet preparations'

The Standard Industrial Classification (SIC) codes currently used to define the sector are undergoing revision, as highlighted in Table 2 and recent industry commentary from the British Beauty Council. This development reflects a recognised limitation in how the industry is currently categorised and measured.

In particular, the existing SIC framework does not fully capture the breadth of economic activity within the sector. For example, it excludes a range of enabling services and upstream innovation companies, including biotechnology firms such as Twig and Holiferm, which are increasingly integral to the industry's value chain. As a result, current SIC-based analyses are likely to under-represent the true scale and scope of the UK industry.

Given these limitations, there is a strong case for either expanding the SIC code-based analysis to more accurately reflect the sector's full ecosystem, or at minimum explicitly acknowledging that SIC classifications are not currently fit for purpose. The ongoing revisions themselves underscore this issue and present an opportunity to improve how the industry is defined, measured, and understood in official statistics and policy frameworks.

KEY TAKEAWAYS

1. **Strong global growth trajectory**
   The global beauty and personal care market is expanding rapidly, projected to grow from around USD 557.2 billion in 2023 to USD 937.1 billion by 2030 (CAGR ~7.7%), driven by rising incomes, digital engagement, and innovation in product formulations.
2. **UK market mirrors global expansion but is structurally evolving**
   The UK beauty and personal care market is growing steadily, reaching USD 14.3 billion in 2025 with continued expansion expected across skincare, cosmetics, and wellness, supported by demand for natural, sustainable, and science-led products.
3. **Bio-beauty represents a high-growth frontier opportunity**
   The global bio-beauty segment is forecast to grow at ~7–8% CAGR, with the UK well positioned to lead due to its strong engineering biology ecosystem and potential to shape emerging regulatory frameworks via initiatives such as the Regulatory Innovation Office.
4. **Consumer demand is reshaping product and retail structures**
   Skincare dominates UK spending (33%), while retail is increasingly split between specialist stores (37.4% of sales) and fast-growing online channels (6.65% CAGR), reflecting the influence of digital engagement, social media, and personalised beauty trends.
5. **Current industrial classification underestimates sector scale and complexity**
   SIC code analysis shows geographic and productivity concentration (notably in England, London, and Greater Manchester) but fails to capture the full ecosystem—including biotech and enabling innovation firms—highlighting the need for updated classification to reflect the true size and structure of the industry.

2.2 Environmental Potential

The products we use every day to enhance our appearance are part of a global industry whose environmental impact is often overlooked. Yet the cosmetics sector is a significant contributor to climate change, emitting an estimated 50 million tonnes of CO_2 annually — comparable to the total emissions of a country such as Belgium[15]. A major driver of this impact is the industry's continued reliance on fossil carbon: around 87% of cosmetic

[15] https://gitnux.org/sustainability-in-the-cosmetics-industry-statistics

formulations contain petrochemical-derived ingredients, directly linking routine beauty consumption to the release of additional carbon into the atmosphere[16],[17].

This climate impact is only one dimension of a broader environmental footprint. The cosmetics industry produces billions of units of single-use plastic packaging each year, much of which is difficult to recycle due to mixed materials and small formats. It also consumes vast quantities of water, over 120 billion litres annually[18], both in manufacturing processes and across product lifecycles.

At the level of individual products, these impacts become more tangible. A single lipstick can generate around 5 kg of CO_2 over its lifecycle—roughly equivalent to driving 25 kilometres[19] —while a standard 360 mL shampoo bottle produces approximately 1.6 kg of CO_2, comparable to powering a 60-watt light bulb continuously for 12 days[20]. While these figures may appear modest in isolation, the scale of global consumption—billions of units produced and sold each year—means that the cumulative footprint of the cosmetics industry rivals that of major sectors such as European aviation.

At the same time, the industry is facing a convergence of economic and operational pressures. Companies are contending with rising input costs, volatility in petrochemical supply chains, and increasing regulatory scrutiny around ingredients, packaging, and environmental claims. Product consistency and batch quality are becoming harder to maintain as traditional supply chains are disrupted. Meanwhile, consumer expectations are shifting rapidly. There is growing demand for products that are not only high-performing but also demonstrably sustainable, ethically sourced, and aligned with broader environmental values. These pressures are not temporary—they signal a structural shift in how the sector must operate.

Addressing these challenges requires a fundamental rethink of raw material sourcing and production models. The issue is not carbon itself, but its origin. Today's system is heavily dependent on fossil carbon—carbon that has been locked underground for millions of years and is released into the atmosphere through industrial processes. A more sustainable alternative lies in transitioning to renewable carbon sources, such as biomass, captured carbon, or bio-based feedstocks, which operate within a shorter, more balanced carbon cycle. This shift represents a move away from an extractive, linear model toward a more regenerative and circular approach to production.

Such a transition also opens significant innovation opportunities. Advances in biotechnology, green chemistry, and engineering biology are enabling the development of novel ingredients that can replicate or outperform petrochemical equivalents while reducing environmental impact. These technologies can support more resilient supply chains, improve product performance, and enable new categories of sustainable beauty products that meet evolving consumer expectations.

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[16] Plastic Soup Foundation
[17] www.unep.org
[18] Plastic Pollution Coalition
[19] https://worldmetrics.org/sustainability-in-the-makeup-industry-statistics
[20] https://lifetips.alibaba.com/eco-cleaning/shampoo-powder-hot-new-trend-eco-friendly-hair-care

Ultimately, the environmental impact of the cosmetics industry is not just a sustainability challenge—it is an economic one. Markets, investors, and consumers are increasingly rewarding businesses that can demonstrate credible progress toward lower-carbon, resource-efficient models. Companies and countries that move early to decarbonise and redesign their value chains will be best positioned to capture this value. Conversely, failure to act risks locking the industry into outdated, high-carbon systems that are increasingly exposed to regulatory, financial, and reputational risks.

To fully realise the economic potential of the global beauty market, the industry must address its environmental footprint at its core. Transitioning away from fossil carbon, reducing waste and water use, and embedding sustainability into product design are no longer optional—they are essential conditions for long-term growth. By aligning environmental responsibility with innovation and market demand, the cosmetics sector can not only reduce its impact on the planet but also unlock new sources of competitive advantage and economic reward.

KEY TAKEAWAYS

1. **The cosmetics industry has a significant and often underestimated climate footprint**
   The sector emits an estimated ~50 million tonnes of CO_2 annually, comparable to a mid-sized country, largely driven by its reliance on fossil carbon-based ingredients used in around 87% of formulations.
2. **Environmental impacts extend beyond carbon emissions**
   The industry also generates large-scale plastic waste, consumes over 120 billion litres of water annually, and contributes to microplastic pollution through persistent synthetic polymers in formulations.
3. **Individual products have small footprints, but scale drives major impact**
   Everyday items such as lipstick (~5 kg CO_2 per unit lifecycle) and shampoo bottles (~1.6 kg CO_2) appear low impact individually, but billions of units sold globally result in a cumulative footprint comparable to major industrial sectors such as aviation.
4. **The industry is under growing structural pressure to change**
   Rising input costs, petrochemical volatility, tightening regulation, and shifting consumer expectations for sustainable, ethical products are collectively forcing a fundamental transformation in how cosmetics are formulated, sourced, and produced.
5. **Decarbonisation and bio-based innovation represent a strategic opportunity**
   Transitioning from fossil carbon to renewable carbon sources, enabled by biotechnology and engineering biology, offers a pathway to reduce environmental impact while unlocking innovation, resilience, and competitive advantage in a rapidly evolving global market.

3.1 Engineering Biology for the UK Cosmetics Sector

3.1 Introduction

Engineering Biology — the cornerstone of this new industrial era and one of the Industrial Strategy's 8 growth-driving sectors (IS-8)[21] — drives the sustainable design and manufacture of fuels, chemicals, materials, food, and medicines. Globally valued at over £30 trillion by 2050[22], the bioeconomy represents a transformative opportunity for the UK. The government has already committed £2 billion over the next decade, including £380 million for research, development, and infrastructure to scale bio-based products[23].

The transition from extractive to regenerative beauty is no longer aspirational — it is structural. As regulatory pressure intensifies, carbon accounting becomes mandatory, and consumers demand verifiable sustainability, the industry is being compelled to rethink not just what goes into products, but how those ingredients are designed at the molecular level.

Biotechnology, and in particular precision fermentation, offers a transformative pathway. Using microbial cell factories, precision fermentation enables the production of complex molecules such as peptides, proteins, antioxidants, emulsifiers, and moisturisers with high purity and consistency. This approach allows for the precise design and scalable manufacture of ingredients, delivering improved performance while significantly reducing environmental impact. It also enhances supply chain reliability by reducing dependence on volatile natural or petrochemical sources.

The benefits of this approach are substantial. Bio-based production enables the creation of identical molecules with higher purity from renewable sources, eliminates reliance on animal-derived inputs, and reduces both environmental and biodiversity impacts. It also ensures consistent quality and supports scalable manufacturing processes.

Bio-beauty sits at the centre of this transformation. By leveraging engineering biology, the sector is moving beyond the limitations of fossil-derived chemistry toward a new paradigm where performance, sustainability, and scalability are co-designed. Bio-based ingredients — derived from renewable biological systems — now span a diverse and increasingly sophisticated portfolio, from plant-based actives and algae-derived compounds to fermentation-enabled molecules such as peptides, biosurfactants, and hyaluronic acid. Advances in biodegradable polymers and bio-fabricated emulsifiers further demonstrate how biology can deliver both functional performance and environmental compatibility.

The case for switching from fossil-based to bio-based inputs is both urgent and compelling (Table 3). Traditional petrochemical supply chains are inherently carbon-intensive, finite, and increasingly exposed to geopolitical and price volatility. In contrast, bio-based systems offer renewable feedstocks, lower lifecycle emissions, improved biodegradability, and the potential for localized, resilient production. Crucially, they also

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[21] Industrial Strategy Sector Definitions List - GOV.UK
[22] TheGlobalBioeconomy
[23] assets.publishing.service.gov.uk/media/6892104df15b237bf6610996/industrial_strategy_digital_and_technologies_sector_plan_accessible.pdf

enable traceability and ethical sourcing — attributes that are rapidly becoming non-negotiable for consumers and regulators alike.

Table 3. Comparison of attributes of fermentation -derived and fossil derived cosmetic ingredients

Feature / Metric	Fermentation-Derived Ingredients	Conventional Fossil-based Ingredients
Feedstock Source	Renewable biological substrates (sugars, biomass, industrial byproducts)	Fossil-derived chemicals or petroleum-based precursors
Carbon Footprint	Low; production can be carbon-efficient with optimized bioprocesses	High; significant GHG emissions associated with petrochemical synthesis
Biodegradability	Often inherently biodegradable; reduced environmental persistence	Many synthetic compounds are slow to degrade
Purity & Consistency	High; controlled bioprocessing ensures batch-to-batch reproducibility	Variable; may require extensive purification to remove byproducts
Functional Complexity	Can produce complex biomolecules (peptides, proteins, polysaccharides) not easily made synthetically	Limited to simpler molecules; complex bioactives often unavailable or costly
Bioactivity	Enhanced; fermentation can produce more potent or bioavailable forms	Often inert or less biologically active
Supply Chain Resilience	Year-round, scalable production independent of seasons or geography	Dependent on petrochemical supply chains; vulnerable to price and geopolitical volatility
Customizability	High; synthetic biology enables tailored molecular design	Limited; molecular structures fixed by chemical synthesis
Formulation Multifunctionality	Possible; single molecules can combine moisturizing, emulsifying, and bioactive functions	Usually require multiple ingredients to achieve same effect

3.2 Key Market Drivers

A number of converging market, policy, and technology trends are accelerating the shift toward more sustainable and bio-based approaches in the cosmetics industry.

First, consumer demand for "clean beauty" is reshaping product development and brand positioning. Increasingly, consumers—particularly younger demographics such as Millennials and Gen Z—are prioritising products that are perceived as safe, transparent, and environmentally responsible. This includes preferences for ingredients that are sustainably sourced, traceable, cruelty-free, and not derived from animals. "Clean beauty" has evolved beyond the absence of perceived harmful chemicals to encompass broader ethical considerations, including supply chain transparency and environmental impact. According to Mintel[24], a significant proportion of UK consumers actively seek out products with ethical or sustainability credentials, while Grand View Research highlights growing global demand for natural and organic ingredients as a key market driver. Brands such as The Ordinary and Lush have successfully capitalised on this shift by emphasising ingredient transparency, vegan formulations, and minimal packaging, demonstrating how sustainability can directly translate into commercial success.

Second, corporate Net Zero and ESG commitments are placing increasing pressure on companies to decarbonise their value chains. Large beauty companies are setting ambitious targets to reduce Scope 1, 2, and 3 emissions, which includes everything from

[24] Mintel, 2026

manufacturing processes to raw material sourcing and product end-of-life. This is driving a transition toward low-carbon, bio-based ingredients and more sustainable packaging solutions. Certification schemes and reporting frameworks—such as those aligned with the Science Based Targets initiative and CDP—are increasingly used to demonstrate progress and maintain investor confidence. Major industry players, including L'Oréal and Unilever, have committed to significant emissions reductions and are investing heavily in sustainable chemistry and renewable feedstocks. These commitments are not only reputational but are becoming essential for access to capital, as ESG performance is increasingly integrated into investment decisions.

Third, UK policy is increasingly aligned with circular economy and bioeconomy objectives, creating a supportive environment for sustainable innovation. Government strategies are encouraging the transition toward renewable materials, reduced waste, and the adoption of industrial biotechnology. Initiatives linked to the UK's bioeconomy strategy and net zero targets promote the use of bio-based feedstocks and circular production models, while regulatory frameworks are gradually evolving to support innovation in sustainable chemicals and materials. Organisations such as Innovate UK and the Department for Energy Security and Net Zero are actively funding and supporting projects that aim to decarbonise manufacturing and scale bio-based solutions. This policy direction signals long-term government backing for a transition away from fossil-derived inputs, helping to de-risk investment in emerging technologies.

Finally, rapid technological advances are making sustainable alternatives increasingly viable at scale. Innovations in fermentation, microbial engineering, and enzymatic synthesis are enabling the production of high-performance ingredients from renewable sources.

Taken together, these drivers—consumer demand, corporate commitments, supportive policy, and technological innovation—are reinforcing one another. They point toward a structural transformation of the cosmetics industry, in which sustainability is no longer a niche concern but a central pillar of competitiveness and growth.

Market signals reinforce this shift. The global bio-based chemicals market, valued at over $136 billion in 2024, is projected to more than double by 2034[25], while the bio-based cosmetics segment alone is expected to nearly triple in the same period. This growth is not simply a substitution effect; it reflects a deeper reconfiguration of the industry. Beauty is no longer about replacing petrochemicals ingredient by ingredient — it is about re-engineering performance chemistry through biological design.

For the UK, this transition presents a strategic opportunity. With strong capabilities in synthetic biology, green chemistry, and advanced manufacturing, the UK is well-positioned to build a competitive, innovation-led bio-based cosmetics sector. By aligning scientific leadership with supportive policy frameworks and rising consumer demand, bio-beauty can become a cornerstone of a more resilient, sustainable, and future-facing industry.

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[25] https://www.thebrainyinsights.com/report/bio-based-chemicals-market-14817

3.3 Engineering Biology for Beauty: Technology & Innovation Trends

Engineering biology is transforming the cosmetics sector through the integration of synthetic biology, industrial biotechnology, and computationally driven design frameworks. This current wave of innovation is characterised not only by accelerating commercial adoption, but also by its foundation in a rapidly expanding body of peer-reviewed scientific literature. Advances in biological system design, metabolic engineering, and functional ingredient development are enabling a shift away from fossil-derived inputs toward biologically engineered, high-performance alternatives.

Key areas of transformation include fermentation, biosynthesis, sustainable materials, and personalised beauty—collectively redefining how cosmetic products are developed, manufactured, and delivered.

> *Engineering biology is enabling the design and manufacture of cosmetic ingredients through biologically engineered systems that are more precise, scalable, and environmentally efficient than traditional approaches. The convergence of fermentation, synthetic biology, AI-driven design, and materials science is reshaping both ingredient innovation and supply chains.*

3.3.1 Enzymatic Biosynthesis and Biocatalysis

A major technological trend is the application of enzymes as highly selective biocatalysts to drive chemical transformations under mild conditions. Enzymes such as lipases, esterases, and oxidoreductases enable regioselective and stereoselective reactions that reduce by-products and minimise energy inputs. These systems are increasingly used to synthesise antioxidants, emollients, UV-filters, and functional lipids for cosmetic formulations[26],[27]. Enzyme-based biocatalysis is widely recognised as a cornerstone of green chemistry and sustainable manufacturing[28],[29].

Recent advances in AI-driven enzyme engineering are accelerating discovery and optimisation. Machine learning models can predict enzyme structure–function relationships, enabling the rapid design of novel catalysts tailored to specific industrial processes[30],[31].

3.3.2 Precision Fermentation and Microbial Biosynthesis

Precision fermentation is emerging as a foundational production platform for cosmetic ingredients. This approach uses engineered microbial systems—yeast, bacteria, algae, and filamentous fungi—as programmable “cell factories” to biosynthesise complex molecules, including peptides, proteins, surfactants, lipids, and polysaccharides.

Through metabolic engineering and pathway optimisation, microbial strains can be designed to produce high-value ingredients with defined functionality, high purity, and

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[26] https://www.mdpi.com/2079-9284
[27] https://www.sciencedirect.com/science/article/pii/S1369703X21000815
[28] https://www.ncbi.nlm.nih.gov/pmc/
[29] https://www.nature.com/articles/s41578-021-00334-9
[30] https://arxiv.org/
[31] https://www.nature.com/articles/s42256-021-00392-8

reproducibility. This represents a significant shift from extraction-based supply chains to controlled, scalable biomanufacturing systems[32],[33].

Biosurfactants represent a key innovation frontier. These fermentation-derived molecules provide effective emulsification, foaming, and cleansing properties, while offering biodegradability and improved skin compatibility[34],[35].

They are increasingly replacing petrochemical and palm-derived surfactants in formulations. Fermentation-derived ingredients are increasingly valued not only for sustainability, but for enhanced biological functionality. Research demonstrates that fermentation can improve antioxidant capacity, antimicrobial activity, and skin-conditioning properties[36],[37].

For example, microbial and algal systems enable the production of bioactive lipids, carotenoids, omega fatty acids, UV-protective compounds. These systems require significantly less land and water than conventional agriculture and can be tuned to produce specific molecular profiles.

Precision fermentation also improves formulation performance. Functional attributes are engineered at the biosynthetic level, reducing batch variability, simplifying downstream processing, and enabling multifunctional ingredients.

Engineering biology is also enabling the production of bio-based solvents and chemical intermediates from renewable feedstocks such as agricultural residues. These solvents offer lower toxicity, improved biodegradability, and reduced lifecycle emissions compared to petrochemical alternatives.

3.3.4 Engineering Biology and Engineered Biofactories

Engineering biology enables the rational design and genetic programming of microorganisms to produce complex and high-value cosmetic ingredients that are otherwise difficult, costly, or unsustainable to source. This includes bioidentical versions of collagen, hyaluronic acid, antioxidants, and fragrance molecules, produced with enhanced purity, consistency, and supply chain resilience[38].

Beyond replication, synthetic biology enables the design of entirely new molecules with optimised functionality, stability, and bioactivity.

3.3.4 AI-Integrated Design–Build–Test–Learn Cycles

Artificial intelligence is increasingly central to engineering biology, enabling the integration of computational design into biological innovation workflows. AI is used to design metabolic pathways, optimise microbial strains, predict bioactive functionality and accelerate formulation development. These tools are compressing the design–

[32] https://www.mdpi.com/journal/biotechnology
[33] https://www.nature.com/articles/s41587-020-0714-5
[34] https://www.ncbi.nlm.nih.gov/
[35] https://www.sciencedirect.com/science/article/pii/S0141813020333443
[36] https://www.ncbi.nlm.nih.gov/
[37] https://www.frontiersin.org/articles/10.3389/fbioe.2021.743230
[38] https://www.cosmeticsdesign-europe.com/; https://www.nature.com/articles/s41467-019-10047-w

build–test–learn cycle, reducing development timelines from years to months and significantly lowering R&D costs[39].

3.3.5 Bio-Based Polymers and Sustainable Materials

Biopolymers derived from renewable feedstocks—including cellulose, starch, PHAs, and mycelium—are enabling new classes of functional materials for cosmetics[40], [41]. These materials are being applied in emulsification and rheology control, film-forming polymers, encapsulation systems, sustainable packaging.

3.3.6 Personalised Skincare and Microbiome-Targeted Bioactives

A major frontier is personalised skincare, enabled by advances in microbiome science, biomarker analysis, and AI diagnostics. The skin microbiome plays a critical role in barrier function, inflammation, and ageing, and can be modulated using bioengineered actives such as prebiotics, postbiotics, and peptides[42],[43]. This enables a shift from mass-market formulations to precision skincare tailored to individual biological conditions.

KEY TAKEAWAYS

1. **Engineering biology is a major growth engine**
   It underpins a £30 trillion global bioeconomy by 2050 and is a UK IS-8 priority sector, supported by significant public investment.
2. **The shift to regenerative beauty is now structural**
   Regulation, carbon accounting, and consumer demand are forcing a move from fossil-based ingredients to bio-based, renewable carbon systems.
3. **Precision fermentation is a core enabling technology**
   It produces high-performance cosmetic ingredients with greater purity, consistency, and lower environmental impact than petrochemical processes.
4. **Bio-based systems offer clear performance and sustainability advantages**
   They use renewable feedstocks, reduce emissions and waste, improve biodegradability, and enable new multifunctional molecules.
5. **Converging technologies are accelerating transformation**
   AI, synthetic biology, biopolymers, and microbiome science are enabling faster R&D and more personalised, sustainable beauty products.

4. Engineering Biology in Action in the UK Cosmetics Industry

The case studies below highlight how biotechnology is reshaping the chemicals and materials landscape, using biology as a manufacturing platform rather than fossil resources. Across diverse approaches - from precision fermentation and microbial engineering to waste valorisation and biorefining - these examples demonstrate that biotech is not a future concept but a rapidly scaling reality, enabling the transition to circular, sustainable production systems for the next generation of chemicals and materials.

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[39] https://www.ncbi.nlm.nih.gov/pmc/;
[40] https://www.nature.com/articles/s41587-023-01775-4
[41] https://www.nature.com/articles/s41467-020-20646-8
[42] https://www.ncbi.nlm.nih.gov/pmc/
[43] https://www.nature.com/articles/s41564-020-00856-y

From wool to biotech

A vegan, human-identical keratin enabling brands to access the bond-building market at scale

Challenge

Traditional keratin is extracted from sheep's wool but it is not hair-identical, limiting its bonding efficacy and "biomimetic" performance story.

Solution

KeraBio™ K31: The first ingredient supplier solution for biomimetic hair repair. Engineered via fermentation to be 100% hair-identical, offering a scalable, vegan alternative to niche retail technologies.

Benefits

- Identical to human hair keratin to form durable peptide bonds and recharge keratin.
- Performance at unprecedently low dosage (vs. wool-based keratin). Lower inclusion levels mean significantly less raw materials required per formulation.
- 100% stronger hair vs. benchmarks; performance is consumer and stylist-validated.
- A vegan suitable pathway to keratin, supporting the growing demand for high-performance protein sources independent or animal agriculture.

After 10 applications of a regime containing 0.05% active total KeraBio K31

CRODA | Beauty

SMART SCIENCE TO IMPROVE LIVES™

Fats from foodwaste

Microbial Oils for Low-Carbon Ingredients

Challenge

Conventional oils often derived from petrochemicals and agriculture with high land use & emissions.

Solution

Microbial fermentation using engineered microorganisms uses food industry by-products as feedstocks to produce cosemtic grade oils and fats.

Benefits

- Up to ~90% reduction in greenhouse gas emissions
- Reduced land use and fertilisers
- Supports circular economy and food waste reduction
- Sustainable alternative – replaces palm oils, reducing environmental impact
- High performance – matches emollient properties of traditional oils
- Better skin feel – rich texture without greasy residue
- Consistent quality – uniform performance via fermentation
- Traceable sourcing – transparent, controlled production
- Planet-positive – supports sustainable beauty without compromise

CLEAN FOOD GROUP

Healthy longevity from oilseed

Significant bioactivity supports cell health

Challenge

Single synthetic molecule cosmetic actives are expensive and lack the synergistic efficacy of complex natural ingredients.

Solution

Biotechnological processing of abundant and low-cost agri-food by-products generates sustainable and high-efficacy active ingredients also generating multiple side-streams for other uses.

Benefits

- Upcycles agricultural waste into value – transforms low-value by-products like rapeseed meal into high-value ingredients, supporting a circular economy
- Sustainable & low-impact sourcing – uses abundant agri-food side-streams, reducing resource use and environmental footprint
- High-performance bioactive ingredients – peptides deliver functional benefits across nutrition, cosmetics, and healthcare applications
- Significant & dose-dependent bioactivity in cell viability, reducing inflammation and mitochondrial function
- Versatile, cross-sector applications – suitable for food, personal care, and medical markets, enabling broad commercial use

valogen

Biosurfactants from Bugs

Fermentation using natural yeasts and renewable feedstocks

Challenge

Many conventional surfactants derived from petrochemicals or palm oil. Growing demand for mild, microbiome-friendly cosmetic ingredients.

Solution

Fermentation using natural yeasts and renewable feedstocks produces sophorolipid biosurfactants.

Benefits

- Sustainable & bio-based – produced via fermentation from renewable or waste feedstocks, reducing reliance on petrochemicals
- Biodegradable with low environmental impact – break down naturally and can deliver significantly lower CO_2 emissions than conventional surfactants
- High performance, like-for-like replacement – match or outperform petrochemical surfactants in cleaning, foaming, and emulsification
- Mild and non-toxic – gentle on skin and suitable for sensitive applications like personal care and pet products
- Multifunctional ingredients – provide cleansing, solubilisation, conditioning benefits in one molecule
- Scalable and cost-competitive – innovative fermentation processes enable production at commercial scale and competitive pricing

holiferm

Waste to high value chemicals

Transforming industrial effluent into low-carbon, high-purity feedstocks for pharmaceuticals, cosmetics, and advanced materials

Challenge

Industrial waste streams like distillery effluent are high-volume and hard to treat, while chemical production still relies on carbon-intensive petrochemical feedstocks. As a result, valuable molecules are usually lost rather than recovered, despite rising pressure to decarbonise and build more resilient supply chains.

Solution

Ripcell addresses this by using a circular bioprocessing platform that upcycles industrial waste streams into high-purity platform chemicals, such as bio-lactic and bio-acetic acid, which can be used across sectors including pharmaceuticals, cosmetics, food, and battery recycling. This creates a domestic, low-carbon supply of critical chemicals by transforming waste into valuable inputs rather than relying on fossil-derived production

Benefits

- Carbon reduction – delivers significantly lower-carbon (and potentially carbon-negative) chemical production pathways
- Circular economy impact – turns industrial waste into high-value inputs rather than disposal burdens
- Supply chain resilience – reduces reliance on imported petrochemical intermediates
- High recovery efficiency – enables >98% recovery of critical metals in battery recycling applications
- Industrial integration – can be deployed alongside existing sectors like distilleries and manufacturing plants
- Cross-sector value creation – produces inputs for pharma, cosmetics, food, solvents, and advanced materials

RIPCELL

Photosynthetic Manufacturing

Converting CO2 into carbon-neutral, cost-competitive hyaluronic acid

Challenge

'Green' chemicals are frequently more expensive and/or less efficacious than the chemicals they seek to replace.

Solution

Engineered cyanobacteria, powered by light, using industrial CO2 as the feedstock to produce premium quality hyaluronic acid and other cosmetics ingredients.

Benefits

- CO_2-to-value conversion – Engineered cyanobacteria turn CO_2 directly into valuable chemicals, treating emissions as a feedstock.
- Ocean-derived biology platform – Uses marine cyanobacteria, harnessing naturally efficient ocean photosynthetic systems.
- Low environmental footprint – Photosynthesis-based production enables low- or potentially carbon-negative manufacturing.
- No sugar feedstocks – Runs on sunlight, CO_2 and water, avoiding agricultural inputs like sugar or starch.
- High-performance ingredients – Produces biotech ingredients (e.g. hyaluronic acid) with equivalent or improved functionality vs conventional routes.
- Scalable modular system – Photobioreactor units can be expanded incrementally, supporting flexible scale-up.

deep blue BIOTECH

Packaging made by microbes

Circular Biomaterials for Sustainable Packaging

Challenge

Beauty packaging heavily reliant on fossil-based plastics, that take hundreds of years to degrade.

Solution

Microbial fermentation converts waste biomass into polymer precursors, and then into biodegradable packaging.

Benefits

- Plastic-free, bio-based material – made from renewable feedstocks via fermentation, with no fossil polymers
- Fully compostable – breaks down at home without leaving microplastics or toxic residue
- Safe for people – free from harmful chemicals like BPA, PFAS, and phthalates
- High performance – matches conventional plastic in durability, barrier properties, and shelf life
- Manufacturing ready – compatible with existing plastic production processes and formats
- Circular by design – designed to return safely to nature, solving hard-to-recycle packaging challenge

SHELLWORKS

AI-Powered Ingredients

Accelerating Sustainable Ingredients with AI-Driven Biomanufacturing

Challenge

Many everyday ingredients used in consumer goods—such as cosmetics and industrial chemicals—are derived from fossil fuels, intensive agriculture, or animal sources, creating significant environmental impact and supply chain constraints. Traditional bioengineering approaches are often slow, costly, and unreliable, meaning most promising microbial designs never reach commercial scale.

Solution

twig combines AI, machine learning, and high-throughput automation to design and optimise microbes that can produce sustainable ingredients via precision fermentation. Its proprietary platform (bio:drive and grow:bot) rapidly explores millions of microbial designs, identifies top-performing strains, and delivers production-ready solutions for scalable manufacturing.

Benefits

- Sustainable alternatives to petrochemical and animal-derived ingredients, reducing environmental impact
- Faster R&D cycles, cutting development timelines from weeks to minutes or rapid iteration cycles
- Higher success rates, using data-driven design instead of trial-and-error experimentation
- Cost-competitive production, enabling bio-based ingredients to compete with incumbents
- Scalable, production-ready microbes, accelerating time to market
- Broad application potential, across personal care, chemicals, and consumer goods

Novel active for suncare

tw:g

Biosurfactants from biomass

Converting waste biomass into high-performance, cost-competitive surfactants

Challenge

Most cleaning and personal care products rely on fossil fuel-derived surfactants, contributing significantly to carbon emissions and environmental harm. At the same time, existing bio-based alternatives often fail to match the performance and cost-effectiveness of conventional chemicals, limiting widespread adoption.

Solution

Bioataraxis has developed a proprietary chemical process (Ecosaf) that converts agricultural and biomass waste into high-performance, bio-based surfactants. These molecules are designed to match or exceed the cleaning efficiency of petrochemical ingredients while remaining cost-competitive and scalable for industrial use.

Benefits

- Reduced reliance on fossil-based chemicals, lowering carbon footprint in cleaning products
- High-performance surfactants, comparable to conventional detergents
- Cost-competitive with incumbents, enabling real market adoption
- Valorisation of agricultural waste, supporting a circular economy
- Drop-in compatibility for formulators, easing integration into existing products
- Scalable technology platform, supporting industrial deployment and licensing

Bioataraxis

By-products to biochemicals

Transforming whisky and agricultural by-products into high value cosmetic ingredients

Challenge

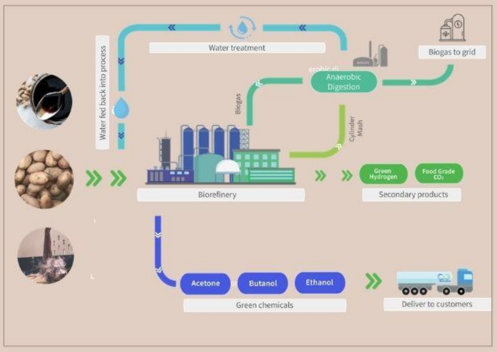
Large industries such as whisky, agriculture, and food processing generate vast volumes of low-value by-products and waste that are costly to manage and often underutilised. At the same time, chemical production remains heavily dependent on fossil fuels, driving emissions and limiting progress toward net zero.

Solution

Celtic Renewables uses a patented Acetone-Butanol-Ethanol (ABE) fermentation process to convert industrial by-products—such as whisky residues and agricultural waste—into high-value green chemicals including bioacetone, biobutanol, and bioethanol. This process operates at commercial scale in its biorefinery, creating a circular system that replaces fossil-derived chemicals.

Benefits

- Significant carbon reduction, with up to ~65% lower emissions compared to petrochemicals
- Valorisation of waste streams, turning costly residues into valuable products
- Drop-in green chemicals, usable across cosmetics, pharmaceuticals, and cleaning products
- Circular economy model, using renewable "above-ground" carbon instead of fossil sources
- Scalable, proven technology, already owns and operates a commercial biorefinery
- Supports net zero goals, enabling industries to defossilise supply chains



Celtic Renewables

5. Challenges and Opportunities

The transition to a bio-based, engineering biology-enabled cosmetics sector presents a significant economic and environmental opportunity for the UK. However, this transition is constrained by a set of interrelated structural, regulatory, and market challenges that must be addressed to unlock scale.

5.1 Key Challenges

Cost competitiveness vs. petrochemical inputs

Bio-based materials remain more expensive than fossil-derived equivalents in several categories. While costs are expected to decline with scale, process optimisation, and technological advancement, petrochemical inputs continue to benefit from mature infrastructure, embedded subsidies, and highly optimised global supply chains. This creates a persistent structural cost disadvantage for emerging bio-based alternatives.

Limited domestic feedstock capacity

The UK remains reliant on imported feedstocks for fermentation and plant-derived inputs. This limits supply chain resilience, increases exposure to geopolitical and commodity price volatility, and constrains the ability to scale domestic biomanufacturing. Expanding access to sustainable, domestic feedstocks—including waste streams and industrial by-products—will be critical to enabling growth.

Regulatory complexity and post-Brexit fragmentation

Despite strong policy ambition, the UK's regulatory framework for bio-based chemicals and materials remains outdated, fragmented, and poorly aligned with innovation. Existing systems are historically structured around fossil-based inputs, creating uncertainty and inefficiencies for novel bio-based substances[44,45].The introduction of parallel UK REACH and EU REACH regimes has added further complexity, alongside overlapping requirements across multiple regulatory bodies, including HSE, OPSS, FSA, and Defra. This results in duplicated testing, inconsistent guidance, and increased administrative burden.

Evidence from the Bio-based and Biodegradable Industries Association (BBIA) and BB-REG-NET identifies regulatory complexity as the second-largest barrier to commercialisation[46,47]. The impact is significant:

- Bio-based cosmetic ingredients require 11 regulatory stages, compared to 7 for fossil-based equivalents
- Approval timelines are approximately 72 weeks vs. 50 weeks
- Costs are more than double (~£815,000 vs. ~£372,000)
- In practice, this means bio-based ingredients take up to 45% longer to approve and are significantly more expensive to bring to market.
- For a small sample of UK SMEs, this equates to £35.7 million in lost annual GVA and over 473 unrealised jobs[48]. Scaled across the broader bioeconomy, the total economic loss is likely to reach into the tens of billions annually.

[44] https://assets.publishing.service.gov.uk
[45] https://bbregnet.com
[46] www.bbia.org.uk
[47] https://bbregnet.com
[48] BBIA, unpublished, 2025

This regulatory misalignment risks the UK falling behind global competitors such as the US, EU, and Singapore, which are actively modernising regulatory systems to support bio-based innovation[49],[50].

To succeed, companies consistently identify three critical regulatory needs (1) Predictable timelines and decision-making processes (2) Proportionate, risk-based data requirements (3) Market incentives that reward sustainability. Current UK frameworks fall short across all three.

Life Cycle Assessment (LCA) limitations

Life Cycle Assessment methodologies remain insufficiently harmonised and are often structurally biased toward petrochemical systems. Current frameworks can fail to fully account for biogenic carbon, land-use benefits, and circular feedstocks.

As highlighted in BBIA's "Standardised, but Unfair?" study[51], methodological limitations can result in bio-based products appearing up to 103% more environmentally damaging than fossil-based equivalents. These distortions undermine investor confidence, skew procurement decisions, and slow adoption of lower-carbon alternatives.

Consumer confusion and inconsistent claims

The proliferation of terms such as "bio-based," "natural," "clean," "organic," and "vegan" without consistent definitions creates confusion for consumers and weakens trust. This lack of standardisation also complicates regulatory enforcement and makes it difficult to differentiate genuinely sustainable products from those making unsubstantiated claims.

Global Access and Benefit Sharing (ABS) complexity

Access and Benefit Sharing frameworks are essential for ensuring fair and equitable use of biological resources. However, their complexity and lack of harmonisation across jurisdictions can restrict access to novel feedstocks and biological materials, limiting innovation and increasing compliance costs.

5.2 Emerging Opportunities

Circular Feedstocks and Responsible by Design

A core pillar of engineering biology is the transition from linear, extractive supply chains to circular, low-impact feedstock systems. This involves moving beyond first-generation agricultural inputs toward:

- Industrial by-products (e.g. lignocellulosic sugars, glycerine from biodiesel production)
- Food waste streams
- Carbon capture and utilisation (CCU), converting industrial emissions into chemical inputs

These approaches reduce dependence on land-intensive agriculture, lower lifecycle emissions, and increase supply chain resilience. When feedstocks are derived from waste streams or recycled carbon land use is significantly reduced, carbon intensity decreases,

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[49] https://www.theglobalbioeconomy.org
[50] https://www.gov.uk
[51] Do LCA standards limit comparison?

scope 3 emissions are lowered and supply chains become more stable and less exposed to external shocks. This represents a shift toward Responsible by Design, where sustainability considerations are embedded at the earliest stages of product and process development.

Materials, Packaging, and Circular Chemistry

Engineering biology is also enabling innovation in materials and formulation chemistry. Bio-based polymers derived from renewable feedstocks—including cellulose, starch, and microbial polyesters—are emerging as alternatives to conventional plastics in both formulations and packaging.

In parallel, bio-based solvents and intermediates derived from biomass and waste feedstocks offer lower-toxicity, biodegradable alternatives to petrochemical solvents, supporting greener formulation systems.

These innovations are critical for addressing microplastic pollution, improving end-of-life outcomes, and aligning with evolving regulatory frameworks such as Extended Producer Responsibility (EPR) and plastics taxation.

LCA as a Design Tool, Not Just a Reporting Metric

As the sector matures, Life Cycle Assessment is evolving from a retrospective reporting tool into a forward-looking design constraint. Increasingly, LCA is being applied at the R&D stage to inform feedstock selection, process optimisation, energy use, product end-of-life strategies. Embedding LCA into early-stage decision-making ensures that sustainability is engineered into products, rather than assessed after development.

Intellectual Property and Regulatory Support for Sustainable Innovation

An example of policy support for sustainability-focused innovation, which could be mirrored for regulations in the form of an additional 'Green Innovation Pathway' is the UK Intellectual Property Office's "Green Channel" initiative[52]. The Green Channel enables applicants to request accelerated processing of patent applications for inventions that provide environmental benefits, including technologies that improve sustainability, reduce emissions, conserve resources, or support circular economy objectives. By shortening examination timelines, the scheme helps businesses bring sustainable innovations to market more quickly and provides earlier certainty around intellectual property protection.

The Green Channel demonstrates how government policy and regulatory frameworks can actively support businesses pursuing sustainability objectives. Rather than acting solely as a compliance mechanism, regulation and public policy can also function as enablers of innovation by reducing administrative barriers and improving access to commercialisation pathways for environmentally beneficial technologies.

This approach also highlights broader challenges associated with intellectual property protection in emerging sustainable technologies and materials markets[53]. As discussed in industry commentary on green chemistry and sustainable materials innovation,

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[52] UK IPO Green Channel guidance

[53] Green chemistry, grey areas – understanding patent protection for sustainable materials - Chemical Industry Journal

existing patent systems can face difficulties when assessing inventions that rely on incremental sustainability improvements, novel feedstocks, or complex lifecycle benefits. These "grey areas" can create uncertainty for innovators and investors, particularly in sectors where regulatory standards and environmental performance metrics continue to evolve.

Industry guidance from intellectual property specialists further suggests that accelerated patent mechanisms such as the Green Channel may become increasingly important as businesses seek to secure competitive advantage in rapidly developing low-carbon and circular economy sectors. Faster access to patent protection can support investment, encourage collaboration, and strengthen confidence in the commercial viability of sustainable technologies.

This model could also be extended beyond intellectual property into a broader "Green Innovation Pathway" within regulatory systems. Such an approach could provide accelerated assessment, streamline approvals, or coordinate regulatory support for products, materials, and technologies that demonstrate clear sustainability benefits. In the same way that the Green Channel supports environmentally beneficial patents, a regulatory Green Innovation Pathway could help reduce barriers to market entry for low-carbon and circular bioeconomy innovations while maintaining appropriate standards for safety, quality, and environmental performance.

KEY TAKEAWAYS

1. **Scale-up is held back by structural cost barriers**

Bio-based ingredients remain more expensive than petrochemical equivalents due to mature fossil-based infrastructure and economies of scale.

2. **Feedstock limitations constrain UK bio-manufacturing growth**

Reliance on imported inputs reduces resilience, while greater use of domestic waste and by-products could unlock scaling potential.

3. **Regulation is the single biggest bottleneck to commercialisation**

Fragmented post-Brexit frameworks, long approval times, and high compliance costs significantly disadvantage bio-based ingredients versus fossil-based ones.

4. **Measurement systems are distorting market signals**

Inconsistent LCA methodologies and unclear sustainability claims undermine confidence and can unfairly disadvantage bio-based products.

5. **Major opportunities exist in circular and bio-designed systems**

Engineering biology enables waste-based feedstocks, biodegradable materials, and early-stage LCA-driven design, supporting a shift to a circular, lower-carbon cosmetics industry.

6. Recommendations: Unlocking UK Leadership in Bio-Based Innovation

To support this transition in 2024 the BBIA, in collaboration with the Cosmetics Cluster UK (CCUK), established the "Beauty and the Bioeconomy" Taskforce. This initiative focuses on three key areas: the development of sustainable ingredients to replace petrochemical inputs with biodegradable, plant-derived alternatives; the advancement of green biotechnology, including engineered biology and fermentation-based production; and the design of eco-friendly packaging solutions that minimise waste and promote recyclability or compostability.

Building on previous BBIA and CCUK, and BB-REG-NET research, there is a clear need for regulatory reform to unlock the full potential of the UK bio-based chemicals and materials sector.

Bio-based cosmetic ingredients highlight both the opportunity and the systemic barriers. While regulations are nominally feedstock-neutral, in practice they remain fossil-biased, disproportionately burdening low-carbon innovations due to complexity in composition, variability, and global regulatory inconsistency.

To address this, five priority actions are recommended:

1. **Establish a UK Bio-Based Materials Regulatory Roadmap (2026–2030)**

Develop a coordinated, cross-sector framework with:

- Clear approval timelines and service-level agreements
- A single-window submission portal
- Alignment across Defra, DBT, DSIT, and relevant regulators

2. **Create a Green Innovation Pathway**

Introduce fast-track approval mechanisms for low-risk, sustainable bio-based materials - such as the AI-designed suncare actives from Twig Bio or the waste-derived oils from Clean Food Group - within UK REACH and OPSS frameworks, incorporating lifecycle and circularity considerations.

3. **Enable Data Equivalence and Read-Across**

Reduce duplication and cost by recognising comparable safety data across bio-based analogues - for example, by leveraging existing safety profiles for fermentation-derived sophorolipids like Holiferm's HoliSurf - and harmonising non-animal testing approaches across agencies.

4. **Integrate Sustainability into Regulatory Decision-Making**

Embed environmental metrics—such as carbon intensity, recyclability, and circularity—into regulatory assessments and procurement frameworks. Substantial climate benefits, such as the 90% reduction in greenhouse gas emissions achieved by microbial oil fermentation, should be weighted as key factors in preferential regulatory treatment.

5. **Strengthen International Alignment**

Enhance global competitiveness by aligning with OECD and WTO standards, harmonising definitions, and ensuring mutual recognition of data and testing approaches.

7. Conclusion

The UK bio-based cosmetics sector stands at a critical inflection point. Driven by accelerating consumer demand for sustainable products, rapid advances in engineering biology, and mounting environmental pressures on the traditional cosmetics industry, the foundations for a structural market transformation are already in place. However, realising this opportunity at scale will require coordinated action across innovation, industry, and regulation.

Engineering biology offers a step-change in how cosmetic ingredients are developed and manufactured. Technologies such as precision fermentation, enzymatic biosynthesis, and AI-enabled molecular design are enabling the production of high-performance, bio-based ingredients with improved consistency, functionality, and environmental profiles. These innovations have the potential to reconfigure supply chains, reduce dependency on petrochemicals, and enable entirely new categories of sustainable beauty products.

The UK is particularly well positioned to lead this transition, with strengths in synthetic biology, green chemistry, and advanced manufacturing. However, several structural barriers continue to limit commercialisation and scale-up. Chief among these are higher production costs relative to petrochemical incumbents, limited domestic feedstock capacity, and a regulatory system that remains fragmented, complex, and poorly adapted to novel bio-based innovations. In particular, current approval pathways can significantly increase time-to-market and cost burden, disproportionately affecting SMEs and early-stage innovators.

Alongside these constraints, significant opportunities are emerging. The development of circular feedstock systems, integration of waste-derived and carbon-captured inputs, and advances in bio-based materials and packaging are all enabling a shift toward a more regenerative industry model. Embedding Life Cycle Assessment and sustainability considerations into early-stage product design further strengthens the potential to align innovation with environmental outcomes.

To unlock this potential, regulatory reform is essential. A more streamlined, proportionate, and innovation-friendly framework—supported by clearer approval pathways, harmonised standards, and sustainability-aligned decision-making—would significantly accelerate the commercialisation of bio-based cosmetics in the UK. This would not only reduce barriers for innovators but also improve investor confidence and strengthen the UK's global competitiveness in the bioeconomy.

In conclusion, bio-based cosmetics represent both a major economic opportunity and a necessary environmental transition. The UK has the scientific capability and industrial base to lead globally in this space, but success will depend on its ability to align regulation, innovation, and market incentives. With decisive action, the UK can move from early scientific leadership to full-scale commercial dominance in sustainable, engineering biology-enabled beauty products.

Appendix

Appendix Table 1. Manufacture of perfumes and toilet preparations in UK in 2024

	Count	Employment	Turnover (£'000s)	Turnover (£)	Turnover Per Employee	Turnover Per Business
England	755	12,485	..C	£1,131,721,051.72		£1,498,968.28
London	230	1,169	223,761	£223,761,000.00	£191,412.32	£972,873.91
Liverpool	5	..C	..C			£-
Bristol	10	22	2,304	£2,304,000.00	£104,727.27	£230,400.00
Birmingham	10	25	3,834	£3,834,000.00	£153,360.00	£383,400.00
Bradford	5	26	1,992	£1,992,000.00	£76,615.38	£398,400.00
Leeds	10	196	..C		£-	£-
Manchester	30	559	315,818	£315,818,000.00	£564,969.59	£10,527,266.67
Scotland	45	..C	99,787	£99,787,000.00		£2,217,488.89
City of Edinburgh	5	..C	..C			£-
Glasgow City	5	21	..C		£-	£-
Northern Ireland	5	..C	..C			£-
Belfast	0	..C	..C			
Wales	35	..C	..C			£-
Cardiff	10	14	1,030	£1,030,000.00	£73,571.43	£103,000.00