

9. ANNEXES

This annex document provides the evidence and research in support of the full report: *The State of Biorefining in 2025, Progress, Performance and Pathways for Growth*.

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9.1 Biorefining landscape review (Alder BioInsights)



This report provides a review of literature, relating to Task 1: Landscape review, delivered by Alder BioInsights. It includes the outcomes of a PESTLE analysis, to capture the key attributes of the biorefining landscape. The landscape review is focused on the UK but also places UK activity in an international context.

Specific areas of focus include the science and innovation landscape (research and innovation facilitation programmes), the policy context stimulating biorefining, and the prevailing regulatory environment. The review also describes how the UK's research, development and innovation (RD&I) landscape has evolved over the last ten years highlighting key investments in facilities and capabilities, where facilities have been lost, and how projects and collaboration have been used to facilitate and coordinate scale-up activities.

It also highlights how a focus on regional/place-based RD&I ecosystem can stimulate biorefining research and commercial development, such as the impact of Scotland's bioeconomy strategy.

9.1.1 The UK's biorefining landscape

Biorefining refers to the process of converting biomass, such as plants, agricultural residues, food waste and microorganisms, into a range of valuable products (e.g., biofuels, bio-based chemicals, polymers, bioenergy, materials, or food and feed ingredients). It can be thought of as the bio-based equivalent of a conventional petroleum refinery, but instead of using crude oil as the primary feedstock, it uses renewable biological resources. Biorefining is a fundamental component of the broader bioeconomy concept – the part of the economy that uses biological resources, biological processes and biotechnology to produce sustainable goods and services.

The UK's bioeconomy is positioned as being one of the strongest outside of the USA and China, having contributed roughly £153 billion in gross value added (GVA) to the UK economy in 2022 and supporting approximately 4 million jobs nationwide.¹ The UK is a recognised global leader in the sustainable production and utilisation of biological resources for food, energy, materials and chemicals, with successive UK governments subsequently recognising the bioeconomy as being a strategic frontier for national security and economic growth, as well as an important route to reducing fossil fuel dependency, lowering carbon emissions and advancing the circular economy.

Following the publication of the "UK's Modern Industrial Strategy" in June 2025, further support for the UK's bioeconomy was signalled through the government's commitment to invest £380 million in engineering biology,² a key enabling technology within biorefining that utilises engineered organisms to manufacturer novel products and offer innovative solutions to global problems.

But how did the UK get here? And what challenges does the wider bioeconomy and biorefining still face today? This report investigates these questions and outlines the key events and influencing factors that have shaped the UK's biorefining landscape over the past 10 years.

1 BBSRC. Building the bioeconomy. URL: <https://webarchive.nationalarchives.gov.uk/ukgwa/20250701131000/https://www.ukri.org/publications/building-the-bioeconomy-presentation-and-posters/>

2 UK Government. The UK's Industrial Strategy. URL: https://assets.publishing.service.gov.uk/media/68595e56db8e139f95652dc6/industrial_strategy_policy_paper.pdf

9.1.2 The UK's science and innovation landscape

The UK has an ambition to become a global science and technology superpower by 2030, with this vision being laid out in the “Science and Technology Framework” in 2023.³ The UK has a long and proud history of supporting science and innovation across a wide range of fields, with the biorefining sector being no exception.

The UK's biorefining landscape has developed and evolved over many years. But the sector of today would not be what it is without the establishment of the Industrial Biotechnology Innovation & Growth Team (IB-IGT) in 2007. The IB-IGT was a UK Government initiative led by the Department for Business, Innovation and Skills (BIS). Its purpose was to work with industry to explore and address challenges to innovation and growth in the industrial biotechnology (IB) sector.⁴ This team played a key role in shaping policy and strategy for the UK's wider bioeconomy and was heavily involved in promoting the sector through public engagement and stakeholder collaboration.

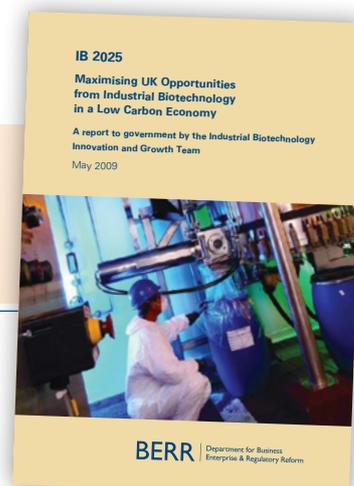
In 2010, the IB-IGT published “IB2025”, a horizon-scanning and road-mapping report on “Maximising UK Opportunities from Industrial Biotechnology in a Low Carbon Economy”. The report projected that the UK's IB market could grow to between £4-12 billion by 2025, driven particularly by high-value, low-volume chemical production.

In the foreword to this report the Department of Business Enterprise & Regulatory Reform's (BERR) then Secretary of State, Lord Mandelson stated that:

“IB will be one of the strongest driving forces behind the world's low-carbon revolution. Offering businesses, the capability to develop and use less carbon intensive products and processes, whilst also reducing costs and opening-up new, emerging and established markets.”

The IB-IGT report laid out over 20 strategic recommendations designed to help the UK become a global leader in IB. These recommendations can be grouped into five key themes, each addressing critical barriers and opportunities relating to the sector. They included:

- 1. Policy and strategic coordination** – Recommendations included the development of a national strategy for IB; the integration of IB into wider UK industrial and environmental policy; the establishment of cross-government coordination for IB development; and the alignment of IB with sustainability and net zero goals.
- 2. Research, innovation and commercialisation** – Increase funding for IB R&D, especially in synthetic biology and bioprocessing; support interdisciplinary research across biology, chemistry and engineering; promote translational research to bridge the gap between academia and industry; and facilitate the commercialisation of IB innovations.
- 3. Skills, education and workforce development** – Create targeted training programmes for IB-related skills; integrate IB into university and vocational curricula; support industry placements, internships and apprenticeships; and build capacity in regulatory and technical expertise.
- 4. Infrastructure, investment and market creation** – Invest in pilot-scale and demonstration facilities across the country; improve access to venture capital and innovation funding; support regional IB clusters and innovation hubs; and encourage public procurement of bio-based products.



³ UK Government. Press Release: Plan to forge a better Britain through science and technology unveiled. URL: <https://www.gov.uk/government/news/plan-to-forge-a-better-britain-through-science-and-technology-unveiled>

⁴ Industrial biotechnology refers to the use of biological systems, such as microorganisms, enzymes, and cells to produce and process materials, chemicals, and energy in a sustainable way. It's a key part of the bioeconomy, offering alternatives to fossil-based manufacturing and contributing to net zero and clean growth goals.

5. Regulation, public engagement and communication – Streamline regulatory pathways for IB products; harmonise standards across the EU and globally; launch a national campaign to raise awareness of IB; and engage stakeholders in dialogue around ethics, sustainability and innovation.

These recommendations later formed the backbone of the UK's Industrial Biotechnology Strategy and directly influenced the creation of initiatives like the Networks in Industrial Biotechnology and Bioenergy (NIBB), the formation of the IB Leadership Forum (IBLF), and the IB Catalyst. The government responded to this report directly by committing to the support of cutting-edge research in this area, by creating a favourable operating environment for IB, by investing in open-access demonstrator facilities, and by funding collaborative networks and partnerships.

The IB-IGT played a critical strategic role in helping the UK's IB sector mature from fragmented R&D to market-ready industrial applications. By highlighting the projected size of the IB market and by outlining the required development levers, it provided an invaluable steer for future policy, investment and collaborative efforts. The IB-IGT helped materialize a vision for the UK's IB sector and the bioeconomy as a whole, this is evidenced by successful funding calls, and policy and investments that have resulted in successful spin-outs, academic-industry partnerships, and commercial biotech innovations.

9.1.2.1 Networks in Industrial Biotechnology and Bioenergy (NIBB)

Following the publication of the IB-IGT "IB2025" report, one of the most notable outcomes in terms of the science and innovation landscape was the formation of the Networks in Industrial Biotechnology and Bioenergy (NIBB).

NIBBs are collaborative research communities funded by the Biotechnology and Biological Sciences Research Council (BBSRC) with additional support from the Engineering and Physical Sciences Research Council (EPSRC). Their mission is to foster partnerships among academia, industry, policymakers and NGOs, and to accelerate the translation of biotechnological research into industrial and environmental applications. The NIBBs were funded across two distinct phases from 2014 to 2024. **Phase I** was funded from 2014–2019; and **Phase II** funded from 2019–2024.⁵

The BBSRC initially committed £18 million in investment (with EPSRC support) to fund 13 Phase I NIBBs. These 13 networks independently focussed on different areas relevant to industrial biotechnology and the wider bioeconomy e.g., anaerobic digestion (AD), biocatalysts, bioprocessing, chemical production, lignocellulosic biomass, waste and by-product utilisation, bioengineering, and microalgae.⁶ Key outcomes and impacts of the Phase I NIBB initiative included:⁷

- 277 businesses contributed funding to collaborative projects.
- >40 spin-out companies created.
- The NIBBs contributed to 31% of BBSRC-attributable IP, and 34% of BBSRC-attributable spin-outs, despite representing only 11% of BBSRC's total funding.
- 11% of NIBB publications had industry co-authors (vs. 4% BBSRC average).
- 33% of businesses reported increased turn over or expected growth due to NIBB engagement.

5 The COVID pandemic temporarily curtailed some programmes and as a result several NIBB extended activities into 2025 and 2026.

6 The 13 Phase I NIBBs were: Anaerobic Digestion Network (ADNet), Network in Biocatalyst Discovery, Development and Scale-Up (Biocatnet), Bioprocessing Network (BioProNET), Chemicals from C1 Gas Network (C1NET), Crossing biological membranes (CBMNet), Food Processing Waste and By-Products Utilisation Network (FoodWasteNet), High Value Chemicals from Plants Network (HVCfP), Glycoscience Tools for Biotechnology and Bioenergy (IBCarb), Lignocellulosic Biorefinery Network (LBNet), The elements of Biotechnology and Bioenergy (Metals in Biology), Natural Products Discovery and Bioengineering Network (NPRONET), A Network of Integrated Technologies: Plants to Products (P2P), Unlocking the IB potential of microalgae (PHYCONET).

7 BBSRC. Evaluation of the effectiveness and impact of BBSRC's investments in Industrial Biotechnology. URL: <https://www.ukri.org/wp-content/uploads/2024/09/240924-BBSRC-12066-BBSRC-Industrial-Biotechnology-report-FINAL.pdf>

- 67% of businesses increased R&D investment in IB after participating in the NIBB initiative.
- 68% of projects funded by the BBSRC NIBB involved at least one industry partner, these projects leveraged 39% of funding (cash or in-kind) from industry, alongside the funding provided by BBSRC.
- The BBSRC NIBB leveraged £98 million in additional funding from a mixture of public and private funders.
- Over £92 million of this leveraged funding supported new research grants. £4.6 million supported early career researchers (ECRs) and students.
- The BBSRC NIBB initiative had a good level of international engagement. 16% of members were from outside of the UK, with 553 members based in Europe and 492 based elsewhere.

Following the success of the Phase I networks, the BBSRC (supported by EPSRC) awarded an additional £11 million to fund 6 new NIBBs, which focused on priority areas within IB and the bioeconomy. These Phase II NIBBs intended to continue the original mission of promoting research translation and fostering communities of IB specialists, across industry and academia. The 6 Phase II NIBBs included:

- **BBNet (Biomass Biorefinery Network)** – Focussed on the conversion of non-food biomass into fuels, chemicals, and materials.
- **Algae-UK (Algal Biotechnology Network)** – Focussed on the valorisation of microalgae, macroalgae, and cyanobacterial synthetic biology.
- **Carbon Recycling Network** – Focussed on the conversion of waste-derived greenhouse gases (e.g. CO₂, CO) into valuable products.
- **E3B (Elements of Bioremediation, Biomanufacturing & Bioenergy)** – Investigated the role of metals in biology and their industrial applications.
- **EBNet (Environmental Biotechnology Network)** – Focussed on microbial systems for environmental protection, waste treatment, and resource recovery.
- **HVB (High Value Biorenewables Network)** – Focussed on the discovery and development of high-value bio-based products

The NIBB have played an essential role in the growth of the IB sector and the wider bioeconomy over the past decade, serving as innovation hubs for the transformation of research into viable and impactful industrial biotech applications. Through the promotion of academic-industry partnerships and the funding of pilot-scale testing, the NIBB have helped to reduce the so called “valley of death” for science and innovation across the IB sector. Furthermore, one of the most beneficial aspects of the NIBB is that they have helped to create pockets of specialised communities across the sector and a support structure for researchers, startups and established companies alike. This has been instrumental in driving the development of the UK’s bioeconomy and biorefining landscape since the inception of the NIBB in 2014.

9.1.2.2 IB Catalyst

Another key outcome of the IB-IGT ‘IB2025’ report was the recommendation to increase strategic public investment in industrial biotechnology research. This ultimately led to the formation of the IB Catalyst in 2014.

The IB Catalyst was a £76 million funding initiative jointly delivered by Innovate UK (formerly the Technology Strategy Board), BBSRC (Biotechnology and Biological Sciences Research Council), and EPSRC (Engineering and Physical Sciences Research Council). It delivered three rounds of funding from 2014 to 2017 supporting IB projects across three distinct stages: feasibility studies; industrial research; and experimental development. Funding calls were targeted at projects across five key challenge areas, including:

- Production of fine and speciality chemicals and natural products (e.g. fragrances, flavours, pharmaceutical intermediates)
- Production of commodity, platform and intermediate chemicals and materials (e.g. plastics, resins, silks)
- Production of liquid and gaseous biofuels
- Production of peptides and proteins (e.g. enzymes, antibiotics, recombinant biologics)
- Novel or improved upstream or downstream processes to reduce costs or improve efficiency in industrial biotechnology applications

The IB Catalyst ran from 2014 to 2018, and was designed to bridge the gap between early-stage research and commercialisation. The overarching aim was to support collaborative R&D between academia and industry, help the UK become a global leader in the bioeconomy, and stimulate economic growth, job creation and sustainability through industrial biotechnology.

In total, the IB Catalyst funded 82 projects across the five key challenge areas with the scheme recognised for producing high-quality, internationally competitive research. It has been reported that 16% of journal articles published as a result of IB Catalyst funded projects were ranked within the top 10% of citation impact globally. Generally, publications linked to the IB Catalyst had a higher citation impact than those originating from other G7 countries within the same field.⁸

Furthermore, 75% of all grant holders reported forming new collaborations with non-academic stakeholders as a result of securing funding, and 7% of related publications had industry co-authors (compared to the 4% BBSRC average). After IB Catalyst funding, 84% of postdocs remained research-active, and 26% of staff moved into private sector roles (vs. 14% BBSRC average).⁹

Although the IB Catalyst has ended, its legacy includes a strengthened pipeline of industrial biotech innovation and proof-of-concepts (PoC) across multiple value chains. It also highlighted the need for adaptive funding strategies to sustain long-term commercial translation, covering specialty chemicals and bio-based materials. The IB Catalyst programme, along with the NIBB, played a pivotal role in enabling commercialisation and the formation of spin-out companies, helping to translate research into market-ready industrial biotech solutions.

9.1.2.3 Industrial Biotechnology Leadership Forum (IBLF)

The Industrial Biotechnology Leadership Forum (IBLF) is a UK-government-backed initiative whose aim is to provide strategic coordination and leadership for the UK's industrial biotechnology (IB) sector. The IBLF was formed as recommendation of the IB-IGT "IB2025" report published in 2010. The principal aims of the IBLF were to unite industry, academia, and government to help drive the UK's bioeconomy; to promote industrial biotechnology as a key enabler of clean growth and sustainability; and to coordinate strategic planning, policy alignment, and investment to unlock IB's potential. Its overarching goal was to help the UK realise the £12 billion market potential as set out in the "IB2025" report.

The forum acted as a visible point of contact between industry, academia, government, funders and public access scale-up facilities. It included representatives from:

- Industry e.g., Croda, Mitsubishi Chemical, Biome Bioplastics
- Academia and research e.g. BBSRC, EPSRC, CPI
- Government and policy e.g. DSIT, Innovate UK
- Public access scale-up facilities and funders

8 BBSRC. Evaluation of the effectiveness and impact of BBSRC's investments in Industrial Biotechnology. URL: <https://www.ukri.org/wp-content/uploads/2024/09/240924-BBSRC-12066-BBSRC-Industrial-Biotechnology-report-FINAL.pdf>

9 BBSRC. Evaluation of the effectiveness and impact of BBSRC's investments in Industrial Biotechnology. URL: <https://www.ukri.org/wp-content/uploads/2024/09/240924-BBSRC-12066-BBSRC-Industrial-Biotechnology-report-FINAL.pdf>

The IBLF contributed to several major UK strategies and reports aimed at advancing industrial biotechnology and the bioeconomy, including:

- National Industrial Biotechnology Strategy to 2030
- Strategic Roadmap for Standards and Regulations
- Growing the Bioeconomy: A national Strategy to 2030
- Challenge-Driven and Responsible Innovation in IB.

Another key output of the IBLF was the report titled “Journey of Industrial Biotechnology: The Opportunity for Growth” which was intended as a follow up to the original IB-IGT “IB2025” report which paved the way for much of the IB sector and bioeconomy from 2010 onwards. Published in 2015, the principal aim of this report was to assess the UK’s progress in terms of IB development over the previous five years and highlight key achievements and ongoing challenges facing the sector.¹⁰

The key achievements highlighted in this report included the expectation that the UK’s IB sector was on track to contribute £12 billion annually to the UK economy by 2025. Furthermore, the launch of the NIBB Phase I networks (e.g., LBNet, P2P, FoodWasteNet) laid the groundwork for the UK Bioeconomy Strategy and the Phase II networks with the UK government recognising IB as a strategic priority for a low-carbon economy.

Companies like Biocatalysts Ltd. were showcased as having reduced enzyme development timelines from months to weeks through positive academic collaboration; and funding from Innovate UK, BBSRC, and other bodies were shown to have enabled feasibility studies and commercialisation efforts across the sector. The establishment of pilot and demonstration facilities were also celebrated as having supported the scale-up of a wide range of IB technologies, contributing to developments in the sector.

However, despite notable progress since the 2010 “IB2025” report, the 2015 update identified several key challenges that continued to hinder the IB sector in the UK, including:

- **Commercialisation bottlenecks** – Slow transition from lab to market with many promising technologies remained stuck at the pilot or demonstration stage due to lack of scale-up infrastructure and investment, or limited access to finance with SMEs and startups facing difficulties securing funding for IB ventures, especially for capital-intensive projects.
- **Technical and process limitations** – i.e., bioprocessing inefficiencies (compared to chemical processes, microbial and enzymatic methods were still less competitive in terms of cost and scalability), feedstock challenges (agricultural raw materials becoming more expensive, and low-cost options like cellulose not yet easily usable in microbial processes), and water usage concerns (bioprocessing often required large volumes of fresh water, raising sustainability issues in water-scarce regions).
- **Market and policy uncertainty** – Volatility in energy markets and policy inconsistency i.e., a lack of long-term, stable policy frameworks made it difficult for businesses to plan and invest confidently in IB technologies.
- **Skills and knowledge gaps** – Shortage of interdisciplinary expertise; there is a need for more professionals trained across biology, chemistry and engineering to support IB innovation. There was generally found to be a slow transfer of knowledge from academic research into industrial applications.

These challenges flagged that despite the positive progress and achievements of the sector, there was still work to be done by the government, industry and academia in order to realise the full potential of the IB sector. The report further reinforced the need for consistent policy, regulatory support and public engagement in order to successfully support further sector development.

¹⁰ UKRI. The journey of Industrial Biotechnology: The opportunity for growth. 2015. URL: <https://iuk-business-connect.org.uk/perspectives/the-journey-of-industrial-biotechnology-the-opportunity-for-growth/>

9.1.2.4 BBSRC IB portfolio funding

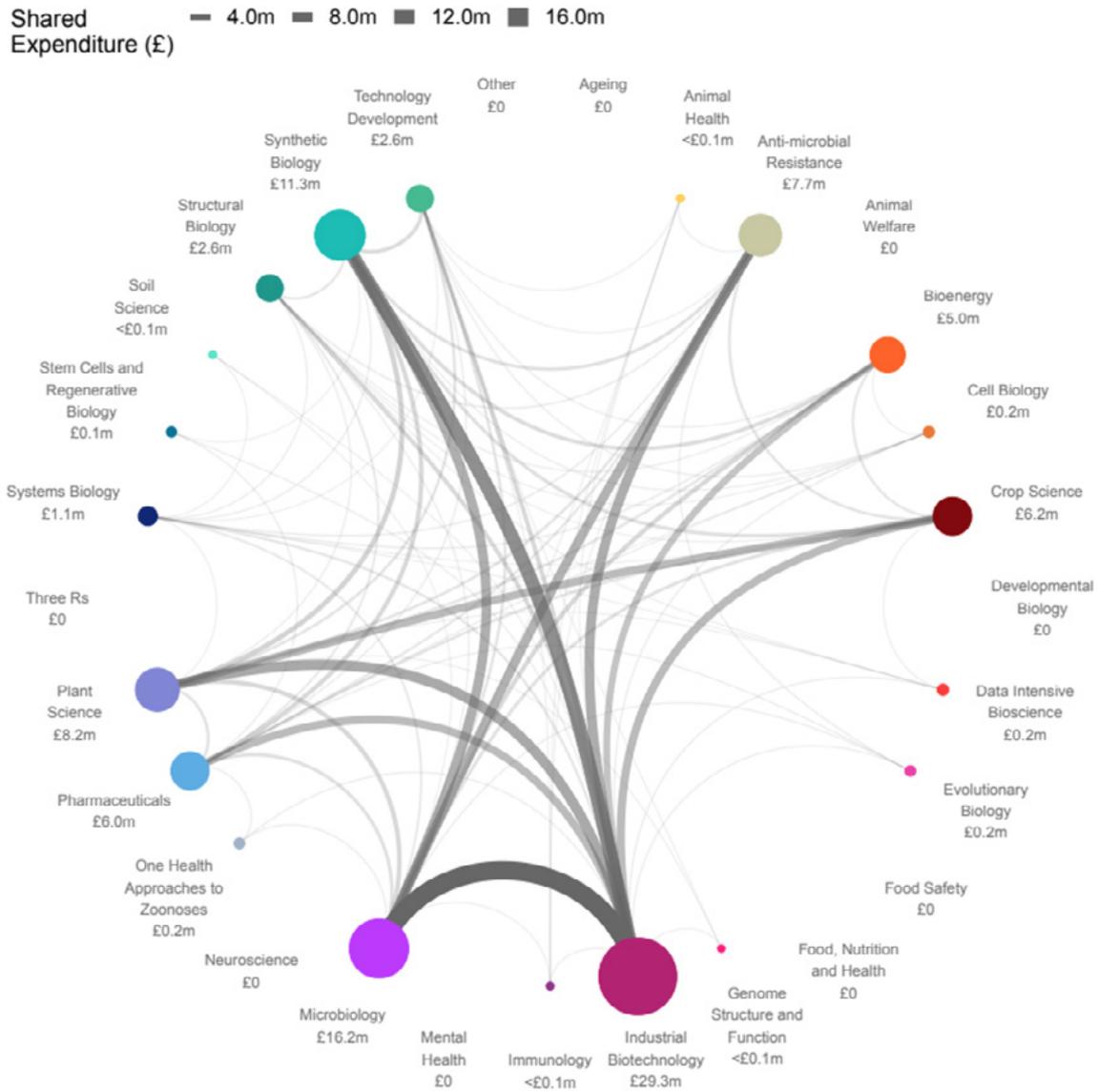
The previous sections in this report focussed on the most noteworthy initiatives recognised for helping the science and innovation landscape of the IB sector to progress over the past decade. However, other initiatives were also introduced in the same period and were provided funding from the BBSRC – the principal agency for supporting biotechnology and biological sciences research in the UK. The main funding mechanisms used to support the BBSRC’s IB portfolio between 2010/11 and 2020/21 are highlighted in Table 9.

Table 9: Main funding mechanisms used to support BBSRC’s IB portfolio between 2010/11 to 2020/21.

FUNDING MECHANISM	TOTAL SPEND	LIFESPAN	DESCRIPTION
RESPONSIVE MODE	£129.6 million	2010/11–2020/21	BBSRC’s standard research grant application scheme, open for applications at any time.
STRATEGIC INSTITUTE INVESTMENTS	£49.1 million	2010/11–2020/21	Strategic funding awarded to the BBSRC strategically supported institutes.
FELLOWSHIPS	£8.9 million	2010/11–2020/21	Various types of fellowship awards were operated by BBSRC/UKRI. Fellowship grants are to support early and mid-career scientists transitioning to an independent research career.
BIOPROCESSING RESEARCH INDUSTRY CLUB (BRIC)	£13.8 million	2006–2011	Research club launched in partnership with EPSRC and industry. Jointly managed by BBSRC and the Health Tech and Medicines KTN. 18 company members contributed to funding and steering of the club.
INTEGRATED BIOREFINING RESEARCH AND TECHNOLOGY CLUB (IBTI)	£5.9 million	2008–2016	Research and technology club launched in partnership with EPSRC and the Bioscience Knowledge Transfer Network (KTN). Nine company members contributed to funding research and directed activities of the club.
NETWORKS IN INDUSTRIAL BIOTECHNOLOGY AND BIOENERGY (NIBB)	£21.2 million	2014–2019	Network funding across BBSRC’s IB remit to establish communities.
IB CATALYST	£39.8 million	2014–2016	Joint venture with Innovate UK and EPSRC, set up to accelerate the commercialisation of IB derived products and processes.
ERA-IB AND ERA-IB-2	£5.8 million	2016–2022	Funded via the European Commission’s Framework Programme. Joint initiatives to foster the exchange of IB knowledge across borders.
ERA COBIOTECH	£3.4 million	2016–2022	Joint research initiative funded via Horizon 2020, bundling three predecessor ERA-Networks in IB.
NEWTON FUND	£5.2 million	2014–onwards	UK Government funding to build research and innovation partnerships with middle-income countries in Africa, Asia and Latin America.
GLOBAL CHALLENGES RESEARCH FUND	£7.9 million	2016 onwards	UK Government funding to support UK and international researchers tackling key issues affecting developing countries.

Table 9 demonstrates that a considerable amount of investment was committed to the science and innovation IB landscape in the years between 2010/11 and 2020/21. Figure 19 illustrates the research topics funded across the BBSRC IB research portfolio, including shared expenditure between different topics. It highlights that the fields of industrial biotechnology, microbiology and synthetic biology were the most heavily funded over the 10-year period, indicating where national research efforts have been focused.

Figure 19: Research topic co-occurrence network of BBSRC IB research portfolio (2021 to 2022 expenditure).¹¹



11 BBSRC. Evaluation of the effectiveness and impact of BBSRC’s investments in Industrial Biotechnology. URL: <https://www.ukri.org/wp-content/uploads/2024/09/240924-BBSRC-12066-BBSRC-Industrial-Biotechnology-report-FINAL.pdf>

9.1.3 Biorefining policy in the UK

As well as support for the science and innovation landscape, the bioeconomy and biorefining sector relies heavily upon Government backing and its long-term vision for the nation.

In 2015, the UK Government published a report titled “Building a high value bioeconomy” which placed emphasis on the opportunities available from utilising biological waste streams. The report described the landscape of the UK’s bioeconomy at the time, the stakeholders active in the sector and the main gaps in knowledge and information that may be preventing further sector development.

To address these knowledge gaps, action was taken to collect economic data and undertake a call for evidence (CfE). The data and information gathered during this CfE underpinned two flagship strategy documents relating to the bioeconomy, both published in 2018. The first, published by the IBLF, described a UK strategy for the development of a National Industrial Biotechnology Strategy to 2030. It laid out a roadmap of actions required to grow UK’s industrial biotechnology sector. The second, published by the UK Government, was a policy paper titled “Growing the Bioeconomy: A National Strategy to 2030”. The paper outlined the Government’s view of the bioeconomy and how it relates to other national strategies, including the required actions needed to implement it.

9.1.3.1 National Industrial Biotechnology Strategy to 2030

In 2018, the IBLF co-authored the National Industrial Biotechnology Strategy to 2030 along with two other collaborative networks in industrial biotechnology, CBMNet (Crossing Biological Membranes Network) and BIOCATNET (Biocatalysis Network).¹² This report presented a long-term vision for positioning the UK as a global leader in clean growth through IB. The strategy aimed to embed IB at the heart of the UK’s Industrial Strategy and Bioeconomy Strategy, driving innovation, sustainability and economic prosperity. The strategy was structured around seven key themes, each with targeted actions:¹³

- 1. External environment** – Establish a consistent, long-term policy landscape to support IB. Align government departments and regulatory bodies to reduce fragmentation.
- 2. Funding and access to finance** – Create a supportive financial ecosystem for IB SMEs. Improve access to public and private investment for scale-up and innovation.
- 3. Infrastructure and regional footprint** – Develop regional hubs and open-access biorefinery centres. Ensure IB contributes to clean growth across all UK regions.
- 4. Trade, investment and commercialisation** – Position the UK as a global hub for IB innovation and commercialisation. Promote exports of bio-based products and attract inward investment.
- 5. Regulations and standards** – Ensure UK frameworks are robust yet innovation-friendly. Support risk-aware innovation and international harmonisation.
- 6. Skills** – Foster interdisciplinary skills across biology, chemistry and engineering. Promote IB as an attractive career path and support workforce development.
- 7. Communication** – Build a unified IB community voice. Engage the public and stakeholders in Responsible Research and Innovation (RRI).

Key outcomes of this strategy to support sector growth included: the development of a strategic framework using the seven key themes outlined above; the provision of a long-term vision for IB to become a mainstream sector across UK industry; integration with national priorities (embedded IB within the UK’s Industrial Strategy and Bioeconomy Strategy, and positioned

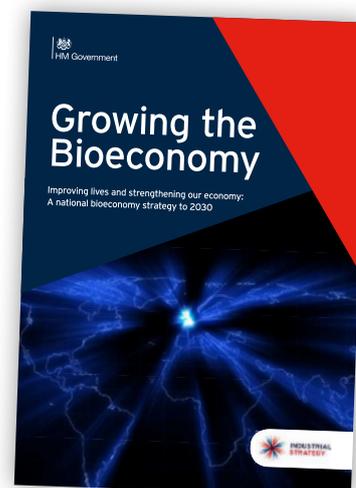
¹² Two of the UK’s BBSRC Phase I Networks in Industrial Biotechnology and Bioenergy (NIBBs).

¹³ UKRI. A National Industrial Biotechnology Strategy to 2030. 2018. URL: <https://iuk-business-connect.org.uk/news/a-national-industrial-biotechnology-strategy-to-2030/>

IB as a key enabler of clean growth, net zero, and circular economy goals); the promotion of access to finance, scale-up infrastructure and regional innovation hubs; the creation of the Strategic Roadmap for Standards and Regulations (BSI, 2020); alignment with UN Sustainable Development Goals (SDGs); and called for unified messaging and better public understanding of IB's benefits.

9.1.3.2 Growing the Bioeconomy: A National Strategy to 2030

In 2018, the UK Government published the Bioeconomy Strategy, formally titled "Growing the Bioeconomy: A National Strategy to 2030". The key aims of this strategy were to boost clean growth through a reduced reliance on fossil resources and the promotion of low-carbon, bio-based alternatives. It outlined aims to drive innovation through support for R&D in bioscience, biotechnology and synthetic biology; to encourage the commercialisation of bio-based products; and to support the creation of economic value by growing the bioeconomy's contribution to GDP, job creation and regional development. Another key aim was to coordinate national efforts by aligning government, industry and academia objectives, and provide a unified framework for policy and investment.



The strategy identified a number of key challenges associated with the sector which needed to be addressed in order to drive the industry forward. These included fragmentation across sectors and regions, scale-up barriers for SMEs and innovators, skills shortages in biotechnology and bioengineering, regulatory complexity and lack of clarity, limited public awareness and engagement, and competition for biomass between food, energy, and materials. Most of these challenges had not changed since the publication of the IB-IGT "IB2025" report in 2010.

Key outcomes of this strategy included: the expression of a clear national vision to position the UK as a global leader in bio-based innovation, manufacturing, and exports; integration with broader government strategies (e.g., Clean Growth Strategy, Industrial Strategy, Life Sciences Strategy); and recognising the role of open-access biorefinery centres (e.g., York, Redcar, Aberystwyth, and Glasgow), with these centres becoming the focal points for commercialisation and scale-up of bio-based technologies.

The strategy also highlighted the bioeconomy's contribution to the wider UK economy as £220 billion GVA and supporting over 5 million jobs. This policy set the ambition to double the size of the UK's bioeconomy by 2030, outlining considerable potential for growth in this sector.

This strategy helped pave the way for the National Vision for Engineering Biology, published in 2023, which committed £2 billion over 10 years to engineering biology R&D and infrastructure. It also contributed to the UK Government's Life Sciences Sector Plan, which included £2 billion investment, support for Genomics England, UK Biobank, and AI-ready health data platforms, and a focus on biotech scale-up and vaccine manufacturing capacity.

Alongside the 2018 Bioeconomy Strategy was the creation of BioPilots UK – mirroring the strategy's emphasis on regional capability. BioPilots UK aimed to coordinate and align the development and technical services provided by the UK's key pilot-scale facilities (see scale up infrastructure section for more details). These scale up facilities offer the technical expertise and process development support critical in helping organisations bridge the gap between lab-scale research and commercial production.

The strategy was withdrawn in 2021 with its principles absorbed into broader frameworks such as the UK Innovation Strategy and the Net Zero Strategy. While these two strategy documents do not focus explicitly on the bioeconomy and industrial biotechnology, they do recognise the significant potential for reducing emissions in sectors such as chemicals, textiles and plastics, by replacing fossil-based inputs with bio-based alternatives.

9.1.3.3 Industrial Biotechnology: Strategic Roadmap for Standards and Regulations

“The Strategic Roadmap for Standards and Regulations in Industrial Biotechnology”, published by BSI (British Standards Institution) in 2020, is a foundational document aimed at guiding the UK’s transition to a bio-based economy. Commissioned by Innovate UK and the IBLF, the roadmap identifies how standards and regulations can help to support the growth of IB in the UK, and especially in achieving net zero by 2050.

The strategy included insight on the potential CO₂ reduction potential of different IB related sectors over a short to medium-term time scale (Table 10). This insight was based on 50+ stakeholder interviews conducted with experts across industry, academia and policy. As well as desk-based research on existing standards, regulations and sector-specific literature. The sectors were assessed based on:

- Scale of current emissions (e.g., transport for biofuels, agriculture for agritech).
- Readiness of IB technologies (e.g., sustainable aviation fuels, enzyme-based crop protection).
- Market and regulatory receptiveness.
- Barriers to adoption (e.g., niche applications, lack of infrastructure).
- Potential for rapid deployment of IB solutions.

However, there are some limitations to this analysis including the fact that no CO₂ savings were quantified (the roadmap explicitly stated that comprehensive data was not yet available), and the immaturity of many technologies making empirical impact assessments difficult. As such, one of the roadmap’s key recommendations was to develop tools and frameworks for measuring IB’s environmental impacts more rigorously.

Table 10: Potential CO₂ reduction potential of different IB related sectors over a short to medium-term time scale.

SECTOR	CO ₂ REDUCTION POTENTIAL	REASONING
BIOFUELS	High	Large-scale transport emissions; sustainable aviation fuels expected online in <5 years
AGRITECH	High	GHG reduction targets, sustainability, and productivity make it receptive to IB
PLASTICS	Medium	Bioplastics need a jump-start to overcome roadblocks
FINE AND SPECIALITY CHEMICALS	Lower	High-value, low-volume profile limits short-term impact
TEXTILES	Lower	Niche applications; longer-term potential

Key actions of the roadmap were structured around four strategic pathways:

- **Circular resource use** – promote the use of sustainable feedstocks and waste valorisation. Encourage standards for biomass sourcing, traceability and lifecycle analysis. Support development of bio-based alternatives to fossil-derived products.
- **Communication tools** – Improve public and stakeholder understanding of IB. Develop consistent terminology and labelling (e.g. “bio-based”, “biodegradable”). Use standards to build trust in bio-based products.

- **Science-led approaches** – Align standards with cutting-edge research and innovation. Encourage collaboration between academia, industry and regulators. Support testing methods and certification schemes for new bio-based materials.
- **Supportive regulatory environment** – Identify regulatory gaps and barriers to IB adoption. Promote harmonisation across UK, EU and international frameworks. Ensure regulations are agile and responsive to innovation.

Key strategic recommendations of this document includes:

- Need for a national IB standards strategy aligned with industrial and environmental goals.
- Create a standards map to guide stakeholders through existing and emerging standards.
- Engage with international bodies to ensure UK leadership in global IB standards.
- Support SMEs and innovators in navigating regulatory landscapes.

9.1.3.4 The Biomass Strategy

In November 2021, the UK Government published the “Biomass Policy Statement” which outlined the government’s strategic view on the role of biomass in achieving net zero emissions by 2050. It was first published in 2021 and was later expanded upon in the Biomass Strategy in 2023. The statement and the subsequent strategy aimed to guide how biomass should be used across energy sectors (e.g., electricity, heat, transport, industry) and non-energy applications to support decarbonisation in the UK.

The initial statement outlined key requirements for the use of biomass, including compliance with strict sustainability criteria in order for it to be considered low carbon. As part of this statement the government planned to implement a cross-sectoral sustainability framework, subject to consultation, to ensure that biomass use reflected the latest thinking on environmental standards.

It also emphasised that biomass is a finite resource and so its use must be prioritised where it delivers the greatest environmental and economic benefits. A number of aims were flagged as part of this statement ranging from short to long term opportunities, including:

- **Short-term (2020s):** Support biomass deployment via incentives in power, heat and transport.
- **Medium-term (by 2035):** Transition toward Bioenergy with Carbon Capture and Storage (BECCS) to deliver negative emissions.
- **Long-term (by 2050):** Focus on hard-to-decarbonise sectors and applications that can deliver genuine negative emissions.

Some of the key sectoral opportunities flagged for the use of biomass included electricity and heat with biomass already contributing significantly here (e.g., 11% of UK electricity in 2022), transport where it can be used in biofuels and sustainable aviation fuel, industry where biomass can replace fossil fuels in materials and chemicals, and hydrogen production where biomass can be used to produce low-carbon hydrogen. The statement also identified key R&I gaps, such as flexibility in biomass sourcing, technological development for BECCS (Bioenergy with Carbon Capture and Storage), and air quality impacts.

This statement then led to the development of the UK Biomass Strategy in 2023 which addressed many of the same themes but demonstrated the development of clear policy in the area.

The Biomass Strategy was published by the Department for Energy Security and Net Zero in 2023, with the aim of clarifying the role of biomass in achieving the UK’s net zero emissions target by 2050, updating and expanding on the 2021 Biomass Policy Statement. It outlined that biomass should be used to respond to global energy challenges, including the Ukraine conflict, climate change and energy security concerns. Much like the previous statement it aimed at defining the strategic role of biomass across energy and non-energy sectors, ensuring sustainability through robust governance and criteria, prioritising biomass use in sectors where it delivers the greatest environmental and economic benefit, supporting innovation and scale-up of domestic biomass

feedstocks, enabling negative emissions through technologies like Bioenergy with Carbon Capture and Storage (BECCS), and developing a cross-sectoral sustainability framework for biomass use.

Many of the key challenges highlighted in the strategy mirrored concerns previously raised by the sector, such as sustainable feedstock supply (i.e. ensuring sufficient, affordable, and sustainable biomass feedstocks from both domestic and international sources); and food security (i.e., balancing biomass cultivation with the UK's commitment to maintain food production levels). Other challenges included managing emissions from biomass combustion and its impact on public health, as well as addressing public concerns around BECCS and biomass sustainability. Furthermore, predicting biomass supply and demand beyond 2035 is complex due to market and environmental variables.

Much like the previous statements, the biomass strategy proposed a tiered approach to biomass use in the form of short-long term goals. For example, short term (2020s): continue support for biomass in power, heat and transport; medium term (to 2035): shift toward BECCS and reduce unabated biomass use; long term (to 2050): focus on hard-to-decarbonise sectors and negative emissions technologies.

As a result of this strategy, £36 million was awarded to innovative projects under the Biomass Feedstocks Innovation Programme. It set the foundation for a common sustainability framework across sectors and reinforced the UK's position as a global leader in biomass sustainability standards. The Biomass Strategy positioned biomass as a critical enabler of net zero, especially in applications such as renewable electricity, biomethane generation and gas grid greening, industrial decarbonisation, low-carbon hydrogen production and non-energy uses (e.g. bio-based materials).

9.1.3.5 The UK's Modern Industrial Strategy

The "UK's Modern Industrial Strategy" published in June 2025 is the most recent of all national strategies to have potential impacts on the UK's bioeconomy and biorefinery landscape. This strategy is important as it signals the Government's intentions and priorities for driving economic growth, innovation and a sustainable future for the UK.

The Industrial Strategy sets clear priorities on the strategic direction for innovation, particularly in science, technology and infrastructure. It encourages cross-sector collaboration, especially between academia, industry and government. Furthermore, a key aspect of the strategy is to ensure alignment with net zero and sustainability goals, and while not explicitly mentioned in the strategy, IB and the bioeconomy is known to play an essential role in decarbonising sectors like energy, agriculture and manufacturing. Thus, the sector is well placed to benefit from the aims of this strategy.

The Government did, however, commit to investing £380 million in engineering biology,¹⁴ a key element of the bioeconomy and type of biorefining that utilises engineered organisms to manufacturer novel products and offer innovative solutions to global problems. Therefore, despite not mentioning IB and the bioeconomy in general, these sectors are heavily supported through investment in this area.

9.1.4 The UK's regulatory landscape

One of the common themes raised throughout national strategies and UK policy is the need for a favourable regulatory environment towards biorefining and the bioeconomy. This includes the need for regulatory alignment in order to facilitate market access for new bio-based products, and to avoid the duplication of testing, certification and compliance efforts. Alignment also allows for the mutual recognition of standards (e.g. compostability, bio-based content), which is vital for trade and global supply chains.

14 UK Government. The UK's Modern Industrial Strategy. URL: https://assets.publishing.service.gov.uk/media/68595e56db8e139f95652dc6/industrial_strategy_policy_paper.pdf

Regulatory misalignment can lead to delays in product development and approval, and lead to SME and innovator confusion around fragmented or conflicting rules. Clear and harmonised regulations provide predictability for stakeholders, which can help to encourage investment and innovation. Emerging IB technologies would benefit from flexible and adaptive regulatory frameworks and alignment would allow for the fast scaling of innovations from lab to market. Furthermore, a favourable regulatory environment for this sector would encourage more collaborative R&D to take place across borders.

Consistency across the regulatory environment would ensure that the sustainability claims made by novel products (e.g. biodegradability, carbon savings) are credible and comparable across jurisdictions. Furthermore, regulatory alignment will also help to build consumer confidence in new bio-based products, which is critical for encouraging market uptake and overall sector growth.

Key regulations currently impacting on the UK's biorefinery landscape include:

- **UKCA Marking (Post-Brexit Product Regulation)** – This regulation replaces the European CE marking for products in Great Britain. The implication of this on the UK's biorefining sector is that bio-based products must now meet UKCA requirements for safety and performance, instead of the CE marking which is used across the EU.
- **Northern Ireland Protocol** – Northern Ireland remains aligned with certain EU regulations, creating a dual regulatory environment. Therefore products may need to meet both UK and EU standards, depending on where they are sold or used. This creates additional bureaucracy, potentially impacting on timelines and the economic viability of new products.
- **REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) Regulations** – Biorefinery chemical products must comply with REACH, which can be challenging due to a lack of clarity around the classification of bio-based vs. fossil-based equivalents, and the need for tailor testing protocols for novel bio-based substances.
- **Renewable Transport Fuel Obligation (RTFO)** – Sets sustainability criteria for transport fuels. Biofuels must meet strict sustainability and carbon intensity standards, therefore biorefining fuel products are directly affected by RTFO compliance.
- **Packaging Waste and Compostability Regulations** – Governs the end-of-life treatment of packaging materials. But bio-based materials, particularly bio-based plastics, face hurdles due to a lack of harmonised standards on biodegradability, as well as unclear compostability certification pathways.
- **Plant Protection and Animal Feed Regulations** – Controls the use of biological agents in agriculture. The implications of this regulation on biorefining are that products used in agritech applications (e.g., enzyme-based crop protection, bio-based feed additives) will require risk assessments, field trial approvals and regulatory clarity on novel biological inputs.
- **Environmental Permitting Regulations (EPR)** – Affects industrial processes and waste management. Therefore, biorefining processes that use waste feedstocks must navigate complex permitting systems, which may not be well adapted to novel technologies.

Key recommendations, as set out in the “Strategic Roadmap for Standards and Regulations” BSI report, suggest the development of a regulatory map to guide stakeholders around the complex regulatory landscape. But there is also a need to create adaptive, risk-based regulatory models, and regulators should be engaged early in innovation processes to ensure that time and funding is not wasted on novel products that do not align with the regulatory landscape. The UK should also support standardisation that complements new and existing regulations which may impact on the UK's biorefining landscape. The aim of which would be to build trust amongst key stakeholders, including industry, policy makers and the general public.

9.1.5 Biorefining success stories

Over the past decade, a wide range of initiatives have impacted on the UK's biorefining landscape. This section will now explore the impact that these initiatives have had on overall sector development.

A report published by BBSRC titled "Evaluation of the effectiveness and impact of BBSRC's investments in Industrial Biotechnology" outlined where key investments were made over a ten-year period (2010/11 to 2020/21) in industrial biotechnology related initiatives. The review was conducted by an independent expert panel and assessed 568 grants with active spend during the review period. It revealed that the total investment in IB over this period was roughly **£413 million, including £42.4 million in co-funding** from EPSRC and Innovate UK.

The report outlined that BBSRC's IB investments had supported the generation of new knowledge across the breadth of the IB research area. The investments enabled the community to conduct high quality research, demonstrated by the portfolio's knowledge outputs. For example, 16% of journal publications within the BBSRC IB publication portfolio ranked in the top 10% of Web of Science (WoS) publications in terms of citation impact.

BBSRC's investments in IB had contributed to an excellent level of IP generation and covered a good variety of potential applications. Furthermore, BBSRC's IB investments had made very positive contributions to the establishment of spin-out companies. For example, 9% of grants with start dates between 2013 and 2017 reported a spin out arising from their grant. In total, IB investment had contributed to the establishment of 44 spin-out companies with incorporation years between 2010 and 2021. The majority of spinouts formed by BBSRC funded IB researchers were still active at the time of evaluation (2022) (Table 11).

Table 11: Spin-out companies reported as arising from BBSRC's IB portfolio.¹⁵

COMPANY NAME	INCORPORATION	DESCRIPTION	LOCATION
3D BIO-TISSUES	November 208	3D bio-printing of transplantable corneal replicates for the treatment of corneal stromal disorders.	Newcastle
AGROCEUTICAL LTD.	February 2012	Natural production of galanthamine – an active pharmaceutical ingredient in the treatment of Alzheimer's disease.	Hereford
ALPHACELLS BIOTECHNOLOGIES LTD.	February 2019	Development of novel cryopreservation technologies for banking of human cells intended for medical use.	Sutton
ALTERNOX SCIENTIFIC LTD.	February 2020	Development and upscaling of novel proprietary inhibitors of the enzyme alternative oxidase to be used in fungicides, for food crop and human anti-fungal treatment.	East Sussex
AMPROLOGIX LTD.	June 2018	Development and upscaling of a microbial production system for Epidermicins – a class of antimicrobial biologics that have the potential to treat antibiotic resistant bacterial diseases.	Plymouth
ANTIMICROBIAL DISCOVERY SOLUTIONS LTD.	June 2015	Antimicrobial resistance focussed business, providing consulting advice, reagents and assays to the AMR community.	Warwick

¹⁵ BBSRC. Evaluation of the effectiveness and impact of BBSRC's investments in Industrial Biotechnology. URL: <https://www.ukri.org/wp-content/uploads/2024/09/240924-BBSRC-12066-BBSRC-Industrial-Biotechnology-report-FINAL.pdf>

COMPANY NAME	INCORPORATION	DESCRIPTION	LOCATION
AR CITEKBIO LTD.	October 2018	Sustainable solutions for the manufacturing of xylitol – a natural sweetener with wide ranging applications as a sugar substitute from agricultural waste.	Aberystwyth
ARKVAX LTD.	November 2016	Using protein glycan coupling technology to produce low cost glycoconjugate vaccines from E.coli cells for use in veterinary settings.	London/ Cambridge
ATELERIX LTD.	June 2017	Transformative technology for the storage and transport of viable organic cells at room temperature, overcoming barriers and limitations presented by the current need for cryo-shipping.	North Shields
BENEFICIAL BIO	July 2019	A network of social enterprises run by biologists with the goal of helping labs around the world secure reagents quickly and economically, focusing on open-source registries.	Cambridge
BIO-SHAPE LTD.	November 2015	Cutting edge synthetic and analytical tools available for bioindustry needs, to analyse large and complex biomolecules with a focus on biopharmaceuticals.	Cheshire
C3 BIOTECHNOLOGIES LTD.	June 2015	Licensing company for technology that enables production of bio-propane.	Lancaster
CAMBRIDGE GLYCO SCIENCE LTD.	February 2017	Development and marketing of carbohydrates from plant cell walls for the food industry.	Cambridge
CELLULAREVOLUTION LTD.	December 2018	Refined continuous cell culturing techniques employable in various industries.	Sunderland
COLORIFIX LTD.	March 2016	Development of a new method to dye textiles using microbes to produce, deposit and fix pigments to fabric.	Norwich
CROMERIX LTD.	April 2021	Rapid phenotypic identification of bacteria and antibiotic susceptibility using priority nonlinear acoustic technique.	Loughborough
CYTECOM LTD.	March 2018	Fast and economic detection of microorganisms in a range of sample, for example, wastewater, food etc.	Coventry
DEEP BRANCH BIOTECHNOLOGY LTD.	July 2021	Carbon dioxide recycling via microorganisms to convert CO ₂ into high-quality protein substrate for livestock and agricultural feed.	London
EREBAGEN LTD.	March 2020	Engineering of soil bacteria to produce new bioactive natural products with hit-rates 20x better than synthetic chemicals currently being used in industrial screens.	Coventry
GREEN BIOACTIVES	January 2019	Utilising plants and cultured plant cells to produce biomolecules and cell extracts for the cosmetic, pharmaceutical, food and agricultural markets.	Edinburgh

COMPANY NAME	INCORPORATION	DESCRIPTION	LOCATION
GYREOX LTD.	May 2019	Creating novel medicines addressing complex intra-cellular targets in a wide range of diseases, via a proprietary platform technology based on a combination of chemistry and synthetic biology deploying a set of rationally engineered enzymes.	Oxford
HUMANE TECHNOLOGIES LTD.	January 2018	Design and development of life sciences research equipment.	Coventry
ICENI GLYCOSCIENCE LTD.	March 2014	Development of carbohydrate-based therapeutics and point-of-care diagnostics for infectious diseases.	Norwich
IMPERAGEN LTD.	November 2021	Development of fast enzyme engineering platforms.	Manchester
LABGENIUS LTD.	August 2012	Development of an autonomous AI-driven evolution engine for discovering high-value protein components.	London
LEAF SYSTEMS INTERNATIONAL LTD.	December 2014	Production of proteins, metabolites and complex natural products for research and bio-medical applications using plants.	Norwich
NUSPEC OIL LTD.	November 2019	Processing of novel rapeseed (and other) oils for industrial applications.	York
OGI BIO LTD.	February 2020	Development of a microbioreactor, to automate microbe culture (bacterial, yeast, or algae) thus replacing manual flask culturing.	Edinburgh
OXFORD BIOTRANS	August 2013	Development and commercialisation of enzymatic process technologies to produce high-value chemical compounds used for flavouring and fragrances.	Thame
PERSEPHONE BIO LTD.	July 2014	Production of bioactive compounds for the cosmetics and skin therapeutics sector from tomatoes.	Norwich
PHASE BIOLABS	May 2020	Development of carbon capture and utilisation (CCU) technology for industrial scale carbon dioxide recycling.	Nottingham
PURIDIFY	March 2013	Development of a nanofiber-based platform purification technology for biopharmaceutical production.	Stevenage
ROXIEN LTD.	November 2020	Commercialisation of novel analytical instrumentation for bioprocess monitoring and formulation of biologics.	St Albans
YOUNG OWL MICROFLUIDICS LTD.	December 2021	Commercialisation of novel microfluidic cell culture devices.	London
ZENTRAXA LTD.	March 2017	Design, production and testing of complex novel peptides for wider industry, utilising a proprietary peptide biosynthesis platform.	Bristol

Case studies for noteworthy successes in the biorefining industry are outlined below.

Celtic Renewables



Celtic Renewables is a spin out company founded in 2011 at Edinburgh Napier University. It was born from a research project aimed at finding sustainable alternatives to fossil fuels using biogenic carbon resources.

The company addresses a major challenge facing the biofuels sector – competing with petrochemical processes, which are often cheaper due to the cost of raw materials, meaning that there is a need for cost-effective, sustainable feedstocks.

Scotland's whisky industry produces vast amounts of draff (sugar-rich barley kernels) and pot ale (a yeast-based liquid remaining after distillation). These are considered relatively low-value, carbon-rich by-products of the whiskey production process. Celtic Renewables developed a novel process to convert these into biobutanol, a sustainable biofuel that can directly replace petrol in vehicles, requires no engine modification and offers a low-carbon alternative to fossil fuels.

Celtic Renewables uses a modernised version of the Acetone-Butanol-Ethanol (ABE) fermentation process. It converts whisky residues into high-value chemicals, producing biobutanol, bioacetone and bioethanol. These chemicals can be used in cleaning products, cosmetics and pharmaceuticals, as well as fuels.

Celtic Renewables has raised over £60 million in funding from a mix of public and private sources. Key milestones include:

- 2020–2024: Multiple equity crowdfunding rounds via Crowdcube, raising over £8.8 million from more than 5,700 investors.
- Scottish Enterprise contributed approximately £20 million, a third of the total investment for the Grangemouth biorefinery.
- Earlier rounds included grants from the Department of Energy and Climate Change (DECC) and venture capital backing from UK innovation funds.

In late 2021, Celtic Renewables completed the construction of their flagship Grangemouth Facility, with commercial operations beginning in 2024. The facility has the capacity to process 100,000 litre fermentations for the production of bioacetone, biobutanol and bioethanol. The carbon savings associated with these products are an estimated 65% compared to petrochemical equivalents, equating to nearly 3 tonnes of CO₂ saved per tonne of product produced.

Celtic Renewables is planning the development of 3–4 larger scale biorefineries over the next 4–5 years, demonstrating positive growth in the industry.

Holiferm



Holiferm is a pioneering UK-based biotechnology company driving innovation in sustainable biosurfactants. Founded in 2018, in Manchester, Holiferm aims to replace petrochemical surfactants with biodegradable, non-toxic biosurfactants using fermentation-based processes. Their patented gravity separation technology enables continuous fermentation, making production more efficient and scalable. This process is understood to use 50% less energy than conventional processes, meaning that Holiferm products can save up to 3 tonnes of CO₂ per tonne of biosurfactant produced compared to petrochemical alternatives.

Holiferm produces sophorolipid biosurfactants in high-foaming (HF) and low-foaming (LF) variants, marketed under brands like:

- Holisurf
- HoneySurf
- AgriSurf
- GranuSurf

Key applications for Holiferm products include in personal care (shampoos, cleansers and baby products), home care (dishwashing liquids, laundry detergents), industrial cleaning and agriculture (soil health, biocontrol, nutrient delivery).

The company raised over \$38 million across multiple rounds of funding, with support from the Clean Growth Fund, Rhapsody Venture Partners, Icos Capital and Greater Manchester Combined Authority. It now employs roughly 70 employees, and in February 2023 it opened its first commercial processing facility in the Wirral, UK. The initial capacity of this commercial plant was 1,100 tonnes per year, but it has since increased to 1,600 tonnes per year. It is further expected that by the end of 2025 the facility will be able to process 3,500 tonnes per year, and, eventually, it is planned that the site will be able to scale up to 15,000 tonnes per year.

Unilever

Unilever is a key example of an existing UK corporation who are actively transitioning towards a bio-based business model as part of its broader sustainability strategy. This shift is driven by the need to reduce greenhouse gas emissions, improve supply chain resilience and meet consumer demand for environmentally responsible products.



Unilever's bio-based transition goals are based on:

- Reaching net zero emissions across the value chain by 2039
- 100% sustainable sourcing of key crops by 2030
- Implementation of regenerative agriculture on 1 million hectares by 2030
- Reduction of Scope 3 emissions by 39% by 2030, with raw materials accounting for ~52% of total emissions

Examples of Unilever products and initiatives include:

- **Quix Dishwashing Liquid** – in partnership with Evonik, represents the first commercial launch of a biosurfactant-based cleaning product by Unilever.
- **Geno Partnership** – \$120 million joint venture with Genomatica to develop the use of fermentation-derived fatty alcohols to replace palm oil in surfactants. This has the potential to reduce the carbon footprint of palm-derived ingredients by up to 50%.
- **REN Clean Skincare** – production of fermented bisabolol as a bio-based ingredient for the replacement of wild-harvested chamomile extract, reducing pressure on natural ecosystems.
- **Plant-based foods** – in partnership with Algenuity for brands like Magnum, Hellmann's and the Vegetarian Butcher. Producing microalgae-derived proteins for climate-friendly, vegan products.

9.1.6 UK scale-up infrastructure

A key part of building a successful and resilient bioeconomy relies on the ability to scale up lab-based innovations into commercial, scalable solutions. Therefore, support for scale-up infrastructure plays an essential role in the development of the biorefining landscape.

BBSRC's "Evaluation of the effectiveness and impact of BBSRC's investments in Industrial Biotechnology" report highlighted that barriers to infrastructure access, especially scale-up facilities, can hamper development in this sector. According to this report, 42% of researchers cited lack of scale-up infrastructure or funding for scale-up activities, as being a barrier to commercialisation.

BioPilots UK, officially launched in October 2016, was formed as a strategic alliance between five open-access biorefining centres across the UK, to address the barriers associated with technology scale-up. The centres provided pilot-scale equipment, process development expertise and technological support for SMEs and researchers. The five centres included:

- 1. Biorenewables Development Centre (BDC) (York, England)** – The BDC operates as a subsidiary of the University of York. It works at the interface between academia and industry and has received funding from the UK Shared Prosperity Fund, ERDF and UKRI to expand its capabilities. Services offered at the BDC include raw materials characterisation (e.g. chromatography, water analysis, oxidative stability, nucleic acid analysis, microscopy), system development (e.g., fermentation, microbiology, molecular analysis), pre-processing and processing (e.g., pelletising, maceration, microwave hydrothermal equipment, distillation, ultrafiltration, spinning cone, supercritical CO₂ extraction), and product evaluation (such as expertise in analytical chemistry, microbiology, plant growth trials). The BDC supports projects across the bioeconomy, including the food and drink sector, bio-based chemical production, bioenergy production, bio-based textiles and construction materials, cosmetics, and agriculture. The BDC has delivered over 1,500 bio-based projects since the centre's inception, and it has supported more than 300 local SMEs since 2012.
- 2. Centre for Process Innovation (CPI) (Redcar, England)** – CPI is a key player in the UK's innovation ecosystem. It operates 10 innovation centres across England and Scotland and is a founding member of the High Value Manufacturing Catapult. CPI provides end-to-end support for innovation, from concept to commercialisation, including: product and process development (i.e., lab-to-pilot scale support for bioprocessing, formulation and manufacturing); prototyping and scale-up; pilot production; commercialisation support (including business modelling, IP protection and regulatory guidance); funding navigation (helping projects access Innovate UK, EU Horizon and private investment). CPI operates a number of national centres covering a wide range of disciplines, but the National Industrial Biotechnology Facility (NIBF) in Wilton, Redcar is the one most relevant to the UK's biorefining landscape. In 2021, the NIBF received £4 million in funding from the Tees Valley Combined Authority to expand its bio-manufacturing capabilities.
- 3. Industrial Biotechnology Innovation Centre (IBioIC) (Scotland)** – Founded in 2014, IBioIC is a European centre of excellence for industrial biotechnology. It continues to grow, recently surpassing 300 member organisations and securing long-term funding from the Scottish Funding Council. IBioIC supports innovation from concept to commercialisation through scale-up facilities, innovation support, skills development, networking and collaboration, and facilities access. The centre has supported over 200 collaborative research projects and over 260 companies (including startups, SMEs, and corporates). It has also leveraged £6.8 million in initial support, followed by £35 million in additional investment. This has allowed IBioIC to deliver £25 million worth of training and support nearly 500 students, launch 25+ startups, and attract £140 million in inward investment. The centre is on track to generate £1.2 billion in turnover and create 4,000 jobs by 2025.¹⁶

16 Azo Life Science. Decade of IBioIC Support Boosts Scotland's Bioeconomy with £35 Million of Innovation Investment. 2024. URL: <https://www.azolifesciences.com/news/20240312/Decade-of-IBioIC-Support-Boosts-Scotland-28099s-Bioeconomy-with-c2a335-Million-of-Innovation-Investment.aspx>

- 4. BEACON (Wales)** – A collaborative project between Aberystwyth University, Bangor University, Swansea University and later the University of South Wales. It was active between 2011 and 2023, funded primarily by the European Regional Development Fund (ERDF) through the Welsh Government. Its mission was to promote low-carbon technologies, support SMEs in developing bio-based products, facilitate inward investment and job creation, and expand upon Wales’ scientific skill base. The BEACON centre hosted pilot-scale fermentation equipment (2L to 340L bioreactors and 500L solid-state fermentation), downstream processing equipment (including high-pressure homogenisation, membrane filtration (MF/UF/NF/RO), evaporation, spray drying, and fluid bed granulation), food-grade processing, advanced analytics and access to academic expertise. The centre drew on multidisciplinary expertise in: microbiology, enzymology and metabolic engineering, chemistry and physicochemical processing, biocomposites and biodegradable materials, and life cycle assessment and sustainability analysis. The centre supported over 140 companies over its lifetime, delivered 50+ collaborative R&D projects, created 52 green jobs in Wales, and helped to develop platform chemicals (e.g. lactate, succinate), bioplastics and biocomposites.
- 5. The Biorefinery Centre (Norwich, England)** – The Biorefinery Centre was launched around 2011 as a pilot-scale facility, focussed on converting agricultural and food waste biomass into biofuels and bio-based chemicals. It formed part of the Institute of Food Research (IFR), which has since been merged into the Quadram Institute. The centre was designed to support early-stage industrial biotechnology and bioenergy projects, including a steam explosion pilot plant (used to break down lignocellulosic biomass to extract fermentable sugars), bio-based alcohol production (e.g., fermentation of sugars into bioethanol and other alcohols), industry collaboration, validation and testing. The centre received initial funding of £350k from the East of England Development Agency (EEDA) and BBSRC.

The aim of BioPilotsUK as an alliance was to combine capabilities, infrastructure and expertise in order to help to commercialise bio-based technologies. While it no longer exists as a strategic alliance, a number of centres remain operational (namely CPI, BDC and IBiolC) and they continue to make invaluable contributions to the UK’s biorefining industry.

9.1.7 Regional place-based investment

In addition to specific companies and scale-up facilities, there have been several success stories across the UK when whole regions have been supported, making use of local strengths for the generation of national assets.

Regional support can be very effective at driving bioeconomy growth, as funding can be tailored to the region’s capabilities (e.g., whiskey by-products in Scotland, and farming strengths in Yorkshire). This also encourages SMEs working within supported regions to innovate with local feedstock and infrastructure, leading to more sustainable, place-based solutions.

In these regions, universities can work with local businesses to co-develop technologies, with regional authorities acting as conveners and funders. Furthermore, open-access centres (e.g., CPI, BDC) can provide lab and pilot-scale facilities.

A key example of regional investment to create a thriving bioeconomy hub can be seen in Scotland. Scotland’s drive to build its bio-based capacity is integrated into its economic policymaking, making bio-based production more likely to scale. For example, the National Plan for Industrial Biotechnology (2013) is now incorporated into the nation’s “National Strategy for Economic Transformation” (2022), a 10-year plan to develop Scotland’s economic potential.

Scotland is building a thriving bioeconomy centred around high-value biotech to leverage the research outputs of its world-renowned universities and highly skilled workforce. The main axis of implementation are the 300 organisation members¹⁷ of Scotland's Industrial Biotechnology Innovation Centre (IBiolC), many of which are headquartered in Scotland¹⁸. The innovation centre is split between two locations. The FlexBio site, hosted at Heriot-Watt University in Edinburgh, which focuses on de-risking the scale-up of biotech production; and RapidBio, hosted at the University of Strathclyde in Glasgow, which focuses on microbial media improvement through process scale-down, cell-line selection. Scotland also has a Bioeconomy Cluster Builder (BCB) that supports Scottish micro-companies and SMEs looking to develop products or services that use biotechnology.

Scotland is moving towards linking traditional food sectors with industrial bio-based production. For example, Scotland's whisky industry generates waste by-products that can have multiple uses across different sectors, including biogas, with new value chains being tested under a collaboration between the Scotch Whisky Association and IBiolC. Scottish companies have been exploiting crossovers between agriculture and industry by producing high-value products from vegetables and food waste. CelluComp is a key example of a company working in this sector that already operates commercially in the region – the company extracts root vegetable fibres to make additives for paints, coatings, inks and personal care products.

Grangemouth, located on the Firth of Forth, is one of Scotland's most significant industrial hubs. Historically, it has been home to INEOS and Petroineos, chemical and petrochemical industries, and the Port of Grangemouth. However, the site is undergoing a major transition due to the planned closure of the Petroineos refinery in 2025, which threatens roughly 400 jobs. This shift represents a broader strategy to decarbonize the region and repurpose the site for sustainable industrial activities.

The Grangemouth Industrial Cluster is now being reimagined through a Just Transition Plan, aiming to support affected workers and communities, attract new investment and develop low-carbon manufacturing and energy projects. Project Willow was a £1.5 million feasibility study jointly funded by the UK and Scottish Governments, designed to explore low-carbon alternatives for the Grangemouth site. This study evaluated 300 technologies, selecting nine promising projects, and outlined that £3.5 billion in private investment would be needed to realise their base case scenario. The study indicated that the site could create up to 800 new jobs and add £700 million to the economy by 2040. One of nine promising projects identified was the ABE fermentation process, that converts by-products and waste from industries such as food, drink and agriculture into bio acetone, bio butanol and bio ethanol (ABE). Scottish biotechnology company Celtic Renewables' operate a flagship processing plant in Grangemouth which is branded as Scotland's first biorefinery. The refinery was commissioned 2024 with the first shipments of commercial product made in November 2024.

17 IBiolC. Press Release: Innovation network gains 100 new members in less than a year. 2024. URL: <https://www.ibioic.com/news-database/innovation-network-gains-100-new-members-in-less-than-a-year>

18 Future Scot. More than 150 companies join Scotland's industrial biotechnology innovation centre. 2023. URL: <https://futurescot.com/more-than-150-companies-join-scotlands-industrial-biotechnology-innovation-centre/>

9.1.8 Summary

This report describes the biorefining landscape in the UK over the past decade, including the role of science and innovation, effective policy and a favourable regulatory framework on building a bioeconomy.

Since the formation of the NIBB in 2014, the sector has seen a considerable amount of investment into R&D with BBSRC committing £413 million in funding to projects in IB, including £42.4 million in co-funding from EPSRC and Innovate UK. As a result of this, the sector has seen a large number of spin-outs forming across the different application areas, and companies large and small are finding success in this space.

A PESTLE analysis can be used to summarise the biorefining landscape:

- **Political** – The UK government actively supports the bioeconomy through policy and national strategies, positioning the bioeconomy as a key pillar for achieving net zero. Public-private partnerships are encouraged with initiatives like the NIBB and regional biorefining hubs.
- **Economic** – The UK's bioeconomy contributes £220 billion in GVA, and supports over 5 million jobs. Investment in biotechnology and biorefining is growing, with £3.5 billion secured in 2024 alone. Key challenges facing the sector include high capital costs for scale-up, limited access to infrastructure and the need for sustained private investment. Biorefineries are seen as engines for regional economic development, especially in rural areas.
- **Social** – Public awareness of sustainability and climate change is driving demand for bio-based products. Biorefining offers job creation, supports food security and contributes to community resilience. Social acceptance is generally positive, but concerns around land use and feedstock sourcing (e.g., food vs. fuel debates) persist.
- **Technological** – The UK is a world leader in engineering biology, incorporating synthetic biology and biomass conversion technologies. Technology transfer and scale-up remain bottlenecks, requiring better infrastructure and skilled workforce development.
- **Legal** – The UK's regulatory framework supports innovation but must balance safety, environmental standards and market access. Post-Brexit divergence from EU regulations offers flexibility but may complicate international trade. Regulatory alignment and the development of standards are recognised as key regulatory needs of the sector.
- **Environmental** – Biorefining is central to the UK's net zero strategy, offering carbon-neutral alternatives to fossil-based products.

Despite the vast number of successes experienced by this sector, there remain instances where commercial goals have not materialised, indicating that more should be done going forward to help UK biorefining realise its full potential.

9.2 Stakeholder perspectives (Frey Consulting)



Stakeholder engagement formed a central element to this project, providing critical insights into the evolution of the UK biorefining sector and the wider bioeconomy over the lifetime of the BBSRC NIBB, and into the future.

The engagement was designed to capture a broad range of perspectives – from academia, industry, policy, funding, regulation and investment, and to build a deeper understanding of how research, technology development, scale-up and commercial activities have progressed, as well as the opportunities and challenges that remain.

This engagement complemented the quantitative findings from the landscape reviews and economic analysis, ensuring that the project's outputs were informed by real-world experiences and validated against the views of those directly involved in biorefining. To achieve these aims, the project adopted a structured, two-tiered approach to stakeholder engagement:

- **An online survey of BBNet members and other key stakeholders**, designed to capture developments in biorefining activities between 2014 and 2024 and to identify key barriers, achievements, and future needs.
- **Follow-up one-to-one interviews** with a subset of survey respondents, undertaken to explore findings in greater depth and to capture nuanced perspectives on scale-up challenges, international comparisons and lessons for the future of UK Biorefining.

The outputs of both the survey and the interviews are combined and highlighted in this report.

9.2.1 Stakeholder engagement demographics

In total 76 individuals responded to the online survey, from 70 different organisations.

- 45% of respondents were from academia, 35% from industry and the remaining 20% were from scale-up companies, Government, NGOs and 'others' that do not fall into a defined category.
- 41 individuals were interviewed, from 39 organisations. Of these organisations, 16 were from academia and 23 were from industry.

Figure 20: Survey respondents by stakeholder type.

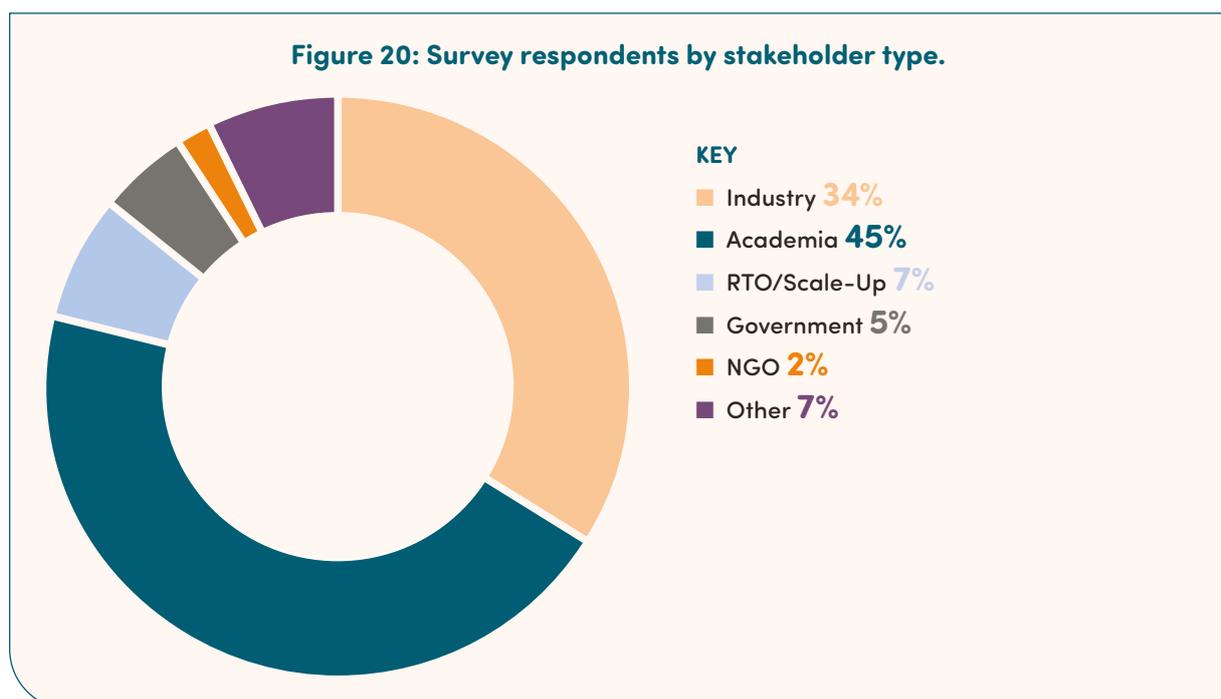


Figure 21: Survey respondents by sector.

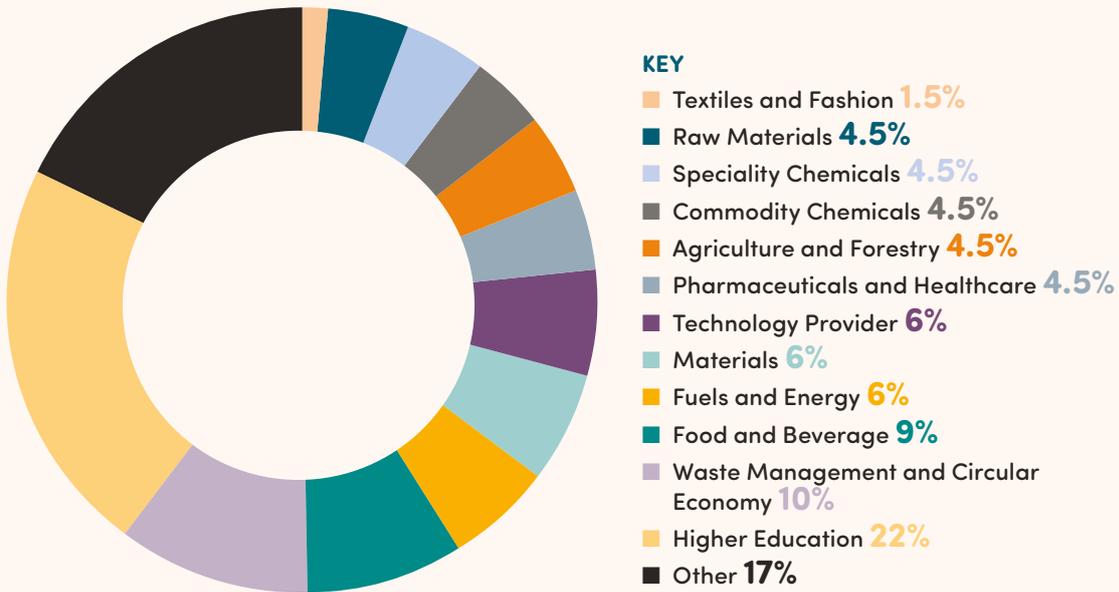
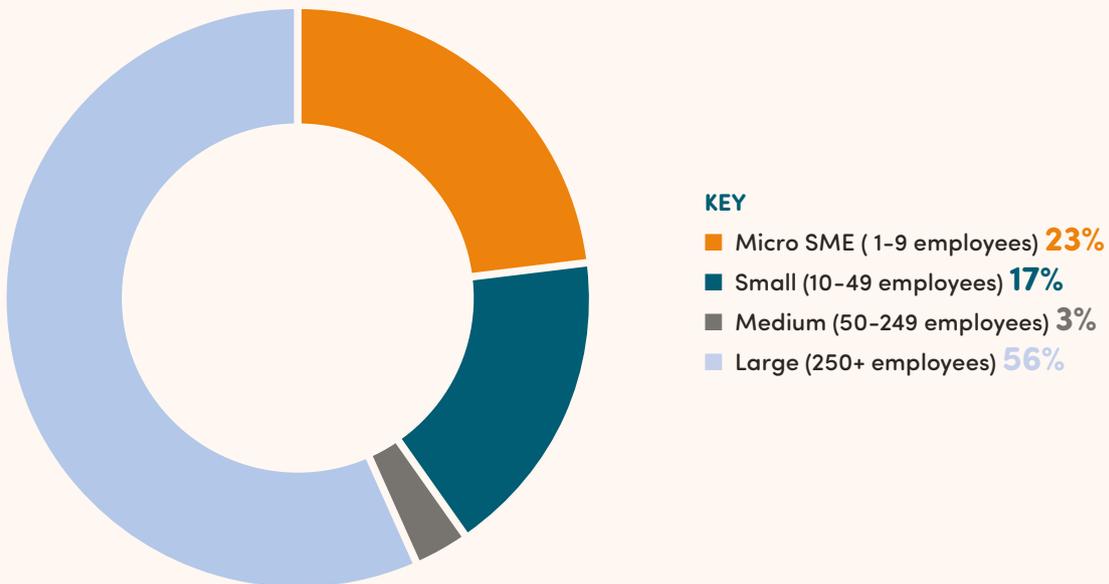


Figure 22: Survey respondents by size of organisation.



9.2.2 A decade of progress

To capture a comprehensive picture of how UK biorefining has evolved over the past decade, stakeholders were engaged through both online surveys and in-depth interviews. Participants were invited to reflect on key aspects of progress and change across the sector, including:

- **Technological progress** – the extent to which UK biorefining research and innovation have delivered meaningful scientific and technological advances.
- **Industrial growth** – whether the UK’s biorefining industry has expanded significantly in scale, capacity and economic contribution.

- **Market and regulatory environment** – how far the UK’s policy and regulatory landscape has become more favourable to biorefining and bio-based innovation.
- **Policy alignment** – whether national industrial strategies, innovation frameworks and government initiatives have become increasingly supportive of the sector.
- **Major achievements** – the most significant successes in UK biorefining over the last ten years.
- **Missed opportunities** – areas where potential was not realised or where progress fell short.

Over 70% of survey participants agreed that, over the past decade, UK biorefining research and innovation has delivered important technological advances.

However, only 36% felt that the sector itself has grown significantly during this period.

Interviews reinforced this view, highlighting that much of the innovation remains concentrated at the university level and has not successfully scaled into industry.

In addition, confidence in the policy and regulatory landscape remains low. More than 64% of respondents disagreed or were neutral on whether government strategies have become more supportive, and over 77% expressed the same view regarding the regulatory environment.

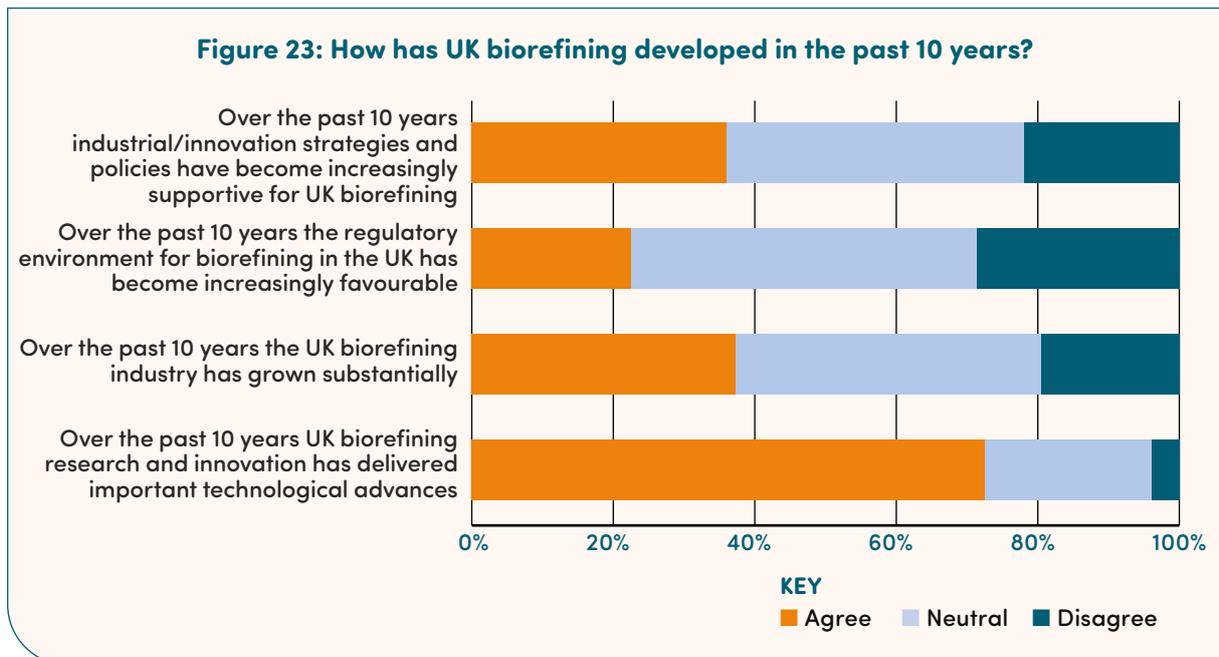


Table 12: Biggest UK biorefining success in the last 10 years.

AREA	INFORMATION
COMPANIES	Several companies were frequently named as the UK's biggest biorefinery successes, including Holiferm, ENOUGH, Celtic Renewables, MiAlgae, Ensus and Vivergo. Azotic Biotechnologies and Calysta were also mentioned as having moved from lab to commercial product at scale over the past 10 years.
PRODUCTS	Bioethanol, sustainable aviation fuels, fermentation for high value chemicals, anaerobic digestion and biogas were identified as having been key in the last decade. In addition, the increasing diversification of biorefining technologies not just looking into fuels and chemicals but into the food sector was noted, with large projects such as the UKRI Mission food hub for Microbial foods and the Bezos Centre for Sustainable Proteins.
POLICY AND REGULATIONS	Recognition in strategy and policy that biorefining offers an opportunity to provide benefits to industry and sustainability, was seen as very positive. The nationwide rollout of E10 petrol in 2021 was also highlighted, as it created a mass and durable market for bioethanol in the UK – delivering immediate emissions reductions and catalysing domestic production capacity. Recognition in policy of the need for both decarbonisation and defossilisation was also cited as progress.
FUNDING	The IB Catalyst and Innovate UK funding into industrial/academic partnerships was highlighted as being key to many successes in the last ten years. BBSRC NIBB were also seen as being instrumental in laying the foundations of UK Biorefinery research and connecting academia and industry.

Table 13: Biggest UK biorefining lost opportunity in the last 10 years.

AREA	INFORMATION
COMPANIES	The loss of Vivergo following the UK-US trade agreement was widely cited as the biggest setback for UK biorefining in the past decade, highlighting how policy and trade deals can make or break the sector. Similarly, ENOUGH and Lixea relocating their full-scale plants abroad were noted as major losses to the UK.
PRODUCTS	The UK has struggled to scale products in engineering and synthetic biology. A 2025 House of Lords report notes that despite leadership in bioengineered plants, lab-grown materials and waste-to-fuel bacteria, gaps in funding, policy and incentives have hindered commercialisation. As a result, many pioneering companies relocate abroad, losing economic benefits and leadership in this transformative field.
POLICY AND REGULATIONS	A biomass strategy that prioritises BECCS over value-added, integrated biorefineries for sustainable chemicals and materials, coupled with insufficient support for bioethanol production as a foundation for future biorefineries is a lost opportunity. This, alongside the withdrawal of the UK Bioeconomy Strategy, has weakened the sector.
FUNDING	Discontinuation of the IB Catalyst programme. Limited public funding for TRL 6 – 9. Lack of government understanding of sector needs have left industrial early adopters unsupported. Many promising biorefining and bio-based companies fail just before reaching financial stability.

9.2.3 Current landscape and challenges

To capture a comprehensive picture of how UK biorefining has evolved over the past decade, stakeholders were engaged through both online surveys and in-depth interviews. Participants were asked to reflect on key areas, including:

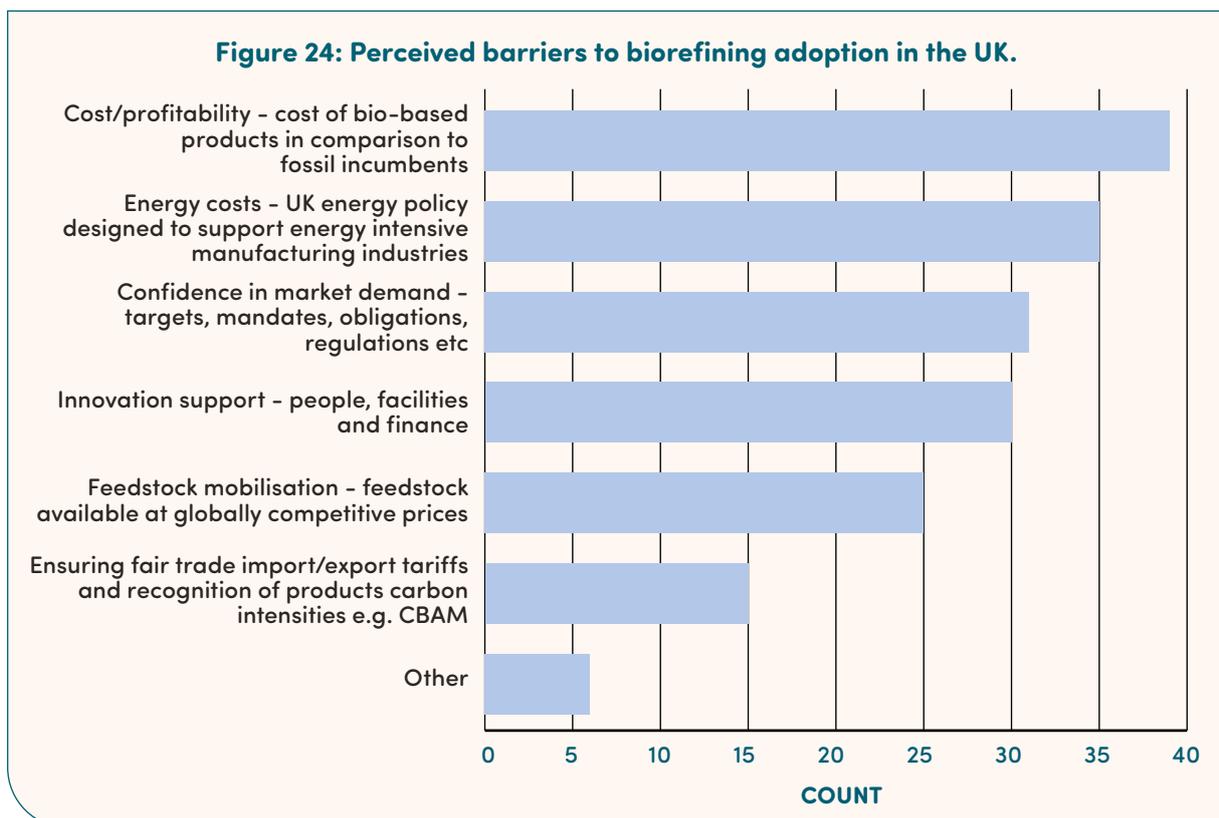
- **Barriers to adoption in the UK** – Examining the main obstacles preventing widespread adoption of biorefining, including feedstock availability and cost, energy and operational expenses, regulatory and market uncertainty, competition from fossil-based alternatives, trade challenges, and gaps in innovation support such as skills, funding and facilities.

- **Access to scale-up infrastructure** – Assessing the UK’s capacity to advance biorefining technologies from lab and pilot stages to commercial-scale production. This includes the availability of demonstration facilities, processing plants, logistics, and supportive manufacturing environments that enable industrial-scale operations.

9.2.3.1 Barriers to biorefining adoption in the UK

Stakeholders were asked “What are the main barriers to the adoption of biorefining in the UK?”. The answers can be outlined as follows:

- **Cost and profitability (43 respondents):** The most significant barrier is the high cost of bio-based products compared to fossil incumbents. This indicates that economic competitiveness is the biggest challenge for scaling biorefining. Unless bio-based solutions can achieve cost parity, market adoption will remain limited.
- **Energy costs (35 respondents):** UK energy policies and the high costs associated with energy-intensive manufacturing are another major challenge. Since biorefining is energy-intensive, unfavorable energy pricing undermines competitiveness.
- **Market confidence and demand (33 respondents):** A lack of clear market signals – such as binding targets, mandates, regulations or obligations – creates uncertainty for investors and businesses. Without assured demand, companies hesitate to invest in biorefining infrastructure.
- **Innovation support (30 respondents):** While innovation is happening, barriers exist in securing sufficient people, facilities and financing to accelerate progress. This reflects gaps in the broader innovation ecosystem, which are vital for scaling up new technologies.
- **Feedstock mobilisation (28 respondents):** The availability of sustainable feedstock at globally competitive prices is another constraint. Ensuring secure, affordable and reliable access to raw materials is critical for the sector’s growth.
- **Fair trade and carbon recognition (15 respondents):** Tariffs and mechanisms like the Carbon Border Adjustment Mechanism (CBAM) could influence competitiveness. Recognition of the lower carbon intensity of bio-based products is necessary to level the playing field internationally.



The UK government's Industrial Strategy sets a bold ambition: to make the UK a top three global hub for fast-growing technology businesses by 2035.

A central pillar of this vision is engineering biology, a sector pivotal to the £30 trillion global industrial bioeconomy. The government has committed £2 billion over the next decade to this field, including £380 million for R&D and infrastructure.

However, the UK's outdated and fragmented regulatory framework poses a significant threat to this ambition. Without urgent reform, the UK risks losing its competitive edge to global rivals like the US, EU and Singapore, who are already modernising their regulatory environments.

Three Critical Risks:

- **Company exodus:** UK bio-based SMEs are relocating to countries with more supportive regulatory ecosystems, leading to a loss of jobs, IP and taxpayer-funded innovation.
- **Investment drain and company failure:** Regulatory uncertainty and extended timelines are increasing perceived risk for investors, causing startups to fail or downscale and putting billions in public R&D at risk.
- **Delayed economic gains:** Every regulatory delay defers significant economic and environmental benefits, including green jobs, tax revenues and market leadership.

For just 3 UK SMEs the UK is losing £35.7 million in annual GVA – and over 473 potential jobs remain unrealised, representing a significant and avoidable economic drain. With hundreds of similar bio-based SMEs in the UK, the actual annual loss could easily be estimated to be well into the tens of billions.

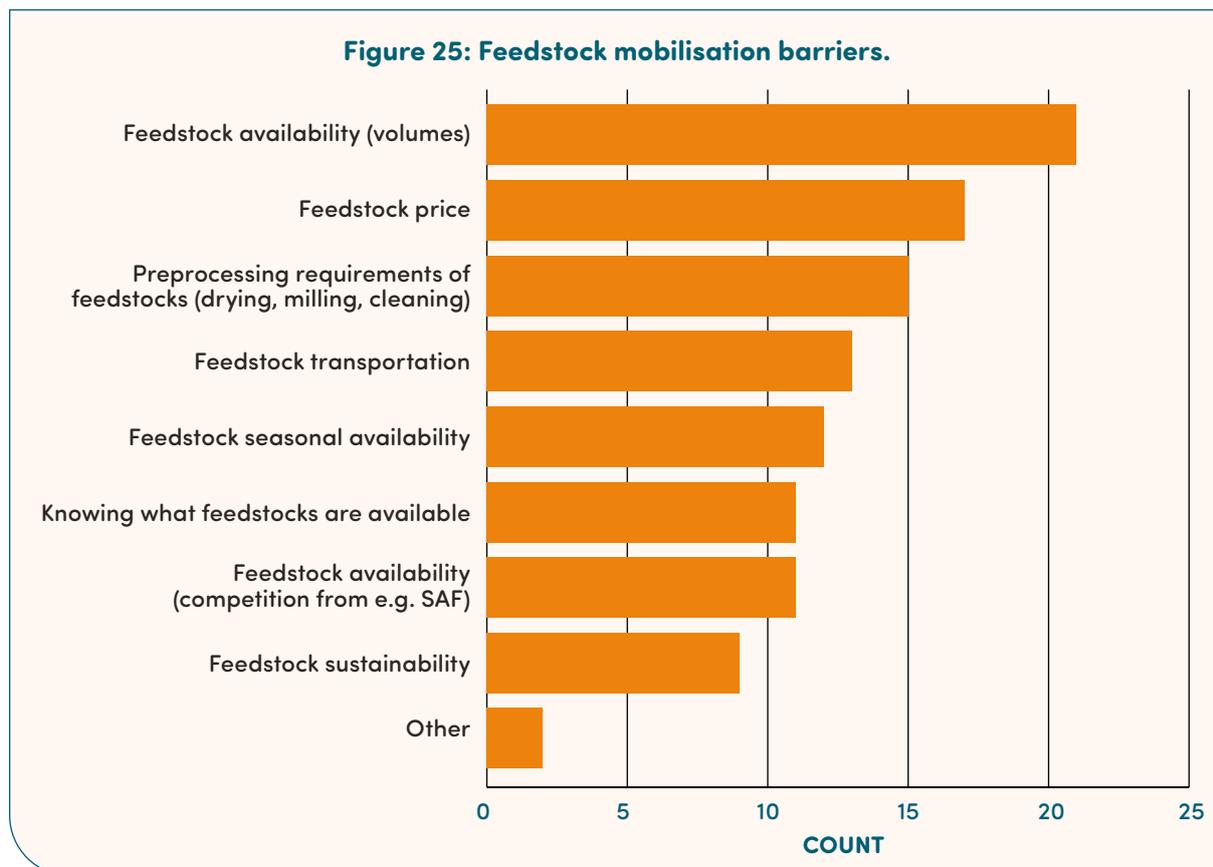
While the UK has world-leading research and early-stage innovation in bio-based technologies, companies face regulatory systems that are outdated, fragmented and not designed for the novel aspects of bio-based products. As a result, commercialisation is slow, investment is deterred, and SMEs are disproportionately affected.

- 1. No bio-based-specific regulatory frameworks** – UK regulations often fail to differentiate between fossil-based and bio-based products, applying the same rules despite their very different environmental and toxicological profiles. UK REACH offers no streamlined routes for low-toxicity, renewable alternatives. Food contact regulations do not yet accommodate biodegradable coatings, bio-based films, natural additives, or emerging sustainable packaging materials.
- 2. Lengthy, high-cost authorisation procedures** – Approval processes are complex, slow and costly – often requiring the same burden of proof as petrochemical substances. SMEs, in particular, face barriers in terms of both time and cost. Lack of risk proportionality creates unnecessary delays for low-risk innovations.
- 3. Lack of clarity for novel materials** – New materials such as fibre-based packaging, algae-derived films and mycelium-based trays don't fit neatly into existing regulatory categories. Companies often get passed between agencies (HSE, FSA, OPSS, Defra) with no clear lead authority. The Engineering Biology Regulators Network is a good initiative but experience to date is not positive.
- 4. Fragmented oversight and lack of coordination** – Regulatory responsibilities are dispersed and overlapping. A product like a biodegradable lubricant may be regulated under REACH (chemical safety), Defra (environmental impact), and OPSS (consumer safety). For food-contact packaging made from seaweed, responsibilities may span FSA, OPSS and Defra. The lack of coordination creates delays and confusion, especially for resource-constrained companies.

9.2.3.2 Feedstock mobilisation barriers

Stakeholders were asked “In terms of feedstock mobilisation, which aspects are barriers to biorefining in the UK?”. The answers can be outlined as follows:

- **Feedstock availability (volumes)** – The most frequently cited barrier. This reflects limited large-scale, consistent supply of suitable biomass or waste materials in the UK, driven by competition between sectors (e.g. energy, transport, and chemicals) and regional disparities in resource availability.
- **Feedstock price** – High costs are a major deterrent for biorefining investment. Limited domestic supply, fragmented markets and transportation costs often make bio-based feedstocks more expensive than fossil-based alternatives.
- **Preprocessing requirements (drying, milling, cleaning)** – Many potential feedstocks (e.g. agricultural residues, food waste) require costly and energy-intensive pre-processing before they can be used, reducing the overall economic viability of biomass utilisation.
- **Feedstock transportation** – Biomass is bulky and often produced far from processing sites, making logistics and transport costs significant. This issue is amplified by the lack of regional collection and aggregation infrastructure.
- **Feedstock seasonal availability** – Agricultural and forestry residues are produced cyclically, leading to supply fluctuations and storage challenges for biorefineries that require year-round operation.
- **Knowing what feedstocks are available** – Stakeholders report a lack of clear, up-to-date data on local and national feedstock sources, qualities and quantities, which limits planning and investment confidence.
- **Feedstock availability (competition from e.g. SAF)** – Growing demand for bioresources from other sectors, particularly sustainable aviation fuels (SAF), increases competition and drives up prices, constraining supply for chemicals and materials production.
- **Feedstock sustainability** – Ensuring feedstocks meet sustainability standards (e.g. carbon footprint, land use, biodiversity) adds complexity and cost and can limit the types of materials that can be sourced.



9.2.3.3 Innovation support barriers

Stakeholders were asked “In terms of innovation support, which are the barriers to biorefining in the UK?”. The results can be outlined as follows:

Top barriers:

- The lack of long-term, patient capital and investment security, and limited access to pilot and demonstration facilities were identified as the most significant barriers. This reflects the capital-intensive nature of biorefining, and the high risk associated with scaling technologies from lab to commercial scale.
- Fragmentation between research, industry and government support programmes, and difficulty securing public funding or grants, were also frequently cited. These point to systemic issues in coordination and access to consistent support mechanisms.

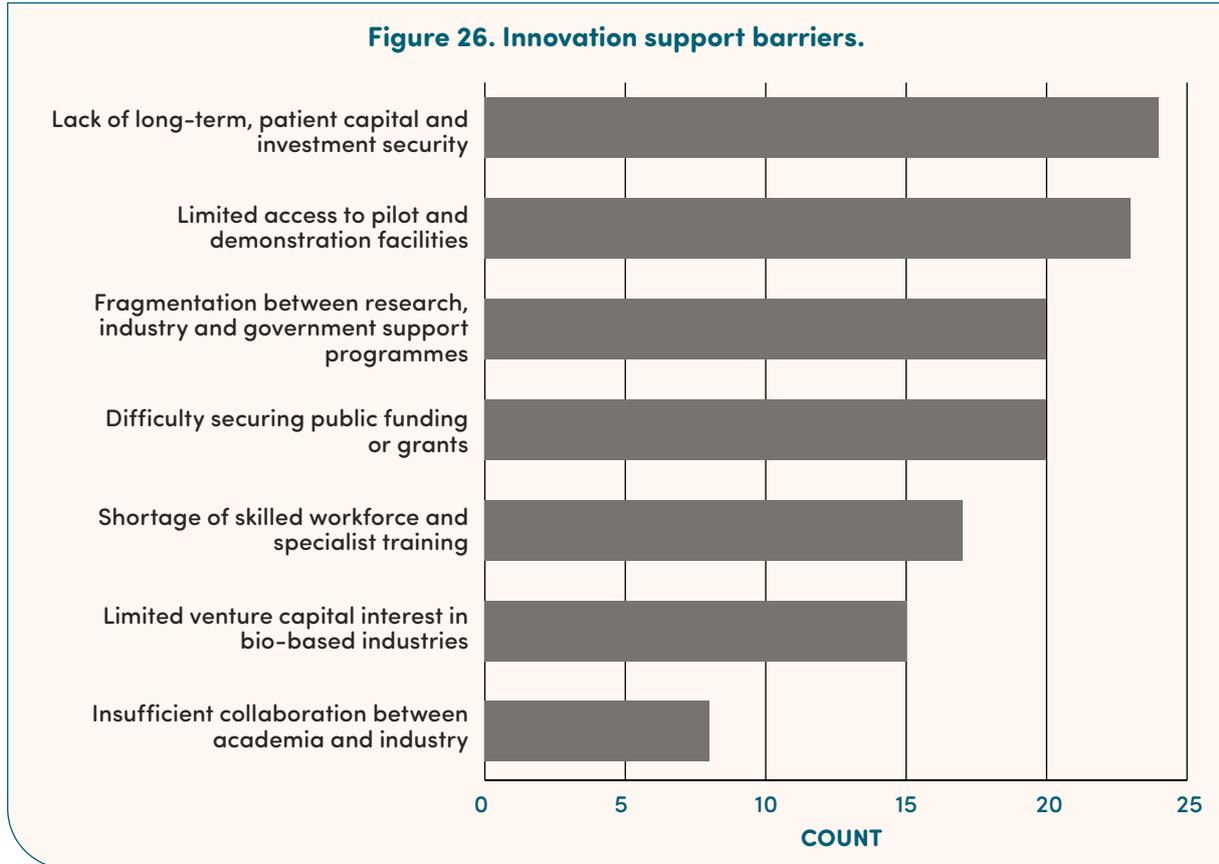
Moderate barriers:

- Shortage of skilled workforce and specialist training, and limited venture capital interest in bio-based industries indicate human capital and investor confidence challenges.

Lower barriers:

- Insufficient collaboration between academia and industry was seen as less of a constraint, suggesting that partnerships exist but may not be fully leveraged to support commercialisation.

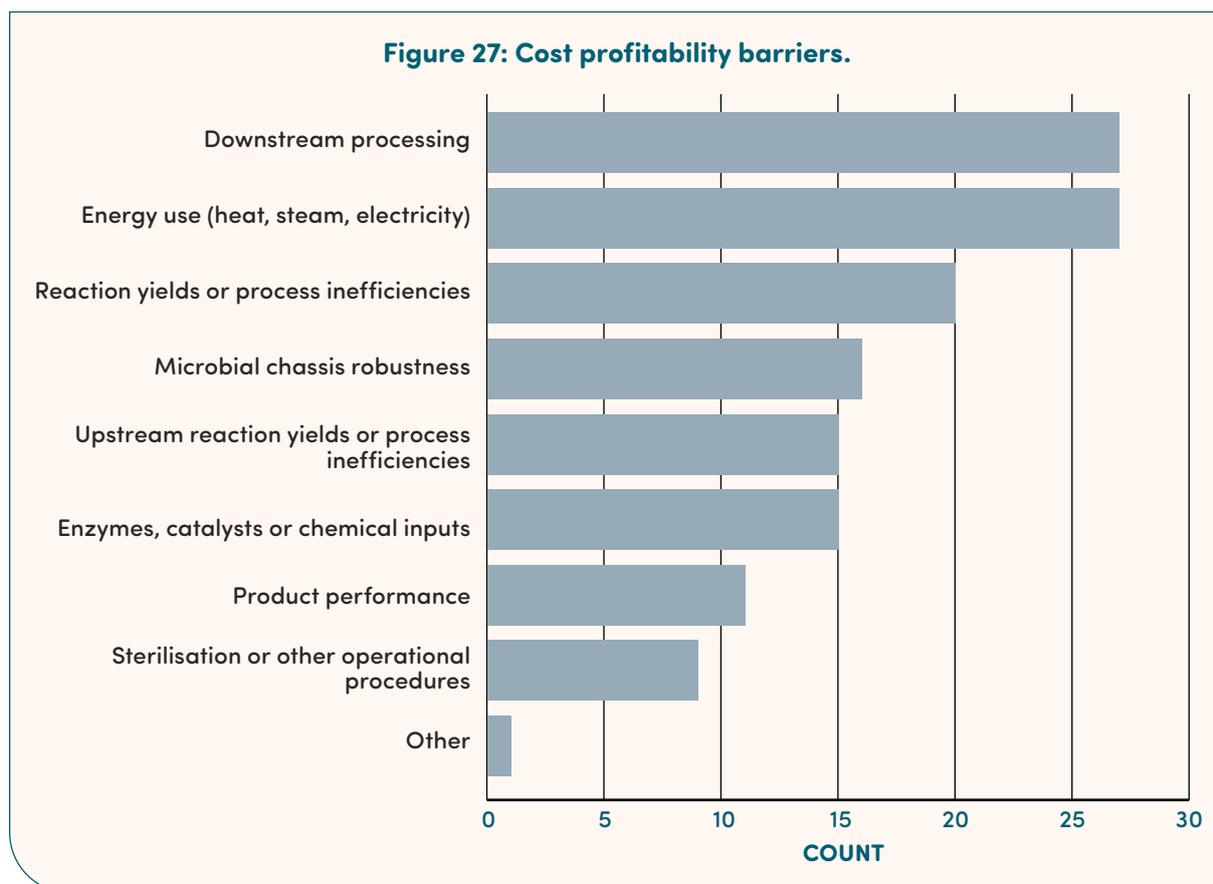
Overall, the responses suggest that while the UK has a strong research base, translating innovation into commercial biorefining success is hindered by funding gaps, investment insecurity and infrastructure limitations.

Figure 26. Innovation support barriers.

9.2.3.4 Cost/profitability barriers

Stakeholders were asked “In terms of cost/profitability, which are barriers to biorefining in the UK?”. The answers can be summarised as follows:

- The main barriers identified are downstream processing and energy use, followed by process inefficiencies and biological or input-related challenges.
- Downstream processing and energy use (heat, steam, electricity) are the leading cost drivers. Both require high energy inputs and complex equipment, making purification and operation expensive.
- Reaction yields and process inefficiencies limit productivity and scalability, often due to suboptimal biological systems or variable feedstocks.
- Microbial chassis robustness issues reduce reliability under industrial conditions, while enzyme, catalyst and input costs remain high due to limited supply and reuse options.
- Upstream inefficiencies – such as costly biomass pretreatment – further add to production costs.
- Product performance and operational demands like sterilisation contribute additional costs, especially when bio-based products underperform compared to petrochemical alternatives.

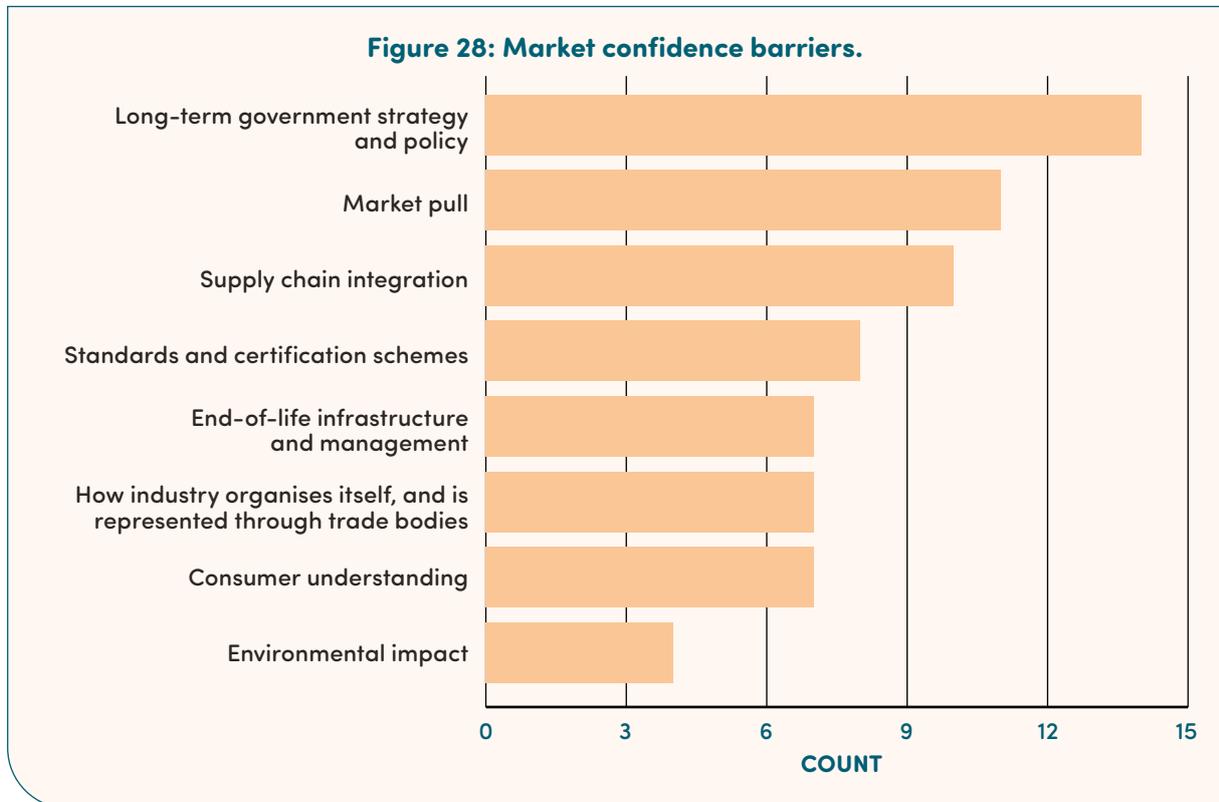


9.2.3.5 Market confidence barriers

Stakeholders were asked: “In terms of confidence in market demand, which are barriers to biorefining in the UK?”. The answers can be summarised as follows:

- **Long-term government strategy and policy:** Identified as the most significant barrier, reflecting widespread uncertainty around consistent and supportive policy frameworks. The absence of clear, long-term strategies, incentives and funding mechanisms undermines investor confidence and limits commitment to biorefining projects.
- **Market pull:** A lack of strong market demand from consumers and industry reduces incentives for investment and scale-up. Without clear market signals or procurement support, biorefining products struggle to compete with fossil-based alternatives.
- **Supply chain integration:** Challenges in linking feedstock suppliers, processing facilities and end-users hinder the development of efficient value chains. Limited coordination across sectors slows commercialisation and adds operational risk.
- **Standards and certification schemes:** The absence of clear, trusted and widely recognised standards for biorefining products generates uncertainty among buyers and investors. This gap constrains market acceptance and confidence.
- **End-of-life infrastructure and management:** Concerns persist around the disposal, recycling and broader circularity of biorefining products. Weak end-of-life systems limit the sector’s sustainability potential and environmental credibility.
- **Industry organisation and trade representation:** A fragmented industry landscape with limited collective voice makes it more difficult to influence policy, coordinate action and attract investment at scale.
- **Consumer understanding:** Low public awareness of biorefining and its benefits restricts market uptake. Improved communication and education could strengthen consumer demand for bio-based products.

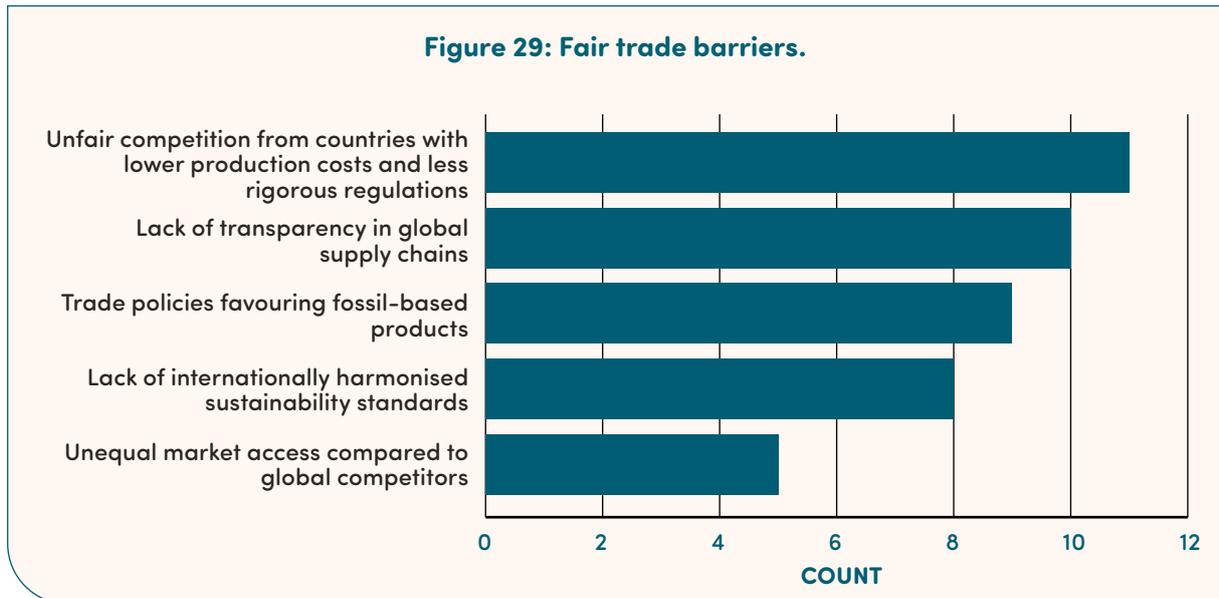
- **Environmental impact:** While less frequently cited, ongoing questions about genuine sustainability performance and lifecycle impacts highlight the need for transparent assessment and communication.



9.2.3.6 Fair trade barriers

Stakeholders were asked: “In terms of ensuring fair trade, which are barriers to biorefining in the UK?”. The answers can be summarised as follows:

- **Unfair competition from countries with lower costs and weaker regulations:** UK bio-based producers face higher costs due to strict environmental, labour and quality standards, while competitors abroad benefit from cheaper energy, lower wages and looser rules. This price gap allows imports (often with higher carbon footprints) to undercut UK products, discouraging investment and driving ‘carbon leakage’.
- **Limited transparency in global supply chains:** Feedstocks for biorefining are often sourced globally, but opaque supply chains make it difficult to verify sustainability or ethical standards. This undermines consumer trust and gives less transparent suppliers unfair cost advantages.
- **Trade policies that favour fossil-based products:** Current trade and subsidy systems provide preference to fossil-derived materials through tax breaks and legacy infrastructure. Bio-based products face higher costs and fewer incentives, distorting markets and limiting fair competition despite environmental benefits.
- **Lack of harmonised international sustainability standards:** Inconsistent definitions of ‘sustainability’ across countries complicate trade. UK producers may meet strict domestic criteria that aren’t recognised abroad, while imports from regions with weaker standards enter freely. Global alignment through ISO or trade agreements could create a level playing field.
- **Unequal market access for UK producers:** UK biorefineries face tariffs, regulatory barriers and a smaller home market compared to competitors in the EU, US and Asia, where government support is stronger. Post-Brexit uncertainty and limited bioeconomy incentives further weaken competitiveness.

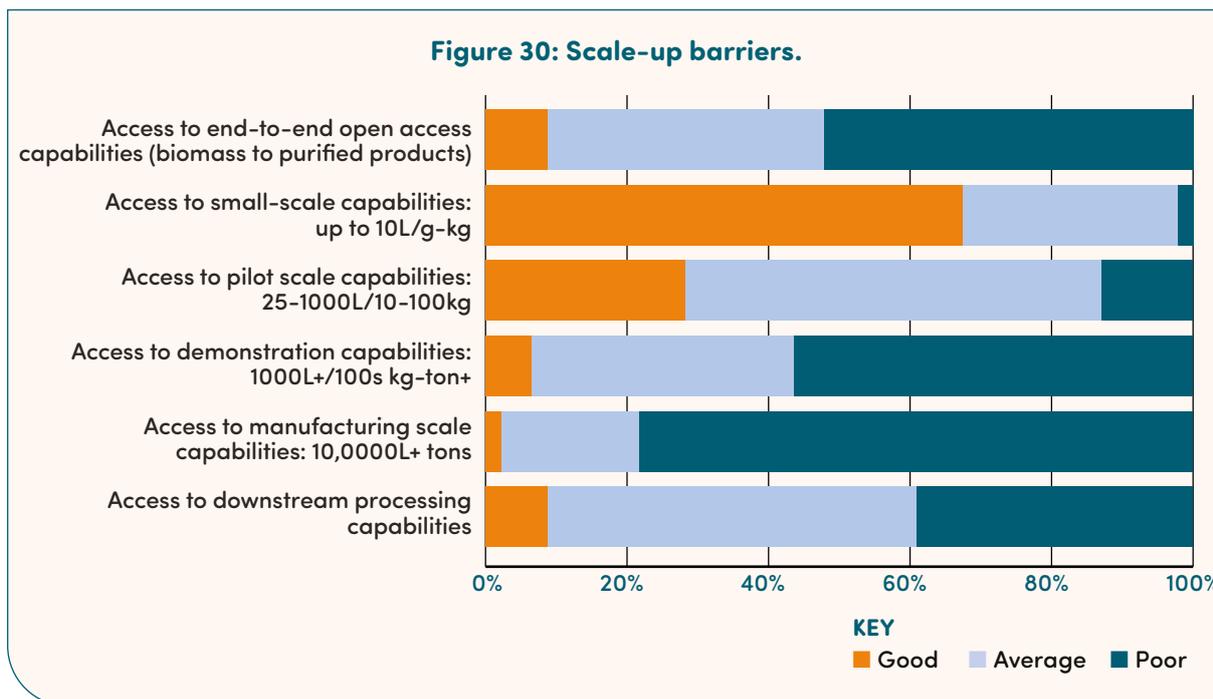


9.2.3.7 Scale-up barriers

Survey respondents were asked to rate the availability of different scale-up capabilities in the UK biorefinery sector (1 = poor, 5 = excellent). The results highlight a clear imbalance in capacity across the value chain:

- **Small-scale capabilities (up to 10L/g–kg):** Rated most positively, with the majority of respondents assessing provision as good or average.
- **Pilot- and demonstration-scale capabilities (25–1000L/10–100kg and 1000L+/100s kg–ton+):** Responses were mixed, with moderate levels of provision recognised but significant gaps still apparent.
- **End-to-end open access facilities (biomass to purified products):** Predominantly rated poor, indicating limited integrated capability.
- **Manufacturing-scale capabilities (10,000L+ tons):** Overwhelmingly rated poor, highlighting a critical weakness in the UK's ability to scale beyond pilot and demonstration stages.
- **Downstream processing capabilities:** Also rated largely poor or average, reflecting insufficient support for process completion and product purification.

In summary, the UK currently has strong provision at the small scale but major limitations at pilot, demonstration, manufacturing and downstream stages, constraining the ability to scale biorefinery processes effectively.



9.2.3.8 Other challenges and opportunities

Table 14: Other challenges and opportunities highlighted by stakeholders operating in this area.

CHALLENGES	OPPORTUNITIES
Narrow technology focus – UK biorefining overly centred on fermentation, overlooking other viable conversion routes (e.g. hydrothermal, thermochemical).	Diversify technology platforms to include hydrothermal, gasification, electro-biochemical and hybrid systems that can valorise all biogenic carbon streams.
Lack of early techno-economic assessment (TEA) and commercial roadmaps limits investor confidence.	Embedding TEA early in R&D can improve investor confidence and guide viable business models.
Regional and departmental fragmentation – competition between UK regions and siloed government departments (DESNZ, DBT, DEFRA) reduce efficiency.	Develop a coordinated national biorefining strategy aligning policy, R&D and industry priorities across government and regions.
Weak market pull – construction, NHS, and public procurement not driving demand for bio-based materials.	Use public procurement to create early markets for bio-based and low-carbon materials.
Low public awareness of the role of chemicals, leading to misinformation and lack of social acceptance.	Public engagement and education campaigns to raise awareness of bio-based solutions and counter misinformation.
Policy focus skewed toward bioenergy, pharma, AI and defence, leaving industrial biotechnology under-supported.	Rebalance R&D and funding priorities to include renewable chemicals and materials; consider government-backed offtake agreements (e.g. SAF-style mandate).
Skills and training gaps – academics lack commercialisation experience; limited understanding of readiness levels (TRL, CRL, MRL, PLR, SRL).	Upskill researchers and innovators in commercial, process and scale-up disciplines to improve technology translation.

CHALLENGES	OPPORTUNITIES
Bioenergy more advanced than biorefining for chemicals, creating policy and funding imbalance.	Leverage lessons from bioenergy sector to accelerate biorefining deployment and integration.
Regulatory barriers on feedstocks – waste directives, classification, “end-of-waste” protocols, and ethical considerations (e.g. vegan/halal certification rules) can complicate use of secondary biomass.	Streamline regulatory frameworks and provide clear guidance on waste-to-product pathways to accelerate second-generation feedstock adoption.
UK government’s definition of engineering biology’ can leave many bio-based chemicals and materials out of scope, and this hinders the sector.	Enable non-engineering biology industrial biotechnology companies to access EB funding earmarked for planetary health outcomes.

9.2.4 The future of UK biorefining

To explore how stakeholders envision the future of the UK biorefining sector, participants were asked to share their views across several key themes. These themes were designed to assess both the technological and structural factors that could shape the competitiveness, resilience and growth of the bio-based economy.

Future innovations – breakthroughs to reduce bio-based product costs: Stakeholders were invited to identify technological, process, or business-model innovations that could reduce the cost of bio-based products and enhance their competitiveness with fossil-based alternatives.

National resilience and supply chains – vulnerabilities and critical dependencies: Participants were asked to consider the vulnerability of the UK’s chemical and materials supply chains to external shocks, including geopolitical instability and trade disruptions. This analysis sought to highlight where biorefining could play a role in strengthening supply chain security and reducing import dependency.

Global leadership in biorefining and the bioeconomy: Stakeholders also reflected on which countries and regions currently lead in biorefining and the wider bioeconomy. They considered factors such as, technological innovation and R&D investment, policy frameworks and regulatory clarity, market development and scale-up infrastructure, and public and private investment landscapes. The goal was to understand how the UK compares internationally and what strategies could enhance its global competitiveness and leadership position.

Business outlook under future scenarios: Finally, stakeholders were asked how they would expect their business revenues and employment levels to change under five distinct future policy and investment scenarios:

- **Feedstock mobilisation:** The UK secures long-term agreements for affordable feedstock through international partnerships and domestic feedstock mobilisation. However, businesses have to fund their own scale-up facilities, and government coordination remains limited with fragmented policies across departments.
- **Infrastructure investment:** Government successfully establishes shared scale-up facilities and industrial clusters with co-location incentives, enabling companies to access pilot plants and demonstration facilities. Feedstock remains at market rates with limited coordination, and sector oversight stays fragmented across departments.
- **Government coordination:** A dedicated biorefining body coordinates activity across departments, streamlines regulations, and aligns policies between devolved nations. However, feedstock costs remain high, and public investment in scale-up infrastructure is limited.
- **Status quo:** Government maintains current levels of biorefining support without significant expansion or reduction, with existing R&D programmes continuing at present funding levels. Familiar regulatory processes remain in place alongside modest private investment and existing skills ecosystem.

9.2.4.1 Achieving cost parity with fossil incumbents

Reaching cost parity between bio-based and fossil-based industries will require a multifaceted approach that combines technological innovation, process integration, policy reform and market-driven incentives. The challenge is not purely technical; it also depends on systemic coordination, scale, and the creation of fair market conditions that account for environmental externalities.

Technological and process innovation

- **Improved biological and catalytic efficiency:** Development of robust microbial chassis, engineered enzymes and durable catalysts to increase yields, titres and conversion rates while reducing energy and raw material inputs. Enhanced metabolic and enzyme engineering, process intensification and co-product valorisation will drive higher productivity and lower operational costs.
- **Advanced upstream and downstream processing:** Feedstock pre-processing innovations – reducing the cost of collecting, separating and converting complex lignocellulosic materials (e.g., agricultural residues, wood waste) into standardised intermediates. Streamlined and continuous downstream processing (DSP) to match large-scale upstream productivity and reduce capital and energy intensity. Electrification of processes and adoption of AI-driven digital twins to optimise bioprocess design, integration and control for maximum efficiency.
- **Flexible and continuous biorefineries:** Implementation of flexible biorefinery systems capable of processing diverse, seasonal feedstocks using a mix of enzyme-based and environmentally friendly physical-chemical methods. Development of continuous production methods to ensure higher asset utilisation and lower unit production costs compared to batch processes.

Feedstock strategy and supply chain integration

- **Utilisation of low-cost, underutilised feedstocks:** Exploiting local, low-value biomass and waste streams—including agricultural residues, forestry by-products and post-consumer waste plastics—can reduce raw material costs while promoting circularity. Securing feedstock supply year-round through integrated logistics and partnerships is critical for stable operations.
- **Integration with existing industrial infrastructure:** Co-locating biorefineries with existing industrial sites allows the use of waste heat, utilities and CO₂ streams to reduce both cost and emissions.
- **Retrofitting existing assets** and linking biorefining processes with available infrastructure lowers capital requirements and accelerates scale-up.

Scale-up, demonstration and collaboration

- **Access to scale-up facilities:** Broader access to pilot and demonstration plants is essential for process optimisation and risk reduction before full-scale deployment. Linking UK biorefining scale-up centres through digital platforms could pool national expertise and infrastructure, enabling pre-validation of processes in silico.
- **Academic-industry partnerships:** Funding for collaborative R&D between academia and industry is crucial to translate laboratory successes into commercially viable technologies. Focused investment should target platform technologies and building block chemicals, avoiding direct competition with low-margin fossil commodities.

Policy and market measures

- **Creating a level playing field:** Removing fossil fuel subsidies, adjusting tax and tariff structures, and internalising carbon costs (e.g., through carbon taxation) will correct price distortions that currently disadvantage bio-based products. Transparent carbon accounting for bio and fossil feedstocks will highlight the true environmental costs and benefits of each.
- **Incentivising bio-based markets:** Public procurement policies should prioritise low-carbon and bio-based products, stimulating demand and de-risking early investments. Regulatory clarity on the use of genetically modified organisms (GMOs) and recognition of bio-based carbon value will support innovation and market growth.

- **Driving fossil cost increase and bio market expansion:** As fossil-based incumbents face stricter waste, carbon and pollution regulations, the relative competitiveness of bio-based products improves. Expanding high-value bio-based markets (specialty chemicals, materials, nutraceuticals) will enable profitable entry points before scaling to commodity sectors.

Energy and systems considerations

- **Reducing energy costs** –for example, through integration with SMR nuclear, fusion or renewable sources – could have a significant impact on bio-based production economics.
- **Integration of circularity principles** and carbon capture within biorefineries can create negative-emission products, improving both environmental and financial performance.

Stakeholders were asked whether the UK should own, collaborate on or access technologies and services required for biorefining. In the context of UK biorefining, “own” refers to holding and operating production assets, “collaborate” involves jointly developing or sharing facilities and expertise, and “access” means relying on third-party infrastructure or services without direct ownership.

Overall, the data suggests a balanced strategy, where the UK aims to own core scientific and process capabilities, collaborate on large-scale infrastructure, and access specialised or capital-intensive technologies through partnerships.

Areas to own: The UK should prioritise ownership in foundational technologies that drive innovation and competitiveness. These areas underpin the knowledge base and scientific autonomy of the UK’s biorefining sector.

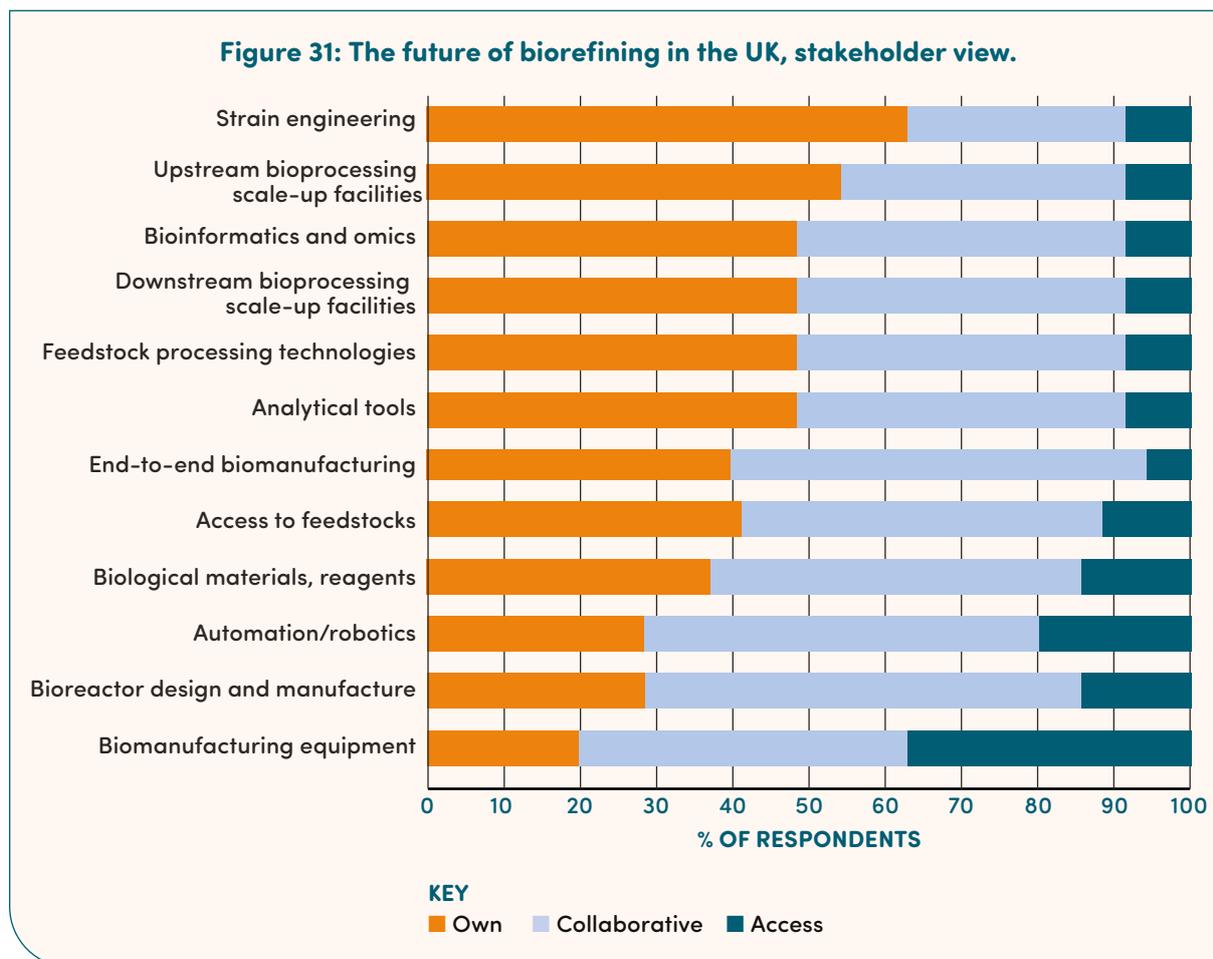
- **Strain engineering** – strong emphasis on ownership, reflecting the need to control intellectual property (IP) for bio-based production.
- **Bioinformatics and omics** – ownership supports data sovereignty and R&D capability.
- **Feedstock processing technologies** and **analytical tools** – owning these allows domestic control over efficiency and quality.

Areas for collaboration: Collaboration is viewed as most appropriate for infrastructure-heavy or cross-disciplinary areas, where shared investment reduces cost and risk. These partnerships could be formed through innovation clusters or public-private consortia:

- **Upstream and downstream bioprocessing scale-up facilities** – high levels of collaboration reflect the cost and complexity of scale-up.
- **Automation/robotics** and **bioreactor design** – joint development supports technology transfer and best practice sharing.
- **End-to-end biomanufacturing** – collaboration helps integrate universities, industry and research centres.

Areas to access: Access dominates in capital-intensive or globally available services, where direct ownership may not be cost-effective:

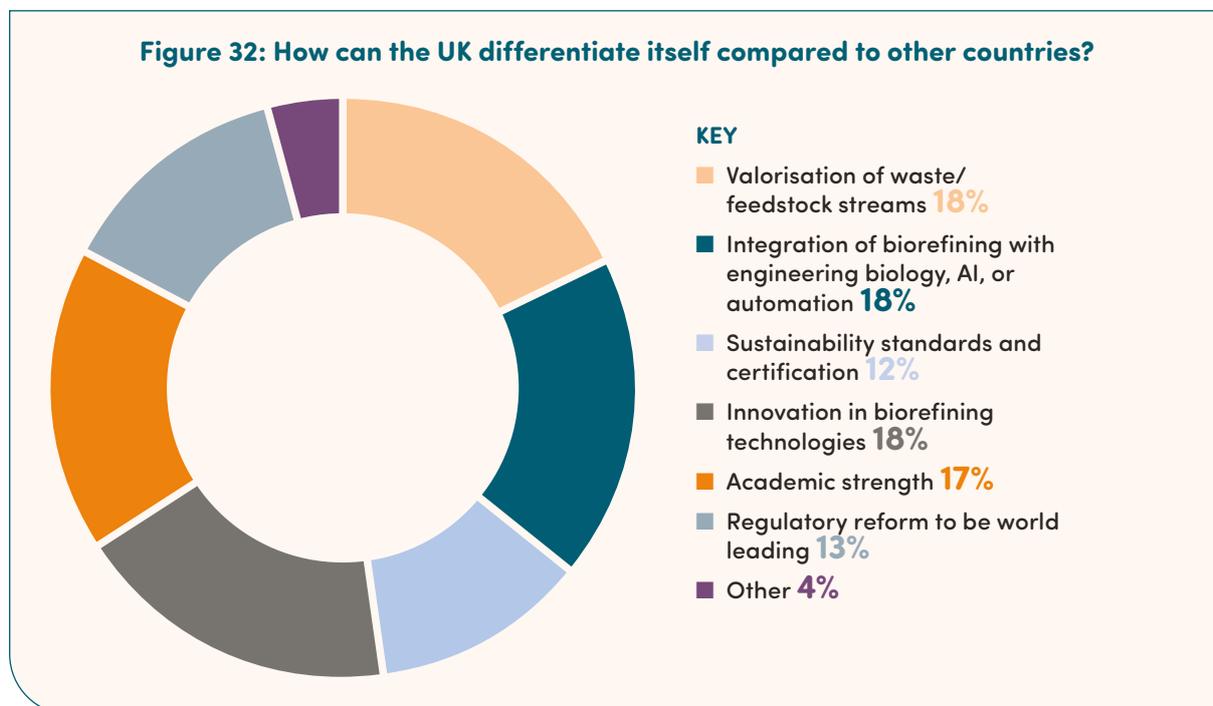
- **Biomanufacturing equipment, biological materials and reagents**, and **feedstock access** are largely seen as better sourced externally.
- These are areas where **international suppliers or shared facilities** already exist, reducing the need for UK-specific infrastructure.
- Accessing such capabilities ensures flexibility and cost efficiency while avoiding duplication of global resources.



Stakeholders were asked in what areas could the UK differentiate itself from other countries. The results indicate several clear areas of perceived strength and opportunity for the UK's bioeconomy:

- **Valorisation of waste/feedstock streams (18%)** – Respondents see the UK's strong waste management systems, industrial symbiosis initiatives and circular economy policies as key enablers. The UK generates large volumes of diverse biogenic waste and turning these into higher-value bio-based products could provide both environmental and economic advantage.
- **Integration of biorefining with engineering biology, AI, or automation (18%)** – This reflects confidence in the UK's world-leading capabilities in synthetic biology, digital innovation and automation. Leveraging these strengths could make UK biorefineries more efficient, adaptive and globally competitive, enabling smarter process control and optimisation.
- **Innovation in biorefining technologies (18%)** – The UK's strong innovation ecosystem positions it well to lead in developing new processing technologies and integrated biorefinery models. This focus on innovation also reflects the need to overcome scale-up barriers that have historically constrained the sector.
- **Academic strength (17%)** – The UK's universities and research centres remain internationally recognised for excellence in biosciences, chemical engineering and materials research. This strong academic base provides a foundation for talent, collaboration and discovery-driven innovation across the biorefining value chain.
- **Sustainability standards and certification (13%)** – Respondents recognise growing global demand for traceability, verified sustainability claims and harmonised certification. The UK could differentiate itself by developing robust standards that build trust and facilitate international trade in sustainable bio-based products.

- **Regulatory reform to be world-leading (12%)** – There is awareness that clearer, more enabling regulation could accelerate investment and deployment. Respondents feel the UK has the chance to set progressive frameworks post-Brexit that align environmental, industrial and innovation goals – but also recognise that regulatory progress has been slower than desired.



Stakeholder responses highlighted that there is significant regional variation in the UK's capacity to develop and lead in biorefining, with several areas demonstrating strong potential based on a combination of feedstock availability, industrial heritage, academic expertise and infrastructure.

1. Humber-Yorkshire-Tees Valley-Northwest Corridor

- Large industrial legacy and technical workforce, particularly in Hull and Teesside.
- High levels of CO₂ emissions, providing incentive for decarbonisation through biorefineries.
- Access to agricultural residues, food manufacturing by-products and potential for new feedstock crops.
- Existing high-value biomanufacturing sectors (pharma, life sciences) can be leveraged.
- Proximity to renewable energy (offshore wind) for sustainable biorefinery operations.
- Historical industrial and chemical sectors providing infrastructure, equipment and skilled workforce.
- Academic expertise in bioprocessing, downstream separations and pilot-scale biorefining (BDC, CPI).
- Access to freeports and transport networks facilitates feedstock import/export.

2. Scotland

- Well-established innovation ecosystem and legacy process industry skills, focused on Grangemouth.
- Availability of forestry, fishery and distillery by-products as feedstocks.
- Whisky industry provides expertise in fermentation, feedstock handling and byproduct valorisation.
- Strong research institutions and pilot-scale facilities, including IBIoIC and other demonstration sites.

3. East Anglia and Lincolnshire

- Significant agricultural activity, providing large-scale crop residues such as wheat, barley and sugar beet pulp.
- Established grain and crop-processing infrastructure.
- Potential for demonstration and production-scale biorefining pilots with European market connections.

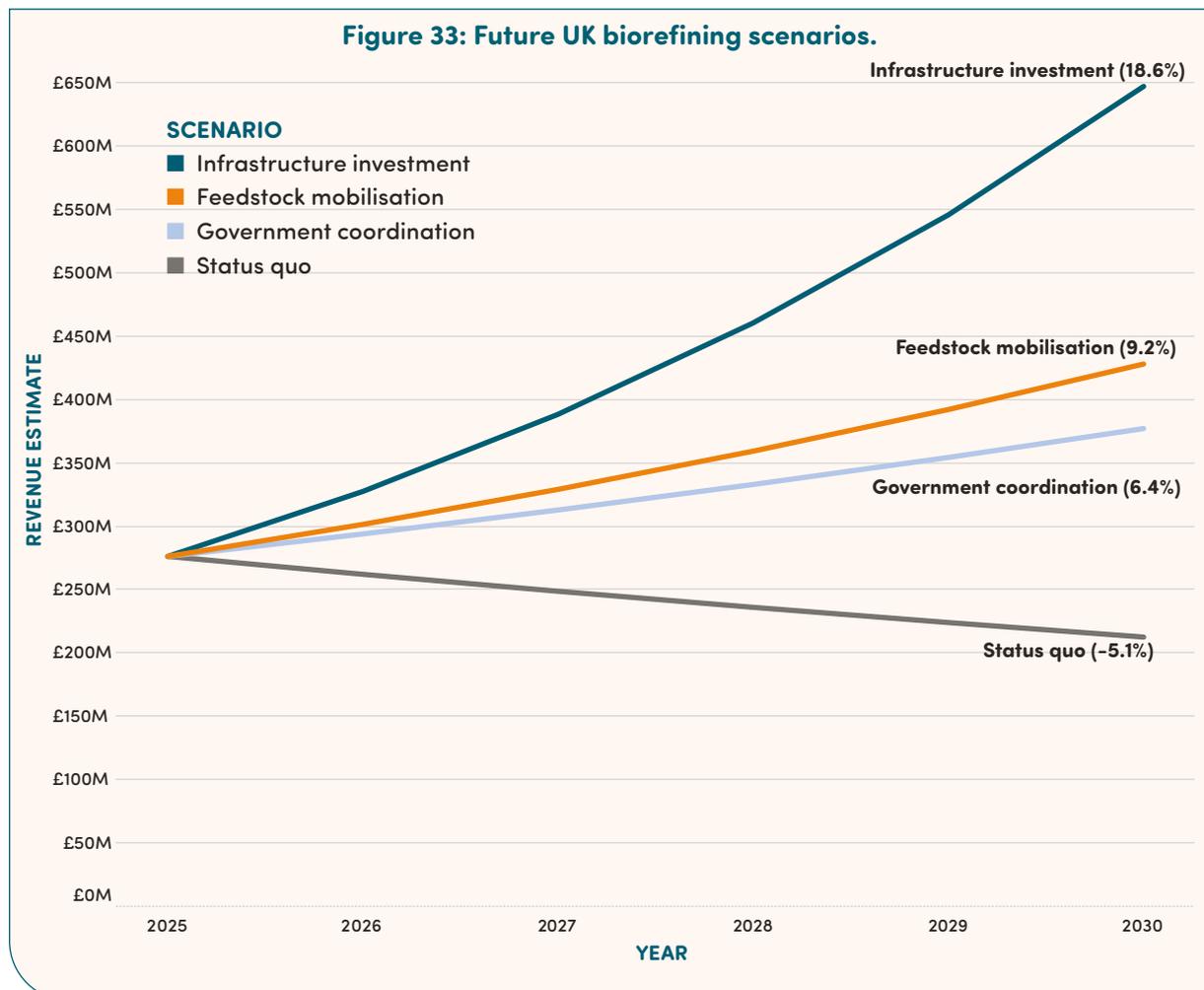
9.2.4.2 UK future biorefining scenarios

Survey respondents were asked to estimate how their business would change, in terms of annual revenue and employment, under four future scenarios.

Results show that respondents believe investment in scale-up infrastructure would have the most positive impact on growth (+18%) followed by feedstock mobilisation and government coordination (+9% and +6% respectively).

Results also suggest that any of the proposed actions are better than doing nothing – reflected in overall negative growth estimates (-5%) returned under that scenario.

When applied to current revenues among bio-based SMEs within the scope of this study, the potential gap between future revenue under the status quo and highest impact scenarios is wide – amounting to almost £0.5bn in lost revenues to bio-based SMEs.



Infrastructure investment – Government successfully establishes shared scale-up facilities and industrial clusters with co-location incentives, enabling companies to access pilot plants and demonstration facilities. Feedstock remains at market rates with limited coordination and sector oversight stays fragmented across departments.

Feedstock mobilisation – The UK secures long-term agreements for affordable feedstock through international partnerships and domestic feedstock mobilisation. However, businesses have to fund their own scale-up facilities and government coordination remains limited with fragmented policies across departments.

Government coordination – A dedicated biorefining body coordinates activity across departments, streamlines regulations and aligns policies between devolved nations. However, feedstock costs remain high and public investment in scale-up infrastructure is limited.

Status quo – Government maintains current levels of biorefining support without significant expansion or reduction, with existing R&D programmes continuing at present funding levels. Familiar regulatory processes remain in place alongside modest private investment and existing skills ecosystem.

Table 15: Other countries' best practice.

COUNTRY	BEST PRACTICE
USA	<ul style="list-style-type: none"> • The US is the global frontrunner, combining scale, stable policy and private investment. • The California LCFS has shown that market-driven, performance-based regulation can accelerate investment and innovation in low-carbon alternatives. By applying a similar framework to chemicals, governments could foster a competitive low-carbon chemicals industry, reduce dependency on fossil-based feedstocks and help scale up sustainable biorefineries • The Renewable Fuel Standard (RFS) created a guaranteed biofuels market, spurring billion-dollar plants. • The US is the largest biofuel producer, with corn ethanol evolving into advanced biofuels, renewable diesel (HVO), and cellulosic ethanol. A strong VC ecosystem and firms like Gevo and LanzaTech drive innovation.
BRAZIL	<ul style="list-style-type: none"> • Brazil has decades of ethanol blending mandates and one of the most efficient sugarcane-based bioindustries. Its system benefits from high yields, low fossil inputs and cogeneration from bagasse residues. • With policies like RenovaBio, Brazil is now expanding into biochemicals and aviation fuels.
EU	<ul style="list-style-type: none"> • The EU combines national strategies, investment, and collaborative networks. • Netherlands, Belgium, France: hubs with clusters of bio-innovators, strong policy and world-class pilot/demo plants (e.g., Biobase Europe, Toulouse White Biotechnology). • Germany: leader in engineering, biogas and specialty chemicals. • Finland, Sweden, Denmark: global leaders in forest-based biorefineries. Firms like UPM and Stora Enso integrate pulp and paper with biofuels and biomaterials. • Collectively, the EU benefits from the Pilots4U network, connecting 100+ open-access pilot plants (approx. 500 pilot/demo facilities) to help SMEs scale bio-based processes.
INDIA AND CANADA	<ul style="list-style-type: none"> • India's progress is slower but supported by subsidies and large biomass availability. • Canada benefits from supportive policy and strong infrastructure, especially in fuels and chemicals.
OTHERS	<ul style="list-style-type: none"> • Norway: strong facilities but limited commercial rollout. • UK: strong pre-commercial capacity, but commercial projects often move to the EU. • Australia: active VC funding and CSIRO-led innovation. • Japan and South Korea: emerging, with Japan strong in advanced tech. • Thailand: regional biofuel leader with strong biomass base.

Stakeholders were asked what measures could help accelerate UK biorefining, which are summarised below:

Table 16: Stakeholder views on what could help to accelerate UK biorefining.

TYPE	MEASURE
FISCAL AND TRADE MEASURES	<p>Zero VAT on domestically produced bio-based chemicals to boost competitiveness and market uptake.</p> <p>Introduce selective tariffs to protect and promote UK-produced bio-based materials.</p> <p>Corporate tax relief for start-ups: For the first ten years of a new biorefinery company, introduce a 2% reduction in corporation tax and fixed, lower energy prices to encourage early-stage growth and stability.</p> <p>Awareness of tariff dispensations within biorefining community.</p>
STRATEGIC AND REGULATORY FRAMEWORK	<p>Convene a cross-disciplinary economic taskforce (“British Bio First”) to explore legally viable mechanisms to prioritise domestic bio-based production.</p> <p>Drive market demand with public procurement, renewable content mandates and underwritten off take agreements.</p> <p>The California LCFS has shown that market-driven, performance-based regulation can accelerate investment and innovation in low-carbon alternatives. By applying a similar framework to chemicals, governments could foster a competitive low-carbon chemicals industry, reduce dependency on fossil-based feedstocks and help scale up sustainable biorefineries.</p> <p>Create a regulatory sandbox for bio-based products (similar to the FSA’s one) to accelerate product approvals and market entry.</p> <p>Establish “Bio Innovation Hubs” (building on existing NIBB and EB programmes) to coordinate regional and sectoral innovation.</p>
TARGETED FUNDING AND R&D SUPPORT	<p>Expand targeted funding streams for biorefinery demonstration projects and technology scale-up.</p> <p>Strengthen UKRI R&D and innovation programmes focused on second-generation feedstocks, techno-economic analysis (TEA) and life cycle assessment (LCA).</p> <p>Support anaerobic digestion-to-chemicals (AD-to-chemicals) innovation pathways.</p> <p>Fund research into fermentable carbon sources and dark fermentation enzymes for advanced feedstock digestion.</p>
ENTREPRENEURSHIP AND SKILLS	<p>Embed entrepreneurship and industry mentorship within universities and research institutions to de-risk commercialisation and accelerate spinouts.</p>
INFRASTRUCTURE AND TECHNOLOGY INTEGRATION	<p>Connect all UK biorefining scale-up facilities and pilot plants into a national network for shared access and data exchange.</p> <p>Encourage smaller, repeated pilot runs across facilities to validate processes and de-risk full-scale investment.</p> <p>Invest in digital twins and process simulation tools to improve design, optimisation and operational efficiency.</p>

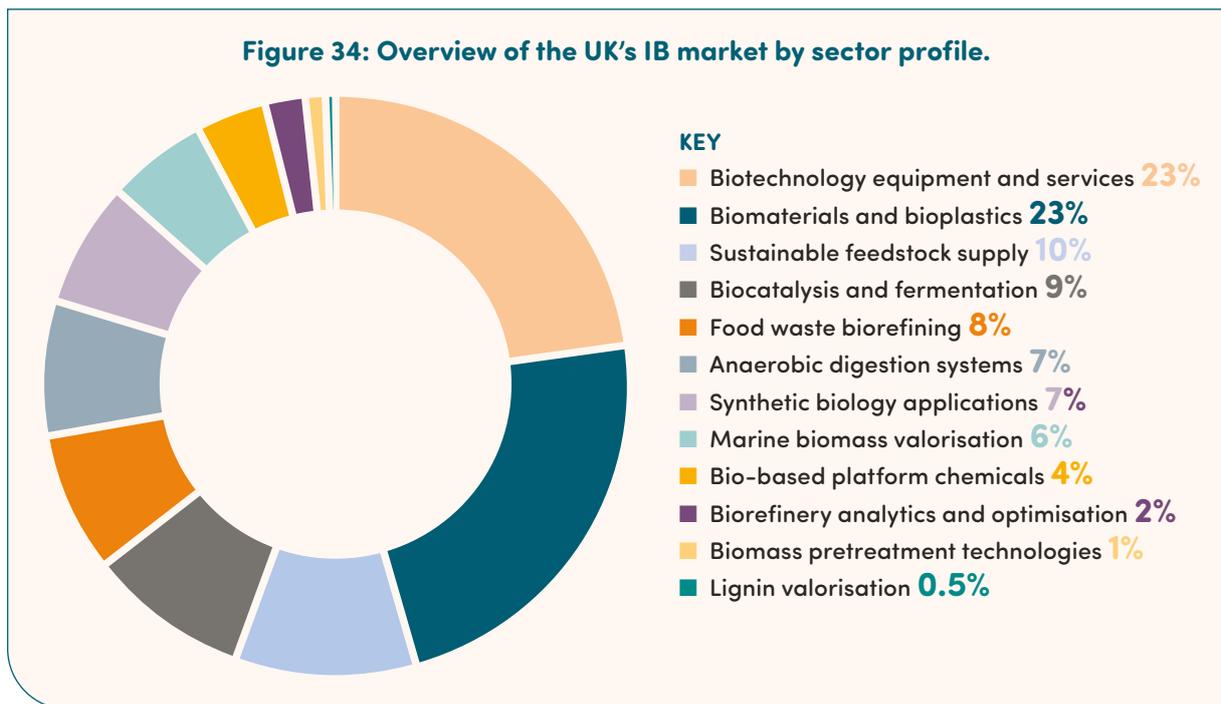
9.3 Economic analysis (Perspective Economics)



This economic analysis considers the current state and future potential of bio-based companies that fall within the scope of BBNet’s operations. It identifies ~1,200 companies generating £12.5 billion in annual revenues, contributing £5.1 billion in gross value added (GVA) and employing over 20,000 people. However, in recent years the sector appears to have faced headwinds, reflected in falling revenues, employment and investment since 2022. The analysis suggests that without targeted intervention, the sector could contract by 5%, but that strategic investments in scale-up infrastructure, feedstock mobilisation and government coordination could unlock growth of up to 18%, and prevent the loss of almost £0.5 billion in revenues to bio-based small and medium-sized enterprises.

9.3.1 Sector profile and market composition

There are approximately 1,200 companies that fall within the scope of BBNet activities, right across the value chain, and across every region of the UK. Most of these companies operate within one of five main segments: sustainable feedstock supply (15% of companies), biotechnology equipment and services (22%), biomaterials and bio-based plastics (22%), biocatalysis and fermentation (9%), and food waste biorefining (9%).



In 2024, these companies generated approximately £12.5 billion in revenues and contributed £5.1 billion in gross value added to the UK economy. The sector employs 20,300 people across the UK, representing a significant source of skilled employment in advanced manufacturing and biotechnology.

Small and medium-sized enterprises (SMEs) make up 93% of all businesses (n~1,100). The distribution of companies by size varies considerably across segments.

The chemicals sector and food waste biorefining activities involve a greater proportion of large companies, reflecting the capital intensity and economies of scale required in these segments. Conversely, synthetic biology and biorefinery optimisation segments are characterised by greater shares of smaller companies, suggesting these areas remain in earlier stages of technological and commercial maturity.

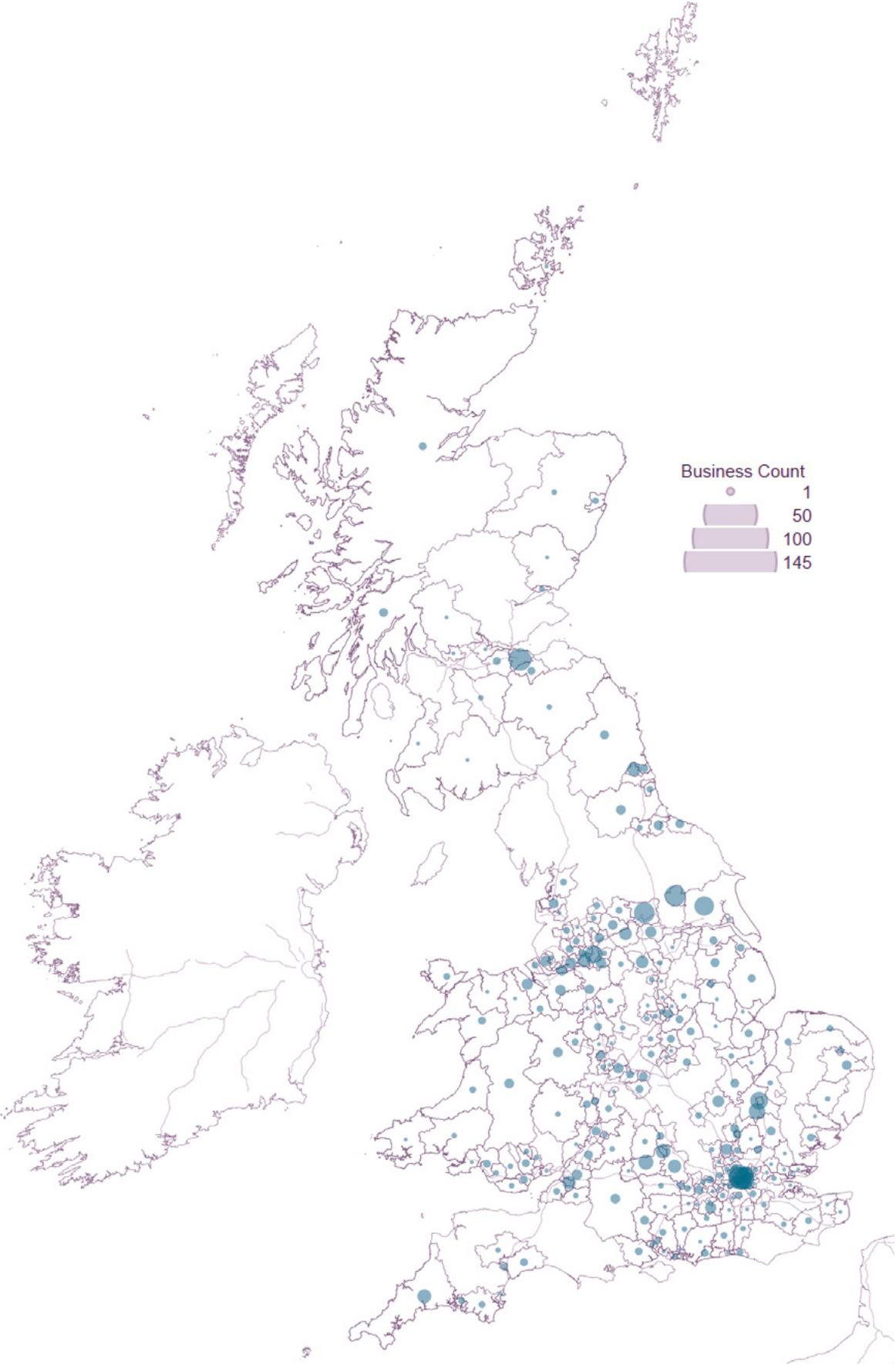
Figure 35: Size and type of IB companies operating in the UK (2025).¹⁹

	MICRO	SMALL	MEDIUM	LARGE
Advanced biofuels	27.50%	37.50%	27.50%	7.50%
Anaerobic digestion systems	24.40%	54.70%	12.80%	8.10%
Bio-based platform chemicals	20.00%	31.10%	35.60%	13.30%
Biocatalysis and fermentation	31.70%	48.50%	11.90%	7.90%
Biomass pretreatment technologies	30.80%	61.50%	7.70%	
Biomaterials	34.20%	43.10%	15.80%	6.90%
Biorefinery analytics and optimisation	41.70%	58.30%		
Biorefinery process integration	46.70%	40.00%	6.70%	6.70%
Biotechnology equipment and services	28.10%	50.00%	15.80%	6.20%
Food waste biorefining	29.20%	44.90%	14.60%	11.20%
Sustainable feedstock and processing	33.70%	44.40%	15.20%	6.70%
Synthetic biology applications	24.40%	67.90%	5.10%	2.60%

BBNet-relevant companies provide economic benefits right across the UK, with notable clusters outside of London in Yorkshire and the Humber, the North West, and the North East of England, as well as in Scotland. This geographic distribution highlights the breadth of economic opportunity created by BBNet-relevant businesses.

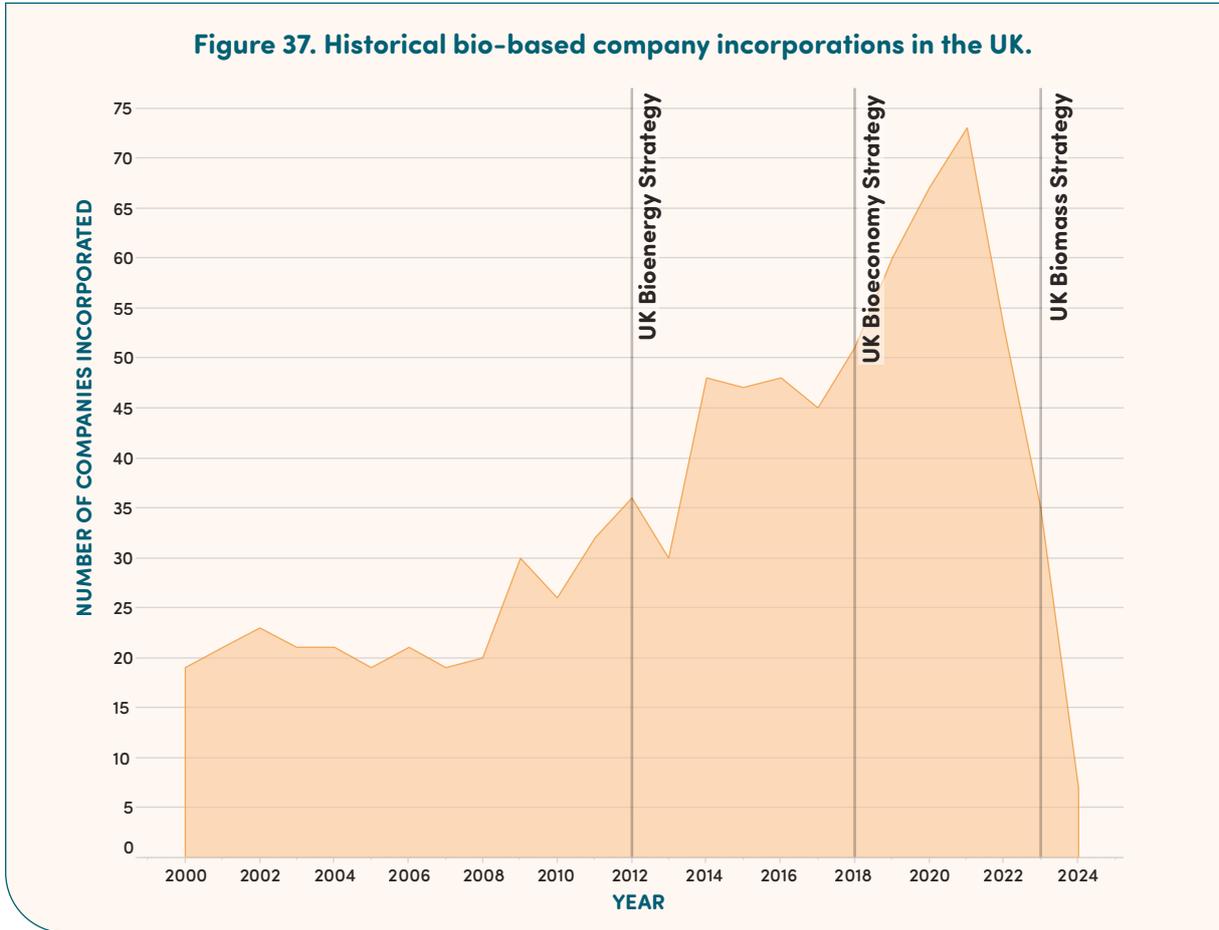
¹⁹ Economic analysis carried out by Perspective Economics.

Figure 36: Geographic distribution of BBNet-relevant companies.

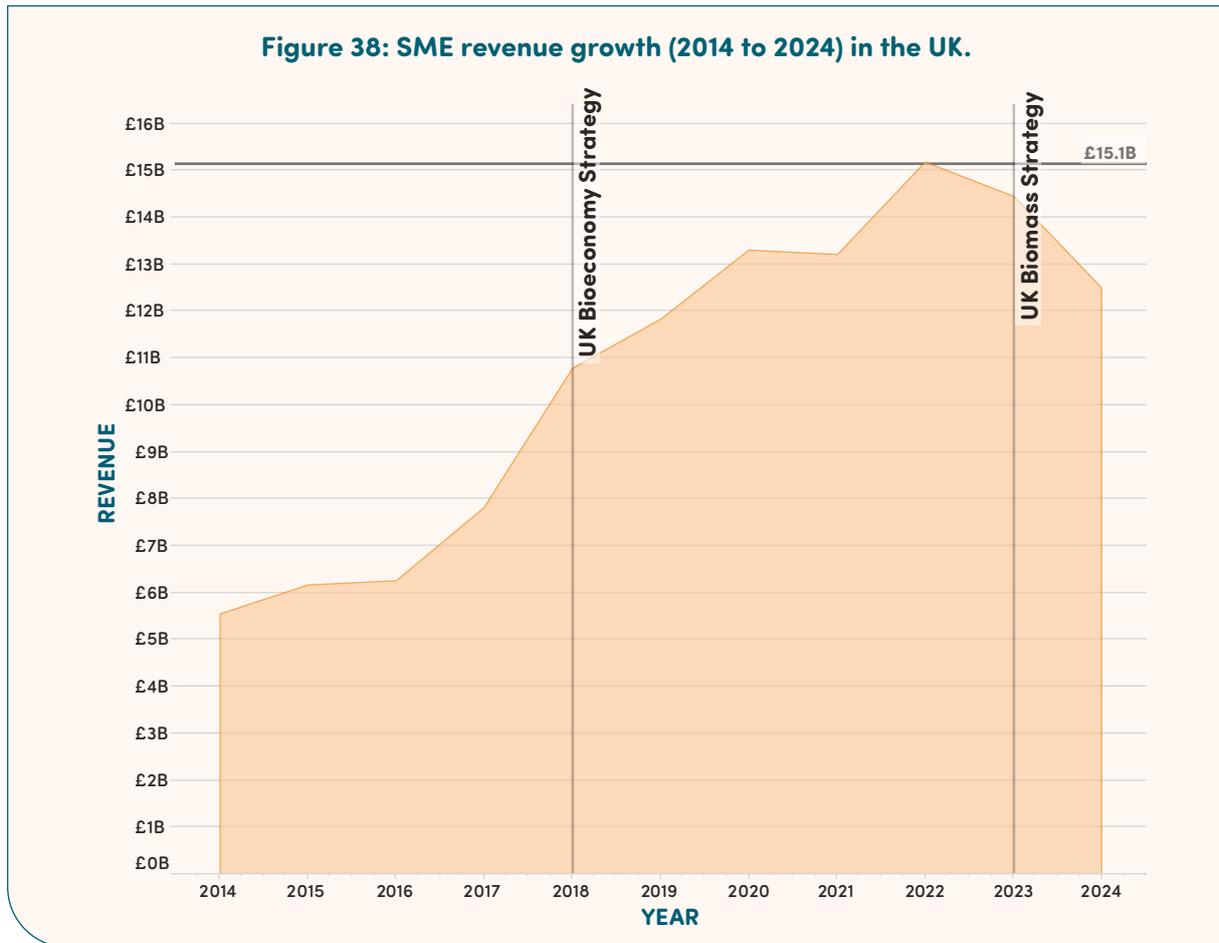


9.3.2 Historical performance and recent trends

Between 2008 and 2020, there was a steady increase in new company incorporations, suggesting growing commercial opportunities and entrepreneurial confidence in bio-based solutions. New company incorporations peaked in 2021 and has since seen a slight decline. While the low number recorded in 2024 may be partly attributable to a lag in company data records, the broader trend suggests a potential cooling of entrepreneurial activity in recent years.



SMEs within the scope of BBNet activity demonstrated strong revenue growth between 2014 and 2022, reflecting maturing market opportunities and commercial traction, to a peak of just over £15bn. However, this positive trajectory has reversed since 2022. Large companies have experienced a similar pattern, with revenues growing steadily between 2014 and 2022 before flatlining between 2022 and 2023. In 2024, large company revenues declined by approximately 10%, representing a substantial contraction in the sector’s economic output.

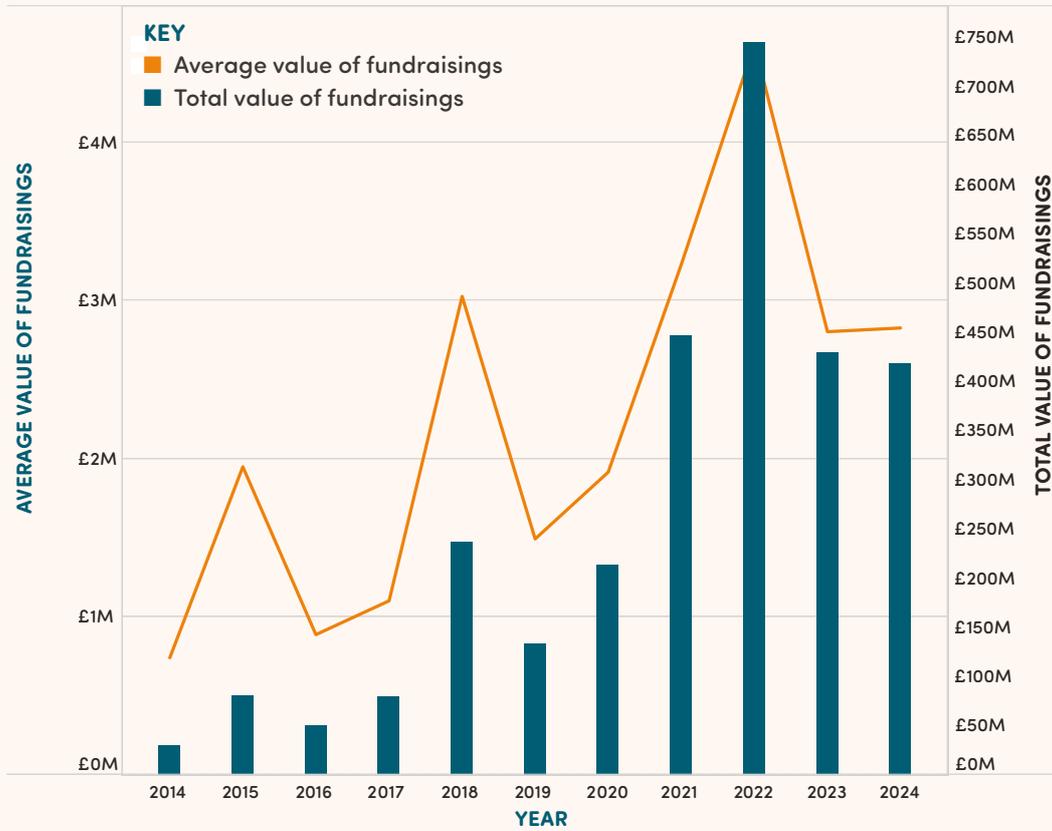


These parallel trends across companies of different sizes suggest systemic challenges rather than firm-specific difficulties. Potential contributing factors may include increased competition from international markets, regulatory uncertainties, or challenges in scaling bio-based solutions.

SMEs also experienced strong employment growth between 2014 and 2023, and more modest growth between 2023 and 2024. Employment within large companies has remained relatively flat since 2017 and has also declined since 2022.

Companies within the scope of BBNet activity have secured 1,260 substantive levels of private funding, totalling £3.2 billion since 2007. Both the number and value of fundraising activities showed an upward trajectory until 2022, indicating growing investor confidence in bio-based technologies and expanding capital requirements. However, this positive momentum shifted markedly in 2023, when both the total value of fundraising and the average value per raise declined. These metrics remained flat in 2024, suggesting a sustained cooling of investor enthusiasm. This trend is particularly concerning given the capital-intensive nature of scaling bio-based businesses to commercial production.

Figure 39: Fundraising by in-scope IB companies (2014 to 2024).



Analysis by segment reveals that biomaterials and bio-based plastics companies have secured the highest total fundraising value at £707 million, reflecting both commercial potential and the substantial capital required to develop alternative materials at scale. Synthetic biology companies have achieved the highest average value per fundraise at £8.2 million, suggesting that whilst these ventures may be fewer, they attract substantial investment commitments when they do raise capital, likely reflecting the transformative potential and intellectual property value associated with synthetic biology applications.

Figure 40: Total fundraising by in-scope companies by sector.

Biomaterials Total: £707M Per fundraise: £2.7M	Anaerobic digestion systems Total: £277M Per fundraise: £3.2M	Biocatalysis and fermentation Total: £249M Per fundraise: £2.5M
Biotechnical equipment and services Total: £662M Per fundraise: £2.5M	Food waste biorefining Total: £158M Per fundraise: £1.8M	Marine biomass valorisation Total: £157M Per fundraise: £2.5M
Synthetic biology applications Total: £642M Per fundraise: £8.2M	Bio-based platform chemicals Total: £153M Per fundraise: £3.4M	Other Total: £105M Per fundraise: £4.4M
	Advanced biofuels Total: £119M Per fundraise: £3.0M	

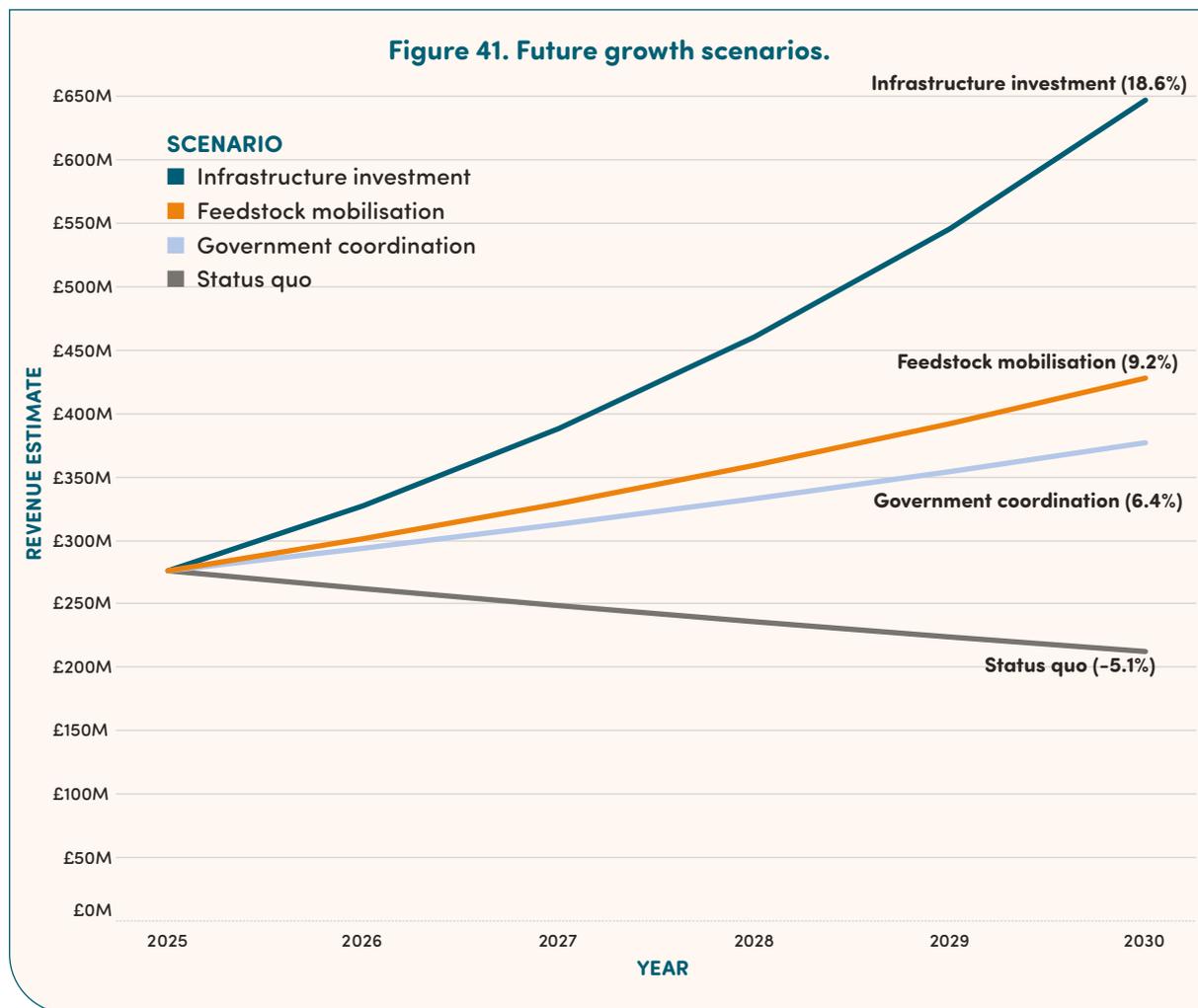
9.3.3 Future growth scenarios and strategic implications

When asked to estimate the impact that different scenarios could be expected to have on revenue and employment in the next five years, responses from ~20 bio-based business representatives suggested that investment in scale up infrastructure would have the most positive impact on growth (+18%), followed by feedstock mobilisation and government coordination (+9% and +6% respectively). In contrast, survey respondents believed that without intervention, revenue and employment could be expected to contract by ~5%.

Survey responses offered clear guidance on the interventions most likely to catalyse growth. Investment in scale-up infrastructure was perceived to be the single most beneficial intervention, with respondents estimating that it could generate ~18% growth in the sector. This finding echoed recent research that points to a critical gap in the current ecosystem: while the UK has strengths in early-stage research and development, the infrastructure required to demonstrate and scale biological processes to commercial production remains a barrier.

Feedstock mobilisation was estimated to contribute 9% growth in revenue and employment on average, and more effective government coordination was perceived as potentially adding 6% growth, reflecting the potential impact of coherent policy frameworks that span multiple government departments and align regulatory, innovation and industrial support mechanisms.

The gap between future revenue under the status quo and the highest impact scenarios amounts to almost £0.5 billion in lost revenues to bio-based SMEs – the opportunity cost of doing nothing. Beyond the direct revenue impact, this lost activity would translate to forgone employment, reduced innovation, diminished competitive positioning and lost contributions to UK climate and sustainability objectives. Focused investments in scale-up infrastructure, feedstock systems, and coordination mechanisms could yield notable economic returns.



9.3.4 International expansion

The study team used data from news articles referencing international activity and web data (website office locations and LinkedIn) to identify which UK headquartered SMEs have international offices. An estimate of the number of international employees was produced following a manual review of LinkedIn people data. A total of 101 companies were identified as employing people across 39 unique international locations.

The United States is by far the most common location for international activity (42 of 131 international offices identified, 32%²⁰), followed by India, the Netherlands, Germany, Canada, Spain, Singapore, Portugal, Poland and Japan (making up the top 10 most common international locations). Highest numbers of employees are in Belgium (21%, n=436 employed by Inovyn including at two PVC chemical recycling pilot plants at Jemeppe-sur-Sambre), in the United States (18%, n=372 including companies such as Whitefox Technologies and AlgaeCytes), in India (11%, n=222) and in the Netherlands (10%, n=201)²¹.

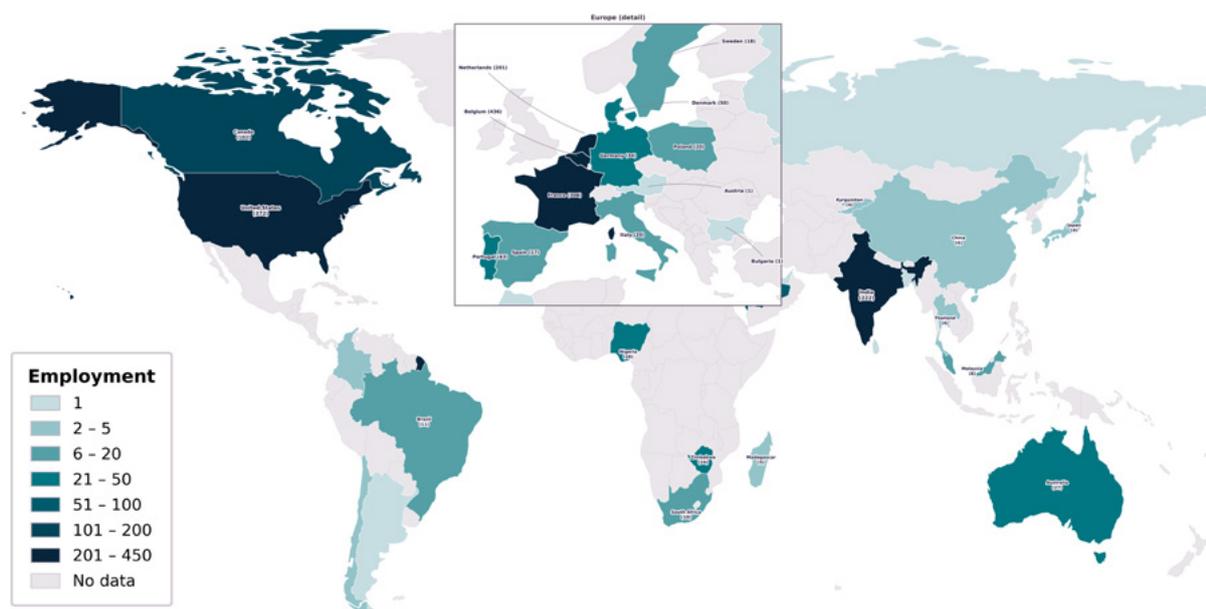
More detailed analysis of businesses particularly relevant to BBNet activity identifies multiple instances of where micro and small sized bio-based businesses are expanding internationally, and in some cases employing more people internationally than they are in the UK. Among forty

²⁰ Some companies have multiple international offices hence a higher total number of international locations.

²¹ Ineos. Inovyn also employs roughly ~300 people in France but has recently announced plans to mothball the Tavaux. 2025. URL: <https://www.ineos.com/businesses/inovyn/news/ineos-inovyn-announces-the-mothballing-of-its-chloromethane-production-facility-in-tavaux-france/>

companies identified as having expansion activity particularly relevant to BBNets scope, 14 companies employed 125 people in the United States and just five companies employed 200 people in the Netherlands. Having acquired a biodiesel facility in Amsterdam in 2018, Argent Energy now employs ~114 people in the Netherlands (nearly as many as it employs in the UK, n=172). Greenergy (another producer of biofuels from waste) announced a 10-year extension to its lease at the Port of Amsterdam and employs ~34 people there. West Yorkshire functional ingredients specialists Ulrick + Short has established its European headquarters in Zoetermeer and employs more than 10 people there. Chemical recycling company Itero Technologies has recently announced plans to build its plastic waste recycling plant at the Brightlands Chemelot Campus in Sittart-Geleen. The 27 kiloton facility will convert hard-to-recycle plastic waste into raw materials that can be used to produce new plastic products.

Figure 42. UK headquartered bio-based SME international employment.



9.3.5 Conclusions and recommendations

This analysis suggests that companies within the scope of BBNets activity are at an inflection point. Having experience almost a decade of strong revenue and employment growth, the UK's bio-based businesses appear now to be facing challenging headwinds

The analysis identifies clear pathways for reigniting growth. Strategic investments in scale-up infrastructure, feedstock mobilisation and government coordination could unlock growth of up to 18% and prevent the loss of almost £0.5 billion in revenues. The substantial gap between do nothing and high-impact scenarios suggests that targeted interventions could yield significant economic returns.

The bio-based economy represents a critical component of the UK's transition to a sustainable, net zero economy. The sector's technologies offer pathways to decarbonise chemicals, materials, energy and food systems whilst creating skilled employment and economic value. However, realising this potential requires deliberate action to address the structural constraints currently inhibiting sector growth.

Without such action, the UK risks losing its competitive position in bio-based technologies to international competitors who are making substantial investments in scale-up infrastructure, feedstock systems and coordinated industrial strategies. The preliminary findings of this analysis suggest that the time for such action is now, whilst the UK retains a substantial base of companies, capabilities and expertise that can be mobilised for growth.

Disclaimer

While Alder BioInsights considers that the information and opinions given in this work are sound, all parties must rely on their own skill and judgement when making use of it. Alder BioInsights will not assume any liability to anyone for any loss or damage arising out of the provision of this report.

Alder BioInsights is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels and bio-based products.

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