Response from the Royal Society of Biology to the BEIS consultation on the UK Bioeconomy

January 2017

Introduction

The UK government, working with 5 industry sector leadership councils, would like your input to help shape a UK bioeconomy strategy. Our aim is to produce a strategy which will foster a world leading bioeconomy in the UK, which takes into account objectives in related sectors across the economy.

This call for evidence is open to all who have an interest in the bioeconomy – both individuals and organisations.

The data you supply will provide us with valuable evidence to support the development of the strategy and allow us to understand the full range of issues and opportunities facing the bioeconomy.

You will find the questions divided into the following headings:

- Bioeconomy definition
- Economic growth
- Sustainability
- Investment
- Research and Development
- Sectoral co-operation
- Supply Chain co-operation
- Government and Policies
- European Issues
- International Issues
- Standards
- Other questions

NB: Questions 1-6 concern personal and organisational details and a confidentiality statement.

Bioeconomy definition

What is the bioeconomy?

The bioeconomy is the economic opportunity of using biology to help solve challenges we face in agriculture, energy, health and more, which has the potential to deliver economic, environmental and social benefits to the UK.

The bioeconomy includes all economic activity derived from bio-based products and processes. These have the potential to contribute to sustainable and resource-efficient solutions to the challenges we face in food, chemicals, materials, energy production, health and environmental protection.

The bioeconomy comprises all economic activities that are either:

i. Feedstocks which could be biomass based (including domestic, commercial, agricultural or industrial waste) or fossil fuel based (including industrial and metropolitan wastes) which are treated by a combination of physical, chemical and biotechnological processes;
ii. 'bio-transformative activities – Those which add value through the inclusion of a physically or chemically transformative process that involves either as outputs or as processors, biological resources (the tissues, cells, genes or enzymes of living or formerly living things);
iii. 'bio-based upstream activities' – Those that add economic value as upstream suppliers of bio-transformative activities; or
iv. 'bio-based downstream activities' – Those which add economic value as downstream users of the outputs of bio-transformative activities.

7. Does our definition of the bioeconomy (see overview above) include within its scope all of the relevant bio-based products and processes? If not, please explain.

Various definitions exist for the term 'bioeconomy'. We would largely agree with the broad definition above, which explicitly states the inclusion of 'all economic activity derived from bio-based products and processes.' The inclusion of upstream (e.g. financial services) and downstream (e.g. construction) activities gives the definition of the bioeconomy a wide scope, capturing a broad spectrum of related economic activities.

However, the definition may appear to describe industrial biotechnology, biomass and the bio-based chemical industry. There is little to indicate that it also includes agriculture, fishing, the manufacture of food and drink. Determining ways to integrate the agri-food sector – the main purpose of agriculture – with industrial elements of the bioeconomy, rather than seeing them as distinct, presents a real opportunity for adopting a bioeconomy approach. Biobased diagnostic systems and healthcare applications also appear not to have been included explicitly in this definition.

Furthermore, some potential aspects of the bioeconomy are not explicitly mentioned within this definition, which could be a missed opportunity. For example, the definition does not mention the potential to build a

collaborative and circular bioeconomy, where systems and processes feed into one another across a broad range of sectors and industries.

Knowledge is also a key output from the life sciences sector. The sharing and application of knowledge contributes significant economic benefit to the UK economy in general, often through avoided costs, and this is an important output of research and development.

Economic growth

Through the various types of bio-based activities, the bioeconomy makes a significant contribution to output and employment in the British economy. The whole bioeconomy, comprising transformative, upstream and downstream elements generated approximately £220 billion in gross value added and supported 5.2 million jobs in 2014.

8. Within your sector or organisation, what are the prospects for economic growth that are related to the bioeconomy?

The agri-food sectors are the largest part of the bioeconomy.[1] The entire agri-food sector, from farm to sale to the consumer, contributed £108 billion to the UK economy in 2014 and employed one in eight of the national workforce. The largest manufacturing sector in the UK is our food and drink industry, which added £26.9 billion gross value added to the economy in 2014 and providing 3.8 million jobs. Exports of UK food and drink were worth over £18.1 billion in 2015, with opportunities for growth to take advantage of emerging markets.[2]

Additionally, the Chemistry Growth Strategy Group has estimated that the industrial biotechnology and bioenergy sectors will quadruple in the next 20 years, and could grow faster than this, given their potential for new products, new markets, and their innovative nature.[3] However, growth in the biofuel and bioenergy sectors will be significantly influenced by the policy environment. Uncertainty surrounding the future of the Renewable Transport Fuels Obligation in the UK, and the removal of subsidies for renewable energy,[4] along with low costs for fossil fuels, could constrain growth in this part of the bioeconomy.

Use of biomass or waste as a material has also been identified as an area with significant potential for growth, with potential long-term benefits of £8 billion estimated to the economy by 2030.[5] Substantial

[1] Defra 2016. British food and farming at a glance. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/515048/food-farming-stats-release-07apr16.pdf

[2] Defra and DFIT 2016. UK food and drink – International action plan 2016-2020. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/560786/food-drink-export-action-plan-2016-2020.pdf

[3] Chemistry Growth Strategy Group 2013. Strategy for delivering chemistry-fuelled growth of the UK economy. http://www.cia.org.uk/Portals/0/Documents/Growth%20Strategy%20FINAL.PDF

[4] https://www.gov.uk/government/news/controlling-the-cost-of-renewable-energy

[5] Chemistry Growth Strategy Group 2013. Strategy for delivering chemistry-fuelled growth of the UK economy. http://www.cia.org.uk/Portals/0/Documents/Growth%20Strategy%20FINAL.PDF

growth is also expected in synthetic biology, with applications in medicines, healthcare, and new, as yet undiscovered markets. [6]

9. Given your expectations, do you think there are potential issues that are holding back further economic growth in the sector?

For example:

- feedstock availability
- demand or ability of downstream users to adapt to the new products
- demand or ability of end users to adapt to the new products
- workforce skills
- input/output price uncertainty
- confidence in future of the sector

There are several potential barriers to growth of the UK bioeconomy.

Investors (and some research programmes) are deterred by uncertainty and a lack of stability in policy. Examples of recent policy changes include the sell-off of the Green Investment Bank, the removal of climate change levy exemption for renewables, and the ending of grandfathering for biomass conversions in the Renewable Obligation.

Innovative products and services can fail to reach the market through a lack of translational research, falling victim to the well-known 'valley of death'. Government has recently created initiatives to address this, though it is too soon to review their impact.

There are barriers to entry for new products and services, including high initial costs, and a lack of awareness and confidence among investors and the public.

Burdensome regulation can act as a barrier to growth in the bioeconomy, with the EU's approach to GM organisms a potential example. The transfer by BASF of its R&D facility from Germany to the US may arguably be illustrative of a potential effect of regulation on business.

The UK industrial biotechnology sector includes many small and medium-sized enterprises (SMEs). Small companies can by focused, highly innovative and disrupt established markets. However, the fragmented nature of the industry is cited as an obstacle to its growth, because it:

- *makes it difficult for SMEs to attract and retain a stable, skilled workforce*
- *makes it difficult for large companies to know where to look for partners*

[6] Technology Strategy Board. A synthetic biology roadmap for the UK.

- *tends to lead to an excess of networks, industry associations and government departments which are focused on developing a sector that consists of a relatively small number of companies* [7]

A shortage of suitably skilled workers has also been cited as a barrier to growth; especially in skills that extend beyond the laboratory, related to commercial awareness and entrepreneurship.

Another potential barrier to development in this sector is a negative public perception of new technologies that could be linked to a failure of the scientific and science policy communities to engage appropriately. In the case of genetically modified organisms, communication failures have contributed to the generally adverse position. It is important to avoid repeating any such mistakes for other technologies that may arise in the bioeconomy. Training for scientists in public engagement and attentive communication, in addition to instigation of a communications strategy (in private and public institutions) with clear lines of responsibility for development, could help to address this barrier and ensure less contentious outcomes.

10. Do you think that growth in a particular sector of the bioeconomy impacts growth in other sectors in a way that should affect priorities?

Sectors of the bioeconomy may be dependent on other sectors. For instance, cellulosic crops provide feedstocks for the production of biofuels and bioproducts. Increases in primary production through plant breeding innovation could ensure the continued supply of economically priced, domestically produced feedstocks. However, growth in (for instance) the biofuel sector could lead to competition with other sectors for raw materials. Effects on supply and demand will need to be carefully reviewed if granting or removal of subsidies is considered.

The introduction of subsidies for biofuel has distorted the market for timber, a resource over which various sectors compete. Owing to insufficient recycled and marginal wood for biomass, small logs are incinerated as an alternative. The prices paid for this material by biomass projects are subsidised[8] *and therefore other sectors are unable to compete to use it for other purposes, such as construction.*

Antimicrobial resistance (AMR) is a threat to public and ecosystem health. Development of AMR is accelerated by poor practice and inappropriate use of products in the control of diseases, and by global trade and travel. Growth of sectors of the bioeconomy that make use of antibiotics and other products to control disease in plants, humans and other animals risk contributing to the spread of AMR, with knock-on effects on other sectors, unless more is done to improve practices regarding the use of these products.

11. What do you think the UK's bioeconomy goals should be in the long term i.e. 15 years or more?

Over the long-term, in order to generate a world-leading bioeconomy, the UK should aim to capitalise on its strong research base, translating the expertise in its researchers into innovative products and processes. The UK should then ensure support for the industrial development and job market that grows up around such processes, while encouraging their collaboration and integration, to induce a sustainable and efficient system.

[7] NESTA 2011. Financing Industrial Biotechnology in the UK. https://www.nesta.org.uk/sites/default/files/financing_industrial_biotech.pdf
[8] https://www.timcon.org/Publications/PressReleases/Releases/Default.asp

As well as the opportunity to reindustrialise, the transition away from the petroleum-based economy to a bioeconomy should be accompanied by a commitment to sustainability and leaving the environment in a better state, as the Government has pledged. This involves action to decrease reliance on fossil fuels, rebuild natural capital, reduce wastes and recycle them into new feedstocks, and design agricultural systems that support soil fertility and biodiversity.

Britain's departure from the EU presents an opportunity to review land-use options and implement a strategic, systems approach to land management- which recognises the connectivity between rural and urban systems. Over the last 40 years under the Common Agricultural Policy, intensification of farming has had an overall detrimental effect on the UK's environment, in spite of the benefits arising from agri-environment schemes. With the opportunity to rethink farm subsidies, the UK could develop an agricultural funding mechanism that better integrates agriculture and the environment, shifting the balance away from income support towards payment for the delivery of ecosystem services – the benefits we receive from the environment such as clean water, soil quality and biodiversity. The new mechanism could focus on outcomes based on a principle of "public money for public goods". There is also an opportunity to support markets for environmental goods and services, for example a scheme in which farmers and land managers are compensated for providing clean water and enhanced flood resilience by businesses and public sector organisations downstream within a catchment. Alternative support could also be provided to encourage the sustainable production of other biotechnology related outputs, such as specialist crops and industrial feedstocks.

The British Ecological Society has suggested that rethinking land-use in such a manner will require an evidence informed approach, where monitoring, research and evaluation at agreement and scheme level should be embedded within the policy, including collection of baseline data and field studies of interventions. Investment in monitoring and evaluation should be increased beyond the current level of agri-environment scheme value.

In relation to this, building prosperity in rural communities should be a goal for the UK bioeconomy. The development of the agri-food sector presents an opportunity to stimulate rural development with employment opportunities close to natural resources and create higher value-added products. The development of the biomass sector, with the potential for projects that use biomass close to their source, presents further opportunities for rural communities.

Improved health of UK citizens should be a goal for the bioeconomy, incorporating the development of probiotics, functional foods and the expansion of efficacious and affordable natural products. The agri-tech and food sectors should aim to provide affordable healthy food for the population.

12. What do you think the UK's bioeconomy goals should be in the short term i.e. the next 5 years?

In the short term, the UK should aim to maintain and develop a skilled workforce; reduce geographic fragmentation in various sectors of the bioeconomy by enabling national and international collaboration; and improve awareness of the benefits of bio-based products among the general public- for example through discussion in educational curricula about sustainability at all levels.

In addition the UK needs to understand the ecological carrying capacity for elements of the bioeconomy; developing knowledge about production limits and impacts, and the same for use impacts.

13. Can you tell us about any "quick wins" to increase the growth of the bioeconomy?

The introduction of higher-level apprenticeships presents an opportunity for companies to develop superior technical skills in their workforce. The Government could explore the possibilities for tailoring advanced technical training to take account of the structure of this sector.

The bioeconomy offers the opportunity to substitute conventional materials with renewable and sustainable alternatives. Construction offers an example. A successful long-term partnership to promote sustainable construction, with Government, business and the University sector, has led to the commercial development of highly engineered, modern timber buildings that deliver energy and carbon efficiency using domestically grown wood, a renewable resource. The new technology allows multi-storey, modular construction. Buildings can be fabricated quickly and inexpensively off-site and erected on lightweight, low-cost foundations.[9] Supporting the replacement of conventional products with biodegradable alternatives would also help to reduce landfill and the build-up of waste or pollution in the environment. Utilising renewable materials in this manner, for example when producing low-cost domestic and commercial accommodation, could enable substantial energy and carbon footprint advantages.

Targeted public procurement of sustainable bio-based products in preference to conventional alternatives will help to drive markets directly, improve awareness of these products and support new products entering the market. We welcome the commitment to 'buying greener products and services' in the recent policy paper 'Greening Government Commitments 2016 to 2020',[10] and would like to see this approach extended across public sector organisations. The Government's green paper 'Building Our Industrial Strategy' discusses improving procurement, with actions to assist small businesses through public procurement.[11] However, a greater commitment to support businesses creating innovative and sustainable products in order to achieve the best overall value for money for society over the long-term would be welcome.

The development of enterprise hubs or clusters has been important in the growth of the bioeconomy in France and Germany, and measures to support their development here would help to reduce fragmentation, enable the sharing of expertise and create a critical mass to attract skilled workers. In the UK, bioeconomy clusters are developing, including the BioVale cluster in Yorkshire and the Humber, an IB hub in Scotland around IBiolC, and a biorefining cluster in Wales supported by the BEACON project. Science parks that develop as centres of excellence can allow for supply chain collaborations in the medical, healthcare, agri-tech and food sectors.

Developing a skilled workforce and supporting businesses are key priorities for the UK bioeconomy. Attracting inward investment from innovative multinational companies would help to increase the growth of the bioeconomy, increasing investment in facilities and training, which may improve industry confidence and stimulate more investment.

The Government should also foster sustainable growth of UK companies. The bioeconomy is an opportunity for the emergence of UK companies to expand worldwide, using the platform of our strong

[9] http://scotland.forestry.gov.uk/supporting/forest-industries/sustainable-construction

[10] https://www.gov.uk/government/publications/greening-government-commitments-2016-to-2020/greening-government-commitments-2016-to-2020

[11] https://www.gov.uk/government/consultations/building-our-industrial-strategy

research base. Promoting university/business partnerships (along-side the spin-off model) could help to bring this about. Universities working in partnership with companies may have the equivalent of enhanced in-house R&D so that they can deliver cutting-edge products.

Ultimately, to address future needs for skills in the bioeconomy, it is crucial to engage more young people with STEM, and to provide good information about STEM careers. The introduction of higher-level apprenticeships presents an opportunity for companies to develop superior technical skills in their workforce. The Government's Post-16 Skills Plan sets out the proposed route for advanced technical training in 'Agriculture, Environmental and Animal Care', which should increase access to training in these areas.[12] It will be important to consider how this route can be developed to take account of the skills needed in the UK bioeconomy. There is also a need to support the upskilling of the current workforce. Initiatives have developed to support professional registration and continual engagement with professional development in some disciplines that were not traditionally recognised professions. Examples include the professional registers organised by the Royal Society of Biology for Registered Science Technicians (RSciTech) and Plant Health Professionals.[13,14]

The UK should aim to see development across sectors of the bioeconomy. In Germany, this has been achieved by the creation of the Bioeconomy Council.[15] A similar advisory body for the UK, along with the new strategy for the Bioeconomy, could help to achieve this coordination here, and is worthy of investigation.

In the fields of pest and disease control, highly promising and much needed new products need to be considered in the registration process. Efficient registration of products could stimulate development by shortening time to market and reducing costs. Guidance and support for SMEs when navigating this process could also help such companies.

14. Do you think the UK is likely to miss any of these "quick wins"? If so, why is that?

The sale of the Green Investment Bank may damage confidence that investment will continue in sustainable innovation, potentially deterring investment by others.

15. Can you tell us about any other issues in the broader environment that are holding back economic growth in the bioeconomy?

Fundamental research is needed to maximise the opportunities for developing new initiatives to advance growth in the bioeconomy; gateways such as the future UKRI will be interested in funding this research. Incentives for academic researchers need to value research in policy creation and real-world application as well as traditional publication. Alongside this, support for applied research is needed so that knowledge already attained can be exploited.

However, it must be ensured that the research is worthy of funding. REF2014 provided a useful tool to focus efforts on research excellence and ensure that academic researchers put detailed thought into the

[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536043/Post-16_Skills_Plan.pdf
[13] https://www.rsb.org.uk/careers-and-cpd/registers
[14] https://www.rsb.org.uk/careers-and-cpd/registers/plant-health-register
[15] http://biooekonomierat.de/en/

impact of their work. As such, impact is now something that the majority of academic researchers are happy to engage with. What is likely to be most needed at this point is support and incentives for the creation of creative ideas to allow excellent basic research to be rapidly translated into economically viable products. To do this we need more bioscience-educated entrepreneurs, more strategies for developing translational pipelines and larger portfolio projects to mitigate the inevitable risks in product development.

Sustainability

As demand for bio-based resources increases, there can be concerns regarding feedstock sustainability, including the direct and indirect impacts of changes in land use, soil quality and carbon stocks. However, there are also opportunities to increase resource efficiency by using residues from agriculture, forestry, and industry.

16. How sustainable is your sector of the bioeconomy in respect of infrastructure issues, e.g. roads, planning issues, telecommunications, energy and water supply?

The bioscience sector as a whole is very broad and arguably intersects with most the majority of economy. Some areas are fast-changing and require updated infrastructure (the newest diagnostic or analytical facilities for example) and other areas rely on infrastructure upgrades at a different pace. Some sectors are reported to us as highly sustainable, for example, forestry. The UK forestry sector has achieved international certification for its sustainable forest management (UKWAS,[16] FSC) and the Government's forest estate has ISO14001 accreditation. The sector also delivers social and ecosystem benefits; it occupies 12% of the UK land area but has 60% of all environmentally designated sites and it receives perhaps 700m recreational visits each year.[17]

17. How does your sector contribute to or impact on sustainability in respect of environmental issues including concerns about high energy use, water, greenhouse gas emissions, air and land pollution and destruction of animal habitats?

18. How should the strategy take into account UN sustainable development goals?

These include: ending hunger and poverty, improving food security and nutrition, cleaner water and improved sanitation, affordable and clean energy, sustainable industrialization with responsible production and consumption, reducing climate change, and protecting ecosystems on land and in water. See: https://sustainabledevelopment.un.org/?menu=1300

Bioeconomy sectors are central to at least half of sustainable development goals (SDGs), from ensuring health and energy access to food security.[18] The transition from a petroleum-based economy to the bioeconomy is anticipated to contribute towards the SDGs. The SDGs could provide guiding principle for the strategy, and set out pathways to progress. This progress should be measured and monitored.

19. How sustainable is your sector of the bioeconomy with respect to workforce skills?

[16] *http://ukwas.org.uk/*
[17] *http://www.forestry.gov.uk/pdf/SummaryReport2014.pdf/$FILE/SummaryReport2014.pdf*
[18] El-Chichakli 2016. Five cornerstones of a global bioeconomy. Nature 535: 221-223.

The land-based disciplines, such as farming and forestry, face difficulties in recruiting technical and professional personnel. Our members have identified that this issue is partly to do with the very low profile of land-based jobs among school-leavers making their study choices. Advanced apprenticeships may prove to be a real opportunity to address the recruitment shortfall.

The British Pharmacological Society has highlighted particular concerns about workforce skills in pharmacology with implications for the UK's future competitiveness in the pharmaceutical sector. The pharmaceuticals sector accounts for more UK-based research and development than any other manufacturing sector, and is a sector in which the UK has a strong advantage over other parts of the world. Particular STEM skills concerns highlighted by the British Pharmacological Society are the merging of specialist academic pharmacology departments into broader life sciences departments, the lack of investment in clinical pharmacology and the urgent need to maintain support for in vivo *skills (the use of laboratory animals for research). The Association of the British Pharmaceutical Industry has also drawn attention to major skills gaps in mathematical and computation areas that have emerged with the development of fields such as systems biology, bioinformatics, data mining and health informatics, as well as reinforcing the seriousness of the skills shortage in translational medicine/clinical pharmacology.*[19]

20. Has your organisation or businesses had difficulty in obtaining finance from one (or more) of these sources in relation to its bioeconomy activities? Tick all that apply and please provide additional details about the issue. You may use the tick-boxes to show amounts, but this is entirely voluntary.

☐ Venture capital ☐ Equity crowdfunding ☐ Corporate venture capital ☐ Private equity ☐ IPO/public offering ☐ Angel Finance ☐ Seed Finance ☐ Peer-to-peer lending ☐ Start-up loan ☐ Growth finance ☐ Bank loan/bond ☐ Export or trade finance ☐ Asset-based finance ☐ Leasing & hire purchase (asset finance) ☐ Overdraft ☐ Inward Investment ☐ Other

21. Has your organisation or businesses had difficulty in obtaining finance from one (or more) of these sources in relation to its bioeconomy activities? Tick all that apply and please provide additional details about the issue. You may use the tick-boxes to show amounts, but this is entirely voluntary.

☐ Venture capital ☐ Equity crowdfunding ☐ Corporate venture capital ☐ Private equity ☐ IPO/public offering ☐ Angel Finance ☐ Seed Finance ☐ Peer-to-peer lending ☐ Start-up loan ☐ Growth finance ☐ Bank loan/bond ☐ Export or trade finance ☐ Asset-based finance ☐ Leasing & hire purchase (asset finance) ☐ Overdraft ☐ Inward Investment ☐ Other

○ Below £1m ○ £1m to £4.9m ○ £5m to £9.9m ○ £10m to £100m ○ Over £100m

[19] http://www.abpi.org.uk/our-work/library/industry/Documents/Skills_Gap_Industry.pdf

22. More generally, does your sector, or sub-sectors within it experience difficulties in attracting investment? If so, why?

Many areas of bioscience require significant investment for development, and return on investment may be slow – i.e. patient capital is needed. Conditions favouring this are essential.

23. What sort of challenges does your sector face in terms of financial sustainability?

Research and innovation

The United Kingdom is particularly strong in the research and development aspect of the bioeconomy ranking second on the 2015 Global Innovation Index. We would like to build on this and create an environment where our world-class research is fully exploited by industry and society, and different sectors of the bioeconomy collaborate and tackle untapped opportunities, leading to the bioeconomy becoming 'greater than the sum of its parts.

24. What are the key areas for investment in research and development in your area of the bioeconomy?

Most private investments in the bioeconomy have been directed at the pharmaceutical and biomedicine industries.

However, research in agriculture and other land-based industries has been underfunded for decades. There are a declining number of researchers in some specialisms (areas such as agronomy, weed science, crop physiology and forest ecology have been brought to our attention).

The technological advances that have brought about the bioeconomy are anticipated to drive transformational changes in agriculture, for instance accelerating the breeding of more resilient crops and developing smart crop protection systems.[20]

25. Where do you see gaps in investment in research and development in your area of the bioeconomy?

A key gap for research is to understand how best to integrate crops that produce feedstocks for fuel and chemicals, with those that produce food. Developing effective crop rotations for these different commodities would mean farmers could grow industrial crops as a break crop between the years in which a field is planted with food crops, reducing pressure from pests, weeds and disease.

Investment in bioenergy, particularly energy crops, is lacking, as the area competes with oil, and investment is affected by volatility in oil prices and the changes of direction in regulation and policy. Industry tends to prefer stable prices that allow longer term planning and investment, rather than subsidies. The scope for substitution of materials from non-renewable sources with renewable materials, both from primary and recycled sources, is under-researched. Prior to the free availability of oil many chemicals were derived from organic materials such as wood, seaweed and agricultural residues. There has been little

[20] Karp et al. 2015. Growing innovations for the bioeconomy. Nature Plants 1: 1-3.

research to explore how modern technology might be applied to deliver industrial chemical feedstocks from renewables.

As a separate but related point, there is a serious investment deficiency at the stage of development or translation, in taking an early stage idea into a full-scale fully-tested proposition, according to a recent report by Capital Economics.[21]

Furthermore, there are opportunities to incentivise, develop and speed up delivery of new diagnostics and therapies for cancer patients and others.

26. What are the most notable types of new products or technologies that can be expected in your sector in the next few years that are related to the bioeconomy?

27. What are the barriers and opportunities for bioeconomy related research?

Examples might include:

- Collaboration;
- Technical/scientific challenges;
- Gaps in research knowledge.
- Lack of early stage research funding
- Lack of translational research funding
- Skills

The UK has a strong research base in its higher education institutes, some cutting-edge companies, and active support from funding bodies and policymakers, which are great assets for bioeconomy related research, and offer great potential to be a world-leader in bioeconomy innovation. Further support for translational research and for pilot and large-scale demonstration of technologies is an opportunity to ensure that innovation translates into commercial success.

A key barrier to bioeconomy related research is the lack of long term vision. Fundamental research is valuable but may not have marketable products in mind at the outset. Even research that could lead to new products may need decades to bring anything to the market. There should be a focus on producing platform technologies that deliver a step change, but these will take significant investment, which small companies are generally unable to provide.

In the Royal Society of Biology's response to the Dowling Review of collaborations between business and university researchers in March 2015, our members told us that 'Intermediaries' or third parties could help to mitigate some of these issues, both nationally and internationally. In sitting between researchers and research users, intermediary forums (a role which could be further developed by Catapult Centres and Learned Societies) can facilitate industry, universities and private researchers to discuss IP and other issues, thus increasing the efficiency of research translation into economically beneficial outputs. "The

[21] Bauen et al. 2016. Evidencing the Bioeconomy. Capital Economics, TBR and E4tech.

development of standard agreements for research collaborations (for instance the Lambert toolkit), also has a role to play in overcoming some of these challenges" [22].

Other barriers to bioeconomy-related research include the lack of recruitment into STEM, and related skills shortages. Responses to previous questions have already mentioned this, but there are several skills gaps that present a barrier to research in the bioeconomy. In a 2014 review of vulnerable skills and capabilities produced collaboratively by the BBSRC, MRC and Royal Society of Biology, the need for more cross-disciplinary working in the biosciences was highlighted, particularly in the industrial biotechnology sector. Also of concern are skills gaps in plant science, field studies and several 'niche' areas that require few individuals but have high strategic importance, such as plant breeding and entomology. These disciplines have seen a long-term decline in skills, with shortages worldwide, not just in the UK, and are facing a lack of succession planning when current professionals reach the end of their careers. A 2014 report by the UK Plant Sciences Federation indicated that shortages of plant scientists and an inadequate skills base were the greatest barriers to meeting future challenges in UK plant science. Particular shortages of UK expertise were emphasised in identification specialists, taxonomists, and plant pathologists.

28. Are you aware of difficulties in commercialisation or translating R&D outputs into the marketplace in your area of the bioeconomy?

The implementation of the Agri-Tech Catalyst has been valuable in helping to bring products to market. However, researchers continue to experience difficulties in finding commercial partners. For instance, in agricultural engineering and the manufacturing of robotic farming products, UK researchers have suffered a dearth of commercial partners, and may have lost the head-start that their expertise initially gave them over other countries making similar technological advances. Further, as the funding for the Agri-Tech Catalyst is now exhausted, a helpful source of funds to pump-prime late-stage research has disappeared. There is a need for an information service of some kind that might encourage new entry by substantial players, who can see the advantages and do not have embedded investments in traditional methods.

Sectoral cooperation

Collaboration and integration of individual sectors brings with it substantial opportunities to create additional value. Opportunities can include use of by-products or waste and implementing best practice from other sectors.

29. What strong links does your sector have with the other sectors of the bioeconomy?

30. To what extent is your sector reliant on links to other sectors?

[22] Royal Society of Biology response to the Dowling Review of collaborations between businesses and university researchers March 2015; URL: https://www.rsb.org.uk/images/Society_of_Biology_Response_-_DOWLING_REVIEW_2015.pdf

31. Are there potential ways in which your sector would benefit from more cooperation with other bioeconomy sectors?

32. Is there anything we could learn on sectoral cooperation from other sectors of the economy?

33. Are there any barriers to collaboration with other bioeconomy sectors? If so, what are they?

The fragmented nature of the bioeconomy can create gaps in supply chains and presents a barrier to innovation. The development of collaborative clusters (e.g. in terms of geographic situation, personnel and funding) can alleviate this fragmentation.

34. How can government ensure that bio-resource is used in the best way across the different sectors, taking into account the objectives and impacts of use in these sectors?

The Government's procurement provides opportunities to encourage smaller companies in this sector and we propose a more pro-active approach to promoting biotechnology within procurement procedures.

Supply chain cooperation

In addition to different sectors collaborating more efficiently, improving how elements of the supply chain work together could also bring substantial benefits both to the individual organisations and the bioeconomy more broadly. Added complexity might come through geographical barriers.

35. What strong links does your business have with others in the supply chain, including links to overseas companies?

36. Are there potential ways in which your business would benefit from more cooperation with others in the supply chain?

37. Are there any barriers to collaboration with other businesses in your supply chain? If so, what are they?

Government and policies

In this section we would like to hear about issues where the government could remove obstructions to growth for the bioeconomy. But we would also like to hear about things that are already done, but could be done better or be more widely used. These could be things that stimulate innovation or new ways of doing things.

38. Please tell us about any programmes, policies, regulations, laws or taxes which are helping the growth of the bioeconomy.

Programmes that provide incubation services and assist in the translation of research into commercial products are helpful to the growth of the bioeconomy, with the Agri-Tech Strategy and Knowledge Transfer Network as clear examples. The biofuels and bioenergy sectors have become established with the support

of policies (the Renewable Transport Fuels Obligation and the renewables obligation) that created a market pull, though whether these sectors continue to grow will depend on the continuation of policy support.

The Scottish Government's Timber Development Programme and associated collaborative cluster programmes run by Scottish enterprise and Highlands and Islands Enterprise (HIE) have modernised the sector and encouraged innovation.[23] As a result the UK has a sustainable, competitive, self-sufficient and technologically advanced wood production and processing sector, despite its small scale. The wood products sector, unlike agriculture, is unprotected and is completely exposed to global competition and to currency movements. This is seen as helping to drive efficiency. Without Government support it would be less able to innovate.

39. Please tell us about any new programmes, policies, regulations, laws or taxes that you would like to see introduced in order to help the growth of the bioeconomy. Please describe why this growth would be positive and how it might affect other sectors.

Greater clarity and stability in policy could be more important to the growth of the bioeconomy than any specific intervention, by giving greater confidence to potential investors. Several reports have suggested the creation of an advisory body, similar to Germany's Bioeconomy Council, to ensure that long term policy reflects a vision shared by stakeholders and Government.[24]

A programme to facilitate contacts between UK SMEs and multinational companies and plan joint public and private investment in sectors of strategic importance could help to attract large investors and companies that will aid the development of biotech clusters.

Continued support for deserving academic and applied research and development (R&D) programmes, in combination with support for efficient and effective links to the commercialisation pipeline, is needed to maintain the strong and economically viable knowledge-base of the UK. To help further growth, support for demonstrating technologies such as biorefining, cellulosic fermentation and microalgae will help to showcase the bioeconomy innovation system in the UK, and underline its status as a viable place for investment in manufacturing and new bio-based products.

Targets for bio-based products in public procurement, similar to the EU Green Public Procurement programme, will help to drive markets of bio-based products, improve awareness, and improve sustainability.

40. Please tell us about any programmes, policies, regulations, laws or taxes that are holding back the growth of the bioeconomy.

41. How could the government further assist collaboration or research cooperation between the public and private sectors?

[23] http://scotland.forestry.gov.uk/images/corporate/pdf/timber-development-programme-report-2014-15.pdf

[24] Burns et al. 2016. Bio-based UK: A review of barriers and interventions needed to stimulate growth of the bio-based economy and improve UK competitiveness. NNFCC and Aberystwyth University.

In the Royal Society of Biology's response to the Dowling Review of collaborations between business and university researchers in March 2015, our members told us that "a productive research partnership between business and academia is built on established trust, clearly defined goals and deliverables in terms of the science and timescale, and regular and good communication. Central to this is having adequate time to find the right partner with synchronous and timely interests, and to have open discussions about expectations, cost, ownership and in-kind support." This holds true for those collaborations which will factor into the bioeconomy.

In this response, our members also noted that challenges to joint working between industrial and academic personnel may include:

- *regulatory guidelines, which must keep pace with emerging technologies in order for academia and industry to benefit from one another's research efforts*
- *the differing impetus put on generating publications (academic staff must be allowed to factor this into their work to maintain their funding and reputations)*
- *a misalignment in the definition of timescales (Industry is typically quicker to react to new developments and can change strategy rapidly) - which may also vary according to sector.*

"These differences can make organising collaborative PhD funding and support challenging although evidence from the BBSRC's highly competitive Industrial CASE partnerships (ICPs) shows that many companies (e.g. GSK, AZ, Syngenta, Unilever, Oxitec, UCB) place significant value on this type of collaboration and have overcome potential barriers to enable participation in these schemes".[25]

Furthermore, continuation of support for Catalyst and Catapult programmes, Innovate UK, and similar mechanisms that assist innovation, is required. PhD studentships themselves also offer opportunities to develop partnerships between researchers in private and public settings, particularly through the ICP programme (as mentioned above). Partnerships with industry can also form to build on successful public research and bring complementary expertise. An example is the Rothamsted-Syngenta partnership on sustainable wheat.[26] *Similar such partnerships should be supported.*

42. How could the government further assist the growth of the bioeconomy, in a way that accounts for any impacts on other objectives?

Government procurement is a powerful driver of the sustainable bioeconomy. Also, Government initiatives provide opportunities; the recent announcement of plans for new settlements in England could be partnered with specifications for the buildings that encourage the highest standards of energy and carbon efficiency, thus encouraging developers to look beyond traditional building methods and towards bio-based building technology.

Our members also provided advice which is relevant in this instance, in the Society of Biology response to the Dowling Review: "Industry members tell us that the UK's many mechanisms that foster collaborative

[25] Royal Society of Biology response to the Dowling Review of collaborations between businesses and university researchers March 2015; URL: https://www.rsb.org.uk/images/Society_of_Biology_Response_-_DOWLING_REVIEW_2015.pdf

[26] http://www.rothamsted.ac.uk/news/rothamsted-and-syngenta-announce-multi-million-pound-scientific-partnership-develop-high

research between academia and industry (i.e. the aforementioned CASE Studentships, Industrial Partnership Awards (IPA), LINK[27], and Innovate UK competitions for example), make the UK stand out as a place to invest in R&D by allowing a combination of public and private funding. Expansion of these schemes, and designing and choosing further tailored initiatives might therefore help retain companies in the UK and attract new R&D-based businesses".

European issues

Whilst the UK's relationship with the EU is in the process of changing, we would still like to learn from our European neighbours, make best use of opportunities that exist and will continue to exist and grasp the new opportunities that will exist outside the EU.

Input from our members which is of relevance in the following sections is generally derived from the RSB response to the Inquiry into the Implications and Opportunities of Leaving the EU for Science and Research[28], unless stated otherwise. Direct quotes from the submission in question are shown in quotation marks.

43. Can you tell us about any European Union initiatives or programmes that affect your sector of the bioeconomy?

Examples might include the Circular Economy package, the Horizon 2020 Programme for Research and Innovation or other areas of EU funding.

Horizon2020 (and successor framework programmes), ERC, Erasmus, Marie Sklodowska-Curie and Structural Funds all contribute. However, the appropriate use of EU funding (such as that derived from ERC) needs careful consideration, specifically, some programmes have not put enough impetus on research excellence in the past.

Additionally, any new strategy will need to be diverse to be resilient. These research efforts require infrastructure that is beyond the scope of any individual country, international collaboration and outlook is key. The European Union as an environment allows for collaboration within the Bioeconomy and other sectors. Therefore, reasonable steps should be taken in a UK outside of the EU, to create policies that enable continued international collaboration by letting researchers, scientists, students and other technical personnel enter and work in the UK efficiently and effectively.

The Erasmus programme offers researchers and students an invaluable opportunity to gain new knowledge and skills, as well as build new networks in other European countries (and vice versa) it is valued and should be protected. New visa barriers and immigration rights may make this impractical or may even be "detrimental to recruitment of postdoctoral workers who are highly skilled but modestly paid".

[27] http://www.bbsrc.com/business/collaborative-research/stand-alone-link.aspx

[28] Royal Society of Biology response to the House of Commons Science and Technology Committee Select Inquiry into the Implications and Opportunities of Leaving the EU for Science and Research http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/science-and-technology-committee/leaving-the-eu-implications-and-opportunities-for-science-and-research/written/36017.pdf

The highly successful European Research Council (ERC) provides much needed responsive mode funding for blue skies research, which is especially valuable for early career researchers and accommodates collaboration between research institutions internationally- the UK after exit should try to retain access to funding and (less likely) influence on programme design, for the proven benefits this will bring to various sectors of the economy, including the bioeconomy. Similarly, retaining access to Horizon2020 and its successors as an Associated Country would ensure that UK scientists are still able to participate in collaborative projects as they currently do. However, due to likely rescindment of the UKs involvement in strategic decision making after Brexit, the UK will need to consider how to employ indirect influence to shape decisions in these areas.

"EU funds, for example Marie Sklodowska-Curie fellowships, are particularly valuable to early career researchers in what is an intensely competitive funding environment. [29] *In addition, international development support funds, for example through EuropeAid, have provided a mechanism for UK involvement with EU funded projects. Access to international scientific collaborations and research infrastructures, such as EMBO and ELIXIR, is not necessarily dependant on EU membership and the UK could maintain its seat in the European Strategy Forum on Research Infrastructures among other things, if we secure Associated Membership".*

Access to data is also an important aspect for food security; mechanisms like the Irish Universities Nutrition Alliance were enabled by the EU and have been successful.

As an example of social benefit through the structural fund mechanism, the European Regional Development Fund has supported the development of the University of Exeter's Penryn Campus, including the Centre of Ecology and Conservation and the Environment and Sustainability Institute. As these funds were locally directed they offered "support to science in less research-intensive institutions with pockets of excellence and established links to the local economy".

European Cooperation in Science and Technology (COST) has been an important resource for forestry in the UK, giving UK researchers and practitioners access and exposure to the very large European forest sector.[30] *It has resulted in innovation in recreation provision, the use of forests for health, in standards in timber for construction and in developing specifications for new products such as composite joists and panels.*

The Society for Applied Microbiology has highlighted the BIO-TIC project, which, funded by the EU under its FP7 programme, brought together experts on industrial biotechnology for a series of workshops, to review opportunities and barriers to growth, both in supply and demand of bio-based products, within the EU.[31] *The programme produced reports about market projections, research and innovation, and overcoming non-technological barriers, which are useful sources of information.*[32]

[29] *A member of the BES reported: "Countless UK researchers have launched their careers on Marie Curie fellowships, and brought their knowledge and experience back to the UK with them. We risk short-changing our early career scientists if we don't provide them with the same or equivalent access: I know lots of incredibly talented people who likely wouldn't be working in science now if they hadn't been given the opportunity of an EU fellowship."*

[30] http://www.cost.eu/

[31] http://www.industrialbiotech-europe.eu/

[32] http://www.industrialbiotech-europe.eu/bio-tic/deliverables/

44. Are there European Union laws or regulations which affect your sector in a positive way? If so, what are these laws or regulations, what is their impact, and would you like them to be kept for the UK after we leave the EU?

The British Society for Plant Breeders (BPSB) has spotted a major problem around how variety rights operate and generate royalty payments, which could mean that rights owners would lose their income stream in the UK post Brexit if this were not addressed. Many plant breeding companies are global and taking investment decisions from outside the UK, influenced by a generally long plant breeding timescale, about where to place breeding programmes globally. The UK currently has a good pre-competitive environment that is attractive. However, should the 'Brexit effect' on variety rights not be appropriately addressed, this would be a crisis for the industry. Steps need to be taken urgently by Defra and other bodies, to give companies confidence to continue investment in breeding in the UK. Enabling related regulations to be harmonised with the EU, or at least similar in their creation of an environment as attractive as (or more attractive than) the EU, would be advisable.

Additionally, the use of animals in research (for example, in the development of medicines) has recently been harmonised across the EU through the development of Directive 2010/63/EU. "Retaining harmonisation and continuing to promote standard development would be a significant advantage for collaboration" in affected industries related to the bioeconomy.

On a related but separate note, the new EU data protection legislation could make it more difficult to share UK clinical trial data with EU partners, if UK legislation post-Brexit differs significantly on this issue.

The UK has signed and ratified important international conventions such as the convention on Biological Diversity (CBD) and its Nagoya Protocol on Access to Genetic Resources and Benefits Sharing. These have been regulated under common agreed EU mechanisms. Moving outside of EU law will require new or adapted natural environmental legal regulations to be put in place.

45. Are there European Union laws or regulations which affect the bioeconomy in a negative way unnecessarily? If so, what are these laws or regulations, what is their impact, and how could they be improved?

"An important consideration following the UK exit from the EU would be the regulations concerning the use of GMOs in agriculture and the status of genome editing. The current EU approval process is viewed by many scientists as burdensome and dissuading innovation". However, it must be noted that any opportunity for the UK to develop its own regulations in this area may not necessarily lead to adoption or commercial growing of approved GMOs in the UK. This is due to public, political and economic considerations, which also affect investment, research and development in this area.

A highly important issue for forestry is plant health. EU rules do not allow us to prevent the importation of plant material from Europe, and this, in part, has led to the introduction of fungal disease. We have lost economically important species: pines and larches. There have also been environmentally damaging diseases affecting native and amenity species including Ash, Oak, Chestnut and Plane. Forest crops are multi-annual, thus unlike agriculture, they cannot be rapidly replaced by another crop if a disease appears.

46. Where do you see the greatest UK bioeconomy opportunities that will arise outside of the European Union?

"To continue to thrive, the UK needs a multiplicity of funding approaches and involvement with the broadest talent pool." If the UK wishes to increase global collaboration in relation to the bioeconomy then it must increase the funding and support to make it possible, ideally encouraging collaborations both in Europe and further afield. "A survey by the Biochemical Society ahead of the Referendum (receiving 376 responses) highlighted collaboration as a main theme [for the Biochemical Society's membership], with 87% feeling it was essential or very relevant. Further comments in relation to the survey stated that 'mobility restrictions [on the movement of labour into and out of the UK post Brexit] will impair the recruitment of top scientists, engineers, health professionals and technologists, which in turn would jeopardize the economic development of the country'". As well as leading scientists, a skilled workforce is needed at all levels within the scientific community, in both academic and technical roles, and many dedicated EU nationals currently support UK science in various positions. It must also be noted that collaborations with non-EU nations may well include partnerships with EU collaborators.

"Effective international responses to global challenges e.g., climate change depend on effective international science collaboration and the free flow of people and ideas. Whilst it will remain important to retain and foster good collaboration with our near neighbours in Europe, it will be important that the UK government addresses facilitating new arenas for international research collaboration beyond the EU."

"Closer relationships and collaboration could be developed with the United States, as the world's leading producer of research, as well as strengthening links with Canada, Australia and New Zealand. India and China have expanding science research and development communities and an increasing science output and UK universities and institutes are already establishing strong bonds; this should continue. The relative economic growth of several African nations is helping to fuel increased investment in science that has huge potential to have impact in their developing economies and internationally". This applies to science research in general, including that related to the bioeconomy.

International issues

We aim to make the UK the most welcoming country for those researching or investing in the bioeconomy in a sustainable way; the 'go-to' nation for developing, implementing, and exporting sustainable solutions. In doing this we would like to learn from other countries around the world (as well as transnational bodies such as the European Union and the Organisation for Economic Cooperation and Development) where they have put in place specific strategies or other initiatives that support the bio-based industries.

Input from our members which is of relevance in the following sections is derived from the RSB response to the Inquiry into the Implications and Opportunities of Leaving the EU for Science and Research[33] , unless stated otherwise. Direct quotes from the submission in question are shown in quotation marks.

[33]Royal Society of Biology response to the House of Commons Science and Technology Committee Select Inquiry into the Implications and Opportunities of Leaving the EU for Science and Research http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/science-and-technology-committee/leaving-the-eu-implications-and-opportunities-for-science-and-research/written/36017.pdf

47. Are you aware of any government policies or regulations in other countries that are more or less supportive to growth in the bioeconomy?

If so, it would be helpful if you would outline:

- The countries;
- The policies; and
- Their impact or why they are particularly useful or beneficial.

Despite being high-wage economies, Switzerland, Austria and the Scandinavian countries use biofuels extensively (these are often locally produced). They also build using a much higher proportion of renewable materials. There is scope for research to compare the supply chains in these countries, and the regulations and costs influencing them, with those in the UK.

48. Are there any barriers to collaboration with organisations in other countries? If so, what are they?

Collaborations beyond Europe may require greater time and money than EU projects, given logistic constraints such as travel costs. Additionally, changing currency conversion rates can lead to increases in living costs for personnel working overseas. In order to mitigate these issues, targeted investment will be needed.

In the Royal Society of Biology's response to the Dowling Review of collaborations between business and university researchers in March 2015, our members also highlighted that "the impact of company takeovers on the management of jointly-relevant IP [is a concern] particularly where companies are taken over by non-European competitors and their IP shifts overseas", in order to mediate this, as in IP disputes between UK national partners (e.g. universities and industry, which can heavily impede collaborative research) , there should be further promotion and incentives for early pre-competitive collaborations; openness in sharing IP and project risk; and establishing the framework on IPR and confidentiality at the outset. For example, the BBSRC Industrial Partnership Award encourages this outlook for collaboration. Development of an umbrella agreement that covers all future collaborations and discussions has also worked for some businesses. The Society explored the IP issue in some depth in our response to the Select Committee inquiry on the Commercialisation of Research[34], much of which is relevant to collaborations forming the basis of the bioeconomy.

49. How does UK policy and funding environment compare with other countries?

50. What is the degree of reliance on overseas supply chains (for example raw materials) in UK companies?

51. Please describe any trade problems you are aware of that are causing obstructions for imports or exports.

[34] https://d1g8qexchac5be.cloudfront.net/images/SB_response_commercialisation_of_research.pdf

"Within the EU single market, there is an established framework for the free movement of research materials, especially biological materials (for example genetic strains of plants and animals, DNA and tissue samples), which benefits ecological, evolutionary and medical research, [of importance to the bioeconomy]. These regulations, and whether any import or export permits will be required in the future, will require review and clear resolution. Many research projects and collaborations are long-term and require regular movement of people and materials. Reassurance or pre-emptive planning will be necessary to ensure that contact and exchange can continue along necessary or planned schedules".

52. Are there global pressures such as changes in demand or supply that affect your sector?

It will be important to monitor potential changes in US policy towards fossil fuels. Promoting the use and reducing regulation surrounding fossil fuels is likely to reduce the competitiveness of renewable energy and bio-based chemicals generally, with knock-on effects for the bioeconomy, and particularly for the UK, once it leaves the regulated market of the EU.

Standards

National and supranational standards have been proven to catalyse innovation and fuel GDP growth.

A number of standards have been developed, or are currently in development, that address specific aspects of the bioeconomy, e.g. bio-based energy, bio-based products, bio plastics, circularity and resource management standards.

Link to BSI website page on the benefits of standards:
http://www.bsigroup.com/en-GB/standards/benefits-of-using-standards/research-reports/

53. How do you think standards could be used to help promote growth in the bio-economy?

Standards can help to make sure that claims made for products are genuine. Examples of such claims might be the biodegradablilty and compostability of bioplastics, or their bio-based carbon content, recyclability and sustainability.

Standards harmonised across the industry would facilitate clear labelling of products that are 'eco-friendly'. A single, harmonised label for sustainable products could encourage consumer confidence, and increase market uptake of bio-based products.

The OECD has identified that a lack of standardisation and limited harmonisation of standards internationally could act as a barrier to trade in bioplastics, particularly concerning terms and concepts such as 'sustainability'.[35] There are currently no standard definitions of sustainability or internationally agreed tools to measure it. Work between countries to develop and harmonise such standards could increase international trade and help to grow the bioplastics sector, and similar efforts would likely support other sectors too.

[35] OECD (2013), "Policies for Bioplastics in the Context of a Bioeconomy", OECD Science, Technology and Industry Policy Papers, No. 10, OECD Publishing, Paris. http://dx.doi.org/10.1787/5k3xpf9rrw6d-en

54. What types of standards are best suited to support the bioeconomy?

For instance, these could be: Standards that define the concept and explain its relevance to individual organisations, sectors or product groups; standards establishing technical criteria for bio-based products; sustainability schemes and criteria for bio-based products.

Other questions

55. Are there any relevant work studies, case studies or reports that you would like us to be aware of? Please provide a link if you can.

The following examples were published as part of the RSB response to the Dowling Review in 2015, and are still applicable at the present time.

NCIMB Ltd[36]*provides specialist products and services to industry, including the pharmaceuticals, oil and gas, food and drink, agriculture, and environmental sectors. It manages the UK's biggest repository for reference strains of environmentally and industrially useful bacteria. The organisation has a history of public ownership, before being transferred to the University of Aberdeen, but was then spun out from the University to become and independent company in 2000.*

Beneforte Broccoli[37]*is a broccoli variety developed in the UK that has three times more glucoraphanin, a nutrient which studies indicate may offer protection against cancer and cardiovascular diseases. Beneforte Broccoli emerged from the research of Professor Richard Mithen, a research leader at the John Innes Centre (JIC) who discussed his idea with technology transfer company Plant Bioscience Limited (PBL), also located on the Norwich Research Park. With assistance from Kathy Faulkner, a PhD student with funding from BBSRC, a patent was filed and the product was later marketed successfully by PBL in the UK and Monsanto in the United States. It was launched in British supermarkets in 2012, and more research is being undertaken into the health effects of its nutrient glucoraphanin. However, the patent was challenged, and the IP surrounding this has been in dispute for 18 years, and the case highlights the lack of legal certainty that businesses face when considering investment in new plant breeding approaches.*

Reducing fresh produce waste. *Cranfield University, in conjunction with Johnson Matthey Plc (JM) developed a novel ethylene adsorbing material (E+™ Ethylene Remover) which is now sold commercially across the globe. By controlling ethylene, the material avoids premature ripening of fruit, fading or wilting in flowers, early sprouting of root vegetables, and the loss of colour or development of a bitter flavour in vegetables. The development of the product began with contract work in 2006, publications, and then a fully funded JM studentship. This was followed by Defra FoodLINK project in 2010, a EPSRC CASE studentship, and two MSc by Research funded by ItsFresh! in 2012. The timeline from research to commercial exploitation took less than five years and demonstrates the advantages of both industrial contract and public funding.*

56. Are there any other points on the subject of the bioeconomy that you would like to make?

[36] http://www.ncimb.com/
[37] http://www.superbroccoli.info/

Public engagement efforts should be a priority alongside technological progress in the bioeconomy, in order to convey its benefits and assist understanding of scientific advances. A thriving bioeconomy will create jobs, support communities, reduce our impact on the environment and biodiversity and create products that enhance everyday life. However, understanding of the benefits of science, and particularly science-based industry, has been eroded, and it could be said that an attitude of mistrust towards both science and business prevails. Public engagement could help to rebuild trusting relationships, valuable in the context of assessment of bio-based products. Such efforts should be encouraged and supported. Researchers and business must also collaborate to generate responsible industry standards in order to enable this trust and build listening capacity to understand public concern requiring a response.

********** END OF SURVEY**********