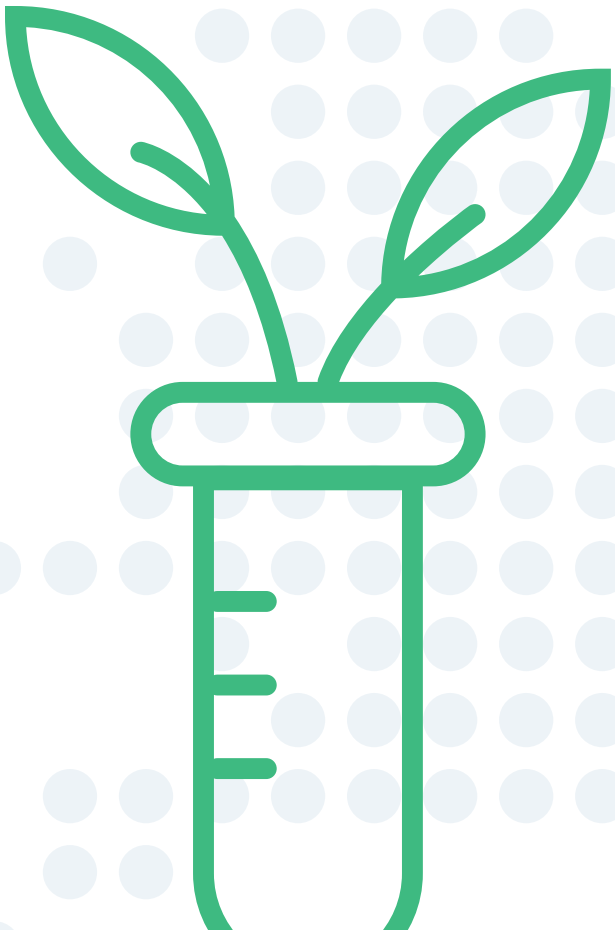
Industrial Biotechnology
Leadership Forum

Growing the UK Industrial Biotechnology Base

Enabling Technologies for a Sustainable Circular Bioeconomy: A National Industrial Biotechnology Strategy to 2030



Contents

Acronyms

BBIA
Bio-based and Biodegradable Industry Association

BBSRC
Biotechnology and Biological Sciences Research Council

BDC
Biorenewables Development Centre

BEACON
BEACON Biorefining Centre of Excellence

BEIS
Department for Business, Energy and Industrial Strategy

BIA
BioIndustry Association

BIOCATNET
Network in biocatalyst discovery, development and scale up

BioPilots
The Alliance of Open Access Biorefining Centres

BioProNET
Network in Bioprocessing

CAGR
Compound Annual Growth Rate

CBMNet
The Crossing Biological Membranes Network

CIA
Chemical Industry Association

CPI
Centre for Process Innovation

CRISPR
Clustered Regularly Interspaced Short Palindromic Repeats

DIT
Department for International Trade

EPSRC
The Engineering and Physical Sciences Research Council

ERGF
Exceptional Regional Growth Fund

GMDI
Genetically Modified Derived Ingredient

GVA
Gross Value Added

IB
Industrial Biotechnology

IB Catalyst
Industrial Biotechnology Catalyst

IBioIC
Industrial Biotechnology Innovation Centre

IBLF
Industrial Biotechnology Leadership Forum

IKC
Innovation and Knowledge Centre

IUK
Innovate UK

KTN
Knowledge Transfer Network

KTP
Knowledge Transfer Partnership

NIBB
Networks in Industrial Biotechnology and Bioenergy

RRI
Responsible Research and Innovation

RTO
Non-profit Research and Technology Organisations

SDG
Sustainable Development Goals

SMEs
Small to medium size enterprises

SynbiCITE
UK Synthetic Biology Industry and Engineering Biology Industrial Accelerator

TRL
Technology Readiness Level

UKRI
UK Research and Innovation

USDA
The U.S. Department of Agriculture

Foreward

“Industrial Biotechnology (IB) offers huge potential for the UK, providing jobs and economic growth across a wide range of market and industry sectors. IB can mitigate climate change through the development of greener, cleaner manufacturing processes, as well as offering opportunities for waste utilisation and new products that benefit society which cannot be made any other way.

Steve Bagshaw

Chair, Industrial Biotechnology Leadership Forum

Our exploitation of the planet’s resources has and continues to fuel economic growth and, overall, a general improvement in the human condition. However, these activities bring responsibilities, which perhaps have been neglected, or ignored, until relatively recently. The Earth’s resources are finite; its ability to buffer rapid perturbations in the cycling of elements, such as carbon, is being tested to the limit; and so to continue to improve the quality of life for all, a more sustainable economy that is less reliant on petrochemicals is essential.

The great promise of IB is that it offers a realistic opportunity to make a major contribution to creating a sustainable circular economy, where waste is closer to zero. It is imperative that the UK leads in leveraging the breadth of possibilities IB offers, not just for the future well-being of the UK population, but for the future of the planet and all its inhabitants. IB can be the highway to a sustainable chemicals industry based on world-class scientific discoveries, but this will not happen spontaneously. We need supportive long-term government policies, investments to nurture academic-industrial partnerships and rapid commercialisation, enhanced access to pilot facilities for SMEs, and simplified but rigorous regulatory frameworks, to make the UK a world leader. We cannot afford to be left behind.

This document describes the vision of the UK IB community, driven by the IBLF, in harnessing the world-class science we have in the UK in order to enable IB to become a mainstream part of UK industry. By leveraging the assets and capability already in place, this will ensure that the UK maintains and extends its position to become a world leader in IB and its effective adoption by wealth creating industries. The IBLF has set out what we think is necessary to achieve this vision in the coming years and we see this as a vital first step in realising the contribution of IB to the fulfilment of the Bioeconomy Strategy.

Executive Summary

Background

In October 2017, four Networks in Industrial Biotechnology and Bioenergy (NIBB) published *Developing a Strategy for Industrial Biotechnology and Bioenergy in the UK*. Industrial biotechnology is the use of biological resources for producing and processing materials, chemicals and energy. It is an enabling technology that will underpin the new manufacturing processes that are essential for delivering the Clean Growth element of the Industrial Strategy. The report considered: (i) recent government, academic and industry analyses of the state of UK industrial biotechnology; (ii) the current UK IB landscape; (iii) IB investment and commercialisation; (iv) how UK IB activity compares with competitor countries; and (v) short- and long-term recommendations to support IB and help UK global competitiveness. In order to keep pace with international competition, UK policymakers need to demonstrate foresight to develop a long-term strategic plan that places trust in UK industrial and academic expertise to grow the IB sector.

To realise the potential benefits of IB in providing new methods for manufacturing chemicals, consumer products, and liquid and gaseous fuels, whilst reducing greenhouse gas emissions and making effective use of household and agricultural waste, a clear and coherent National Industrial Biotechnology Strategy is needed. A coordinated approach involving government, industry, academia, investors and civil society is essential to enable the benefits of IB in the context of the Industrial Strategy and Clean Growth Strategy to be delivered.

The directors and network managers of two NIBB (BIOCATNET and CBMNet) have worked with the Industrial Biotechnology Leadership Forum (IBLF) to set out a vision for the future of IB in the UK. This document, *Growing the UK Industrial Technology Base: A National Industrial Biotechnology Strategy to 2030*, takes the evidence-based recommendations of the *Developing a Strategy for Industrial Biotechnology and Bioenergy in the UK* report and sets out a vision of the UK IB community that harnesses world-class UK science and engineering to enable IB to become a mainstream part of UK industry. The goal is to maximise the value of existing assets and capabilities to ensure that the UK becomes a world leader in IB and that IB approaches are widely adopted by wealth creating industries.

Industrial Biotechnology and the UK Industrial Strategy

Industrial biotechnology in the UK demonstrates strength in four of the five foundations of the government's Industrial Strategy: **Ideas**, the UK is a world leader in bioscience research; **People**, employment growth in IB has outpaced national averages by increasing by more than 10% per year (2014-2016) and annual median earnings are ~£20,000 above the national average; **Infrastructure**, centres such as CPI, BDC, BEACON, and IBioIC, consolidated through the BioPilots UK alliance, provide a solid IB infrastructure base; **Places**, there are notable IB regional clusters, but business activity is dispersed across the UK, highlighting the need for coordinated regional and national strategies. The fifth foundation, **Business Environment**, presents a challenge. Often IB commercialisation is regarded as 'high-risk, low probability' and there are other sector specific challenges to translate world-class research into new business opportunities.

The need for a National Industrial Biotechnology Strategy

A National Industrial Biotechnology Strategy is required to ensure that the UK harnesses the potential of its excellent IB research base and maintains its competitive edge when other countries are realising and exploiting the disruptive potential of IB. The recent *Developing a Strategy for Industrial Biotechnology and Bioenergy in the UK* report concluded that the UK IB sector has some strong assets, but is in danger of falling behind the best in the world. The National Industrial Biotechnology Strategy will ensure continuity of research priorities, funding and investment, informed by the needs of industry and playing to the natural strengths of the UK to realise increased productivity. Uptake of industrial biotechnology technologies and processes will have far-reaching positive impact on the UK economy and society, realised through the creation of jobs in high technology industries delivering better, safer and cleaner products across a range of sectors.

The scope of a National Industrial Biotechnology Strategy

The UK has strengths in high growth and emerging industrial biotechnology markets, exploiting the academic expertise in genomic, systems and synthetic biology in partnership with SMEs and multi-national companies. UK IB has a presence in all of the elements required to formulate a coherent national strategy for the IB sector: (i) creating high-skill, high-reward jobs; (ii) reducing greenhouse gases; (iii) utilising waste and reducing reliance on fossil fuels; (iv) growing the agri-food sector; (v) improving medicine manufacturing; (vi) future proofing the UK chemicals industry; (vii) creating new materials and fuels. Supporting and expanding these areas will be crucial to deliver the UK government's Bioeconomy and Clean Growth Strategies.

Key elements of National Industrial Biotechnology Strategy to 2030

The key elements of the proposed strategy and the long-term goals are:

- External environment (led by the KTN): **Consensus on a long-term policy landscape to support UK IB**
- Access to funding and finance (led by BBSRC): **Supportive financial environment that recognises the potential of IB for driving growth and innovation**
- Infrastructure and regional footprint (led by BioPilots UK): **IB is a major contributor to clean economic growth across all of the UK**
- Trade, inward investment and commercialisation (led by DIT): **The UK is an international IB innovation and commercialisation hub**
- Regulation and standards (led by IBLF): **UK frameworks are recognised as robust and support risk aware innovation**
- Skills (led by IBLF): **IB sector is recognised as an attractive career option**
- Communications (led by IBLF): **One IB community voice, with consistent clear messages, where wider society is well-informed and supportive of responsible research and innovation in IB**

This vision for UK IB is one that transcends politics, where finance is available for business growth and innovation, driven by regional infrastructure. The goal is for the UK to be internationally recognised as a major player in the IB value chain, with a robust, easily navigated regulatory framework.

1

Significance of Industrial Biotechnology for the UK

A strong industrial biotechnology sector is essential to build a sustainable and inclusive economy that serves the whole population of the UK.

The global economy faces many societal challenges, including dealing with climate change, a burgeoning population to feed and keep healthy and an unsustainable dependence on non-renewable resources. Manufacturing of most chemicals, energy, materials and consumer products today demands ever-increasing supplies of oil and natural gas, coal and rare metals and other elements. These are extracted from the ground through intensive efforts, damaging the environment not only at the point of recovery, but also throughout their often-hazardous transport to large chemical production hubs. The environmental impact of traditional manufacturing processes extends beyond the use of these non-renewable feedstocks, through high energy demanding processes, greenhouse gas emissions and production of potentially hazardous and polluting side streams and waste. At the end of their useful life, many of the products of such processes present additional challenges of poor recyclability, damaging persistence in nature and high toxicity and although they have undoubted specific highly desirable functionality, many products have a poor reputation with end consumers. These are challenges, which must be addressed immediately and the transition to using low carbon, sustainable technologies that support future economic growth, but with greatly reduced environmental impact, is one way of mitigating these challenges.

Industrial biotechnology is underpinned by innovative technologies in biology, chemistry, and engineering to harness biological resources for producing and processing materials, chemicals and energy. IB delivers new production and processing technologies, utilising renewable bio-based sources, which will contribute to overcoming global challenges, such as food security, resource scarcity and environmental damage, resulting from unsustainable exploitation of ever more scarce natural resources. IB can deliver clean processes, which operate at lower pressures and temperatures, with less need for energy intensive and expensive heating, cooling and pressure, using relatively benign reaction conditions that reduce the use of expensive rare metals and other environmentally damaging reagents. A strong IB sector is essential to build a sustainable and inclusive economy that serves the whole population of the UK.

Industrial biotechnology is a critical enabling technology to address major societal challenges through novel methods of manufacturing consumer products, whilst simultaneously reducing greenhouse gas emissions and making effective use of agricultural, food and municipal wastes. IB will underpin future manufacturing of existing products using cleaner processes, but also makes possible new materials, such as bio-derived industrial composites and biodegradable plastics, and sustainable energy in the form of liquid and gaseous biofuels (Table 1, Figure 1), as well as products not yet imagined.

The McKinsey report[1] indicated a four-fold increase in white biotechnology global sales between 2008 and 2020, an increase from approximately €110 billion to €450 billion. The proportion of chemicals produced by biotechnology is expected to increase significantly within a generation, with biotechnology products expected to dominate the speciality chemicals sector by 2030. IB success is to date dominated globally by countries and regions with established bioeconomy and IB strategies, which are already reaping the benefits of bio-based products and processes.

1 Significance of Industrial Biotechnology for the UK

Examples of products industrial biotechnology can produce:

Personal care products

Transport fuels

Biodegradable plastics

Detergent enzymes

New therapeutics

Flavours and fragrances

Industrial biotechnology is central to the bioeconomy, which is defined as any economic value derived from bio-based products and processes; contributing to sustainable and resource efficient solutions to the challenges we face today. IB can be deployed wherever bioeconomy activities are evident throughout the UK, including rural and coastal areas. IB has the potential to disrupt UK markets worth more than $34 billion (Figure 1). Growth in these established markets is either low, or negative and the maturity of these markets indicates that future growth is likely to remain low, with an average CAGR of just 0.2% to 2022.

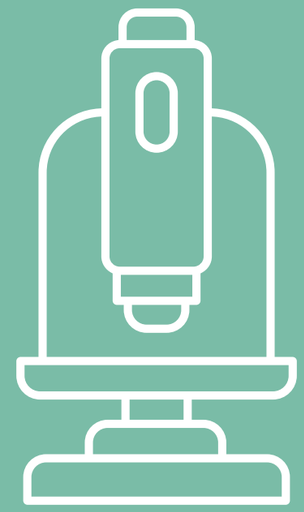
IB can transform these prospects; the UK has core strengths in potential high growth areas such as manufacturing high value chemicals and recombinant biologics. Public and private sector support have combined to allow businesses to build emerging markets and there are major opportunities to exploit UK expertise in synthetic biology to create new medicines, green chemicals and fuels. Global markets addressed by IB, including drop-ins and replacements, often promise higher CAGR: bio-surfactants 5.1% CAGR, 2017-2022[2]; bio-plastics 28%, 2017-2023[3]. There is significant evidence[4] to show that investment in IB will grow the UK economy, driving the creation of jobs commanding significant wage premiums, whilst providing high technology solutions to the challenges of implementing the UK government's Clean Growth Strategy. The soaring estimated value of the global IB market by the middle of the next decade makes it imperative that the UK is at the forefront of this growing sector and it is well-placed to do so, but an integrated strategy for the sector is essential.

"The UK is at the forefront of this growing sector and it is well-placed to do so, but an integrated strategy for the sector is essential.

The biopharmaceuticals (biologics) sector is a prime example of established good practice in UK IB, with a record of academic-industrial collaboration supported by strong networking (e.g. BioProNET, a BBSRC NIBB), with national funding and infrastructure to support innovation (e.g. the High Value Manufacturing Catapult). These are examples of timely and powerful interventions that place the UK at the forefront of disruptive technology in a major global market. In 2016, seven of the top ten drugs by sales, and 11 of the top 20, were biopharmaceuticals[5], unable to be manufactured via other routes, and the market for biopharmaceuticals and biosimilar is expected to grow at 8.5% CAGR from 2016-2024[6]. The lessons of this sector can be applied more broadly to leapfrog into other emerging sectors where IB has the potential to revolutionise the way in which consumer products are developed and manufactured.

In September 2015, the United Nations adopted a set of 17 Sustainable Development Goals[7] (SDGs) to end poverty, protect the planet, and ensure prosperity for all. IB directly addresses at least six of these SDGs (Figure 2). At a national level there is significant evidence[5] to show that investment in IB will help the UK economy and society, where growth of the sector will drive creation of jobs commanding significant wage premiums, whilst providing high technology solutions to the challenges of reducing waste and carbon emissions.

A government-industry-academic-financial-civil society alliance is required to realise the potential of UK IB (Table 2). This alliance will deliver a National Industrial Biotechnology Strategy to provide policy certainty, support for innovation and process scale-up, de-risking of early-stage investment in disruptive technologies and longer-term incentives to finance what is regarded as a high-risk sector and thereby contribute to delivering the Clean Growth Strategy.



1 Significance of Industrial Biotechnology for the UK

Case Studies
Solving Global Challenges
Lucite International

Lucite International is the global leader in the design, development and manufacture of acrylic-based products. Its ultimate goal is to convert renewable feedstocks directly into its main products using completely new white biotechnology processes.
To achieve this, it is addressing the many technological challenges in designing complex new biochemical routes using completely novel biochemistry. Most importantly for large-scale manufacture, the fermentation process must be able to deliver high concentrations of the product at acceptable output rates, which plays a major role in defining both the physical size of the plant (and hence resources) and the energy required to achieve a pure chemical product. Lucite International is particularly interested in the sustainable production of Methacrylate esters (MAEs). MAEs are at the heart of a multi-billion dollar industry, supplying a global demand of polymethyl methacrylate primarily using petrochemical sources. Green production of MAEs by fermentation of sugars and using engineered bacterial strains is influenced by the tolerance of the selected organisms to the build-up of the product to commercially viable concentrations. A key factor in the survival of industrial bacterial strains is membrane structure and stability in the presence of MAEs. Lucite has benefited from BBSRC NIBB funding and Innovate UK funding in its quest to improve the lifetime of cell factories and in engineering efficient transport of reactants and products.

Info: luciteinternational.com

Case Studies
Solving Global Challenges
Colorifix

Textile dyeing consumes over 6 trillion litres of water per year. All dyes used in the industry, even natural dyes, require the use of harmful chemicals. These include organic solvents, acids and heavy metals used in their production and application. In many instances, wastewater from the dye industry is released directly into surface waters without treatment. Colorifix has developed a revolutionary dyeing process to help the textile industry dramatically reduce its environmental impact in a cost-effective manner using a synthetic biology based approach. Microorganisms are engineered to produce, deposit and fix the desired pigment colour. In this way, agricultural by-products are converted into pigments and dyed fabrics. As a result, Colorifix use ten times less water than traditional dyeing processes and does not use heavy metals, organic solvents or acids. Instead of using ubiquitous petrochemicals that are non-renewable and toxic, it uses microbiology, biofabrication, and the DNA from nature responsible for pigment production. Colorifix was the winner of the Rainbow Seed Fund "Breaking New Ground" Award in the Bio-start 2017 pitching competition, receiving funding which it planned to use to enable certification of its products.

Info: colorifix.com

Table 1. Examples of the Industrial Biotechnology at work

– Clean energy and transport fuels from waste and industrial by-products
– Bio-based plastics and chemicals manufacturing that preserves the environment
– Using microbes instead of chemical processes to create medicines and personal care products
– Strong, lightweight materials for the automotive and aerospace industries
– Using plants to manufacture vaccines to quickly tackle disease epidemics

Figure 1. Markets that Industrial Biotechnology can disrupt

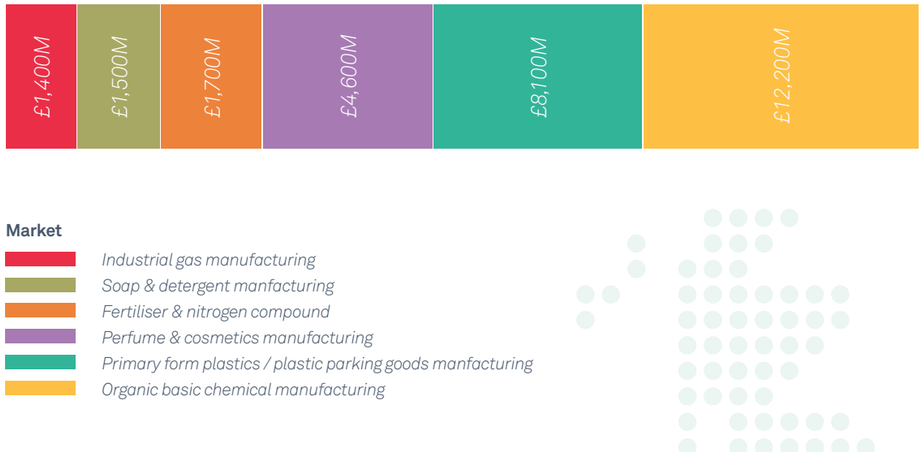


Table 2. Industrial Biotechnology strategy consortium

– Crossing Biological Membranes Network, a BBSCR NIBB (CBMNet)
– Network in biocatalyst discovery, development and scale up (BIOCATNET)
– Industrial Biotechnology Leadership Forum (IBLF)
– Biotechnology and Biological Sciences Research Council (BBSRC)
– Department for Business, Energy and Industrial Strategy (BEIS)
– Department for International Trade (DIT)
– Innovate UK (IUK)
– Knowledge Transfer Network (KTN)
– BioPilots UK

Figure 2. The 6 sustainable development goals IB helps achieve

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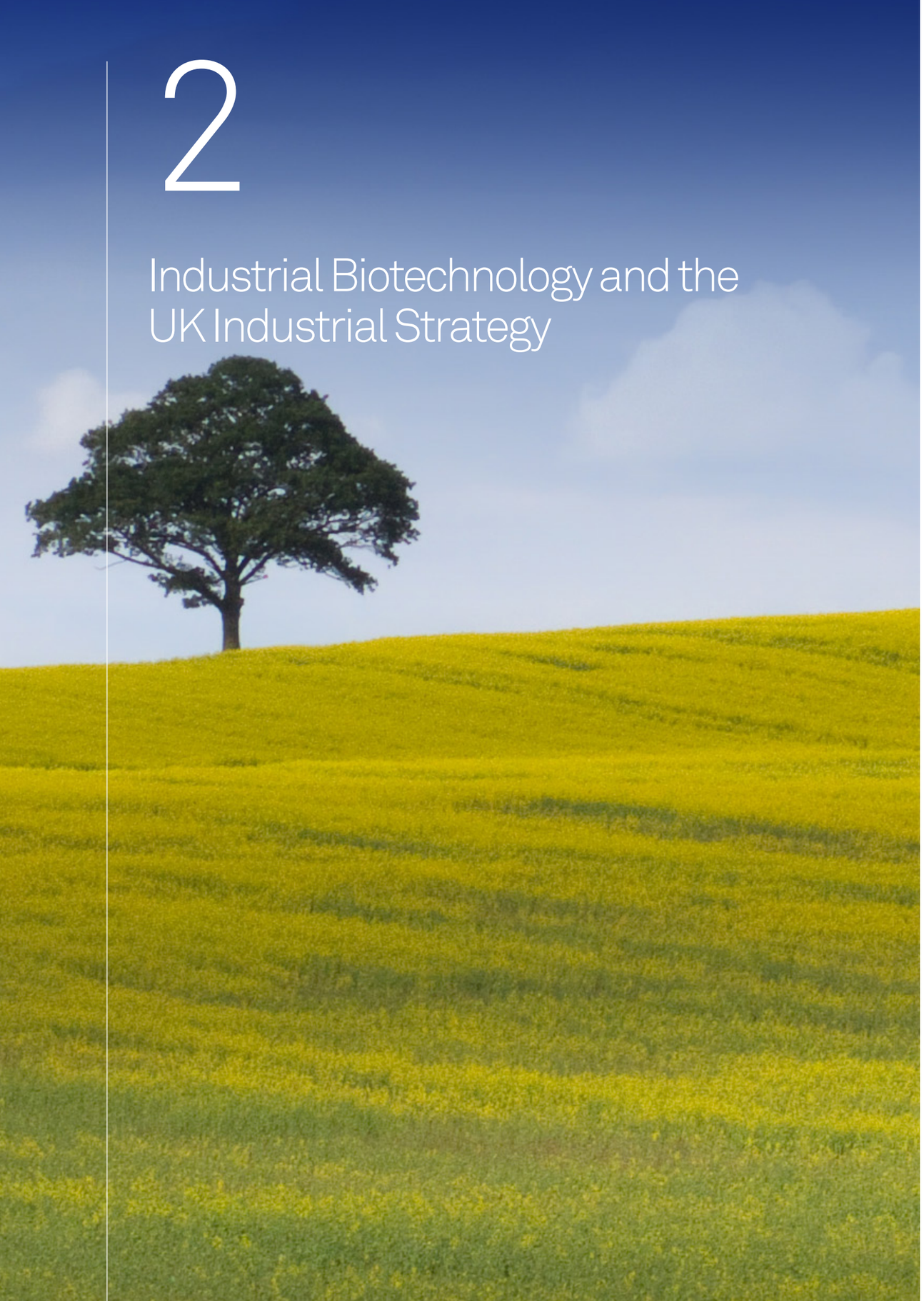
Industrial Biotechnology and the UK Industrial Strategy

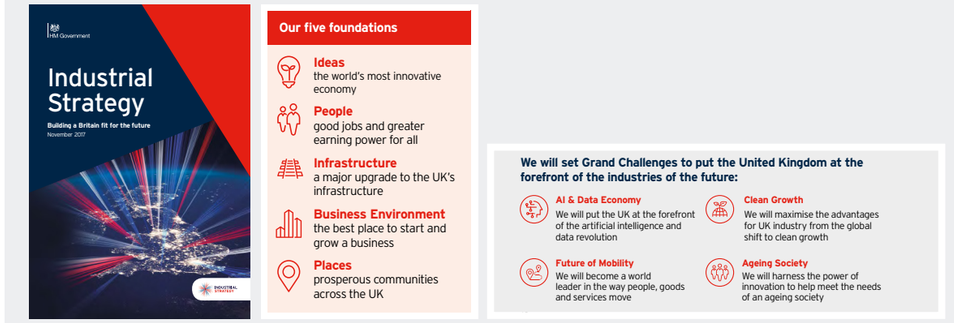


> *Minimising waste; clean air; using resources from nature more sustainably and efficiently; mitigating and adapting to climate change; and managing exposure to chemicals.*

In 2017, the UK government launched the Industrial Strategy, setting out five foundations of productivity through which to address grand industrial challenges that will ensure the future prosperity of the country (Figure 3)[8]. Industrial biotechnology in the UK demonstrates strength in four of the five foundations: Ideas through an excellent research base, and People and Place through highly skilled and networked research organisations and companies distributed throughout the UK. Infrastructure is well developed, with significant capabilities in centres such as CPI, BDC, BEACON, and IBioIC consolidated through the BioPilots UK alliance. UK infrastructure is good therefore, but there is scope for further improvement by targeted expansion of capacity and capabilities to bridge recognised gaps, which also requires improved funding for access to demonstration and scale-up facilities. The fifth foundation, Business Environment, presents a challenge to development of the IB sector, but we now have an opportunity to change and shape that environment to ensure that world beating research translates into the benefits of new products and processes. This national strategy will play a large role in creating and connecting the UK IB community, and ultimately in driving IB uptake and acceptance.

Alongside the Industrial Strategy, IB will also be essential to meet the targets of the 25-year environmental plan[9] and Clean Growth Strategy[4]; in particular hitting targets of: *minimising waste; clean air; using resources from nature more sustainably and efficiently; mitigating and adapting to climate change; and managing exposure to chemicals.* Finally, IB is at the heart of the UK Bioeconomy Strategy, in terms of transforming the UK economy through the power of bioscience and biotechnology.

Figure 3. The Industrial Strategy five foundations and four grand challenges



2 Industrial Biotechnology and the UK Industrial Strategy

Industrial biotechnology and the bioeconomy

Industrial biotechology is central to the bioeconomy, which is defined as any economic value derived from bio-based products and processes; contributing to sustainable and resource efficient solutions to the challenges we face today. IB can be deployed wherever bioeconomy activities are evident throughout the UK, including rural and coastal areas.

Although there are great opportunities for IB in the UK, a coordinated approach is essential to provide the policy certainty, access to finance and knowledge exchange in a National Industrial Biotechnology Strategy. Business, academia, civil society and the government must work together to deliver on the Grand Challenges by integrating expertise, entrepreneurial spirit, and the policy landscape to maximise the chances of success. The National Industrial Biotechnology Strategy to 2030 will ensure that the correct framework is in place to facilitate such a collaborative response.

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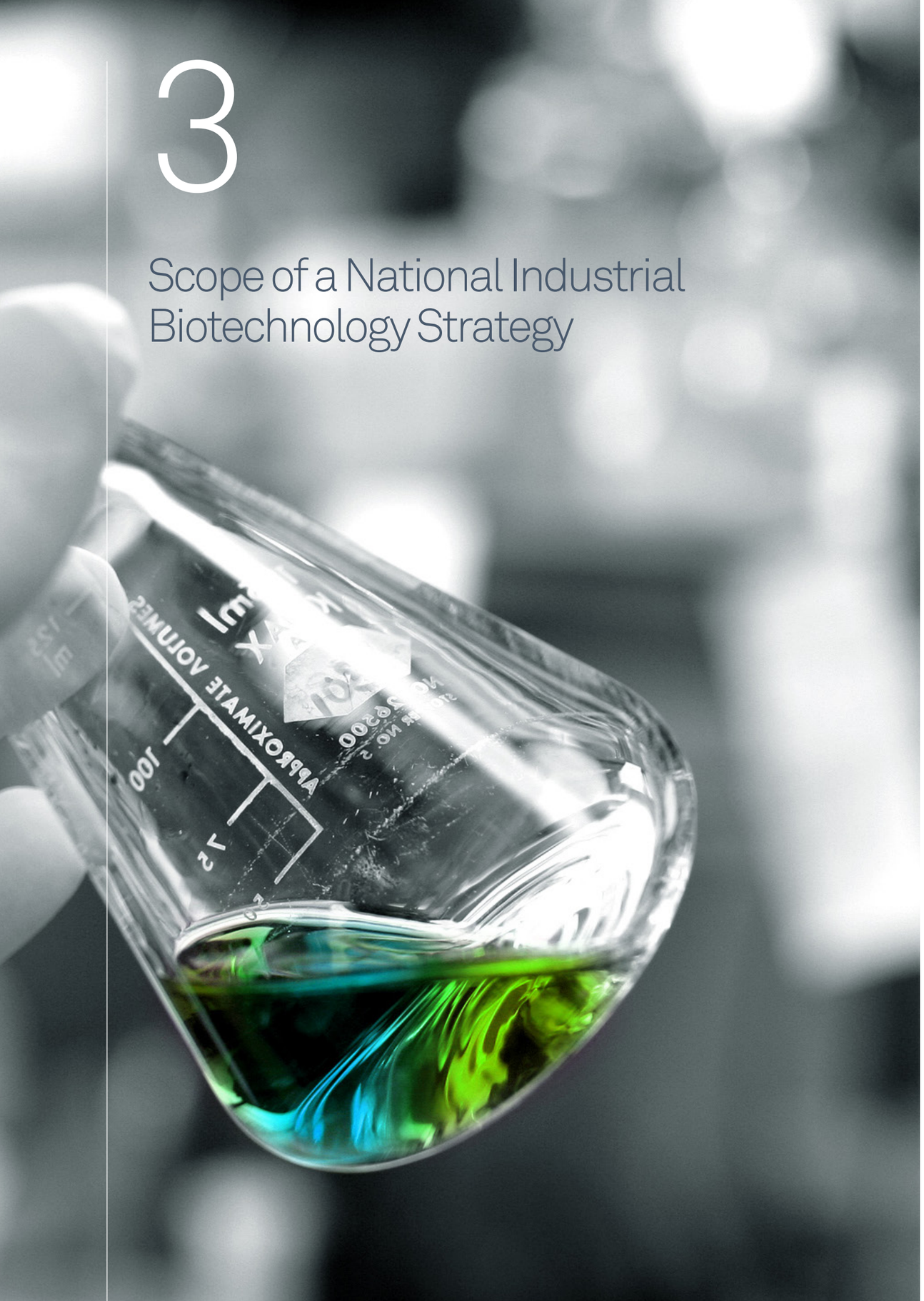
Unlike in the past, industrial strategy must be about creating the right conditions for new and growing enterprise to thrive, not protecting the position of incumbents. A modern British industrial strategy must make this country a fertile ground for new businesses and new industries which will challenge and in some cases, displace the companies and industries of today.

Rt Hon Greg Clark MP, Secretary of State for Business, Energy and Industrial Strategy



3

Scope of a National Industrial Biotechnology Strategy

> *Significant 'downstream' effects from the use of IB in a host of sectors which use it, estimated to be £4.5 billion GVA and 63,000 jobs.*

Increased uptake of IB technologies and processes will have far-reaching positive impact on the UK economy and society, realised through the creation of jobs in high technology industries delivering better, safer and cleaner products across a range of sectors.

1. Creating high wage jobs & a skilled national work-force

Economic analysis indicates that there are over 14,000 full-time jobs in the sector, and location quotient analysis, which assesses the relative concentration of employment regionally, suggests potential for significant employment growth. IB promotes regional growth beyond London and the South East, with the earnings premium in the North of England outpacing the regional median by over 60%. In addition, employment growth in IB is outstripping that of the national economy, and as a high skill, high value sector attracts significant wage premiums. IB skilled and networked personnel will support growth of high-tech, low carbon industries that sustain the environment and the UK economy.

Case Study
Skills development through tailored Degree Apprenticeships

Apprenticeships offer an alternative study option and career pathway to other more traditional routes of academic study, especially now with the introduction of the degree apprenticeship and the ongoing development of level 7 and 8 apprenticeships. The importance of apprenticeships in creating a highly skilled workforce is invaluable. In 2016, CPI embarked on a new apprenticeship initiative, launching its first roles on a degree apprenticeship. Together with Teesside University, Cogent Skills and Fujifilm Diosynth Biotechnologies, CPI enroled a cohort on the new degree level Laboratory Scientist Standard. The degree apprenticeships offer the potential to break down financial barriers to accessing higher education, whilst employing workers to immediately address the skills gaps of industry. CPI is based across four sites in the North East of England and, as part of the High Value Manufacturing Catapult, has a social responsibility to support the local and UK economy and help to grow the next generation of highly skilled scientists and engineers.

Info: uk-cpi.com

3 Scope of a National Industrial Biotechnology Strategy

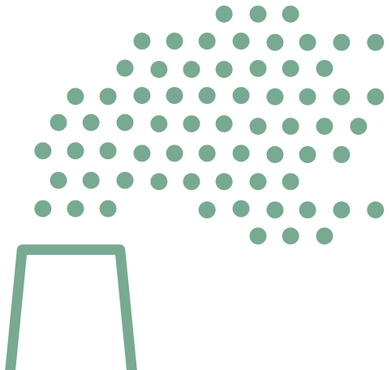
2. Meeting Paris Agreement Targets By Reducing CO2

The UK is a world leader in action to reduce carbon emissions. From the Climate Change Act[10] passed by Parliament in 2008, to the Paris Agreement[11] and the recent publication of the Clean Growth Strategy[4], we have been one of the first countries to recognise the challenge posed by climate change. However, the UK currently produces the second highest volume of CO_2 of any European country[12]. IB has to be an inherent part of the UK's strategy to meet its targets, since IB processes produce significantly less CO_2 than fossil fuel processes and can also utilise ambient CO_2.

Case Studies
Reducing CO2 and Securing Inward Investment
Calysta

Calysta, Inc. Menlo Park, CA, is a company working towards sustainable products, and its innovative process can capture carbon from waste, reducing greenhouse gas emissions. Calysta has developed and commercialised fish and livestock nutritional products, improving food security worldwide. The company chose to invest in Teesside, alongside the National Industrial Biotechnology Facilities, operated and managed by the Centre for Process Innovation (CPI), as the base for its state-of-the-art facility to manufacture sample quantities of FeedKind® protein, a proprietary competitively priced new fish and animal feed ingredient. By investing on Teesside, Calysta was able to maximise the beneficial impact on its business of the UK government's investment in IB demonstration facilities, and the skilled scientists and technicians employed at CPI, to operate the world's only commercially validated gas fermentation process. Teesside emerged ahead of a number of other potential locations for the facility, and since the investment decision was made, Calysta has developed a full technical team and laboratories on Teesside, working hand-in-glove with the CPI team. FeedKind® protein is a natural, traceable and safe non-animal source of protein. FeedKind® protein is approved for sale and use in many animal feeds in the EU and other locations, and has been tested on multiple fish species including salmon. By 2050, the global population is expected to rise from 7.4 billion today to 9.6 billion and require 70% more protein than is currently available. Calysta can help meet this need by supplying the feed industry with a naturally produced, sustainable and traceable feed alternative. Calysta's proprietary technology enables retailers and consumers to have increased confidence in the integrity of their food. The plant was financially supported by a conditional Exceptional Regional Growth Fund (ERGF) award and represents a total potential investment of £30 million.

Info: calysta.com



"2.5 billion tonnes of CO_2 could be saved per year by development of products with IB - this is equivalent to taking 490 million cars off the roads or to 68% of the EU's total emissions in 2013.

3. Exploiting waste & reducing reliance on fossil fuels

With limited sovereign supplies of petrochemical feedstocks and dwindling global reserves, the UK must look to alternatives. In addition to CO_2, the UK also produces one of the highest densities of household and restaurant waste in Europe, at just under 150 kilograms per head per annum[13]. IB is able to take advantage of the inherent selectivity of biological systems to exploit such complex feedstocks, which are unsuitable as inputs to traditional chemical processes, to make (often chemically identical) products with equivalent or better performance than their fossil-derived counterparts. IB can reduce energy imports through the generation of energy from bio-derived products, such as ethanol, methane and propane. Anaerobic digestion and gas fermentations can prevent the release of greenhouse gases into the environment, whilst generating fuel products, and microbial fuel cells based on electrogenic microorganisms have the potential to replace batteries in low power applications. Photo-bioreactors can harvest sunlight, or light generated from renewable energy sources, to generate algal biomass, which can fuel larger power plants.

Case Study
Solving global challenges
Celtic Renewables

Celtic Renewables Ltd, is an innovative Scottish start-up providing next generation biofuel, performance chemicals and animal feed. The company has recently secured planning permission from Falkirk Council to build a commercial demonstrator plant, which will produce over half a million litres of biofuel each year. The pioneering young company has recently closed a funding campaign, which raised over £5.25 million through an ISA eligible investment with leading investment platform, Abundance Investment. Based in Grangemouth, the funds will allow the demonstrator to be built, which will produce Biobutanol, a sustainable biofuel made using whisky residue that is a direct replacement for petrol and diesel.

Info: celtic-renewables.com

"In 2013 an estimated 36 billion laundry loads were done every year in Europe. IB reduces consumer energy bills by the inclusion of enzymes in laundry detergents that enable low temperature wash cycles to be used.

3 Scope of a National Industrial Biotechnology Strategy

4. Growing The UK Agri-Food Sector

IB is already embedded in food manufacturing through the use of enzymes and fermentation for production. Selective breeding and enhancement of plants is currently increasing disease and drought resistance, and improving yields of high value chemicals in diverse, multi-billion dollar markets, such as nutrition, pharmaceutical ingredients, personal care, and manufacturing. Furthermore, the UK is a leader in the use of IB for production of flavours and fragrances (addressing a potential global market worth $27.5 billion[14]); non-caloric sweeteners ($3 billion[15]); and functional food ingredients, such as prebiotics and soluble fibre ($20 billion[16]).

“New technologies such as CRISPR will transform crop production.

Case Study
High value products
Oxford Biotrans

Oxford Biotrans is a University of Oxford spin-out company which has developed and commercialised enzymatic process technologies that yield high value chemical compounds. Oxford Biotrans is now producing natural grade nootkatone, the flavour and scent of grapefruit, in commercial quantities. Grapefruit flavouring is in high demand but short supply. It can be produced synthetically from more plentiful orange oil, but this process requires a high energy input and generates toxic by-products. The new process is more environmentally sustainable and produces flavouring that can be labelled ‘natural’ under EU regulations, making it preferable to consumers. Oxford Biotrans has received £5.3 million in private investment and employs 13 people. The company is now working on producing other useful products using its enzyme technology. Oxford Biotrans has also benefited from IB Catalyst funding, which built upon results from a study funded by BBSRC NIBB Proof-of-Concept awards.

Info: oxfordbiotrans.com

“Industrial biotechnology is the only way of producing modern biologic drugs that treat some of the most serious and debilitating diseases. IB is the principal source of current antibiotics and is helping to produce novel compounds to combat antimicrobial resistance.

5. Improving Our Medicines Manufacturing Capability

The global pharmaceuticals market is increasingly dominated by biopharmaceuticals; drug molecules manufactured in or extracted from biological sources, so-called *biologics*. The increasing use of biologics, heralds a new era of personalised medicines, where the specificity of biomolecules can be rapidly tailored to both the disease and the individual biology of patients. Currently valued at more than $200 billion, the global biologics market will reach more than $450 billion by the middle of the next decade[6]. IB-enabled diagnostics based on expanded ranges of biomarkers promise to reduce the time taken to diagnose diseases, and to aid effective prescription of new treatments.

Biocatalytic manufacturing and IB-enabled bioprocesses will also help create the next generations of small molecule drugs, where computational design, based on the structures of biological targets, along with powerful new chemistries to enable synthesis of novel drug molecules, will lead to more effective, safer treatments for disease.

Case Study
Solving Global Challenges
Excivion Limited

Excivion was formed in response to the need to develop affordable solutions to the present and looming health crises of a changing world. It produces novel vaccines that can be used to prevent emerging pandemic infectious diseases. Flaviviruses are a family of viruses spread by mosquitoes, and which cause a range of disorders, such as dengue fever and Zika microcephaly (part of the Zika congenital syndrome). Global travel, urbanisation, and expanding mosquito habitats have conspired to make flavivirus infections an even greater threat to humanity than was previously recognised, with over a billion people at risk worldwide. Latterly it has become apparent that development of novel flavivirus vaccines may be complicated by a risk of inadvertent *disease enhancement*. Conserved structural elements among different flaviviruses and flavivirus vaccines are responsible for serial boosting of antibodies that may paradoxically enhance dengue infection. The recently licensed vaccine product against dengue (Dengvaxia™), the only dengue vaccine so far, was recently withdrawn for the immunisation of persons naïve to dengue (principally children), over concerns that it was setting them up for enhanced disease, causing its manufacturer to write-off €100 million of annual revenue. These events were anticipated in the design and development of the novel vaccine prototypes used in this project. Excivion received funding from CBMNet to implement a molecular ‘cloaking’ strategy whereby the offending structure of the vaccine protein is effectively obscured - preventing it from being recognised or ‘remembered’ by the immune system. The data from the project provided the collaborating company with sufficient confidence to successfully apply for a new round of Innovate UK funding (valued at £2 million) to develop a novel vaccine for the prevention of the spread of Zika virus and the developmental disorders it is known to cause.

Info: excivion.com

3 Scope of a National Industrial Biotechnology Strategy

6. Understanding And Controlling Microbiomes

The microbes in our gut play an important role in human health and disease and over the last five years, the number of scientific papers linking the gut microbiome to a broad range of diseases has grown exponentially[17]. The UK has considerable academic expertise in gut and rumen microbiology and growing commercial activity, primarily driven by SME's. Gaining a better understanding of how gut microbes function and uncovering the mechanisms involved in microbiota-host interactions offers tremendous potential for developing new treatments for diseases ranging from colorectal cancer, Inflammatory Bowel Disease, type 2 diabetes and even depression. Consequently, there has been significant interest by large pharmaceutical companies, and since 2010, microbiome specialists have raised over $1.8 billion of investment[18]. However, more than 95% of the microbial biome remains undiscovered and is still poorly explorable, particularly beyond the genomic level due to lack of developed tools and methodologies. IB is required to accelerate microbial strain identification and characterisation as well as to elucidate function at the gene and protein level. The microbiome also contains a deep reservoir of genetic information and microbial strains that could be exploited for IB products and applications.

Case Study
Novel discoveries
CHAIN Biotechnology Limited

Founded in 2014, CHAIN has developed a novel microbial platform for targeted drug delivery to the gut. Delivery to the gut using murine models has been exemplified with two proprietary targets. The company, led by Dr Edward Green (ex-Green Biologics) with an experienced board, has 10 employees, headquarters in Marlow and a technical team based at the University of Nottingham. The company has unrivalled expertise in microbiology, synthetic biology and fermentation with anaerobic bacteria that are prevalent in the gut. More specifically, CHAIN uses genetically engineered Clostridium to produce and deliver therapeutics to the gut. To date, CHAIN's proprietary platform has delivered two products for pre-clinical testing, an anti-inflammatory metabolite targeting ulcerative colitis and an anti-microbial peptide targeting C. difficile infection. CHAIN is building a product pipeline focused on therapeutic peptides and exploring vaccine delivery to the colon for specific pathogens. The company has raised £1.8 million primarily from seed investment and grant funding.

Info: chainbiotech.com

"No microbiome based drugs are currently on the market, but there are a significant number in the clinic. Research forecasts a market size of nearly $9.9 billion for microbiome therapeutics by 2024 with CAGR of 70%[19]. IB is closely aligned to development and commercialisation activity.

7. Future-Proofing The UK Chemicals Industry

IB offers powerful new tools for the sustainable production of chemicals, with the potential to replace multistep processes using traditional chemistry with synthetic biology pathways and biocatalytic cascades, where biological agents perform sequential modifications of starting materials to deliver complex synthetic products. By reducing the need for reagents based on rare and toxic metals, the requirement for laborious purification of intermediates and through use of water as a universal solvent in place of hazardous organic solvents, IB is able to promise better environmental performance. In addition, many bioprocesses can operate at or below physiological temperatures, alleviating the need for the energy intensive and expensive heating and cooling associated with traditional chemical manufacturing.

Case Study
Bio-based chemicals and inward investment
BASF

In 2016 the German chemical giant BASF opened a world scale production facility at its site in Bradford to produce bio acrylamide. Its process uses less energy and produces less waste than conventional methods, with a better end product. This major investment will help to ensure the long-term future of one of the UK's largest chemical manufacturing facilities, which employs around 600 people.

Info: basf.com

"Industrial biotechnology is already reducing energy costs in manufcturing through the use of low temperature and pressure processes with reduced carbon footprint and cleaner manufacturing with less waste.

3 Scope of a National Industrial Biotechnology Strategy

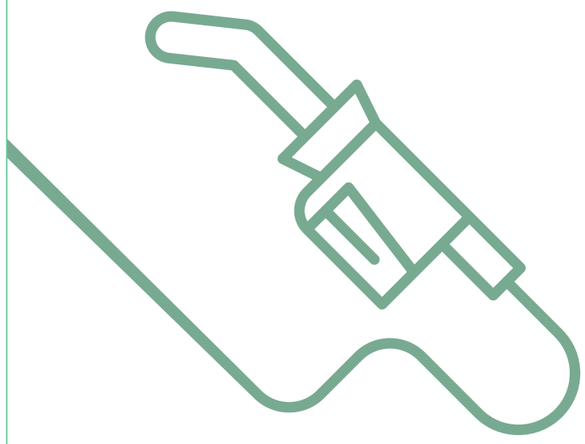
8. Developing New Materials And Fuels

The use of biological systems can also allow us to access new processes to make products which are impossible using traditional methods, leading to bio-based materials and fuels that offer new properties and superior performance. Bioplastics and biodegradable packaging promise superior recyclability and compostability, meaning that sustainable production can be linked to better end of life performance, a key objective of the circular economy. Production of fuels through IB processes utilising low value non-crop biomass and waste products will lead to lower carbon transport solutions and reduced wastage.

Case Study
Solving global challenges:
Biome Bioplastics

Biome Bioplastics is one of the UK's leading developers of intelligent bioplastics. A bioplastic is a plastic that is made partly or wholly from materials derived from biological sources, such as sugarcane, potato starch or the cellulose from trees and straw. Biome's products are 100% biodegradable and compostable, and suitable for the wide array of plastic processing applications including food, drink and agriculture. Revenues grew 44% to £2.3 million in 2017, as the business benefitted from an increase in the use of its material for the coffee market following the commercialisation of the innovative BiomeMesh filter material. The shifting perception of plastic waste, both in public opinion and amongst policy-makers, particularly in the UK, provides encouragement for future growth in the use of bioplastic products.

Info: biomebioplastics.com

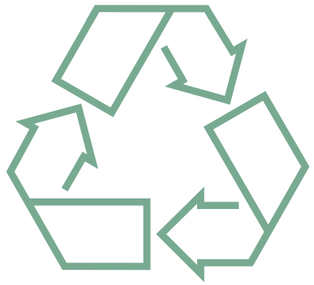


"Industrial biotechnology can convert waste to high value products, such as clothes, flavours and fragrances and composites for automobile and paint manufacture.

Case Study
High value products:
Prozomix Ltd

Incorporated in 2008, Prozomix Ltd. is a privately owned SME focussed on novel enzyme discovery for biocatalysis. Prozomix uses proprietary GRASP™ genome- and metagenome-mining technologies to discover novel enzymes, developing large panels of sequence-diverse enzymes. In 2011, Prozomix launched the Biocatalysis Enzyme Toolkit, comprising large panels of biocatalysts aimed towards synthetic organic chemists, particularly within the pharmaceuticals sector. Customers access the Biocatalysis Enzyme Toolkit of novel / maximum diversity biocatalyst panels free of charge, including user-friendly colorimetric screening kits, such as IREDy-to-go™ for ketoreductases, and IREDy-to-go™ for imine reductases. When a Toolkit enzyme is identified by the customer against an application, Prozomix offers larger amounts of the enzyme at known list prices. Prozomix is a supplier to a number of multinational companies, offering multi-kilogram scale production of enzymes. Prozomix is a highly research active company, supporting non-grant-funded fundamental and applied collaboration with academic and industrial partners around the world. Prozomix has collaborated on 25 grant-funded projects since it was founded, including EU FP7 (KYROBIO, BIOOX) and H2020 (CARBAZYMES, METAFLUIDICS) collaborative grants, BBSRC, EPSRC, Innovate UK / IB Catalyst, ERA-NET and from the Newton Fund. Prozomix is a strong supporter of IB skills development, hosting a number of industrial PhD students (10), sandwich students and visitors from schools, and partnering on the IBioIC Collaborative Training Partnership.

Info: prozomix.com



4

The Need for a National Industrial Biotechnology Strategy

> *Innovation driven by the agility of small firms and the UK is rich in these, with 99% of businesses in the IB sector classified as SMEs.*

A recent analysis[5] of UK IB provides the evidence base to assess the current national landscape, and the sector's strengths and weaknesses, along with foreseeable opportunities and risks (Table 4).

Table 4. UK IB SWOT analysis

Strengths	Weaknesses
– UK research base – Well dispersed, regional, IB community – Highly networked – Innovation driven by the agility of small firms – High quality research infrastructure	– Access to scale-up facilities – Low levels of commercial success – Lack of commercialisation skills – No dedicated IB funding stream – Finance fragmented – Lack of a UK IB policy framework
Opportunities	**Threats**
– High potential GVA – Industrial Strategy Challenge Fund – BBSRC NIBB Phase II – Bioeconomy Strategy – Response to waste reduction legislation – Emerging sector investment	– Lack of understanding of IB by policy and decision makers – Access to private finance limited by perceived risk of IB innovation – Changes in government – Brexit

The SWOT analysis shows that the UK has core strengths in IB. The strength of the UK research base is a great asset for innovative high technology industries. The UK has 1% of the global population and 3% of global research funding, but produces 8% of peer reviewed scientific papers, leading to 16% of global citations. The UK IB community is highly networked and connected at both local and national levels through organisations such as KTN, BBSRC NIBB, BioVale, BioPilots UK and the IBLF, meaning that strong interdisciplinary links exist within and across sub-sectors. Alongside leading academic institutions and industry, a healthy high technology economy relies on the innovation driven by the agility of small firms and the UK is rich in these, with 99% of businesses in the IB sector classified as SMEs. The UK also boasts high quality research infrastructure within higher education institutions and purpose-built open access facilities, such as BioPilots UK.

4 The Need for a National Industrial Biotechnology Strategy

Uncertainty about the investment and regulatory environment is exacerbated by the lack of an overarching UK policy framework for IB, which leads to coordination failures and unnecessary duplication of efforts. Moreover, by implementing a coordinated strategy, the UK will demonstrate commitment to a unified long-term vision for the sector underpinned by realistic actions to support growth and innovation, providing a stable environment to attract inward investment to IB. Thus, the UK IB sector has some strong assets, but is in danger of falling behind the best in the world. A National Strategy for IB will ensure continuity of research priorities, funding and investment, informed by the needs of industry and playing to the natural strengths of the UK to realise increased productivity.

The magnitude of the opportunity available to the IB-enabled end-users is clear, with more than $34 billion of addressable established product markets in the UK, and estimates of the global IB revenues reaching $450 billion by the middle of the next decade. The UK National Strategy for IB aims to increase public and private investment in industrial biotechnology. Key to this goal will be the establishment of a dedicated funding stream for translational IB research. Industrial biotechnology is also ideally positioned to respond to the UK Industrial Strategy Clean Growth Grand Challenge through the Industrial Strategy Challenge Fund, the additional £4.7 billion fund provided by the UK government from 2017-2021 to support R&D.

The Scottish National Plan for Industrial Biotechnology was launched in 2013 with the aim of growing IB-related turnover in Scotland to £900 million and increasing the number of companies using IB to 200 by 2025. One of the key actions was to establish the Industrial Biotechnology Innovation Centre (IBioIC), as a centre for open innovation and skills. By 2015, IB turnover in Scotland had increased from £189 million to £230 million, and the number of companies from 43 to 50[20]. The UK National Strategy for IB will be aligned with regional plans, where those already exist, and provide vital coordination to grow the sector across the UK.

The potential for coordination to elevate the status of enabling technology sectors and thereby increase funding and investment is also well-illustrated by the example of synthetic biology in the UK. Implementation of a coordinated strategy for technology development and supporting R&D infrastructure has seen research spending on synthetic biology in the UK grow, including more than £300 million of public sector investment over the last decade. Spin-out, start-up, and investment in synthetic biology companies is booming, with an average of seven start-ups per annum between 2000-2016, and more than £620 million raised to 2016, including £564 million of private investment[21]. The first UK centre for synthetic biology research in the UK, the Centre for SynBio Research and Innovation (CSynBi), was established in 2009 at Imperial College London. This has been followed by the strategic development of a series of

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Spin-out, start-up, and investment in synthetic biology companies is booming, with an average of seven start-ups per annum between 2000-2016, and more than £620 million raised to 2016, including £564 million of private investment.

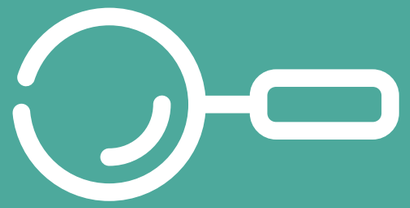
research centres and coordinating entities that have transformed the prospects of synthetic biology in the UK. The stewardship of the Synthetic Biology Leadership Council has been key to this continued success, set up following the publication of A Synthetic Biology Roadmap for the UK in 2012. This was a pivotal document, setting out a persuasive vision created through an industry-led stakeholder group, and leading subsequently to the creation of the UK Synthetic Biology Strategic Plan in 2016, focusing on translation and commercialisation of synthetic biology technologies. The sector was also able to leverage investment and expertise through SynbiCITE, the Innovation and Knowledge Centre (IKC) in SynBio, established in 2013 at Imperial College London. The IKC was co-funded through a £28 million commitment from EPSRC, BBSRC, and Innovate UK, with a diverse range of stakeholders, including industry, business and academia, as well as regional and local government.

Through these various coordinated initiatives, the UK has created a thriving synthetic biology innovation ecosystem, addressing sector challenges holistically across skills and training, research and innovation, commercialisation, ethics and societal awareness. Through these efforts, synthetic biology is beginning to realise the commercial success of those tools and products. The UK Synthetic Biology Strategic Plan aims to deliver a £10 billion synthetic biology based sector in the UK by 2030. Timely intervention by the public and private sector during a period in which the underpinning genetic and computational technologies and services have become cheaper and faster, has been key to this. Industrial biotechnology shares considerable synergies with synthetic biology, and the latter is also well-placed to enable IB. The lessons of that sector also help to illustrate the opportunity available to IB and the value of implementing a coordinated strategy to realise that potential.

Case Study
Supporting innovation
BioPilotsUK

BioPilotsUK is a collaboration of open access biorefining centres across England, Scotland and Wales that recognises the importance of partnerships to develop UK bio-based value chains. The founding organisations are BEACON, BDC, CPI, IBioIC, and The Biorefinery Centre. Together, they de-risk the commercialisation of bio-based products and processes by trialling new technologies to ensure partners are investing in the right technologies for their business.

Info: BioPilotsUK.com



4 The Need for a National Industrial Biotechnology Strategy

Case Study
Knowledge transfer
BBSRC Networks in Industrial Biotechnology and Bioenergy

The Networks in Industrial Biotechnology and Bioenergy (NIBB) launched in 2013 have resulted in a robust community of academic and business members with a pipeline of projects at various stages of translation that will deliver key benefits across the bioeconomy. BBSRC has recently announced funding for a second phase of networks.

Info: bbsrc.ukri.org

Case Study
Supporting translational IB research
The Industrial Biotechnology Catalyst

The Industrial Biotechnology Catalyst helped accelerate the commercialisation of IB-derived products and processes.

Key features:

– Dedicated translational funding aiming to accelerate technology development through subsequent rounds

– £76m awarded between 2014 and 2016

– Support for businesses and researchers

– Over 300 applications received

– Nearly 60% of partners were SMEs

Feedback from industry suggests it was highly effective in the translation of research to move towards the commercialisation of new products.

Info: bbsrc.ukri.org

UK bioscience academic research is world leading and should be encouraged to continue to deliver the new knowledge and technological innovation that the commercial IB sector needs to thrive. However, the perception is that the UK's commercialisation report card still reads 'could do better' and improved conversion of fundamental research knowledge into IB know-how and profitable processes still needs to be supported. Funding to access demonstration and scale-up facilities is one aspect that could help bridge the gap between operational delivery and research knowledge, where micro- and small enterprises in particular often find these costs prohibitively expensive in the absence of either suitable public funding schemes or private investment.

There are particular challenges in the UK funding and investment landscape, for example, although Innovate UK funding is one route to support the translation of IB research, the withdrawal of the dedicated IB Catalyst scheme leaves a significant gap. In the absence of funding that offers natural pathways to higher technology readiness levels, Innovate UK funding does not necessarily dovetail with earlier stage research funded within the academic sector by the research councils. Innovate UK provides funding to businesses to support and stimulate innovation in the UK, encouraging collaboration with other companies and research organisations. However access to this funding remains a particular challenge to SMEs, since 30% of total eligible project costs are available to research organisations such as universities and RTOs. This necessarily restricts the minimum realistic cost of a project if

> *"Industrial biotechnology cannot be ignored if the UK wishes to develop a thriving bioeconomy supporting clean growth.*

research organisations are involved, since a meaningful contribution to the project by those organisations will swell the total eligible project costs. Beyond fundamental research, feasibility studies and industrial research are funded at less than 100% for businesses, 70% in the case of micro and small enterprises, and this represents a significant burden. Where more than one research organisation is involved in a proposal, their combined costs are capped at 30%, and therefore total project costs can quickly become prohibitive due to affordability and call restrictions on project size. The BBSRC NIBB have successfully broadened, deepened and financially supported R&D partnerships; the renewal of these networks is a welcome boost to the sector, but without a dedicated IB funding stream, any gains made are in jeopardy.

Attracting the awareness of decision makers can be difficult for platform technology areas such as IB, particularly when in competition with easily communicated, product-oriented sectors, such as the aerospace and automotive industries. However, the case for IB cannot be ignored if the UK wishes to develop a thriving bioeconomy supporting clean growth. Dedicated public investment is vital because IB is seen as high-risk, underpinned by highly specialised intellectual property and, at least initially, characterised by little or no cash flow by private investors. It is imperative to address and mitigate these perceptions; a comprehensive set of investment and commercialisation initiatives as part of the National Industrial Biotechnology Strategy will educate and encourage private investors to invest based on sound commercial judgements.

Case Study
Inward investment
LabGenius

LabGenius is a London based start-up working at the interface of synthetic biology and artificial intelligence. The company was founded in 2012 and has been backed by the BBSRC and IUK. LabGenius has developed EVA, an autonomous AI-driven evolution engine for discovery of functional protein products. Using a combination of machine learning, gene synthesis technologies, and robotic automation, LabGenius creates biotherapeutics, protein-based materials and personal care products. As an example of their success, the company has secured a number of projects funded by the UK Defence Science and Technology Laboratory (Dstl) to develop novel protein-based materials. In 2017, founder Dr James Field was awarded BBSRC Early Career Innovator of the Year, and identified by Forbes as one of the 600 most influential people in the world aged under 30. In 2017, LabGenius secured $3.66 million in seed funding jointly led by Kindred Capital and Acequia Capital, with participation from Backed VC, Beast Ventures, Berggruen Holdings Ltd, and System.One.

Info: labgeni.us

4 The Need for a National Industrial Biotechnology Strategy

The recent successes of both Celtic Renewables and LabGenius in securing private inward investment demonstrate that there is the appetite for investment when companies can articulate their proposal to specific sectors (i.e. fuel and pharmaceuticals respectively). Ongoing specialist support for companies seeking investment will strengthen the IB SME sector. Start-ups and spin-outs in particular can benefit from dedicated investment pitch training to ensure that they are able to effectively communicate strong value propositions. This should be complemented by introducing investment-ready companies to potential investors.

Industrial biotechnology operates in a complex and extensive regulatory landscape. Regulatory instruments that could impact on this area span everything from health and safety to product design and specification, from environmental protection to renewable energy and fuels, and from intellectual property to finance and trade. There are therefore a variety of policy instruments, guidelines and incentives already in place that impact upon the IB community. Further policy recommendations that can be put in place to incentivise the movement towards a more sustainable society should therefore be considered.

The UK IB sector cannot 'do everything'; we must be strategic. For example, the UK does not have the feedstock capacity to be a major player in global supply of bulk, low value bio-based chemicals, but it does have the innovation expertise to develop processes and technologies that can then be implemented to manufacture overseas. In many cases, the UK does not have internal markets to support large-scale manufacturing, but manufacturing localised within regions of demand can still be supported by the UK R&D expertise. It is also often the case that IB processes utilise feedstocks which cannot be practically or economically transported and therefore where co-localisation of manufacturing is the only viable possibility, for example alongside low density feedstock production, such as agricultural wastes.

Case Study
Inward Investment
Biocatalysts Ltd

Biocatalysts Ltd., and its American subsidiary, Biocatalysts Inc., offers a customised enzyme discovery, development and manufacturing service. Founded in 1983, the company was initially located in West London as part of Grand Metropolitan, before moving to South Wales a few years later, and to a purpose-built factory in Cardiff in 2004. Biocatalysts were pioneers of speciality enzyme in production in the 1980s, providing custom enzymes to the food and fine chemicals industries. Biocatalysts offer a "Design for Manufacture" service allowing development of enzymes from concept to routing manufacturing in 12 months or less, through a process which considers potential regulatory, technical and commercial limitations at the beginning of the project. Biocatalysts generated £9.5 million revenue in financial year 2016/17, with CAGR of 12% on turnover between 2014/15 and 2016/17. In early 2018, a share purchase agreement to acquire a majority stake in Biocatalysts Ltd. was signed by BRAIN AG, a developer of enzymes, biocatalysts, and bioactive natural substances for manufacturers in the chemical and consumer goods markets in Germany, France and the US. Biocatalysts Ltd. is currently expanding production facilities and will continue to operate under its current name after the acquisition.

Info: biocatalysts.com

"The UK IB sector cannot 'do everything'; we must be strategic.

Case Study
UK innovation, manufacturing overseas
Green Biologics Limited

Green Biologics is a renewable chemicals company focused on developing and delivering new green alternatives for everyday products. It aims to provide sustainable and high value alternatives to petroleum-based products for the global chemicals market. The company has expertise in advanced Clostridium microbial fermentation, using a technology platform that converts a wide range of sustainable feedstocks into high value green chemicals including n-butanol, acetone and, through chemical synthesis, derivatives for downstream formulations. Over the last 14 years, the company has grown significantly. In 2014, Green Biologics acquired a 20 million gallon corn ethanol plant in Little Falls, Minnesota, USA, which has now been repurposed by Green Biologics to produce bio-based n-butanol and acetone, with the company supplying customers in North America, Europe and Asia. The UK remains the global headquarters of the company, with a strong R&D, commercial and corporate presence. The focus of the R&D team in the UK, which has patented technology across synthetic biology tools, applications and advanced fermentation technologies, is now on developing new products utilising the company's clostridia platform. As well as generating further business growth for Green Biologics and with benefits accruing to the UK economy, it is anticipated that some of these may be high value products suited to production in the UK, where the relatively lower volumes and higher feedstock costs mean it is not a competitive location for higher volume, intermediate price renewable chemicals. The UK has significant strength in training scientists and supporting innovation and therefore remains the optimal location of the headquarters and intellectual hub.

Info: greenbiologics.com

4 The Need for a National Industrial Biotechnology Strategy

In addition to UK IB innovation for manufacturing abroad, as exemplified by Green Biologics, we must direct efforts to exploit the feedstocks that are indigenously available, particularly where industry is able to upgrade by-products, which must otherwise be processed as waste. Diverse raw materials are available in the UK, but these are strongly regionalised and available on relatively small scales sufficient to supply either high value, low volume manufacturing, or to satisfy immediate local demand for lower value products, for example, energy. Coordinated strategy is required to maximise use of limited resources by understanding feedstocks and capabilities mapped at both national and regional levels, with evidence-based UK investment in flexible regional infrastructure capable of modular manufacturing to support local needs. A deeper understanding of these assets will enable effective decision making during research and commercialisation. The UK must however take a pragmatic approach, maintaining secure international supply chains as necessary for feedstocks where local value can be added through IB processes. Such an approach must be informed and rooted in comprehensive understanding of global supply and value chains, coupled with robust life cycle assessment, to enable economic and environmental evaluation when deciding where and how to deploy IB technologies.

Driving demand for IB technologies will only result in uptake if a skilled workforce is available to implement them. Indeed, that demand will in part be driven by entry into the workplace of early career science graduates knowledgeable on the state of the art in IB. This also needs to be a balanced workforce, including skilled technologists and designers, senior scientists, and business managers who understand the scope and benefits of IB. The sector will need to draw talent from the full range of disciplines required, including across the life sciences, chemistry, chemical and process engineering, intellectual property law and regulation, and ethics. Excellence in scientific disciplines must be matched by talented individuals with skills in commercialisation, including those budding entrepreneurs who will grow the thriving SME base needed to support innovation in the sector.

"Biotechnology requires multidisciplinary skills, with teams of chemists, biologists and engineers needing a common understanding and 'language.'"

Science Industry Partnership.

Several recent studies have identified skills required for scientific roles in the UK and more specifically for IB roles, and it has been calculated that as bio-based IB processes develop and become more established, an increase in technician level roles will be required, but with an understanding of bioprocesses. It was estimated that an extra 1,500 trained employees will be required every year by 2025[22].

At present, tailored IB training for both the early and established career workforce is patchy and inconsistent, hampered by the infancy of IB as a recognised career path in the UK. The risk faced by potential training providers can be mitigated by working with the Catapult centres, such as CPI, to develop training programmes. Relevant training courses should also be developed so that content serves a dual purpose, forming CPD modules for more established workers and thereby increasing demand and contributing to consistency of knowledge and skills across levels[23]. Knowledge Transfer Partnerships (KTP) should be promoted as a mechanism to transfer IB knowledge from academia into industry, whilst also training early career scientists in the vital skills of translation and commercial awareness. In addition, the IBLF should develop and maintain a directory of relevant short course training provision[24].

"Industrial biotechnology is a minor but increasingly recognised academic discipline in the UK, and is more generally supported by strength across STEM teaching at degree and postgraduate level. However, there remains a shortage of graduates with the required IB skills.

Skills lacking in UK workforce:

General STEM skills gap in UK workforce

- Lack of STEM-qualified non-graduates
- Broader competency gaps, e.g. written and mathematical capability amongst science graduates[25]
- Graduates with more practical skills and experience
- Lower training amongst STEM professionals than international competitors
- Maths and Statistics/Computational science capability
- Digital Skills, including data science, informatics, AI, robotics/automated systems, virtual/augmented reality, IoT
- Process analytical technology
- Continuous manufacturing and additive manufacturing (3D printing)
- Control & Instrumentation Engineers

IB specific skills gap in the UK workforce

- Commercialisation skills - graduates & post graduates who combine business, commercial, entreprenuerial and leadershop skills with sector knowledge
- Bioinformatics
- Production and Process Engineers with bioscience knowledge
- Translational skill
- Microbiology
- Fermentation skills
- Bio-manufacturing conversion courses for technicians and graduates (inlcuding aseptic techniques.)

It is important that the future IB workforce is fostered by design and not left to chance, since the skills required are diverse and highly interdisciplinary, and the UK must ensure that skills gaps do not stifle growth when its international competitors are also growing the sector. This is particularly pertinent if UK technologies are being implemented abroad, creating potential demand for UK-trained scientists in lucrative overseas jobs markets. UK exit from the EU also presents a potential threat if there is no longer ready access to skilled IB workers from the rest of Europe. UK industry must partner with education and skills providers to anticipate skills requirements across levels and responsibilities, ensuring adequate domestic training provision leading to recognised career paths in IB.

Industrial biotechnology is a minor but increasingly recognised academic discipline in the UK, and is more generally supported by strength across STEM teaching at degree and postgraduate level. However, there remains a shortage of graduates with the required IB skills. The increasing gap in supply of skilled technical and professional workers in STEM fields as demand grows was the driving force for apprenticeship programmes in the UK that prioritise those sectors[26 27]. Industrial biotechnology is not currently specifically recognised within those frameworks, although it is capable of delivering many of the roles required by the IB sector. Industry must evaluate whether the current provision of training in the UK, including full time education programmes and science apprenticeships, fulfil the requirements of the IB sector, and if not, take coordinated action to close any gaps.

4 The Need for a National Industrial Biotechnology Strategy

Many of these skills are already present, not only within the growing IB sector, but also within those established sectors which IB might disrupt, such as traditional chemicals manufacturing. Reskilling and cross-skilling will harness that talent pool and increase uptake of IB. Indeed, this is already evident from the co-location of IB clusters with former sites of large chemicals companies in the UK, where the decline of commodity chemical manufacturing throughout recent decades also unleashed a skilled workforce that refocused on industrial biotechnology processes. Upskilling within industries already engaged in IB is also essential to ensure that the UK maintains a leading position in cutting edge industries. Curation of training resources will increase uptake by those already employed in industry, and also enable the IB sector to evaluate and identify gaps in provision.

To effectively and efficiently deliver a mixed UK IB sector that delivers for the economy, is sustainable, and satisfies UK commitments to international environmental agreements, coordinated action is needed. The risk of doing nothing is huge. The UK risks lagging behind global competitors in realising the transformative impact of IB and action must now be taken to prevent this. Failure will mean the UK cannot meet its sustainability targets. Therefore, a coordinated long-term National Industrial Biotechnology Strategy, supported by the UK government through specific policies and investment, is essential to fulfil the potential of a sector which can draw upon world leading research expertise at the academic-industrial interface.

Case Study
Policy landscape
BioPreferred® Program

The U.S. Department of Agriculture (USDA) BioPreferred® Program illustrates how a federal procurement programme can stimulate the market place. The most recent report, in 2016, shows that the growing bio-based products industry contributes almost $400 billion and more than 4 million jobs to the American economy.

Info:biopreferred.gov

> *To effectively and efficiently deliver a mixed UK IB sector that delivers for the economy, is sustainable, and satisfies UK commitments to international environmental agreements, coordinated action is needed. The risk of doing nothing is huge.*

Case Study
Licensing industrial biotechnology
Plaxica

Plaxica was a technology licensing company founded in 2008 as a spin-out from Imperial College, London to commercialise the research in PLA and lactic acid technology from the laboratory of Dr Ed Marshall and Professor Vernon Gibson. Between 2008 and 2017, Plaxica developed and commercialised three patented technologies in the renewable chemicals field: Xylex technology takes waste streams from the forest products industry and converts them into valuable hydrolysed sugar-rich streams rich in C5 sugars, whilst removing and isolating lignin. Versalac technology is a novel approach to racemic lactic acid production using a chemical process. The feedstock includes, but is not limited to, the Xylex products. In August 2017, Plaxica sold the Xylex and Versalac technology to Sappi Limited – and the majority of the company's employees located at the Wilton Technical Centre transferred to Sappi's employment. Sappi is the leading global producer of speciality cellulose. Optipure technology produces optically pure L- and D-lactic acid from racemic lactic acid and lactides using an enzymatic resolution process. In addition, Optipure can convert L-lactic acid into D-. In May 2017, Plaxica licensed the Optipure technology to the world's leading PLA producer, NatureWorks LLC, and completed a sale of the technology to them in December 2017. Having successfully achieved its objective of developing and commercialising its technologies with the strategic customers who are best placed to implement the technologies, Plaxica ceased trading in December 2017.

Info: plaxica.com

5

A National Industrial Biotechnology Strategy to 2030

The IB strategy consortium (Table 2) has developed an action plan to implement the recommendations of the report 'Developing a Strategy for Industrial Biotechnology in the UK'[5]. The vision for UK IB is a long-term plan based on clear policy direction and investment (Figure 4).

The vision for UK IB is one that transcends politics, where finance is available for business growth and innovation across Technology Readiness Levels (TRL). This should be driven by regional infrastructure. We want the UK to be internationally recognised as a part of the IB value chain, with a robust, easily navigated regulatory framework. Finally, IB will be recognised as an attractive career option, with multiple entry points, in a society where everyone understands its importance.

The National Industrial Biotechnology Strategy to 2030 has seven components: External Environment; Funding and Access to Finance; Infrastructure and Regional Footprint; Trade, Inward Investment & Commercialisation; Regulation and Standards; Skills; and Communication. Each area is championed by a specific organisation (Table 5), but with overall ownership belonging to the IBLF. The three-phase implementation plan sets out actions for the short-term to the end of 2019, building upon the launch of the wider Bioeconomy Strategy, for which IB and synthetic biology underpin, and the renewed NIBB to develop awareness of IB amongst a broad stakeholder group.

Table 5. National IB strategy areas and champions

Strategy Area	Champion
External Environment	KTN
Funding and Access to Finance	UKRI (BBSRC & IUK)
Infrastructure and Regional Footprint	BioPilots UK
Trade, Inward Investment & Commercialisation	DIT
Regulation and Standards	IBLF
Skills	IBLF
Communication	IBLF

In Phase 1, the consortium has identified initial actions to provide first steps towards long-term strategic goals, beginning with alignment of the National Industrial Biotechnology Strategy with the Bioeconomy Strategy, maintaining cognisant with the Chemical Growth Partnership Strategy and UK Synthetic Biology Strategy. These actions call for the launch of a dedicated IB funding stream, improved access to infrastructure, identification of key export markets, simplified robust regulatory frameworks, recognition of new routes to careers in the sector, and the identification of high-profile advocates for IB. The actions for implementation Phase 1 are indicated below.

5 A National Industrial Biotechnology Strategy to 2030

		PHASE 1: 2018 SHORT-TERM								PHASE 2: MEDIUM-TERM			PHASE 3: LONG-TERM VISION
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	2020	2021	2022	
External Environments	Industrial Strategy	Alignment with Clean Growth Strategy			IB embedded in Clean Growth Strategy implementation plans					Coordination with relevant delivery partners to ensure that UK IB delivers against other national/ regional strategies		Alignment after General Election	Consensus on a consistent long-term policy landscape that supports IBBE
	Bioeconomy Sector	Alignment with Bioeconomy Strategy			IB embedded in Bioeconomy Strategy implementation plans								
	Wider Policy Landscape	Identification of key UK IB stakeholder contacts (across the political landscape)				Coherent vision for UK IB communicated and understood, particularly across EU							
	Monitoring	Monitor and report potential implications/identify opportunities arising from wider government policy actions, e.g. Bioeconomy Sector Deal, Brexit								Continue to monitor and report potential implications/identify opportunities arising from wider government policy actions			
Funding & Access to Finance	Funding	Revise generic research call regulations to include the strategic				Dedicated IB funding to support translation				Development of UK Plc 'Equity' loans			Supportive financial environment that recognises the potential of IBBE for driving growth & innovation
	Finance	Database of investors in IB arena. Build relationship with global VCs				Support for a small number of academic-industry strategic demonstration projects (£10-£50m) a specific ISCF call				Demonstration and commercialisation of technologies arising from dedicated IB translation funding			
	Policy	Work with IB policy makers to promote IB		IBLF & NIBB respond to the current BEIS Patient Capital Review			Learn lessons from international Bioeconomy/IB strategies			Coordination with policymakers and funders to ensure continuity of research priorities and support through finance is maintained through implementation phase of UK exit from EU and beyond			
	Overcoming Barriers	Continuity of provision for BDC, BioPilots, NIBB								Foster innovation by expanding long term capital			
Infrastructure and Regional Footprint	Strategy	Identify long term UK-wide infrastructure IB strategy				Collate and promote UK facilities				BEIS and UKRI modular manufacturing feastibility study			IBBE is a major contributor to clean economic growth across all regions of the UK
	Community Expansion	Expand IBLF to include infrastructure sub group				IBLF establishes a panel of experts in IB advanced manufacturing available to support SME use of infrastructure							
	Accessibility	Dedicated pump priming/ confidence building funding			UKRI & IUK improve financial support to SMEs for accessing existing infrastructure						Establish & evalute modular manufacturing pilot in at least 2 UK regions		
Trade, Inward Investment & Commercialisation	IB Sector Partnerships	Promote success stories in IB sector through curated case studies to demonstrate ROI			Establish IBLF panel of IB commercialistion industry experts to advise SMEs								UK is an international IBBE innovation hub
	Global Opportunity	UKRI scopes feasibility & benefit to UK Plc of exporting UK scientific expertise - borderless value chain				UKRI, IBLF, NIBB & DIT scope international export markets, followed by trade delegations				Promote UK as a cost-effective Innovation hub			
	Large Companies	Large companies help SME to leverage international funding			Identify & incentivise future indigenous anchor businesses to engage in government policy development					Encourage FDI and indigenous investment in innovative science and technology			

5 A National Industrial Biotechnology Strategy to 2030

		PHASE 1: 2018 SHORT-TERM								PHASE 2: MEDIUM-TERM			PHASE 3: LONG-TERM VISION
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	2020	2021	2022	
Regulations & Standards	Simplification	Review existing regulatory frameworks. Assess post-Brexit implications & adjust UK regulatory landscape accordingly								Simplify GMDI labelling	BEIS & DIT promote the UK's support for innovation		UK regulatoryframeworks are recognized as robust and support risk aware innovation
	Alignment with Innovation	Establish 'Regulation for Innovation' working group so that regulations match advances in capability				Utilising regulation to IB advantage e.g. bio-prefered programme							
	Risk Management	Examine where informed rish management techniques can be implemented with respect to emerging technologies					Develop strategy for legislation of new materials and safety of IB ingredients						
	SME Support	Support businesses to navigate regulatory requirements, especially SME's											
Skills	In HEIs	Document and evaluate current training provision and best practice				Develop proposal for IB degree apprencticeships, via Catapults				Develop comprehensive road map of routes to IB careers with case studies			IBBE sectory is recognized as an attractive career option for highly skilled bioscientists and engineers
	In Industry	Industry up-skilling and cross-skilling strategy				UKRI & NIBB establish a programme for seconding early career academics into industry							
	Cross-sector	Career guidance resources				Develop industry-recognised validation scheme for IB training							
Communication	Government/ Policy Makers	Work with e.g. BIA, BBIA				High profile endorsement by industry Champion/Influencer				Develop brand and communication channels, e.g Great British Biotech Youtube channel, videos of pitches for investors, case studies			Wider society is well informed and supportive of RRI in IBBE
	Investors	IB Pitch event		Delegation to IB World Congress			IB Pitch event II						
	IB Community	Awareness of funding available			IBLF fund permanent co-ordinator for IBBE		One IBLF member to be sponsor for each NIBB Phase II						
	Society	Develop a strategy for targeting masses			Celebrity IB Champion			Public Advertisements					
	Resources	Develop simple unifed materials to promote benefits of IB			New IBLF website including public outreach and media resources								

5 A National Industrial Biotechnology Strategy to 2030

External Environment
Action Holder: KTN

Long-term vision: Consensus on a consistent long-term policy landscape that supports IB

It is imperative that the UK leads in the IB sector, not just for the future well-being of the UK population, but for the future of the planet and all its inhabitants. That leadership requires commitment and investment from policymakers that extend beyond typical political cycles. We need agreements that have cross -party support to provide an environment in which UK IB has time and certainty to develop and thrive.

Phase 1 key actions

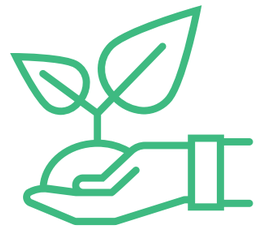
- Alignment with Clean Growth Strategy and IB embedded in resulting implementation plans
- Alignment with Bioeconomy Strategy and IB embedded in resulting implementation plans
- Identify key stakeholders across parties and government departments
- Work with national, regional, and local policy makers to develop an understanding of IB and the benefits to UK Plc
- Monitor potential implications of Brexit impact for IB strategy
- Identify opportunities for IB in wider government policy actions, e.g. Bioeconomy Sector Deal

Phase 1 deliverables

- Distribution list identifying key stakeholders
- IB is specifically referenced in other relevant strategy implementation plans
- Register of key stakeholders who understand and are advocates for IB
- Report on impact of Brexit negotiations outcome on IB community
- Briefing paper on wider opportunities for IB in government

End of Phase 1 milestones

Increased awareness of principles of IB and strategy through engagement across UK and regional government departments and political parties. IB strategy is aligned with key overarching strategy documents, communicating well-defined unified goals to all stakeholders, embedded in relevant action plans. UK vision for IB sector is communicated to international partners, in particular developing awareness throughout Europe.



Access to Funding and Finance
Action Holder: UKRI

Long-term vision: Supportive financial environment that recognises the potential of IB for driving growth and innovation

The IB Catalyst was a valuable and effective source of funding and provided for the sharing of risk in commercialising technology, supporting the development and the demonstration of technology, products and processes. Its cessation has exacerbated what is already a highly challenging funding landscape, given lead times to commercialisation, and is disadvantaging the IB sector against international competition and other innovative UK sectors. In addition, private investment is hampered by a lack of understanding of IB as an underpinning, cross-cutting technology, spanning several market sectors.

Phase 1 key actions

- Dedicated funding to be reinstated with structure to support translation of IB
- Support for SMEs to access finance enabling demonstration of technologies
- IBLF establishes a panel of experienced mentors in IB to support SMEs
- Development and maintenance of a database of investors in IB arena and annual investor pitching events with the aim to build relationships with global investors and attract new investment
- Joint government/industry initiatives to fund demonstration and pilot projects with input from IBLF to ensure strategic value
- IBLF and NIBB to work together in responding to the current BEIS Patient Capital Review
- Document best practice in IB innovation and enabling policies from international competitors

Phase 1 deliverables

- Two rounds of funding for IB translation competition
- First and second annual pitching events
- Panel of IBLF mentors established with procedures for introduction documented
- Database of investors in IB available to key stakeholders
- Report on best practice and enabling policies of international competitors

End of Phase 1 key milestones

Two rounds of dedicated funding competitions completed and projects initiated. Availability of appropriate new finance for SMEs to access demonstration facilities. International best practice in supporting innovation case studies available to the IB community.

5 A National Industrial Biotechnology Strategy to 2030

Infrastructure & Regional Footprint
Action Holder: BioPilots UK

Long-term vision: IB is a major contributor to clean economic growth across all of the UK

UK IB infrastructure is already relatively strong, but there is a need for greater support to allow access to existing infrastructure by SMEs, and less capital intensive, relatively lower cost 'scale-out' infrastructure. The development of regional clusters will foster this ease of access and supports specifically the place and people/ideas foundations of the industrial strategy to develop regional centres of excellence broader than individual universities.

Phase 1 key actions

- Map UK IB infrastructure, including open access facilities, made available in open database
- Delivery of BioPilots business case including work packages for: i) business support; ii) infrastructure and capabilities investment; iii) business tools; iv) policy support; v) communications
- Consolidation of UK IB coordination activities and formation of IBLF IB sub-group that acts as governance for BioPilots
- Dedicated financial support to SMEs for accessing existing infrastructure
- IBLF establishes a panel of experts in IB to support and mentor SMEs in scale-up and process development
- Consolidation and coordination of regional infrastructure plans and databases
- Identification, development and promotion of clusters to include academic excellence in specific themes

Phase 1 deliverables

- Long-term UK-wide strategy for IB infrastructure
- Open database of UK IB infrastructure
- Academic representatives invited to IBLF meetings
- Clusters of expertise and infrastructure are developed and widely publicised

End of Phase 1 key milestones

IB infrastructure strategy in place for long-term view to 2030 and 2050, with IB champions identified and briefed at the highest levels of policymaking to ensure IB and its capabilities for growing the UK remains visible to ministers, so they can understand and respond to future needs. IB Infrastructure sub-group to have completed at least two meetings. Asset database available and promoted nationally and globally by NIBB, IBLF, BioPilots UK, and KTN, with support identified to enable UK SME access. New support promoted for long-term sustainability and growth of SMEs. Development of and evidence for regional support for modular manufacturing principles.

Trade, Inward Investment & Commercialisation
Action Holder: DIT

Long-term vision: UK is an international IB innovation and commercialisation hub

IB is recognised as an area with considerable revenue growth potential for the UK in exports and GVA. With a maturing R&D landscape, it is imperative that private investment is supported, sustained and grown in future years; and that the UK is viewed as 'a key destination' for investment in IB.

Phase 1 key actions

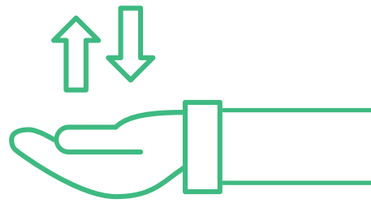
- Establish panel of IB commercialisation industry experts to advise SMEs on inward investment
- Promote success stories in IB sector to government to demonstrate ROI
- Scope high impact international export markets
- Scope feasibility and benefit to UK Plc of exporting UK scientific expertise as part of borderless value chain
- Large companies identified to help SMEs to leverage (international) funding
- Identify and incentivise future indigenous anchor businesses to engage in government policy

Phase 1 deliverables

- Evidence available for impact of IBLF panel: access by SMEs; stage of commercialisation
- Case studies (written and video) available and in use by a variety of stakeholders to promote UK IB
- At least one trade delegation completed to each of the high impact international markets identified
- Report evaluating benefits to UK of exporting UK scientific expertise
- Report on large companies actively engaging with the SME sector
- Register of large anchor companies with active policy engagement

End of Phase 1 key milestones

Potential markets identified, with key international markets scoped and trade delegations completed. UK recognised as leading source of appropriately protected but exploitable intellectual property.



5 A National Industrial Biotechnology Strategy to 2030

Regulation and Standards
Action Holder: IBLF

Long-term vision: UK frameworks are recognised as robust and support risk aware innovation

EU and international regulation and standards are likely to still apply to UK IB post-Brexit, nevertheless, the UK could enhance its competitive advantages by putting in place UK support structures that speed up responsiveness to the needs of IB businesses, and offer ongoing financial and advisory support to SMEs. It is essential that a 'level playing field' is created such that bio-based products are treated equally to biofuels.

Phase 1 key actions

- Establish 'Regulation for Innovation' working group
- Review existing regulatory frameworks and assess implications of UK exit from EU
- Begin to develop a strategy for legislation of new materials and safety of IB ingredients
- Utilise regulation to IB advantage e.g. bio-preferred programme
- Work towards simplification of GMDI labelling
- Support businesses to navigate regulatory requirements, especially SMEs

Phase 1 deliverables

- 'Regulation for Innovation' working group constitution and remit documented
- Two meetings of working group completed with published assessment of existing regulatory frameworks and implications of UK exit from EU
- Call for green paper on regulation of new materials
- Report on principles and proposals for simplified labelling scheme, including recommendations for next phase
- Infographic conveying key information on regulatory bodies and processes for IB technologies and products

End of Phase 1 key milestones

'Regulation for Innovation' working group set up and two meetings completed. Green paper announced for regulation of new materials. Principles agreed and proposals for simplified labelling system. Resources available and promoted to provide SMEs with regulatory guidance, including signposting of existing resources. Risk register review complete, with recommendations for next phase.

Skills
Action Holder: IBLF

Long-term vision: IB sector is recognised as an attractive career option

The UK is globally renowned for its excellence in life sciences, chemistry and engineering technical capabilities, and both industry and academia benefit from the capability of graduates from UK universities. However, there is a shortage of graduates with the relevant IB skills. In addition, the upskilling of the UK IB workforce is essential, especially due to the threat of a nationwide talent drain, due to Brexit.

Phase 1 key actions:

- Evaluate current IB training provision in the UK to identify gaps
- Evaluate potential for IB apprenticeships via Catapults which meets industry requirements
- Develop industry-recognised validation scheme for IB training
- Develop industry upskilling and cross-skilling strategy
- Establish a recognised programme for seconding early career academics into industry
- Develop IB career guidance resources, including annual two-day careers event to promote

Phase 1 deliverables:

- Report on IB training provision in the UK, including potential for IB validated academic and vocational qualifications fit for industry need
- Existing up- and cross-skilling opportunities catalogued and promoted
- Strategy for industry up- and cross-skilling published
- Recognised programme for seconding early career academics to industry established
- Annual two-day careers in IB event in conjunction with cogent skills

End of Phase 1 key milestones:

Review of current and potential future IB training in UK completed. IB apprenticeships scoped with significant progress towards implementation; programme structure proposed with validation methodology; industry and funders engaged. Implementation plan for IB upskilling. Resourced secondment programme in place.

5 A National Industrial Biotechnology Strategy to 2030

Communications
Action Holder: IBLF

Long-term vision: One IB community voice, with consistent clear messages, where wider society is well informed and supportive of Responsible Research and Innovation (RRI) in IB

Public commitment by academia and industry to the principles of RRI in conjunction with development of public awareness of IB will help to foster positive social attitudes to new technologies and drive the market pull for responsibly developed IB products. It is important to develop clear messages for different audiences, including industries that may benefit from but have yet to engage with IB. Resources such as simple glossaries of terminologies can help to demystify IB to enable effective communication with key decision makers within established industries where IB is not yet a technology of choice.

Phase 1 key actions

- Series of fit for purpose messages using common language to support IB community needs, including public outreach materials, made available through new outward facing IBLF website
- Create IB infographic on strategy that clearly outlines the benefits and impact of IB in the UK with a supporting commentary document
- Benchmark communications used in other countries
- Annual IB pitch event to communicate opportunities and encourage investment
- Coordinated delegation to BIO-World Congress on IB
- Awareness of funding available
- One IBLF member to be sponsor for each NIBB Phase II and IBLF fund permanent coordinator
- Develop public awareness campaign, including high profile IB champion
- Work with trade bodies and societies to promote IB

Phase 1 deliverables

- Public outreach and media resources to promote awareness of IB, including technology/industry case studies, made available through new IBLF website
- Glossary of IB terminology supported by narrative case studies to promote industrial awareness of IB technologies and benefits
- IB infographic outlining the benefits and impact of IB in the UK
- First and second annual IB pitch events
- Coordinated UK delegation to BIO-World Congress on IB
- IBLF UK Industrial Biotechnology Strategy Coordinator appointed

End of Phase 1 key milestones

BIA, CIA and BBIA advocates identified with action plans to influence policy. Strong industry champion and/or 'celebrity' advocates for IB engaged in active promotion to government and society. (Inward) investment discussions initiated as a result of pitch event and World Congress. IBLF IB coordinator role funded and appointment made. IBLF NIBB sponsors appointed and mechanisms in place for streamlined NIBB/IBLF interaction. Public awareness campaigns to raise the profile of IB, including coordinated activities, such as advertising campaign, on line material and newly launched IBLF website.

The National Strategy for Industrial Biotechnology 2030 presents a unified vision for development of the sector that places IB at the heart of the future UK economy. Implementation of the strategy through three phases is designed to ensure that the delivery plan is responsive to the changing industrial landscape throughout the lifetime of the strategy, so that the UK can respond effectively to challenges such as the emerging trade and regulatory environments following the exit of the UK from the EU. Actions and deliverables in Phase I have therefore been defined in detail above, establishing strength in each of the five foundations identified in the UK Industrial Strategy, which will form the basis for subsequent phases.

Phase 2, to 2023, will consolidate these efforts, building upon a broad evidence base gathered in Phase 1 to ensure a fully coordinated and long-term strategic approach to ensure a more self-sufficient community, supportive policy environment through an informed and engaged government and future-proofed UK industry. Establishment of recognised career paths to create the skilled academic researchers, industrialists, and particularly entrepreneurs required in the sector, along with increased and long-term investment and patient capital provision will generate a productive sector able to respond to macro trends and global needs. This joined up approach will support innovation which is responsive to the needs of industry, with an informed consumer base driving market demand for IB products and processes.

Phase 3 will cement the position of the UK as a first-choice destination for development and deployment of IB processes, with seamless provision to a global market of end-users. Ongoing evaluation of this strategy will ensure that it is refreshed so that it is fit for purpose in an evolving and highly competitive international market. Ongoing coordination and a united national vision for IB will ensure that the sector can respond to emerging technologies and global events, which might otherwise adversely affect UK society and the economy.

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Industrial Biotechnology
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