# BBSRC Synthetic Biology for Growth Programme Economic Impact Evaluation - Final Report

**Report**

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# Executive summary

The UK was an early proponent of synthetic biology, launching the £114 million Synthetic Biology for Growth (SBfG) programme in 2014 to support early-stage research that could support future industrial activity and foster a strong, collaborative network of academic and industrial researchers across the UK.

The purpose of this study was to evaluate the effectiveness and impacts of the SBfG programme. The evaluation covered the wider impact resulting from the support provided to the following research and development infrastructure:

- six Synthetic Biology Research Centres (SBRC): BrisSynBio (Bristol), OpenPlant (Cambridge and Norwich), SBRC Nottingham, SynBioChem (Manchester), SynthSys-Mammalian (Edinburgh), WISB (Warwick)
- four foundries and two centres funded to provide DNA synthesis and DNA construct capability: Earlham Institute - Automated DNA Assembly, Edinburgh Genome Foundry, Liverpool GeneMill, London DNA Foundry, Synthetic Biology facility at the MRC Laboratory of Molecular Biology (Cambridge), Next Generation DNA Synthesis (Oxford, Liverpool, Bristol, Southampton, and Birmingham)
- two Centres for Doctoral Training (CDT): CDT in Bioprocess Engineering Leadership (UCL), Synthetic Biology CDT (Oxford, Bristol and Warwick)

The evaluation did not include the SBfG investment within the Rainbow Seed Fund which was allocated £10 million to invest in early-stage synthetic biology companies, as this has been subject to an independent assessment.

Globally, synthetic biology is expected to drive novel biological production of goods and services, which could have a direct economic impact of up to $4 trillion (approximately £3.16 trillion) over the next 10 to 20 years[1].

## SBfG programme funding recipients

The SBfG programme supported significant collaborations within and between funded centres and with other academic researchers and industry both domestically and internationally. Over 300 different collaborations were identified, including with 47 early-stage companies (spinouts and startups) that collectively raised over £79 million of funding and investment and employed more than 250 people by the end of 2023. It also supported the careers of 185 research staff in the SBRCs and 139 postgraduate students that trained through the CDTs. Most of these individuals remain in research positions in the UK, with the majority of CDT postgraduates taking on industrial research roles.

Centre leads predominantly considered that the SBfG programme was instrumental in establishing the UK as a global leader in synthetic biology research. It enabled many new research partnerships, and delivered new capabilities to the supported institutions. Notably, for the universities of Bristol, Edinburgh and Manchester this catalysed a shift in senior institutional management to adopt synthetic

1 The Bio Revolution: Innovations transforming economies, societies, and our lives (McKinsey, 2020)

biology as a strategic priority. This has meant that dedicated, permanent staff are now employed to manage and deliver external facing aspects of these institutions' synthetic biology capabilities.

The SBfG programme funding also facilitated engagement with many different stakeholders, from members of the wider public to policymakers (both UK and from other countries) and wider industry. This included staff exchanges and dedicated funding to seed new collaborations.

Two significant challenges were noted by both recipients of SBfG programme funding and those they worked with:

1. the lack of clarity regarding the future direction for synthetic biology in the UK
2. although UKRI provided additional targeted funding for engineering biology[2] between the end of the SBfG programme and the start of the UKRI Engineering Biology and Mission Award call[3], there was a reduction in the overall level of UKRI funding available for this research area during this period

As a result, there was a sense that the UK could lose some capability in synthetic biology. However, the announcement in December 2023 of £2 billion in targeted funding over the next ten years for engineering biology will help to reassure the community of the level and intent of future support.

## External collaborators, partners and customers of the SBfG programme

Thirty three stakeholders who were not direct recipients of SBfG programme funding provided feedback on their experience of engaging with SBfG programme funded centres and this feedback was overwhelmingly positive. Tangible benefits included access to specialised equipment, expertise and the opportunity to consider novel approaches with regards to research directions. The majority of early-stage companies that were engaged indicated that they would either not exist, or at the very least be significantly delayed in their development trajectories without the SBfG programme collaboration.

The assets that were described by stakeholders as being of great benefit included:

- a dedicated contact person at each SBRC, who was pro-active at understanding different external stakeholder needs and identifying research within their centres that would have commercial interest to the external stakeholder
- a pro-business approach from the institution itself
- presenting wider institutional attributes, i.e., extending beyond the SBRC to include other research activities across the institution
- access to advanced, automated equipment that is expensive to buy and to run, including the need to have expert trained staff
- leveraging the reputation of the centre to secure private investment
- networking with other relevant researchers and companies from the host institution and its collaborators
- the high calibre of PhD students, in particular from the CDTs, and postdoctoral researchers that the centres produced

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[2] UK Engineering Biology receives £20.6 million funding boost – UKRI

[3] Engineering Biology Missions Hubs and Mission Awards – UKRI

## Economic impacts of the programme

The economic impacts of the programme were assessed using a bottom-up model, based on programme monitoring data and feedback gathered from external stakeholders, and a top-down model, that used historical and industry forecast data to estimate the potential value of the global markets for synthetic biology products and applications and estimate the share the UK could expect to control. Impact analysis was performed for the programme period (2014 to 2022) and the 10-year post-programme (2023 to 2032). These assessments were also combined to provide figures for total impact.

For the sectors the SBfG programme ultimately impacted, the bottom-up model identified a total net additional Gross Value Added (GVA) of between £360 million and £419 million, representing a return on investment (RoI) of between 2.9 and 3.4 times the initial investment (including economic multipliers[4]).

The top-down model indicated a total net additional GVA of up to £1,065 million, representing an RoI of 8.7 times the initial investment. This model identifies a larger RoI as it considers a wider set of potential impacts driven by increased or new economic activity within the UK's industry base. This includes startups and spinouts, existing SMEs and large scale national and international enterprises developing, utilising and enhancing synthetic biology products and processes to drive growth.

In conclusion, the SBfG programme can be considered transformational for the UK, driving innovation, fostering collaboration, and unlocking the economic potential of synthetic biology. As the landscape of synthetic biology continues to evolve, sustained investments and collaborative efforts, such as those fostered by the SBfG programme and the UKRI Engineering Biology Mission Hubs and Mission Awards call will be essential to realise its full potential in addressing global challenges and driving technological innovation.

[4] These are official multipliers from the Office of National Statistics that reflect the additional economic impact expected from different industry sectors.

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# 1 Introduction to the evaluation

Synthetic biology has been defined as 'the application of engineering tools and principles to design and engineer novel biologically based parts, devices and systems that do not exist in the natural world, as well as the redesign of existing natural biological systems for useful purposes'[5]. The terminology has subsequently evolved into 'engineering biology' as research institutes and companies have become more adept at taking synthetic biology concepts and translating them into real world solutions.

The UK published a roadmap for synthetic biology in 2012[6] which recognised the opportunities arising from synthetic biology and set out a series of actions, over a number of thematic areas, to benefit business and the UK economy, develop global scientific excellence in the UK and demonstrate clear public benefit. The UK was widely regarded as one of global frontrunners at that time. A review by the Woodrow Wilson Centre the following year identified more synthetic biology research across UK industry and academia than in any other country, apart from the US[7].

The UK's roadmap led to the establishment of the Synthetic Biology Leadership Council (later the Engineering Biology Leadership Council) and the launch of the Synthetic Biology for Growth (SBfG) programme[8]. In total, the initial SBfG programme represented investments of £102 million, including:

- £50 million Autumn Statement capital
- £1.37 million capital from BBSRC
- £50.5 million resource funding provided for six Synthetic Biology Research Centres by the Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC) and the Medical Research Council (MRC)

The main objectives of the SBfG programme were to:

- develop and sustain an internationally competitive research programme that would be relevant to one or more industrial sectors
- enable a strong, collaborative and multidisciplinary culture across UK research
- provide the necessary equipment and facilities across the community to enable adoption and uptake of synthetic biology
- foster collaboration with and knowledge transfer to the UK's industrial base
- train the next generation of multidisciplinary academic and industrial researchers

The SBfG programme had four distinct investment streams:

- multidisciplinary Synthetic Biology Research Centres (SBRCs) to 'boost national synthetic biology research capacity and ensure that there is diverse expertise to stimulate innovation in this area'. This included funding for people, equipment and facilities to undertake new research activities
- DNA synthesis, to address bottlenecks in the high throughput synthesis of large genetic constructs, and to connect academia and industry

5 Synthetic biology – UKRI
6 A synthetic biology roadmap for the UK (Technology Strategy Board, 2012)
7 Tracking the Growth of Synthetic Biology: Findings for 2013 (The Wilson Centre, 2013)
8 Synthetic Biology for Growth – UKRI

- Capital investments in two Centres for Doctoral Training (CDT) to enhance student training by providing state-of-the-art equipment and facilities
- A £10 million Synthetic Biology Seed Fund, to support early-stage synthetic biology companies

The purpose of this study was to evaluate the effectiveness and impacts of the SBfG programme, focusing on the SBRCs, the DNA synthesis investment and the two CDTs. The seed fund has been subject to an independent assessment and therefore is not considered in this study. The evaluation covered the wider impacts resulting from the support provided to the following research and development infrastructure:

- Six SBRCs:
  - **BrisSynBio** (at the University of Bristol). Aim: to develop new techniques, technologies and reagents that will allow biologically-based products to be made easily, quickly and cheaply, and in sufficient quantities to make them useful
  - **OpenPlant** (jointly delivered by the University of Cambridge and the John Innes Centre, Norwich). Aim: to establish internationally-linked DNA registries for sharing information about plant specific parts and simple testbeds. The development and exchange of new foundational tools and parts will directly contribute to the engineering of new traits in plants
  - **SBRC Nottingham** (at the University of Nottingham). Aim: to provide sustainable routes to important chemicals that modern society needs. The aim is to use synthetic biology to engineer bacteria to convert atmospheric gases, such as carbon monoxide, carbon dioxide and methane, into more desirable and useful molecules, reducing reliance on petrochemicals
  - **SynBioChem** (at the University of Manchester). Aim: to bring scientists together to design and engineer biological parts, devices and systems for sustainable fine and speciality chemicals production. This includes new products and intermediates for drug development, agricultural chemicals and new materials for sustainable manufacturing
  - Centre for Mammalian Synthetic Biology (**SynthSys-Mammalian**) (at the University of Edinburgh). Aim: to build in-house expertise in synthetic biology in mammalian systems for use in areas such as:
    - the pharmaceutical and drug testing industries
    - biosensing cell lines for diagnostics
    - novel therapeutics
    - production of protein-based drugs, for example antibodies
    - programming stem cell development for regenerative medicine applications
  - Warwick Integrative Synthetic Biology Centre (**WISB**) (at the University of Warwick). Aim: to utilise state-of-the-art principles of biosystems design and engineering. This is in order to develop:
    - next-generation synthetic biology tools
    - biosynthetic pathways that generate valuable bioactives
    - synthetic communities of microbes that could help improve the environment as well as skin and gut health

        - plants with enhanced resistance to stress and pathogens
- Four foundries and two centres funded to provide DNA synthesis and DNA construct capability:
    - **Automated DNA Assembly** (at the Earlham Institute, Norwich). Aim: to support the design, generation and exploitation of high-value compounds and bioactives obtained from plants and microbes
    - **Edinburgh Genome Foundry** (at the University of Edinburgh). Aim: to provide end-to-end design, construction and validation of large gene constructs (up to 1 million base pairs) for academia and industry, based on the automation of technologies. Also to enable the rapid design and synthesis of multiple varied DNA circuits (for example, metabolic pathways, biosensors, counting or memory devices) and interrogate the utility of these circuits within host cell chassis via an array of assays
    - **Liverpool GeneMill** (at the University of Liverpool). Aim: to develop a high throughput, automated workflow for synthesising genes and DNA parts in bacteria, fungus, plant and mammalian cells
    - **London DNA Foundry** (at Imperial College London, Imperial). Aim: to develop an experimental platform to enable a standardised framework for DNA synthesis, gene and genome assembly and assembly verification. Also to establish a platform to support a suite of synthetic biology software tools, allowing the seamless integration of hardware, management and analysis of generated data. This is for the purpose of building a professional DNA synthesis workflow
    - **Synthetic Biology facility at the MRC Laboratory of Molecular Biology**. Aim: to invest in a robotic platform to automate assembly of short DNA fragments into expressible genes. This includes the picking, growth and analysis of DNA from bacterial colonies
    - **Next Generation DNA Synthesis** (jointly delivered by the universities of Oxford, Liverpool, Bristol, Southampton, and Birmingham). Aim: to analyse DNA made by modern ultra-high throughput chemical methods and optimise the process, and explore new ways to make large pieces of DNA
- Two CDTs:
    - **CDT in Bioprocess Engineering Leadership** (at University College London, UCL). The SBfG programme provided capital funding for the acquisition of state-of-the-art bioprocess and analytical equipment and establishment of dedicated training laboratories
    - **Synthetic Biology CDT** (jointly delivered by the universities of Oxford, Bristol and Warwick). The SBfG programme provided capital funding for a dedicated synthetic biology laboratory in Oxford accessible to all students throughout their PhD and specialist facilities in Warwick and Bristol

This evaluation had five phases:

1. A review of the background context to the SBfG programme in terms of:
    a. policy
    b. opportunity for economic growth
    c. education and training
    d. investment and business support
    e. regulatory environment
    f. growth and trends of market sectors that are expected to be impacted by synthetic biology: enabling technologies, chemical manufacturing, agriculture, and therapeutics and biomedical
2. A detailed review of SBfG programme evidence made available by the BBSRC (through Researchfish[9] and reports from recipients of funding). This included details of:
    a. the awards to each recipient through the SBfG programme
    b. further funding secured by recipients of SBfG programme funding
    c. collaborations and partnerships
    d. next destinations of staff employed by the SBRCs and two of the DNA foundries
    e. publications and IP arising from the SBfG programme funding
    f. spinouts that were formed to exploit SBfG programme research results
    g. details of engagement activities between recipients of funding and external stakeholders, including policymakers, industry and the wider public, and the impacts from these activities.
3. Gathering external evidence through engagement with recipients of SBfG programme funding. In total, 22 individuals were interviewed, representing all six SBRCs, the four DNA foundries and two centres for DNA synthesis, and the two CDTs.
4. Consultation with organisations that engaged with recipients of SBfG programme funded centres (but who were not direct recipients of SBfG funding), including spinout and startup companies. In total, 26 external organisations were interviewed and a further seven completed an online survey. In addition, eight academic researchers that were not recipients of SBfG programme funding were interviewed as part of a counterfactual group.
5. Economic impact modelling and analysis using both bottom-up and top-down approaches. This included an assessment of the impacts accrued from the SBfG programme in terms of the staff employed within the SBRCs and students trained, and of the companies that engaged with the SBRCs. It also included an analysis of global market conditions that could be impacted by synthetic biology developments and an assessment of the UK's share of these impacts. It provided an assessment of the overall RoI for the SBfG programme.

In addition, eight case studies were produced that reflect the broad range of applications, market sectors and types of companies that benefited from engaging with centres funded through the SBfG programme.

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[9] A software platform that is used globally by funders and universities to track research and evidence impact – see https://researchfish.com/researchfish/. The data used in this study covered the period up to March 2023.

# 2 Background context to the SBfG programme

The purpose of this chapter is to provide background context in which to consider the SBfG programme. Section 2.1 reviews wider public policy and external factors such as skills, education and research capability, investment and business support, and the regulatory environment that have and will continue to influence the development of synthetic biology in the UK. Section 2.2 examines the expected market impacts from synthetic biology, by assessing current and future market sizes in four key synthetic biology applications areas: enabling technologies - life sciences tools; chemical manufacturing; agriculture; and therapeutics and biomedical.

## 2.1 External and policy factors

This section reviews the wider external and policy factors that are relevant to the SBfG programme, including: how national economic and strategy policy could impact the growth of the synthetic biology sector, and further considers a series of external factors including skills, infrastructure, linkages with other programmes, the investment landscape and the regulatory environment.

### 2.1.1 Public policy landscape

As synthetic biology is an emerging sector reliant on new and developing technologies, the most relevant policy areas focus on innovation.

In the main, UK public policy suggests a supportive national commitment and recognition of the strategic importance of innovation, including within the biosciences industries, to promote economic growth. This begins with the government's Build Back Better[10] plan for growth which places innovation as a key pillar of growth (alongside skills and infrastructure). The innovation pillar outlines a broad commitment to incentivise investment in R&D with a target to reach 2.4% of GDP by 2027. This target has subsequently been met, as a result of a re-evaluation of how the Office for National Statistics (ONS) estimates R&D spend[11]. Innovation will also be supported by R&D tax reliefs, an expansive and accessible finance and investment landscape and an evolving regulatory system adaptive to the needs of innovative industries.

Further to this, at the national level, the UK Innovation Strategy[12] sees the UK as a global hub for innovation by 2035. There is public sector commitment to increase direct public expenditure on R&D to £22 billion per annum and recognition that private sector investment will need to increase to keep up with other leading nations.

Aimed specifically at the life sciences sector, the National Life Sciences Vision[13] is designed to build on the commitments of the Build Back Better plan. The vision also notes several key advantages of the UK ecosystem including the potential role of the National Health Service (NHS). The NHS underpins a well-developed domestic market for novel synthetic biology products that have health applications (for

10 Policy paper: Build Back Better: our plan for growth (March 2021)
11 Research & Development Spending (House of Commons Library, 2023)
12 Innovate UK strategic delivery plan 2022 to 2025 (September 2022)
13 National Life Sciences Vision (2021)

example, treatments, diagnostics, etc.). Further, the NHS is recognised as being critical to the delivery of nearly every element of the Vision, at both a national and operational level.

In terms of access to finance, London's global standing as a centre of finance offers the opportunities for promising companies to attract the private financing needed to support growth.

Specific policy around growing the synthetic biology sector is supported by the UK Synthetic Biology Strategic Plan 2016[14] which follows the earlier UK Synthetic Biology Roadmap from 2012. The key guiding principles are summarised as:

- accelerate industrialisation and commercialisation - by promoting investment in, and translation of, empowering biodesign technologies and assets to drive growth in the bioeconomy
- maximise the capability of the innovation pipeline - by continuing to research and develop platform technologies that will improve manufacturing efficiencies and unlock future opportunities
- build an expert workforce - by distilling the skills required for biodesign and implementing them through education and training
- develop a supportive business environment - by ensuring that regulation and governance systems are proportionate and appropriate to the needs of industry and that these are aligned with the needs and desires of stakeholders
- build value from national and international partnerships - by fully integrating the UK synthetic biology community to position UK research, industry and policy makers as partners of choice for international collaboration

Taken together, there is a clear direction of UK government support for innovation within the life sciences sector more broadly, which carries over to synthetic biology.

### 2.1.2 Opportunity for economic growth

The UK Government has put into place policies and strategies to support the life sciences sector and innovation. In particular, its commitment to public sector investment in R&D can be critical. Research has shown that there is a crowding-in effect on private sector R&D expenditure from public sector R&D spend. In the long run, for every £1 of public R&D investment, between £1.96 and £2.34 in private R&D spend is stimulated[15]. The £22 billion per annum public R&D spend target, in addition to the £2 billion for engineering biology over the next ten years announced in December 2023[16], will leverage additional private investment and will support synthetic biology innovation and growth.

### 2.1.3 Skills, education and research capacity

The research capacity of the UK's higher education institutions is a clear strength. According to the Times Higher Education World University Rankings 2023 for Life Sciences, four UK universities are ranked within the top 25, including Cambridge, Oxford, Imperial College London and University College

14 UK Synthetic Biology Strategic Plan (2016)
15 The relationship between public and private R&D funding (Oxford Economics, 2020)
16 National Vision for Engineering Biology (DSIT, 2023)

London ranking 2nd, 4th, 14th and 22nd respectively[17]. The UK also performs well globally in its share of research publications. From 2007 to 2018, the UK's field-weighted citation impact was the highest amongst G7 nations[18]. Taken together, the UK's science and research offering is amongst the best in the world.

The UK's higher education system consistently produces top end talent. This combined with the UK's new immigration measures - particularly the Global Talent visa[19] - supports the provision of high-level skills that are useful for research and technology development, and company formation. However, it is at the first-degree and lower levels where skills gaps are most pronounced, specifically in the technology and biochemistry subject areas. The lack of a steady pipeline of skills is a potential limiting factor for the growth of the synthetic biology sector. This will impact companies' ability to recruit the skills needed within the UK. There is a potential push factor in which companies that are looking to scale up may relocate some activities abroad. Further, lack of available skills may also result in synthetic biology companies recruiting from other related sectors inducing displacement effects, which, while supporting the growth of synthetic biology, will inhibit growth of those other sectors. The potential markets most affected by the skills gaps include strain engineering and biotechnology scale-up and optimisation. The government has stated its ambition to support life sciences skills at apprenticeship and further education levels thorough increase apprenticeship levies. If this initiative is successful in recruiting more apprentices to the sector, some of the potential negative impacts will be eased.

Synthetic biology is a multi-disciplinary sector combining skills and expertise from a wide range of fields including engineering principles, mathematical modelling, advanced molecular biology, microbiology, biochemical engineering and chemistry. Further, the life sciences sector requires skills across a range of occupations. Table 1 summarises the occupation composition of the UK life sciences sector.

| Standard Occupational Classification | % of UK Life Sciences Workforce |
|---|---|
| Managers, Directors and Senior Officials | 9% |
| Professional Occupations | 45% |
| Associate Professional and Technical Occupations | 26% |
| Administrative and Secretarial Occupations | 7% |
| Skilled Trades Occupations | 3% |
| Sales and Customer Service Occupations | 1% |
| Process, Plant and Machine Operatives | 4% |
| Elementary Occupations | 5% |

**Table 1: Share of the UK life sciences sector by occupation[20].**

27% of the Life Sciences workforce comes from overseas, with those from the EU accounting for 12% of the sector[20]. This illustrates a need to continue the flow of international talent and, in particular, the flow of talent from the EU after the UK's exit from the European Union.

The National Life Sciences Vision has an overarching skills ambition to "develop a strong talent pool across industry, academia, and the NHS, ensuring the life sciences sector has access to the variety of

17 World University Rankings 2023 by subject: life sciences
18 International comparison of the UK research base (BEIS, 2019)
19 https://www.gov.uk/global-talent
20 Life Sciences 2030 Skills Strategy (Science Industry Partnership, 2020)

skills it needs to support innovation, and entrepreneurs feel they can access the human capital required to grow their companies in the UK."  Specific actions within this objective include the government taking a partnership approach with industry to ensure the life sciences sector, has the tools it needs to recruit, reskill and develop talent in both specialist and non-specialist roles. This includes government's commitment to a free flow of talent globally, underpinned by the UK's new immigration system which includes routes such as the Global Talent visa.

There is a recognition that links between university life sciences courses and industry need to be built, so that new graduates are educated in the cutting-edge skills and techniques that industry needs and are 'industry-ready' when starting life sciences jobs. Concerning further education, the provision of life sciences apprenticeship training across levels 2 to 7 will be essential in providing diverse skills sets to the sector and better engagement and co-ordination between life sciences employers and further education is critical. The overarching skills ambition is to boost the proportion of the apprenticeship levy recovered by the life sciences sector from 24% to surpass that of the national average of 31%[20].

Table 2 and Table 3 present student enrolment in higher and further education courses in subject areas related to synthetic biology, respectively. The tables do not include subjects that are also important to synthetic biology (such as software engineering, data science, materials science), but where a smaller number of graduates might be expected to enter the sector.

| Subject area | 2019/20 | 2020/21 | 2021/22 | 3-year change | % change |
|---|---|---|---|---|---|
| **Undergraduate** | | | | | |
| Biomedical sciences | 28,950 | 31,320 | 33,535 | 4,585 | 16% |
| Biosciences (non-specific) | 9,900 | 10,375 | 10,610 | 710 | 7% |
| Biology (non-specific) | 12,480 | 13,140 | 12,545 | 65 | 1% |
| Microbiology and cell science | 1,970 | 1,975 | 2,025 | 55 | 3% |
| Genetics | 1,615 | 1,760 | 1,735 | 120 | 7% |
| Molecular biology, biophysics and biochemistry | 11,225 | 11,275 | 11,075 | -150 | -1% |
| Other biosciences | 2,270 | 2,260 | 2,270 | 0 | 0% |
| Bioengineering, medical and biomedical engineering | 4,215 | 4,860 | 4,890 | 675 | 16% |
| Biotechnology | 550 | 565 | 365 | -185 | -34% |
| **Total** | **73,175** | **77,530** | **79,050** | **5,875** | **8%** |
| **Postgraduate** | | | | | |
| Biomedical sciences | 4,665 | 6,240 | 6,740 | 2,075 | 44% |
| Biosciences (non-specific) | 2,670 | 2,900 | 2,425 | -245 | -9% |
| Biology (non-specific) | 2,915 | 3,045 | 2,845 | -70 | -2% |
| Microbiology and cell science | 1,950 | 2,025 | 2,230 | 280 | 14% |
| Genetics | 1,355 | 1,400 | 1,565 | 210 | 15% |
| Molecular biology, biophysics and biochemistry | 2,710 | 2,745 | 2,705 | -5 | 0% |
| Other biosciences | 315 | 360 | 395 | 80 | 25% |
| Bioengineering, medical and biomedical engineering | 1,625 | 1,770 | 1,910 | 285 | 18% |
| Biotechnology | 560 | 735 | 1,005 | 445 | 79% |
| **Total** | **18,765** | **21,220** | **21,820** | **3,055** | **16%** |

**Table 2: Higher education student enrolment in undergraduate and postgraduate programmes**[21]
(based on Common Aggregation Hierarchy (CAH) Level 3 subject areas)

| Subject area | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 4-year change* | % change |
|---|---|---|---|---|---|---|---|
| **Further Education Enrolments** | | | | | | | |
| Science | 11,290 | 10,340 | 10,330 | 9,550 | 7,840 | -1,740 | -15% |
| Engineering | 30,740 | 21,800 | 26,150 | 27,350 | 20,290 | -3,390 | -11% |
| Total | 42,030 | 32,140 | 36,480 | 36,900 | 28,130 | -5,130 | -12% |
| **Apprenticeship Achievements** | | | | | | | |
| Sciences | 170 | 60 | 20 | 90 | 110 | -80 | -47% |
| Engineering | 8,580 | 6,710 | 7,850 | 10,600 | 8,480 | 2,020 | 24% |
| Total | 8,750 | 6,770 | 7,870 | 10,690 | 8,590 | 1,940 | 22% |

**Table 3: Further education student enrolment in synthetic biology related programmes (England)**[22]

* Data for the 2022/23 academic year reflects enrolments and achievements through Q3, not the entire year. Therefore 4-year change and % change figures represent differences between the 2018/19 and 2021/22 academic years.

21 Higher Education Statistics Agency (HESA) data on subject enrolments

22 See here. Enrolment data: Subject - Enrolments by STEM, SSA, Level, Age dataset. Data covers England only. The data is at the Sector Subject Area Tier 2. Achievements data: Apprenticeships Subjects - Starts, Achievements, Enrolments by Detailed level data. Data covers England only. The data is at the Sector Subject Area Tier 2.

The data suggest an overall increase in students enrolled in synthetic biology related subjects over the past three years (an increase of 8% at the undergraduate level and 16% at the postgraduate level). There is some variability between subject areas, for example, a sharp decline (-34%) in the number of biotechnology undergraduates. This is, however, contrasted with a 79% increase in the number of biotechnology postgraduate enrolments. Also of note is the slight decrease in non-specific biology and bioscience subjects at the postgraduate level. Overall, there has been a moderate increase in the student throughput in synthetic biology related subject areas, with variations in different subject areas suggesting a change in preference for students and/or a response to career opportunities within certain industries and the skills and qualifications needed.

The data further suggests that trends in enrolments/achievements in the further education and apprenticeship levels within synthetic biology related subjects are variable. In particular, further education enrolments in science and engineering have seen a significant drop between the 2018/19 and 2021/22 academic years, with enrolment across both subjects falling by 12%. In terms of apprenticeships, there was an initial dip in engineering achievements (during the academic years most affected by the COVID-19 pandemic), but these have since surpassed pre-pandemic levels. Science remains a relatively small subject area for apprenticeships with just 90 achievers in the 2021/22 academic year, although with a modest increase through the first three quarters of the 2022/23 academic year. These are in the following frameworks: Food Industry Technical Professional, Research Scientist, and Technician Scientist. The data suggests support may be needed to bolster apprenticeship qualifications and encourage greater science further education enrolment to support the diverse skills need of the synthetic biology sector.

#### 2.1.4 Investment and business support

Innovation within the synthetic biology sector and, more generally, the life sciences sector is often a long-term, capital-intensive process. As a result, the sector is particularly reliant on long-term investment to finance growth.

HM Treasury's Patient Capital Review[23] identified that there is a shortage of this type of capital, particularly at later stages. The review suggests that there is strong investment in the life sciences sector overall, but still some key challenges.

Some strengths of the investment landscape include strong public investment in health research, where the UK ranks second only to the US in per capita government funding (as of 2019)[24]. The UK is seen as an attractive market for investment in the life sciences. Only the US is ahead in the number of foreign direct investment (FDI) projects financed in 2019[25]. The business environment is unpinned by favourable global rankings in the Ease of Doing Business Index (8th)[26] and Global Innovation Index (4th)[27]. An important factor that influences investment attractiveness is the UK's development of regulation in life sciences, for example gene editing in crops. This is discussed further in Section 2.1.2.3.

23 Policy paper - Patient Capital Review (HM Treasury, 2017)
24 Government budget allocations for R&D (OECD)
25 Life Sciences Visions 2021 (UK Government)
26 Ease of Doing Business Rankings (World Bank)
27 Global Innovation Index (2022)

Despite this some key challenges remain. These include a notable funding gap between the life sciences companies in the US and in the UK, with the average size of private capital per company raised at £20.5 million compared to £8.8 million, respectively. Further, this gap is most notable at the later growth stages. Public markets in the UK face a similar shortfall. Public offerings for life sciences companies achieve valuations 20% to 30% higher on the US Nasdaq compared to the London Stock Exchange (LSE).

There has been significant activity led by the UK government to overcome some of these challenges, including interventions to improve the availability of capital. Of note is the UK-UAE Sovereign Investment Partnership. The UAE state-owned investment company Mubadala has made an £800 million commitment to investment in the UK Life Science sector, alongside an additional investment of £200 million from the UK's Life Sciences Investment Programme[28]. Work is also underway to support greater investment into the life sciences sector by Institutional Investors and pension funds.

British Patient Capital has developed a sector specific investment fund, the Life Sciences Investment Programme (LSIP)[29] which is a £200 million initiative managed by British Patient Capital. It aims to specifically address the key challenge area of late-stage growth equity funding. It is further expected that this fund will leverage an additional £400 million in private investment.

Although not life sciences sector specific, the Future Fund: Breakthrough[30], with £375 million provided by the UK government, will support direct co-investment products to support the scale up of the most innovative, R&D-intensive businesses. The British Business Bank will take equity in larger funding rounds led by private investors to ensure that these companies can access the capital they need to grow and deliver prosperity to communities across the UK.

In addition to access to capital, a wide range of business support programmes, accelerators and research funding mechanisms are in place to support the synthetic biology sector. These are additional to the SBfG programme, and though not all are specifically aimed at synthetic biology companies, it is likely that some will benefit. A non-exhaustive list includes:

- Connecting Capability Fund, which is supporting a number of regional commercialisation initiatives, including the Midlands Innovation Commercialisation of Research Accelerator, the Northern Accelerator (in the Northeast), and Northern Gritstone
- Higher Education Innovation Funding (HEIF) which supports and incentivises universities in England to engage and work with business
- BBSRC and EPSRC Impact Acceleration Account (IAA) programme investment - strategic awards provided to research organisations to allow them to respond to impact opportunities in more flexible, responsive and creative ways
- SynbiCite - an EPSRC, BBSRC and Innovate UK funded synthetic biology accelerator fostering collaboration between leading academic institutions and industry partners

[28] UAE and UK launch sovereign investment partnership with initial £1 billion in life sciences (March 2021)
[29] Life Sciences Investment Programme (LSIP)
[30] Future Fund: Breakthrough (British Patient Capital, part of British Business Bank)

- the Engineering Biology Leadership Council[31] provided a steering structure governance body to assess progress and update recommendations and shape priorities for future implementation of the synthetic biology roadmap for the UK

The UK has some key strengths in public investment in health research, FDI in life sciences and ease of doing business which likely have a positive impact on potential synthetic biology sector growth. However, growth will be limited if funding and investment gaps remain – particularly long-term growth capital at both early and later stages. Lack of capital will negatively impact emerging startups, spinouts and other early-stage companies. This in turn constrains the pipeline of new business and new innovative ideas and products. Filling this identified gap in the investment landscape will be important to support the scale up of emerging technologies and companies.

Investment activity in other countries will also play a large role in shaping the future global landscape of the synthetic biology sector, as the UK will need to keep pace with the rest of the world to maintain its position as a global leader in the industry and ensure economic and societal benefits are retained.

At present, the US is considered the global leader in the synthetic biology sector. North America has the largest market share, at 41.1% of global revenue in 2021 with the US owning the largest share. In fact, the five largest publicly traded and the five largest privately held synthetic biology companies by revenue are all headquartered in the US. US firms attract the majority of venture capital investment, at $1.1 billion during the second quarter of 2019; while the rest of the world attracted $147 million during the same period. Further to this large level of private investment, the sector is also supported by government funding, including the US Department of Defense, National Science Foundation, Department of Energy and National Institutes of Health.

Europe, including the UK, has the second-largest synthetic biology market share, but the Asia-Pacific region has the fastest growing market. China is leading the growth in the Asia-Pacific region, driven by large scale academic-industry partnerships and state-funded research programmes. Thus far, the Chinese government has invested over $100 billion in life sciences, including the establishment of two synthetic biology research centres[32].

### 2.1.5 Regulatory environment

The UK's exit from the European Union is expected to provide an opportunity to create a more agile regulatory system. In particular, some application areas of synthetic biology have been restricted by EU regulations including agricultural applications, where only one genetically modified crop (maize MON 810) is authorised for cultivation in the EU, and, even so, the crop is only grown in Spain and Portugal[33]. A shift to alternative regulatory environments could unlock opportunities for new product development and markets to support the growth of the synthetic biology sector. Some reviews and initiatives currently underway include the Taskforce on Innovation, Growth and Regulatory Reform (TIGGR)[34] which established the Regulatory Horizons Council that is tasked with promoting the

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31 The Engineering Biology Leadership Council is no longer active as of December 2023, being replaced by a governmental Engineering Biology Steering group. However, the Council was active during the SBfG programme.

32 US International Trade Commission, A Brief Introduction to Synthetic Biology. 2023. Accessed here.

33 https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/754549/EPRS_BRI(2023)754549_EN.pdf

34 The Taskforce on Innovation, Growth and Regulatory Reform report (May 2021).

adoption of a regulatory environment which is both pro-innovation and safe. The Council is examining regulation, particularly in the agri-environment and clinical trials spheres, to support regulatory decision making that is based on proportionate and high-quality scientific evidence on the safety of new products. This aims to unlock potential economic and societal benefits.

During the period of the SBfG programme, organisms that had artificially introduced genetic modifications, were classed as genetically modified organisms (GMOs). This grouped older technologies that introduce DNA sequences derived from other organisms (so-called foreign DNA) to enhance a feature, such as productivity, with newer, gene-editing techniques enabled by synthetic biology which precisely alter DNA sequences in the target organism that ultimately contains no foreign DNA. Crops produced by gene-editing techniques can, in theory, be produced through conventional crop breeding techniques.

The regulatory frameworks concerning food products produced using gene editing technologies were initially based on the EU legislation which has been "grandfathered in" since the UK's exit from the EU. However, in March 2023 the UK government passed the Genetic Technology (Precision Breeding) Bill[35], which removes crops and animals produced through gene-editing, from the GMO regulatory system. It is interesting to note that the EU Parliament voted in February 2024 to reduce regulatory oversight on gene-edited crops[36]. This direction of travel, led by the UK, should open up new opportunities in global agriculture markets including food for human consumption.

As noted previously, the NHS will play a major role in pharmaceutical/health product markets, however, the government will have a large role in shaping the regulatory environment. This is particularly important in the clinical trials sphere as drug development is globally competitive and being first to market is crucial (as evidenced by the rapid development of COVID-19 vaccinations). How these markets evolve in the future and what percentage will be won by the UK will in part depend on the regulatory system in place, which, based on proposed national strategy and reviews, suggests an environment supportive to a more fast-paced pharmaceutical market.

## 2.2 Market growth and trends

### 2.2.1 Overview

According to some wider estimates, biological production of goods and services, directly supported by advances in synthetic biology, could have a direct economic impact of up to $4 trillion (£3.16 trillion)[37] over the next 10 to 20 years[38].

As an enabling technology, synthetic biology has applications across a diverse range of existing and emerging markets. Established life sciences companies are rapidly expanding their engagement with synthetic biology technologies as illustrated by, for example, Joyn Bio, a joint venture between an American strain engineering company Ginkgo Bioworks and Bayer, with a focus on engineered

35 https://commonslibrary.parliament.uk/research-briefings/cbp-9557/
36 https://www.europarl.europa.eu/news/en/press-room/20240202IPR17320/new-genomic-techniques-meps-back-rules-to-support-green-transition-of-farmers
37 Converted to GBP using an exchange rate of 1 USD : 0.79 GBP. This rate is used throughout the report.
38 The Bio Revolution: Innovations transforming economies, societies, and our lives (McKinsey, 2020)

microbial probiotics for soil nitrogen fixation. Nevertheless, spinouts and startups appear to be the main channel of synthetic biology industrial exploitation[39]. In 2017, a report for the UK Synthetic Biology Leadership Council indicated that there were 37 synthetic biology startups in the UK[40], and this number has been rapidly expanding and changing as more companies adopt synthetic biology tools and techniques to accelerate their product development. In 2022, the BIA reported that the UK's life sciences and biotech sectors raised over £1.78 billion[41], illustrating the scale of interest in the industry enabled, to a significant extent, by synthetic biology tools and techniques.

Synthetic biology-enabled companies can be broadly divided into four segments based on type of products or services that are characterised as tools, chemicals, biologicals, or cells and organisms with various applications (Figure 1).

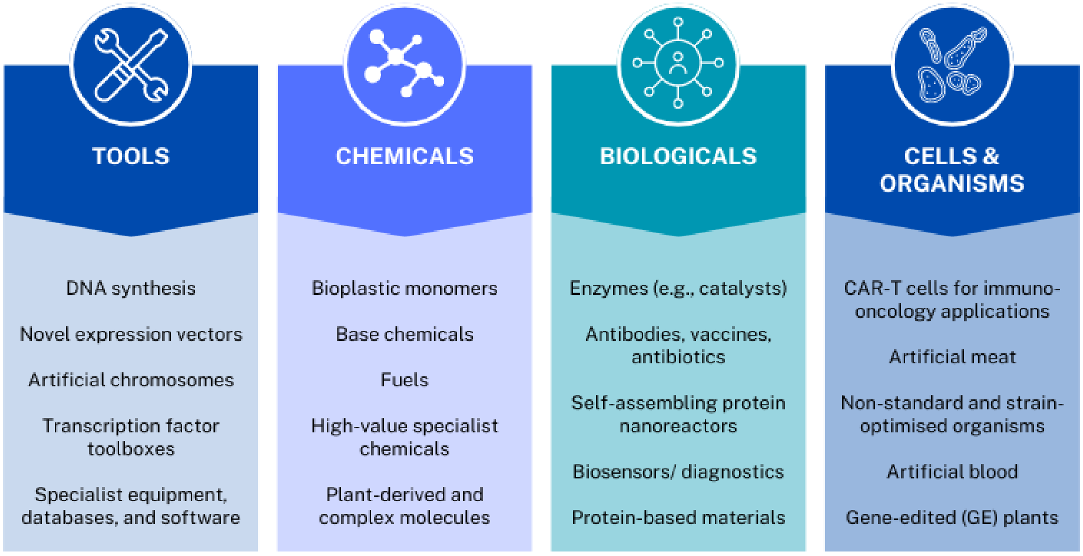


**Figure 1: Types of products and services in synthetic biology-enabled companies as exemplified by SBfG programme activities.**

[39] Synthetic biology – pathways to commercialisation (2019)
[40] Synthetic Biology Start-ups in the UK and Worldwide (Cambridge Consultants, 2016). See here
[41] UK Biotech Financing report 2022. See here

SBfG programme centres and foundries facilitated a broad scope of research that applies to different markets that exhibit varying degrees of technological, regulatory, and scale-up challenges which influences the time to impact. This is visualised in Figure 2, below, where we have described four principal markets where SBfG programme technologies have demonstrated impacts and applications.

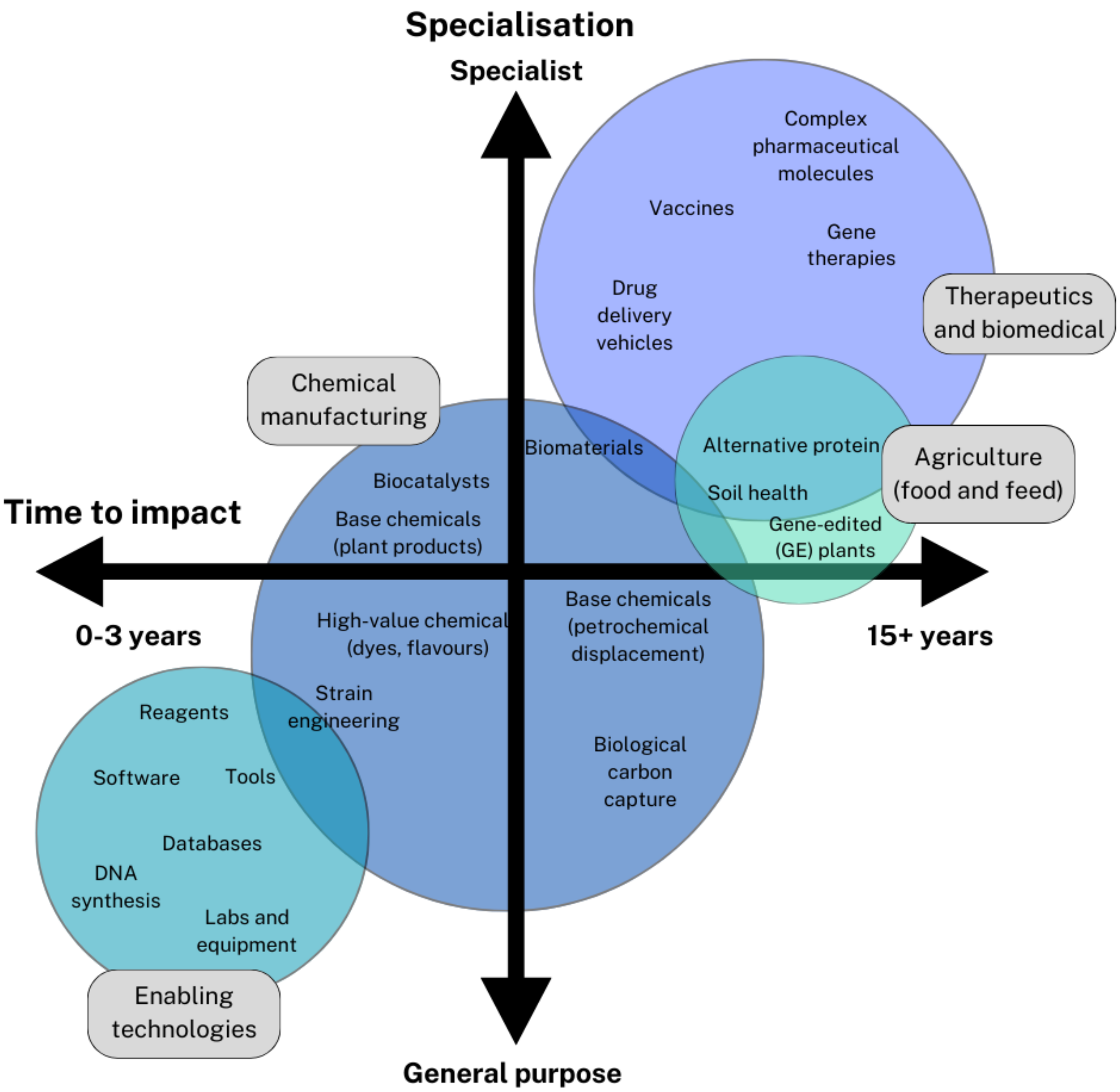


**Figure 2: Synthetic biology technology applications across specialisations and their time to impact (SBfG programme technologies).**

### 2.2.2 Enabling technologies: life sciences tools

Synthetic biology, as an applied science, leverages Design–Build–Test–Learn cycles for developing biological components, presenting distinct early market opportunities for each cycle phase. In the Design phase, computer-aided design tools and software are pivotal for pathway modelling and prediction. The Build phase employs DNA synthesis, assembly, sequencing, and the integration of robotics and automation. Testing involves strain and metabolic engineering, often utilising robotics and automation. The Learn phase incorporates artificial intelligence, additional software, databases, and digital cells, which in turn inform and refine the Design tools, thus completing the cycle.

The market for synthetic biology tools illustrates the early adoption of technological progress, with scientific advancements catalysing further market demand. Synthetic biology research characteristically converts discoveries into practical tools and services. The broader life sciences tools market encompasses a diverse array of technologies, instruments, and reagents. These are indispensable in biological and medical research, drug discovery, diagnostics, and related fields. Collectively, these enabling technologies and services are fundamental to the advancement of research across scientific disciplines.

The global market size for life sciences tools was estimated at $144.9 billion (£114.5 billion) in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 10.8% from 2023 to 2030[42]. Internationally, the largest life sciences tools companies include ThermoFisher, Danaher, and Illumina. In addition, many international companies operate on a ‘synbio as a service’ business model, for example Ginkgo Bioworks, ATUM/DNA2.0, Microsoft Station B, Twist Biosciences, and Molecular Assemblies.

In the UK, there are over 944 companies active in the engineering biology supply chain with a total turnover of £54.6 million and 67,000 employees [43] (N.B., for most of these companies, synthetic/engineering biology will only be a part of their business activities). This includes companies such as Deepmind Technologies, Oxford Instruments, Lonza Biologics, Oxford Nanopore, Touchlight Genetics, LabGenius, and Ingenza. Figure 3 provides some examples of how the SBfG programme has impacted the enabling technologies sector.

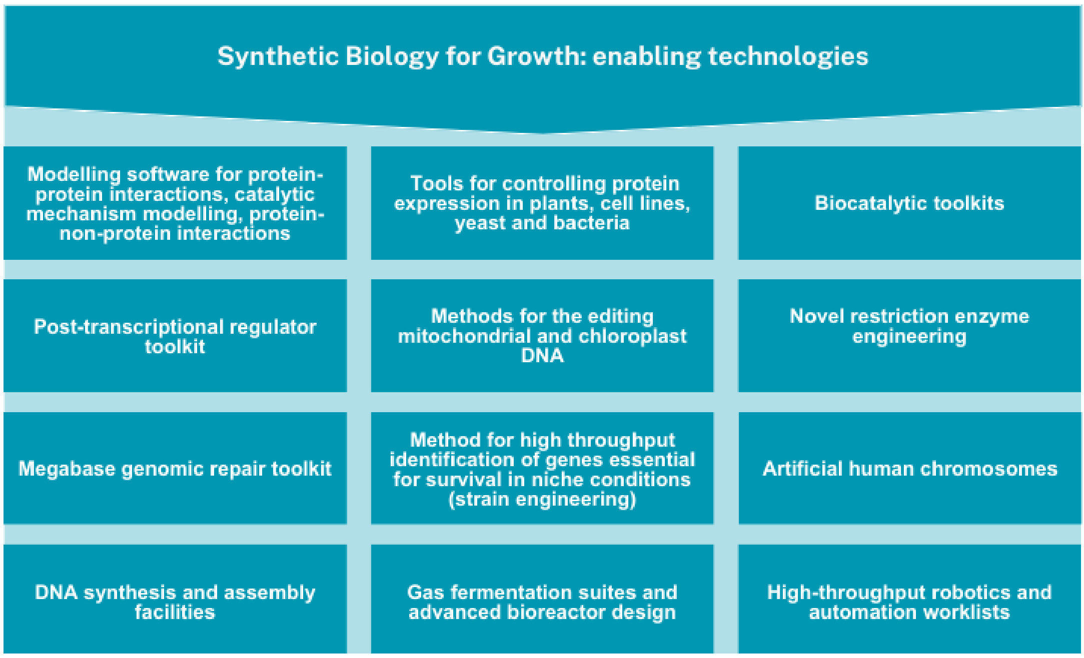


**Figure 3: Examples of SBfG programme projects in the enabling technologies sector.**

42 Life Science Tools Market Size, Share & Trends Analysis Report (Grand View Research, 2023)

43 Database: The Data City

Several of these technologies are being commercialised through early-stage companies that have been supported by the SBfG programme, as illustrated in Figure 4, and further described in Sections 3.3 and 4. Examples of such companies are provided as case studies in Appendix F.

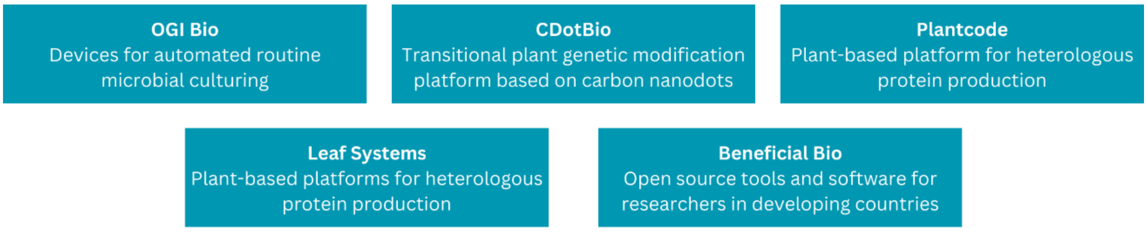


**Figure 4: Early-stage companies supported by the SBfG programme that are active in the enabling technologies markets and their core technology.**

### 2.2.3 Chemical manufacturing

Producing base and polymer chemicals through biological systems is a strategy aimed at replacing petrochemicals in chemical manufacturing for more sustainable supply chains. Living systems are used to process various feedstocks, including waste biomass or gases, to grow and create valuable products, contributing to a future circular economy.

Synthetic biology is driving the next generation of industrial biotechnology by designing biological systems capable of producing chemicals and materials on a large scale. The range of chemicals produced by synthetic biology is growing and includes base chemicals, monomers, fuels, and complex molecules that are challenging to make chemically.

The bio-based chemical production market has seen rapid growth, with engineered biological systems increasingly substituting traditional petrochemical methods. For instance, the current market for bio-based platform chemicals is estimated at $14.5 billion (£11.5 billion) in 2023, with CAGR 6.61%[44], compared to the total global organic chemical market at $53.3 billion (£42.1 billion), growing at CAGR 6.5%[45]. The biofuel market, valued at $91.2 billion (£72.1 billion) and growing at CAGR 11.1%[46], has a significant displacement opportunity in the global fuel oil market that is valued at $172.7 billion (£136.4 billion)[47].

A notable example of bio-based chemical production is the partnership between DuPont and Genencor in 1997 to produce 1,3-propanediol, a key component for polyester, from glucose. This product, Bio-PDO, was commercially scaled in 2006 through a collaboration with Tate & Lyle. The Bio-PDO production is notable for using 40% less energy and cutting greenhouse gas emissions by 20% compared to its petroleum-derived counterpart. Currently, numerous chemical companies are engaged in bio-based chemical production, such as Solugen Inc, Amyris, NatureWorks, Industrial Microbes, and Viridos. Additionally, large fuel companies like Lanzatech and Shell are making strides in bio-based chemicals and fuels.

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[44] Bio-based Platform Chemicals Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029) (Mordor Intelligence, 2023)
[45] Organic Chemicals Market Size, Share, Competitive Landscape and Trend Analysis Report (Allied Market Research, 2023)
[46] Biofuels Market Size, Share & Trends Analysis Report (Grand View Research, 2023)
[47] Global Fuel Oil Market Size Worth USD 276.4 Billion By 2032 (Spherical Insights, 2023)

The UK is home to at least 68 companies that are active in engineering biology applications in chemicals, fuels, materials, and $CO_2$ capture for value-added chemical production with the total turnover of £146.5 million and over 600 employees[48]. This includes companies such as Holiferm (surfactants), Amyris (speciality chemicals), and biocatalyst (enzyme) companies such as Epoch Biodesign, Novozymes, and FabricNano. Figure 5 provides some examples of how the SBfG programme has impacted the chemical manufacturing sector.

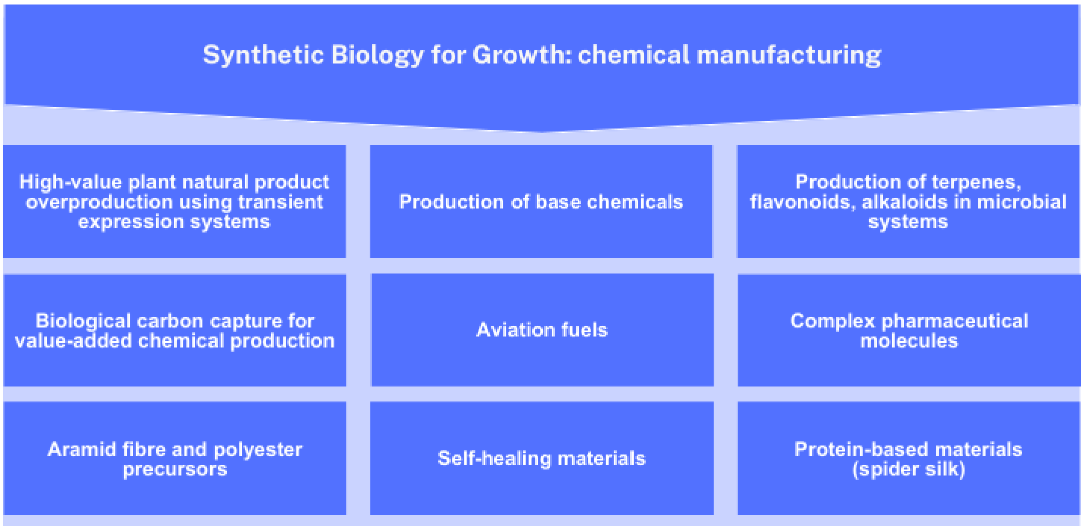


**Figure 5: Examples of SBfG programme projects in the chemical manufacturing sector.**

Examples of early-stage companies that have engaged with SBfG programme centres and are active in the chemical manufacturing markets are listed in Figure 6, and further described in Sections 3.3 and 4. Examples of such companies are provided as case studies in Appendix F.


**Figure 6: Early-stage companies that have engaged with SBfG programme centres and are active in chemical manufacturing markets and their core technology.**

### 2.2.4 Agriculture (food and feed)

Agricultural and food systems, including food and feed, are currently under unprecedented pressure due to the climate crisis, deteriorating soil health, and a burgeoning global population. There is a pressing need for innovation in these industries to satisfy the escalating demand for nutritious and sustainable food and feed. Companies employing synthetic biology are pioneering this space through diverse strategies, such as developing genetically modified plants that boast enhanced nutritional

[48] Database: The Data City

value or resistance to disease, as well as creating alternative proteins including lab-produced milk, eggs, and cultured meat.

Food and feed markets are highly dependent on scalability of their technology to meet market demand. In many cases, this represents a bottleneck for alternative protein's route to market as the existing fermentation and processing techniques need to adapt to facilitate the growth of non-traditional cells, for example, animal muscle cells, at scale. Furthermore, traditionally the GM plant route to market is notoriously long due to lengthy development times for the technology, and also some resistance from the general public and regulators —for instance, the case of golden rice that has been in development for over 20 years and is not yet available commercially. Some authorities, notably the European Union, currently have very strict regulations regarding the cultivation of GM plants for field use and human consumption, and the regulations are restrictive for cell-based meat market access. In contrast, Singapore has led the way in granting market access to cultured meat products on a case-by-case basis since 2020, with more such innovations expected to follow suit. However, as described in Section 2.1, in the UK gene-edited approaches are no longer subject to the same regulations as GM approaches and this is expected to accelerate time to market.

The market for alternative proteins is expanding rapidly, with proteins derived from microorganisms exhibiting an extraordinary CAGR of 111%, while the market for proteins based on animal cells is advancing at a CAGR of 66%[49]. The current market valuation for alternative proteins stands at an impressive figure, with forecasts projecting it to reach $290 billion (£229 billion) by 2035. As a comparison, the animal-based protein market is sized at the vast $1.4 trillion (£1.1 trillion)[50], highlighting a substantial commercial opportunity for the replacement of animal-derived products. Further, the market for genetically modified (GM) feed crops was valued at $85 billion (£67 billion) in 2021 and is experiencing steady growth with a CAGR of 5.5%[51].

Some of the major international companies working in plant-based synthetic biology/ agbiotech area include Calyxt (now a part of Cibus group) and Inari. In the alternative protein industry, companies such as Just Inc. (the first regulatory-approved cultured meat product), BioCraft (cultured pet food) and Mosa Meat are spearheading the market. There are over 50 companies in the UK that are active in the engineering biology applications across agriculture (food and feed) applications with a cumulative turnover of over £53.8 million and nearly 6,500 employees[52].

The SBfG programme has facilitated substantial foundational research, paving the way for advancements in food and feed technologies. It has been reported that plant and mammalian synthetic biology development is comparatively slower than that of microbial synthetic biology, owing to the complexity of eukaryotic genomes, the scarcity of standardised methods and tools, and extended development times. Figure 7 provides some examples of how the SBfG programme has impacted the agriculture (food and feed) sector.

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49 Food for Thought: The Protein Transformation (BCG, 2021)
50 Alternative Proteins - A reality check (Deloitte, 2023)
51 Genetically Modified Feed Market (Global Market Insights, 2022)
52 Database: The Data City

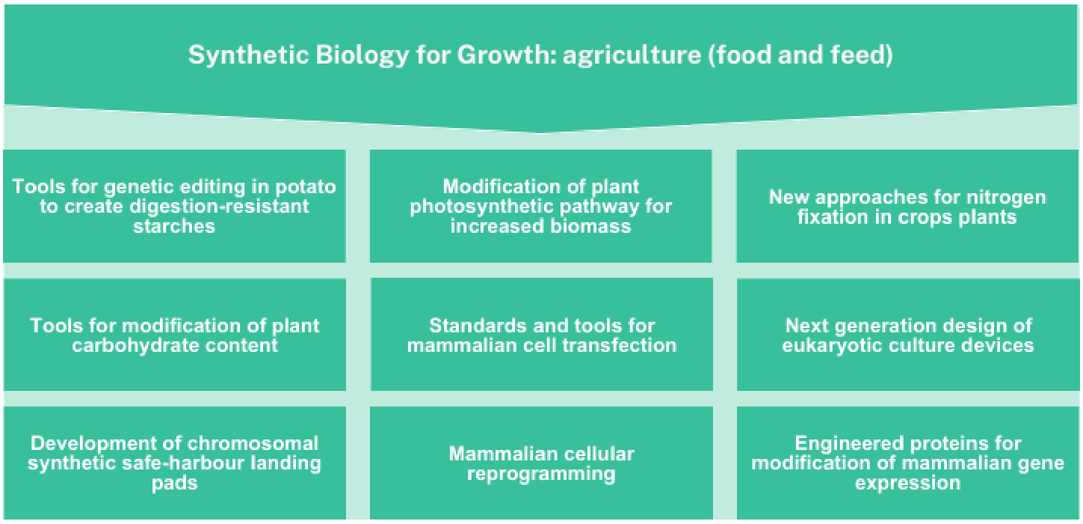


**Figure 7: Examples of SBfG programme projects in the agriculture (food and feed) sector.**

Examples of early-stage companies that have engaged with SBfG programme centres and are active in the agriculture (food and feed) markets are listed in Figure 8, and further described in Sections 3.3 and 4. Examples of such companies are provided as case studies in Appendix F.

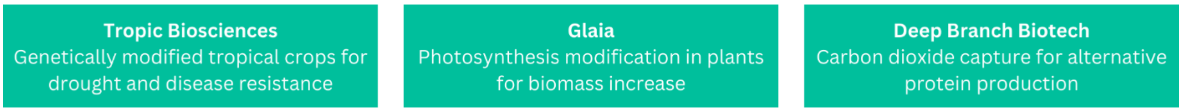


**Figure 8: Early-stage companies that have engaged with SBfG programme centres and are active in agriculture (food and feed) markets and their core technology.**

### 2.2.5 Therapeutics and biomedical

Synthetic biology technologies enable a new era in human health therapeutics, expanding, additionally, into a vast array of biomedical applications, including biosensing and diagnostics. Synthetic biology acts as a suite of tools that enable the customisation of treatments to the genetic and phenotypic profiles of individuals or diseases. This personalisation enhances efficacy while reducing unintended effects. Precision medicine, like disease gene editing, engineered immune cells for cancer treatment (such as CAR-T), and novel cell therapies for degenerative diseases previously thought incurable, are among the advancements in this field. Engineered cells and tissues, mimicking entire organs, may also reduce the reliance on animal testing in health research.

Therapeutic applications of synthetic biology are not limited to mammalian cells; it's also used to craft live therapeutics or diagnostics from bacterial cells, as well as engineered proteins and nucleic acids. Multi-protein structures, like viral capsids for vaccines, and novel biological structures for drug delivery, represent such innovations. Synthetic antibodies and bespoke artificial proteins further illustrate synthetic biology's utility in diagnostics and research, potentially reducing animal testing. Additionally, synthetic biology facilitates the discovery and production of complex pharmaceutical molecules beyond the scope of traditional chemical synthesis, including macrolide antibiotics.

Synthetic biology has a major commercial opportunity across large segments of human health markets, and due to the ageing population, this opportunity continues to expand. For example, the value of personalised medicine was estimated at $539 billion (£426 billion) in 2022, with CAGR of 7.2%[53]; diagnostic testing at $165.6 billion (£130.8 billion) in 2021, with a CAGR of 8.6%[54]; vaccines at $124 billion (£98 billion) in 2022, with a CAGR of 1.4%[55]; gene therapy at $7.54 billion (£5.96 billion) in 2022, with a CAGR of 19.1%[56] ; and cell therapy at $4.77 billion (£3.76 billion) in 2022, with a CAGR of 16.5%[57]. Pharmaceutical manufacturing was valued at $516.5 billion (£408.0 billion) in 2022, with a CAGR of 7.63%[58]. Synthetic biology tools have applications in the field of biomaterial design and production that are worth $155 billion (£122 billion), CAGR of 15.5% [59].

Most major pharmaceutical companies are actively developing biotherapeutic pipelines. Novartis, for instance, is progressing with its CAR-T immuno-oncology programme. The versatility of synthetic biology was evident in the rapid development of COVID-19 vaccines, such as AstraZeneca's traditional protein-based vaccine and the pioneering RNA vaccines from Pfizer-BioNTech and Moderna. Some enterprises specialise in providing synthetic biology services to large pharmaceutical companies, like the collaboration between Roche and Synlogic to develop an innovative therapeutic for inflammatory bowel disease. Others, such as Sherlock Biosciences, leverage synthetic biology for bespoke diagnostic solutions. The UK fosters a rapidly expanding landscape of synthetic biology-enabled companies operating in the markets of human health and its enabling activities, including, for example, Immunocore (£179 million turnover) and MeiraGTx (£61.9 million turnover). Further innovative companies in this area include Nanosyrinx (intracellular drug delivery), Artios (oncology drug development platform) and Quell Therapeutics (immuno-oncology cell therapy). According to the Data City, the UK hosts over 1400 companies in the biopharmaceutical sector with over 67,700 employees. More specifically, 774 companies are active in engineering biology across health & life sciences applications, with an annual turnover of over £43.7 million and approximately 114,495 employees[60].

The SBfG programme had a significant contribution to this market segment, as illustrated by collaboration with medium and big pharmaceutical companies and therapy developers. Figure 9 provides some examples of how the SBfG programme has impacted the therapeutics and biomedical sectors.

53 Personalized Medicine Market Size, Share & Trends Analysis Report (Grand View Research, 2023)
54 Diagnostic Testing Market (Precedence Research, 2023)
55 Vaccine Market Size, Share & Trends Analysis Report (Grand View Research, 2023)
56 Gene Therapy Market Size, Share & Trend Analysis Report (Grand View Research, 2023)
57 Cell Therapy Market Size, Share & Trends Analysis Report (Grand View Research, 2023)
58 Pharmaceutical Manufacturing Market Size, Share & Trends Analysis Report (Grand View Research, 2023)
59 Biomaterials Market Size, Share & Trends Analysis Report (Grand View Research, 2023)
60 There is a considerable overlap with the enabling technology market segment.

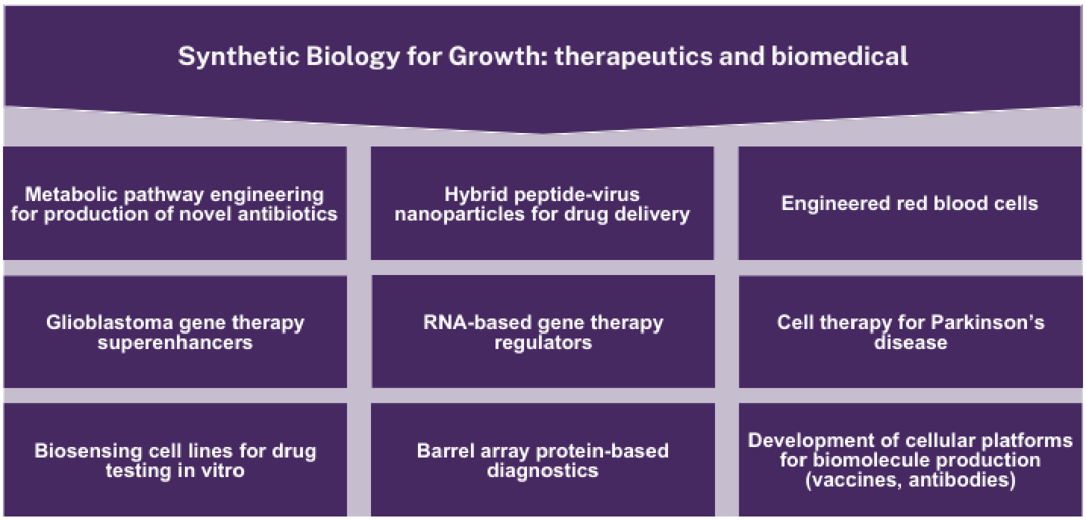


**Figure 9: Examples of SBfG programme projects in the therapeutic and biomedical sectors.**

Examples of early-stage companies that have engaged with SBfG programme centres and are active in the therapeutic and biomedical markets are listed in Figure 10, and further described in Sections 3.3 and 4. Examples of such companies are provided as case studies in Appendix F.

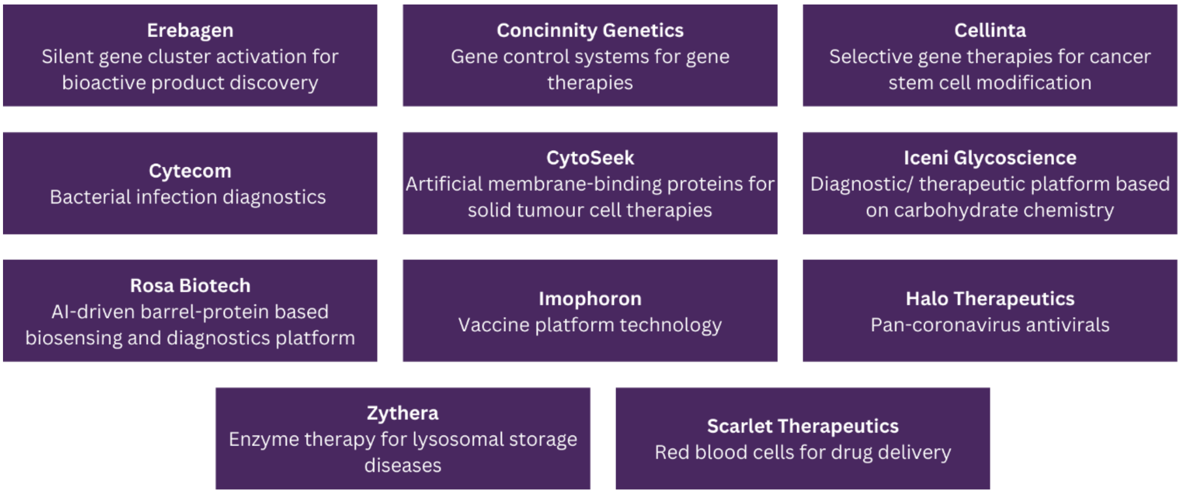


**Figure 10: Early-stage companies that have engaged with SBfG programme centres and are active in therapeutic and biomedical markets and their core technology.**

# 3 Analysis of reporting data from SBfG programme funding recipients

In this section we provide an analysis of the inputs, outputs and impacts of the SBfG programme, based on UKRI data made available to the study team. This analysis formed the foundation for engagement with SBfG programme funding recipients (Section 4) and external stakeholders that engaged with SBfG programme funding recipients (Section 5). Several data sources[61] were made available, of which the most relevant were:

- funding received by synthetic biology research centres (SBRCs), foundries and centres for doctoral training (CDTs)
- collaborations and partnerships undertaken by SBRCs, foundries and CDTs
- spinouts (that were formed to exploit research output from SBRCs)
- next destinations of individuals involved in each of the SBRCs

Analysis of the data identified that there was significant information available for the six SBRCs and some for the Foundries, but there was no additional information for the CDTs, apart from details of the initial funding and the number of doctoral students trained. This information is summarised below.

## 3.1 Funding

In total the six SBRCs, six foundries/centres for DNA synthesis and DNA construct capability and two CDTs received just over £103.5 million in funding from the SBfG programme. This includes extension funding for the SBRCs and additional funding to several of the foundries (Table 4).

[61] An analysis of publications arising from the SBfG programme was not required of this study, as it will be analysed separately by BBSRC . However, 1,295 unique publications were recorded as arising from the SBfG SBRC and Foundry investments in researchfish.. A limited analysis of publications was performed as part of the Economic Impact Assessment, and this is described in Appendix G.

| Award | Initial Grant Funding (£k) | Extension Funding[1](£k) | Total Awarded (£k) |
|---|---|---|---|
| BrisSynBio | 13,528 | 2,218 | 15,746 |
| OpenPlant | 11,788 | 2,223 | 14,011 |
| Nottingham | 14,243 | 3,054 | 17,297 |
| SynBioChem | 10,199 | 1,808 | 12,007 |
| SynthSys | 11,380 | 1,178 | 12,558 |
| WISB | 10,522 | 1,899 | 12,421 |
| Earlham Biofoundry | 1,903 | | 1,903 |
| Edinburgh Foundry | 2,000 | | 2,000 |
| GeneMill | 1,702 | | 1,702 |
| London DNA Foundry (two awards) | 3,366 | | 3,366 |
| SynBio at Cambridge | 1,970 | | 1,970 |
| Next Gen DNA Synthesis | 2,219 | | 2,219 |
| Edinburgh Foundry & Cambridge | 2,376 | | 2,376 |
| Edinburgh Foundry & GeneMill | 1,993 | | 1,993 |
| CDT Bioprocess Engineering[2] | 1,000 | | |
| SynBio CDT[2] | 977 | | |
| **TOTAL** | **91,166** | **12,381** | **103,546** |

**Table 4: Funding awarded through the SBfG programme (data from BBSRC)[62].**

[1] Two tranches of extension funding were awarded in March 2020 (£8.8m) and September 2021 (£3.6m).
[2] for the CDTs, only capital equipment funding is listed. Significant additional operational funding was received from other sources.

The SBRCs and foundries also reported additional funding secured from other sources. These other sources included: other UKRI programmes, charitable / not-for-profit organisations, industry, and EU programmes. In total, additional funding to the SBRCs amounted to over twice the initial funding, indicating significant leverage (Table 5).

[62] £10 million was allocated to the Rainbow Seed Fund (now the UK Innovation and Science Seed Fund) to invest in early-stage synthetic biology companies. This has been independently assessed and therefore is not considered in this study.

| Award | SBfG Programme Funding (£k) | Additional Funding[1] (£k) | Uplift[2] |
|---|---|---|---|
| BrisSynBio | 15,746 | 90,431 | 574% |
| OpenPlant | 14,011 | 21,694 | 155% |
| Nottingham | 17,297 | 10,263 | 59% |
| SynBioChem | 12,007 | 37,155 | 309% |
| SynthSys | 12,558 | 10,661 | 85% |
| WISB | 12,421 | 25,690 | 207% |
| **TOTAL** | **84,040** | **195,894** | **233%** |

**Table 5: Additional funding secured by SBRCs (data from Researchfish)[63].**

[1] Additional funding was reported through Researchfish.
[2] Uplift is based on additional funding as a percentage of SBfG programme funding.
Data for the foundries was incomplete and is not shown.

## 3.2 Collaborations and partnerships

Collaboration and partnership data was only reported by the SBRCs and is summarised below. It should be noted that this dataset is based on numbers reported to BBSRC through interim and final reports, as well as Researchfish. They should be considered conservative estimates, as it is clear, from interviews, that some centres (for example, BrisSynBio, London DNA Foundry, SynBioChem and WISB) had additional contacts, particularly in academia, that were not reported. Appendix D provides a full list of identified partners and collaborators of SBfG programme funded centres.

| SBRC | Academic Collaboration (total) | Academic Collaboration (international) | Industry Collaboration |
|---|---|---|---|
| BrisSynBio | 12 | 7 | 22 |
| OpenPlant | 107 | 77 | 29 |
| Nottingham | 57 | 36 | 59 |
| SynBioChem | Not specified | 65 | 26 |
| SynthSys | 39 | 30 | 20 |
| WISB | Not specified | 11 | 19 |

**Table 6: Collaborations and partnerships between SBRCs and academic institutions and companies (data from Researchfish and centre reports that identifies discrete organisations).** Note: Precise numbers for UK academic collaborations were not available so the total figure provided is a lower-end estimate.

[63] Funding data from Researchfish was used as this allowed duplicated funding data to be removed more easily, e.g., where reported amounts included funding for more than one centre

## 3.3 Spinouts and startups

For this report, we define spinouts and startups as follows:

- Spinout - a private incorporated company/entity created by one or more academics or research staff (where the academic institution retains partial/full ownership of the intellectual property, IP) with the aim of commercialising research that was originally supported through the SBfG programme
- Startup - a private incorporated company/entity created for-profit or a social-purpose, that originated independently of the SBfG programme. This may be as a result of collaboration between academia and industry; however, the academic institution does not necessarily retain any ownership of the IP

In total, the six SBRCs engaged with 47 spinouts and startups as shown in Figure 11.

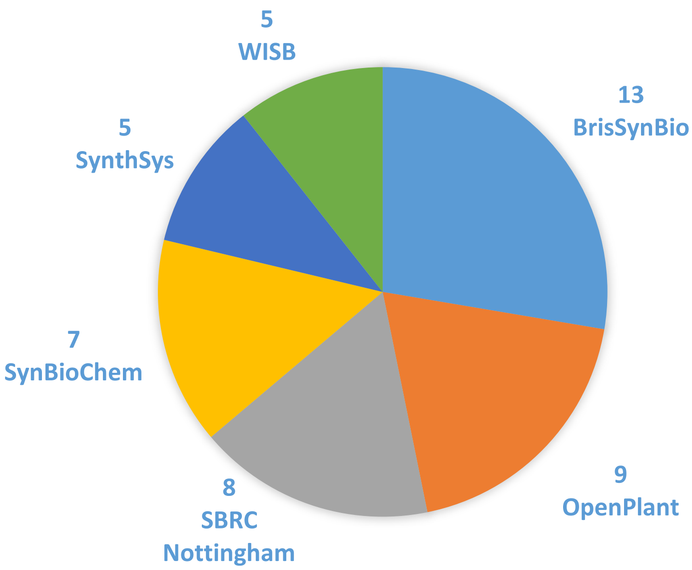


**Figure 11: Spinouts and startups supported by different SBRCs (data from Researchfish and centre reports).**

This engagement did not include direct funding of spinouts and startups from the SBfG programme. Instead, it variously:

- led to the formation of new spinout companies to exploit the results of research funded in the SBRC by the SBfG programme
- gave spinouts and other early-stage (startup) companies, that originated independently of the SBfG programme, access to research expertise and facilities within the SBRCs at commercial rates to progress their technologies
- gave early-stage companies access to early career researchers (ECR), including PhD students, that both assisted in that company's development and provided useful training and experience to the individual ECR

Analysis of the impacts accrued to early-stage companies is described in Section 6 and Appendix G.

Synthetic biology is a platform technology, potentially impacting numerous market sectors. However, it is still relatively nascent and, as such, the companies have been classified into one of four broad sectors. It should be noted that there is overlap between these sectors (see Section 2.2, Figure 2):

- Enabling technologies – including reagents, nucleic acid synthesis, tools, software, databases and equipment to support and deliver synthetic biology
- Chemical manufacturing – including feedstocks for other processes, biofuels, high value chemicals, biomaterials and biocatalysts
- Therapeutics & biomedical – including biopharmaceuticals, vaccines, drug delivery systems and cell and gene therapies
- Agriculture, food & feed – including gene-edited plants, alternative proteins and nutrients

This broadly aligns with the classification of UK engineering biology companies defined by the UK BioIndustry Association (BIA) and the UK Department of International Trade (DIT) in 2022[64]. An analysis of the activities of the startups and spinouts that were engaged with the SBfG programme indicates that most are developing therapeutics, or products or services for enabling technologies (Figure 12).

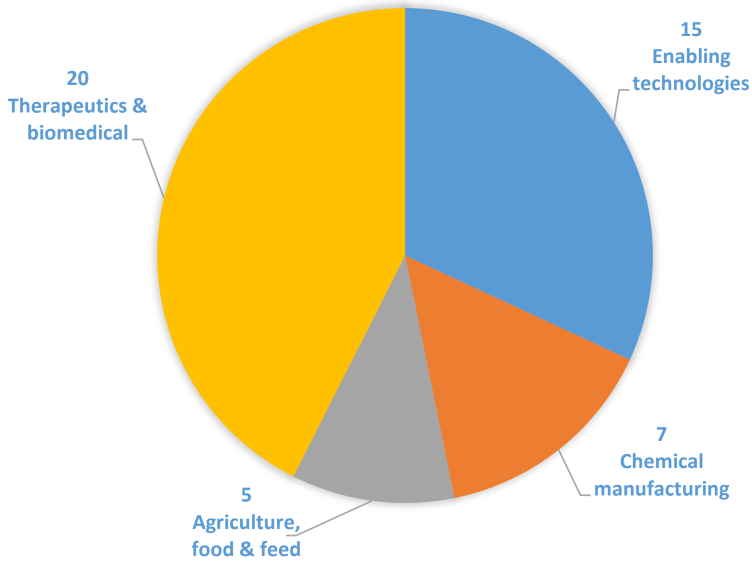


**Figure 12 : Sector activities of spinouts and startups (classification based on review of company information in the public domain, supplemented with company interviews).**

To date, of the 47 spinouts and startups, four have been dissolved. Based on available information (reported in Researchfish, end of award reports or from company interviews), forty companies have collectively raised just over £79 million in additional funding and investment and employ over 250 people. It should be noted that investment data was not available for the other seven companies (including three of the companies that have been dissolved).

64 Power of Biology: Directory of UK engineering biology companies (BIA & DTI, 2022)

## 3.4 Next destinations

Researchfish data on destinations of staff and research students during and following the end of awards was provided by the six SBRCs (only partial data was available for the foundries so these are not included). In total, data for 178 individuals across seven different roles was provided, the majority of whom were postdoctoral researchers (Figure 13). Information on next destinations of graduates from the CDTs is provided in Section 4.3.

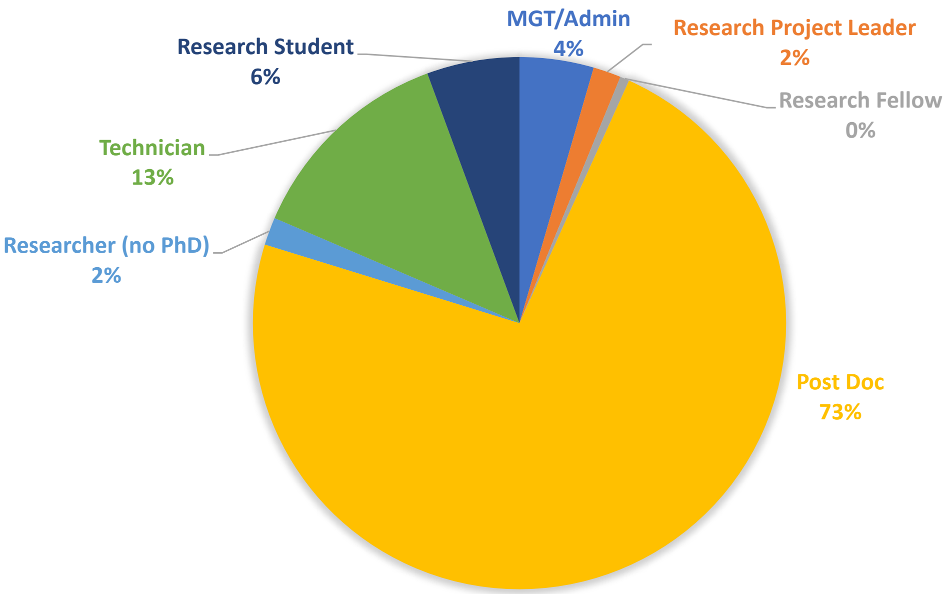


**Figure 13: Breakdown of roles of individuals funded by the SBfG programme in the SBRCs (data from Researchfish).**

104 of these individuals remained in academia following their SBfG programme funded posts, with 60 entering companies and 14 entering other organisations (for example, not-for-profit and public organisations). A total of 133 (75%) remained in the UK ( Figure 14). There were 16 other country destinations including: the US (9), Germany (6), and China (4).

Figure 15 provides further information of the destination of individuals in different roles within the SBfG programme.

The vast majority (86%) of these individuals remained in active research roles following their SBfG programme funded positions.

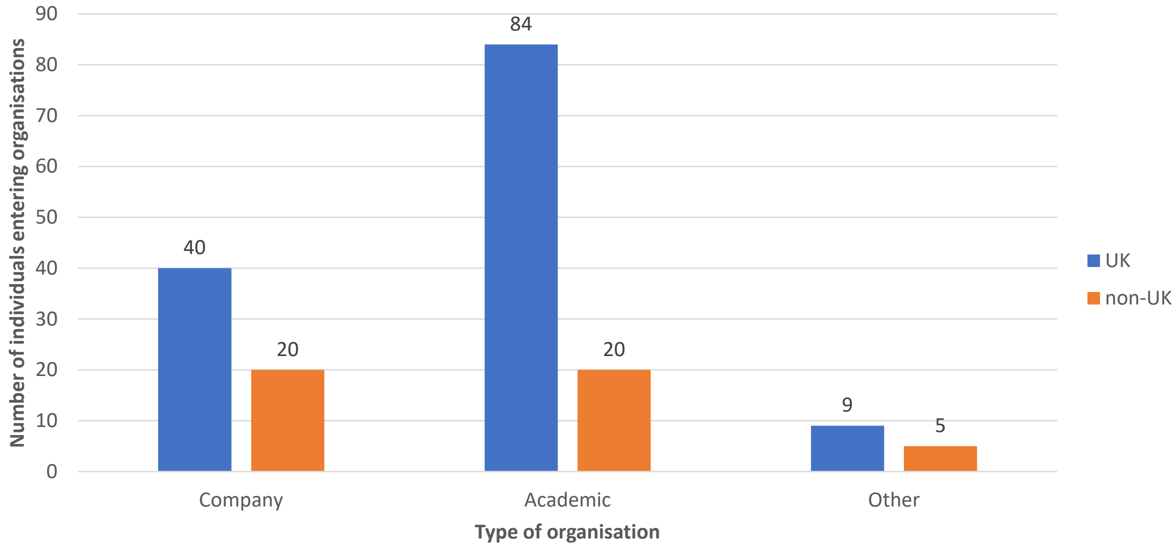


**Figure 14: Destinations of staff and students from the six SBRCs following SBfG programme funding (data from Researchfish).**

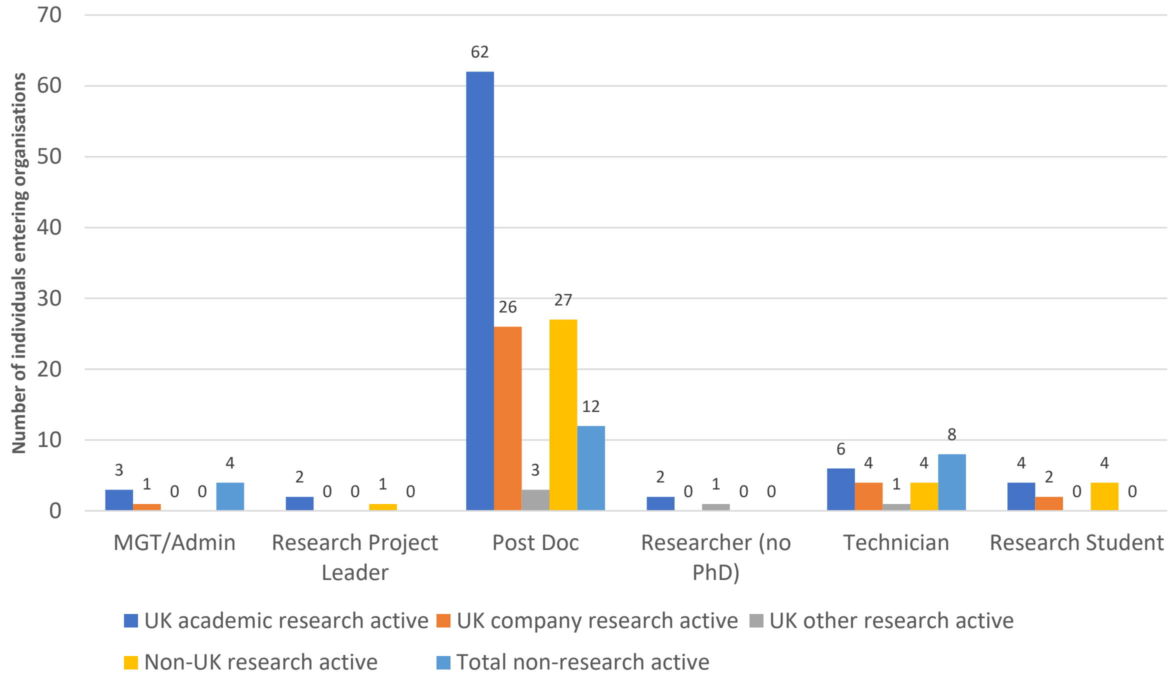


**Figure 15: Destinations of staff and students by role from the six SBRCs following SBfG programme funding (data from Researchfish).**

Partial data (from information shared during interviews) was available for the destinations of graduates from the CDT programmes indicating that most entered industry (75 to 80% of graduates from the CDT in Bioprocess Engineering Leadership and 40% from the Synthetic Biology CDT). Most of the remainder pursue careers in academic research, with some joining public or not-for-profit research organisations. The majority of these individuals remain in the UK (~80% from the CDT in Bioprocess Engineering Leadership and 87.5% from the Synthetic Biology CDT). More details are provided in Section 4.3.

# 4 Interview programme with SBfG programme funding recipients

The purpose of the interview programme with SBfG programme funding recipients was to:

- make initial connections with each of the SBRCs, foundries and CDTs
- obtain qualitative views on the SBfG programme
- determine what additional information centres would be able to provide, including contacts for company and academic partners, that could be followed up in subsequent external consultations

Representatives from every SBfG programme funded centre (22 individuals in total) were interviewed. Appendix A provides full details of these individuals and the discussion topics. The following areas were discussed:

- experience of the programme
- impacts as a result of funding
- training and professional development
- challenges, barriers or issues
- opinion of the synthetic biology landscape in the UK

## 4.1 Experience of the programme

The majority of SBRC, foundry and CDT leads considered the SBfG programme to be highly valuable and world-leading, particularly following on from the original 2012 Roadmap for Synthetic Biology. It came at an opportune time when the field was first developing at scale, and its standing was such that many of those interviewed indicated that stakeholders from other countries came to the UK to learn and understand how they could implement similar programmes in their own countries. For several of the centre leads, it also raised their international profile, contributing to new research partnerships.

Recipients of SBfG programme funding indicated that the breadth of platforms supported by the programme was also groundbreaking – leading to capabilities in microbial, plant and mammalian synthetic biology, including gas fermentation, developing mammalian cell systems and plants as molecular factories, and in protein design. This was considered world class and strongly supported by the interdisciplinary nature of those facilities that received funding. There was also strong evidence that the CDTs provided the 'glue' for a range of different collaborative activities between centres, and between centres and external, mainly industrial, stakeholders. Recipients of funding believe that the programme changed the focus of academics in the field from prioritising high-impact publications to delivering impact to the UK economy.

As a result, many interviewees reported significant additional funding secured, new strategic partnerships with industry and/or other academic institutions, and support for a wide range of spinouts and startups. This has included longer-term collaborations between centres and multinational companies such as AkzoNobel, Fujifilm Diosynth Biotechnologies, GSK and Oracle, as well as partnerships with globally renowned research institutions such as the Max Planck Society in Germany.

Many are now pro-actively seeking industry engagement and have employed staff within the SBRC or foundry that are dedicated to this purpose.

In most cases, there was clear evidence of collaboration between different centres, for example, all foundries became part of the Global Biofoundries Alliance[65], an initiative established by a group of founding members, including Edinburgh Genome Foundry, Earlham Institute, London DNA Foundry, SynBioChem Manchester and Liverpool GeneMill, to improve communication and collaboration between commercial and non-commercial biofoundries for the purpose of addressing common technical and operational challenges. Others collaborated on joint grant applications, including bids to the recent UKRI Engineering Biology Mission Hubs and Mission Awards call. There was also evidence of staff moving between centres and of companies engaging across multiple centres. The programme has also contributed to the development of the wider community including the Biochemical Society's annual Synthetic Biology UK conference[66] and the student-run SynBioUK[67]. These initiatives and other outcomes from the SBfG programme (as highlighted throughout this report) clearly demonstrate the UK's thought leadership, and this has been recognised by others in the international community, for example, Woodrow Wilson Centre[68]and SynBioBeta[69].

The vast majority of those interviewed stated that without SBfG programme funding they would not have been able to develop the capabilities that they have now. Furthermore, they believe that without the funding the UK, as a whole, would have lost its leading global position.

## 4.2 Impacts as a result of funding

The SBfG programme enabled researchers to engage with many different stakeholders, including industry, policymakers, the international research community and the wider public. The SBRCs, in particular, were able to effectively engage across multiple disciplines within their organisations and were able, in many cases, to develop new 'internal' projects as a result of these interactions. The approach benefited from the fact that postdoctoral researchers were involved in multiple, different principal investigator (PI)-led projects, thus broadening individual researcher experience as well as strengthening cross-cutting collaborative opportunities. In three cases (Bristol, Edinburgh and Manchester), this contributed to the university's senior management adopting synthetic biology as a strategic institutional priority.

In some cases, the engagement with external stakeholders was informal – for example, via serendipitous discussions at meetings, invitations to external stakeholders to visit centres, conversations around potential research activities, etc. However, the resource available in the SBRCs meant that these could be explored further through structured visits and discussions, planning joint research grant applications and delivering initial, smaller, exploratory pieces of work that could be followed up with larger ones for different partners.

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65 https://www.biofoundries.org/
66 https://www.biochemistry.org/about-us/resources-and-videos/packages/synthetic-biology/
67 https://www.synbiouk.org/
68 Tracking the Growth of Synthetic Biology: Findings for 2013 (The Wilson Centre, 2013)
69 https://www.synbiobeta.com/read/uk-synthetic-biology-basic-research-moving-towards-commercialization

All SBRCs also undertook significant public engagement and science communication activities through centre-led and institutional activities (for example, open days, public debates, science cafes and science fairs), and many also participated in Science Art Writing (SAW)[70], an initiative that was started in 2005. SAW works with young people, teachers and scientists to support greater understanding of, and engagement with, science by wider society. In some cases, researchers produced animations, artworks, poetry, plays and even stand-up comedy to present and discuss their science in new ways with wider society. Many were also interviewed for national and local TV and radio. By taking a broad approach to how this engagement and dialogue with the wider public was delivered, researchers were able to raise awareness of synthetic biology with the wider public in terms of how it can benefit society and the economy, as well as highlighting potential careers for younger people. Members of the public reported that their opinion and views regarding synthetic biology had changed as a result, for example, they were more interested in how synthetic biology could solve some of society's challenges, and in pursuing academic studies that would allow them to get involved in synthetic biology research. Many of the scientists that were involved became more interested and willing to engage with the wider public. In many cases this led to ongoing engagement between centre scientists and different societal groups.

In addition to public engagement and science communication, SBRC scientists also supported UK government policy, including participation in expert working groups (industry and/or government-led) and in presentations to the UK's Parliamentary Science Committee. These had various outcomes, including advice to Government Ministers, inputs to national policy and regulatory guidelines (such as developing the framework for the Engineering Biology Leadership Council, consultations on emerging issues such as artificial intelligence, ethics and environment), and training recommendations (such as contributing to BSI standards for responsible research and innovation). Ultimately these will have supported the UK's synthetic biology community to deliver socioeconomic impacts. Some of these activities also fed into the policies of international organisations and governments in other countries (e.g., contribution to EU policy on potential risks associated with synthetic biology, and establishment of an international network of biofoundries). Several of those interviewed indicated that policy makers and research leaders from elsewhere in the world came to their centres to understand how the UK was delivering its synthetic biology strategy, with the view of replicating the approach in their own countries. This truly exemplified the international reach and influence of UK science and opinion in synthetic biology, and led to research partnerships between the SBRCs and institutions in other countries.

For the foundries, the funding enabled significant new capabilities. Although most of this supported research within the host institution, there were also good examples of external academic and company access, in particular for spinouts and startups. In the case of Earlham and Edinburgh, the foundries are now seen as part of the wider institutional strategy and as such receive core institutional funding, which has helped maintain activity. For the London DNA Foundry, there has been significant support for companies based at SynbiCITE[71].

70 https://sawtrust.org/

71 SynbiCITE is the UK's national centre for the commercialisation of synthetic biology

The CDTs were seen as delivering significant impact for both the host institutions and industry partners, and this is discussed in the next section.

Overall, the long duration of funding (for the SBRCs) enabled an extended relationship to be built with external collaborators, many based on initial connections with individual researchers, that later developed into more comprehensive networks where, for example, multiple researchers across different thematic areas engaged with one or more company representatives. The nature of the funding allowed a degree of flexibility enabling each centre to respond to new opportunities, for example staff exchanges, establishing strategic partnerships with other institutions, investigating new research opportunities with multiple industry and academic partners or providing small amounts of 'seed' funding to its researchers through mini competitions to explore new ideas. This was enriched by the diversity of disciplines and individuals within each SBRC and, in many cases, this was extended through collaborations across SBRCs, for example, Bristol and Warwick, Manchester and OpenPlant, Edinburgh and Manchester. As a result, the funding leveraged far more than was originally invested. The qualitative impacts resulting from this (to industry and other partners) are described in Section 5, while the economic impacts are described further in Section 6.

Further evidence of the cohesiveness of the community is demonstrated by the fact, as already highlighted, that many collaborated on joint bids to the recent Engineering Biology Mission Hubs and Mission Awards call.

## 4.3 Training and professional development

Although the two CDTs were the main formal route to train the next generation of synthetic biologists, all of the funded centres supported PhD studentships and early career researcher (ECR) development through a range of mechanisms. In many cases this went beyond practical lab and technical skills and extended to entrepreneurial, business, leadership and public engagement skills. SynbiCITE's LEAP programme and four-day MBA were pursued by researchers at Bristol and Edinburgh, for example, as well as at Imperial, SynbiCITE's host university. In Bristol, there was evidence of students spending part of their time in startups engaged with the centre – something that benefited both the company and the students.

The CDTs trained 139 doctoral students and partnered with companies in a variety of sectors including biotechnology, pharma and instrumentation. All students of the CDT in Bioprocess Engineering Leadership had training on pilot scale facilities that UCL purchased using a capital grant funding opportunity in 2014. Around 75-80% of these graduates entered industry: 42% into industrial process R&D, 20% into design and consultancy companies, 13% into spinout companies, and 5% into business development. A further 16% remained in academic research pursuing careers that are relevant to the bioindustry sector. Some of the spinouts resulted from CDT students' thesis work, or were supported by students during their training, including some that resulted from iGEM[72] competitions (where undergraduate students were mentored by CDT students). The remaining Bioprocess Engineering

[72] iGEM is an independent, non-profit organisation that is dedicated to the advancement of synthetic biology, education and competition, and the development of an open, collaborative, and cooperative community. It holds an annual competition for young scientists and engineers. See: https://igem.org/

Leadership CDT graduates remained in academic research (16%) or went on to other careers (4%). The majority (~80%) of these graduates remain in the UK.

The Synthetic Biology CDT was perceived as a global first, as before it there were no other training programmes on synthetic biology in any other country that benefited from expertise across multiple partnering institutions. This has been recognised by both startups and established companies which are increasingly engaging with the Synthetic Biology CDT as they value the skillsets offered. In terms of destinations, around 40% of graduates go to work in industry, 12.5% go abroad and at least 4 (5%) have started their own companies. Most of the remainder remain in academia, with some joining public or not-for-profit research organisations.

Across all SBRCs that were interviewed there was a sense that PhD graduates and ECRs were more likely to be interested in pursuing a career via a spinout or startup than remaining in academia. While this demonstrates the practical and industrial nature of the environment that individuals have been exposed to and is encouraging for the talent pipeline into industry (in addition to those progressing from CDTs), it raises some concerns regarding the availability of people with interdisciplinary skills to feed into academic research.

In Edinburgh, three modern apprentices were hired, thus supporting the technician pipeline. Although they did not remain within the SBRC, one left to work in industry, as a direct result of the training received through the SBfG programme.

## 4.4 Challenges, barriers or issues

The main issues reported by all SBRC, Foundry and CDT staff interviewed were the uncertainty regarding the future direction of UK government support for synthetic biology research, and a reduction in the overall level of UKRI funding available for synthetic biology research following the end of the first tranche of SBfG programme funding. There was a sense from interviewees that the original UK strategy for synthetic biology research was linked too closely to parliamentary terms rather than having a much longer horizon, which is necessary to fully exploit the significant investment in equipment, infrastructure and people to realise socioeconomic impacts.

UKRI and the Defence Science and Technology Laboratory (Dstl) provided £20.6 million additional targeted funding[73] for engineering biology between the end of the first tranche of SBfG funding and the start of the UKRI Engineering Biology Hubs and Mission Awards calls. However, SBfG programme recipients believed that the overall level of UKRI funding was not sufficient, and this exacerbated the situation regarding the UK's long-term strategy for synthetic biology. Many staff on short-term contracts left and tenured staff were unclear as to the future direction and strategy of the UK's synthetic biology programme. Most stated that the UKRI Engineering Biology call needed to have been in place two to four years earlier, although all recognised the disruption that the COVID-19 pandemic caused. Centre leads reported that there were no alternative funds that could maintain the variety and breadth of their research activities. Many submitted bids for, and won, strategic Longer and Larger (sLoLa) awards, but these were of far lower value and difficult to reconcile with the operating costs of

[73] https://www.ukri.org/news/uk-engineering-biology-receives-20-6-million-funding-boost/

centres. OpenPlant suffered in particular and the centre level collaboration between Cambridge and John Innes Centre has largely ended, although individual partnerships remain. As a result, most of these centres are operating with fewer people and significant expertise and experience has been dispersed from the centres into the broader synthetic biology community. This may be good for the wider community but potentially leads to centres operating sub-optimally in terms of capacity, capability and expertise, which can be time-consuming and expensive to redress.

It should be noted that this sentiment is not specific to synthetic biology. Feedback from academics active in other disciplines is very similar. Feedback from the community, supported by a review of available literature, indicates that other countries address these issues through a variety of means. For example, providing longer-term core funding to individuals or centres as is the case in the US and the Fraunhofer in Germany, which provides the foundation on which other research can be built.

Wider industry, however, has been a beneficiary of this. Several centres reported that staff were attracted to industry, not just because of higher salaries, but also by the offer of permanent contracts. Others were attracted to positions outside the UK. In some cases, such staff had received thousands of pounds worth of training on expensive equipment, that the institution could not afford to pay for again – meaning, at best, that equipment becomes used less, and at worst not at all.

To counteract this issue, several centres (for example, Bristol, Earlham, Edinburgh, and Manchester) have negotiated effectively with their institutional senior management to secure open-ended contracts for key members of staff – thus ensuring continuity. In these cases, senior management was persuaded that the centre was a strong fit with the wider institutional strategy, such that core funding for key staff was provided through institutional reserves.

For the foundries, the main challenge was to cover operational costs, as the original grants were for capital expenditure only. Most institutions elected to recoup these through higher access charges, recognising the need to cover individual Foundry staff members' salaries, training, consumables and, particularly, servicing costs.

Overall, there was a sense from interviewees that human capital needs to be considered more in such programmes. Particularly in a field that is as complex and multidisciplinary as synthetic biology, loss of individuals leads, at best, to a delay in a centre's research programme while a replacement is found, and, at worst, to the closing down of a research avenue because a replacement cannot be found or attracted to the centre, or the centre cannot afford to train someone else to operate the equipment. For example, £5k training costs for Hamilton automated liquid handling systems and £30k training costs for Berkeley Lights Beacon were quoted by different individuals.

In this regard, the recently published National Vision for Engineering Biology[74], will go some way to reassuring those in the community of continuity in funding and support. Engineering biology is now positioned as one of five critical technologies to enable the UK to become one of the most innovative economies in the world. This strategy focuses on six priorities: world-leading R&D, infrastructure, talent and skills, regulations and standards, take up by the broader economy, and responsible and trustworthy innovation. The strategy is supported by £2 billion investment over the next ten years.

[74] National Vision for Engineering Biology (Department for Science, Innovation & Technology, 2023)

## 4.5 Opinion of the synthetic biology landscape in the UK

While the wider opinion of the interviewed SBfG programme funding recipients was that the UK was a global leader at the start of the SBfG programme, most consider that this position has now been eroded. Centre leads cited other countries including the US, Germany and South Korea as having more coherent strategies in place that are practitioner-led (as with the UK's original 2012 roadmap), with substantially greater investment which extends over ten to fifteen-year periods.

The perceived lack of a long-term strategy is particularly important considering the significant capital equipment investment in centres and foundries, the true value of which can only be realised over an extended period of time, with the skilled people available to operate them. Yet, facility owners report that they are not operating at capacity. This appears to be due to access fees that are levied by the university to recover costs (as discussed above) which, feedback suggests (from both academics and some companies), can be too high for academics not directly supported by the SBfG programme funding and early-stage companies to afford. However, this is a sentiment that is common across all academic disciplines as well as early-stage companies – it is not specific to synthetic biology. The solution requires a more systemic approach by public sector funders, perhaps in partnership with the private sector, to provide additional finance to access facilities where the technology is closer to market, but still carries significant risks and costs.

There was additional feedback from Foundry leads that wider industry and academic researchers, beyond the existing collaborative sphere, still do not truly understand the opportunities that the equipment offers. This could be due to ineffective marketing by the Foundry, or a poor understanding of what industry needs in terms of not just specific capabilities, but service models. While there were evident examples of successful and impactful industry engagement across centres, this could be improved and accelerated through a coordinated approach by the centres and UKRI to promote the advantages of these facilities across a broad range of industry sectors and applications.

Foundries also identified issues with UKRI's support for service contracts and maintenance of equipment. As part of the SBfG call, applicants could request support to cover the cost of service contracts and maintenance of equipment, which could be included as part of a package with a piece of capital equipment or purchased separately. However, those interviewed indicated that the issues experienced by Foundries are further compounded by the fact that equipment service contracts have, up until recently, not generally been eligible as UKRI grant expenses, and so must be borne by the host institution and/or recouped through access fees. In some cases, centres effectively mothball equipment that is out of service contract, because they cannot afford to renew these. It is useful to note that under specific circumstances service contracts can now be considered eligible costs[75].

Feedback from centre leads is that they perceive the future focus of government support for engineering biology will be on applications of existing research. There is clear enthusiasm for this and many have identified opportunities to exploit research from the SBfG programme, as evidenced by the large number of spinouts and of industry collaboration with SBRCs, foundries and CDTs (see Section 5). However, centre leads believe that much more work needs to be undertaken to fully understand

75 For example, this can apply to specific calls and have a maximum duration. The ALERT 2023 call provides a recent example: www.ukri.org/opportunity/mid-range-equipment-for-biosciences-research-alert-2023/

the underlying science of the genetic systems on which such exploitation will be built. There is a concern that support for underpinning science in engineering biology will be left to responsive mode grants, that are of too low value and insufficiently coordinated to ensure this will happen. They would argue that failure to continue to support such research will jeopardise the UK's long-term innovation pipeline and leave such opportunities open to exploitation by other countries. In this regard, UKRI has indicated its intent to continue its support of fundamental underpinning research through its National Engineering Biology Programme[76], which aims to support both discovery- and application inspired research and innovation.

[76] BBSRC-010721-Funding-Opp-DevelopingEngineeringBiologyBreakthroughIdeas-Overview.pdf (ukri.org)

# 5 External consultations

A programme of semi-structured interviews and a structured online survey were carried out to gather additional qualitative and quantitative data required to inform the economic impact modelling and analysis, to identify potential case studies and provide information on lessons learned from the SBfG programme.

External consultations were undertaken with a broad range of different types of stakeholders that engaged with the centres (SBRCs, foundries or CDTs), namely:

- spinouts originating from the funded SBRCs
- startups that engaged with one or more centres
- established companies that collaborated with or funded research and/or students at one or more centres
- academics that collaborated with one or more of the funded centres
- UK academics that were not funded by the SBfG programme, yet are highly active in synthetic biology research (see Section 5.4)

## 5.1 Interview topics and questionnaire development

A set of topics and questions were developed that were used in both the interviews and the online survey. Due to the range of different stakeholders, there were some common core questions, but most were specific to different stakeholder groups. This is presented in Appendix B.

## 5.2 Stakeholder database

In total, 306 organisations were identified that had engaged in some way with the SBfG programme funded centres (from the centres' interim and final reports, and review of partners/collaborators listed on UKRI's gateway to publicly funded research and innovation). However, contact details were only available for 75 of these organisations, with more than one contact identified for three. This is summarised in Table 7, with further details in Appendix D. The figure of 306 should be seen as a conservative estimate of the total number of organisations that engaged with the SBfG programme centres in some manner or other. There were many other ad hoc engagements and collaborations that were not formally reported, either because they fell outside the SBfG programme reporting periods or were through individuals that were not core SBfG programme funded staff. Furthermore, the foundries and CDTs were largely not required to report on engagements and collaborations with external stakeholders.

| Stakeholder Type | Number Identified | Number with Contact Details |
|---|---|---|
| Spinout/startup | 54 | 46 |
| Company - UK | 68 | 18 |
| Company - international | 76 | 3 |
| Academic - UK | 31 | 5 |
| Academic - non-UK | 59 | 0 |
| Other | 18 | 3 |
| **TOTAL** | **306** | **75** |

**Table 7: Identified collaborators, partners and funders of SBfG programme centres (data from BBSRC, centre reports and information provided during interviews).**

The spread of these organisations across the different centres is summarised in Table 8. Some organisations had contact with more than one centre, so the grand total in Table 8 is higher than Table 7. Furthermore, the LMB at Cambridge and the Oxford-led DNA synthesis did not report any engagement with external stakeholders and are not included. Also, it was not possible to identify specific industry co-funders of CDT students from the available data and so these are not listed here either.

| Relationship with Centre | BrisSynBio | Mammalian SynthSys | OpenPLant | Nottingham SBRC | SynBioChem | WISB | Earlham | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|
| Partner | 7 | 4 | 11 | 0 | 1 | 0 | 9 | 1 | 0 | 0 |
| Customer | 9 | 7 | 0 | 2 | 0 | 1 | 4 | 1 | 21 | 10 |
| Collaborator | 8 | 31 | 18 | 56 | 62 | 19 | 0 | 1 | 0 | 0 |
| Spinout | 8 | 5 | 9 | 1 | 4 | 1 | 0 | 0 | 0 | 1 |
| SAB | 1 | 2 | 6 | 3 | 6 | 5 | 0 | 0 | 0 | 0 |
| Multiple | 1 | 0 | 1 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| Other | 3 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Unclear | 3 | 18 | 8 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| **TOTAL** | **40** | **69** | **54** | **63** | **78** | **31** | **14** | **3** | **21** | **12** |

**Table 8: Summary of relevant organisations connected with each SBfG programme centre and the nature of the relationship.**

In total 26 stakeholders were interviewed and, in addition, seven completed the online survey. Table 9 summarises this data, from an organisational level, rather than individual stakeholders.

| Stakeholder Type | Total | Contacted | Interviewed | Surveyed (but not interviewed) | Percentage interviewed or surveyed of those contacted | Percentage of total that were interviewed or surveyed |
|---|---|---|---|---|---|---|
| Spinout/ startup | 54 | 46 | 16 | 3 | 41% | 35% |
| Company - UK | 68 | 18 | 5 | 2 | 39% | 10% |
| Company - international | 76 | 3 | 2 | 1 | 100% | 4% |
| Academic - UK | 31 | 5 | 0 | 1 | 20% | 3% |
| Academic - non-UK | 59 | 0 | 0 | 0 | 0% | 0% |
| Other | 18 | 3 | 1 | 0 | 33% | 6% |
| **TOTAL** | **306** | **75** | **26** | **7** | **44%** | **11%** |

**Table 9: Summary of stakeholders who were interviewed or completed the online survey (data presented at an organisational rather than stakeholder level).**

## 5.3 Stakeholder interviews and surveys

The overwhelming sense from the interviews was that the SBfG programme resulted in tangible benefits: to the host institutions, the spinouts and startups they fostered, and the established companies they engaged with. This covered a range of outcomes that are described in more detail below. It should be noted that many of the responses echoed those of the centre leads that were interviewed earlier in the study.

### 5.3.1 Anchor points

BrisSynBio, Mammalian SynthSys and SynBioChem were highlighted as being particularly active in engaging a broad scope of external stakeholders and were, in fact, anchor points of the synthetic biology community. SBRC Nottingham was highlighted for its activity as a “neonatal company incubator” which illustrates its critical contribution at the earliest stages of technology commercialisation. This opinion, from several different interviewees, identified key attributes demonstrated by these institutions:

- there was a dedicated contact person at each SBRC, who was pro-active at understanding different external stakeholder needs and identifying research within their centres that would have commercial interest to the external stakeholder. This person connected relevant researchers with external stakeholders, for example, through organising site visits and presentations/discussions. This person maintained a regular contact with external stakeholders and followed up on visits and information requests from them
- the institution itself adopted a pro-business approach, which could include, for example, upfront collaboration agreements (to avoid any issues as results are generated) and realistic IP valuation to avoid stifling investment
- presenting wider institutional attributes, i.e., extending beyond the SBRC to include other research activities across the institution

Overall, this was seen as the SBRC presenting a business-centric interface that was tailored to the needs of individual external stakeholders.

### 5.3.2 Networking

The SBRCs, in particular, were seen as offering fantastic opportunities to network and strengthen research relationships, because such a broad range of activities were funded and involved researchers from across different disciplines and embraced a range of different spinouts, startups and established companies. The SBfG programme funding offered the opportunity to think "outside of the box" and bring many different ideas and approaches to bear on specific challenges or opportunities. This in turn allowed some of the companies to pivot towards new research areas and commercial objectives. Several of the early-stage companies that were interviewed also stated that being associated with a centre introduced them to larger companies (which could one day be partners, licensees or buyers of their technology) and investors. The significant contribution of SBRCs in establishing synthetic biology as an attractive field for larger, more established industrial players was highlighted. Initially, these companies were hesitant about the potential of synthetic biology. However, as SBRCs continued their work, many of these companies developed a keen interest and subsequently set up dedicated synthetic biology research units, for example, within their biotechnology departments.

### 5.3.3 Training

As mentioned earlier, training was a significant impact of the programme. It was stated by one of the centres that the output of high-calibre students was the most impactful outcome of SBRCs. PhD students (through the CDTs or other programmes) gained significant industrial experience through engaging with spinouts, startups and established companies. In turn these young companies benefited by being able to progress their technologies, which would have been difficult, if not impossible, otherwise. Established companies funded PhD students to explore new research areas, that were seen as early stage/high risk but potentially high reward. In many cases, these PhD students went on to work for the startup or took up industry positions.

Several of those who accessed BrisSynBio or WISB commented that the SynBio CDT acted as the glue that connected many of the other parts. Altogether, this is predicted to have a significant impact on industry's ability to innovate and bring new products and services to market as CDTs were the first dedicated providers of synthetic biology training.

Despite this, several of those interviewed believed that the wider education, skills and training offered in the UK needs to be bolstered. Their opinion is that there are far too few individuals being trained with the skills required by companies and that the skills shortages include engineering biologists, data scientists and software engineers. With respect to the latter two, it is also the case that the emerging synthetic biology sector cannot afford to compete on salaries with other sectors that are more traditionally associated with hiring individuals that have these skillsets. Furthermore, these skills shortages are not just at graduate and postgraduate level. Many believe that it is becoming increasingly difficult to recruit suitably skilled technicians.

It should be noted that, as with funding and investment, skills issues are not confined to the synthetic biology sector. There are numerous studies that have indicated significant existing skills shortages that would affect the synthetic biology sector, as well as others, including:

- the Institution of Engineering and Technology's (IET), estimates that there is a shortfall of 173,000 workers in STEM sectors, with 49% of engineering businesses having difficulty in recruiting skilled staff[77]
- an Association of the British Pharmaceutical Industry (APBI) report on changing skills requirements notes a shortage of individuals with skills in bioinformatics, systems biology, computational chemistry and others, which has been compounded by barriers to attracting talent into the UK[78]
- research by the Science Industry Partnership (SIP) highlights skills shortages at technician level and in genomics, informatics, data science, engineering and several others, as well as an increased demand for digital, computational, statistical and commercial skills in the life-sciences sector to 2030[79]

### 5.3.4 Critical mass and commercialisation

In total, 47 spinouts and startups have been associated with the SBfG programme. All 16 that were interviewed stated that they had benefited from the centres themselves or the wider innovation ecosystem they were located in. From speaking with external stakeholders in established companies, it is clear that these ecosystems are continuing to attract new startups, thus building critical mass.

This critical mass involves the research staff and students at the centres, equipment and facilities available, including incubator space for early-stage companies, and the wider mix of companies, investors and entrepreneurs.

The focus of the different centres was also clearly of benefit to several of the larger companies, for example:

- AbbVie engaged with Nottingham SBRC because of its unique capabilities in Clostridia strain engineering and found them highly responsive to progressing and achieving research objectives
- AstraZeneca worked with BrisSynBio on various research programmes, including novel antibiotics from biocatalytic pathways, small molecule switching in de novo peptide-peptide interactions, addressing drug resistance in cancer and megabase repair for genome editing. AstraZeneca also engaged with Mammalian SynthSys and SynBioChem
- FujiFilm Diosynth Biotechnologies (FDB) interacted with Mammalian SynthSys and SynBioChem, and in the case of the former this led to a £2 million investment to pump-prime a Centre of Excellence in Bioprocessing at Edinburgh, and a successful application to the EPSRC Prosperity Partnership for a further £8.7 million funding in this area
- GlaxoSmithKline (GSK) had strong interactions with both BrisSynBio and SynBioChem, and in the case of the latter, this influenced their research programme in biocatalysis, resulting in increased research staff and budget focused on this area. GSK also hired four people from SynBioChem as a result of this engagement

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77 Engineering Kids' Futures (IET, 2022)
78 Evolution of an innovation based biopharmaceutical industry: how skill requirements are changing (ABPI, 2023)
79 Life Sciences 2030 Skills Strategy (SIP, 2022)

The overarching view of those interviewed is that the SBRCs were focal points for the development of wider UK capability in synthetic biology. The complex and dynamic engagement between academic institutions and the private sector on many different levels, across different disciplines and with different purposes, supported a better understanding of the opportunities to advance and commercialise research output from the SBfG programme. The impact on the early-stage companies that engaged with the SBRCs was more profound. As part of the interview and questionnaire, companies were asked to estimate the timing and extent of the impacts of the engagement with the SBRCs on their business. 48% of those interviewed or surveyed stated that they would not have existed without this support, and most of the remainder acknowledged that this engagement had a significant impact on their business activities. These findings input to the economic impact assessment (EIA) described in Section 6 and Appendix G.

### 5.3.5 Growing early-stage companies

Access to finance continues to be an issue for early-stage companies (in general, as well as those interviewed as part of this study), and several individuals commented on the difficulty to secure translational funding/investment. In some locations, for example, BrisSynBio and SynbiCITE, there are angel investors already engaged through a strong incubator system, and this environment can help support spinouts and startups. However, these have taken many years to develop and generally have been initiated and driven by high-net-worth individuals with an active interest in supporting new technology, that in turn have attracted others.

It has been highlighted that the public funding to bridge the gap between early-stage translation and commercialisation activities is lacking across all sectors, and often requires match-funding to access. While for some this has been achievable through angel investors and is attractive to such individuals as it de-risks their investment, others are still at too early a stage and need the public funding to deliver the results necessary to secure this initial private investment. What this means in practice is that several very early-stage companies do not spinout of academia but continue in a partially funded state with PIs and PhD students delivering the research in an ad hoc manner. This inevitably extends the innovation cycle and potentially leads to loss of talent/know-how and others getting to the market first.

That said, most of the startups and spinouts had secured initial funding from angel investors, in some cases supplemented with public funding. A lot of this success can be attributed to the reputation of the host centres, which in turn attracts the right calibre of Board-level individuals that can steer the company through to investment. Some of the centres also benefited from the wider innovation environment they were located in. For example, Bristol has developed a relatively young (last ten years or so) but highly dynamic investment culture through Science Creates[80] that is supported by Bristol entrepreneurs and investors and which also provides incubator space[81] for young companies. In London, Imperial has established the successful SynbiCITE[82], the UK's Innovation and Knowledge Centre for synthetic biology, that provides access to the London DNA Foundry, as well as lab and incubator space, an accelerator programme and investment opportunities. In both of these examples,

80 https://sciencecreates.co.uk/
81 Unit DX and DY (https://sciencecreates.co.uk/incubators/)
82 http://www.synbicite.com/

it is clear that the breadth of activity and individuals in technology, investment and business support at these sites has led to a higher number of spinouts and startups, than might have been the case. For example, BrisSynBio has reported 16 spinouts or startups supported, the largest number of any of the centres.

Securing Series A investment, however, is a different matter, and for those developing therapeutics this is essential to fund clinical trials, which might require budgets of £15 million or more. All of those interviewed indicated that this is where the greatest challenges lie. Those that had been successful had built these relationships over a number of years, through being introduced to venture capitalists (VCs) via angel investors or through larger corporate partners. Again, this appeared to happen more often at centres where there was a critical mass. One of the issues faced by early-stage companies is that there is not the same opportunity for VC funding in the UK as in, for example, the US, although the UK's biotechnology sector attracts more VC funding than any other European country[83]. Some early-stage companies commented that the UK's investment scene appears to be dominated by generic investors that lack the knowledge to understand the USP of many synthetic biology companies.

Finally, and also highlighted through the interviews with centre leads, scaling-up of bioprocesses was considered a barrier to some early-stage company growth. Several commented on the cost associated with accessing CPI facilities (the UK's main facility to support manufacturing scale-up) and no clear way to support that, except through investors, who are often reluctant to invest the £100,000 or so that this might require. Additionally, many synthetic biology companies operate in markets where scalability is the key aspect of their work, as is the case, for example, in chemical manufacturing where a company would be expected to own and operate facilities that are bespoke to their process. It was noted that public support and investor appetite for pilot plant and scale-up facility development is insufficient due to high capital expenditure of such facilities, and that this aspect requires strategic intervention to de-risk the so-called "valley of death". Feedback from other studies suggests that many companies would benefit from smaller scale (one to a few hundred litres) processing facilities that could be more widely available, i.e., co-located near their RTD sites.

## 5.4 Opinions from counterfactual group

As part of this study, we engaged with a group of UK academics specialising in synthetic biology and related fields, who were not direct recipients of the SBfG programme funding. Our objective was to gather insights into the nature of the funding that supported their research, their activities in translational and commercialisation efforts outside of the SBfG programme centres and foundries, and to understand their perspectives on the outputs of SBfG programme and the UKRI Engineering Biology programme. Twenty-seven UK academics were identified and contacted, of which eight were interviewed.

The group of academics approached for this consultation was selected based on their self-reported and publication activity in synthetic biology. Most of these academics have been involved in commercialisation efforts, with many having established at least one spinout company. Additionally, several have licensed their intellectual property to industrial collaborators for further development.

83 Resilient UK biotech sector lands £1.8 billion investment in 2023 (BIA, 2024)

These stakeholders have received funding from a variety of sources, including BBSRC, EPSRC, MRC, and Innovate UK through direct awards and studentships, as well as from the private sector and, historically, from European funding programmes, in the range of £2 million to £4 million over the last five years. Those academics who had successfully attracted substantial private sector funding shared that the most beneficial public funding sources for their work were iCASE studentships and IUK Knowledge Transfer Partnerships.

The counterfactual group perceived the SBfG programme to be a highly positive endeavour when it launched in 2014 with strong potential to enhance collaboration and thus accelerate innovation. In particular, the centres were seen as the first to adopt an 'open doors policy' aimed at streamlining access to university knowledge bases and facilities. Moreover, there was a strong belief that SBfG programme funding would focus on translational and commercialisation efforts, facilitating the delivery of synthetic biology-enabled products and services to the market. However, this group asserted that some of these expectations were not met, for example, that the centres tended to operate in silos and were perceived as being closed off to new external collaborations.

The academics in the counterfactual group largely expressed positive opinions about the UKRI Engineering Biology programme, noting that the calls demonstrated a genuine strategic interest in translational research.

In summary, the academics expressed the opinion that the UK remains an excellent place for synthetic biology research, second only to the US. The innovation landscape in the country is highly active and productive, though they perceive a loss of momentum due to relatively low rates of spinout and startup creation. Additionally, they identified an opportunity for the UK to capitalise on the changing regulatory landscape in areas such as gene-edited crops and other non-therapeutic applications, thus affirming its position as a global leader in engineering biology. Lastly, they suggested creating more focus within the engineering biology applications by identifying what the country's knowledge base does best and what is uniquely British about the UK's synthetic biology, to better understand strategic funding priorities.

# 6 Economic impact assessment

A key objective of the SBfG programme evaluation is to measure the Gross Value Added (GVA)[84] impact that has been generated through the SBfG programme. This section presents the output of the economic impact assessment (EIA) that was undertaken to better understand and (where appropriate) quantify the wider economic value and benefit that has been generated through the programme.

As highlighted in Section 1, two approaches to measuring the economic value and benefit were adopted:

- 'Bottom-up' approach which uses programme monitoring data and feedback gathered through engagement and survey to develop a bespoke impact model for the various benefits streams. The model measures the impacts generated to date and in the future – covering a 15-year impact horizon, on an annual basis, 2014 - 2029. This recognises that the intervention is targeting an emerging and relatively nascent sector and there may be periods of time elapsed before impacts emerge
- 'Top-down' approach which uses historical and industry forecast data to estimate the potential value of the global markets for synthetic biology products and applications and estimate the share the UK could expect to control. We have used the UK share of global research publications as a proxy for global market share. This model considers impacts during the SBfG programme period: 2014 to 2022 and a 10-year post-programme period: 2023 to 2032 to allow for lagged effects in the economic returns to research and development

Further information on both models is available in Appendix G.

## 6.1 Bottom-up economic impact assessment

Using the logic model that has been developed for the SBfG programme (see Appendix E), we developed a route to impact model - covering the full range of ways in which the programme generates economic value to consider the approaches by which we could robustly quantify the GVA impact of the programme. For example, a key consideration in developing our approach was the granularity of data available, the level of responses from industry and from those that have either started up a business or spun out a company as a result of engaging with the programme.

The 'bottom-up' economic assessment has used the following indicators to measure the impacts/benefits:

- **startups and spinouts –** the entrepreneurial activity that has been supported and catalysed within the SBRCs that has resulted in academics and/or industry partners starting up or spinning out a company.
    - Spinout – defined as a private incorporated company/entity created by one or more academics or research staff (where the academic institution retains partial/full ownership of the IP) with the aim of commercialising research that was originally supported through the SBfG programme

[84] ONS, see here: https://www.ons.gov.uk/economy/grossvalueaddedgva

  - Startup – defined as a private incorporated company/entity created for-profit or a social-purpose, that originated independently of the SBfG programme. This may be as a result of collaboration between academia and industry; however, the academic institution does not necessarily retain any ownership of the IP
- **research staff** – the programme/funding allowed the partners to employ additional research staff and enhance the productive capacity of the institutions
- **postdoctoral training** – 'in-study impacts' and wage/GVA premiums resulting from additional postdoctoral places
- **PhD training and CDTs**– 'in-study impacts' and wage/GVA premiums resulting from additional PhD graduates

In Section 6.1.1 we have considered each of the routes to impact separately.

**Areas that have been excluded from the assessment**

A key focus of the evaluation was to ensure that the impact assessment was robust, defensible, and transparent. There are two key areas of activity supported through the SBfG programme that, while, as noted in the evaluation have had a significant positive impact and benefit, we have been unable to gather the relevant data and feedback that would support a robust impact assessment.

Therefore, the following activities have been excluded from the impact assessment:

- collaborations and partnerships between academia and industry
- creation and subsequent licensing of IP (some institutions did report this as a benefit; however, the financial value/returns are commercially confidential and have not been disclosed)
- the DNA foundries

This will ultimately lead to an underestimate of the total economic value generated through the programme; however, it is the study teams professional view that a conservative approach would be most appropriate given some of the limitations in the dataset.

### 6.1.1 EIA approach and principles

A high-level guide to support readers' understanding of technical terms and concepts referred to within this chapter is provided. The approach adopted is consistent with the guidance outlined within HM Treasury Green Book[85].

#### Economic indicators and coefficients

A summary and description of the (quantitative) economic indicators used within the assessment is provided below:

- **FTE posts** - used to measure the direct annual employment effects within the companies that have/are forecast to startup/spinout, and the research staff, postdoctoral researchers and PhD students/staff that have been supported. FTE posts are calculated based on monitoring and evaluation data and evidence provided directly from surveyed funding recipients

85 https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020

- **GVA** - is a measure of economic output that considers the value of goods and services produced before allowing for depreciation or capital consumption. At a micro-level, GVA is the contribution of each individual producer, industry or sector to the economy and measures the income generated by businesses after the subtraction of input costs, but before costs such as wages and capital investment. It is the UK government's key measure for productivity

The evaluation has found that the SBfG programme has had a positive effect on GVA and is assessed in the following ways:

- **startups and spinouts –** FTE jobs have been converted to annual GVA effects using co-efficient data derived from ONS for the following 2-digit SIC industry, 72: Scientific research and development. The data has been adjusted to reflect that it is unlikely that new startups and spinouts would generate the same level of GVA per head as the industry average. Therefore, we have assumed that 1-year post incorporation the average GVA per head within supported startups and spinouts would be equivalent to 10% of the wider industry average, 20% after 2 years, 30% after 3 years, etc. The interview programme and survey of external stakeholders had questions to help inform and understand the level of attribution that the programme has had on supporting spinout and startup companies, and achieving their growth forecasts
- **research staff** – Data has been provided by the supported institutions as part of the programme monitoring. As the universities and research institutions engaged are quasi-public sector organisations, they are non-profit making. Therefore, we have used employee costs (salary, pension contribution, and National Insurance) as a proxy measure for GVA per head. Our assumptions on the breakdown of research staff and associated employment costs are provided below
- **postdoctoral training** – Data has been provided by the supported institutions as part of the programme monitoring**:**
    - In-study impacts – as above, we have used labour costs (salary, pension contribution, and National Insurance) as a proxy measure for GVA per head. Our assumptions on the breakdown of postdoctoral training posts and associated costs are provided below
    - Wage/GVA premiums – the uplift in productive capacity is based on average salaries/wages (upon completion of the postdoctoral training) and converted to GVA using co-efficient data derived from ONS for the following 2-digit SIC industry, 72: Scientific research and development
- **CDTs and PhD training** – Data has been provided by the supported institutions as part of the programme monitoring:
    - 'In-study impacts – we have used the stipend paid to PhD students as a proxy measure for GVA per head. Our assumptions on the breakdown of PhD training posts and associated costs are provided below
    - Wage/GVA premiums – the uplift in productive capacity is based on average salaries/wages (upon completion of the PhD) and converted to GVA using co-efficient data derived from ONS and evaluation research

### Gross and net impacts

**Gross impacts** – the direct impacts that measure the overall change in economic activity that has occurred over the appraisal period.

**Net additional impacts** – is the difference between what would have happened anyway in the absence of the SBfG programme (i.e., the reference case) and the impacts/benefits generated by the support (i.e., the intervention case), adjusted for displacement, leakage, deadweight, and multiplier effects.

Additionality is described as "the extent to which activity takes place at all, on a larger scale, earlier or within a specific designated area or target group as a result of the intervention"[86]. In lay terms, this means the level of benefit or impact that can be attributed to an intervention.

The additionality factors have been derived through survey feedback, wider engagement with stakeholders, and the consultant team's professional judgement. The multipliers have been sourced form ONS input-output tables[87].

The assessment of additionality factors is set out below:

- deadweight refers to the benefits and costs of an intervention that would still have occurred if support were not provided. For example, within the survey of spinouts and startups, beneficiaries were asked whether the programme had a direct impact on the timing and scope of the company spinning out/starting up
- displacement – the impact that growth within supported spinouts and pipeline companies is estimated to have on other businesses and the labour market
- leakage – the proportion of impacts that will benefit those outside the defined spatial area (leakage outside the UK)
- income multipliers – the positive spin-off benefits generated through indirect income effects (i.e., paying suppliers)

Please note, as per UK Treasury guidance, we have provided the net additional impacts with and without the application of type 1 multiplier effects.

[86] https://assets.publishing.service.gov.uk/media/5a7ec4b9e5274a2e87db1c92/additionality_guide_2014_full.pdf
[87] www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

| | GVA multiplier |
|---|---|
| R&D | 1.98 |
| Chemicals | 1.85 |
| Pharmaceuticals/therapeutics | 1.51 |
| Agriculture/agritech | 2.16 |
| Medical technology | 1.52 |
| Energy | 3.23 |
| Water management / environment | 1.34 |
| Waste management / environment | 1.60 |
| Food and drink | 2.87 |
| Healthcare/cosmetics | 1.42 |

**Table 10: GVA multipliers (type 1).**

The approach can, therefore, be presented schematically as follows:

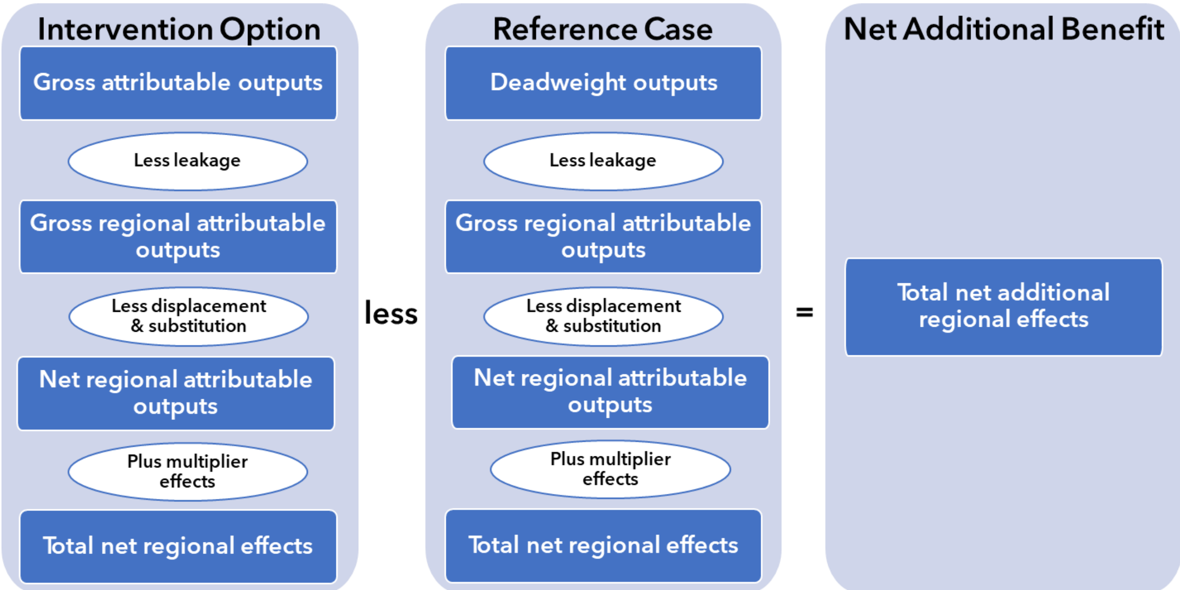


**Figure 16: Calculation of net additional benefits.**

### Other technical considerations

**Present values (PV)** – the total quantified value of the costs and net additional GVA over a defined timescale taking account of the time value of money (i.e., £1 today is worth more than £1 next year). Impacts are discounted at the HM Treasury Social Time Preference Rate (3.5%). Note that the base year for the evaluation is 2014.

**Constant prices** – the total quantified value of the costs and net additional GVA are presented in nominal prices (i.e., not adjusted for inflation). Financial values are set at the base year and economic coefficients (where specified) are adjusted to 2023 prices using data from the ONS GDP Deflator.

**Impact horizon and profile** is considered as follows:

- startups and spinouts – on an annual basis over a 10-year period. This recognises that the intervention is targeting an emerging and relatively nascent sector and there may be considerable periods of time elapsed before impacts emerge
- research staff – programme period, 2014 – 2022
- postdoctoral training:
  - In-study impacts – programme period, 2014 – 2022.
  - Wage/GVA premiums – 30-year period post-completion
- CDTs and PhD training:
  - In-study impacts – programme period, 2014 – 2022
  - Wage/GVA premiums – 30-year period post-completion

**Optimism bias and sensitivity** is the demonstrated, systematic tendency for EIAs to be overly optimistic in forecasting outcomes (for example, time taken to implement interventions, costs of implementation, and impacts achieved). When assessing the impacts of the startup and spinout companies we have therefore applied optimism bias at 20% on all forecast impacts to provide an element of sensitivity.

**Grossing up and confidence intervals** – to calculate the overall impact of the SBfG programme on supporting startups and spinouts, it is necessary to 'gross up' the results to reflect the population of supported organisations. The impact data that is captured through the survey sample are 'grossed up' to the entire population based on the inverse of the proportion responding to the survey (for example, a response rate of 20% generates a grossing up factor of 100%/20% = 5).

As the data has been 'grossed up' based on a sample population, we have included a Confidence Interval (CI) to include additional sensitivity. Based on a sample size of 19 startups and spinouts and population of 47, at a 95% confidence level, the confidence interval (or margin of error) is +/- 17.77%. The impact data has therefore been calculated and presented at a lower-point and upper-point estimate. To avoid skewing the 'grossed up results', outliers (considered as annual effects that lie out with twice the standard deviation of the mean) were removed from the sample prior to "grossing up" and then added back in. The 'low-point' and 'high-point' estimates reported in the tables below have been calculated by applying the (17.77 +/-) Confidence Interval to the 'mid-point'.

### 6.1.2 Total impact 2014-2029

Bringing all the benefit streams together, the total combined PV net additional GVA impact that is estimated to be supported through the SBfG programme is provided in Table 11 (this incorporates impacts to date and projected impacts as a result of the SBfG programme).

| **Including multipliers** | | **Lower-end estimate** | **Mid -point** | **Upper-end estimate** |
|---|---|---|---|---|
| Startups and spinouts | | £109m | £138m | £168m |
| Research staff | | £185m | £185m | £185m |
| Postdoctoral training | in-study impacts | £14m | £14m | £15m |
| | Wage premium impacts | £32m | £32m | £46m |
| PhDs | in-study impacts | £2m | £2m | £2m |
| | Wage premium impacts | £5m | £5m | £5m |
| CDTs | in-study impacts | £4m | £4m | £4m |
| | Wage premium impacts | £8m | £8m | £8m |
| **Total PV net additional GVA** | | £360m | £389m | £419m |
| Total PV costs | | £124m | £124m | £124m |
| RoI | | 2.9 | 3.1 | 3.4 |
| **Excluding multipliers** | | **Lower-end estimate** | **Mid -point** | **Upper-end estimate** |
| Startups and spinouts | | £63m | £80m | £97m |
| Research staff | | £92m | £92m | £92m |
| Postdoctoral training | in-study impacts | £7m | £7m | £7m |
| | Wage premium impacts | £16m | £16m | £16m |
| PhDs | in-study impacts | £1m | £1m | £2m |
| | Wage premium impacts | £3m | £3m | £3m |
| CDTs | in-study impacts | £2m | £2m | £2m |
| | Wage premium impacts | £4m | £4m | £4m |
| **Total PV net additional GVA** | | £188m | £205m | £222m |
| Total PV costs | | £124m | £124m | £124m |
| RoI | | 1.5 | 1.7 | 1.8 |

Note: Figures presented as Present Value @3.5%

**Table 11: SBfG programme – total present value net additional GVA supported.**

Including multiplier effects, the SBfG programme is estimated to support PV £360 million to PV £419 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers a RoI of 2.9:1 to 3.4:1. This means that for every £1 invested in the SBfG programme, it will generate a net additional GVA impact within the UK economy of £2.90 to £3.40. NB, as discussed earlier, the Rainbow Seed Fund was not included in this analysis as it is being assessed in a separate study.

Excluding multiplier effects, the SBfG programme is estimated to support PV £188 million to PV £222 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers a RoI of 1.5:1 to 1.8:1.

As noted in Section 6.1, we have adopted a conservative approach to quantifying the economic impacts and have not included any potential benefits to the industry partnerships/collaborations or the DNA foundries - the analysis will almost certainly underrepresent the impacts.

We have also not considered the potential diffusion or adoption effects for downstream users, i.e., those that will benefit from the technologies, services, or products that the R&D activity supported through the SBfG programme. Given the cross-cutting nature of the synthetic biology these could be significant in terms of health, environmental and fiscal impact.

It is also worth noting that generating economic value (GVA) is not a core objective of the SBfG programme, therefore the estimated net additional GVA return of £328 million to £388 million is a significant positive finding.

## 6.2 Top-down economic impact assessment

The top-down economic model provides an additional level of economic analysis for estimating the benefits generated as a direct result of the SBfG programme. The model is designed to indirectly capture the contribution made by the programme to the UK achieving additional synthetic biology market share.

### 6.2.1 Methodology summary

The top-down model has a number of underpinning steps and assumptions:

1. Estimate the value of the global synthetic biology market during the period of the SBfG programme (2014 to 2022) and for a 10-year post-programme period from 2023 to 2032.
2. Estimate the UK's share of the global synthetic biology market based on the UK's share of total scientific research publications related to synthetic biology.

   **Key assumption**: Market share is directly proportional to research publication activity.

   **Key assumption**: Research publication activity is a good proxy for research expenditure which is shown to influence economic returns.

   a. Estimate the global and UK number of research publications by searching the Web of Science database for the following search terms:
      i. Synthetic biology; or
      ii. Engineering biology
      iii. Within the "title" or "abstract" or "topic" or "keyword"
   b. Determine the UK's annual share of global publications in synthetic biology and use this to proxy market share
3. Construct a counterfactual projection of UK annual publications in synthetic biology in the absence of the SBfG programme using historical Web of Science data from 2008 to 2013.

   **Key assumption**: the SBfG programme is the main driver of change in publications in synthetic biology for the 2014 to 2022 period.

   a. A best fit pre-programme trendline is extrapolated over the programme period
   b. Counterfactual annual publications are compared to global data to estimate a counterfactual UK market share

4. Determine the value of the additional market share captured due to the SBfG programme by comparing the "intervention" case (i.e., the case when the SBfG programme happens – as in step 2) against the "counterfactual" case (i.e., the SBfG programme does not happen). Apply this methodology for the programme period and for the 10-year post programme period.

   **Key assumption**: When considering the 10-year post programme period, the UK annual market share for the intervention and counterfactual cases are assumed to be equal to the average market share for the intervention and counterfactual cases during the programme period, respectively.

5. The value of gross additional market share (gross additional turnover) as calculated in step 4 is converted to economic impact (GVA) by applying economic turnover to GVA coefficients based on ONS data. GVA impacts are then adjusted for additionality factors – leakage, displacement, and multiplier effects.
6. Incorporate a five-year lag in GVA returns in line with the wider literature which suggests time lags between R&D expenditure and economic returns[88].

### 6.2.2 Technical considerations

**Present values (PV)** – the total quantified value of the costs and net additional GVA over a defined timescale taking account of the time value of money (i.e., £1 today is worth more than £1 next year). Impacts are discounted at the HM Treasury Social Time Preference Rate (3.5%). Note that the base year for the evaluation is 2014.

**Constant prices** - the total quantified value of the costs and net additional GVA are presented in nominal prices (i.e. not adjusted for inflation). Financial values are set at the base year and economic coefficients (where specified) are adjusted to 2023 prices using applicable data from the ONS GDP Deflator and global inflation rates.

**Impact horizon** is considered as follows:

- SBfG programme period: 2014 to 2022
- 10-year post-programme period: 2023 to 2032

### 6.2.3 Estimating the value of global synthetic biology markets

The potential value of the global market for synthetic biology was estimated to determine the scale of opportunity and economic value of which the UK has gained a share. See Appendix G for further information.

Note that all values have been converted from USD to GDP using annual average exchange rates sourced from ONS official exchange rates[89], and are in constant 2023 global prices using global inflation rates sourced from the International Monetary Fund[90].

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88 Rate of return to investment in R&D. A report for the Department for Science, Innovation and Technology. Frontier Economics, March 2023. Accessed here

89 https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/auss/mret

90 https://www.imf.org/external/datamapper/PCPIPCH@WEO/WEOWORLD

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| Global | 3.53 | 4.83 | 6.93 | 9.28 | 11.45 | 11.78 | 13.85 | 6.74 | 9.64 |

**Table 12: Global market size – evaluation period (£bn).**

| | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 |
|---|---|---|---|---|---|---|---|---|---|---|
| Global | 12.47 | 13.89 | 19.14 | 23.75 | 29.50 | 36.67 | 38.09 | 46.93 | 58.68 | 74.90 |

**Table 13: Global market size – 10-year future impact period (£bn).**

### 6.2.4 Estimating the UK's share of the global market

To estimate the UK's share of the synthetic biology market and associated market value we assume that market share is directly proportional to the level of research activity within the synthetic biology field – measured by the number of scientific research publications. Comparing the UK's number of publications to the global total, provides an estimate of the UK's share of research and thus its share of the overall global synthetic biology market (Table 14).

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| UK | 49 | 49 | 73 | 70 | 98 | 117 | 84 | 72 | 56 |
| Global | 362 | 430 | 512 | 558 | 656 | 651 | 654 | 656 | 727 |
| UK Share | 14% | 11% | 14% | 13% | 15% | 18% | 13% | 11% | 8% |

**Table 14: UK and global synthetic biology publications 2014 to 2022**.

The UK synthetic biology market value from 2014 to 2022 can then be estimated based on these assumptions (Table 15).

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| UK | 477.9 | 549.9 | 988.1 | 1,164.6 | 1,710.8 | 2,116.5 | 1,779.3 | 739.6 | 742.5 |

**Table 15: Value of the UK synthetic biology market (£m).**

Note that this represents the size of the UK synthetic biology market under the "intervention" case.

### 6.2.5 Impact of the SBfG programme

To determine the SBfG programme's impact on publications, we constructed a counterfactual scenario, modelling the number of UK research publications in the absence of the programme. We used historical bibliometric data from 2008 to 2013 and identified a best-fit line for the data.

The data suggests that a linear regression equation is best fit. The equation is y=5.4857x + 0.4667. Extrapolating this trend over the 2014 to 2022 programme period gives an estimate of what would have happened to research publications in absence of the SBfG programme.

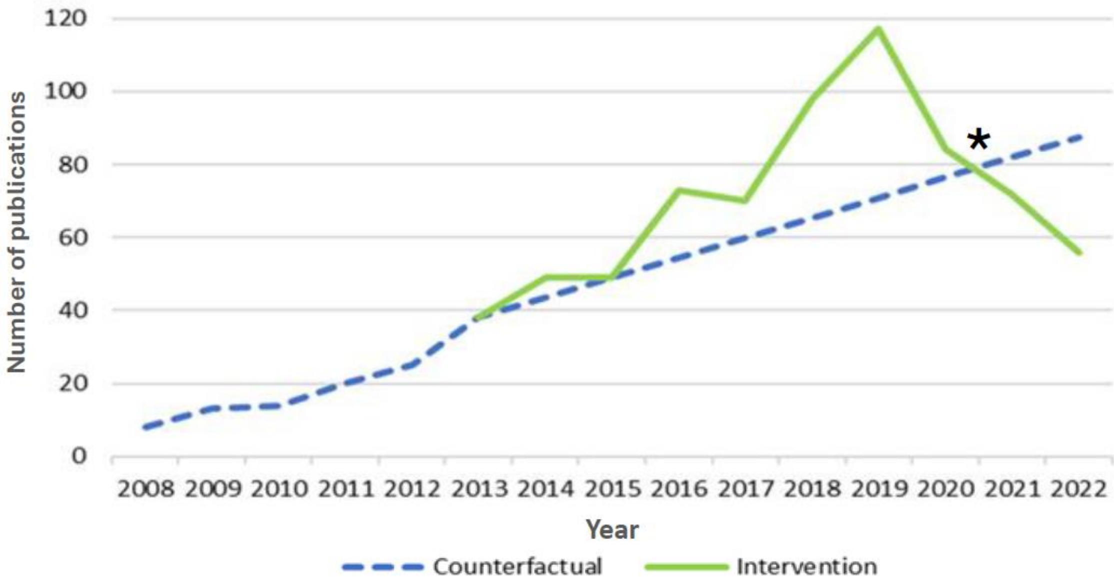


**Figure 12: UK synthetic biology publications – intervention vs. counterfactual.**

*the decrease in the number of recorded publications from 2020 coincides with the start of the COVID-19 pandemic, which had a negative impact on research activity and publication numbers.

The dashed blue line represents annual pre-programme synthetic biology publications from 2008 to 2013, and from 2014 to 2022 it represents the counterfactual scenario. The solid green line represents the actual annual level of publications during the SBfG programme period. Any difference between the solid green line and dotted blue line represents the impact on publications that the programme has had. However, the counterfactual data require careful interpretation. It should be noted that the counterfactual plot (dashed blue line) is modelled on publication rates which may or may not have followed this trajectory in the absence of the SBfG programme, i.e., the counterfactual values post 2014 could be significantly lower than shown. In addition, the negative impact of the COVID-19 pandemic on research activity and publication rates are not predicted by the counterfactual model. The implied negative 'uplift' in years 2021 and 2022 seen in the counterfactual analysis may be the result of these factors. It should also be noted that the reduction in publication numbers over the pandemic period is not specific to synthetic biology research and is also observed across other research areas.

While there is annual variation in uplift, the main conclusion from the analysis is that over the entirety of the SBfG programme period, there is a significant uplift in publications. Translating this to market share indicates an average annual uplift of £168.7 million and total uplift of £1,518 million over the lifetime of the programme. See Appendix G for further details.

### 6.2.6 Gross impacts programme period 2014 to 2022

The uplift in market value is equivalent to total sector turnover. To estimate gross additional GVA (i.e., GVA accounting for deadweight but not the other additionality factors of leakage, displacement and multiplier effects), we applied a turnover to GVA coefficient of 32%.

**Lagged effects**

Wider research[88] on the returns to research and development suggests that there is a time lag ranging from 2 to 10 plus years until economic returns are realised. We assume there is a five-year time lag for the market impact to be realised. This time lag is applied to all market value uplifts so that impacts during the SBfG programme period are realised from 2019 to 2022 (originating from research activity uplift in 2014 to 2017). Note this implies research uplifts achieved from 2018 to 2022 will generate economic returns during the 10-year post-programme period.

As a result, the programme is estimated to have generated £118.5 million in PV gross additional GVA from 2014 to 2022.

### 6.2.7 Net additional impacts programme period 2014 to 2022

To move from gross additional to net additional GVA impacts the following additionality factors are considered:

- **leakage**: is assessed at 0%
- **displacement**: is assessed as low at 15%
- **GVA multiplier**: A multiplier of 1.95 is applied

When considering the net additional GVA impacts when the economic multiplier is applied, the SBfG programme is estimated to have generated £196.2 million in PV net additional GVA to the UK economy between 2014 and 2022. When the multiplier is not applied, this figure reduces to £100.7 million.

### 6.2.8 10-year post-programme impacts

Modelling the 10-year post-programme impacts relies on the same methodology as applied for the programme period, but with intervention case and counterfactual case market shares applied to global synthetic biology market size forecasts for 2023 to 2032 (12.8% and 11.3%, respectively).

It is estimated that the programme could generated a market value uplift from £189.6 million in 2023 to £1,138.6 million by 2032 (before applying the lag effect). This equates to £525.1 million in PV gross GVA with lags applied and £869.3 million in net additional GVA when applying multipliers and £446.3 million in net additional GVA without multipliers.

### 6.2.9 Total impacts and RoI

Bringing together the programme period and 10-year post programme period benefits, the total combined PV net additional GVA impact supported through the SBfG programme is presented in Table 16.

| | Present Value including multipliers | Present Value excluding multipliers |
|---|---|---|
| Programme Period | £196m | £101m |
| 10-year post period | £869m | £446m |
| Total Impact | £1,065m | £547m |
| Cost | £124m | £124m |
| **RoI** | **8.7** | **4.4** |

**Table 16: Impact summary – total net additional GVA and SBfG programme RoI.**

Including multiplier effects, the SBfG programme is estimated to support PV £1,065 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers a RoI of 8.7. This means that for every £1 invested in the SBfG programme, it will generate a net additional GVA impact within the UK economy of £8.70.

Excluding multiplier effects, the SBfG programme is estimated to support PV £547 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers a RoI of 4.4.

We note that this 'top-down' analysis suggests an impact and return on investment greater than that described in the 'bottom-up' analysis. This is driven by the different areas of impact quantified by each model. While the 'bottom-up' approach focuses on direct, on-site impacts (staff, postdocs, etc) and impacts from startups and spinouts, the 'top-down' analysis quantifies a wider range of impacts across the synthetic biology economy, particularly the impacts that are generated by larger scale, established, and in some cases international companies and wider industry. Therefore, one would expect the top-down analysis to yield a greater level of impact and return on investment.

# 7 Conclusions

The SBfG programme is widely considered to have been transformational, by those it funded and those that engaged with funded centres. It established the UK as a global leader in synthetic biology R&D when it was launched in 2014, and attracted many global stakeholders who were interested in learning from it and implementing similar programmes in their own countries. It effectively led to innovation ecosystems in Bristol, Cambridge, Edinburgh, London, Manchester, Norwich, Nottingham and Warwick, each with a vibrant mix of academic researchers, spinouts, startups and more established companies. In locations where there was a co-located foundry (Edinburgh, Manchester and Norwich) or CDT (Bristol and Warwick) this effect was amplified, and at least in the cases of Bristol, Edinburgh and Manchester has evolved into a stable environment that did not exist before, where senior institutional management have identified synthetic biology as a strategic research focus and are supporting this with dedicated permanent staff. These centres have gone onto attract further industrial and academic collaboration, and further funding of at least double the initial investment. In this way, the SBfG programme has served as a major enabler of synergistic network effects across the synthetic biology ecosystem. The programme has supported research activity in academia and industry across a broad range of sectors, primarily in tools and enabling technologies (that will underpin further research and development) and in therapeutics, where there have been massive steps forward in terms of cell and complex biological therapies.

The SBfG programme funding has directly supported 47 early-stage companies through providing access to facilities and expertise at the SBRCs. This in turn has leveraged £79 million in investment for these companies and allowed them to grow to around 250 staff. The impact on the companies has been significant, with 48% being spun out of or supported by the SBRCs asserting that they would not have existed without this support. While a further 40% believe that they would have formed and grown without this support, most of those companies also agreed that the SBRC engagement had a significant impact on their business activities.

For wider industry it was clear that access to multidisciplinary teams across different institutions, had an impact on company research programmes and led to longer term collaborations in some cases. This interaction also appeared to change the mindset of the academic researchers involved, as more individuals became interested in exploring industrial partnerships and in spinning out their own companies. For the younger researchers, completing PhDs or early in their postdoctoral careers, this offered opportunities to explore working in an industrial environment, even if only on temporary basis.

In this regard, significant numbers of early career researchers have gone onto work in industry, around 55% across the two CDTs, with most of the others remaining in active research roles (in academia or other research performing organisations). In terms of staff employed on fixed-term contracts by the SBRCs, around 36% moved into industrial roles and only around 16% moved into non-research active roles following their contract.

Two models have been used to estimate the economic impacts arising from the wider SBfG programme. The bottom-up model, which is based on impacts on the companies supported and their projected market share over the coming decade, and of wage premiums due to the enhanced education and training delivered by the programme, delivers an RoI of between £360 million and £419 million (with economic multipliers) in net additional GVA within the UK economy, or between 2.9 and 3.4 times the initial investment.

The top-down model suggests that the economic impacts arising from the SBfG programme could be up to £1,065 million when including economic multipliers. This implies a return of 8.7 times the initial investment. The RoI calculated by this model is higher because it incorporates a wider set of potential impacts driven by increased or new economic activity within the UK's industry base. These include startups and spinouts, existing SMEs and large scale national and international enterprises which would all develop, utilise and enhance synthetic biology products and processes to drive growth.

Many of those interviewed as part of this study had concerns regarding UK government strategy for synthetic biology following the end of the first tranche of funding in 2018, that was exacerbated by limited follow-on funding and delayed decisions to the longer-term strategy. Although UKRI provided additional targeted investment for engineering biology following the end of the first tranche of SBfG funding, SBfG programme recipients believed that the overall level of funding was not sufficient. However, the announcements last year of £2 billion in funding for engineering biology and the establishment of a broad base advisory group to oversee future directions will assuage concerns to a significant extent and align the future UK engineering biology programme with approaches being taken in other countries.

In conclusion, the SBfG programme has achieved measurable impacts in terms of building UK capacity in synthetic biology, networking the community on multiple levels and disciplines, enabling commercial opportunities for wider UK industry and underpinning the future prospects of engineering biology.

## Abbreviations and acronyms

| | |
|---|---|
| APBI | Association of the British Pharmaceutical Industry |
| BBSRC | Biotechnology and Biological Sciences Research Council |
| BIA | BioIndustry Association |
| BrisSynBio | SBRC at the University of Bristol |
| CAGR | compound annual growth rate |
| CAPEX | capital expenditure |
| CDT | centre for doctoral training |
| CI | confidence interval |
| CPI | Centre for Process Innovation |
| ECR | early career researcher |
| EIA | economic impact assessment |
| EPSRC | Engineering and Physical Sciences Research Council |
| FDB | FujiFilm Diosynth Biotechnologies |
| FDI | foreign direct investment |
| FTE | full-time equivalent employee |
| G7 | Group of Seven, which is an intergovernmental political and economic forum consisting of Canada, France, Germany, Italy, Japan, the United Kingdom and the United States |
| GDP | gross domestic product |
| GE | genetically engineered |
| GM | genetically modified |
| GMO | genetically modified organism |
| GVA | gross value added |
| HEIF | higher education innovation funding |
| iCASE | industrial cooperative awards in science and engineering |
| IET | Institution of Engineering and Technology |
| iGEM | international genetically engineered machine, a worldwide synthetic biology competition |
| Imperial | Imperial College London |
| LMB | MRC Laboratory of Molecular Biology |
| LSE | London Stock Exchange |
| Mammalian SynthSys | SBRC at the University of Edinburgh |

| | |
|---|---|
| MRC | Medical Research Council |
| NHS | National Health Service |
| Nottingham SBRC | SBRC at the University of Nottingham |
| ONS | Office for National Statistics |
| OpenPlant | SBRC at the University of Cambridge and John Innes Centre |
| PI | principal investigator |
| PV | present values, the total quantified value of the costs and net additional GVA over a defined timescale taking account of the time value of money |
| R&D | research and development |
| RoI | return on investment |
| RTD | research and technology development |
| SBfG | synthetic biology for growth |
| SBRC | synthetic biology research centre |
| SIC | standard industrial classification |
| SIP | Science Industry Partnership |
| sLoLa | strategic longer and larger funding awards |
| SME | small and medium enterprises |
| SynbiCITE | the UK's innovation and knowledge centre (IKC) for synthetic biology |
| SynBioChem | SBRC at the University of Manchester |
| TRL | technology readiness level |
| UCL | University College London |
| UKRI | UK Research and Innovation |
| USD | US dollars |
| USP | unique selling point |
| VC | venture capital (or capitalist) |
| WISB | SBRC at the University of Warwick |

## Appendices

# Appendix A: List of SBfG programme funding recipients interviewed and discussion topics

| Centre Name | Type | Contact Name |
|---|---|---|
| BrisSynBio | SBRC | Prof Dek Woolfson (Bristol)<br>Dr Kathleen Sedgley (Bristol)<br>Prof Imre Berger (Bristol) |
| SynthSys (Centre for Engineering Biology) | SBRC | Prof Susan Rosser (Edinburgh) |
| OpenPlant | SBRC | Prof Jim Haseloff (Cambridge) |
| OpenPlant | SBRC | Prof Anne Osbourn (John Innes Centre) |
| SBRC Nottingham | SBRC | Prof Nigel Minton (Nottingham)<br>Dr Alan Burbidge (Nottingham) |
| SynBioChem | SBRC | Prof Nigel Scrutton (Manchester)<br>Dr Ros Le Feuvre (Manchester) |
| WISB | SBRC | Prof John McCarthy (Warwick) |
| Centre for Chemical and Synthetic Biology | Foundry | Prof Jason Chin (Cambridge)<br>Dr Philipp Holliger (Cambridge) |
| Earlham Institute - Automated DNA Assembly | Foundry | Dr Nicola Patron (Earlham)<br>Dr Carolina Grandellis (Earlham) |
| Edinburgh Genome Foundry | Foundry | Prof Susan Rosser (Edinburgh) |
| Liverpool GeneMill | Foundry | Dr Jesus Enrique Salcedo Sora (Liverpool) |
| London DNA Foundry | Foundry | Prof Paul Freemont (Imperial)<br>Prof Richard Kitney (Imperial) |
| Next Generation DNA Synthesis (involved Oxford, Liverpool, Bristol, Southampton, and Birmingham) | Foundry | Prof Tom Brown (Oxford) |
| CDT in Bioprocess Engineering Leadership | CDT | Prof Gary Lye (UCL) |
| Synthetic Biology CDT | CDT | Prof Antonis Papachristodoulou (Oxford) |

Discussion topics:

- experience of the SBfG programme
- impacts on the organisation as a result of the funding
- timings of these impacts
- training and professional development of technical staff, postgraduate students, and postdoctoral research assistants
- status of the spinouts from centre (*if appropriate*)
- key contacts in partner organisations (i.e., spinouts, supported companies, industrial and academic partners) that should be followed up with
- any challenges, barriers or issues in accessing the SBfG programme
- what would have happened in the absence of SBfG programme funding
- opinion of the synthetic/engineering biology landscape in the UK now, compared with the situation before the SBfG programme, and how this compares with international competitors

## Appendix B: Stakeholder interviews & survey

The full online survey is presented below, with routings highlighted. These were used as the basis of discussions with different types of stakeholders to ensure that similar quantitative feedback was obtained.

## INTRODUCTION

Optimat Ltd has been commissioned by UK Research and Innovation (UKRI) to evaluate the Synthetic Biology for Growth (SBfG) Programme. This programme represents investments of £114 million and ran between 2014 and 2022. It supported six synthetic biology research centres (SBRCs), DNA foundry capability in six academic institutions and two centres for Doctoral training (CDTs). We are inviting all partners, collaborators and customers of the SBRCs, foundries and CDTs to complete a short survey. The purpose of this survey is to assess the impacts that the SBfG programme has had on the UK's economy and its research and innovation ecosystem. This will assess actual impacts (since 2014) and forecast impacts (to 2029).

A report will be produced using the aggregated results of this study. No individual organisation will be identified in this report without their specific written permission and no identifiable organisation level data, opinions, etc., will be included within its contents. By taking part in this research, you agree to the use of your anonymised data for this research. You have the right to withdraw consent at any time.

Participation in this study is completely voluntary. The data collected via this interview programme will be processed by market research consultant Optimat Ltd. All data will be held securely in line with the data privacy policies of Optimat and UKRI. Your personal details will not be shared with any other parties or used for any other purpose without consent. Their respective privacy policies are available on request.

For further information, please contact the study lead, Mark Morrison

### *About this survey*

*The survey should take about 15 minutes to complete.*

*You can navigate through the survey using the buttons at the bottom of each page.*

*The first 3 questions (marked *) require an answer before you can progress to the next section of the survey. Please make sure your contact details are correct as you will not be able to return to this page. If you need to close the survey and return to it later you can select the Save & Continue Later option at the bottom of each page. We recommend you go to the next page to save your responses on the current page before you click the Save & Continue Later. You will then be asked for an email address. This is where you will receive an email with a direct link to your survey response. Please keep it safe until you wish to return to the survey. If it doesn't appear in your Inbox please check your Junk Folder.*

## Contact Details

Full Name

Company Name

Email Address

Which centre(s) have you engaged with? (names of academic institutions are in brackets, please select all that apply)

1. BrisSynBio (Bristol)
2. OpenPlant (Cambridge & John Innes Centre)
3. SBRC Nottingham
4. SynBioChem (Manchester)
5. SynthSys-Mammalian (Edinburgh)
6. WISB (Warwick)
7. Centre for Chemical and Synthetic Biology (Cambridge)
8. Earlham Institute
9. Edinburgh Genome Foundry
10. Liverpool GeneMill
11. London DNA Foundry
12. CDT in Bioprocess Engineering Leadership (UCL)
13. Synthetic Biology CDT (Oxford, Bristol & Warwick)

What was your organisation's relationship with the SBfG programme? (please select the most appropriate)

1. A spinout company resulting from SBfG programme funding awarded to one of the SBRCs, foundries or CDTs
2. A startup company, established independently of the SBfG programme, that received considerable support from one or more of the SBRCs, foundries or CDTs
3. A revenue-generating company that was a partner, collaborator or customer of one or more of the SBRCs or CDTs
4. A revenue-generating company that was a customer of one or more of the foundries
5. An academic or research performing institution that was a partner or collaborator in one or more research grants with one or more SBRCs or foundries

***– for the online survey, respondents were subsequently routed to the selected option***

## Spin-out Company

What year did you first access support with the centre?

What year did you spin out/incorporate?

When do you expect to begin trading, i.e. generating revenue?

What was the motivation to engage with the centre in the first place?

Did you consider alternatives? If so, which organisations and why?

What has been the nature of your engagement and support received through the SBfG programme?

Can you provide details on the key sectors where your technology, products, services are/will be deployed i.e. the sectors you operate within?

| | Please tick all that apply | Estimated % of (future) sales attributed to this sector |
|---|---|---|
| Research and development services (e.g., equipment, constructs, data) | | |
| Chemicals | | |
| Pharmaceuticals/therapeutics | | |
| Agriculture/agritech | | |
| Medical technology (e.g., devices, drug discovery) | | |
| Energy | | |
| Water management | | |
| Environment (monitoring and remediation) | | |
| Waste Management | | |
| Food and drink | | |
| Healthcare and cosmetics | | |
| Other, please specify below | | |

Other key sectors.

How much pre-revenue financial support and investment has your company raised to date?

| | Tick if Yes | Value (£) | Was this Single or Multiple award/funding? |
|---|---|---|---|
| SBfG | | | |
| Public sector/govt funding | | | |
| Private Investment | | | |
| Other funding, loans, awards | | | |
| Other | | | |

How much more investment do you forecast that you will need (and from what sources) before the company is able to begin trading?

| | Tick if Yes | Value (£) |
|---|---|---|
| Public sector/govt. funding | | |
| Private investment | | |
| Other funding, loans, awards | | |
| Other | | |

Thinking about the company that you spun out, what do you think would have/will happen if you had not engaged with the SBfG?

| | Tick if Yes | How many months delay AND/OR How much smaller in scope? |
|---|---|---|
| No difference to the timing or scope of the spin-out | | |
| Slightly delayed | | |
| Significantly delayed | | |
| Slightly smaller in scope | | |
| Significantly smaller in scope | | |
| No spin-out company at all | | |

Since spinning out in ${SO1} what has been, and what do you forecast will be, the business revenue and employment?

| | Business revenue created or safeguarded | FTE employment created or safeguarded (inc yourself) | Actual or Forecast |
|---|---|---|---|
| For ${SO1} | | | |
| +2 years | | | |
| +4 years | | | |
| +6 years | | | |
| +8 years | | | |

With regards your levels of employment...

| | Tick if Yes | Number FTE outside UK | Actual or Forecast |
|---|---|---|---|
| are any of these jobs based permanently outside the UK? | | | |

What do you think would have happened to the revenue and employment impacts if you had not been involved in the SBfG?

| | Revenue | | Employment | |
|---|---|---|---|---|
| | Actual impacts achieved to date | Forecast impacts (to 2029) | Actual impacts achieved to date | Forecast impacts (to 2029) |
| All the impacts would have occurred anyway (no attribution to the SBfG i.e. no change) | | | | |
| Most of the impacts would have occurred (<33% of impacts attributed to the SBfG) | | | | |
| Around half the impacts would have occurred (33% - 66% of impacts attributed to the SBfG) | | | | |
| Some of the impacts would have occurred (>66% of impacts attributed to the SBfG) | | | | |
| None of the impacts would have occurred (100% of impacts attributed to the SBfG | | | | |

Based on the previous question can you provide the specific values of these impacts?

| | Actual impacts achieved to date | Forecast impacts (to 2029) |
|---|---|---|
| Revenue (£) | | |
| Employment (FTE) | | |

What proportion of your **actual revenue** is based in the following locations? Please use the slider to allocate 100% across these areas.

- UK ___________
- Europe ___________
- Rest of World ___________

What proportion of your **forecast revenue** do you anticipate will be based in the following locations? Please use the slider to allocate 100% across these areas.

- UK ___________
- Europe ___________
- Rest of World ___________

Which of the following statements best describes the location of your competitors? If you are able to, please estimate a percentage value.

| | Tick if Yes | % in UK |
|---|---|---|
| All my competitors are based in the UK | | |
| The majority of my competitors are based in the UK | | |
| Around half of my competitors are based in the UK | | |
| A minority of my competitors are based in the UK | | |
| None of my competitors are based in the UK | | |

How would you describe the market for your main products or services since spinning out and what do you anticipate will happen in the future?

| | Growing strongly | Growing | Static | Declining | Declining strongly |
|---|---|---|---|---|---|
| Since spinning out in ${SO1} | | | | | |
| In the future (up to +8 years) | | | | | |

Considering your answers above, what were the 3 most important benefits from engaging with the centre(s)? You do not need to rank all in this list, just your top 3.

- Enhanced ability to attract R&D and/or business investment? __________
- Improved knowledge and understanding of Syn Bio / academic collaboration __________
- Increased commitment to R&D (increased BERD) __________
- Increased research profile (e.g. publications) __________
- Higher company profile in Syn Bio __________
- Strengthen ongoing research relationships __________
- New supply chain partners __________
- Other, please tell us below what this is __________

If you selected Other in the previous question, please tell us what the Other benefit is.

What, if any, unanticipated benefits did you gain from your interaction with the centre?

Would you work with the centre again?

1. Yes
2. No

Are there any capability gaps that you identified in the centre, or elsewhere in the UK?

If applicable, have you experienced issues (barriers) that have affected commercialisation timescales?

Any other comments?

Can we contact you again if we need to?

1. Yes
2. No

If Yes, please confirm your email address below:

## Startup Company

What year did you first access support with the centre?

What was the motivation to engage with the centre in the first place?

Did you consider alternatives? If so, which organisations and why?

What has been the nature of your engagement and support received through the SBfG programme?

Can you provide details on the key sectors where your technology, products, services are/will be deployed i.e. the sectors you operate within?

| | Please tick all that apply | Estimated % of (future) sales attributed to this sector |
|---|---|---|
| Research and development services (e.g., equipment, constructs, data) | | |
| Chemicals | | |
| Pharmaceuticals/therapeutics | | |
| Agriculture/agritech | | |
| Medical technology (e.g., devices, drug discovery) | | |
| Energy | | |
| Water management | | |
| Environment (monitoring and remediation) | | |
| Waste Management | | |
| Food and drink | | |
| Healthcare and cosmetics | | |
| Other, please specify below | | |

Other key sectors.

Since your initial engagement with SBfG, what type of and how much financial support and investment has your company raised to date, that specifically relates to your engagement activities?

| | Tick if Yes | Value (£) |
|---|---|---|
| SBfG | | |
| Research grant funding | | |
| Other public sector/govt. funding | | |
| Private investment | | |
| Other funding, loans, awards | | |
| Other | | |

Since your initial engagement with the SBfG programme in ${G1}, what has been, and what do you forecast will be, the revenue and employment impacts that can be directly attributed to your engagement?

| | Business revenue created or safeguarded | FTE employment created or safeguarded (inc yourself) | Actual or Forecast |
|---|---|---|---|
| For ${G1} | | | |
| +2 years | | | |
| +4 years | | | |
| +6 years | | | |
| +8 years | | | |

With regards your levels of employment attributed to the engagement activity...

| | Tick if Yes | Number FTE outside UK | Actual or Forecast |
|---|---|---|---|
| are any of these jobs based permanently outside the UK? | | | |

Thinking specifically about your engagement, what do you think would have happened to the Revenue and Employment impacts if you had not been involved in the SBfG?

| | Revenue | | Employment | |
|---|---|---|---|---|
| | Actual impacts achieved to date | Forecast impacts (to 2029) | Actual impacts achieved to date | Forecast impacts (to 2029) |
| All the impacts would have occurred anyway (no attribution to the SBfG i.e. no change) | | | | |
| Most of the impacts would have occurred (<33% of impacts attributed to the SBfG) | | | | |
| Around half the impacts would have occurred (33% - 66% of impacts attributed to the SBfG) | | | | |
| Some of the impacts would have occurred (>66% of impacts attributed to the SBfG) | | | | |
| None of the impacts would have occurred (100% of impacts attributed to the SBfG | | | | |

Based on the previous question can you provide the specific values of these impacts?

| | Actual impacts achieved to date | Forecast impacts (to 2029) |
|---|---|---|
| Revenue (£) | | |
| Employment (FTE) | | |

If the revenue and employment impacts would have happened anyway, do you think that the SBfG helped you to achieve these impacts faster or on a greater scale?

| | Revenue | Employment | How many months faster or How much greater in scope? |
|---|---|---|---|
| Impacts would have been/will be achieved slightly faster | | | |
| Impacts would have been/will be achieved significantly faster | | | |
| Impacts would have been/will be slightly greater in scope | | | |
| Impacts would have been/will be much greater in scope | | | |

What proportion of your actual revenue is based in the following locations? Please use the slider to allocate 100% across these areas.

- UK ___________
- Europe ___________
- Rest of World ___________

What proportion of your forecast revenue do you anticipate will be based in the following locations? Please use the slider to allocate 100% across these areas.

- UK ___________
- Europe ___________
- Rest of World ___________

Which of the following statements best describes the location of your competitors? If you are able to, please estimate a percentage value.

| | Tick if Yes | % in UK |
|---|---|---|
| All my competitors are based in the UK | | |
| The majority of my competitors are based in the UK | | |
| Around half of my competitors are based in the UK | | |
| A minority of my competitors are based in the UK | | |
| None of my competitors are based in the UK | | |

How would you describe the market for your main products or services over the last 3 years, and what do you anticipate will happen in the future?

| | Growing strongly | Growing | Static | Declining | Declining strongly |
|---|---|---|---|---|---|
| In the last 3 years | | | | | |
| In the future (up to +8 years) | | | | | |

Considering your answers above, what were the 3 most important benefits from engaging with the centre(s)? You do not need to rank all in this list, just your top 3.

- Enhanced ability to attract R&D and/or business investment? ___________
- Improved knowledge and understanding of Syn Bio / academic collaboration ___________
- Increased commitment to R&D (increased BERD) ___________
- Increased research profile (e.g. publications) ___________
- Higher company profile in Syn Bio ___________
- Strengthen ongoing research relationships ___________
- New supply chain partners ___________
- Other, please tell us below what this is ___________

If you selected Other in the previous question, please tell us what the Other benefit is.

What, if any, unanticipated benefits did you gain from your interaction with the centre?

Would you work with the centre again?

1. Yes
2. No

Are there any capability gaps that you identified in the centre, or elsewhere in the UK?

If applicable, have you experienced issues (barriers) that have affected commercialisation timescales?

Any other comments?

Can we contact you again if we need to?

1. Yes
2. No

If Yes, please confirm your email below:

## Industrial Collaborator

What year did you first engage with the centre?

| |
|---|
| |

What was the motivation to engage with the centre in the first place?

| |
|---|
| |

Did you consider alternatives? If so, which organisations and why?

| |
|---|
| |

What has been the nature of your engagement and support received through the SBfG programme?

| |
|---|
| |

Has your engagement already, or do you forecast it will lead to any of the following commercial outcomes?

| | Tick if Achieved to Date | Number | Tick if Forecast to be Achieved in the Future | Number | For FORECAST outcomes can you provide the year you expect to achieve these? | Tick if Not Applicable |
|---|---|---|---|---|---|---|
| Products/processes/services – launched in existing markets | | | | | | |
| Products/processes/services – launched in new markets | | | | | | |
| Patents applied for | | | | | | |
| Patents granted | | | | | | |
| Licences | | | | | | |
| Other commercial benefit – please specify | | | | | | |

Can you provide details on the key sectors where your technology, products, services are/will be deployed i.e. the sectors you operate within?

| | Please tick all that apply | Estimated % of (future) sales attributed to this sector |
|---|---|---|
| Research and development services (e.g., equipment, constructs, data) | | |
| Chemicals | | |
| Pharmaceuticals/therapeutics | | |
| Agriculture/agritech | | |
| Medical technology (e.g., devices, drug discovery) | | |
| Energy | | |
| Water management | | |
| Environment (monitoring and remediation) | | |
| Waste Management | | |
| Food and drink | | |
| Healthcare and cosmetics | | |
| Other, please specify below | | |

Other key sectors.

| |
|---|
| |

How much monies have you invested and/or raised to date as a result of your initial engagement with SBfG?

| | Tick if Yes | Please provide details |
|---|---|---|
| Committed own income and in-kind support (£ value) | | |
| Funded a PhD student (no. / £ value) | | |
| Research grant funding | | |
| Other public sector/government funding | | |
| Private investment | | |
| Other funding, loans, awards | | |
| Other | | |

Since your initial R&D collaboration in ${G1}, what has been, and what do you forecast will be, the revenue and employment impacts that can be directly attributed to your collaboration?

| | Business revenue created or safeguarded | FTE employment created or safeguarded (inc yourself) | Actual or Forecast |
|---|---|---|---|
| For start | | | |
| +2 years | | | |
| +4 years | | | |
| +6 years | | | |
| +8 years | | | |

With regards to employment attributed to the collaboration activity...

| | Tick if Yes | Number FTE outside UK | Actual or Forecast |
|---|---|---|---|
| are any of these jobs based permanently outside the UK? | | | |

Thinking specifically about the R&D collaboration you undertook through the SBfG programme, what do you think would have happened to the Revenue and Employment impacts if you had not been involved in the SBfG?

| | Revenue | | Employment | |
|---|---|---|---|---|
| | Actual impacts achieved to date | Forecast impacts (to 2029) | Actual impacts achieved to date | Forecast impacts (to 2029) |
| All the impacts would have occurred anyway (no attribution to the SBfG i.e. no change) | | | | |
| Most of the impacts would have occurred (<33% of impacts attributed to the SBfG) | | | | |
| Around half the impacts would have occurred (33% - 66% of impacts attributed to the SBfG) | | | | |
| Some of the impacts would have occurred (>66% of impacts attributed to the SBfG) | | | | |
| None of the impacts would have occurred (100% of impacts attributed to the SBfG | | | | |

Based on the previous question can you provide the specific values of these impacts?

| | Actual impacts achieved to date | Forecast impacts (to 2029) |
|---|---|---|
| Revenue (£) | | |
| Employment (FTE) | | |

If the revenue and employment impacts would have happened anyway, do you think that the SBfG helped you to achieve these impacts faster or on a greater scale?

| | Revenue | Employment | How many months faster or How much greater in scope? |
|---|---|---|---|
| Impacts would have been/will be achieved slightly faster | | | |
| Impacts would have been/will be achieved significantly faster | | | |
| Impacts would have been/will be slightly greater in scope | | | |
| Impacts would have been/will be much greater in scope | | | |

What proportion of your actual revenue is based in the following locations? Please use the slider to allocate 100% across these areas.

- UK ___________
- Europe ___________
- Rest of World ___________

What proportion of your forecast revenue do you anticipate will be based in the following locations? Please use the slider to allocate 100% across these areas.

- UK ___________
- Europe ___________
- Rest of World ___________

Which of the following statements best describes the location of your competitors (by market share)? If you are able to, please estimate a percentage value.

| | Tick if Yes | % in UK |
|---|---|---|
| All my competitors are based in the UK | | |
| The majority of my competitors are based in the UK | | |
| Around half of my competitors are based in the UK | | |
| A minority of my competitors are based in the UK | | |
| None of my competitors are based in the UK | | |

How would you describe the market for the products, processes, and services that were developed through the R&D collaboration, and what do you anticipate will happen in the future

| | Growing strongly | Growing | Static | Declining | Declining strongly |
|---|---|---|---|---|---|
| Since start | | | | | |
| In the future (up to +8 years) | | | | | |

Considering your answers above, what were the 3 most important benefits from engaging with the centre(s)? You do not need to rank all in this list, just your top 3.

- Enhanced ability to attract R&D and/or business investment? ___________
- Improved knowledge and understanding of Syn Bio / academic collaboration ___________
- Increased commitment to R&D (increased BERD) ___________
- Increased research profile (e.g. publications) ___________
- Higher company profile in Syn Bio ___________
- Strengthen ongoing research relationships ___________
- New supply chain partners ___________
- Other, please tell us below what this is ___________

If you selected Other in the previous question, please tell us what the Other benefit is.

| |
|---|
| |

What, if any, unanticipated benefits did you gain from your interaction with the centre?

Would you work with the centre again?

1. Yes
2. No

Are there any capability gaps that you identified in the centre, or elsewhere in the UK?

If applicable, have you experienced issues (barriers) that have affected commercialisation timescales?

Any other comments?

Can we contact you again if we need to?

1. Yes
2. No

If Yes, please confirm your email address below:

## Customer of a Foundry

What year did you first access support with the centre?

What was the motivation to engage with the centre in the first place?

Did you consider alternatives? If so, which organisations and why?

What has been the nature of your engagement and support received through the SBfG programme?

What is the total value (e.g. contract value) of all your engagement activity to date?

| | Start date (DD/MM/YY) | End date (DD/MM/YY) | Value | Institution |
|---|---|---|---|---|
| Contract 1 | | | | |
| Contract 2 | | | | |
| Contract 3 | | | | |

As a result of engaging with the DNA foundries, has this already, or do you forecast it will lead to any of the following commercial outcomes?

| | Tick if Achieved to Date | Number | Tick if Forecast to be Achieved in the Future | Number | For FORECAST outcomes can you provide the year you expect to achieve these? | Tick if Not Applicable |
|---|---|---|---|---|---|---|
| Products/processes/services – launched in existing markets | | | | | | |
| Products/processes/services – launched in new markets | | | | | | |
| Patents applied for | | | | | | |
| Patents granted | | | | | | |
| Licences | | | | | | |
| Other commercial benefit – please specify | | | | | | |

Can you provide details on the key sectors where your technology, products, services are/will be deployed i.e. the sectors you operate within?

| | Please tick all that apply | Estimated % of (future) sales attributed to this sector |
|---|---|---|
| Research and development services (e.g., equipment, constructs, data) | | |
| Chemicals | | |
| Pharmaceuticals/therapeutics | | |
| Agriculture/agritech | | |
| Medical technology (e.g., devices, drug discovery) | | |
| Energy | | |
| Water management | | |
| Environment (monitoring and remediation) | | |
| Waste Management | | |
| Food and drink | | |
| Healthcare and cosmetics | | |
| Other, please specify below | | |

Other key sectors.

| |
|---|
| |

Since your initial engagement with SBfG, what type of and how much financial support and investment has your company raised to date, that specifically relates to your engagement activities?

| | Tick if Yes | Value (£) |
|---|---|---|
| SBfG | | |
| Research grant funding | | |
| Other public sector/govt. funding | | |
| Private investment | | |
| Other funding, loans, awards | | |
| Other | | |

Since your initial collaboration with the DNA foundry in ${G1}, what has been and what do you forecast will be the business revenue and employment impacts that can be directly attributed to your engagement?

| | Business revenue created or safeguarded | FTE employment created or safeguarded (inc yourself) | Actual or Forecast |
|---|---|---|---|
| For ${G1} | | | |
| +2 years | | | |
| +4 years | | | |
| +6 years | | | |
| +8 years | | | |

With regards your levels of employment attributed to the engagement activity...

| | Tick if Yes | Number FTE outside UK | Actual or Forecast |
|---|---|---|---|
| are any of these jobs based permanently outside the UK? | | | |

Thinking specifically about the collaboration you undertook with the DNA foundry and subsequent commercial activity, what do you think would have happened to the Revenue and Employment impacts if you had not been involved in the SBfG?

| | Revenue | | Employment | |
|---|---|---|---|---|
| | Actual impacts achieved to date | Forecast impacts (to 2029) | Actual impacts achieved to date | Forecast impacts (to 2029) |
| All the impacts would have occurred anyway (no attribution to the SBfG i.e. no change) | | | | |
| Most of the impacts would have occurred (<33% of impacts attributed to the SBfG) | | | | |
| Around half the impacts would have occurred (33% - 66% of impacts attributed to the SBfG) | | | | |
| Some of the impacts would have occurred (>66% of impacts attributed to the SBfG) | | | | |
| None of the impacts would have occurred (100% of impacts attributed to the SBfG | | | | |

Based on the previous question can you provide the specific values of these impacts?

| | Actual impacts achieved to date | Forecast impacts (to 2029) |
|---|---|---|
| Revenue (£) | | |
| Employment (FTE) | | |

If the revenue and employment impacts would have happened anyway, do you think that the SBfG helped you to achieve these impacts faster or on a greater scale?

| | Revenue | Employment | How many months faster or How much greater in scope? |
|---|---|---|---|
| Impacts would have been/will be achieved slightly faster | | | |
| Impacts would have been/will be achieved significantly faster | | | |
| Impacts would have been/will be slightly greater in scope | | | |
| Impacts would have been/will be much greater in scope | | | |

What proportion of your actual revenue is based in the following locations? Please use the slider to allocate 100% across these areas.

- UK __________
- Europe __________
- Rest of World __________

What proportion of your forecast revenue do you anticipate will be based in the following locations? Please use the slider to allocate 100% across these areas.

- UK __________
- Europe __________
- Rest of World __________

Which of the following statements best describes the location of your competitors (by market share)? If you are able to, please estimate a percentage value.

| | Tick if Yes | % in UK |
|---|---|---|
| All my competitors are based in the UK | | |
| The majority of my competitors are based in the UK | | |
| Around half of my competitors are based in the UK | | |
| A minority of my competitors are based in the UK | | |
| None of my competitors are based in the UK | | |

How would you describe the market for the products, processes, and services that were developed through the DNA foundry collaboration, and what do you anticipate will happen in the future?

| | Growing strongly | Growing | Static | Declining | Declining strongly |
|---|---|---|---|---|---|
| Since ${G1} | | | | | |
| In the future (up to +8 years) | | | | | |

Considering your answers above, what were the 3 most important benefits from engaging with the centre(s)? You do not need to rank all in this list, just your top 3.

- Enhanced ability to attract R&D and/or business investment? __________
- Improved knowledge and understanding of Syn Bio / academic collaboration __________
- Increased commitment to R&D (increased BERD) __________
- Increased research profile (e.g. publications) __________
- Higher company profile in Syn Bio __________
- Strengthen ongoing research relationships __________
- New supply chain partners __________
- Other, please tell us below what this is __________

If you selected Other in the previous question, please tell us what the Other benefit is.

| |
|---|
| |

What, if any, unanticipated benefits did you gain from your interaction with the centre?

Would you work with the centre again?
1. Yes
2. No

Are there any capability gaps that you identified in the centre, or elsewhere in the UK?

If applicable, have you experienced issues (barriers) that have affected commercialisation timescales?

Any other comments?

Can we contact you again if we need to?
1. Yes
2. No

If Yes, please confirm your email address below:

## Academics

What year did you first engage with the centre?

| |
|---|
| |

What was the motivation to engage with the centre in the first place?

| |
|---|
| |

Did you consider alternatives? If so, which organisations and why?

| |
|---|
| |

How much research funding was secured for your organisation as a result of the engagement with the SBfG centre(s)?

| |
|---|
| |

Did engagement with the centre(s) increase in research output? If Yes, please tell us in what way/by how much?

1. No
2. Yes, please provide details ___________

Did engagement with the centre(s) extend your research activity into new areas? If Yes, please tell us which areas and what were the benefits?

1. No
2. Yes, please provide details ___________

Did engagement with the centre(s) enhance the breadth or quality of your research activities? If Yes, please tell us how.

1. No
2. Yes, please tell us how ___________

Did engagement with the centre(s) enable new research collaborations?

| | Tick if Yes | Who with? | What did specific research collaborations result in? |
|---|---|---|---|
| With other academic groups | | | |
| With external public organisations | | | |
| With industry | | | |
| Other | | | |

In terms of the impacts you have described above, what would have happened without this engagement with the SBfG-funded centre?

1. All the impacts would have occurred
2. Most (>66%) of the impacts would have occurred
3. Around half (33% - 66%) of the impacts would have occurred
4. Some (<33%) of the impacts would have occurred
5. None of the impacts would have occurred

Would you work with the centre again?

1. Yes
2. No

Are there any capability gaps that you identified in the centre, or elsewhere in the UK?

| |
|---|
| |

Any other comments?

| |
|---|
| |

Can we contact you again if we need to?

1. Yes
2. No

If Yes, please confirm your email address below:

| |
|---|
| |

# Appendix C: Stakeholder emails

Stakeholders, where contact details were available, received the following email (highlighted text was edited appropriately for each recipient):

Dear [NAME],

Optimat Ltd. has been commissioned by UK Research and Innovation (UKRI) to evaluate the Synthetic Biology for Growth (SBfG) Programme. This programme represents investments of £114 million and ran between 2014 and 2022. It supported six synthetic biology research centres, DNA foundry capability in six academic institutions and two centres for Doctoral training. As a [SPINOUT/PARTNER/CUSTOMER] of [CENTRE NAME] we would like to arrange a convenient time to speak with you to understand the benefits your [COMPANY/RESEARCH GROUP/INSTITUTION] has derived from the centre and the extent to which this is still important to you.

The purpose of the interview is to gather qualitative and quantitative data to inform an economic impact modelling and analysis, identify potential case studies that illustrate the benefits that the UK's company base has derived from the SBfG programme and to inform future government strategy. The interview will be structured around the following topics and last no more than one hour:

- Your relationship with the centre
- Tangible outcomes from the interaction
- Impact on your [BUSINESS/RESEARCH ACTIVITIES] going forward
- What would have happened without this interaction
- Your overall views on the centre and the wider SBfG programme (if relevant)

We will send a full list of questions and discussion topics prior to the interview. All information, including partial data and estimates that you are able to provide, will support a more robust overall economic analysis of the SBfG programme.

A report will be produced using the aggregated results of this interview programme. No individual organisation will be identified in this report without their specific written permission and no identifiable organisation level data, opinions, etc., will be included within its contents. By taking part in this research, you agree to the use of your anonymised data for this research. You have the right to withdraw consent at any time.

Participation in this study is completely voluntary. The data collected via this interview programme will be processed by market research consultant Optimat Ltd. All data will be held securely in line with the data privacy policies of Optimat and UKRI. Their respective privacy policies are available on request.

I hope that you and/or other colleagues will be available to participate and would be grateful if you could suggest some convenient dates and times over the coming weeks for an MS Teams meeting.

Thank you for your time and please get in touch if you have any questions.

Best regards,

Where there was no response or no contact details available, the relevant SBfG centre contact was approached to assist in making contact with the identified organisation and provided with the following cover email. This was necessary to avoid GDPR issues.

Dear [NAME],

As a previous partner of [CENTRE NAME] we would like to invite you to complete an online survey that seeks to evaluate the UK's Synthetic Biology for Growth (SBfG) Programme. This programme represents investments of £114 million and ran between 2014 and 2022. It supported six synthetic biology research centres (SBRCs), DNA foundry capability in six academic institutions and two centres for Doctoral training (CDTs).

The purpose of this survey is to assess the impacts that the SBfG programme has had on the UK's economy and its research and innovation ecosystem. This will assess actual impacts (since 2014) and forecast impacts (to 2029). The survey has been commissioned by UK Research and Innovation (UKRI) and is being delivered by Optimat Ltd.

The survey should take around 15 minutes to complete and is available via this link.

Thank you for your help in this. If you have any questions, then please contact Mark Morrison at Optimat

Best regards,

**Counterfactual stakeholder group**

The following email was sent to UK academics that are active in synthetic biology research, but were not funded under the SBfG programme:

Dear [NAME],

Optimat Ltd. has been commissioned by UK Research and Innovation (UKRI) to evaluate the Synthetic Biology for Growth (SBfG) Programme. As an active researcher in synthetic biology, although not a direct recipient of SBfG Programme funding, we would be interested in hearing your opinion of the programme and the current status of synthetic biology research in the UK.

The purpose of the interview is to gather qualitative and quantitative data to inform an economic impact modelling and analysis and to inform future government strategy in engineering biology funding. The interview will be structured around the following topics and last no more than one hour:

- Sources of funding you have received for synthetic biology research, e.g., UK, EU, industry
- Outcomes and impacts on your research group and institution as a result of funding
- Any experience you have had with the SBfG programme or funded centres
- Your opinion of the synthetic/engineering biology landscape in the UK now, compared with the situation before SBfG, and how this compares with international competitors
- Your opinion of the future National Engineering Biology Programme and what needs to happen next, to deliver success for the UK's synthetic / engineering biology capability

A report will be produced using the aggregated results of this interview programme. No individual organisation will be identified in this report without their specific written permission and no identifiable organisation level data, opinions, etc., will be included within its contents. By taking part in this research, you agree to the use of your anonymised data for this research. You have the right to withdraw consent at any time.

Participation in this study is completely voluntary. The data collected via this interview programme will be processed by market research consultant Optimat Ltd. All data will be held securely in line with the data privacy policies of Optimat and UKRI. Their respective privacy policies are available on request.

I hope that you and/or other colleagues will be available to participate and would be grateful if you could suggest some convenient dates and times over the coming weeks for an MS Teams meeting.

Thank you for your time and please get in touch if you have any questions.

Best regards,

## Appendix D:Stakeholder database

Key: Co – collaborator, Cu – customer, Mu – multiple, Ot – other, Pa – partner, SAB – scientific advisory board, Sp – spinout/startup, Un – unknown

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AB Agri | Company - UK | | | | Co | | | | | | |
| AB Sugar | Company - international | | | Un | | | | | | | |
| Aberystwyth University | Academic - UK | | | | | | | | | Cu | |
| ABinBev | Company - international | | | | | Co | | | | | |
| Abolis | Company - international | | | | | Co | | | | | |
| Acea Pinerolese Industriale Spa | Academic - non-UK | | | | Co | | | | | | |
| Achaogen (liquidation) | Company - international | | | | | Co | | | | | |
| Adaptive Diagnostics | Spinout/start-up | | | | | | Sp | | | | |
| Aeirtec | Company - UK | | | | | Co | | | | | |
| Africa's first synthetic biology centre in Uganda | Academic - non-UK | | Co | | | | | | | | |
| Agilent | Company - international | | | | | Mu | | | | Cu | |
| Airbus | Company - international | | | | | Co | | | | | |
| Alan Turing Institute | Academic - UK | | | Co | | | | | | | |
| Alborada Drug Discovery Institute, University of Cambridge | Academic - UK | | Co | | | | | | | | |
| Alder Hey Children's NHS Foundation Trust | Academic - UK | | | | | | | | | Cu | |
| Algenuity | Company - UK | | | | | Co | | | | | |
| Allergan Pharmaceuticals (now AbbieVie) | Company - international | | | | Co | Co | | | | | |
| Amgen | Company - international | | | | | Co | | | | | |
| Amyris | Company - international | | | Un | | Co | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Anheuser-Busch InBev | Company - international | | | | | Co | | | | | |
| Aptalink | Spinout/start-up | | Sp | | | | | | | | |
| Arecor | Company - UK | | | | | Co | | | | | |
| ARM | Company - UK | | | | | Co | | | | | |
| Asja Ambiente Italia Spa | Company - international | | | | Co | | | | | | |
| AskBio | Company - UK | | Cu | | | | | | Cu | | |
| Aspen Neuroscience | Company - international | | O | | | | | | | | |
| AstraZeneca | Company - UK | Cu | Un | | | Co | | | | | |
| Autodesk | Company - international | | Co | | | | | | | | |
| Autolus | Company - UK | | | | | Co | | | | | |
| AzkoNobel | Company - international | | | | | Co | | | | | |
| Badrilla | Company - UK | | | | | | | | | Cu | |
| BAE Systems | Company - UK | | | | | Co | | | | | |
| BaoSteel | Company - international | | | | Co | | | | | | |
| BASF | Company - international | | | Un | Co | Co | Co | | | | |
| BDS Biofuels | Company - UK | | | | | Co | | | | | |
| Beneficial Bio | Spinout/start-up | | | Sp | | | | | | | |
| Better Dairy | Spinout/start-up | | | | | | | | | | Cu |
| BGI | Academic - non-UK | | Pa | | | | | | Pa | | |
| Biocatalysts | Company - UK | | | Pa | | | | | | | |
| Biochemistry and Plant Molecular Physiology | Academic - non-UK | | | Co | | | | | | | |
| Bio-Environmental Solutions | Company - UK | | | | | SAB | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Biomakespace | Other | | | Co | | | | | | | |
| Biomar | Company - UK | | | | Co | | | | | | |
| Biome Plastics | Company - UK | | | | Co | | | | | Cu | Cu |
| BioMedValley | Company - international | | | | Co | | | | | | |
| BioOrbic | Academic - non-UK | | | | Co | | | | | | |
| Bioserve (Reprocell company) | Company - international | Cu | | | | | | | | | |
| Borregaard | Company - international | | | | Co | | | | | | |
| Boston University Biological Design Center | Academic - non-UK | | | | | | Mu | | | | |
| BP | Company - UK | Cu | | | | | | | | | |
| British Standards Institute (BSI) | Other | | Co | SAB | | Co | | | | | |
| Bruker Corporation, Germany | Company - international | Co | | | | | | | | | |
| Bruker UK Ltd, United Kingdom | Company - UK | Pa | | | | | | | | | |
| Buddi | Company - UK | | | | | Co | | | | | |
| C3 Biotech | Spinout/start-up | | | | | Sp | | | | | |
| California Institute of Technology | Academic - non-UK | | | | | | SAB | | | | |
| Calysta | Company - international | | | | Co | | | | | | |
| Cambridge company to screen antigens | Company - UK | | | | | | | Cu | | | |
| Cambridge Glycoscience Ltd | Company - UK | | | Un | | | | | | | |
| Carbometrics | Spinout/start-up | Cu | | | | | | | | | |
| CCBio | Spinout/start-up | | | | | Co | | | | | |
| CDotBio | Spinout/start-up | Sp | | | | | | | | | |
| Cell and Gene Therapy Catapult | Other | | Co | | | | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cellinta | Spinout/start-up | | Sp | | | | | | | | |
| Chain Biotechnology | Spinout/start-up | | | | Cu | | | | | | |
| Charles River | Company - UK | | SAB | | | | | | | | |
| Chinese Academy of Sciences (CAS) | Academic - non-UK | | | | | SAB | | | | | |
| Chinese Academy of Sciences (Institute of Microbiology) | Academic - non-UK | | | | | | Co | | | | |
| CNRS | Academic - non-UK | | | Co | | | | | | | |
| Cobra Biologics | Company - UK | | | | | Co | | | | | |
| Colorado State University | Academic - non-UK | | Co | | | | | | | | |
| Colorifix | Spinout/start-up | | | Sp | | | | Cu | | | |
| Concinnity Genetics | Spinout/start-up | | Sp | | | | | | | | |
| Consejo Superior de Investigaciones Cientificas CSIC) | Academic - non-UK | | | Co | | | Mu | | | | |
| Corbion-Purac | Company - international | | | | Co | | | | | | |
| CPI | Other | | | | | Co | | | | Cu | |
| CroBio | Spinout/start-up | | | | | | | | | Cu | |
| Croda | Company - UK | | | Pa | | Co | Co | | | Cu | |
| Cyanetics | Spinout/start-up | | | | Co | | | | | | |
| Cypex (now BioIVT) | Spinout/start-up | | | | | Co | | | | | |
| Cytecom | Spinout/start-up | | | | | | Sp | | | | |
| Cytoseek | Spinout/start-up | Sp | | | | | | | | | |
| DARPA | Other | | | | | Co | | | | | |
| DeepBranch | Spinout/start-up | | | | Mu | | | | | | |
| Demuris | Spinout/start-up | | | | | Co | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dept. of Energy Joint Genome Institute | Academic - non-UK | | | | | | Co | | | | |
| DGS Antibodies | Company - UK | | Cu | | | | | | | | |
| Dhampur Sugar Mills L | Company - international | | | | Co | | | | | | |
| DNA2.0 (ATUM) | Company - international | | | | Co | | SAB | | | | |
| DRAX | Company - UK | | | | Co | | | | | | |
| DrReddys | Company - international | | | | | Co | | | | | |
| DSM | Company - international | | | | | Co | | | | | |
| Dstl | Other | O | O | | | Co | | | | | |
| Eden Bio | Spinout/start-up | | | | | | | | | | Sp |
| Elsom Seeds | Company - UK | | | Un | | | | | | | |
| Entomics (now better origin) | Company - UK | | | Un | | | | | | | |
| Enza Zaden | Company - international | | | | | Co | | | | | |
| Enzbond | Spinout/start-up | | | | | | | | | | Cu |
| Epoch Biodesign | Company - UK | | | | | | | | | Cu | |
| Erebagen | Spinout/start-up | | | | | | Sp | | | | |
| Esox Biologics | Spinout/start-up | | | | | | | | | | Cu |
| ETH Zurich | Academic - non-UK | | | | | SAB | | | | | |
| Evolva | Company - international | | | | | Co | | | | | |
| Evonetix | Spinout/start-up | | | | | | | | | Cu | |
| Eyam Therapeutics | Company - international | | Cu | | | | | | | | |
| Folium Science | Spinout/start-up | Cu | | | Co | | | | | | |
| Foresee Pharmaceuticals | Company - international | | Un | | | | | | | | |

| **Organisation** | **Organisation Type** | **BrisSynBio** | **Mammalian SynthSys** | **Open-Plant** | **SBRC Nottingham** | **SynBioChem** | **WISB** | **Earlham Biofoundry** | **Edinburgh Genome Foundry** | **GeneMill** | **London DNA Foundry** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Freeland Horticulture | Company - UK | | | | Co | | | | | | |
| FujiFilm Cellular Dynamics Incorporated | Company - international | | Un | | | | | | | | |
| Fujifilm Diosynth Biotechnologies UK | Company - UK | | Cu | | | Co | | | | | |
| GE Healthcare | Company - UK | Cu | | | | | | | | | |
| Gemini Biosciences Ltd | Company - UK | | | | | | | | | Cu | |
| GeneTech | Company - international | | | | | Co | | | | | |
| Genome Research Limited (Wellcome Sanger) | Company - UK | | | | | Co | | | | | |
| Ghent University | Academic - non-UK | | | Pa | | | | | | Cu | |
| Ginkgo Bioworks | Company - international | | | SAB | | SAB | | | | | |
| Glaia | Spinout/start-up | Sp | | | | | | | | | |
| GlaxoSmithKline | Company - UK | Mu | Un | | SAB | Mu | Co | | | | |
| Global Biofoundries Alliance | Other | | | | | Pa | | | | | |
| Goodfellows | Company - UK | | | | Co | | | | | | |
| GranBio | Company - international | | | | Co | | | | | | |
| Green Biologics | Spinout/start-up | | | | Co | | SAB | | | | |
| Green Fuels | Company - UK | | | | Co | | | | | | |
| Greenskill Ltd | Company - UK | | | | Co | | | | | | |
| Halo Therapeutics | Spinout/start-up | Sp | | | | | | | | | |
| Hamilton | Company - international | | | | | Un | | | | | |
| Hart Innovations | Company - UK | | | | | Co | | | | | |
| Harvard & MIT | Academic - non-UK | | SAB | | | | | | | | |
| Hebrew University of Jerusalem | Academic - non-UK | | Co | | | | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heinrich Heine University Dusseldorf | Academic - non-UK | | Co | | | | | | | | |
| Heriot-Watt University | Academic - UK | | | | | | | | | Cu | |
| Hexagon Bio | Company - international | | | | | Co | | | | | |
| Holiferm | Spinout/start-up | | | | | Co | | | | | |
| Horizon Discovery | Company - UK | | Un | | | | | | | | |
| HotHouse Bio (Hothouse Therapeutics) | Spinout/start-up | | | Sp | | | | | | | |
| Humane Technologies | Spinout/start-up | | | | | | Co | | | | |
| Huvepharma | Company - international | | | | Co | | | | | | |
| Hydrogenics Europe | Company - international | | | | Co | | | | | | |
| Hypha Discovery | Company - UK | Un | | | | Co | | | | | |
| Hysytech S.R.L | Company - international | | | | Co | | | | | | |
| IBioIC | Other | | | | | Co | | | | | |
| Iceni Diagnostics (Iceni Glycoscience) | Spinout/start-up | | | Sp | | | | | | | |
| Imophoron | Spinout/start-up | Sp | | | | | | | | | |
| Imperagen | Spinout/start-up | | | | | Sp | | | | | |
| Imperial College London | Academic - UK | Co | Co | | | Co | | | Co | Cu | |
| India Oil | Company - international | | | | Co | | | | | | |
| Ingenza | Company - UK | | Cu | | Co | | Mu | | | | |
| Institute of Food Research | Academic - UK | | | Pa | | | | | | | |
| Integrated DNA Technologies | Company - international | | Un | | | | | | | | |
| Intelligent Synthetic Biology Centre of Korea | Academic - non-UK | | Co | | | | | | | | |
| Interdisciplinary Research Centre | Academic - UK | | | O | | | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| International Gene Synthesis Consortium | Other | | Co | | | | | | | | |
| International Livestock Research Institute | Academic - non-UK | | | | | | | | | Cu | |
| Invista | Company - international | | | | Co | | | | | | |
| Invista | Company - UK | | | | | | | | | Cu | |
| Ionscope | Company - UK | | | Mu | | | | | | | |
| IPSEN Pharmaceuticals | Company - international | | | | Co | | | | | | |
| Isomerase Therapeutics | Spinout/start-up | | | | | | Co | | | | |
| John Innes Centre | Academic - UK | | Co | Pa | | | SAB | Pa | | | |
| Johnson & Johnson Ltd | Company - UK | | Un | | | | | | | | |
| Johnson Matthey | Company - UK | | | | SAB | | | | | | |
| Joint Genome Institute | academic - non-UK | | | | | | | | | Cu | |
| Kazusa DNA Research Institute (Kisarazu, Japan) | Academic - non-UK | | Co | | | | | | | | |
| Keele University | Academic - UK | | Co | Co | | | | | | | |
| Keio University | Academic - non-UK | | Co | | | | | | | | |
| Kenya Medical Research Institute | Academic - non-UK | Co | | | | | | | | | |
| King's College London | Academic - UK | | | | | | | | | Cu | |
| Krajate Gmbh | Company - international | | | | Co | | | | | | |
| KU Leuven | Academic - non-UK | Pa | | | | | | | | Cu | |
| LabCyte | Company - international | | Un | | | Co | | | | | |
| Lancaster University | Academic - UK | | | | | | | | | Cu | |
| Lanzatech | Company - international | | | | Co | | | | | | |
| Leaf Systems International | Spinout/start-up | | | Sp | | | | Cu | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lokmangal Agro Industries | Company - international | | | | Co | | | | | | |
| Lonza | Company - international | | Un | | | Co | | | | | |
| Lubrizol | Company - UK | | | | Co | | | | | | |
| Lucideon | Company - UK | Un | | | | | | | | | |
| Ludger | Company - UK | | | Pa | | | | | | | |
| Lutra | Company - UK | | | | Co | | | | | | |
| Macquarie University | Academic - non-UK | | Co | | | | | | | | |
| Manchester Biofactory (liquidation) | Spinout/start-up | | | | | Sp | | | | | |
| Mara Inc | Spinout/start-up | | | | | | Co | | | | |
| Matter | Other | | | | | SAB | | | | | |
| Max Planck Society | Other | O | | | | | | | | | |
| Medicago (now bust) | Company - international | | | Pa | | | | | | | |
| MedImmune (now AZ) | Company - UK | | | | | Co | | | | | |
| Metabolic Explorer | Company - international | | | | Co | | | | | | |
| Michigan State University | Academic - non-UK | | | Co | | | | | | | |
| Microsoft Research | Company - international | Cu | | | | | Mu | | | | |
| MIT / Broad Institute | Academic - non-UK | Pa | | | | | | | | | |
| Multus Biotechnology | Company - UK | | | | | | | | | | Cu |
| National Institute of Biology | Academic - non-UK | | | Co | | | | | | | |
| National University of Singapore | Academic - non-UK | | Pa | | | | | | | | |
| NCI (Bethesda, USA) | Other | | Un | | | | | | | | |
| NIZO Food Research | Company - international | | | | Co | | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Norfolk Plant Sciences | Company - UK | | | Pa | | | | | | | |
| Northwestern University | Academic - non-UK | | | | | | Co | | | | |
| Nourish Ingredients | Company - international | | | | | | | Cu | | | |
| Nova Pangaea | Company - UK | | | | Co | | | | | | |
| Novozymes | Company - international | | | | | | Co | | | | |
| NPL | Other | | Co | | | | | | | | |
| Nuclera | Company - UK | | | | | | | Pa | | | |
| Nvidia | Company - international | Un | | | | | | | | | |
| NYU Langhone Medical Centre | Academic - non-UK | | | | | | Co | | | | |
| OGI BIO | Spinout/start-up | | Sp | | | | | | | | |
| Oracle | Company - international | Cu | | | | | | | | | |
| Oregon Health and Science University | Academic - non-UK | | Co | | | | | | | | |
| Pacific Biosciences | Company - international | | | | | Co | | | | | |
| Persephone Bio | Spinout/start-up | | | Sp | | | | | | | |
| Pfizer | Company - UK | | | | | Co | | | | | |
| PhaseBiolabs | Spinout/start-up | | | | Sp | | | | | | |
| Phenotypeca | Spinout/start-up | | | | Co | | | | | | |
| Philipps-Universität Marburg (SYNMIKRO) | Academic - non-UK | | | | | | Mu | | | | |
| Photanol BV | Company - international | | | | Co | | | | | | |
| PlantCode | Spinout/start-up | | | Sp | | | | | | | |
| Prozomix | Company - UK | | | Pa | | Co | | | | | |
| Puraffinity | Company - UK | | | | | | | | | | Cu |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Purespring Therapeutics | Spinout/start-up | Cu | | | | | | | | | |
| Quadram Institute Bioscience | Academic - UK | | | Co | | | | Pa | | | |
| Rebio | Spinout/start-up | | | | Co | | | | | | |
| Research Council of Norway | Other | | Co | | | | | | | | |
| Revance Pharmaceuticals | Company - international | | | | Co | | | | | | |
| Revena | Other | O | | | | | | | | | |
| Rosa Biotech (liquidation) | Spinout/start-up | Sp | | | | | | | | | |
| Roslin Cells | Company - UK | | Un | | | | | | | | |
| Rothamsted Research | Academic - UK | | | Co | | | | | | | |
| Royal Netherlands Academy of Arts and Sciences | Other | | Co | | | | | | | | |
| Royce Institute | Academic - UK | | | | | Co | | | | | |
| Sartorius | Company - international | | Cu | | | | | | | | |
| Sasol | Company - international | | | | Co | | | | | | |
| Scarlet Therapeutics | Spinout/start-up | Sp | | | | | | | | | |
| Scientific Institute for Public Health Belgium | Academic - non-UK | | | | | SAB | | | | | |
| Scindo | Spinout/start-up | | | | | | | | | | Cu |
| Selex-ES | Company - international | | Un | | | | | | | | |
| Shanghai Institute of Biological Sciences | Academic - non-UK | | | | Co | | | | | | |
| Shanghai Jiao Tong University | Academic - non-UK | Co | | | | | | | | | |
| Shell | Company - UK | | Un | | | Co | | | | | |
| Shellworks | Company – UK | | | | | | | | | | Cu |
| Siemens | Company - international | | | | Co | | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Silico Life | Company - international | | | | Co | | | | | | |
| Singer | Company - international | | | | | Co | | | | | |
| SNIPR Biome | Company - international | | | | Co | | | | | | |
| South Korea (Intelligent Synthetic Biology Centre) | Academic - non-UK | | Co | | | | | | | | |
| Sphere Fluidics | Company - UK | | Un | Un | | Co | | | | | |
| Stanford University | Academic - non-UK | | | SAB | | | | | | | |
| State University of Campinas | Academic - non-UK | | | Co | | | | | | | |
| Summit PLC | Company - UK | | | | Co | | | | | | |
| Syngenta International AG | Company - international | Co | | | | Mu | Co | | | | |
| Syngenta Ltd, United Kingdom | Company - UK | | | Pa | | | | O | | | |
| Synthace | Company - UK | | | SAB | | Co | | | | | |
| Tata Steel | Company - international | | | | Co | | Co | | | | |
| Tecan | Company - international | | Un | | | | | | | | |
| Technical University Darmstadt | Academic - non-UK | | | Co | | | | | | | |
| Telethon Institute for Genetics and Medicine (IT) | Academic - non-UK | Pa | | | | | | | | | |
| The BioRoBoost Consortium | Other | | Co | | | | | | | | |
| The Smarter Food Company Limited | Spinout/start-up | | | Sp | | | | | | | |
| ThermoFisher | Company - UK | | Un | | | Mu | | | | | |
| Tianjin University | Academic - non-UK | | Co | | | | | | | | |
| Tropic Biosciences | Spinout/start-up | | | Sp | | | | | | | |
| Twist Bioscience | Company - international | | Un | Un | | Co | | | | | |
| UCB | Company - international | | Cu | | | Co | | | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UCB Celltech | Company - international | Pa | | | | | | | | | |
| UCB Pharma, Belgium | Company - international | SAB | | | | | | | | | |
| UCL | Academic - UK | | Co | Co | | Co | | | | | |
| Unilever | Company - UK | | Un | | SAB | Co | | | | | |
| Universidade de São Paulo | Academic - non-UK | | | | | | Co | | | | |
| Università degli Studi Magna Graecia di Catanzaro | Academic - non-UK | | | | | | Co | | | | |
| Universitat Pompeu Fabra | Academic - non-UK | | | | | | Co | | | | |
| University of Aberdeen | Academic - UK | | | Co | | | | | | | |
| University of Birmingham | Academic - UK | Co | | | | | | | | | |
| University of Boston | Academic - non-UK | | | | | | Co | | | | |
| University of California Davis | Academic - non-UK | | | Co | | | | | | | |
| University of Cambridge | Academic - UK | | | | | | | Pa | | | |
| University of Cardiff | Academic - UK | | Co | | | | Co | | | | |
| University of Delaware | Academic - non-UK | | | | Co | | | | | | |
| University of Dundee | Academic - UK | Co | | | | | | | | | |
| University of East Anglia | Academic - UK | | | | | | | Pa | | | |
| University of Edinburgh | Academic - UK | | | SAB | | Co | | Pa | | | |
| University of Essex | Academic - UK | | | Co | | | | | | | |
| University of Freiburg | Academic - non-UK | | Co | | | | | | | | |
| University of Leeds | Academic - UK | Pa | | Co | | | | | | | |
| University of Liverpool | Academic - UK | | Pa | | | | | Pa | | | |
| University of Manchester | Academic - UK | | Pa | | | | | Pa | | | |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| University of Newcastle | Academic - UK | Co | | Pa | | | | | | | |
| University of Oxford | Academic - UK | | Co | | | | | Pa | | | |
| University of Tartu | Academic - non-UK | | | | | | SAB | | | | |
| University of Turku | Academic - non-UK | | | | | Co | | | | | |
| University of Vancouver | Academic - non-UK | | Co | | | | | | | | |
| University of Veracruz | Academic - non-UK | | | Co | | | | | | | |
| University of Warwick | Academic - UK | | | | | Co | | | | | |
| University of Western Australia | Academic - non-UK | | Co | | | | | | | | |
| University of York | Academic - UK | | Co | | Co | Co | | | | | Cu |
| Utrecht University | Academic - non-UK | | Co | | | | | | | | |
| Valink Therapeutics | Spinout/start-up | | | | | | | | | | Cu |
| Vasantdada Sugar Institute | Company - international | | | | Co | | | | | | |
| Victoria University Wellington | Academic - non-UK | | | | | | Co | | | | |
| Vitamica (liquidation) | Spimout/startup | Sp | | | | | | | | | |
| Vivira Process Technologies | Company - international | | | | Co | | | | | | |
| VU Amsterdam | Academic - non-UK | Pa | | | | | | | | | |
| Wageningen University & Research | Academic - non-UK | | | | Co | | | | | | |
| Walgreen Boots Alliance | Company - UK | | | | Co | | | | | | |
| Waters | Company - UK | | | | | Co | | | | | |
| Woodrow Wilson Centre | Other | | | SAB | | | | | | | |
| Zentraxa | Spinout/start-up | Sp | | | | | | | | | |
| Zuvasyntha (liquidation) | Spinout/start-up | | | | Cu | | | | | | Un |

| Organisation | Organisation Type | BrisSynBio | Mammalian SynthSys | Open-Plant | SBRC Nottingham | SynBioChem | WISB | Earlham Biofoundry | Edinburgh Genome Foundry | GeneMill | London DNA Foundry |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Zymergen (now Ginkgo) | Company - international | | | | | Co | | | | | |
| Zythera | Spinout/start-up | | Sp | | | | | | | Cu | |

## Appendix E: SynBio for growth logic model (BBSRC)

### Syn Bio for Growth Logic Model

#### Objectives

The Synthetic Biology for Growth Programme (SBfG) covers the following objectives:

- To develop and sustain a programme of internationally competitive synthetic biology research focused on strategic areas relevant to one or more industry sectors
- To provide a strong collaborative culture and supportive physical environment to attract excellent scientists and engineers in the collective endeavour of multidisciplinary research relevant to synthetic biology
- To provide the essential equipment and facilities required to enable adoption and uptake of synthetic biology approaches and, where appropriate, make this available to the wider community
- To drive advancement in modern research techniques to underpin synthetic biology
- To lead the development of new technologies and methodologies
- To recognise the specific purpose and position of the SBRC's relative to other funded initiatives, contribute to an overall synthetic biology UK network that acts to integrate the full breadth of UK synthetic biology and offers outreach and exchange opportunities for academia and industry alike
- To enhance the output of trained postdoctoral researchers and specialised technical staff

#### Inputs

- Synthetic Biotechnology research and innovation has been supported by a total investment of £102m in investments including:
  £50m capital from UK Government
  £1.37m capital from BBSRC
  £50.5m resource funding provided by BBSRC, EPSRC and MRC
- Six Multidisciplinary Synthetic Biology Research Centres to boost national synthetic biology research capacity and ensure that there is diverse expertise to stimulate innovation in this area:
  - Bris SynBio
  - SBRC Nottingham
  - OpenPlant
  - UK Centre for Mammalian Synthetic Biology
  - Synbiochem
  - Warwick Integrative Synthetic biology Centre
- **DNA synthesis** Two phases of strategic capital investments totalling £18m to bring academic expertise to bear on bottlenecks in DNA synthesis building bridges between academia and synthetic biology companies
- **Better training for students** Two capital investments of £1m each made to two BBSRC and EPSRC Centres for Doctoral Training (CDTs) in synthetic biology at Oxford/Bristol/Warwick, and UCL. The funding will provide equipment to enhance student training at the CDTs, which are world-leading training environments for students of synthetic biology.
- **Synthetic Biology Seed Fund** £10M capital funding to support synthetic biology start-up companies and 'pre-companies' (launched in 2013).
- Industrial involvement - cash contributions, materials, access to equipment or facilities and staff participation in research or on a project management committee / scientific advisory board
- Delievery/implementation of the capital monies through the SBfG programme, the RCUK Synthetic Biology Working Group

#### Activities

- Support high quality research capacity
- Integrate disciplines including bioscience, engineering, chemistry and IT into programmes of synthetic biology research of the highest international quality
- Bring scientists together to design and engineer biological parts, devices and systems for sustainable fine and speciality chemicals production
- Rapid design and synthesis of multiple varied DNA circuits (e.g. metabolic pathways, biosensors, counting/memory devices)
- Build in-house expertise in synthetic biology in mammalian systems for use in areas such as the pharmaceutical and drug testing industries
- Invest in a robotic platform to automate assembly of short DNA fragments into expressible genes
- Build bridges between academia and synthetic biology companies
- Host a forum for technical exchange and wider discussion of the potential impact of plant synthetic biology on conservation and sustainability
- Support the design, generation and exploitation of high-value compounds and bioactives obtained from plants and microbes
- Establish a Centre for Doctoral Training (CDT) in Synthetic Biology including a dedicated synthetic biology laboratory in Oxford accessible to all students
- Host SBfG Networking workshops summarising strategies for scientific direction and annual conference

#### Outputs

- Research publications
- An integrative programme of synthetic biology is developed from discovery to application.
- New techniques, technologies and reagents are developed that will allow biologically-based products to be made easily, quickly and cheaply, and in sufficient quantities to make them useful
- New traits in plants as a result of direct contribution to the engineering of development and exchange of new foundational tools and parts
- New products and intermediates for drug development, agricultural chemicals and new materials for sustainable manufacturing
- State-of-the-art principles of biosystems design and engineering are utilised to develop next-generation synthetic biology tools, biosynthetic pathways that generate valuable bioactives, synthetic communities of microbes
- A platform to support a suite of synthetic biology software tools will be developed, allowing the seamless integration of hardware, management and analysis of generated data for the purpose of building a professional DNA synthesis workflow
- Internationally-linked DNA registries established for sharing information about plant specific parts and simple testbeds
- State-of-the-art bioprocess and analytical equipment and establishment of dedicated training laboratories

#### Outcomes

- New antibiotics; new routes to vaccines; new anti-cancer drugs
- Reduced reliance on petrochemicals and creating sustainable routes to important chemicals that modern society needs
- Deliver sustainable route to renewable chemical and fuels towards "net zero" sustainable, circular economies
- Deliver new solutions to key challenges across the bioeconomy including global health and clean energy production
- Improve the environment as well as skin and gut health, and plants with enhanced resistance to stress and pathogens
- Advanced materials, capable of providing stronger, lighter, biodegradable alternatives to current polymers are explored
- Smart response systems such as biosensors; to engineer plants for disease or drought resistance; to engineer mammalian cells for drug testing, stem cell production or tissue engineering; to engineer bacteria for human digestive and environmental health, and for waste management are developed
- Renewable feedstocks are turned into biofuels, transforming wastes back into useful products, and improving the productivity of biomanufacturing processes
- Develop faster, more predictable, novel routes to fine and speciality chemicals production (including new products/ intermediates for drug development, agrochemicals, flavour/ fragrance components and new materials)
- Progression along the Technology Readiness Levels towards commercialisation
- Increase the breadth and depth of synthetic biology training by exposing students to a wide range of cutting-edge capabilities

#### Economic and societal impacts

- Support growth of a £10bn UK synthetic biology market by 2030
- Creation of jobs and driving economic growth through nurturing the UK's growing synthetic biology industry and boosting UK's capability in the area
- Enhance national capacity of synthetic DNA design and manufacture, and to ensure the UK is internationally competitive and increase both national and international collaboration
- Encouraging inward investment into the UK
- Public acceptance of Synbio technology

## Appendix F: Case studies

### Case study: Eden Bio

| Title | AI-Powered Leap Towards Intelligent Optimisation of Protein Production |
|---|---|
| **The Opportunity** | The essence of Eden Bio's mission lies in confronting the yield bottleneck in protein production, a pervasive issue across biotech sectors. The escalating demand for sustainable, efficient, and scalable methods of producing proteins — ranging from novel foods and materials to biopharmaceuticals and industrial enzymes — underscores the urgency of this challenge. Traditional approaches have struggled to meet these demands, hampered by inefficiencies and the limitations of existing technologies. |
| **Technology** | Eden Bio's innovative approach integrates artificial intelligence (AI) with synthetic biology, marking a significant advancement in bio-production. By focusing on the engineering of microorganisms essential for precision fermentation, Eden Bio addresses the industry's challenges of suboptimal yields and underperforming microorganisms. Unlike traditional trial-and-error methods, Eden Bio's application of machine learning algorithms to guide the engineering process dramatically enhances the speed and effectiveness of developing optimized strains, thus reducing the required time and financial investments. This AI-first strategy not only improves strain engineering processes but also establishes a new standard in the field by enabling the creation of microorganism strains with superior performance capabilities. |
| **About the Company** | Founded in 2022 by Dr. Christopher Reynolds, with co-founders Dr Rachel Shaw and Dr Evgenia Markova, Eden Bio emerges from a deep understanding of the potential synergies between AI and synthetic biology — a relatively unexplored territory due to the rare combination of expertise in these fields. Dr Reynolds leveraged his experience and insights gained as co-founder and CTO at Better Dairy to develop Eden Bio's R&D activities, illustrating the company's strong interdisciplinary foundation that spans bioinformatics, synthetic biology, and AI. The company raised a £1 million seed round led by SynBioVen in November 2022, a further £200k in grants, and has successfully worked with paying customers. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | The support from the SBfG programme has been pivotal to Eden Bio's development through access to the London Biofoundry's resources and expertise. This engagement has significantly accelerated Eden Bio's machine-learning platform development, enhancing private investment appeal and reinforcing investor confidence. Collaborations facilitated by SBfG, such as those with Imperial College London, have further enriched Eden Bio's research capabilities and integration within the innovation ecosystem. Dr Reynolds said: "At this early stage, companies like Eden Bio are still building their resources and networks, so Synthetic Biology for Growth's assistance in building these collaborations is crucial and benefits all parties involved." |
| **Next Steps** | Eden Bio is poised for growth, aiming to refine its technology, broaden its product spectrum, and scale its solutions globally. Future plans include advancing machine-learning algorithms, forging new partnerships, and extending market reach. The company's progress in delivering research contract work to its first customer showcases its potential for early-stage success in engineering biology. With continued support from investors and strategic partners, Eden Bio is well-equipped |

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| | to lead transformative changes in protein production, contributing to a more sustainable and secure food future. |

## Case study: Imophoron

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| **Title** | Bristol's Strong Entrepreneurial Ecosystem Attracts Innovative Vaccine Development Company |
| **The Problem** | The COVID-19 pandemic has underscored the urgent need for swift responses to rapidly evolving pathogens, which can trigger widespread disease and mortality. Conventional vaccine production methods have proven too slow to keep pace with such emerging threats, necessitating innovative approaches to expedite the process. Imophoron has developed a promising solution to this challenge, potentially reducing vaccine development from a number of years to a matter of weeks. |
| **Technology** | The company has pioneered a groundbreaking technology platform named ADDomer™, which combines a self-assembled protein construct with potentially hundreds of protein segments specific to the pathogen of interest. This innovative approach is designed to stimulate a robust immune response. Initially, the company is directing its efforts towards addressing three diseases: respiratory syncytial virus (RSV), COVID-19, and Chikungunya. Through the use of this cutting-edge platform, the company aims to revolutionise vaccine development and combat these significant health challenges effectively. |
| **About the Company** | Imophoron, a pre-clinical stage company, was founded in Grenoble, France. However, due to insufficient support for startups in the region, the company's founder (Dr. Fred Garzoni) used his connections with BrisSynBio staff to relocate to Bristol. This move was prompted by Bristol's vibrant entrepreneurial ecosystem, which offered more favourable conditions for the company's growth and development. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | Establishing in Bristol initially presented challenges due to the founder’s nationality, but BrisSynBio played a crucial role in facilitating the transition within a few months. Since relocating to Bristol the founder has participated in the SynbiCITE 4-day MBA programme and secured two awards, including one year of free rent at UnitDX (Bristol’s incubator for technology startups). Bristol’s supportive ecosystem, comprising access to cutting-edge equipment, a pool of skilled professionals, and extensive networks has been instrumental in Imophoron's success and expansion. In addition, its sponsorship of Bristol PhD students not only exposes these young researchers to the startup environment but also provides Imophoron with access to fresh talent, reinforcing its commitment to fostering innovation and growth. |
| **Next Steps** | Imophoron expects to remain at the incubator and maintain its engagement with BrisSynBio, recognising that as the company expands, this will encourage further interest from students and researchers thus continuing to support its growth. In addition, the company values the opportunity to engage with the larger pharmaceutical companies that have established connections with the university. |

## Case study: OGI Bio

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|---|---|
| **Title** | Accelerating Biotechnology Advances with Smart Cultivation Solutions |
| **The Opportunity** | In industrial biotechnology, researchers engineer genetic constructs to make useful products such as proteins, chemicals and drugs using microbial cells. At the early stages this typically involves manually culturing microbes and monitoring their growth, a process that is slow and susceptible to errors. Currently, there is a shortage of cost-effective automated systems that can monitor and optimise growth conditions during these early research stages. Addressing this gap could significantly enhance productivity and accelerate research and development within the industrial biotechnology sector. |
| **Technology** | OGI Bio offers a solution to the challenges faced in industrial biotechnology research with its innovative modular micro bioreactors. These bioreactors eliminate the need for manually monitoring microbial growth by incorporating advanced sensors within culture vessels. These sensors enable real-time monitoring, analysis, and control of growth parameters at bench, significantly improving efficiency and reducing errors. By automating these processes, OGI Bio's technology enables researchers to streamline their workflows, increasing throughput by over 400%. |
| **About the Company** | OGI Bio was founded in 2020 by Dr. Alex McVey and Prof. Teuta Pilizota, who identified the opportunity to facilitate high throughput culture of different microbes whilst working on bacteria-environment interactions. OGI Bio has developed cutting-edge micro bioreactors that have secured attention and interest within the biotechnology industry. The company's mission is to provide researchers with the tools they need to accelerate the pace of industrial biotechnology research and development, ultimately driving innovation and progress in the field. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | The Synthetic Biology for Growth (SBfG) Programme played a crucial role in supporting OGI Bio's early growth and development. Through a flexible talent mobility account and the 4-day MBA at BrisSynBio in association with SynbiCITE, Dr. McVey and other key individuals were able to further refine the company's concept and expand its capabilities. The support provided by SBfG not only helped OGI Bio secure its footing in the industry but also fostered a network of talent that continues to contribute to the company's success. |
| **Next Steps** | As OGI Bio continues to grow and establish its market position, the company is actively seeking new investment opportunities from both public and private sources. With interest already secured from competitors' customers and a global market estimated at $5 billion a year, OGI Bio is poised for significant expansion. The next steps for the company involve scaling up operations, further refining its technology, and solidifying its position as a key supplier to the biotechnology sector. |

## Case study: Phase BioLabs

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| **Title** | The Use of Waste Carbon for Value-Added Chemical Bioproduction |
| **The Problem** | Phase Biolabs has emerged in response to a critical environmental challenge: the heavy reliance on fossil fuels in chemical production and the resultant greenhouse gas emissions exacerbating global climate change. With the chemical sector contributing to approximately 6% of global emissions, Phase Biolabs aims to transform 'waste' carbon dioxide ($CO_2$) from industrial processes into valuable sustainable chemicals. This effort aligns with the broader ambition of achieving net-zero emissions and promoting a circular economy. |
| **Technology** | Utilising advanced carbon capture and utilisation (CCU) technology, Phase Biolabs employs gas fermentation to convert waste $CO_2$ emissions into carbon-neutral and even carbon-negative chemicals. This process, significantly more efficient and quicker than traditional photosynthesis by plants or algae, allows microorganisms to metabolise $CO_2$ into ethanol and other chemicals. This innovation not only offers a technical solution for recycling $CO_2$ but also an economically viable alternative by producing cost-competitive fuels and chemicals, heralding a potential paradigm shift in industrial and chemical production. |
| **About the Company** | Phase Biolabs was founded on the vision of leveraging gas fermentation technology to address environmental challenges. The company's journey from concept to reality was propelled by the support of academic and innovation networks, including mentorship and guidance from institutions like the University of Nottingham and the University of Bristol, as well as crucial funding and partnership facilitation by the Knowledge Transfer Network (KTN). This collaborative foundation underscores the importance of supportive ecosystems in nurturing technological innovation. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | Phase Biolabs was founded by Dr David Ortega who worked on gas fermentation technologies during his PhD at the SBfG-funded Synthetic Biology Research Centre (SBRC) hosted at the University of Nottingham. Dr Ortega received entrepreneurship training during his QTEC BioDesign and Innovation Fellowship that was supported by SBfG's BrisSynBio centre hosted at the University of Bristol. Phase Biolabs then spun back into the SBRC to continue developing the advanced gas fermentation technology using the extensive in-house facilities that are not available elsewhere in the country. |
| **Next Steps** | Phase Biolabs is focused on advancing its gas fermentation technology, showcasing its commitment to research and development, coupled with the strategic expansion of collaborations that it to make a substantial impact on reducing industrial emissions and moving towards a more sustainable future in chemical production and beyond. Looking forward, Phase Biolabs is committed to enhancing their technology, expanding collaborations, and scaling their operations with the ambitious goal of capturing and recycling one gigaton of $CO_2$ annually by 2050, significantly contributing to global sustainability objectives. |

## Case study: Phenotypeca

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| **Title** | Revolutionising Biopharmaceutical Manufacturing with Yeast Strain Engineering |
| **The Problem** | The biopharmaceutical industry faces significant scalability challenges in the production of therapeutic proteins, resulting in excessively high manufacturing costs. Phenotypeca addresses these issues by exploiting the capabilities of *Saccharomyces cerevisiae*, a yeast strain known for its efficiency and safety in biologics production. The company's goal is to utilise the power of its technology to make valuable new protein and peptide products while also enhancing the production efficiency of biologics, making therapeutic proteins more accessible and affordable worldwide. |
| **Technology** | Phenotypeca introduces a revolutionary approach with its proprietary Quantitative Trait Loci (QTL) technology, enabling the optimization of yeast strains to produce recombinant proteins and premium biosimilars. Phenotypeca's technology is fundamentally different from the approaches currently on the market, offering the capability to optimise a range of features associated with recombinant protein manufacturing, ultimately aimed at addressing production cost challenges. |
| **About the Company** | Founded in 2018 by Dr Chris Finnis and Professor Ed Louis, Phenotypeca has revolutionised the development of biopharmaceutical manufacturing strains with its QTL technology, enabling the creation of a new generation of premium biosimilars tailored to market needs. This innovation has also opened the way to increased vaccine accessibility in low and middle-income countries, earning the company recognition and support from the Bill & Melinda Gates Foundation, alongside grants from Innovate UK, Vax-Hub and the Royal Society. Phenotypeca's industry-changing approach has attracted multiple commercial contracts, reflecting the market's awakening to the benefits of optimized recombinant protein production. The team, now over 20 strong, possesses a growing library of patented recombinant proteins available for licensing, showcasing the company's robust R&D capabilities. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | Phenotypeca is a spin-in company at the University of Nottingham embedded as a part of Synthetic Biology Research Centre (SBRC). The access to equipment and laboratory resources within SBRC was critical for performing the initial proof-of-concept studies, as well as early scale-up steps prior to the company's expansion into BioCity Nottingham. SBRC equipment and knowledge base have been critical in the early stages of the company's growth to de-risk further investment. Phenotypeca has also engaged with the knowledge base at other SBfG-supported centres, including BrisSynBio, Earlham Institute, Liverpool Genemill, and has hosted and employed students from the Synthetic Biology CDT. |
| **Next Steps** | The collaborative support from both philanthropic and commercial sectors underscores Phenotypeca's significant impact on the biopharmaceutical landscape. Phenotypeca is actively seeking investors and partners who share its vision for transforming drug development and manufacturing with its QTL technology. Through strategic partnerships and continuous innovation, Phenotypeca is poised to lead a new era in therapeutic protein production. |

## Case study: plantcode

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| **Title** | Revolutionising Protein Production: A Low-cost, Large-scale Plant-based Manufacturing Solution |
| **The Opportunity** | There is significant interest in manufacturing proteins at commercial scales for various applications. However, current systems for doing so face limitations. While microbes like yeasts and algae have been widely used, they require sterile and well-defined conditions for growth. Plant-based systems are gaining attention, but they typically entail a longer timeframe, with transgenic tobacco plants, for instance, taking up to six to nine months to generate new plants and seeds. In contrast, Marchantia (liverwort) offers a much shorter timeframe of approximately eight weeks for the same process, with a subsequent vegetative generation time of less than two weeks. This accelerated turnaround time allows researchers to rapidly test new constructs, enhancing efficiency, productivity and early harvest. |
| **Technology** | Plantcode has developed proprietary technology that allows easy genetic modification of chloroplasts within the plant cell. Only a few plant species are suitable for this method, and the focus has been on the well-studied liverworts due to their ability to grow quickly in hydroponic systems. Such systems can be assembled inexpensively using readily available components. Chloroplasts are a significant producer of proteins in plant cells, generating target proteins at levels of over 15% of total soluble plant protein. Furthermore, gene expression in chloroplasts is stable, meaning the plants can be grown continuously without any loss in production levels. |
| **About the Company** | Founded from research in Prof. Jim Haseloff's lab as part of the OpenPlant initiative (www.openplant.org), plantcode's focus lies in medium-scale culture and making their technology accessible to a wide range of commercial and non-commercial organisations. They aim to offer both open-source/low-cost solutions, particularly beneficial in developing countries, as well as higher-value options. This strategy allows them to cater to various market applications effectively. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | All of the technology came from research carried out at the SBfG-funded OpenPlant, which has undertaken extensive research on the liverwort Marchantia to understand how it functions on a genetic level. This enabled scientists to identify individual genetic parts and combine these in different ways to control how the plant grows and what it produces. The result is a plant-based system that can now be routinely edited and controlled. Plantcode has seized this opportunity and established a liverwort-based 'factory' to harness the potential of this technology. |
| **Next Steps** | The hydroponic systems developed by the company have the capability to deliver 8kg of total plant biomass per square metre. These systems are not only low cost and accessible, but highly scalable. The company intends to adopt a business-to-business model focused on producing large quantities of proteins cost-effectively for various applications, including growth factors, culture media components, therapeutics, industrial enzymes, structural proteins, diagnostics, and others. Engineered proteins of this nature typically have retail prices of around £100 per 100 microgrammes, and are increasingly in demand at scales of grammes and kilogrammes. The company aims to significantly reduce this cost by orders of magnitude and is already in discussion with a number of potential customers. |

## Case study: Scarlet Therapeutics

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| **Title** | Engineered Blood to Treat Metabolic Diseases |
| **The Problem** | Initially, the goal was to create a method for manufacturing blood cells without relying on transfusions, addressing the shortage of blood both in the UK and worldwide. However, the team's scientists soon realised the potential to leverage this process for engineering blood cells to rectify genetic mutations, paving the way for innovative therapies. While numerous attempts have been made by others to do so, Scarlet Therapeutics stands out for achieving unprecedented success in this endeavour. |
| **Technology** | The technology developed by Scarlet Therapeutics involves isolating stem cells from donated blood and using them to produce red blood cells in the laboratory. These stem cells can be genetically modified to express therapeutic proteins. Initially, the focus is on addressing two rare metabolic diseases: hyperammonemia and hyperoxaluria. The blood cells are matched to a patient's blood type and the whole process of producing the cells takes approximately two to three weeks. |
| **About the Company** | Scarlet Therapeutics was spun out of BrisSynBio in 2021 as a result of more than a decade of research in Prof. Ash Toyes lab. At its core it is using genetically engineered stem cells to produce red blood cells containing therapeutic proteins and which are themselves devoid of any genetic material. Red blood cells circulate all around the body and can survive for up to 120 days, making them ideal therapeutic agents for the treatment of various diseases. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | The SBfG programme facilitated valuable interactions with many people, fostering idea generation and accelerating progress for Scarlet Therapeutics. The company's affiliation with BrisSynBio also led to inquiries from various investors interested in funding the company. Additionally, several team members were recruited from the centre. The collaborative environment at BrisSynBio encouraged innovation and minimised risk aversion, with access to equipment facilitating research activities. The Centre for Doctoral Training hosted by Bristol, Oxford and Warwick universities was also very important, providing skilled PhD students who played a crucial role in advancing Scarlet's technology. |
| **Next Steps** | Scarlet Therapeutics aims to secure small investments to fund pre-clinical work, enabling the development of functional prototypes of its system. The results of these experiments will be used to engage with regulators, to enable progress towards clinical trials involving human subjects. They anticipate that this process will take several more years. |

## Case study: Zythera

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|---|---|
| **Title** | Revolutionising Treatment for Lysosomal Storage Diseases: A Platform Technology that Integrates AI with Cell Engineering |
| **The Problem** | LSDs (Lysosomal Storage Disorders) are a group of highly variable genetic disorders that affect as many as one in 5,000 to 10,000 people. Untreated, they cause serious, progressive disease affecting multiple body systems, and are often fatal. Treatments for LSDs typically involve life-long weekly or fortnightly intravenous enzyme infusions (to replace those that are defective in the cell). This costs approximately £300,000 per patient per year, and as much as £3 million to 6 million per person over their lifetime. Most treatments have significant side effects, particularly immune reactions, which impacts both prognosis and treatment burden. New treatments usually take over a decade to reach the clinic. |
| **Technology** | ZYTHERA is using artificial intelligence (AI) to rapidly identify new enzyme candidates that are more effective and have fewer side-effects than existing therapies. The genes for these enzymes are inserted into a CHO (Chinese Hamster Ovary) cell-line, developed within Mammalian SynthSys for long-term and stable expression. Currently, new enzymes have been initially tested *in vitro*, and will be validated against human samples from affected patients (clinical collaboration with the Scottish Inherited Metabolic Disorders Service). The aim is to achieve a far lower immune response, or ideally none at all, while also developing a treatment that costs a fraction of the price of existing therapies. |
| **About the Company** | ZYTHERA is a direct result of research conducted by Dr. Giovanni Stracquadanio and Prof. Susan Rosser at Mammalian SynthSys at the University of Edinburgh. The team are working with the support of Scottish Enterprise High Growth to spinout in the coming year. |
| **Impact of the Synthetic Biology for Growth (SBfG) Programme** | The SBfG programme funded both the Mammalian SynthSys and the Edinburgh Genome Foundry, without which ZYTHERA would not have been possible. These facilities provided access to cell engineering expertise and DNA construction, and strong credibility, particularly when it came to fundraising efforts, including grant awards. Additionally, ZYTHERA has received support from individuals within Edinburgh's research and innovation office, as well as from local biotech entrepreneurs, further enhancing its prospects for success. |
| **Next Steps** | Although LSDs are rare, they are increasing in prevalence and orphan and ultra-orphan drug pathways accelerate standard regulatory approval pathways. This allows therapies to go straight to patients after animal studies, without the need for head-to-head clinical trials, as patients can continue using their current therapies.<br>The ZYTHERA team have confirmed therapeutic manufacture at lab-scale and are now looking to scale up while preparing to spinout. |

## Appendix G:Technical economic impact approach and method

A key objective of the evaluation is to measure the Gross Value Added (GVA)[91] impact that has been generated through the SBfG programme. This section presents the output of the economic impact assessment that was undertaken to better understand and (where appropriate) quantify the wider economic value and benefit that has been generated through the programme.

As highlighted in Section 1, two approaches to measuring the economic value and benefit were adopted:

- "Bottom-up" approach which uses programme monitoring data and feedback gathered through engagement and survey to develop a bespoke impact model for the various benefits streams. The model measures the impacts generated to date and in the future – covering a 15-year impact horizon, on an annual basis, 2014 to 2029. This recognises that the intervention is targeting an emerging and relatively nascent sector and there may be periods of time elapsed before impacts emerge.
- "Top-down" approach which uses historical and industry forecast data to estimate the potential value of the global markets for synthetic biology products and applications and estimate the share the UK could expect to control. We have used the UK share of global research publications as a proxy for global market share. This model considers impacts during the SBfG programme period: 2014 to 2022 and a 10-year post-programme period: 2023 to 2032 to allow for lagged effects in the economic returns to research and development.

A copy of the Excel-based economic models is available.

### Bottom-up economic impact assessment (EIA)

Using the logic model that has been developed for the SBfG programme (see Appendix E), we developed a route to impact model - covering the full range of ways in which the programme generates economic value to consider the approaches by which we could robustly quantify the GVA impact of the programme. For example, a key consideration in developing our approach was the granularity of data available, the level of responses from industry and from those that have either started up a business or spun out a company as a result of engaging with the programme.

The 'bottom-up' economic assessment has used the following indicators to measure the impacts/benefits:

- **startups and spinouts –** the entrepreneurial activity that has been supported and catalysed within the SBRCs that has resulted in academics and/or industry partners starting up or spinning out a company:
    - Spinout – defined as a private incorporated company/entity created by one or more academics or research staff (where the academic institution retains partial/full ownership of the IP) with the aim of commercialising research that was originally supported through the SBfG programme
    - Startup – defined as a private incorporated company/entity created for-profit or a social-purpose, that originated independently of the SBfG programme. This may be as a

[91] ONS, see here: https://www.ons.gov.uk/economy/grossvalueaddedgva

result of collaboration between academia and industry; however, the academic institution does not necessarily retain any ownership of the IP

- **research staff** – the programme/funding allowed the partners to employ additional research staff and enhance the productive capacity of the institutions
- **postdoctoral training** – 'in-study impacts' and wage/GVA premiums resulting from additional postdoctoral places
- **PhD training and CDTs** – 'in-study impacts' and wage/GVA premiums resulting from additional PhD graduates

We have considered each of the routes to impact separately.

**Areas that have been excluded from the assessment**

A key focus of the evaluation was to ensure that the impact assessment was robust, defensible, and transparent. There are two key areas of activity supported through the SBfG programme that, while, as noted in the evaluation have had a significant positive impact and benefit, we have been unable to gather the relevant data and feedback that would support a robust impact assessment.

Therefore, the following activities have been excluded from the impact assessment:

- collaborations and partnerships between academia and industry
- creation and subsequent licensing of IP (some institutions did report this as a benefit; however, the financial value/returns are commercially confidential and have not been disclosed)
- the DNA foundries

This will ultimately lead to an underestimate of the total economic value generated through the programme; however, it is the study teams professional view that a conservative approach would be most appropriate given some of the limitations in the dataset.

### EIA approach and principles

A high-level guide to support readers' understanding of technical terms and concepts referred to within this chapter is provided. The approach adopted is consistent with the guidance outlined within HM Treasury Green Book[92].

### Economic indicators and coefficients

A summary and description of the (quantitative) economic indicators used within the assessment is provided below:

- **FTE posts** - used to measure the direct annual employment effects within the companies that have/are forecast to startup/spinout, and the research staff, postdoctoral researchers and PhD students/staff that have been supported. FTE posts are calculated based on monitoring and evaluation data and evidence provided directly from surveyed funding recipients
- **GVA** - is a measure of economic output that considers the value of goods and services produced before allowing for depreciation or capital consumption. At a micro-level, GVA is the contribution of each individual producer, industry or sector to the economy and measures the

[92] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020

income generated by businesses after the subtraction of input costs, but before costs such as wages and capital investment. It is the UK government's key measure for productivity

The evaluation has found that the SBfG programme has had a positive effect on GVA and is assessed in the following ways:

- **startups and spinouts –** FTE jobs have been converted to annual GVA effects using co-efficient data derived from ONS for the following 2-digit SIC industry, 72: Scientific research and development. The data has been adjusted to reflect that it is unlikely that new startups and spinouts would generate the same level of GVA per head as the industry average. Therefore, we have assumed that 1-year post incorporation the average GVA per head within supported startups and spinouts would be equivalent to 10% of the wider industry average, 20% after 2 years, 30% after 3 years, etc. The interview programme and survey of external stakeholders had questions to help inform and understand the level of attribution that the programme has had on supporting spinout and startup companies, and achieving their growth forecasts
- **research staff** – data has been provided by the supported institutions as part of the programme monitoring. As the universities and research institutions engaged are quasi-public sector organisations, they are non-profit making. Therefore, we have used employee costs (salary, pension contribution, and National Insurance) as a proxy measure for GVA per head. Our assumptions on the breakdown of research staff and associated employment costs are provided below
- **postdoctoral training** – data has been provided by the supported institutions as part of the programme monitoring**:**
  - In-study impacts – as above, we have used labour costs (salary, pension contribution, and National Insurance) as a proxy measure for GVA per head. Our assumptions on the breakdown of postdoctoral training posts and associated costs are provided below
  - Wage/GVA premiums – the uplift in productive capacity is based on average salaries/wages (upon completion of the postdoctoral training) and converted to GVA using co-efficient data derived from ONS for the following 2-digit SIC industry, 72: Scientific research and development
- **CDTs and PhD training** – Data has been provided by the supported institutions as part of the programme monitoring:
  - 'In-study impacts – we have used the stipend paid to PhD students as a proxy measure for GVA per head. Our assumptions on the breakdown of PhD training posts and associated costs are provided below
  - Wage/GVA premiums – the uplift in productive capacity is based on average salaries/wages (upon completion of the PhD) and converted to GVA using co-efficient data derived from ONS and evaluation research

### Gross and net impacts

**Gross impacts** – the direct impacts that measure the overall change in economic activity that has occurred over the appraisal period.

**Net additional impacts** – is the difference between what would have happened anyway in the absence of the SBfG programme (i.e., the reference case) and the impacts/benefits generated by the support (i.e., the intervention case), adjusted for displacement, leakage, deadweight, and multiplier effects:

- deadweight refers to the benefits and costs of an intervention that would still have occurred if support were not provided
- displacement – the impact that growth within supported spinouts and pipeline companies is estimated to have on other businesses and the labour market.
- leakage – the proportion of impacts that will benefit those outside the defined spatial area (leakage outside the UK).
- income multipliers – the positive spin-off benefits generated through indirect income effects (i.e., paying suppliers).

Please note, as per UK Treasury guidance, we have provided the net additional impacts with and without the application of type 1 multiplier effects.

The additionality factors gave been derived through survey feedback, wider engagement with stakeholders, and the consultant team's professional judgement. The Multipliers have been sourced form ONS input-output tables[93].

| | GVA multiplier |
|---|---|
| R&D | 1.98 |
| Chemicals | 1.85 |
| Pharmaceuticals/therapeutics | 1.51 |
| Agriculture/agritech | 2.16 |
| Medical technology | 1.52 |
| Energy | 3.23 |
| Water management / environment | 1.34 |
| Waste management / environment | 1.60 |
| Food and drink | 2.87 |
| Healthcare/cosmetics | 1.42 |

**Table 17: GVA multipliers (type 1).**

The approach can, therefore, be presented schematically as follows:

[93] ONS Input Output Tables, https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

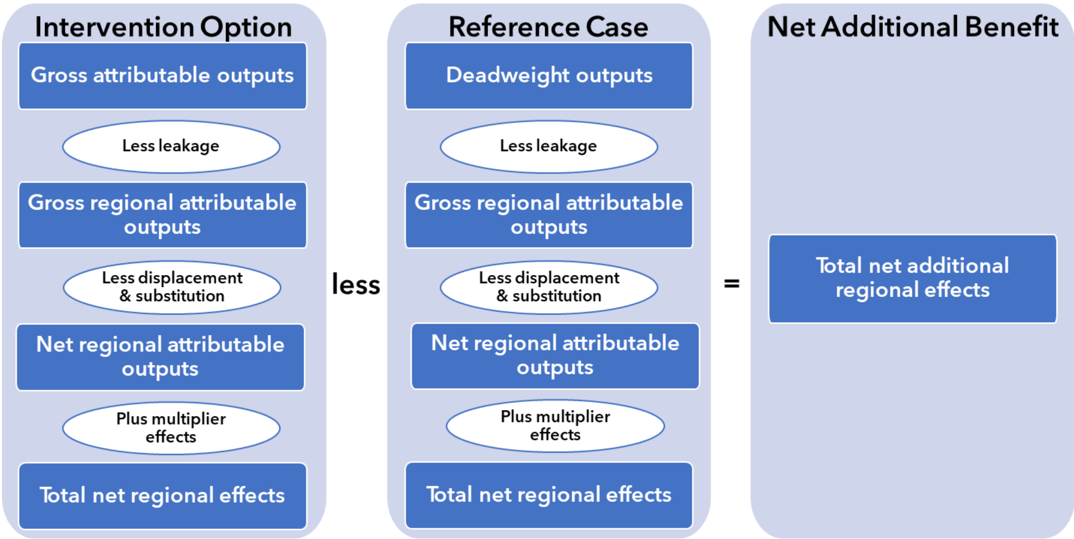


**Figure 17: Calculation of net additional benefits.**

### Other technical considerations

**Present values (PV)** – the total quantified value of the costs and net additional GVA over a defined timescale taking account of the time value of money (i.e., £1 today is worth more than £1 next year). Impacts are discounted at the HM Treasury Social Time Preference Rate (3.5%). Note that the base year for the evaluation is 2014.

**Constant prices** – the total quantified value of the costs and net additional GVA are presented in nominal prices (i.e., not adjusted for inflation). Financial values are set at the base year and economic coefficients (where specified) are adjusted to 2023 prices using data from the ONS GDP Deflator.

**Impact horizon and profile** is considered as follows:

- startups and spinouts – on an annual basis over a 15-year period, 2014 - 2029. This recognises that the intervention is targeting an emerging and relatively nascent sector and there may be considerable periods of time elapsed before impacts emerge
- research staff – programme period, 2014 – 2022.
- postdoctoral training:
  - In-study impacts – programme period, 2014 – 2022
  - Wage/GVA premiums – 30-year period post-completion
- CDTs and PhD training:
  - In-study impacts – programme period, 2014 – 2022
  - Wage/GVA premiums – 30-year period post-completion

**Optimism bias and sensitivity** is the demonstrated, systematic tendency for EIAs to be overly optimistic in forecasting outcomes (e.g., time taken to implement interventions, costs of implementation, and impacts achieved). When assessing the impacts of the startup and spinout companies we have therefore applied optimism bias at 20% on all forecast impacts to provide an element of sensitivity.

**Grossing up and confidence intervals** – to calculate the overall impact of the SBfG programme on supporting startups and spinouts, it is necessary to 'gross up' the results to reflect the population of supported organisations. The impact data that is captured through the survey sample are 'grossed up' to the entire population based on the inverse of the proportion responding to the survey (e.g., a response rate of 20% generates a grossing up factor of 100%/20% = 5).

As the data has been 'grossed up' based on a sample population, we have included a Confidence Interval (CI) to include additional sensitivity. Based on a sample size of 19 startups and spinouts and population of 47, at a 95% confidence level, the confidence interval (or margin of error) is +/- 17.77%. The impact data has therefore been calculated and presented at a lower-point and upper-point estimate. To avoid skewing the 'grossed up results', outliers (considered as annual effects that lie out with twice the standard deviation of the mean) were removed from the sample prior to "grossing up" and then added back in.  The 'low-point' and 'high-point' estimates reported in the tables below have been calculated by applying the (17.77 +/-) Confidence Interval to the 'mid-point'.

### Startups and spinouts

In total, 47 spinouts and startups were supported by the six SBRCs. During the evaluation, we conducted interviews/surveys with 19 of these – representing 40% of the population. Please note that survey responses were based on supported companies 'opting in' – the approach to sampling was therefore randomised. In terms of how representative the sample was of the wider population; we have used date of incorporation as a proxy observation.

The sample is broadly representative of the wider population.

| Year of incorporation | Population | Interviewed/Surveyed |
|---|---|---|
| 2014 | 6% | 19% |
| 2015 | 3% | 0% |
| 2016 | 3% | 13% |
| 2017 | 15% | 13% |
| 2018 | 15% | 0% |
| 2019 | 24% | 25% |
| 2020 | 15% | 13% |
| 2021 | 15% | 6% |
| 2022 | 3% | 13% |

**Table 18: Startups and spinouts by year of incorporation**

The interviews/surveys gathered information on the following key indicators:

- jobs
- turnover
- sector of operations/where technology, products, services are/will be deployed
- competition
- future prospects

- attribution of benefits to the SBfG programme

The data gathered was used to inform the impact model – as noted, GVA was derived from the annual jobs that were/are forecast to be created and converted using an appropriate GVA/employee co-efficient sourced form ONS.

### Gross impacts

Table 19 presents the gross impacts that have been supported by the programme – to date and forecast in the future.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Yr 10 | Yr 11 | Yr 12 | Yr 13 | Yr 14 | Yr 15 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | |
| Gross annual jobs | 11 | 17 | 27.5 | 32.5 | 39.5 | 75 | 102 | 142.25 | 182.75 | 219 | 175.75 | 216 | 220 | 240 | 261.25 | 148 | |
| Gross GVA (£m) | 0.11 | 0.33 | 0.71 | 1.14 | 1.70 | 3.18 | 5.20 | 7.92 | 11.40 | 14.78 | 10.05 | 14.06 | 15.35 | 18.48 | 22.57 | 13.53 | 140.51 |

Note: The startups and spinouts have been considered over a 15-year impact horizon, with the impacts generated through the individual companies attributed to the programme for a 10-year period. Gross jobs are reported on an annual basis

**Table 19: Gross impacts of the sample – startups and spinouts (£m).**

The gross impacts reported through the surveys have been adjusted as follows:

- 20% optimism bias applied to all forecast impacts
- spinout and startup survival rates have been applied to account for those companies that will fail[94,95]. Table 20 presents the adjusted gross GVA impacts

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Yr 10 | Yr 11 | Yr 12 | Yr 13 | Yr 14 | Yr 15 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | |
| Adjusted gross GVA (£m) | 0.1 | 0.3 | 0.6 | 0.8 | 1.1 | 2.2 | 3.5 | 5.3 | 6.4 | 7.8 | 4.9 | 6.7 | 7.4 | 9.0 | 10.8 | 7.1 | 73.9 |

**Table 20: Adjusted gross impacts of the sample – startups and spinouts (£m).**

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94 Spinout survival rates, https://www.ukri.org/wp-content/uploads/2021/11/EPSRC-041121-SpinoutsBooklet.pdf

95 Startup survival rates, https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/datasets/businessdemographyreferencetable

The sample population is estimated to support £74M in gross (non-discounted) GVA over the appraisal period.

### Net additional impact

The net additional economic impacts take into account the additionality factors of deadweight/attribution, leakage, displacement and economic multipliers.

The additionality factors were derived on a case-by-case basis based on direct survey feedback; a summary of the results is provided below.

| | Low | Low-medium | Medium-high | High-medium | No impact |
|---|---|---|---|---|---|
| | 0% | 1% - 33% | 34% - 66% | 67% - 99% | 100% |
| | Number of survey responses | | | | |
| Deadweight | 12 | 2 | 1 | 1 | 1 |
| Displacement | 17 | 0 | 0 | 0 | 0 |
| Leakage | 16 | 1 | 0 | 0 | 0 |

N=17

**Table 21: Summary of additionality factors.**

Multipliers - based on feedback regarding the key sectors where respondents identified that their emerging technology, products, services are/will likely be deployed, the Type 1 GVA multipliers ranged from 1.50 to 2.28.

Overall, the feedback identifies a high level of attribution and additionality to the programme with much of the economic impact achieved to date and forecast in the future unlikely to be achieved in the absence of the SBfG programme. This is a positive finding and suggests that the support is targeted appropriately and valued by those accessing it.

Table 22 presents the net additional impacts.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Yr 10 | Yr 11 | Yr 12 | Yr 13 | Yr 14 | Yr 15 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | |
| GVA (£m) | 0.2 | 0.4 | 0.8 | 1.1 | 1.4 | 2.6 | 4.1 | 5.9 | 6.7 | 7.8 | 3.9 | 5.1 | 5.6 | 6.8 | 7.9 | 5.0 | 65.2 |
| GVA (£m) – excluding multiplier effects | 0.1 | 0.2 | 0.5 | 0.6 | 0.8 | 1.6 | 2.5 | 3.6 | 4.1 | 4.7 | 2.2 | 2.8 | 3.1 | 3.7 | 4.4 | 2.9 | 37.8 |

Note: Figures presented as present value @3.5%

**Table 22: Present value net additional impacts of the sample– startups and spinouts (£m).**

The sample population is estimated to support PV £65 million in net additional GVA over the appraisal period (PV £38 million excluding multiplier effects), representing a gross to net additional ratio of 88% or 51% (excluding multiplier effects). These findings fit with wider research that suggests earlier stage activity (which is further from the market and greater risk) have higher levels of attribution.

Table 23 presents the net additional GVA impact 'grossed up' to the population and presents the lower and higher end estimates based on the +/-17.70% CI achieved.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Yr 10 | Yr 11 | Yr 12 | Yr 13 | Yr 14 | Yr 15 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | |
| GVA (£m) | 0.2 | 0.7 | 1.6 | 1.7 | 2.2 | 4.0 | 7.2 | 11.0 | 13.4 | 16.0 | 8.5 | 11.4 | 14.5 | 17.5 | 20.4 | 8.2 | 138.4 |
| Lower estimate | 0.1 | 0.5 | 1.2 | 1.2 | 1.6 | 2.8 | 5.3 | 8.3 | 10.3 | 12.4 | 6.8 | 9.1 | 12.0 | 14.4 | 16.8 | 6.0 | 108.7 |
| Upper estimate | 0.3 | 0.9 | 1.9 | 2.2 | 2.9 | 5.2 | 9.0 | 13.7 | 16.4 | 19.5 | 10.3 | 13.7 | 17.1 | 20.6 | 24.0 | 10.5 | 168.2 |
| GVA (£m) – excluding multiplier effects | 0.1 | 0.4 | 1.0 | 1.0 | 1.3 | 2.4 | 4.3 | 6.7 | 8.1 | 9.5 | 4.9 | 6.4 | 8.0 | 9.5 | 11.3 | 4.7 | 79.8 |
| Lower estimate– excluding multiplier effects | 0.1 | 0.3 | 0.8 | 0.7 | 1.0 | 1.7 | 3.2 | 5.0 | 6.2 | 7.4 | 3.9 | 5.2 | 6.6 | 7.8 | 9.3 | 3.4 | 62.5 |
| Upper estimate – excluding multiplier effects | 0.2 | 0.5 | 1.2 | 1.3 | 1.7 | 3.2 | 5.4 | 8.3 | 10.0 | 11.7 | 5.9 | 7.7 | 9.4 | 11.2 | 13.3 | 6.0 | 97.0 |

Note: Figures presented as present value @3.5%

**Table 23: Present value net additional impacts of the population – startups and spinouts (£m).**

The startups and spinouts supported through the SBfG programme are estimated to support c. PV £138 million in net additional GVA within the UK economy (PV £80 million excluding multiplier effects), with a lower end estimate of PV £109 million (£63 million excluding multiplier effects), and an upper estimate of PV £168 million (PV £97 million excluding multiplier effects).

### Research staff

The SBfG programme and the additional funding it helped leverage supported the universities and institutions to employ staff across a range of roles and disciplines to undertake research and lead the development of collaborations and partnerships with industry. In total, 359 research posts were supported (including Principal investigator and Co investigator). Please note that limited data was available on the role, salaries, and onboarding of research staff, we have therefore assumed that they came on stream in line with the funding draw down, see Table 24 (new research staff joining the programme) and Table 25 which provides assumptions on the roles and employment costs.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | Total |
| BrisSynBio | 22 | 13 | 8 | 7 | 5 | 3 | 11 | 5 | | | 74 |
| OpenPlant | 23 | 13 | 8 | 7 | 5 | 4 | 12 | 5 | | | 76 |
| SBRC Nottingham | 26 | 15 | 9 | 8 | 6 | 4 | 13 | 6 | | | 87 |
| SynBioChem | 8 | 5 | 3 | 2 | 2 | 1 | 4 | 2 | | | 26 |
| SynthSys | 14 | 8 | 5 | 4 | 3 | 2 | 7 | 3 | | | 48 |
| WISB | 14 | 8 | 5 | 4 | 3 | 2 | 7 | 3 | | | 48 |
| **Total** | **107** | **63** | **37** | **32** | **26** | **17** | **54** | **23** | **0** | **0** | |
| **Cumulative total** | **107** | **170** | **207** | **239** | **265** | **282** | **336** | **359** | **359** | **359** | |

**Table 24: Annual research staff - working assumptions.**

| | Spine point | NI | Pension @20% | Total staff costs | % of staff | Research staff Estimates* |
|---|---|---|---|---|---|---|
| Technician | £27,500 | £2,539 | £5,500 | £35,539 | 10% | 36 |
| Graduate research assistant | £30,000 | £2,884 | £6,000 | £38,884 | 5% | 18 |
| Research assistant | £32,000 | £3,160 | £6,400 | £41,560 | 15% | 54 |
| Research associate | £35,000 | £3,574 | £7,000 | £45,574 | 15% | 54 |
| Research fellow | £40,000 | £4,264 | £8,000 | £52,264 | 15% | 54 |
| Senior research fellow | £55,000 | £6,334 | £11,000 | £72,334 | 17.5% | 63 |
| Co-Investigator | £90,000 | £11,164 | £18,000 | £119,164 | 20% | 72 |
| Principal investigator | £100,000 | £12,544 | £20,000 | £132,544 | 2.5% | 9 |

**Table 25: Annual research staff roles and remuneration - working assumptions.**

* Note: the number of research staff has been estimated based on the total number of research staff supported by institution and applying the assumed breakdown of roles. The actual number of staff within each role will likely differ but we have applied a 'best fit' estimate based on the data available.

### Gross impacts

Table 26 presents the gross direct impacts generated through the research staff over the programme period.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | |
| Technician | 0.4 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.3 | 1.3 | 0 | 8.3 |
| Graduate research assistant | 4.2 | 6.6 | 8.0 | 9.3 | 10.3 | 11.0 | 13.1 | 14.0 | 14.0 | 0 | 90.3 |
| Research assistant | 0.7 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.4 | 0.2 | - | 0 | 2.5 |
| Research associate | 0.7 | 1.2 | 1.4 | 1.6 | 1.8 | 1.9 | 2.3 | 2.5 | 2.5 | 0 | 15.9 |
| Research fellow | 0.8 | 1.3 | 1.6 | 1.9 | 2.1 | 2.2 | 2.6 | 2.8 | 2.8 | 0 | 18.2 |
| Senior research fellow | 1.4 | 2.1 | 2.6 | 3.0 | 3.4 | 3.6 | 4.3 | 4.5 | 4.5 | 0 | 29.4 |
| Co-investigator | 2.5 | 4.0 | 4.9 | 5.7 | 6.3 | 6.7 | 8.0 | 8.6 | 8.6 | 0 | 55.4 |
| Principal investigator | 0.4 | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 | 1.1 | 1.2 | 1.2 | 0 | 7.7 |
| **Total** | 11.1 | 16.9 | 20.3 | 23.4 | 25.9 | 27.4 | 32.9 | 35.0 | 34.8 | 0 | 227.6 |

**Table 26: Gross impacts – research staff (£m).**

Over the programme period, the research staff are estimated to have generated direct benefit of £228 million in gross GVA within the UK economy.

### Net additional impacts

The additionality factors applied to the gross impacts are presented below.

- Deadweight – the SBfG programme has invested a significant level of funding, c. £112 million which has leveraged a significant level of additional funding. Deadweight is assumed to be low-medium (25%)
- Displacement – Based on feedback we have assumed that not all the research staff time will be spent exclusively on research activities funded through the SBfG programme and therefore displacement would cover a broad range (10% to 80%), with more junior staff spending a greater proportion of time on SBfG funded activities in comparison to the senior colleagues
- Leakage is assessed at 0% as all supported staff are based in the UK (0%)
- Multipliers – we have applied the GVA multiplier for 2-digit SIC industry, 72: Scientific research and development (1.98)

Applying the additionality factors, Table 27 presents the net additional GVA impacts.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | |
| Technician | 0.8 | 1.2 | 1.5 | 1.7 | 1.9 | 2.0 | 2.4 | 2.6 | 2.6 | - | 16.6 |
| Graduate research assistant | 5.5 | 8.8 | 10.8 | 12.4 | 13.8 | 14.6 | 17.5 | 18.7 | 18.7 | - | 120.7 |
| Research assistant | 1.0 | 0.6 | 0.3 | 0.3 | 0.2 | 0.2 | 0.5 | 0.2 | - | - | 3.3 |
| Research associate | 0.8 | 1.3 | 1.6 | 1.8 | 2.0 | 2.1 | 2.6 | 2.7 | 2.7 | - | 17.7 |
| Research fellow | 0.9 | 1.5 | 1.8 | 2.1 | 2.3 | 2.5 | 2.9 | 3.1 | 3.1 | - | 20.3 |
| Senior research fellow | 0.6 | 0.9 | 1.1 | 1.3 | 1.4 | 1.5 | 1.8 | 1.9 | 1.9 | - | 12.5 |
| Co-investigator | 0.6 | 0.9 | 1.1 | 1.3 | 1.4 | 1.5 | 1.8 | 1.9 | 1.9 | - | 12.3 |
| Principal investigator | 0.6 | 1.0 | 1.2 | 1.4 | 1.6 | 1.7 | 2.0 | 2.1 | 2.1 | - | 13.7 |
| **PV Total** | 10.8 | 16.2 | 19.4 | 22.3 | 24.6 | 26.1 | 31.4 | 33.2 | 33.0 | - | 217.1 |
| **Net additional effects excluding multipliers** | | | | | | | | | | | |
| Technician | 0.3 | 0.4 | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 | - | 5.6 |
| Graduate research assistant | 2.8 | 4.5 | 5.4 | 6.3 | 7.0 | 7.4 | 8.8 | 9.4 | 9.4 | - | 61.0 |
| Research assistant | 0.5 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.3 | 0.1 | - | - | 1.7 |
| Research associate | 0.4 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.3 | 1.4 | 1.4 | - | 8.9 |
| Research fellow | 0.5 | 0.7 | 0.9 | 1.1 | 1.2 | 1.2 | 1.5 | 1.6 | 1.6 | - | 10.2 |
| Senior research fellow | 0.5 | 0.8 | 1.0 | 1.1 | 1.3 | 1.3 | 1.6 | 1.7 | 1.7 | - | 11.0 |
| Co-investigator | 0.4 | 0.6 | 0.7 | 0.9 | 0.9 | 1.0 | 1.2 | 1.3 | 1.3 | - | 8.3 |
| Principal investigator | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | - | 1.2 |
| **PV Total** | 5.4 | 8.1 | 9.6 | 11.1 | 12.2 | 13.0 | 15.6 | 16.5 | 16.4 | - | 107.9 |

Note: Figures presented as present value @3.5%

**Table 27: Present value net additional impacts – research staff (£m).**

Over the programme period, the research staff are estimated to have generated PV £154 million in net additional GVA within the UK economy (£67 million excluding multiplier effects).

### Postdoctoral training

As well as research staff, the SBRC's provided postdoctoral training opportunities for some 234 posts. These training posts will generate economic impact for the duration of the placement (through trainees being paid) and upon completion through a 'wage premium' effect – positive impact upon lifetime earning potential and raising productive capacity within the labour force.

Again, we have made assumptions on the uptake of the training posts aligned to the funding, and on the remuneration paid to trainees, see below.

### In-study impacts

**Gross impacts**

The data and assumptions that have informed the calculation of the in-study impacts is presented below.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| BrisSynBio | 18 | 11 | 6 | 6 | 4 | 3 | 9 | 4 | | | **62** |
| OpenPlant | 12 | 7 | 4 | 4 | 3 | 2 | 6 | 3 | | | **41** |
| SBRC Nottingham | 17 | 10 | 6 | 5 | 4 | 3 | 9 | 4 | | | **58** |
| SynBioChem | 7 | 4 | 2 | 2 | 2 | 1 | 3 | 1 | | | **22** |
| SynthSys | 7 | 4 | 2 | 2 | 2 | 1 | 4 | 2 | | | **24** |
| WISB | 8 | 5 | 3 | 2 | 2 | 1 | 4 | 2 | | | **27** |
| **Total** | **70** | **41** | **24** | **21** | **17** | **11** | **35** | **15** | | | **234** |

**Table 28: Annual postdoctoral training positions - working assumptions.**

| | Spine point | NI | Pension @20% | Total costs | % of posts |
|---|---|---|---|---|---|
| Research assistant | £32,000 | £3,160 | £6,400 | £41,560 | 100% |

**Table 29: Annual research staff roles and remuneration - working assumptions.**

In addition, we have assumed that each postdoctoral position is employed on a three-year contract and 90% complete the contract. Table 30 presents the gross in-study impacts.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| Gross GVA (£m) | 2.8 | 4.4 | 5.2 | 3.3 | 2.4 | 1.9 | 2.5 | 2.4 | 1.9 | 0.6 | 27.5 |

**Table 30: gross impacts – postdoctoral trainees (£m).**

**Net additional impacts**

To calculate the net additional impacts, we have applied additionality factors at the same level as the research staff. Deadweight – 25%, Displacement – 50%, Leakage – 0%, and Multiplier – 1.98.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| Net additional GVA (£m) | 2.1 | 3.2 | 3.6 | 2.2 | 1.6 | 1.2 | 1.5 | 1.4 | 1.1 | 0.3 | 14.5 |
| Net additional GVA (£m) – excluding multiplier effects | 1.1 | 1.6 | 1.8 | 1.1 | 0.8 | 0.6 | 0.8 | 0.7 | 0.5 | 0.2 | 7.3 |

Note: Figures presented as present value @3.5%

**Table 31: Present value net additional impacts – postdoctoral trainees (£m).**

Through the postdoctoral training, the programme has supported PV £14.5 million net additional GVA (£7.3 million excluding multiplier effects).

## Wage premium impacts

### Gross impacts

Research from UKRI on the benefits and impacts of EPSRC funded postdoctoral research fellows shows that the average uplift to salaries for those that complete a training fellowship is +1.04% per annum[96]. Using the average salary for the 2-digit SIC industry, 72: Scientific research and development (£45,041), 1.04% represents an annual uplift of £468. In addition, to measure the change against the counterfactual we have assessed the difference between average gross annual full-time wages for those with a PhD (estimated at £42,777) and 2-digit SIC industry, 72: Scientific research and development (top 60$^{th}$ percentile) = £8,435. Therefore, the combined annual wage premium effect of the postdoctoral training is estimated at £8,968 per annum. The uplift in salaries is converted to GVA using the average salary per employee / GVA per employee coefficient for the 2-digit SIC industry, 72: Scientific research and development (47%).

Over 30 years, the gross wage premium impact for postdoctoral training is estimated at £110 million.

### Net additional impacts

The additionality factors have been assessed as follows:

- deadweight – it is assumed that in the absence of the SBfG programme then trainees would seek to secure postdoctoral training opportunities within other institutions, which would generate a similar level of wage premium. Deadweight is assessed as low-medium (25%)
- displacement – wider evidence such as that presented within the 'Bridging the skills gap in the 'biopharmaceutical industry' report[97] suggests that there are several skills gaps across the biosciences sector in areas such as immunology and genomics, clinical pharmacology, and medicinal and synthetic organic chemistry - there are high levels of competition to attract skilled staff. However, the sector is also performing well, and experiencing annual growth in employment and turnover. Displacement has been assessed as medium (50%)
- leakage – based on anecdotal evidence and feedback, some of those completing the postdoctoral training would access employment opportunities outside the UK. Leakage is assessed as low (20%)
- multipliers – we have applied the GVA multiplier for 2-digit SIC industry, 72: Scientific research and development (1.98)

96 UKRI Research, https://www.ukri.org/wp-content/uploads/2022/07/EPSRC-070722-ValueEPSRCFellowshipsFinalReport.pdf
97 Bridging the skills gap in the biopharmaceutical industry, abpi, www.abpi.org.uk/media/ya2fjboi/bridging-the-skills-gap-jan-2022.pdf

Taking account of the additionality factors, over 30 years, the net additional wage premium impact for postdoctoral training is estimated at PV £32 million (£16 million excluding multiplier effects).

### Centres for doctoral training and PhD training

The SBRC's hosted PhD placements for 77 individuals undertaking their PhD studies and the two CDTs hosted 139 trainees undertaking 'enhanced' PhD studies which included training placements with industry. These training posts will generate economic impact for the duration of the placement (through trainees being paid) and upon completion through a 'wage premium' effect – positive impact upon lifetime earning potential and raising productive capacity within the labour force.

Again, we have made assumptions on the uptake of the training posts aligned to the funding, and on the stipend paid to the PhD researchers, see below.

### In-study impacts

**Gross impacts**

The data and assumptions that have informed the calculation of the in-study impacts is presented below.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| BrisSynBio | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 |
| OpenPlant | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 2 |
| SBRC Nottingham | 7 | 4 | 2 | 2 | 2 | 1 | 4 | 2 | | | 24 |
| SynBioChem | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 |
| SynthSys | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | | | 11 |
| WISB | 12 | 7 | 4 | 4 | 3 | 2 | 6 | 3 | | | 40 |
| **Total** | **23** | **14** | **8** | **7** | **6** | **4** | **12** | **5** | | | **77** |

**Table 32: Annual PhD training positions - working assumptions.**

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| **Total** | **12** | **12** | **12** | **12** | **28** | **16** | **16** | **16** | **16** | | **139** |

**Table 33: Annual PhD training positions within the CDTs - working assumptions.**

The average annual stipend paid to PhD researchers is estimated at £18,622[98] and we have assumed that the PhDs hosted within the six SBRCs is for a four-year period, while those being hosted at the CDTs spend a year with an industry partner sponsor but also take 4 years to complete. We have assumed an average completion rate of 75%.

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| Gross GVA (£m) | 0.4 | 0.6 | 0.7 | 0.8 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 | - | 4.5 |

**Table 34: Gross impacts – PhD trainees (£m)**

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| Gross GVA (£m) | 0.2 | 0.4 | 0.6 | 0.7 | 1.0 | 1.1 | 1.1 | 1.1 | 0.7 | 0.5 | 7.4 |

**Table 35: Gross impacts – training positions within the CDTs (£m).**

In total, the programme has supported £11.9 million gross GVA through the PhD training across the centres and CDTs.

**Net additional impacts**

To calculate the net additional impacts, we have applied the following additionality factors: Deadweight – 25%, Displacement – 50%, Leakage –20%, and Multiplier – 1.98.

[98] Average stipend, UKRI, https://www.ukri.org/apply-for-funding/studentships-and-doctoral-training/changes-to-the-minimum-stipend-from-1-october-2023/

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| Net additional GVA (£m) | 0.3 | 0.4 | 0.5 | 0.5 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | - | 2.4 |
| Net additional GVA (£m) – excluding multiplier effects | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | - | 1.2 |

Note: Figures presented as present value @3.5%

**Table 36: Present value net additional impacts – PhD trainees (£m).**

| | Yr 0 | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **Total** |
| Net additional GVA (£m) | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 0.7 | 0.7 | 0.7 | 0.4 | 0.2 | 3.9 |
| Net additional GVA (£m) – excluding multiplier effects | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.1 | 2.0 |

**Table 37: Net additional impacts – training positions within the CDTs (£m).**

Through the PhD training and CDTs, the programme has supported PV £2.4 million (£1.2 million excluding multiplier effects) and PV £3.9 million (£2.0 million excluding multiplier effects) in net additional GVA, respectively.

### Wage premium impacts

#### Gross impacts

Research identifies that those with a PhD can earn between £1.60 to £3.10 more an hour (mean average £2.35) than those with other types of postgraduate degree. To measure the uplift/change against the counterfactual we have assumed that candidates undertaking their PhD studies will have a achieved a postgraduate/ MSc qualification and then applied the uplift to the gross annual full-time wages for UK workers with a postgraduate degree (£38,500) = £4,277. The uplift in salaries is converted to GVA using the average salary per employee / GVA per employee coefficient for the 2-digit SIC industry, 72: Scientific research and development (47%).

Over 30 years, the wage premium impact for the PhD training and CDTs is PV £17 million and PV £30 million in gross GVA, respectively.

#### Net additional impacts

The additionality factors have been assessed as follows:

- deadweight – it is assumed that in the absence of the SBfG programme then trainees would seek to secure PhD opportunities within other institutions, which would generate a similar level of wage premium. Deadweight is assessed as medium (50%)
- displacement – wider evidence such as that presented within the 'Bridging the skills gap in the 'biopharmaceutical industry' report[99] suggests that there are several skills gaps across the biosciences sector in areas such as immunology and genomics, clinical pharmacology, and medicinal and synthetic organic chemistry - there are high levels of competition to attract skilled staff. However, the sector is also performing well, and experiencing annual growth in employment and turnover. Displacement has been assessed as low-medium (25%)
- leakage – based on anecdotal evidence and feedback, some of those completing the PhD training would access employment opportunities outside the UK. Leakage is assessed as low (20%)
- multipliers – we have applied the GVA multiplier for 2-digit SIC industry, 72: Scientific research and development (1.98)

Taking account of the additionality factors, over 30 years, the wage premium impact for the PhD training and CDTs is PV £5 million (£2.6 million excluding multiplier effects) and PV £8 million (£4 million excluding multiplier effects) in net additional GVA, respectively.

### Total impact

Bringing all the benefit streams together, the total combined PV net additional GVA impact that is estimated to be supported through the SBfG programme is provided in Table 38 (this incorporates impacts to date and projected impacts as a result of the SBfG programme).

[99] Bridging the skills gap in the biopharmaceutical industry, abpi, www.abpi.org.uk/media/ya2fjboi/bridging-the-skills-gap-jan-2022.pdf

| Including multipliers | | Lower-end estimate | Mid-point | Upper-end estimate |
|---|---|---|---|---|
| Startups and spin outs | | £109m | £138m | £168m |
| Research staff | | £185m | £185m | £185m |
| Postdoctoral training | in-study impacts | £14m | £14m | £14m |
| | Wage premium impacts | £32m | £32m | £32m |
| PhDs | in-study impacts | £2m | £2m | £2m |
| | Wage premium impacts | £5m | £5m | £5m |
| CDTs | in-study impacts | £4m | £4m | £4m |
| | Wage premium impacts | £8m | £8m | £8m |
| **Total PV net additional GVA** | | £360m | £389m | £419m |
| Total PV costs | | £124m | £124m | £124m |
| RoI | | 2.9 | 3.1 | 3.4 |
| **Excluding multipliers** | | **Lower-end estimate** | **Mid-point** | **Upper-end estimate** |
| Startups and spin outs | | £63m | £80m | £97m |
| Research staff | | £92m | £92m | £92m |
| Postdoctoral training | in-study impacts | £7m | £7m | £7m |
| | Wage premium impacts | £16m | £16m | £16m |
| PhDs | in-study impacts | £1m | £1m | £2m |
| | Wage premium impacts | £3m | £3m | £3m |
| CDTs | in-study impacts | £2m | £2m | £2m |
| | Wage premium impacts | £4m | £4m | £4m |
| **Total PV net additional GVA** | | £188m | £205m | £222m |
| Total PV costs | | £124m | £124m | £124m |
| RoI | | 1.5 | 1.7 | 1.8 |

Note: Figures presented as present value @3.5%

**Table 38: SBfG programme – total present value net additional GVA supported.**

Including multiplier effects, the SBfG programme is estimated to support PV £360 million to PV £419 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers a RoI of 2.9:1 to 3.4:1. This means that for every £1 invested in the SBfG programme, it will generate a net additional GVA impact within the UK economy of £2.90 to £3.40.

Excluding multiplier effects, the SBfG programme is estimated to support PV £188 million to PV £222 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers a RoI of 1.5:1 to 1.8:1.

As noted in Section 6.1, we have adopted a conservative approach to quantifying the economic impacts and have not included any potential benefits to the industry partnerships/collaborations or the DNA foundries - the analysis will almost certainly underrepresent the impacts.

We have also not considered the potential diffusion or adoption effects for downstream users, i.e., those that will benefit from the technologies, services, or products that the R&D activity supported through the SBfG programme. Given the cross-cutting nature of the synthetic biology these could be significant in terms of health, environmental and fiscal impact.

It is also worth noting that generating economic value (GVA) is not a core objective of the SBfG programme, therefore the estimated net additional GVA return of £360 million to £419 million is a significant positive finding.

## Top-down economic impact assessment

### Introduction

The top-down economic model provides an additional level of economic analysis of estimating the benefits generated as a direct result of the SBfG programme. The model is designed to indirect capture the contribution made by the programme in the UK achieving additional synthetic biology market share that may be due:

- direct and leveraged research and development activities.
- supporting Company formation.
- supporting Product and process commercialisation.
- supporting academic and industry partnerships.

### Methodology summary

The following high-level overview of the top-down methodology has been provided to give the reader an initial understanding of the steps and assumptions underpinning the top-down economic model.

1. Estimate the value of the Global synthetic biology market for the SBfG programme period 2014 to 2022 and for a 10-year post programme period from 2023 to 2032.
2. Estimate the UK's share of the Global synthetic biology market based on the UK's share of total scientific research publications related to synthetic biology.

   **Key assumption**: Market share is directly proportional to research publication activity.

   **Key assumption:** Research publication activity is a good proxy for research expenditure which is shown to influence economic returns.

   a. Estimate the global and UK number of research publications by searching the Web of Science database for the following search terms:
      i. Synthetic biology; or
      ii. Engineering biology
      iii. Within the “title” or “abstract” or “topic” or “keyword”
   b. Determine the UK's annual share of global publications in synthetic biology and use this to proxy market share
3. Construct a counterfactual projection of UK annual publications in synthetic biology in the absence of the SBfG programme using historical Web of Science data from 2008 to 2013.

   **Key assumption**: the SBfG programme is the main driver of change in publications in synthetic biology for the 2014 to 2022 period.

   a. A best fit pre-programme trendline is extrapolated over the programme period
   b. Counterfactual annual publications are compared to the EU data to estimate a counterfactual UK market share

4. Determine the value of the additional market share captured due to the SBfG programme by comparing the "intervention" case (i.e., the case when the SBfG happens – as in step 2) against the "counterfactual" case (i.e., the SBfG does not happen). Apply this methodology for the programme period and for the 10-year post programme period.

   **Key assumption**: When considering the 10-year post programme period, the UK annual market share for the intervention and counterfactual cases are assumed to be equal to the average market share for the intervention and counterfactual cases during the programme period, respectively.

5. The value of gross additional market share (gross additional turnover) as calculated in step 4 is converted to economic impact (GVA) by applying economic turnover to GVA coefficients based on ONS data. GVA impacts are then adjusted for additionality factors – leakage, displacement, and multiplier effects.
6. Incorporate a five-year lag in GVA returns in line with the wider literature which suggests time lags between R&D expenditure and economic returns[100].

### Technical considerations

**Present values (PV)** – the total quantified value of the costs and net additional GVA over a defined timescale taking account of the time value of money (i.e. £1 today is worth more than £1 next year). Impacts are discounted at the HM Treasury Social Time Preference Rate (3.5%). Note that the base year for the evaluation is 2014.

**Constant prices** - the total quantified value of the costs and net additional GVA are presented in nominal prices (i.e. not adjusted for inflation). Financial values are set at the base year and economic coefficients (where specified) are adjusted to 2023 prices using data from the ONS GDP Deflator and global inflation rates where applicable.

**Impact horizon** is considered as follows:

- SBfG Programme period: 2014 to 2022
- 10-year post-programme period: 2023 to 2032

## Estimating the value of the global synthetic biology markets

We begin by estimating the potential value of the global market for synthetic biology to determine the scale of opportunity and economic value of which the UK has gained a share.

We rely on historic and current forecasts from various market research studies to cover the evaluation period 2014 to 2022 and future forecasts to cover the period 2023 to 2032. A summary of the sources, annual growth rates and forecast periods for each study are summarised in the following table.

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[100] RATE OF RETURN TO INVESTMENT IN R&D. A report for the Department for Science, Innovation and Technology. Frontier Economics, March 2023. Accessed here

| Source | Annual Growth Rate | Forecast Period |
|---|---|---|
| Future Market Insights | 21.7% | 2019 to 2024 |
| Future Market Insights | 23.8% | 2024 to 2034 |
| Allied Market Research | 23.0% | 2014 to 2020 |
| PR Newswire | 35.4% | 2014 to 2020 |
| Brand Essence Research | 26.9% | 2020 to 2028 |
| PS Market Research | 23.1% | 2021 to 2030 |
| Polaris Market Research | 18.6% | 2023 to 2032 |
| Precedence Research | 28.3% | 2022 to 2032 |
| Markets and Markets | 25.6% | 2022 to 2027 |
| Grandview Research | 19.0% | 2023 to 2030 |
| Pharmiweb | 23.0% | 2015 to 2020 |

**Table 39: Summary of global market size sources.**

Final estimate of the global market size is based on averages of all market forecasts mentioned above. Table 40 presents the global synthetic biology market sizes for the SBfG programme period, while Table 41 presents the size for the 10-year post programme period.

Note that all values have been converted from USD to GDP using annual average exchange rates sourced from ONS official exchange rates[101], and are in constant 2023 global prices using global inflation rates sourced from the International Monetary Fund[102].

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| Global | 3.53 | 4.83 | 6.93 | 9.28 | 11.45 | 11.78 | 13.85 | 6.74 | 9.64 |

**Table 40: Global market size – Evaluation Period (£bn).**

| | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 |
|---|---|---|---|---|---|---|---|---|---|---|
| Global | 12.47 | 13.89 | 19.14 | 23.75 | 29.50 | 36.67 | 38.09 | 46.93 | 58.68 | 74.90 |

**Table 41: Global market size – 10-year future impact period (£bn).**

## Estimating the UK's share of the global market

As there is no publicly available data on the size, value or market share of the UK synthetic biology industry, to estimate to UK's market share of the synthetic biology market and associated market value we make the assumption that market share is directly proportional to the level of research activity within the synthetic biology field – measured by the number of scientific research publications. The reasoning for this is two-fold:

101 https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/auss/mret
102 https://www.imf.org/external/datamapper/PCPIPCH@WEO/WEOWORLD

1. Data availability – we are able to extract synthetic biology specific publications at the UK and global levels on an annual basis, whereas wider economic data does not have this level of granular detail.
2. Countries with greater research output are likely to be spending more intensely on synthetic biology and are then more likely to develop the company base and commercialise the processes and products that will drive a greater market share.

To determine the annual value of the UK's public sector expenditure in synthetic biology R&D we rely on bibliometric data sourced from Web of Science[103]. The following search was conducted for papers with a UK based author and for all other global publications:

- Search terms used = "Synthetic Biology" OR "Engineering Biology"
- Fields searched = [TITLE] OR [ABSTRACT] OR [TOPIC] OR [KEYWORD+]
- Publication years = 2006 to 2023[104]
- Publication type = Research Articles

We can then compare UK's number of publication to the global total to estimate the UK's share of research and share of the overall global synthetic biology market. Table 42 presents the bibliometric data and implied market share for the SBfG programme period[105].

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| UK | 49 | 49 | 73 | 70 | 98 | 117 | 84 | 72 | 56 |
| Global | 362 | 430 | 512 | 558 | 656 | 651 | 654 | 656 | 727 |
| UK Share | 14% | 11% | 14% | 13% | 15% | 18% | 13% | 11% | 8% |

**Table 42: UK and global synthetic biology publications 2014 to 2022.**

The UK initially has a higher market share which is maintained throughout most of the SBfG programme period reflecting its early position as a market leader. However, by the end of the programme period, the UK is losing some market share, as other nations appear to be catching up.

Applying the UK research publication share as a proxy for market share to the overall value of the global synthetic biology market we can calculate the value of the UK's share of the synthetic biology market (Table 43).

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| UK | 477.9 | 549.9 | 988.1 | 1,164.6 | 1,710.8 | 2,116.5 | 1,779.3 | 739.6 | 742.5 |

**Table 43: Value of the UK synthetic biology market (£m).**

103 https://clarivate.com/products/scientific-and-academic-research/research-discovery-and-workflow-solutions/webofscience-platform/

104 Note that our analysis focused on publication years 2008 to 2013 to build a counterfactual due to the low volume of UK and global activity in 2006 and 2007. The programme years run from 2014 to 2022, while 2023 is considered within the 10-year post programme period.

105 It should be noted that this search will only produce a subset of all synthetic biology publications, as it lacks a comprehensive keyword search. However, it is appropriate for the purposes set out here – to compare the UK with the rest of the world, and estimate a percentage share of all publications.

Note that this represents the size of the UK synthetic biology market under the "intervention" case.

### Impact of the SBfG programme

To determine the SBfG programme's impact on publications and subsequently market share and value, we construct a counterfactual scenario, modelling the number of UK scientific research publications in the absence of the programme. We use historical bibliometric data from 2008 to 2013 and identified a best-fit line for the data.

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| UK | 8 | 13 | 14 | 20 | 25 | 38 |

**Table 44: UK publications in synthetic biology – pre-SBfG programme.**

The data suggests that a linear regression equation is the best fit. The equation is y=5.4857x + 0.4667 with an $R^2$ = 0.9122 which implies that the regression equation explains a high proportion of the variation in the data. We extrapolate this best fit trendline from the number of publications in 2013, effectively applying the slope to estimate future value while negating the intercept implied by the trendline's equation. Extrapolating this trend over the 2014 to 2022 programme period gives an estimate of what would have happened to research publications in absence of the SBfG programme.

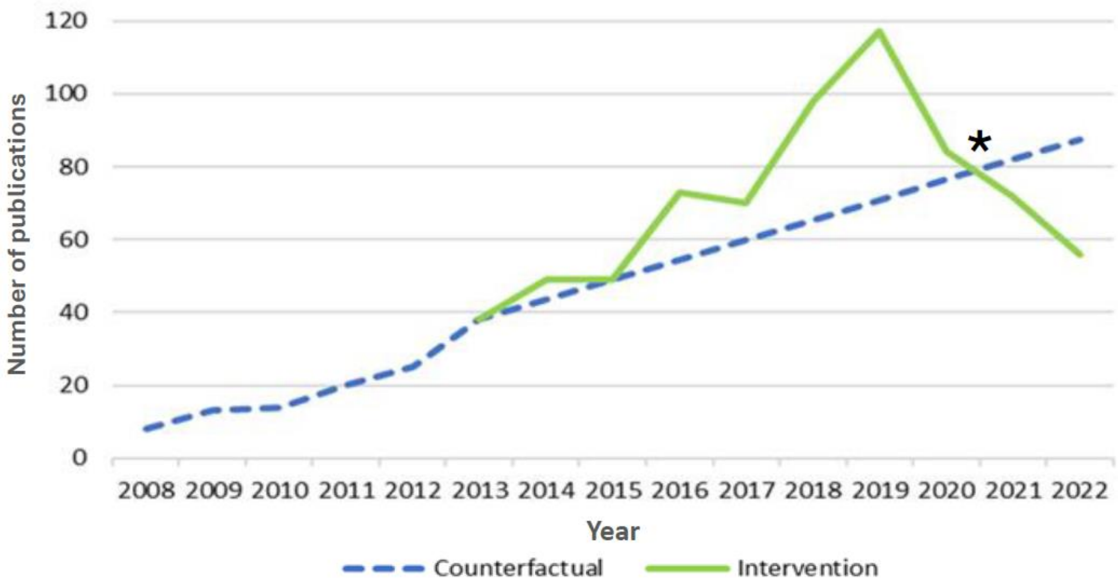


**Figure 18: UK synthetic biology publications – intervention vs. counterfactual.**

*the decrease in the number of recorded publications from 2020 coincides with the start of the COVID-19 pandemic, which had a negative impact on research activity and publication numbers.

The dashed blue line represents annual pre-programme synthetic biology publications from 2008 to 2013, and from 2014 to 2022 it represents the counterfactual scenario. The solid green line represents the annual level of publications during the SBfG programme period. Any difference between the solid green line and dotted blue line represents the impact on publications that the programme has had. However, the counterfactual data require careful interpretation. It should be noted that the counterfactual plot (dashed blue line) is modelled on publication rates which may or may not have followed this trajectory in the absence of the SBfG programme, i.e., the counterfactual values post 2014 could be significantly lower than shown. In addition, the negative impact of the COVID-19 pandemic on research activity and publication rates are not predicted by the counterfactual model. The implied negative 'uplift' in years 2021 and 2022 seen in the counterfactual analysis may be the result of these factors. It should also be noted that the reduction in publication numbers over the pandemic period is not specific to synthetic biology research and is also observed across other research areas.

Table 45 provides a summary of this uplift, noting the 'negative uplift' in 2021 and 2022, likely the result of the COVID-17 pandemic .

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020* | 2021* | 2022* |
|---|---|---|---|---|---|---|---|---|---|
| Intervention | 49 | 49 | 73 | 70 | 98 | 117 | 84 | 72 | 56 |
| Counterfactual | 43 | 49 | 54 | 60 | 65 | 71 | 76 | 82 | 87 |
| Uplift | 6 | 0 | 19 | 10 | 33 | 46 | 8 | -10 | -31 |
| % Uplift | 13% | 0% | 34% | 17% | 50% | 65% | 10% | -12% | -36% |

**Table 45: UK synthetic biology publications – intervention vs. counterfactual.** * during COVID-19 pandemic.

When comparing the annual estimated uplift, the data suggest publication additionality of 40%. Over this period the SBfG programme generated 202 publications and the additional uplift is valued at 81 publications. This implies that while an uplift of 121 publications would have occurred anyway, the SBfG programme has stimulated additional research activity over and above this to a significant extent.

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020* | 2021* | 2022* |
|---|---|---|---|---|---|---|---|---|---|
| Additional uplift | 6 | 0 | 19 | 10 | 33 | 46 | 8 | -10 | -31 |
| Gross SBfG publications | 1 | 7 | 22 | 30 | 39 | 46 | 37 | 12 | 8 |

**Table 46: SBfG programme additionality of research publications.** * during COVID-19 pandemic.

The next stage of the top-down economic model is to compare the annual number of synthetic biology publications under the counterfactual case, to the global number to estimate a counterfactual research share and counterfactual synthetic biology market share. We can then compare the estimated market shares under the intervention and counterfactual cases (Table 47).

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020* | 2021* | 2022* |
|---|---|---|---|---|---|---|---|---|---|
| Intervention | 14% | 11% | 14% | 13% | 15% | 18% | 13% | 11% | 8% |
| Counterfactual | 12% | 11% | 11% | 11% | 10% | 11% | 12% | 12% | 12% |

**Table 47: UK share of global synthetic biology market.** * during COVID-19 pandemic.

Applying these markets shares to the overall financial value of the global synthetic biology market yields annual estimates for the size of the UK synthetic biology market under the intervention and counterfactual cases, with the difference between them representing the uplift in market value attributable to the SBfG programme (Table 48).

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020* | 2021* | 2022* |
|---|---|---|---|---|---|---|---|---|---|
| Intervention | 477.9 | 549.9 | 988.1 | 1,164.6 | 1,710.8 | 2,116.5 | 1,779.3 | 739.6 | 742.5 |
| Counterfactual | 424 | 550 | 737 | 997 | 1,142 | 1,283 | 1,618 | 841 | 1,158 |
| Uplift | 53.8 | 0.3 | 251.0 | 167.3 | 568.6 | 833.7 | 161.0 | -101.5 | -415.9 |

**Table 48: SBfG programme attributable uplift in market value (£m).** * during COVID-19 pandemic.

While there is variability in the uplift in market value year to year, from 2014 to 2022, the SBfG programme has enabled an average annual uplift of £168.7 million and £1,518.2 million over the programme period.

## Gross impacts programme period 2014 to 2022

The uplift in market value is equivalent to total sector turnover. To estimate gross additional GVA (i.e. GVA accounting for deadweight but not the other additionality factors of leakage, displacement and multiplier effects), we apply a turnover to GVA coefficient of 32%. This coefficient is based on ONS industry turnover and GVA data[106]. Synthetic biology processes and products cross multiple sectors and therefore the turnover to GVA coefficient is based on average sector data from the following sectors:

| SIC Division/Section | Sector |
|---|---|
| 01 (Part) | Crop and animal production, hunting and related services activities |
| 20 | Manufacture of chemicals and chemical products |
| 21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations |
| 26 | Manufacture of computer, electronic and optical products |
| D | Electricity, gas, steam and air conditioning supply |
| 36 | Water collection, treatment and supply |
| 72 | Scientific research and development |

**Table 49: Synthetic biology sector SIC codes.**

### Lagged effects

Wider research[107] on the returns to research and development suggests that there is a time lag ranging from two to 10 plus years until economic returns are realised. As we don't know for certain to what extent the synthetic biology publication research activity is industry focused, academic focused, or at a basic research level, we assume there is a 5-year time lag for the market impact to be realised. For example, as presented in Table 48, we estimate a gross attributable market value uplift of £53.8 million in 2014. We consider this value as the magnitude of the economic return to increased research activity and then apply a five-year time lag for this return to be realised – i.e. 2019. This time lag is applied to all market value uplifts so that impacts during the SBfG programme period are realised from 2019 to 2022 (originating from research activity uplift in 2014 to 2017). Note this implies research uplifts achieved from 2018 to 2022 will generate economic returns during the 10-year post-programme period.

[106] ONS Non-financial business economy. See here.

[107] Rate of return to investment in R&D. A report for the Department for Science, Innovation and Technology. Frontier Economics, March 2023. Accessed here.

Table 50 below summarises the annual and total gross additional impacts over the SBfG programme period.

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Total | PV Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GVA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 17.2 | 0.1 | 80.4 | 53.6 | 151.3 | 118.5 |

**Table 50: Gross additional impacts programme period 2014 to 2022 (£m).**

The programme is estimated to have generated £118.5 million in PV gross additional GVA from 2014 to 2022.

### Net additional impacts programme period 2014 to 2022

To move from gross additional to net additional GVA impacts the following additionality factors are considered:

- **leakage**: is assessed at 0% as the top-down model is directly considering only the value of the UK domestic synthetic biology market and all associated economic impacts will be within the UK
- **displacement**: is assessed as low at 15%. While the products and processes reaching market are likely to compete and displace existing technologies and processes used in related sectors (e.g. agriculture, pharmaceuticals) and therefore some level of displacement is expected
- **GVA multiplier**: in line with UKRI and UK Treasury guidance, the model considers net additional impacts with and without the application of economic multipliers. The Type 2 multiplier is constructed of an average of multiple sectors to which synthetic biology products and processes are likely to be aligned (see Table 17). A multiplier of 1.95 is applied

Table 51 represents annual and total net additional GVA during the SBfG programme period, both with and without the application of the economic multiplier.

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Total | PV Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| With Mult. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.5 | 0.2 | 133.1 | 88.7 | 250.6 | 196.2 |
| W/o Mult. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.6 | 0.1 | 68.3 | 45.6 | 128.6 | 100.7 |

**Table 51: Net additional GVA– programme period 2014 to 2022 (£m).**

When considering the net additional GVA impacts when the economic multiplier is applied, the SBfG programme is estimated to have generated £196.2 million in PV net additional GVA to the UK economy between 2014 and 2022. When the multiplier is not applied, this figure reduces to £100.7 million.

### 10 – year post programme impacts

In addition to the assessment of economic impacts during the SBfG programme period, we also estimate impacts during a 10-year after post-programme period from 2023 to 2032. This enables us to capture the longer-term nature of R&D impacts.

Modelling the 10-year post-programme impacts relies on the same methodology as applied for the programme period, but with intervention case and counterfactual case market shares applied to global synthetic biology market size forecasts for 2023 to 3032. These forecasts are presented in Table 52.

| | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 |
|---|---|---|---|---|---|---|---|---|---|---|
| Global | 12.47 | 13.89 | 19.14 | 23.75 | 29.50 | 36.67 | 38.09 | 46.93 | 58.68 | 74.90 |

**Table 52: Global and European market sizes – 10-year post programme period (£bn).**

We assume that the UK's market share over this 10-year period is equal to the average market share assessed over the programme period 2014 – 2022:

- Intervention case – 12.83%
- Counterfactual case – 11.31%

Applying these market shares to the future market value forecasts enables us to estimate the projected uplift in market value due to the SBfG programme (Table 53).

| | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 |
|---|---|---|---|---|---|---|---|---|---|---|
| Intervention | 1,599.9 | 1,782.7 | 2,456.1 | 3,047.9 | 3,785.4 | 4,704.7 | 4,887.8 | 6,021.9 | 7,529.9 | 9,610.3 |
| Counterfactual | 1,410.4 | 1,571.5 | 2,165.1 | 2,686.8 | 3,336.9 | 4,147.3 | 4,308.7 | 5,308.4 | 6,637.8 | 8,471.6 |
| Uplift | 189.6 | 211.2 | 291.0 | 361.1 | 448.5 | 557.4 | 579.1 | 713.5 | 892.1 | 1,138.6 |

**Table 53: SBfG attributable uplift in market value – 10-year post programme period (£m).**

It is estimated that the programme could generated a market value uplift from £189.6 million in 2023 to £1,138.6 million by 2032 (before applying the lag effect).

### Gross additional impacts - 10-year post programme – 2023 to 2032

Following the same methodology for converting turnover to GVA as described above, the gross additional GVA is for the 10-year post-programme period is presented in Table 54. Note that due to the consideration of lags in the returns to research, the first 5-years of the post programme impacts are due to research uplifts that occurred during the programme period.

| | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | Total | PV Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GVA | 182.2 | 267.1 | 51.6 | -32.5 | -133.2 | 60.7 | 67.7 | 93.2 | 115.7 | 143.7 | 816.0 | 525.1 |

**Table 54: Gross additional impacts - 10-year post programme period (£m).**

The programme is estimated to generate £525.1 million in PV gross additional GVA from 2023 to 2032.

### Net additional impacts 10-year post programme – 2023 to 2032

To move from gross additional to net additional GVA impacts the following additionality factors are considered:

- **leakage**: is assessed at 0% as the top-down model is directly considering only the value of the UK domestic synthetic biology market and all associated economic impacts will be within the UK
- **displacement**: is assessed as low at 15%. While the products and processes reaching market are likely to compete and displace existing technologies and processes used in related sectors (e.g. agriculture, pharmaceuticals) and therefore some level of displacement is expected
- **GVA multiplier**: in line with UKRI and UK Treasury guidance, the model considers net additional impacts with and without the application of economic multipliers. The Type 2 multiplier is

constructed of an average of multiple sectors to which synthetic biology products and processes are likely to be aligned (see Table 17). A multiplier of 1.95 is applied

Table 55 presents annual and total Net additional GVA during the SBfG post-programme period, both with and without the application of the economic multiplier.

| | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | Total | PV Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| w/ mult | 301.6 | 442.2 | 85.4 | -53.9 | -220.6 | 100.5 | 112.0 | 154.3 | 191.5 | 237.9 | 1,350.9 | 869.3 |
| w/o mult | 154.8 | 227.0 | 43.8 | -27.7 | -113.3 | 51.6 | 57.5 | 79.2 | 98.3 | 122.1 | 693.6 | 446.3 |

**Table 55: Net additional GVA (with and without economic multipliers) – 10-year post programme period (£m).**

When considering the net additional GVA impacts when the economic multiplier is applied, the SBfG programme is forecast to generate £869.3 million in PV net additional GVA to the UK economy between 2023 and 2032. When the multiplier is not applied, this figure reduces to £446.3 million.

### Total impacts and RoI

Bringing together the programme period and 10-year post programme period benefits, the total combined PV net additional GVA impact supported through the SBfG programme is presented in Table 56.

| | Present Value including Multipliers | Present Value excluding multipliers |
|---|---|---|
| Programme Period | £196m | £101m |
| 10-year post period | £869m | £446m |
| Total Impact | £1,065m | £547m |
| Cost | £124m | £124m |
| **RoI** | **8.7** | **4.4** |

**Table 56: Impact Summary – Total Net Additional GVA and SBfG Programme RoI.**

Including multiplier effects, the SBfG programme is estimated to support PV £1,065 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers an RoI of 8.7. This means that for every £1 invested in the SBfG programme, it will generate a net additional GVA impact within the UK economy of £8.70.

Excluding multiplier effects, the SBfG programme is estimated to support PV £547 million in net additional GVA within the UK economy. Set against a PV cost of £124 million this delivers an RoI of 4.4.

We note that this "top-down" analysis suggests an impact and return on investment greater than that described in the "bottom-up" analysis. This is driven by the different areas of impact quantified by each model. While the "bottom-up" approach focuses on direct, on-site impacts (staff, post docs, etc) and impacts from startups and spinouts, the "top-down" analysis quantifies a wider range of impacts across the synthetic biology economy, particularly the impacts that are generated by larger scale, established, and in some cases large international companies and wider industry. Therefore, one would expect the top-down analysis to yield a greater level of impact and return on investment.

| Business Growth | Economic Development | Technology Commercialisation |
|---|---|---|

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