UK BioIndustry Association

# **Deep** Biotech

## Disruptive innovation for global sustainability

deepbiotech.org

#DeepBiotech

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# Foreword

**Steve Bates OBE**
CEO, BIA

**Modern industrial biotechnologies such as engineering biology offer us solutions to living more harmoniously with nature. By using and augmenting nature's own processes, we can create the building blocks of modern life, whilst reducing our impact on the planet.**

Deep Biotech encompasses innovative companies powered by modern industrial biotechnology that address humanity's greatest challenges, such as environmental pollution and waste, and the climate crisis. This includes innovations such as cellular agriculture, novel biomaterials, enzymatic recycling, and next-generation biofuels.

Deep Biotech has the potential to unlock a healthy bioeconomy by replacing environmentally damaging practices with more sustainable bio-based ones. We, at the BIA, are committed to facing the future head-on. We have seen how engineering biology has made healthcare smarter. We now know it has the power to disrupt traditional industries entrenched in unsustainable practices, such as agriculture, fashion, fuel and packaging. As a result, we have decided to move beyond health, building on our decades of experience to fight for the needs of a broader range of innovative biotech SMEs.

# Executive summary

There is no longer any doubt that the climate crisis requires mobilisation from every section of the economy. Modern industrial biotechnology allows us to leverage the power of biology to live more harmoniously with nature. Our newfound abilities to gain insights from AI, edit genomes, and industrialise biological processes mean we are in an era of truly disruptive biological innovation. The UK is in a position to harness these breakthroughs and deploy them at scale, to mitigate threats to global sustainability.

The BIA has coined the term ‘Deep Biotech’ to capture companies working in this biotech space. This report aims to shine a light on some of the innovative companies using engineering biology to positively disrupt the environmentally damaging industries that modern society relies on. Five case studies showcase how innovative Deep Biotech companies use the power of biology to protect crops and help ensure food security, create sources of energy without the need for fossil fuels, make textiles and packaging from enzymes instead of harmful petrochemicals or resource-intensive cotton, cultivate meat without farming animals, and develop enzymes to turn plastic waste into everyday chemicals. Together, these companies are creating the innovations today that will form the backbone of our economy tomorrow.

The picture we paint may seem bright, but this future is by no means secured. There are regulatory and economic hurdles that must be cleared in order to build a sustainable bioeconomy. Traditional industries are well established and have a huge economic advantage in terms of market competitiveness. Despite the obvious benefits Deep Biotech offers to both consumers and the planet, companies may struggle to get their products into mainstream use, while regulators find themselves in the position of having to create rules for new technologies that are evolving rapidly.

Sustained public and private investment is key to getting these technologies off the ground. The Government’s recent National Vision for Engineering Biology is a welcome step towards taking a coherent and joined-up approach to enabling innovation in Deep Biotech.

We are confident that the UK is the right place to tackle these hurdles and usher in the biorevolution. The BIA already has a burgeoning community of Deep Biotech members who are charting the course of the BIA’s developments in this space, whose disruptive work you will find highlighted in this report. Over the coming months, we will identify policy needs in consultation with our Deep Biotech membership and in close collaboration with key organisations, create networking opportunities, integrate Deep Biotech into the BIA’s existing events and activities, and highlight Deep Biotech companies’ contributions to a global, sustainable bioeconomy. We will use our expertise as the leading UK biotech trade association to support the growth and success of Deep Biotech companies to deliver world-changing innovation and invite you to join us on this mission.

# Understanding Deep Biotech and why it matters

The UK has long understood the power of biology and modern technology to advance medical sciences, creating lifesaving treatments such as cell and gene therapies and COVID-19 vaccines. UK companies are at the forefront of innovations such as new therapeutics based on living bacteria to treat a broad range of diseases, or genetically edited mosquitoes that are less able to spread disease.[1] Advances like these make the life sciences one of the UK's most successful sectors, worth over £94 billion to the UK economy[2] and consistently raising more venture capital than its European counterparts.[3]

It is not just in healthcare where biotechnology is benefitting humankind. The engineering of biology allows us to create bio-based processes and products that can replace some traditional and less environmentally sustainable ones, leading us towards a greener, healthier planet and people. In the non-health biotech space, commonly referred to as industrial biotech, innovative companies have been using fungi to produce proteins as a sustainable alternative to meat,[4] transform whiskey production residues into sustainable biofuels,[5] and create insulation materials from mushrooms with a carbon-negative production footprint.[6]

However, the rise of modern industrial biotechnologies, like CRISPR[7] gene editing, is enabling us to engineer biology in groundbreaking ways. This, combined with advancements in big data, AI,[8] genomics, and DNA sequencing, is paving the way for truly disruptive biological innovations. These innovations have the potential to mitigate and counteract many of the UK's and the world's sustainability challenges, if deployed at scale.

## Engineering biology: Enabling Deep Biotech

Engineering biology is a powerful enabling technology that underpins much of modern industrial biotechnology today. At its core, it involves the manipulation of nucleic acid (DNA/RNA), that is, the genetic code or recipe for life, with the aim to design and build new or improved biological functions. The universal nature of the genetic code across species means that the engineering biology toolkit can be applied across many sectors, including energy, environment, food production, healthcare, chemicals, and materials. An example of this are advancements towards creating 'synthetic' yeast.

Case study

### Synthetic yeast

A testament to the power of engineering biology and scientific collaboration, researchers across UK universities have played a pivotal role in a 15-year endeavour to rewrite the genetic code of life. Their groundbreaking work on reconstructing a large portion of a yeast cell brings us closer to designing organisms with entirely new functionalities, opening up a world of possibilities for the future.[9,10]

Using CRISPR and other gene editing tools, Dr Ben Blount from the University of Nottingham and Professor Tom Ellis from Imperial College London[11] have successfully synthesised Chromosome XI – a crucial milestone in assembling the world's first synthetic yeast genome. This breakthrough paves the way for designer yeasts with tailored metabolic pathways.

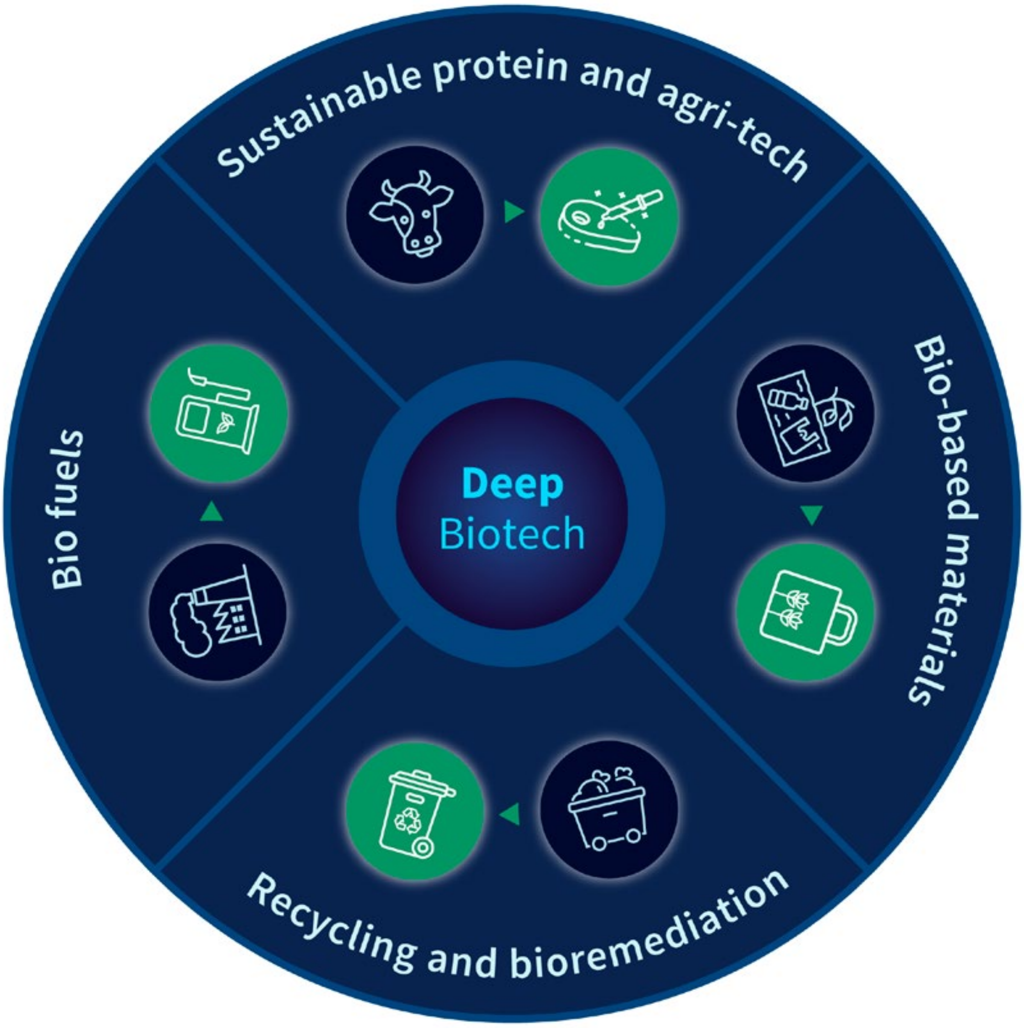
Professor Emily Denninghoff and her team at the Quadram Institute[12] are further advancing this potential, engineering yeast strains for biofuel production from diverse waste materials. Meanwhile, Professor Neil Bruce at the University of Edinburgh[13] is pioneering yeast-based production of natural flavours and fragrances, offering a sustainable alternative to fossil fuel-derived options.

## Deep Biotech and the sustainable global bioeconomy

The emergence and use of these novel biotechnologies is often referred to as the biorevolution, which drives the creation of a sustainable bioeconomy. In 2020, McKinsey estimated that the 'direct annual global impact of the biorevolution could be $2 trillion to $4 trillion in 2030-40',[14] while the Boston Consulting Group reported in 2022 that by the end of the decade, engineering biology could be used extensively in manufacturing industries that account for more than a third of global output, or just under $30 trillion in terms of value.[15]

Underpinning this revolution is the continued development of modern, disruptive biotechnologies such as engineering biology, and their purposeful application. When innovative companies apply these modern industrial biotechnologies to solving complex problems and attacking large-scale sustainability issues with profound impact, we can realise the UK's and global ambitions to create a sustainable bioeconomy.

# This is Deep Biotech – disruptive innovation for global sustainability




**Deep Biotech is disrupting industries across the economy.**

In agriculture, Deep Biotech firms are ushering in an era of food security by providing us with novel sustainable proteins or agri-chemicals with new modes of actions.

Novel materials derived from proteins or biobased hydrocarbons are changing our relationship with traditional fabrics and packaging.

New processes, enabled by enzymes and microorganisms, are allowing use to recycle and clean up pollution in a way that works with nature instead of against it.

Biofuels are delinking carbon intensive industries like transport and shipping from fossil fuels.

Looking at the rapid progression of climate change, environmental degradation, and the growth of the global population, the need for more sustainable products, processes and solutions is evident. Deep Biotech has the potential to unleash the biorevolution and tackle some of humankind's greatest challenges.

The UK is not alone in pursuing the path towards a sustainable bioeconomy. In September 2022, President Biden signed an Executive Order[16] aiming to catalyse the growth of the US bioeconomy, and the European Green Deal sets out the EU's path to a green transition.[17] Most recently, the UK Government has published a National Vision for Engineering Biology[18] which sets out the Government's plan to harness the power of biology to deliver new medical therapies, crop varieties, eco-friendly fuels and chemicals, and increased resilience of supply chains.

## Deep Biotech: A new chapter for the BIA

The adoption of Deep Biotech has been too slow, facing political, economic, and regulatory hurdles, among others. Established industries may struggle to change their operations to incorporate bio-based processes and solutions, which, due to their early stage of development, may be less economically competitive with both existing industries and consumers for the time being. Building consumer confidence in the use of complex technologies takes time, and regulators and policymakers are challenged to create an environment conducive to supporting existing and emerging innovative companies in this space and enabling the far-reaching uptake of their products. In addition, there could be too few private investors with the expertise and risk appetite to support the development of cutting-edge technologies and innovative companies essential to the commercialisation and success of Deep Biotech.

This explainer shines a light on just how disruptive these biology-powered Deep Biotech products and processes are, what this means for our fight against climate change, and how the BIA seeks to drive forward the biorevolution in the UK. Five case studies showcase how innovative Deep Biotech companies use the power of biology[19] to protect crops and help ensure food security, create sources of energy without the need for fossil fuels, make clothing from enzymes instead of harmful petrochemicals or resource-intensive cotton, produce meat in fermentors without farming animals, and develop enzymes to turn plastic waste into everyday chemicals. Together, they lead us to a healthier life, a more sustainable environment and economy, and can help us in the fight against climate change.

The BIA will play the role of an enabler and champion, building on our decades of experience in bringing together the life sciences sector and fighting for the needs of biotech SMEs. We will use our expertise to support the growth and success of companies in the Deep Biotech space to deliver world-changing innovation. Over the coming months, we will identify policy needs in close consultation with our existing Deep Biotech membership, create networking opportunities, integrate Deep Biotech into the BIA's existing events and activities, and showcase BIA members' contributions to a global, sustainable bioeconomy.

# Why Deep Biotech?

Deep Biotech reaches across the distinct yet interconnected ways in which Government, investors, the public, and established industries approach a more promising future.

Deep Biotech encompasses innovative companies powered by modern industrial biotechnology that address humanity's greatest challenges, such as environmental pollution and waste, and the climate crisis. Governments around the world continue to develop national and international policies and treaties (for example, the Paris Agreement[20] or the forthcoming UN treaty on plastic pollution)[21] to address these challenges, by aiming to reach net zero emissions[22] and action the Sustainable Development Goals (SDGs).[23] These policies are accompanied by ambitious long-term concepts such as the growth of a sustainable bioeconomy, adopting a One Health[24] approach, or setting in motion the next industrial revolution, the biorevolution.

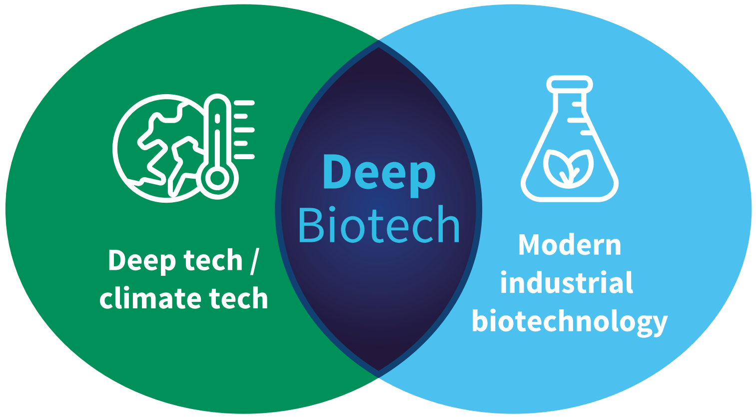
But how do we go about realising these ambitions and reaching our goals? The solution, in part, lies in Deep Biotech. It is the most innovative and disruptive part of biotechnology that is applied to our biggest global sustainability challenges. In this way, it makes up the modern industrial biotechnology-based part of Deep Tech and Climate Tech.

> **"Deep Biotech encompasses innovative companies powered by modern industrial biotechnology that address humanity's greatest challenges, such as environmental pollution and waste, and the climate crisis."**

# What is Deep Biotech?

## What is the biorevolution?

The biorevolution, also known as the fourth industrial revolution, is a 'confluence of advances in biological science' combined with the accelerated development of computing, automation, and artificial intelligence that is fuelling a new wave of innovation. This biorevolution is expected to have a significant impact on global societies and economies, 'from health and agriculture to consumer goods, and energy and materials'.[25] It is linked to 'deep tech'.




## What is a (sustainable) bioeconomy?

The bioeconomy refers to 'using renewable biological resources from land and sea, like crops, forests, fish, animals and microorganisms to produce food, materials and energy'.[30] Biotechnology overall plays a central role in the development of a *sustainable* bioeconomy, as it allows us to promote economic development by deploying tools and techniques that aid us in managing resources efficiently and sustainably.

## What is (modern) industrial biotechnology?

'*Modern* industrial biotechnology is the application of natural, emulated or engineered biological organisms, systems, processes or parts thereof, to provide consumer goods and services in an economic, eco-friendly, sustainable and energy- and resource-efficient manner for the benefit of mankind'.[26] This includes many new underpinning technologies such as gene editing, AI and machine learning, metabolic engineering, polyomics, epigenomics, forced evolution, nanoscience, fluidics, 3D bio-printing, bioinformatics, in silico biology.

This sets it apart from *traditional* industrial biotechnology which uses enzymes and microorganisms to make bio-based products, by drawing on sources of (bio)-feedstock, including processes as old as wine and cheese making.

## What is climate tech?

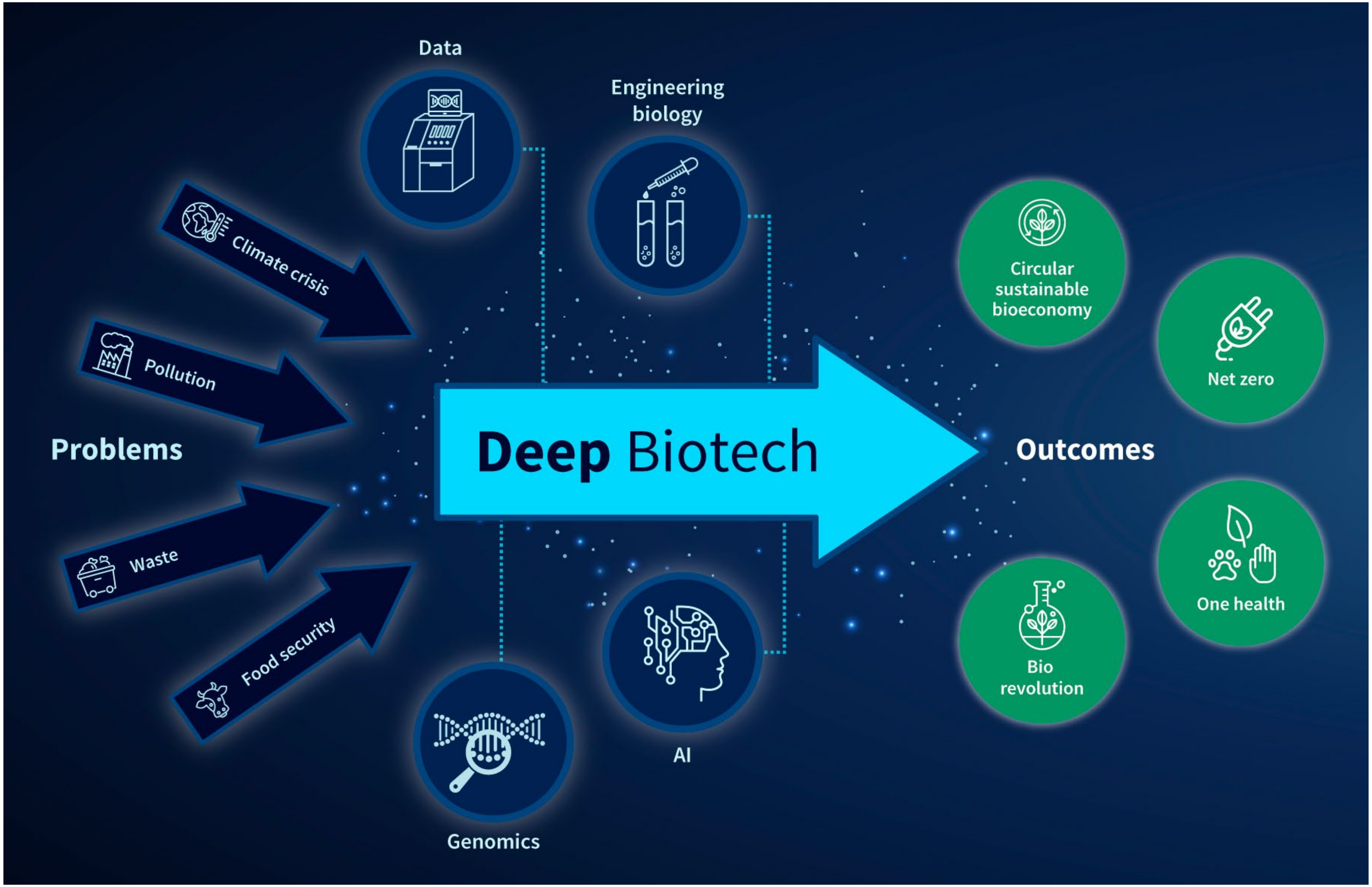
Climate tech are 'technologies that are explicitly focused on reducing greenhouse gas emissions or addressing the impacts of global warming'.[27] Its applications span three broad sector-agnostic groups, including those that directly mitigate or remove emissions, help us to adapt to the impacts of climate change, or enhance our understanding of the climate. 'The term climate tech is purposefully broad in order to incorporate the broad swathe of technologies and innovations being used to address greenhouse gas emissions and the broad array of industries in which they are being applied'.[28] It is a term common among venture capitalists.[29] Most Deep Biotech companies indirectly or directly contribute to mitigating the impacts of climate change.

## What is deep tech?

Deep tech encompasses a range of technological areas, such as machine learning and AI, synthetic (engineering) biology, nanotechnologies, biotechnology, advanced materials, quantum computing, and other advanced technologies. The term is more commonly known among investors. What sets it apart is 'its profound enabling power, the differentiation it can create, and its potential to catalyse [meaningful] change'.[31] Unlike more superficial tech advancements, deep tech aims to solve complex problems, attacking large-scale issues with profound societal impact, and often necessitates interdisciplinary collaboration and substantial investment.

Deep Biotech is considered a part of deep tech because it involves complex scientific research, innovation, and advanced engineering, often leading to breakthroughs that can revolutionise multiple industries and address some of society's most pressing challenges.[32]

# Deep Biotech conceptual map



# How Deep Biotech companies drive the biorevolution

The positive impact of deploying advances in modern biotechnology has been demonstrated in the UK's thriving health life sciences sector. The use of engineering biology in particular has enabled us to insert corrected copies of defective or missing genes into patients with certain genetic diseases, tweak immune system cells to accurately detect and kill cancerous cells, harness gut bacteria to deliver targeted therapeutics and vaccines, and genetically reprogramme mosquitoes that limit the spread of diseases such as dengue fever.[33] By combining engineering, biology and programming, we can create tools, processes, products and organisms that are more efficient and more effective than ever before.

The applications of this combination go well beyond medicine and human health, disrupting almost every sector, from agriculture and energy to fashion and manufacturing.[34] Besides the creation of new vaccines and microbiome therapies, it allows us to create new materials for defence, biofuels for transport, renewable chemicals, plastic-free packaging, and improved fibres for clothing. This is in large part because the genetic code is almost universal across humans, microbes, animals, and plant species, meaning we can apply the same toolkit.

In addition, Deep Biotech is further enabled and defined by a huge amount of developmental progress in digitalisation, genomic sequencing technologies, artificial organisms and intelligence, 'lab on a chip' technologies, big data, and novel and engineered enzyme catalysts.[35] For example, Oxford-based Moa Technology can rapidly screen the microscopic behaviour of plants to discover novel and safe herbicide candidates by using high-content imaging, AI and machine learning techniques, allowing them to fight the rapid rise of herbicide-resistant weeds through new crop protection tools. Other companies such as Edinburgh-based Ingenza offer a proprietary enabling toolkit to support protein production, cell-line engineering and fermentation and bioprocess development for various applications across multiple industries.

Case study

evonetix

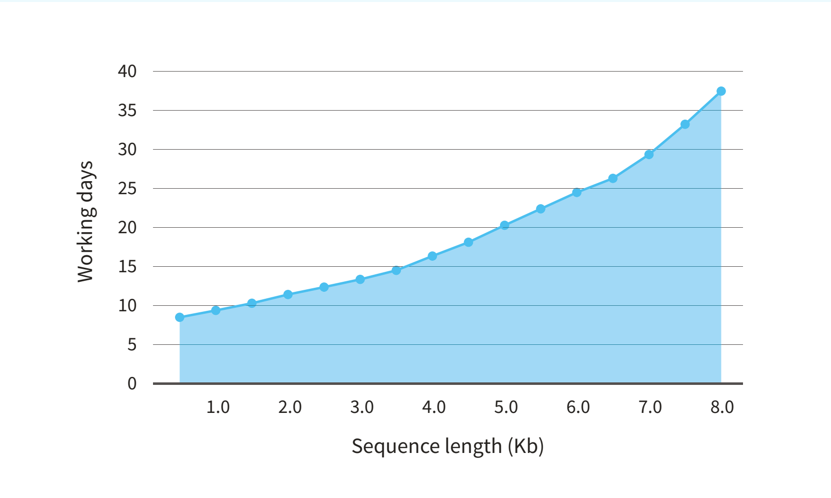
## What does the company do?

Evonetix is developing a revolutionary technology for on-demand gene synthesis. Their platform integrates DNA synthesis with assembly and error correction, all on a specialised silicon chip within a benchtop device. This eliminates the need for time-consuming post-synthesis steps and offers researchers greater control over the process.

## How does this tool benefit the engineering biology industry?

The need for engineering biology-based solutions is expanding across multiple economic sectors. With this, the demand for gene-length DNA is rising rapidly, increasing the pressure on supply chains and bringing attention to the quality and speed of production. Post-synthesis workflows necessary for sequence validation are time-consuming, leading to slow delivery of long DNA sequences.

Innovative technologies are emerging to address the technological challenges of synthesising gene-length DNA. But the methods commonly used in the industry each have their limitations. Due to the significant resources and labour required, DNA synthesis and assembly have become centralised services provided by a handful of reagent manufacturers, constrained by shipping times and costs, and requiring the sharing of confidential information outside of an organisation.

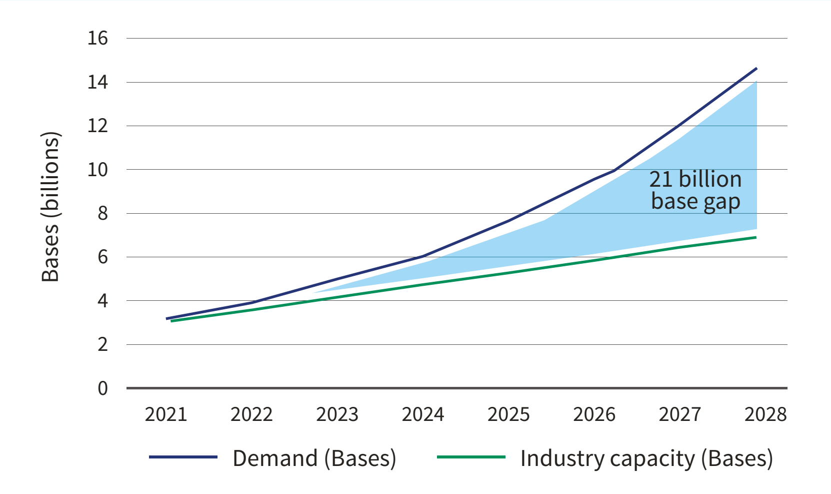



Time to validate a DNA sequence increases as the length of the DNA product increases.

## What is the impact?

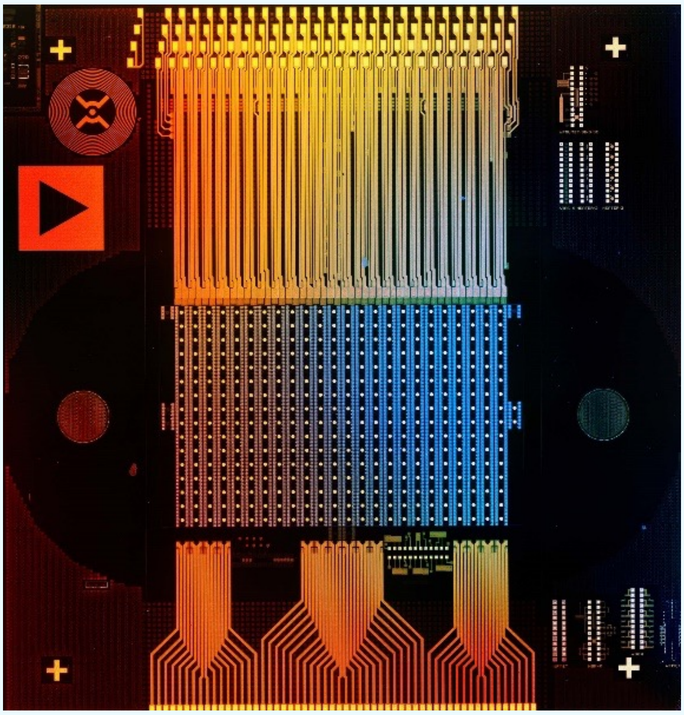
The projected demand for long DNA highlights a future 21 billion-base gap over the current industry capacity. This bottleneck will hamper innovations, causing delays in the design-build-test-learn cycle at the heart of engineering biology development, until accessibility of gene-length DNA is improved. This improved accessibility to long DNA will accelerate research and development in various fields, fostering innovation and leading to breakthroughs in areas like:

- Medicine: For example, Evonetix's technology could be used to create personalised therapies by engineering cells to fight cancer or other diseases. This could involve introducing new genes or modifying existing ones to give the cells specific abilities.
- Agriculture: Scientists can develop crops that are more resistant to pests, diseases, and drought by manipulating their genes with long DNA sequences. For instance, they could introduce genes that produce natural pesticides or improve the plant's tolerance to harsh conditions.
- Biomaterials: Long DNA can be used to create new materials with unique properties, such as self-healing fabrics or biocompatible implants. Imagine clothes that can repair small tears on their own or artificial joints that better integrate with the body.




As DNA demand accelerates, supply constraints created by centralised services lead to a 21 billion base gap.

Evonetix is developing technologies to integrate DNA synthesis with a staged assembly and error-removal process, all on the surface of a groundbreaking semiconductor chip. Its Binary Assembly® process joins complementary DNA strands by selective transfer of DNA from synthesis sites to assembly sites on its silicon chips. After complementary strands are annealed, the assembly sites are heated to sequence-dependent temperatures that promote rapid dissociation of imperfect matches from the chip, thereby separating and removing error-containing sequences whilst maintaining those with correct homology during the assembly process. This offers significant advantages over conventional approaches by lowering error rates and eliminating time-consuming post-synthesis steps. Duplex DNA fragments can be joined, and the process is repeated to assemble gene-length sequences.



Evonetix has developed a semiconductor chip that combines novel synthesis chemistry with thermal control to enable the synthesis of long, accurate DNA.

Moreover, thermal control at distinct sites combined with parallel synthesis may also facilitate the elongation of challenging DNA regions. For example, selective heating can promote the synthesis of DNA segments with high GC content, which have higher melting temperatures and are prone to secondary structure formation.

### What are the opportunities and challenges?

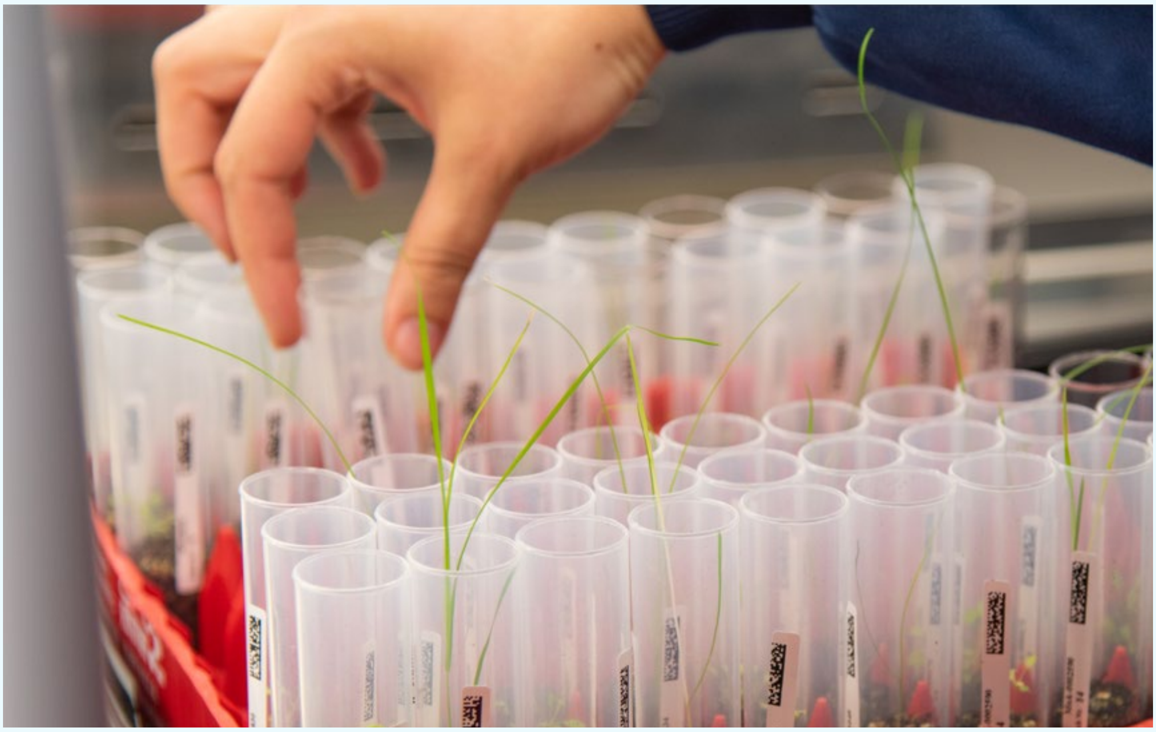
It is critical to prevent research progress from stalling between the "design" and "test" phases of the Design-Build-Test-Learn cycle and keep pace with the increasing demand for gene-length DNA. Further, a shift away from centralised service providers will allow laboratories to gain more control over gene synthesis, maintain confidentiality of proprietary sequences, and judge project timelines more accurately.

The potential for engineering biology to have far-reaching economic impact hinges upon access to fast, accurate long DNA. The development of benchtop gene printers represents a new breakthrough in gene synthesis technologies, meeting the growing need for this process to become more affordable, flexible, and scalable.

Case study

## What does the company do?

Moa Technology is developing next-generation herbicides to tackle a growing crisis in agriculture: herbicide-resistant weeds. The company was spun out of the University of Oxford in 2017 and uses the same kind of advanced approaches employed in health and medicine-focused biotech to identify, understand and develop new herbicides, with game-changing speed and accuracy. Specifically, it is developing herbicides with novel modes of action (MOAs).



## What is the impact?

Without effective herbicides, farmers can lose up to 40% of their crop yield as a result of weed growth. This means that herbicide-resistant weeds are a major threat to global agriculture and food security.

The issue is particularly pressing because of climate change and population growth. If weeds are allowed to reduce agricultural productivity, farmers will need to use more land, fertiliser, diesel, water and other inputs to produce the same amount of food, substantially increasing carbon emissions. Increased land use for farming would also reduce natural carbon sequestration, as well as impacting biodiversity and general resilience. Furthermore, farmers will need effective herbicides to grow new crops and contend with new weed mixes as crop growing areas shift as a result of climate change.

### Why is biotechnology/engineering biology the solution?

Herbicide resistance is a particularly urgent international problem given a 35-year innovation drought in the established herbicide industry, which has not delivered effective new products that can counter the problem.

Working with both synthetic molecules and natural products found in organisms and ecosystems around the world, and using a discovery engine similar to those used in drug discovery, Moa's interdisciplinary team of scientists carry out plant-led high-throughput screening to identify new modes of action. This allows them to find whole new families of herbicides that are safer and better for the environment, and more effectively choose the best candidates for investment and development into products for farmers' fields.

### How do we drive forward the biorevolution in the UK?

The UK should make the most of its remarkable expertise in biotechnology, and in science and technology more broadly. This is in the national economic interest, and vital given international challenges and the need for innovation to address them.

Among other key priorities, the Government and other stakeholders must support and encourage the incredible talent pools in the UK, and the ecosystems around its universities. Moa illustrates these points well. Its technology was developed within the University of Oxford's Department of Plant Sciences by a professor and his French PhD student, and today it employs an international team of more than 60 drawn from disciplines including chemistry, biotechnology, agriculture and artificial intelligence/machine learning.

### What are the opportunities and challenges?

The potential for next-generation herbicides is huge, both in overcoming the immediate challenge of herbicide resistant weeds, and in providing superior performance across a range of other criteria. Moa has a prolific pipeline of both traditional and bioherbicide leads that work in new ways. Additional industry partnerships, robust yet responsive regulation, and international collaboration between governments and regulators all have a vital role to play, too.

Although Moa has strong financial backing, the challenge for governments and other stakeholders is to ensure more broadly that the UK's cutting-edge biotechnology and research continues to be developed to support scale-up businesses that address key challenges facing the world.

## Sustainable proteins: Reinventing agriculture

An area of particular prominence that has made its way into the public eye is the rise of cultivated meat and cellular agriculture. Private sector investment in UK-cultivated meat companies increased by 400% from 2021 to 2022 with £61 million raised, 'totalling more than the rest of Europe combined'.[36] Based on scientific and technological advances in a process called 'reprogramming',[37] animal cells cultivated in large fermentors to create real meat remove the need for emission- and resource-heavy, industrial-scale farming, and are well on the way to becoming price competitive. In 2013, the first lab-developed beef burger cost $330,000[38] to create, while six years later in 2019, the cost of production per burger fell to $9.80.[39] However, to be a strong market competitor, cultivated meat must reach a production cost of $2.92 per pound.[40]

The UK currently has 138 sustainable protein companies, of which 23 develop cultivated meat and 15 use precision fermentation to produce sustainable proteins.[41] Start-ups such as Uncommon, based in Cambridge, use a small sample of animal cells suitable for entering the human food chain and multiply them infinitely through the help of bioreactors adapted from biopharma (called bio-creators)[42] to create pork belly and bacon. Other start-ups such as Extracellular, the first dedicated Contract Development and Manufacturing Organisation (CDMO) for cultivated meat, aim to drive the commercialisation of cellular agriculture at all stages in the UK, while Wales-based Cellular Agriculture supports the scaling of cultured meat, seafood and milk production through their scaled commercial bioprocess technology platform.

Case study

Quest Meat

### What does the company do?

Quest Meat is a UK-based biotechnology company that develops ingredients for cell culture processes in the cultivated meat industry. They aim to replace fetal bovine serum (FBS) and microcarrier scaffolds, two key components of traditional cell culture methods, with more sustainable, food-safe and cost-effective alternatives.

Their primary focus is developing ingredients that can be used to scale up and reduce the cost of cultivated meat production. Their ingredients are circular economy-derived and are designed to be compatible with a variety of cell lines and culture conditions.

### What is the impact?

Quest Meat's products have the potential to significantly reduce the environmental impact of meat production. By replacing FBS and microcarriers with their ingredients, the company can help mitigate the greenhouse gas emissions, water usage, and land use associated with traditional livestock farming whilst removing the cost barrier.

## What is cultivated meat?

### Step 1

Small samples of tissue are taken from an animal. These tissues contain stem cells that have the ability to replicate.

### Step 2

After isolating stem cells from the tissue, they are placed in a safe and controlled cell culture environment.

### Step 3

These animal stem cells are provided with nutrients such as amino acids, vitamins and fats, promoting the cells to divide and grow.

### Step 4

When enough cells have been produced, they can be matured into meat cells. They are then processed into burgers, sausages, mince or nuggets for a delicious, guilt-free experience.

Quest Meat takes a circular economy approach to its product development, seeking to minimise its environmental impact throughout the entire production process. They also focus on localised sourcing and distribution to reduce their carbon footprint.

Quest Meat's ultimate goal is to make cultivated meat production more sustainable and accessible to a wider audience. They believe that their ingredients can play a crucial role in driving the growth of this innovative food sector.


### What are the opportunities and challenges?

Quest Meat faces a number of opportunities in its pursuit of its goals. The cultivated meat industry is rapidly growing, providing a growing market for their products. And where cultivated meat companies are facing significant technical challenges in scaling up their production process, Quest Meat bioprocess experts provide relevant know-how. Challenges still relate to the regulatory uncertainty and technology readiness of the sector.

The process of cellular agriculture and the cultivation of meat in labs instead of fields has gained momentum in part due to its potential to reduce greenhouse gas emissions.[43] Livestock represents a total of 14.5% of all greenhouse gas emissions globally, with cattle being the largest contributor.[44] By contrast, cultivated meat production may cause up to 92% less global warming, 93% less air pollution and use up to 78% less water.[45] In addition, moving the production of meat away from land frees up valuable agricultural land by using up to 95% less land,[46] and helps fight deforestation and biodiversity loss.[47]

Case study

Green Bioactives

## What does the company do?

Green Bioactives specialises in the development and manufacturing of natural ingredients through our patented Plant Cell Culture Technology. This proprietary technology enables the extraction of target plant primary vascular stem cells from leaf materials within whole plants known for producing specific natural products. These dissected cells undergo growth on solid media, supplemented with the necessary nutrients to stimulate proliferation independent of their host plant. Subsequently, the proliferated cells are transferred and cultured in liquid media, facilitating further proliferation and scalable production. They can end up in products for cosmetics, nutraceuticals (also known as dietary supplements in the US or food supplements in Europe), pharmaceuticals, food and beverage or ag-tech.

## What is the impact?

Plant cell culture is a more sustainable alternative to traditional agriculture. It requires less land, water, and resources, reducing the environmental impact associated with large-scale farming. The controlled environment also enables the use of renewable energy sources, further contributing to sustainability goals.

## Why is biotechnology/engineering biology the solution?

Green Bioactives was established to replace current unsustainable methods of extraction and bring cost-effective and improved bioactives to the market using plant vascular stem cells (VSCs). VSCs can adapt into functionally and structurally distinct primary plant tissues. Using our expertise to create the right environment, plant vascular stem cells can be cultured to produce target bioactive molecules which are produced naturally in whole plants.

## How do we aim to drive forward the biorevolution in the UK?

Green Bioactives' goal is to revolutionise the way that businesses source natural ingredients. Not only is their technology sustainable, it also has the following benefits:

Consistency and purity - Plant cell culture ensures the production of standardised and consistent ingredients. The controlled environment eliminates variability caused by external factors such as weather conditions and soil quality, leading to a more reliable and predictable output. Moreover, the process minimises the risk of contamination, resulting in a higher purity of the final product.

Year-round production - Traditional agriculture is often limited by seasonal variations, requiring specific climatic conditions for optimal plant growth. Plant cell culture allows for year-round production independent of weather constraints, ensuring a continuous and reliable supply of ingredients.

Efficiency - Plant cell culture significantly accelerates the production cycle compared to conventional harvesting. With the ability to control growth factors, scientists can manipulate the rate of cell division and target metabolite production, leading to faster and more efficient nutrient extraction.

### What are your opportunities and challenges?

Green Bioactives has developed two of its own products for the personal care market and is currently working on co-development projects with multinational partners.

Key areas of potential development include:

- Personal care (core): Green Bioactives' core market focus, leveraging their technology to create sustainable and high-quality ingredients for cosmetics and fragrances.
- Nutraceutical (core): Developing innovative dietary supplements and functional foods with consistent delivery of targeted health-promoting compounds – these can include dietary supplements, vitamins, minerals and herbal products.
- Ag-tech: Exploring applications in plant science and agriculture to improve crop yields and sustainability.
- Food and beverage: Partnering with food and beverage companies to create products with enhanced nutritional value or functionalities using Green Bioactives' natural ingredients.
- Pharmaceutical: Collaborating with pharmaceutical companies to develop novel plant-based ingredients for potential therapeutic applications.

Green Bioactives are focussing on co-development opportunities in all markets, but with a key focus on personal care (including cosmetics and fragrance) in Europe and North America in order to pioneer sustainable and reliable approaches to bioactive ingredient development.

## Biomaterials: Creating better materials

Another industry with a large global environmental footprint, the fashion industry, is estimated to be causing 10% of global carbon emissions.[48] While natural, plant-derived and bio-degradable fibres such as cotton are being used, polyester (largely derived from petroleum) dominates 54% of the global market due to the competitively low price of fossil fuels.[49] Novel biomaterials have the potential to reduce our reliance on animal- and petrochemical-derived materials in the future. Building on the rapidly evolving technology of biofabrication,[50] London-based Modern Synthesis developed a microbial weaving process that uses bacteria, found in kombucha tea, trailing tiny fibres of nanocellulose to weave a novel biomaterial. The process allows clothing items to be precisely shaped, designing out waste.[51] Norwich-based Colorifix aim to reduce the textile industry's environmental impact with a dyeing process that uses the DNA codes of colours found in nature and has microbes recreate them, removing the need to rely on harsh chemicals. Their revolutionary biology-based approach has earned them a place amongst the finalists of the 2023 Earthshot Prize.[52]

Advances in the development of biomaterials can replace some synthetic, petrochemical-derived fibres, and prevent the pollution of water through microfibre shedding more generally.[53] Globally, 16% and 35% of microplastics released into our environment are from the laundering of synthetic textiles[54] which can end up in the food chain and, ultimately, the human body.[55] Once released, they are difficult to remove from the environment. Tackling the problem from another angle are Puraffinity, a company from Imperial College London, who use a novel material that removes harmful pollutants from water. They design and manufacture a highly cost-effective absorbent media that selectively binds a complex set of chemical materials, called PFAS, commonly used in textiles,[56] In addition, their platform technology can be used by many established industries, helping them become more sustainable in their processes and reach their net zero targets.

Case study

SOLENA MATERIALS

### What does the company do?

Solena Materials is a spin-out from Imperial College London that is developing new types of computationally designed synthetic protein material that is biodegradable and made from non-petroleum feedstocks. The company's goal is to replace synthetic materials made from petroleum with more sustainable and environmentally friendly alternatives.

They have developed a method for designing and synthesising synthetic proteins with specific properties. The company's proteins can be spun into tough continuous fibres with a unique combination of performance and properties that are not available in existing natural or synthetic materials. These fibres are suitable for use in a variety of applications, including textiles, composite materials, and medical devices.

## What is the impact?

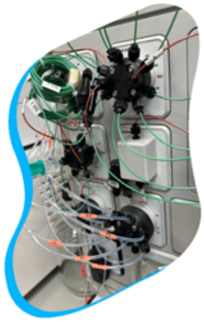
Solena Materials' synthetic proteins have a number of environmental benefits over traditional synthetic materials. The proteins are biodegradable, so they will break down naturally in the environment. Additionally, the proteins are made from non-petroleum feedstocks, which reduces the company's reliance on fossil fuels.

## Why is biotechnology/engineering biology the solution?

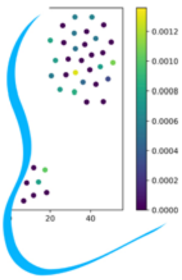
Solena Materials uses engineering biology to design and synthesise its proteins. This approach offers several advantages over traditional methods of making synthetic materials. First, it is more precise and efficient, allowing for the creation of protein fibres with specific properties. Second, it is faster and more scalable, enabling the production of large quantities of proteins. Third, it is more environmentally friendly, as it does not require the use of harmful chemicals or solvents.

### The Process

**AI-based protein design**
We design new-to- world proteins using in-house trained deep learning models to design protein sequences that can form high performance, non-oil derived and biodegradable fibres.



**Automated lab**
Our designer proteins can be produced in small quantities and in parallel using our liquid handling robots.




**Training data**
The data generated using our rapid testing method provides valuable training data to further enhance our deep learning modules.

**High-throughput materials testing**
We have developed a proprietary method for rapidly testing the materials performance of our proteins on a small scale.

## How do we drive forward the biorevolution in the UK?

The UK has a strong and growing bioeconomy, with several companies developing innovative biotechnology solutions. Solena Materials is one of these companies, and the company is well-positioned to take advantage of the UK's supportive ecosystem for biotechnology.

### What are the opportunities and challenges?

Solena Materials faces a number of challenges, including the need to scale up its production processes and to develop new applications for its proteins. However, the company also has many opportunities, including the growing demand for sustainable and environmentally friendly materials.

Investors in Solena Materials are attracted to the company's innovative technology and its potential to address a significant environmental challenge. The company has raised a significant amount of capital from venture capitalists and other investors.

Solena Materials is focused on developing new applications for its proteins, such as in textiles, composites, and medical devices. The company is also working on improving its production processes to make its products more affordable.

Other innovative companies such as Shellworks challenge fossil fuel-based materials, such as plastic packaging used in the cosmetics industry of which 62% is non-recyclable.[57] The company develops a novel material made by microorganisms found in marine and soil environments to make durable, fully compostable tubs or jars.[58] The material's regenerative nature means that once it is composted, the same microbes in the soil used to make the jar will consume it as a source of food, meaning the material biodegrades without generating microplastics.

Case study

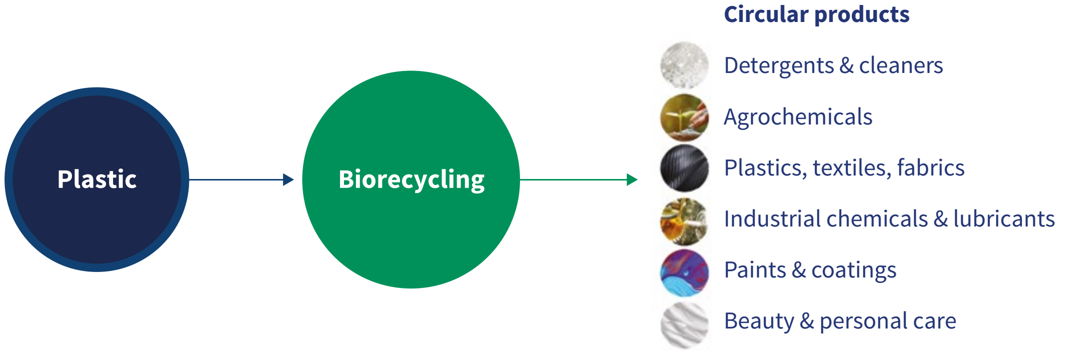
EPOCH BIODESIGN

## What does the company do?

Epoch Biodesign is emerging as a pioneer in the field of engineered biology, aiming to transform the way they manage and utilise plastic waste. Through innovative enzyme engineering, the company is developing a game-changing solution that tackles the root causes of plastic pollution by building an economical, scalable recycling route for complex waste that currently has no end-of-life solution, other than landfill or incineration, paving the way for a more sustainable future.

Epoch Biodesign's core biorecycling technology revolves around the creation of tailor-made enzymes, meticulously engineered using AI and a unique knowledge of biochemistry to transform different types of plastic waste. These nanoscale biomachines possess remarkable specificity and efficiency and are capable of depolymerising a wide range of polymers into recycled plastics and circular chemicals with applications across a range of industries.

### Our vision: The world's waste, transformed by biology




**Epoch's proprietary biology, polymer science and chemistry enables us to work with complex, blended feedstocks and produce carbon-friendly molecules from waste.**

## What is the impact?

The impact of Epoch Biodesign's technology extends far beyond plastic waste management. By eliminating the need for virgin plastic production, the company significantly reduces the extraction and processing of fossil fuels, a major source of greenhouse gas emissions. Additionally, the low-energy consumption of enzyme-based processes further contributes to climate change mitigation efforts.

### Why is biotechnology/engineering biology the solution?

Epoch Biodesign's approach offers a truly circular solution. Unlike conventional methods of plastic processing or advanced recycling technologies, enzymatic recycling can be run at low temperatures and pressures, and without the use of toxic catalysts, significantly reducing processing energy and environmental impact. By unlocking the value of plastic waste, the company aims to divert it from disposal and convert it into valuable feedstock for the production of new plastics, textiles, and other hydrocarbon-derived circular chemicals and products.

### How do we drive forward the biorevolution in the UK?

Biology is a strength of the UK. Epoch Biodesign is an example of an engineering biology firm scaling up, using UK talent and UK knowledge. Epoch Biodesign are driving investment and development within the engineering biology space in the UK. They are currently a growing team of 25, and their next big development is plans to build a pilot facility. They are also looking overseas for opportunities to sell their products and develop capacity.

### What are the opportunities and challenges?

While the company faces the usual technical and R&D challenges associated with scaling up new technologies, Epoch Biodesign is particularly focused on securing sustained funding. The upfront costs required for enzyme engineering research and manufacturing facility construction pose a unique barrier to scale-up.

Despite these challenges, Epoch Biodesign remains optimistic about the future. The company is actively progressing partnerships with investors, industry players, and regulatory bodies to accelerate the commercialisation of its technology. With the growing global momentum for sustainable solutions, Epoch Biodesign is well-positioned to make a substantial impact on the fight against plastic pollution and contribute to the transition towards a circular economy.

## Engineering the next generation of biofuels

Using natural materials and their components to put them to use for another purpose is at the heart of much of traditional industrial biotechnology. Biomass, such as crops or biowastes like residues from whiskey production, can be used to produce liquid and gaseous biofuels, replacing our dependence on fossil fuels. At 24% of the UK's total emissions, the transport sector emits the largest amount of greenhouse gases of any sector in the UK.[59] Biofuels play a significant part in helping us reach net zero by decarbonising our transport sector.[60] Algae are well known as natural 'decarbonisers' through their ability to absorb carbon emissions from the biosphere. Applying the modern 'engineering biology' toolkit allows us to increase algae's absorbing capabilities, turning them into highly efficient producers of algae oils – a sustainable source of fuel more powerful than solar, wind, and lithium.[61]

Case study

phycobloom

### What does the company do?

Phycobloom is a Deep Biotech company that is developing microalgae to produce oil. The oil can be used as a biofuel or as a feedstock for other products. Phycobloom is based in the UK and is currently in the R&D phase.

Phycobloom's long-term vision is to develop microalgae that can produce oil and then secrete that oil into the environment. This would allow for much easier harvesting of the oil than traditional methods.


### What is the impact?

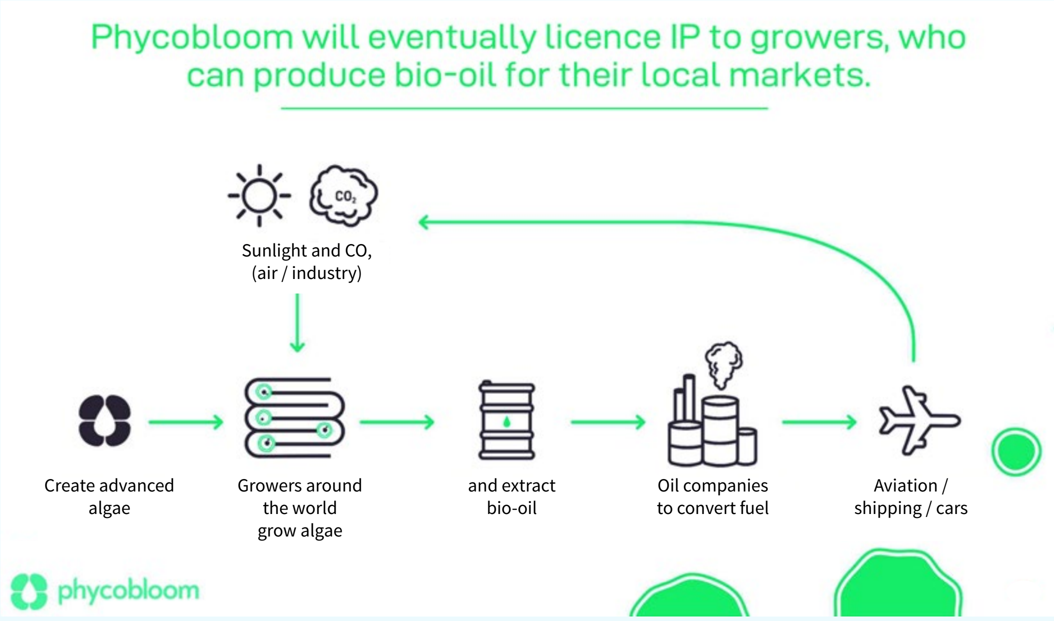
Phycobloom's technology has the potential to significantly reduce greenhouse gas emissions. This is because algae oil can be used as a replacement for fossil fuels.

### Why is biotechnology/engineering biology the solution?

Phycobloom is using biotech because it is the most efficient way to produce complex molecules such as oil. Physics and chemistry are better suited for making smaller molecules, such as liquid petroleum gas or hydrogen.

### How do we drive forward the biorevolution in the UK?

Phycobloom is committed to driving forward the biorevolution in the UK. The company is based in the UK and is working to create a sustainable biofuel industry.




## What are the opportunities and challenges?

Phycobloom's main opportunities are the growing demand for biofuels and the UK's strong talent pool in science and engineering. However, the company also faces challenges such as the cost of R&D and regulatory uncertainty.

The future of biofuels is bright, and Phycobloom is well-positioned to take advantage of this trend. The next phase of development requires additional investment to fully unlock the potential of its technology and address a wider market.

# Unlocking potential

The potential of Deep Biotech to not only help us reach our sustainability goals but to transform our focus from reaching net zero to creating a truly sustainable bioeconomy is enormous. Its cross-cutting nature means that it can provide solutions that support as many as 10 out of 17 Sustainable Development Goals (SDGs).[62,63,64] The use and creation of sustainable bio-based materials and sources of energy allow for more efficient and sustainable use of our natural resources and lower our carbon footprint. Engineered algae can fight climate change by decarbonising the air we breathe. Plastic can be broken down by engineered enzymes,[65] reducing the amount of plastic waste permanently ending up in landfills or polluting our rivers and oceans.

The economic value can also not be overlooked. It is estimated that 'more than half of the impact from applications of biotechnology overall will lie outside healthcare, with the most significant proportion being in agriculture, aquaculture and food ($0.8–1.2 trillion globally by 2030–40), followed by consumer products and services ($0.2–0.7 trillion globally by 2030–40) and materials and energy production ($0.2–0.3 trillion globally by 2030–40)'.[66] The impact of many non-health applications of biotechnology will, in addition, ultimately have a positive impact on the healthcare sector, for example by reducing healthcare costs due to decreased air pollution, expanding the total economic and social value even further.

However, the potential impact relies to a large part on consumer, societal and regulatory acceptance.[67] The role of private investment as well as Government support should also not be underestimated.

## Opportunities and challenges for Deep Biotech

While the potential social, economic and environmental impact is huge, Deep Biotech companies can face many challenges. Government policy has a critical role in ensuring these can be overcome, and regulators need to equip themselves with the right knowledge and create safe new regulatory pathways to bring Deep Biotech products to market. Existing technologies and products such as single-use plastics or conventional beef are often more economically competitive. Competing traditional industries such as the chemical industry are huge and can produce at low cost, whereas building up new infrastructure and facilities to scale new products is costly and takes time. This can often lead to UK companies conducting R&D in the UK, but ultimately carrying out the economically valuable production activity abroad.[68] Where there is no competition, companies are faced with creating an entirely new market and stimulating consumer demand. Consumer confidence can also be a decisive factor in the uptake of novel products, as exemplified by the long road to allowing gene-edited crops onto UK markets.[69] In addition, the novel and emerging technologies which power Deep Biotech bring with them the need for a broad range of new and diverse skill sets, and the need to attract and retain global talent.

## The role of policy and regulation

Government and regulators can play a powerful role in incentivising the research, development and commercial uptake and success of Deep Biotech, thereby actively driving the biorevolution.

To fulfil their responsibilities, regulators systematically review and withdraw market approval of old, unsafe and less effective pesticides and herbicides,[70] putting pressure on improving approved substances, or developing new ones. In the past 25 years, the number of EU-approved substances has been cut down by 50%, creating a demand for the technologies of innovative companies that can help to rapidly identify and develop improved herbicides.[71]

Earlier this year, the EU announced restrictions on the use of PFASs, harmful and widely used 'forever' chemicals that do not break down in the environment and can be absorbed by animals, plants, and humans.[72] The UK is following suit in the development of restrictions that impose controls on their use[73] and limit the amount of PFAS that can be emitted. This new wave of regulation creates a market for innovative Deep Biotech companies with technologies that can bind and remove PFASs from water and water waste products of established industries that must meet new restrictions.[74]

However, as evidenced by the recent failure of the US PFAS Action Act, which had only been approved back in 2020,[75] a stable, predictable and forward-looking regulatory and policy environment is essential to the long-term success of these emerging companies and their solutions. It can send a powerful signal to companies and investors about the attractiveness of the UK market and is recognised as a necessary approach by countries such as Singapore and the US who were the first countries in the world to approve cultivated meat, or Denmark and Germany who together agreed to promote more 'innovation-friendly regulation of biosolutions'[76] by addressing barriers in EU regulations.[77]

The UK policy landscape capturing and supporting Deep Biotech has been fragmented, with briefings sitting across different Government departments. Previous attempts to create a framework for the UK's growing bioeconomy were withdrawn[78] and superseded by new strategies with a lesser focus on realising the UK's biotech potential.[79] However, looking to bring them together are recent initiatives such as the Government's National Vision for Engineering Biology,[80] a £2 billion vision that plans to harness the power of biology over the next 10 years, setting out how investment, policy and regulatory reform will support this critical technology.

Alongside an increasingly comprehensive policy landscape, the UK's new pro-innovation approach to the regulation of emerging technologies[81] is a positive step. The UK has been leading European efforts in enabling genetic technologies with the passing of the Genetic Technologies (Precision Breeding) Act[82] in March 2023 and making use of regulatory sandboxes.[83] Pioneered in the UK,[84] sandboxes allow innovators to test new products in a

**"The Government's National Vision for Engineering Biology is a £2 billion plan to harness the power of biology over the next 10 years."**

real-world environment for a limited period and under close supervision of a regulator.[85] Three to five of those sandboxes will be funded to test and craft suitable regulations for engineering biology-derived products, helping them reach the market.[86] Proactive initiatives such as these send a positive signal to the UK's Deep Biotech ecosystem, driving R&D, investment, and commercialisation in the long term.

## Unlocking investment

Just as important is a continued stream of public and private investment to bring new innovations to market. There is an increased awareness and appetite for impact-focused investment among venture capitalists (VC) and other investors. European deep tech VC funding in synthetic biology increased from $10 million in 2016 to $256 million in 2022,[87] while the UK has seen an overall investment of $13 billion between 2018 and 2023 into all areas of climate tech.[88] Engineering biology firms in the UK collectively fundraised over £5.2 billion between 2017 to 2022, placing them third in the world after the US and China.[89] The UK Innovation & Science Seed Fund (UKI2S), backed by UK Research and Innovation (UKRI), Department for Science, Innovation and Technology (DSIT), Ministry of Defence (MOD) and UK Atomic Energy Authority (UKAEA),specialises in engineering biology and other innovative areas that facilitate sustainable growth, focusing on those innovations that emerged from the UK's publicly funded science and knowledge base.[90] VC funds such as London-based Octopus Ventures and Systemiq Capital have a focus on climate change and climate tech,[91,92] while Oxford-based Oxford Sciences Enterprises specialises in deep tech that fuels the fourth industrial revolution, that is, the biorevolution.[93] The large European fund Sofinnova Partners has an industrial biotech programme focusing on early-stage investments that have a positive impact on sustainability in the food, agriculture, materials, and chemical sectors.[94]

> **"Engineering biology firms in the UK collectively fundraised over £5.2 billion between 2017 to 2022."**

Investors are increasingly looking to invest in novel technologies from the early stages, despite the relative risk and potential for slow returns. The Mansion House Reforms announced in 2023 are set to unlock further capital into high-growth companies. Where private investment is difficult to come by, public funding agencies such as UKRI and its councils, and Innovate UK in particular, play an important role in bridging the valley of death, attracting private investment, and helping the translation and commercialisation of Deep Biotech. Flagship public funding programmes such as the National Engineering Biology Programme[95] and the Technology Missions Fund[96] are integral to this, ensuring the UK leads the way in transformative technologies. The UK's commitment to funding fundamental science and research at universities and research organisations is equally important, underpinning the success and future growth of the UK's Deep Biotech ecosystem.

R&D tax reliefs are also critical support for the innovative companies driving the biorevolution, enabling them to go deeper and faster in their R&D and leverage further capital from investors. The reliefs make the UK an attractive place to start and grow, helping to bring into the ecosystem innovative companies from around the globe.

# Improving the UK landscape: What next for Deep Biotech

The many cross-sector activities of Deep Biotech can make it difficult to quantify their impact and contribution to our global sustainability goals. However, its positive environmental and economic cannot be doubted. In 2014, the bioeconomy was estimated to contribute £220 billion GVA to the UK economy and supporting over five million jobs.[97] Employment growth in the wider UK industrial biotechnology sector has outpaced national averages, increasing by more than 10% per year, with median earnings around £20,000 above the national average.[98]

As the only national trade association representing the innovative life sciences and biotech industry in Westminster, Whitehall, and beyond, we truly believe in the power of Deep Biotech to change the way we live for the better. Deep Biotech contributes to tackling the pollution of our water, land, and air, challenges unsustainable or environmentally unfriendly processes and products with biology-based, more sustainable ones, and supports the UK's net zero ambitions.

In 2023, researchers at the University of Cambridge found that 'there are many reasons why the [UK] Government may wish to support [modern industrial biotechnology], including increasing value, addressing resource pressures, securing energy security, job creation and economic growth, and addressing climate change or waste reduction'. The same study, commissioned by the Government Office for Science, advised that building on 'the strengths of the UK's strong base in the health life sciences sector', the UK 'should use the opportunity to accelerate…biotech beyond health'. With our long-standing expertise in supporting the UK's health biotech sector, the BIA is aiming to drive forward just that.[99]

Throughout the last three decades, the BIA has supported its existing health biotech membership by *influencing* policymakers to ensure life science companies' voices are heard on the matters that are critical to their success, *connecting* the UK ecosystem through industry-leading events, expert committees and overseas missions, and by helping companies *save* money through our business solutions programme. We will work together with institutions in the UK and abroad, and build on the great efforts already made by leading organisations such as EuropaBio in championing modern industrial biotechnology.

Over the coming months, we will identify policy needs in close consultation with our existing Deep Biotech membership and leading organisations and thought leaders, create networking opportunities, integrate Deep Biotech into the BIA's strategic priorities, and highlight BIA members' contributions to a global, sustainable bioeconomy. We will leverage BIA's strengths in *influence, connect, save*, to advance the UK Deep Biotech landscape and raise the profile of our members and their disruptive biotechnologies.

## Influence

In close consultation with our growing Deep Biotech membership, and in collaboration with organisations aligned with our mission, we will identify UK policy needs and work with policymakers and other stakeholders to support the growth of Deep Biotech. We will ensure our members' voice is heard on matters that are critical to Deep Biotech's success. We will work to increase stakeholders' understanding of Deep Biotech, including policymakers and parliamentarians, investors, existing traditional industries, and the public.

## Connect

We will connect the UK Deep Biotech ecosystem through industry-leading events and expert groups and showcase Deep Biotech's contributions to a global sustainable bioeconomy. We will produce further reports and online content highlighting those contributions and their importance, and promote Deep Biotech in the media.

## Save

BIA members benefit from significant savings through our Business Solutions purchasing programme, helping companies grow more cost-effectively.

# About BIA

The BioIndustry Association (BIA) is the voice of the innovative life sciences and biotech industry, enabling and connecting the UK ecosystem so that businesses can start, grow and deliver world-changing innovation. We are an award-winning trade association representing more than 600 member companies including:

- Start-ups, biotechnology and innovative life science companies
- Pharmaceutical and technological companies
- Universities, research centres, tech transfer offices, incubators and accelerators
- A wide range of life science service providers: investors, lawyers, IP consultants and IR agencies

## Explore opportunities to influence, connect and save at bioindustry.org

For more information on the BIA's activities in Deep Biotech, or to share feedback on this report, please contact Linda Bedenik, Senior Policy and Public Affairs Manager, at lbedenik@bioindustry.org or 07864 902 930.

**Not a BIA member?**
If you would like to join the BIA to connect with the Deep Biotech ecosystem and shape policy areas key to Deep Biotech, please contact George Caterer, Membership & Business Development Manager, at gcaterer@bioindustry.org or 07593 379 942.

This report would not have been possible without the input and expertise of BIA member companies and stakeholder organisations, who we thank for their contributions.

## Annual Supporters

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# Endnotes

1 See https://www.bioindustry.org/static/9781537e-8dc1-4dac-abbd97f3b321284b/30c60889-4e53-40f4-a64476d8a05727ab/BIA-DIT-Engineering-Biology-Brochure.pdf
2 Figure for 2021. See https://www.gov.uk/government/news/chancellor-reveals-life-sciences-growth-package-to-fire-up-economy
3 See https://biotechfinance.org/
4 See https://www.quorn.co.uk/mycoprotein
5 See https://www.celtic-renewables.com/ The re-use of waste materials, rather than discarding them and extracting new resources, is the anchor of a 'circular economy' that large parts of industrial biotech play an important part in (UNCTAD, 2023).
6 See https://www.biohm.co.uk/mycelium
7 See https://www.yourgenome.org/facts/what-is-crispr-cas9/. CRISPR-Cas9 is a unique technology that enables researchers to edit parts of the genome by removing, adding or altering sections of the DNA sequence. It is currently the simplest, most versatile and precise method of genetic editing.
8 For example, the company Moa Technology rapidly screens the cellular behaviour of plants and their compounds to discover novel and safe herbicide candidates by using AI and imaging analysis.
9 See https://www.earlham.ac.uk/news/scientists-one-step-closer-rewriting-worlds-first-synthetic-yeast-genome
10 See https://www.nottingham.ac.uk/news/scientists-take-major-step-towards-completing-the-worlds-first-synthetic-yeast
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33 See https://www.bioindustry.org/static/uploaded/01333ebd-43a7-4093-97bd3cf2ef2d64bf.pdf
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46 See https://gfi.org/press/new-studies-further-the-case-for-cultivated-meat-over-conventional-meat-in-the-race-to-net-zero-emissions/#:~:text=The%20LCA%20shows%20that%20cultivated,%2C%20and%20chicken%20by%2029%25.
47 See https://www.climatepolicyinitiative.org/publication/the-economics-of-cattle-ranching-in-the-amazon-land-grabbing-or-pushing-the-agricultural-frontier/#N3. “Estimates show that about 70% of deforested land in the Amazon is used for cattle ranching.”
48 See https://www.europarl.europa.eu/news/en/headlines/society/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographics
49 See https://textileexchange.org/knowledge-center/reports/preferred-fiber-and-materials/
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