Biotech Britain

An assessment of the impact of industrial biotechnology and bioenergy on the United Kingdom economy

A report by Capital Economics for the Biotechnology and Biological Sciences Research Council, the Engineering and Physical Sciences Research Council, Innovate UK, the Industrial Biotechnology Leadership Forum and the Knowledge Transfer Network

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1 EXECUTIVE SUMMARY

Industrial biotechnology and bioenergy is a vital and emerging part of the United Kingdom, and global economies. It has and can continue to produce innovative solutions to finding sustainable and cost effective ways of producing the medicines, chemicals, materials and energy that we need.

In the financial year 2013/14, we estimate that British industrial biotechnology and bioenergy activities involved around 225 companies and generated £2.9 billion of sales revenue annually. The industry also makes a significant contribution to the United Kingdom's net exports, equivalent to £1.5 billion and offsetting over four per cent of the country's total trade deficit. Around 8,800 people are employed in activities involving industrial biotechnology and bioenergy activities, with occupations ranging from highly skilled biological scientists to technicians and analytical staff. In total, it currently adds just under £1 billion of gross value added annually.

Industrial biotechnology and bioenergy activities rely on firms investing in research and development to discover innovative and productivity enhancing technologies and processes. In total, our analysis suggests that firms invested £922 million in 2013/14, representing 4.6 per cent of all private sector research and development spending in the United Kingdom.

But the impact of the industrial biotechnology and bioenergy is much broader than its direct contribution; there are significant 'upstream' impacts through the supply chain and spending of employees and 'downstream' impacts through the use of the end products.

Our analysis suggests that businesses spend approximately £1.8 billion on supplies of equipment, feedstocks, and business services amongst other things, of which almost £1 billion goes to domestic suppliers. This supports over 11,000 jobs and around £580 million of gross value added in the wider economy.

What's more, the spending of the 8,800 employees in turn supports over 5,000 jobs and £200 million of gross value added in businesses in all geographic regions and sectors of the economy.

There are significant 'downstream' effects from the use of industrial biotechnology and bioenergy products. The products and manufacturing processes devised through extensive research and development underpin a whole host of other sectors which use, at least in part, inputs derived from it. These include pharmaceuticals, chemicals, healthcare, personal care products and energy. We tentatively estimate that, together, these sectors utilising industrial biotechnology inputs account for £69 billion of British gross value added – five per cent of the total. Although it is difficult to measure precisely, we estimate that the share of these sectors that are directly reliant on industrial biotechnology and bioenergy amounts to £4½ billion of gross value added and over 63,000 jobs. (See Figure 1.)

The innovations developed through industrial biotechnology and bioenergy activities enhance productivity in the wider economy. A good example of this is the development of anti-tumour necrosis factor alpha; these biologic medicines have led to reduced hospitalisations and risk of joint replacements; reducing costs and improving productivity in the health sector. Not only does the application of industrial biotechnology and bioenergy improve productivity, but it also leads to the development of new drugs and medicines that would not be able to exist through any other process.

Figure 1: Overall impact of industrial biotechnology or bioenergy activities, 2013/14

	Turnover (£ million)	Jobs (number)	Gross value added (£ million)
Direct industrial biotechnology and bioenergy activities	2,900	8,800	995
Indirect effects	1,600	11,300	580
Induced effects	520	5,300	200
Total	**5,020**	**25,400**	**1,775**
Downstream activity supported by industrial biotechnology and bioenergy products	34,000	63,500	4,400

Source: Capital Economics.

Industrial biotechnology and bioenergy currently make a significant contribution to the United Kingdom economy, but there is great potential for it to be much larger. Responses from our survey suggest that in five years, real terms turnover of industrial biotechnology and bioenergy activities will grow by 40 per cent, in ten years, 131 per cent and, in twenty years, 192 per cent. (See Figure 2.)

Figure 2: Estimated turnover figures and respective rates of growth for industrial biotechnology and bioenergy over the next 20 years (2014 real terms)

	2014	2020	2025	2035
Turnover (£ billion)	2.9	4.1	6.8	8.6
Increase over 2014 (per cent)	-	40	131	192

Source: Capital Economics

The British government has adopted a series of targets to fight climate change and mitigate the effects of resource depletion. Consequently, there is an economic and social imperative for it to develop a significant role in moving to a more sustainable economy.

More environmentally friendly manufacturing processes and energy sources produced using biotechnology can help to achieve these targets. A report by the World Wide Fund for Nature found that the climate change mitigation potential of industrial biotechnology ranges between 1.0 billion and 2.5 billion tonnes of carbon dioxide per year by 2030, compared with a scenario in which no industrial biotechnology applications are available. This is equal to approximately 2.8 to 7.1 per cent of total global emissions in 2013.

Bioenergy can also play a part in tackling the issues of energy cost and security. Despite low oil prices at present, the expectation is that higher fossil fuel prices will return in future. These provide a compelling reason to seek out alternative sources of energy from a cost efficiency point of view. Furthermore, much fossil fuel production, particularly oil, is based in geopolitically sensitive parts of the world. Biofuels offer a means to avoid reliance on energy supplies from politically contentious regions.

In summary, industrial biotechnology and bioenergy provides a means to simultaneously:

- Increase economic output
- Provide high-skill, highly-paid employment in the private sector
- Develop new and more efficient means of production
- Reduce greenhouse emissions in production and energy generation
- Realise low cost, secure energy

Taken together, these issues highlight the importance of realising the potential future growth in industrial biotechnology and bioenergy activities.

2 INTRODUCTION AND APPROACH

In this section, we assess the definitional issues relating to industrial biotechnology and bioenergy and outline the approach that we have taken.

2.1 Project objectives

Capital Economics has been commissioned to research and report upon the economic impact of industrial biotechnology and bioenergy, and its potential for growth.

This report presents our findings on those objectives based on a comprehensive review of the recent literature and an extensive survey of potential biotechnology firms within the United Kingdom.

2.2 What is industrial biotechnology and bioenergy?

A host of terms and definitions have been used to try to define and label 'biotechnology' and its constituent parts. Indeed, it is normal to see different reports implicitly adopt quite different definitions of the sector. Industrial biotechnology (sometimes referred to as white biotechnology) is one of these subsets and broadly speaking refers to the application of biotechnology to manufacturing processes.

The underlying issue with attempts to define the 'biotechnology' sector is that rather than being an industry in its own right, it is actually a process which underpins a whole range of other sectors. (See Figure 3.) We define this process as:

A transformative process that uses the tissues, cells, genes or enzymes of plants, algae, marine life, fungi or micro-organisms.

In this report we have worked up from this definition to identify all economic activity which uses a biotechnological process. As our report investigates "industrial biotechnology and bioenergy", we define that as:

Any activity that uses a biotechnological process to produce and process materials, chemicals and energy.[1]

[1] Definition employed by the BBSRC, BERR and EuropaBio

This includes the production of anti-microbial compounds, biopharmaceuticals, flavours and enzymes for improved processing – so we reach wider than some others' concept of industrial biotechnology. Importantly, however, we do not include the production of human food and animal feedstuffs in our definition. The reason for this is simply that these components are so much larger than the other components of biotechnology that our report would essentially become one focused on the application of biotechnology to food production; a study by the European Commission found that these activities comprised 97.3 per cent of all biotechnology turnover in the European Union.[2]

The biotechnological process is used at different stages in production for different products. In some cases it is used to produce intermediary products which are later mixed with other components to make final products. Elsewhere, it is used directly in the manufacture of final products. Our definition of direct industrial biotechnology and bioenergy activities is limited to those stages of the value chain where the biotechnological process is applied (though we do include all such production). Hence, where biotechnological processes are used to create intermediary products, the production of those intermediary products is a direct activity but the manufacture of the final goods is captured as a 'downstream impact' and is therefore excluded from our estimates of direct industrial biotechnology and bioenergy activities (see Figure 3).

Figure 3: Industries that utilise industrial biotechnology or bioenergy

	Use of biotechnological process in the production of intermediate goods	Use of biotechnological process in the production of final goods	Examples of final products
Pharmaceuticals		✓	drugs
Healthcare		✓	vitamins and supplements
Personal care	✓		sun cream, hair colouring
Household goods	✓		detergents, soaps
Energy		✓	bio-ethanol, bio-propane
Plastics	✓		bio-degradable plastics
Electronics	✓		sensors
Textiles	✓		leather
Waste	✓		waste management processes
Agriculture	✓		agro-chemicals

Source: Capital Economics.

Industrial biotechnology has a long history. Ethanol has been an 'industrial biotechnology' product for 6,000 years. The ancient Egyptians used their understanding of the microbiological processes that occur in the absence of oxygen to develop fermentation techniques and produce wine and bread. In

2 Viorel Nita, Lorenzo Benini, Constantin Ciupagea, Boyan Kavalov and Nathan Pelletier, *Bio-economy and sustainability: a potential contribution to the bio-economy observatory*, (European Commission, Luxembourg), 2013

China in 500 BC, the first antibiotic, mouldy soybean curds, was used to treat boils. Around 600 years later, China also saw the production of the first insecticide, manufactured from powdered chrysanthemums.

Processes for the production of compounds such as citric, acetic and lactic acids have been operating commercially for over 100 years. It is thought that citric acid, whose production began in 1916, was the first industrial scale fermentation. The idea of using proteases in industry – specifically in detergents – goes back to the use of pancreatic extracts in 1913.

From these early beginnings, the industry has grown significantly, particularly in the last 20 years, as the potential of the technology to contribute to policy targets for sustainable growth have been recognised and significant advancement of capability has occurred.

Industrial biotechnology uses biotechnological knowledge – about genomes and complex cell functions – to develop new processes for making products such as industrial enzymes. These are used, in turn, in the production of chemicals, detergents, textiles, paper, and much more. This kind of work requires an understanding of enzymes, proteins and DNA at a molecular level. It involves the ability to work with cells, tissues and whole organisms; the use of process engineering and fermentation; and the use of advanced techniques such as bioinformatics and omics technologies including genomics proteomics and synthetic biology.

Underpinning industrial biotechnology and bioenergy is a deep pool of researchers and knowledge working in academia and research and development divisions of commercial enterprises.

2.3 Methodology

Previous studies have employed varying definitions of industrial biotechnology to define and scale the sector through top-down approaches using international data, or by identifying companies for which the predominant activity is the use and application of biotechnology.[3] In contrast, we have sought to capture all activity that deploys a biotechnological process in the areas of industrial biotechnology and bioenergy, no matter what their proportionate share of a company's turnover. This is the first study to assess industrial biotechnology and bioenergy in this rounded way.

[3] See: Arthur D. Little, *Quantitative modelling of industrial biotechnology and renewable chemicals* (Arthur D. Little, Cambridge) May 2009, pp. 25-28.
Department for Business, Innovation and Skills, *Strength and Opportunity 2014*, (BIS, London) 2014.

To do this we have undertaken a survey of companies in the United Kingdom. Our survey was sent to 328 companies, which were identified as potential users of biotechnology processes because they were either (i) organisations known to the Biotechnology and Biological Sciences Research Council through its committees and panels, (ii) identified by the Department for Business, Innovation and Skills as being industrial biotechnology companies and / or (iii) members of the Bioindustry Association. Seven of these companies were identified by the research councils as likely to be particularly sizeable in their biotechnology and bioenergy operations.

A copy of our survey is attached to this report in Annex A. The survey covered a number of key topics:

- The share of a company's products produced utilising biotechnological processes, the share of turnover derived from them, the share of employment dependent on them and the likely future growth in biotechnology-related turnover.

- The categories of industrial biotechnology into which the company's biotechnologically produced output falls, the categories into which the feedstocks fall and the extent to which the industrial biotechnology is necessary to produce the relevant products.[4]

- The research and development spending on either feedstocks or biotechnological processes themselves, the categories into which the company's research and development is focused, whether publicly and privately funded grants and subsidies have been received, how companies intend to commercialise their research and development and whether they foresee difficulties in recruiting skilled staff.

- Company financials, biotechnology customers and suppliers, biotechnology exports and spending on biotechnology inputs from the United Kingdom.

Of the full list of companies that were sent the survey, 75 companies identified themselves as outside of the scope of industrial biotechnology and bioenergy and there were a further 28 firms for which no information could be found. Of the remaining sample of 225 firms, we received 46 responses giving an overall response rate of just over twenty per cent. For the seven largest companies, six provided responses to the survey. The responses to the survey varied in completeness, so the sample for each question within the survey varies.

In addition, for those companies from whom no response was forthcoming, we have been able to extract relevant information from company annual

[4] Feedstocks are the materials that the biotechnological process is applied to.

reports and websites. We reviewed the accounts of 164 companies and were able to extract varying levels of information depending on the size of the company and the comprehensiveness of the reporting.

Please refer to annex B for more detailed methodological notes.

3 'DIRECT' CONTRIBUTION

In this section, we consider the direct contribution of industrial biotechnology and bioenergy to the United Kingdom economy.

3.1 Revenues and spending

Based on desk research, interviews with experts and our survey we have identified a total of 225 companies that deploy biotechnological processes in at least part of their business activities. Combining our survey results with companies' annual accounting information and other publically available statistics, we estimate that the total revenue of these firms was £17.0 billion in 2013/14. This does, however, include activity within these firms that is not related to biotechnology.

From this total figure, we have drilled down into the available information to identify the share of business activity that is directly attributable to biotechnology; we estimate that industrial biotechnology and bioenergy activities generated revenues of £2.9 billion in 2013/14.[5]

Over the same period, the spending of firms related to industrial biotechnology and bioenergy totalled around £1.8 billion, of which £990 million was from suppliers within the United Kingdom.[6] This supports jobs and economic activity through the supply chain. (See Section 4.)

Based on our survey results and analysis of company accounts, we estimate that sales to foreign customers accounted for 79 per cent of total revenues, or £2.3 billion. This is equivalent to ten per cent of all United Kingdom exports of basic pharmaceutical products and around eight per cent of chemical and chemical product exports. Meanwhile available official statistics on the varying sectors that include biotechnological processes suggest purchases from abroad amounted to around £790 million.[7] Consequently, industrial biotechnology and bioenergy activities made a net contribution to the United

[5] This is based on turnover figures from our survey or annual accounts for 88 companies. To produce conservative estimates, all companies were assigned a turnover of zero if they were too small to be required to file full accounts. On a cautious basis, zero turnover was also assigned to companies where no reliable information could be found.
[6] Spending was calculated by using official statistics on the ratio of intermediate consumption to turnover for the most relevant sectors based on the Office for National Statistics' input-output tables.
[7] Export figures based on sample accounting for 55 per cent of turnover of industrial biotechnology and bioenergy activities.

Kingdom's balance of payments of around £1.5 billion. Without this contribution, the United Kingdom's total trade deficit would have been approximately 4½ per cent larger in 2013.

The most recent Strength and Opportunity report estimated that the industrial biotechnology "sector" generates an estimated £860 million in turnover, employing an estimated 2,600 people; considerably lower than our estimate.[8]

The differences can be explained by our varying definitions and approaches. The Department for Business, Innovation and Skills report only includes "companies whose main business activity and turnover is derived directly from the development, manufacture and sale of products and services that use or contain biological material as catalysts or feedstock to make industrial products…where companies are using biotechnology to make products or services that contribute only a minor amount towards their turnover they are excluded from this analysis". In contrast we have broadened our approach by trying to identify the proportion of biotechnological activity in all firms that deploy it to any extent. What is more, the scope of their definition of industrial biotechnology is not as wide as ours. For example, they exclude bio-pharmaceuticals which are included in our study.

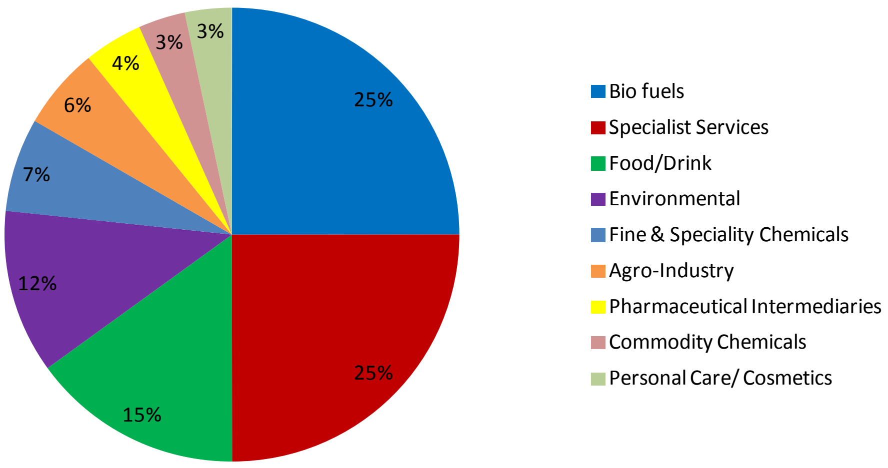
Within industrial biotechnology and bioenergy there are a range of different product areas. These can be split down into four main categories: fine and specialty chemicals and natural products; commodity platform and intermediate chemicals and materials; liquid and gaseous bio-fuels; and glycol-peptides and proteins. Our survey responses on questions about sub-components of industrial biotechnology and bioenergy were not robust enough to draw firm conclusions.

However, although there are differences in definitions and approach, the Department for Business Innovation and Skills' *Strength and Opportunity 2013* report provides some information about the nature of activities undertaken. The figures suggest that firms producing bio-fuels and specialist services make up the largest share of the industry. (See Figure 4.)

The Organisation of Economic Cooperation and Development have looked more broadly at biotechnology firms and provide an alternative breakdown of their activities. The data suggest that the majority of biotechnology firms in the United Kingdom produce healthcare products including drugs and vaccines. Indeed, the concentration of health companies is higher than for any other country in their sample. (See Figure 5.)

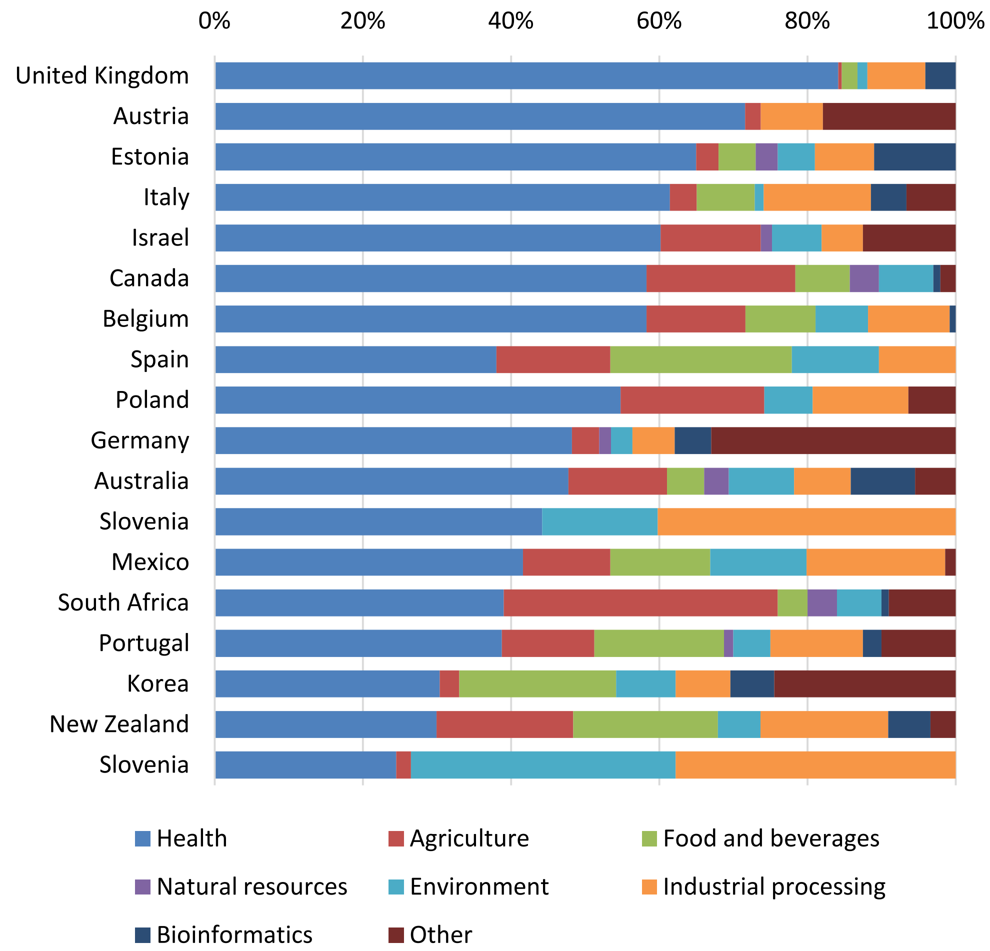
[8] Department for Business, Innovation and Skills, *Strength and Opportunity 2014,* (BIS, London) 2014.

Figure 4: Share of number of companies by sub-component of industrial biotechnology and bioenergy



Source: Department for Business Innovation and Skills, *Strength and Opportunity 2013*. Note: Definition of industrial biotechnology differs from that employed by Capital Economics in this report.

Figure 5: Share of biotechnology companies by application (per cent, latest available year, differs by country)



Source: Organisation of Economic Cooperation and Development. Note: Definition of biotechnology differs from that employed by Capital Economics in this report.

3.2 Employees

In 2013/14, there were 8,800 people employed in the United Kingdom working within divisions of firms deploying industrial biotechnology and bioenergy processes.[9] The jobs provided include high value and highly skilled scientific and professional occupations such as biological scientists, research and development managers, engineers and laboratory technicians. On top of this there are administrative and supporting roles including laboratory assistants finance officers.

Overall, our survey results suggest that the average wage for employees was £48,000 per annum, which is over 40 per cent greater than the national

[9] Employee figures based on a sample accounting for 75 per cent of turnover of industrial biotechnology and bioenergy activities.

average of £33,300. Using official employment statistics we have also produced indicative estimates of how employment is spread across the United Kingdom.[10] There is significant employment in all regions of the country, with the South East, London, North West and Scotland likely to have the largest concentrations.

Figure 6: Number of employees and average wages associated with industrial biotechnology and bioenergy activity by region

	Jobs (number)	Average annual wage in industrial biotechnology and bioenergy (£ thousands)	Average annual wage for all sectors (£ thousands)
North East	350	41	28
North West	850	43	30
Yorkshire and The Humber	790	42	29
East Midlands	610	43	29
West Midlands	830	44	30
East	820	45	31
London	1,070	70	48
South East	1,280	50	34
South West	790	44	30
Wales	380	40	28
Scotland	820	46	31
Northern Ireland	240	40	28
United Kingdom	**8,840**	**48**	**33**

Source: Capital Economics and Office for National Statistics. Note: Regional breakdown of jobs and wages is estimated using best available official statistics; regional data were not obtainable from our survey.

3.3 Research and development

Research and development is an integral part of industrial biotechnology and bioenergy; firms invest significantly to discover innovative, useful and productivity enhancing technologies and processes. In total, our analysis suggests that £922 million was invested by companies in 2013/14 in research and development in the field of industrial biotechnology and bioenergy.[11] This represents 4.6 per cent of all private sector research and development spending in the United Kingdom and 0.7 per cent of expenditure across the whole of the European Union.[12]

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[10] Total employment has been distributed by region using the locational breakdown in the Office for National Statistics' *Business Register and Employment Survey* of the best available official statistics for industrial biotechnology and bioenergy.

[11] Research and development figures based on sample accounting for 22 per cent of turnover in the sector.

[12] Héctor Hernández, Alexander Tübke, Fernando Hervás, Antonio Vezzani, Mafini Dosso, Sara Amoroso and Nicola Grassano, *EU R&D scoreboard 2014* (European Commission, Luxembourg), 2014.

3.4 Gross value added

Overall we estimate that industrial biotechnology and bioenergy processes directly generated £995 million of gross value added in 2013/14. This is larger than sectors such as the manufacture of inorganic basic chemicals or photographic activities. (See Figure 7.)

Figure 7: Size of selected industries in the United Kingdom

	Gross value added £ million, 2013
Amusement and recreation activities	1,296
Software publishing	1,154
Manufacture of clothing	1,008
Industrial biotechnology and bioenergy	**995**
Water based passenger transport	994
Washing and cleaning of textiles	911
Photographic activities	893
Short stay holiday accommodation	865
Manufacture of rolling stock	835
Manufacture of electric lighting	820
Manufacture of weapons	783
Manufacture of paper and pulp	696
Radio broadcasting	535

Source: Capital Economics' analysis of survey results and Office for National Statistics' *Annual Business Survey*

The use of data from companies' annual accounts is problematic when attempting to measure the economic rather than financial dimensions of an industry, and especially one of the key measures of economic activity or output, 'gross value added'. As such, we have used official data for the sectors that include biotechnological activities to calculate an average employee productivity figure, and have applied this to the industrial biotechnology and bioenergy industry to estimate its gross value added.[13]

We estimate that productivity of employees in industrial biotechnology and bioenergy is £113,000 per annum. On average each employee generates similar added value to a typical worker in the telecommunications sector and more than those in air transport or creative industries. (See Figure 8.)

[13] Productivity calculated from gross value added from the Office for National Statistics' input-output tables and employment from the *Business Register and Employment S*urvey. As industrial biotechnology and bioenergy is not disaggregated as a sector in official statistics, we used a mix of industries that include some of its activity.

Figure 8: Productivity estimates for selected industries

	Gross value added per employee (£ thousands per annum)
Financial services	138
Industrial technology and bioenergy	**113**
Telecommunications	114
Information service activities	85
Air Transport	80
Manufacture Of Computer, Electronic And Optical Proc	74
Creative, arts and entertainment activities	42

Source: Capital Economics' analysis of survey results and Office for National Statistics' database

4 'UPSTREAM' IMPACT

In this section we examine the knock-on effects of industrial biotechnology and bioenergy activity, both in terms of the impact of companies' spending on suppliers and the spending of the employees.

4.1 Indirect effects

Industrial biotechnology and bioenergy activity in the United Kingdom generates spending of £990 million on domestic suppliers. This stimulates further economic activity in the upstream supply chain. It supports jobs and generates value added at the firms at which the money is spent, who then also spend a proportion of the income on their own suppliers where similar benefits accrue. This continues through the supply chain until the amount re-spent on suppliers diminishes. These are known as 'indirect' or 'multiplier' effects.

Using our spending estimates, we have deployed the Office for National Statistics' input-output tables and official employment data to estimate the impact of industrial biotechnology and bioenergy related spending on the supply chain in different sectors and regions of the economy.

In total, our modelling suggests that industrial biotechnology and bioenergy activities support approximately 11,300 jobs and over £580 million of gross value added in the United Kingdom through spending of firms on goods and services. This gives a jobs multiplier of 2.3; for each direct job, a further 1.3 are supported in the wider economy.

Figure 9: Economic activity stimulated by the spending associated with industrial biotechnology and bioenergy activities on suppliers, 2013/14

	GVA £ millions	Jobs Number	Turnover £ millions
Primary activities including energy	**45**	**223**	**170**
Construction	**9**	**126**	**24**
Manufacturing	**63**	**936**	**492**
Fabricated metal products	5	109	14
Electronic, electric and optical	3	39	18
Machinery and equipment	2	25	7
Equipment repair and maintenance	3	59	6
Other manufacturing	52	704	446
Services	**466**	**10,052**	**939**
Financial, business and professional	249	3,515	492
Management consultancy and suppo	16	643	35
Employment services	36	2,004	72
Administrative support	29	527	79
Communications	38	513	71
Property services	9	747	19
Transport and storage	26	582	65
Wholesale, retail and other services	24	672	48
Public services	38	848	60
Total	**583**	**11,336**	**1,625**

Source: Capital Economics

4.2 Induced effects

Money that is spent on goods and services by employees that are either directly or indirectly supported by the industry has knock on (multiplier) effects which stimulates further economic activity. These are known as 'induced' effects.

Based on the results from our survey combined with the Office for National Statistics' *Family Spending Survey*, we have estimated that the 8,800 employees working in industrial biotechnology and bioenergy activities spend a total of £300 million on goods and services annually. This supports 5,300 jobs and gross value added of over £200 million in businesses across the country.

Much of the spending by employees goes directly into local retail sectors, which accounts for more than half of the jobs. In turn, this stimulates activity in the supply chain of retailers. Figure 10 shows that there is a positive impact on all sectors of the economy, particularly the manufacturing industries, financial and business activities, and the transport and storage sector.

Figure 10: Economic activity stimulated by the spending of employees within industrial biotechnology and bioenergy activities, 2013/14

	GVA £ millions	Jobs Number	Turnover £ millions
Primary activities including energy	**10**	**48**	**45**
Construction	**2**	**32**	**6**
Manufacturing	**14**	**235**	**93**
Fabricated metal products	1	24	4
Electronic, electric and optical	1	11	5
Machinery and equipment	1	14	4
Equipment repair and maintenance	1	16	3
Other manufacturing	10	170	77
Services	**180**	**4,954**	**376**
Financial, business and professional	30	380	59
Management consultancy and suppo	3	71	7
Employment services	2	72	5
Administrative support	2	79	6
Communications	12	147	24
Property services	1	43	3
Transport and storage	10	224	24
Wholesale, retail and other services	110	3,713	237
Public services	8	225	12
Total	**206**	**5,269**	**519**

Source: Capital Economics and Office for National Statistics

5 ‘DOWNSTREAM’ BENEFITS

In this section we examine the downstream impacts of industrial biotechnology and bioenergy; the value of the products to those who purchase intermediary goods and the efficiency improvements, cost or time savings for consumers or other agents in the economy through the use of products produced using industrial biotechnology and bioenergy.

5.1 Downstream sectors and the pervasiveness of industrial biotechnology and bioenergy

Our concept of industrial biotechnology as an underlying process or enabling technology rather than as a discrete sector of the economy means that we have narrowly focussed on the specific biotechnological activities. Industrial biotechnology also has a much broader impact on the economy.

In some cases, industrial biotechnology and bioenergy firms are the producers of final products – and therefore vendors to wholesalers, retailers or consumers themselves. This is particularly true of (bio)pharmaceutical[15] and bioenergy/biofuel firms. In other cases, they are producers of intermediary products for use in final products made by others. Industrial biotechnology can be an input into the manufacture of, for example, home and personal care, plastics, paper, electronics and textiles products amongst others. A 2008 survey of British industrial biotechnology companies found that 54 per cent regarded it as “vital” to their company function and performance.[16]

Figure 11 shows the overall size of the key manufacturing industries into which the intermediate products feed. In total, the gross value added of these sectors is £69 billion, or around five per cent of the United Kingdom economy. Of course, industrial biotechnology and bioenergy does not underpin all of the activities in these sectors.

Given the lack of disaggregated statistics on industrial biotechnology and bioenergy, it is difficult to precisely isolate its contribution to the wider economy. However, using our survey results combined with our own estimates we have made some indicative estimates of the scale of the downstream industries that are directly reliant on industrial biotechnology

[15] Many small molecule pharmaceuticals (compounds) which do not themselves contain biotech ingredients are nonetheless made using biotechnology processes.
[16] Knowledge Transfer Network, *Survey to Assess the Use and Awareness of Industrial Biotechnology in the Chemicals and Chemistry-using Industries in the UK* (Knowledge Transfer Network, Runcorn), 2008, p. 8.

and bioenergy. We estimate that this amounts to £4.4 billion of gross value added and over 63,000 jobs. (See Figure 11.)

Figure 11: Gross value added for British industrial sectors utilising industrial biotechnology products

	Total gross value added (£ billion)	Total jobs (thousands)	Estimated gross value added reliant on biotechnology (£ billion)	Estimated jobs reliant on biotechnology (thousands)
Textiles	2.5	52.2	0.2	3.4
Chemical products	6.3	80.5	2.1	31.5
Basic pharmaceuticals and preparations	12.3	42.6	0.5	1.6
Plastic products	8.0	155.7	0.5	10.1
Electronics	9.7	131.6	0.6	8.6
Energy	23.2	123.0	0.1	0.6
Waste	6.7	124.4	0.4	8.1
Total	**68.7**	**710.2**	**4.4**	**63.8**

Source: Capital Economics

One example of the downstream application of biotechnology is in plastics where Coca-Cola has, since 2009, been using plant-based materials in the bottles for its products. These were launched in the United Kingdom in 2011.[17] By 2020, the company aims to convert its entire product range to fully recyclable polyethylene terephthalate (PET) bottles, made with 100 per cent plant-based packaging material, which will have a significant impact on environment sustainability.[18]

5.2 Examples of catalytic effects by industry

To understand the real 'value' of industrial biotechnology and bioenergy, it is important to recognise the role that the products play in the downstream sectors that they supply.

5.2.1 Medicines

In medicine, there is strong evidence of catalytic effects. These may stem from benefits derived by patients (i.e. being in better health for a longer period of time), the economy overall (patients who receive better treatments are likely to be able to return work more rapidly) and the public purse / National Health Service (better treatments can mean that patients need to spend less time in hospital, not have to undergo surgery etc.). We review some examples below.

- **Arthritis medication.** Anti-tumour necrosis factor alpha biologic medicines have become some of the leading global pharmaceutical products by sales in recent years. They are used to prevent destructive inflammatory processes associated with rheumatoid arthritis and other inflammatory conditions. In the United Kingdom, these medicines

[17] Greenwise business news, *Coca-Cola to launch 'greener' Coke in UK*, 12 June 2014.
[18] Packaging Gateway, *Coca-Cola's 100% plant-based bottle.*

were reviewed by the National Institute for Health and Care Excellence in 2007, which found that the drugs produced important benefits in terms of reducing hospitalisations and the risk of joint replacement for rheumatoid arthritis patients.[19] In 2010, this was quantified in a subsequent report as a reduction in the incremental costs per additional quality-adjusted-life-year of £2,500.[20] This was therefore a recognition that the medicines provided indirect benefits in the form of cost savings for other parts of the National Health Service.

- **Cholesterol-lowering statins.** Biotechnology techniques have been used to alter the enzyme catalyst cytochrome P450 and so enable it to convert a natural product into the cholesterol lowering drug pravastatin in one step. The new biotechnologically-advanced method forms the basis of a patented process for the efficient production of this blockbuster drug.[21]

- **Flu treatment and prevention.** Scientists at the Roslin Institute, a National Institute of Bioscience that receives funding from the BBSRC, have developed a new generation of broad spectrum anti-influenza peptides with the scope to treat, as well as prevent, flu. Flupep works by preventing the influenza virus from entering cells it usually infects. This differs from currently available anti-virals that work by attacking the viral replication mechanism. It will significantly reduce the risk of target viruses developing resistance to the treatment. Flupep has been under development for three years and has been shown to be effective and non-toxic when tested in animal models. [22]

- **Synthetic biology.** Research is ongoing to use synthetic biology tools to develop new antibiotics from peptides and other bio-based ingredients to combat the increasing problem of antibiotic-resistant pathogens. The biosynthesis and bioengineering of lipoglycopeptide antibiotics of the ramoplanin and enduracidin family is enabling the rapid structural diversification of this class of antibiotics, which are considered to have considerable clinical potential. Meanwhile, a number of projects are currently underway to facilitate the more

[19] National Institute for Health and Care Excellence (2007), "Adalimumab, etanercept and infliximab for the treatment of rheumatoid arthritis", Technology Appraisal 130.

[20] National Institute for Health and Care Excellence, *Adalimumab, etanercept, infliximab, rituximab and abatacept for the treatment of rheumatoid arthritis after the failure of a TNF inhibitor*, Technology Appraisal 195, 2010. Available at: https://www.nice.org.uk/guidance/ta195/chapter/4-Evidence-and-interpretation#summary-of-appraisal-committees-key-conclusions

[21] Manchester Institute of Biotechnology, *Discovery through innovation*, 2014, p. 15.

[22] Biggar Economics (2013), *Economic impact of the Roslin Institute*.

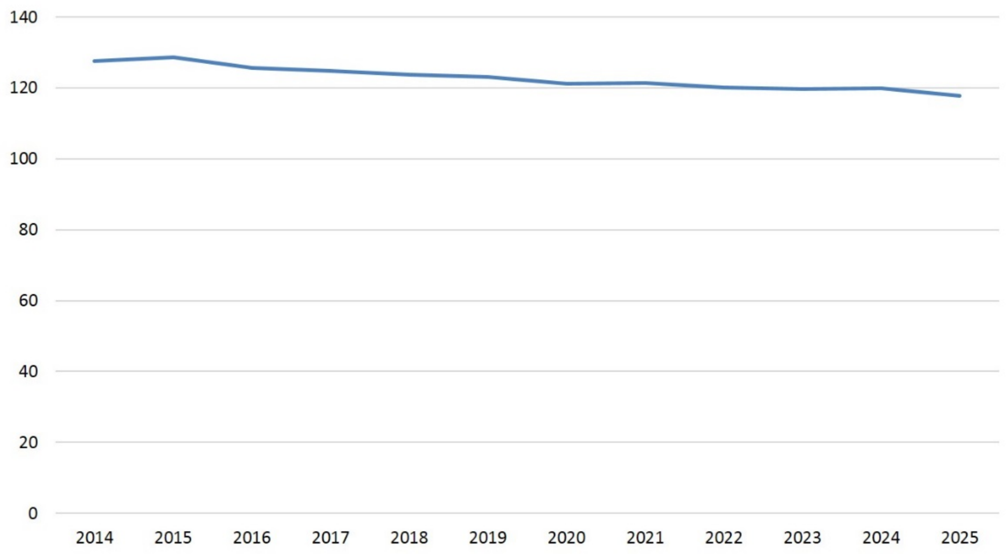
efficient production of biopharmaceuticals using bioprocessing techniques – i.e. using synthetic biology to create "bacterial cellular factories" to improve efficiency and / or reduce cost in manufacturing biopharmaceuticals.[23]

5.2.2 Energy

Concerns about climate change have led to a search for technologies that are less environmentally damaging with lower greenhouse gas emissions. The British government has adopted a series of targets to fight climate change and mitigate the effects of resource depletion. As part of a European Union initiative, the United Kingdom is committed to generating fifteen per cent of energy from renewable sources by 2020. The Climate Change Act of 2008 sets a legally binding target to reduce greenhouse gas emissions by 34 per cent by 2020 and by 80 per cent by 2050.

At the same time, energy demand is expected to fall only slightly. As Figure 12 shows, between now and 2025 total energy consumption is projected to fall by just eight per cent.

Figure 12: Total United Kingdom final energy consumption projection 2014 to 2025, kilotonne of oil equivalent, thousands



Source: Department of Energy & Climate Change updated energy and emissions projections – September 2014, Annex F, reference scenario.

This presents the United Kingdom with a potential shortfall of energy which industrial biotechnology can play a large part in filling.

[23] Manchester Institute of Biotechnology, *Discovery through innovation*, 2014, p. 28.

- **Biofuels.** Biofuels provide one specific means to achieve the emissions reductions that are envisaged. The availability of these energy resources is increasing. State of the art enzymology and laboratory evolution techniques have been combined with synthetic biology to make organisms produce liquid fuels such as ethanol, butanol, methanol and biodiesel. Research is still ongoing to produce a wider range of easily substitutable replacements to current oil-based fuels through biotechnology.[26] Biofuels with such characteristics are termed "drop-ins". There is scope for applying the processes underpinning the production of alkanes in nature and engineered variants to undertake the production of drop-in biofuels.

- **Energy waste.** The ambition of bioenergy innovators is not simply to produce energy, however, but also to consider how the waste products from doing so can be transformed, via biotechnology processes, into things of use. To enable the treatment and recycling of complex biological and chemical wastes and raw materials in a single integrated process, platforms are being developed which integrate biofuel production through modern processing technologies with bacterial fermentation of synthetic gas and the pyrolysis of high complex bio-waste to enable both treatment and recycling of complex biological and chemical wastes. [27]

- **Fuel Cells.** Metal-containing enzymes can be used to replace expensive platinum-group metals that are necessary to speed up the energy conversion process in fuel cells. The enzymes are as effective as the expensive metals and only use abundant elements such as iron, nickel and copper in their processes.[28]

Analyses have indicated that the potential of biotechnology in the production of energy is significant:

- A report by the World Wide Fund for Nature found that the climate change mitigation potential of industrial biotechnology and bioenergy in general ranges between 1.0 billion and 2.5 billion tonnes of carbon dioxide per year by 2030, compared with a scenario in which no such applications are available.[29] This is equal to approximately three to

[26] Royal Society of Chemistry, *The biofuel future*, 2009.
[27] Manchester Institute of Biotechnology, *Discovery through innovation*, 2014, p. 23.
[28] Manchester Institute of Biotechnology, *Discovery through innovation*, 2014, p. 24.
[29] World Wide Fund for Nature, *Industrial biotechnology: More than green fuel in a dirty economy?*, 2009.

seven per cent of total global emissions in 2013.[30] Thus, industrial biotechnology has the potential to make a significant contribution to creating a low carbon economy.

- According to an appraisal commissioned by the Department of Energy and Climate Change, by 2020, the United Kingdom could have access to bioenergy supplies equivalent to twenty per cent of current primary energy demand and domestic feedstocks could provide about one-third of potential bioenergy supply. By 2030, mainly due to the development of energy crops globally, supply could rise substantially to between a half and three-quarters of current primary energy demand in the United Kingdom.[31] The range is due to assumptions about whether the production of energy crops or of biofuels is maximised.

- The likely negative impact of biofuels on greenhouse gas emissions is somewhat complicated by potential knock-on land use changes – i.e. whether the production of energy crops may displace other agricultural products to land where they could cause a reduction in net carbon dioxide absorption. Nevertheless, analysis suggests that, to the extent that energy crops are grown on ‘spare’ agricultural land, they should achieve at least a 35 per cent emissions reduction.[35]

5.2.3 Industrial enzymes

In chemicals and related sectors, biotechnological processes serve three purposes – to produce better products, to do so efficiently and at low cost and to use more environmentally sustainable methods. Industrial enzymes are used to produce an array of products including flavourings, fragrances, fine chemicals, pharmaceuticals and agro-chemicals.

A selection of applications across a range of industries are:

- Bio-polishing, denim finishing and desizing and in the textile industry
- Use in detergents to remove various types of stains from clothes
- Assisting in the treatment of pulp to make paper
- Facilitating the production of leather and rubber

And there many future research avenues:

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[30] Based on figures from Netherlands Environmental Assessment Agency, *Trends in global CO2 emissions: 2014 report*, 2014.
[31] AEA Group, *UK and global bioenergy resource – final report,* (report for the Department for Energy and Climate Change), 2011.
[35] AEA Group, *UK and global bioenergy resource – final report,* (report for the Department for Energy and Climate Change), 2011.

- **Biocatalysis.** Bioprocesses have the potential to overcome the hazardous and environmentally costly impacts of current chemical oxidation processes. The new technology platform of biocatalysis is expected to allow the rapid development of bio-oxidations as a routine technology for the industry for applications in flavourings, fragrances and fine chemicals. Aerobic biocatalytic oxidation reaction currently has the potential for the biggest impact on the future uptake of industrial biotechnology in Europe.[36]

- **Bacterial strains.** Research is ongoing to see that these also can be used to produce flavourings and fragrances. They will reduce the environmental impacts associated with classical synthesis processes and release industry from the constraints imposed by the finite natural of currently used natural resources.[37]

5.3 Knowledge sharing

It is likely that many industrial biotechnology firms cause additional economic effects through knowledge sharing. Whilst this may seem unlikely given the proprietary nature of much knowledge, our survey reported cases where companies at different stages of the value chain would cooperate and even engage in joint research and development projects. This applies to products in personal care, healthcare and home care.

A study by Biggar Economics found that the aforementioned Roslin Institute was responsible for a knowledge transfer impact on the economy of £28.6 million. This is due to the fact the Institute acts in many ways like an information hub. Examples include maintaining close relationships with a variety of industrial partners, participating in knowledge exchange programmes, contributing to the development of government policy and regulation and undertaking public engagement and awareness raising activity. Future impacts from the expansion of its activities could amount to a further £397 million. These include creating an innovation campus, bringing academic and commercial research together to advance and commercially exploit emerging technologies. [38]

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[36] Manchester Institute of Biotechnology, *Discovery through innovation*, 2014, p. 19.
[37] Manchester Institute of Biotechnology, *Discovery through innovation*, 2014, p. 20.
[38] Biggar Economics (2013), *Economic impact of the Roslin Institute*.

6 BRITISH BIOTECHNOLOGY AND BIOENERGY IN A GLOBAL CONTEXT

In this section we assess the United Kingdom's relative position in the global biotechnology and bioenergy market place and discuss its significance in the worldwide setting.

6.1 The size of the industrial biotechnology globally

Because of the definitional difficulties surrounding industrial biotechnology and, indeed, biotechnology more generally, estimates of the size of these markets globally vary as much as national estimates. The most significant drawback with many past estimates is that most have not included all biotechnology activities – for example, excluding firms whose turnover is not mostly derived from biotechnology products – or have gone the other way by including the non-biotech segments of industries that contain a substantial portion of biotech products – for example, including the whole pharmaceutical industry as biotechnology.

In 2011 the Organisation for Economic Cooperation and Development reported estimates of current global revenues for goods produced using industrial biotechnology at between €50 billion and €60 billion annually.[40] Arthur D. Little estimated global industrial biotechnology sales of between £35 and £53 billion, giving the United Kingdom between a 3.4 and a 5.1 per cent share of the world market.[41] In 2014 Ernst & Young estimated that in the previous year the biotechnology sector in the 'four established centers', the United States, Europe, Canada and Australia, had revenues of $99 billion, up ten per cent on the year before that. The revenue figure for Europe was $21 million and for the United Kingdom, biotechnology revenue was estimated to be 5.8 per cent of the global total.[42]

[40] Organisation for Economic Co-operation and Development, *Future prospects for industrial biotechnology* (Organisation for Economic Co-operation and Development, Paris), 2011, p. 10.
[41] Arthur D. Little, *Quantitative modelling of industrial biotechnology and renewable chemicals* (Arthur D. Little, Cambridge) May 2009, p. 7.
[42] Ernst & Young, *Beyond borders - Biotechnology Industry Report 2014 Unlocking value* (Ernst & Young, London), 2014, pp. 37-49.

6.2 Global drivers

One of the major drivers of recent growth has been mandatory use regulations for biofuels. The global biofuels demand in the 2010 was estimated at 59 billion US gallons consisting of mainly ethanol and biodiesel produced from feedstocks such as corn, sugar cane and wheat. The market is particularly strong in North and South America, with revenues in the United States accounting for 45 per cent of the global market in 2011.

The market in 2011 was estimated at £32 billion based on the market value of products such as amino acids, glycerin, lactic acid, vitamins and alcohols and involves some 4,000 companies worldwide. The production of industrial enzymes, a particularly strength of the European region, is another significant market with a global value of £1.9 billion in 2011 for products used in the food, brewing, detergent and animal feed industries.[43]

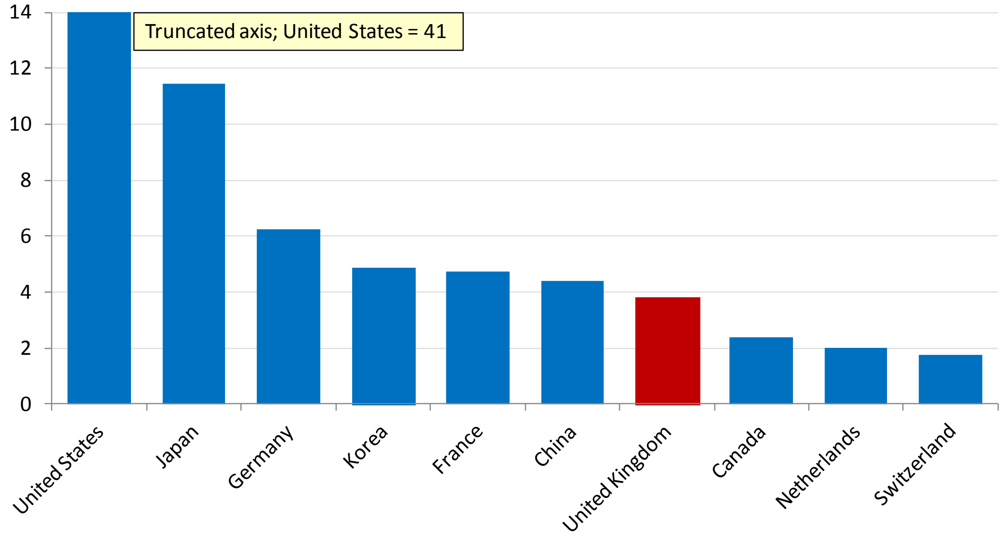
6.3 Research and development

One aspect where Britain has been a leader in industrial biotechnology is in research and development. According to the Organisation of Economic Cooperation and Development, the United Kingdom is one of the leading countries in terms of numbers of biotechnology patent applications filed under the Patent Cooperation Treaty. Figure 13 shows the proportions of such applications by country for the years 2010 to 2012. The United Kingdom is in seventh place, with almost four per cent.

This does not give the complete picture. Biotechnology accounts for a somewhat greater proportion of total technological innovation in the United Kingdom than it does in other leading economies. Figure 14 presents an index of revealed technological advantage in biotechnologies, calculated as the share of the country in biotechnology patents relative to the share of the country in total patents (filed under the Patent Cooperation Treaty), for the G7 economies. The United Kingdom is third behind only the United States and Canada, indicating that biotechnology activities are relatively more important to the British economy than to most other G7 countries.

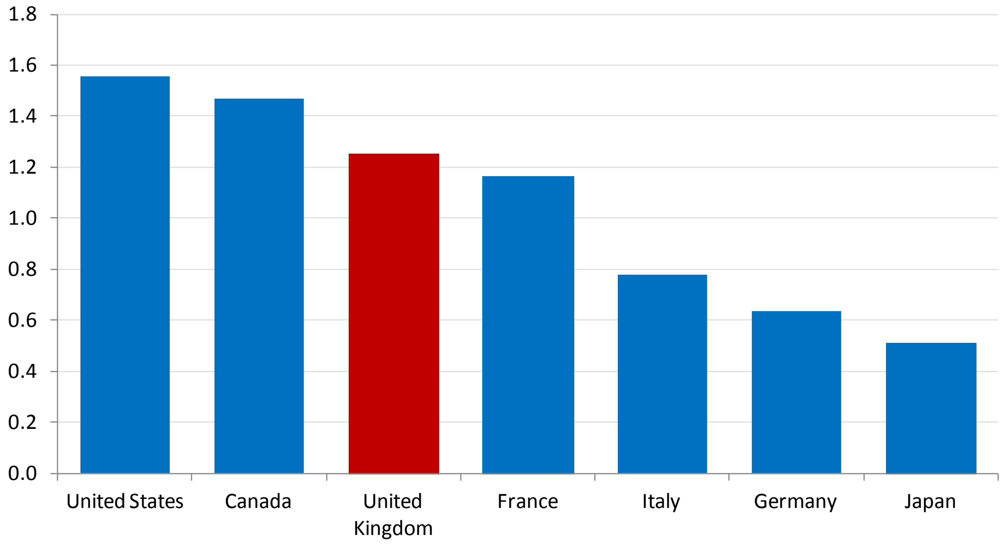
[43] Department for Business, and Skills, Strength and opportunity 2013, 2013, p.12.

Figure 13: Leading countries' shares of total biotechnology patent applications filed under the Patent Cooperation Treaty, latest available year (per cent)



Source: Organisation for Economic Cooperation and Development.

Figure 14: Index of revealed technological advantage in biotechnologies, G7 countries, latest available year (share of the country in biotechnology patents relative to the share of the country in total patents)

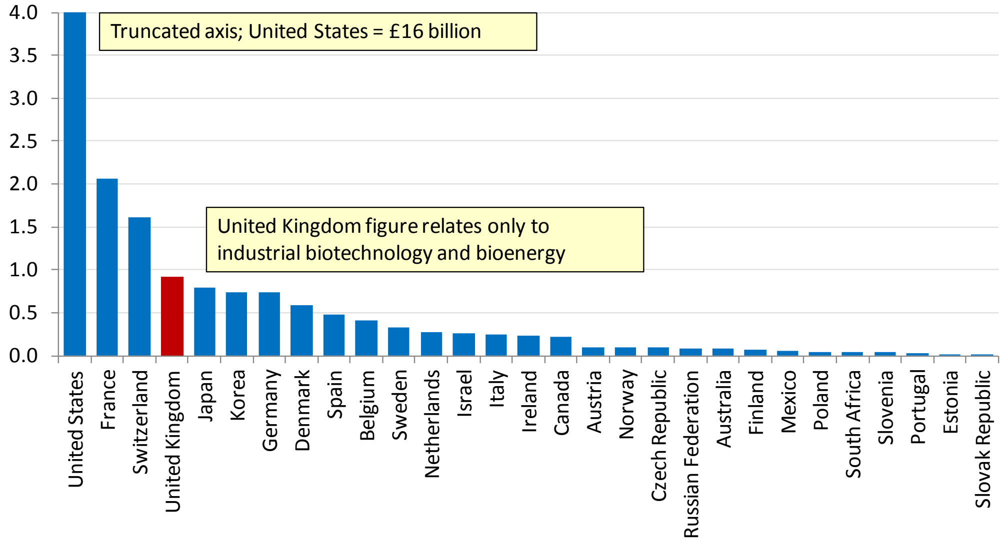


Source: Organisation for Economic Cooperation and Development.

The Organisation for Economic Cooperation and Development also produce data on the overall biotechnology research and development expenditure by businesses for selected countries. On their measure, the United Kingdom is the fourth largest research and development contributor even when only considering the expenditure on industrial biotechnology and bioenergy. (See Figure 15.) Commensurate with this high level of research development activity goes a high level of manufacturing, as evidence by the information provided by respondents to our survey and other evidence on biotechnology and bioenergy activities (e.g. the Strength and Opportunity reports prepared by the government).

Overall, the United Kingdom is in a good position to build on its place within the global industrial biotechnology and bioenergy market. It has both the manufacturing and research and development capabilities, supported by a skilled workforce and a strong link with world-class academic institutions. There is significant potential for growth if the industry continues to be supported.

Figure 15: Biotechnology research and development expenditures in the business sector, 2013 or latest available year, £ billion



Source: Organisation for Economic Cooperation and Development for all countries except United Kingdom. United Kingdom figure comes from Capital Economics' survey.

7 GROWTH POTENTIAL

This final section reviews the projections that have been made for the growth of industrial biotechnology and bioenergy. We provide a considered view of the most probable trajectories of future growth and the environments that underpin them.

7.1 Previous growth estimates

There are many predictions of future market values. For example, one estimate, quoted by the Organisation for Economic Co-operation and Development in 2011, is that by 2030 the global market for industrial biotechnology could reach roughly €300 billion.[44] The same organisation estimated, in 2009, that biotechnology could contribute up to 2.7 per cent of its member's gross domestic product by 2030. This figure could be higher in non-Organisation for Economic Co-operation and Development member countries due to the greater importance to output of primary and industrial production compared to developed countries.[45]

A 2009 study by Arthur D. Little developed four potential scenarios for growth in industrial biotechnology in the United Kingdom. (See .) These scenarios generated growth rates for sales of chemicals derived from industrial biotechnology of between five and eleven per cent per annum between 2008 and 2025. It estimated the global industrial biotechnology market in 2025 at between £150 and £360 billion. This would give the United Kingdom a share of between 2.7 and 3.3 per cent of the global industrial biotechnology market – below its current share. These findings were highlighted in a report for the Department for Business, Enterprise and Regulatory Reform.[46]

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[44] Organisation for Economic Cooperation and Development, *Future prospects for industrial biotechnology* (Organisation for Economic Co-operation and Development, Paris), 2011, p. 10.
[45] Organisation for Economic Cooperation and Development, *The bioeconomy to 2030: Designing a policy agenda* (Organisation for Economic Co-operation and Development, Paris), 2009, p. 13.
[46] Industrial Biotechnology Innovation and Growth Team, *IB 2025 Maximising UK opportunities from industrial biotechnology in a low carbon economy* (Department for Business, Enterprise and Regulatory Reform) May 2009, p. 10.

7.2 Evidence of growth potential

In the healthcare sector, data collected by Ernst & Young shows that biopharmaceutical companies in the United Kingdom have a comparatively strong pipeline of potential new products. Their data includes new chemical entities as well as new biological entities, but nonetheless gives a strong indication of the potential of the British health biotech sector. The United Kingdom is the pipeline leader in Europe, with 464 products, or seventeen per cent of the total, ahead of Switzerland (299) and Germany (287).[47] Furthermore, evidence from EvaluatePharma suggests that 45 of the world's top 100 selling pharmaceuticals in 2020 will be biologics or bioengineered vaccines.[48] It is therefore likely that a substantial number of the pipeline products are biotech products.

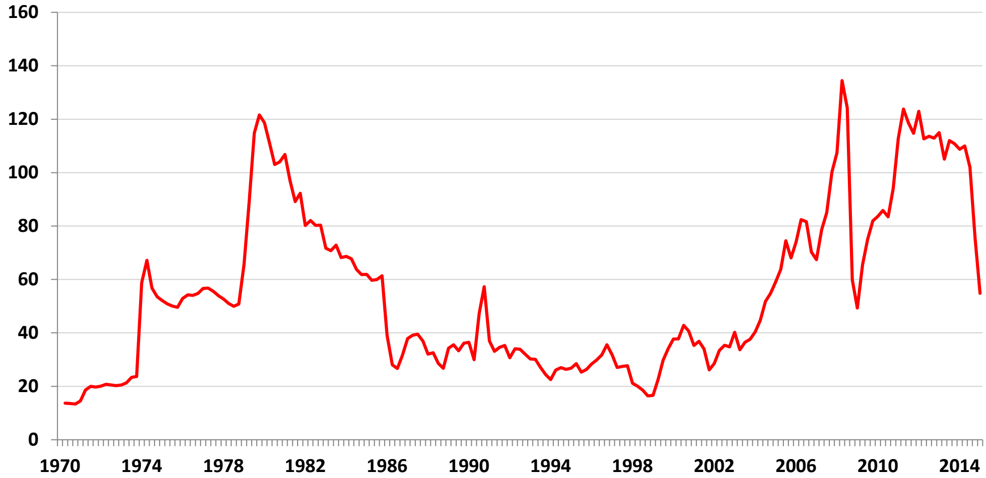
Governments across the world, including the United Kingdom, have signed up to carbon reduction targets and new sustainable biotechnological innovations can help them to achieve them. Industrial biotechnology and bioenergy – the use of biological substances, systems and processes to produce materials, chemicals and energy – represents a major avenue to produce valuable chemicals, pharmaceuticals and antimicrobial compounds, whilst simultaneously meeting carbon reduction targets. As it can itself be used to generate energy with much lower greenhouse gas emissions than traditional sources, it also presents another way in which emissions may be reduced by even more. .

In addition, even setting aside the environmental issues, two other factors are likely to drive the demand for biofuels. In the first place, there is the price of energy from traditional sources. In the last decade oil prices have risen and become more volatile (see Figure 16).

[47] Ernst & Young, *Beyond borders - Biotechnology Industry Report 2014 Unlocking value* (Ernst & Young, London), 2014

[48] EvaluatePharma, *World preview 2014, outlook to 2020*, 2014. Available at: http://info.evaluategroup.com/rs/evaluatepharmaltd/images/EP240614.pdf

Figure 16: Real terms Brent crude oil price, US$ per barrel (2014 prices)



Source: Thomson Datastream.

Although we have indeed seen a fall in oil prices in recent months, we anticipate that oil prices will climb back from $65 per barrel. The International Energy Agency's has projected that crude oil prices will be around $128 per barrel in 2035 (in 2012 dollars).[49] These future likely high oil prices provide a compelling reason to seek out alternative sources of energy from a cost efficiency point of view.

Rising or increasingly volatile energy prices are bad for economic growth. The International Monetary Fund estimates that a ten per cent rise in the price of crude oil knocks 0.2-0.3 per cent off global gross domestic product in one year.

Secondly, energy security is an ongoing concern for the British government (and others). Much fossil fuel production, particularly that of oil, is based in geopolitically sensitive parts of the world, such as the Middle East and Russia. Hence, from both an economic and political point of view, the United Kingdom ought to prefer to have cheap, domestically produced energy rather than be reliant on supplies from politically contentious regions of the world. The use of biofuels provides one of the few means to achieve this objective whilst, at the same time, fulfilling greenhouse gas reductions consistent with climate change legislation and obligations.

[49] International Energy Agency, *World energy outlook 2013 factsheet*, 2013.

7.3 The imperative for industrial biotechnology and bioenergy

Industrial biotechnology and bioenergy activities are driven by research and development. Indeed, in the European Commission's 2013 *Industrial R&D Investment Scoreboard*, 15 of the top 50 companies came from the pharmaceuticals and biotechnology sector, up from eleven in 2004 and the third highest placed sector overall.[50]

There are strong economic arguments for the public funding of the sort of high end research and development which industrial biotechnology requires. The benefits of research and development do not only accrue to those who conduct it, they can also accrue to third parties who can benefit from the research with no cost. This incentive to 'free ride', to reap the benefits of research without incurring the costs, can lead to an under provision of research and development.

Indeed, funding for bioenergy research in the United Kingdom already lags that in competitor countries. Per capita government budgets for biofuel research and development are less than a quarter of the Organisation for Economic Cooperation and Development average.[51]

7.4 Current evidence and estimates for the growth potential of industrial biotechnology and bioenergy in the United Kingdom

Our survey asked respondents about their expectations regarding turnover growth for products manufactured using a biotechnology process. On average, respondents expected that, in five years' time, real terms turnover will grow by 40 per cent, in ten years, 131 per cent and, in twenty years, 192 per cent. For the ten year time horizon, this equates to a compound annual growth rate of rate of 8.8 per cent per year. Based on these rates of growth estimates, turnover would increase from £2.9 billion currently to £4.1 billion within five years, £6.8 billion over the next decade and £8.6 billion in twenty years' time (in 2014 real terms).[52]

[50] European Commission, *The 2013 EU Industrial R&D Investment Scoreboard*, 2013, p. 5.
[51] Organisation for Economic Co-operation and Development, *Future prospects for industrial biotechnology*, 2011, p. 51.
[52] Based on a sample accounting for 32 per cent of total turnover.

Figure 17: Estimated turnover figures and respective rates of growth for industrial biotechnology and bioenergy over the next 20 years (2014 real terms)

	2014	2020	2025	2035
Turnover (£ billion)	2.9	4.1	6.8	8.6
Increase over 2014 (per cent)	-	40	131	192

Source: Capital Economics

As a comparison, the highest performing sectors of the United Kingdom economy have only attained five to seven per cent rates of growth in gross value added over the last sixteen years.

Figure 18: Growth of gross value added in best performing sectors of the British economy, 1997 to 2013

	Compound annual growth rate 1997-2013 (per cent)
Information economy	7.5
Real estate	5.2
Professional and business services	5.1
Health and social care	3.6
Aerospace	3.3

Source: Department for Business, Innovation and Skills, Growth dashboard 2015

These expectations regarding growth are mirrored by other sources. The "Strength and Opportunity" publications by the Department for Business Innovation & Skills, which albeit only cover a portion of total industrial biotechnology and bioenergy, found that growth rates of turnover were 8 per cent per year over the period 2009 to 2014 (the growth mostly coming from biofuels (21 per cent per annum) compared to just three per cent for the sector overall). To the extent that there is a greater shift to biofuels over the years ahead as a result of the need to comply with climate change legislation, these retrospective rates could be adjusted upwards.

The use of biotechnology in pharmaceuticals is the main sector omitted from the "Strength and Opportunity" chapter (as it is covered elsewhere under pharmaceuticals). However, data from EvaluatePharma's forecasts suggests that the turnover associated with bioengineered vaccines and biologics will grow by 8.1 per cent per annum.[53] To this must be supplemented the growth in those small molecules manufactured using a biotechnology process. Our survey estimates that this specific segment may grow at 11.6 per cent per annum.

[53] EvaluatePharma, *World preview 2014, outlook to 2020*, 2014. Available at: http://info.evaluategroup.com/rs/evaluatepharmaltd/images/EP240614.pdf

Broadly, the evidence is approximately consistent with growth of total turnover of approximately nine to ten per cent per annum.

However, it is important to note that these projections are based on the views of businesses today and analyses of previous growth trends. The actual outcome could be much greater given the innovative and exploratory nature of industrial biotechnology and bioenergy. As research and development continues and the knowledge base expands there is always the potential for new products and processes to be developed that transform production practises in certain markets. On current evidence we expect turnover from industrial biotechnology and bioenergy to quadruple over the next twenty years, but developments could make this a significant under estimate.