Written evidence from Professor Frederic Coulon (Cranfield University) and Professor Louise Horsfall (University of Edinburgh) (ENB0035)

1. What are the UK's key strengths in the area of engineering biology?

- What is the current economic impact of engineering biology on the UK and what might its potential economic impact be?

Effective deployment of environmental biotechnology necessitates a focus on research and innovation that yields readily deployable solutions. Key targets include the global waste and wastewater markets, valued at ~US$1,355 and US$328 billion in 2023 , respectively, biosensors for environmental monitoring and surveillance, valued at ~US$29 billion in 2023 . (Precedence Research, 2023)

2. What are the key applications for engineering biology?

- Can you give examples of particularly exciting or interesting applications? In particular, applications which could be taken forward or are being worked on in the UK?

Unlocking precious metals from waste products and used batteries through engineering biology presents a promising frontier in the UK's environmental sector. Microorganisms offer a sustainable alternative to traditional extraction methods, with research showcasing the efficacy of engineered microbes in efficiently recovering metals from diverse waste streams. This not only reduces reliance on environmentally harmful practices but also aligns with circular economy principles by valorising waste materials. For instance, recent studies have demonstrated the synthesis of valuable compounds like vanillin and adipic acid from plastic bottles (Sadler and Wallace, 2021), as well as the recovery of critical metals from spent automotive lithium-ion batteries (Echavarri et al 2022;).

Given the UK's comparatively limited natural resources, embracing circular economy principles has become imperative, driving innovation in waste valorisation. Moreover, stringent regulations regarding genetically modified organisms (GMOs) have spurred researchers to develop economically feasible solutions suitable for controlled environments. This regulatory environment has fostered creativity and encouraged responsible research and innovation practices, leading to accelerated progress in this field and fostering collaboration across interdisciplinary domains ((Tezyapar Kara et al 2023). By harnessing the power of engineering biology, the UK is not only addressing environmental challenges but also advancing resource sustainability in a rapidly evolving global landscape.

- On what timescales might the different applications for engineering biology be realised? Which applications are emerging now, and what is on the horizon in the next 5–10 years or further ahead?
- Are there areas of application for engineering biology where the hype exceeds the reality, or where significant barriers remain?

In the field of engineering biology, particularly within the environmental sector in the UK but also worldwide, there is enthusiasm for various applications. However, a critical analysis reveals instances where the promises may surpass the current realities, and substantial barriers impede progress. A key challenge is scaling up laboratory-based experiments to larger, real-world applications (https://www.nature.com/articles/s41467-021-21740-0). Bridging the gap between controlled laboratory conditions and the complexity of the wider environment is critical. Additionally, ethical, regulatory, and public acceptance considerations play a crucial role in the deployment of SynBio applications in the environmental context (PCSBI, 2020, Ethics of Synthetic Biology and Emerging Technologies CST, 2023, Engineering Biology). Scaling up these technologies to address real-world contamination scenarios necessitates overcoming hurdles such as bioreactor optimisation, ensuring ecological safety, and navigating stringent regulatory frameworks governing genetically modified organisms (GMOs). Similarly, the development of biodegradable plastics derived from biological feedstocks gains significant attention as a sustainable alternative to conventional plastics. Yet, transitioning from laboratory-scale prototypes to commercially viable products demand addressing key challenges including optimising microbial fermentation processes for cost-effective production, ensuring the biocompatibility of resulting materials, and verifying their complete degradation under diverse environmental conditions through rigorous biodegradation testing protocols. Another aspect is bioenergy production, while promising for reducing carbon emissions, is confronted with multifaceted challenges in its realisation. Competing land use demands for biomass cultivation versus food production, the optimisation of biofuel conversion processes for energy efficiency, and mitigating potential negative environmental impacts, such as land-use change-induced emissions, constitute critical hurdles (Supergen Bioenergy hub 2024). Addressing these challenges necessitates interdisciplinary approaches integrating agronomy, bioprocess engineering, and environmental science.

Another aspect is the advancements in gene drive technology present an exciting avenue for targeted pest control, yet they are accompanied by ethical and technical considerations. While laboratory experiments showcase the precision of gene editing tools in population suppression, real-world deployment mandates thorough risk assessment to mitigate unintended ecological consequences and address public concerns regarding genetic manipulation.

One more aspect in our view is lab-grown meat which is receiving considerable attention, touted as a humane alternative to traditional meat production methods. Advocates argue that it allows for meat consumption without slaughter. However, the reality is more nuanced. In many cases, essential culture components and initial cells used in the process still involve animal-derived materials, undermining claims of cruelty-free production. Further to this, assertions of lab-grown meat being a more sustainable option are met with scepticism. Cradle-to-gate analyses by researchers suggest that, for the foreseeable future, lab-grown meat may actually have a higher carbon footprint than conventionally farmed beef (UC Davis, 2023). Such controversies surrounding the environmental and ethical implications of lab-grown meat not only hinder public acceptance of this specific application but also cast doubt on the broader potential of biotechnology in food production.

- Which applications for waste biorefining and the circular economy merit particular attention?

The UK is leading in the application of engineering biology to the recovery of metals from automotive lithium-ion batteries. Through the Faraday Institution this area of research has been supported for six years. The work to date has recently received international recognition as the key innovation in sustainability over the past year, after shortlisting from 3000 to 10 by a panel of experts and a final audience/public vote (https://www.events.netexplo.com/global-trends-forum)

3. How can Government policy support the development of engineering biology?

- Does the Government’s “National Vision for Engineering Biology” set out the right priorities for government to develop the engineering biology field in the UK? Was there anything missing from the strategy that should have been included? Does it build appropriately on earlier approaches to synthetic biology and life sciences?

The Government's "National Vision for Engineering Biology" outlines a strategic roadmap for developing the engineering biology field in the UK. While the document sets out several commendable priorities, such as fostering innovation, supporting research infrastructure, and promoting responsible stewardship of technology, there are areas where additional focus is needed such as

1. . the strategy could benefit from more explicit measures to support SMEs and startups in the engineering biology sector. Providing targeted funding, regulatory guidance, and access to infrastructure could help foster a prosperous ecosystem of innovative companies driving technological advancement and economic growth.
2. while the document touches upon the importance of education and skills development in the field, a more robust plan for talent acquisition and retention may be needed to ensure a skilled workforce capable of driving innovation in engineering biology.

- Which Government departments, and non-departmental public bodies, are engaged or should be engaged with engineering biology?

Several government departments and non-departmental public bodies play crucial roles in engaging with engineering biology and should continue to do so:

Department for Business, Energy & Industrial Strategy (BEIS) oversees policies related to innovation, research funding, and industrial strategy, making it a key player in supporting and promoting engineering biology initiatives.

Department for Environment, Food & Rural Affairs (DEFRA) is responsible for environmental regulations, agricultural policy, and food safety. Given the potential implications of engineering biology on agriculture, food production, and environmental sustainability, DEFRA's involvement is crucial.

Environment Agency (EA) regulates environmental pollution, waste management, and water quality. Its oversight ensures that engineering biology applications comply with environmental regulations and mitigate potential risks to ecosystems.

Department of Health and Social Care (DHSC): DHSC oversees public health policies, healthcare regulations, and biomedical research funding. With applications of engineering biology in healthcare, such as personalized medicine and regenerative therapies, DHSC engagement is essential.

Department for International Trade (DIT) promotes UK businesses abroad and facilitates international trade agreements. Engaging with engineering biology can help showcase UK expertise and attract investment and collaboration opportunities from global partners.

UK Research and Innovation (UKRI) is a major funding agency supporting research and innovation across various disciplines. Its involvement in funding engineering biology research projects and coordinating interdisciplinary collaborations is vital.

Health and Safety Executive (HSE) regulates workplace health and safety, including the handling of hazardous materials and genetically modified organisms (GMOs). Its oversight ensures that engineering biology research is conducted safely and responsibly.

Food Standards Agency (FSA) regulates food safety and standards in the UK. Given the potential implications of engineering biology on food production and consumption, FSA's involvement in assessing and regulating novel food products is critical.

7. What are the possible barriers and limitations to good and effective use of engineering biology?

- What more can the Government do to foster public understanding of engineering biology? Is public acceptability of these technologies a barrier to deployment in the UK?

This is an interesting question posed in a leading manner. Does understanding of engineering biology lead to public acceptability? Does there need to be an understanding of the technology for it to be deployed or for the public to accept it? An illustrative example arises from public interest in the Higgs Boson, suggesting that complex scientific concepts can draw interests without necessitating a deep understanding. Whiteson, "Why Should You Care About the Higgs Boson?" CERN, 2012. (https://www.sciencefocus.com/science/what-has-the-discovery-of-the-higgs-boson-taught-us)

- Does the UK have a sufficient skills base to harness the potential of engineering biology?

The existing skills base in Engineering Biology, particularly in synthetic biology, is inadequate to meet the growing demand for expertise in this field. Despite its increasing importance, there is a notable scarcity of specialised undergraduate programs, with few universities offering dedicated courses in this area. At the master's level, while some programs incorporate elements of synthetic biology, there is a lack of comprehensive, specialised training opportunities. To date, only one specialised PhD program in Engineering Biology currently exists in the UK, limiting the pipeline of highly skilled researchers and professionals entering the field. (https://data.parliament.uk/DepositedPapers/Files/DEP2023-0936/Technical.pdf)

The funding allocated for training in Engineering Biology is also insufficient, particularly when compared to other critical technologies. While synthetic biology holds immense potential for addressing pressing societal and environmental challenges, such as healthcare, sustainable agriculture, and renewable energy, investment in training programs lags behind. This underfunding hampers the development of a robust talent pool equipped with the necessary knowledge and skills to drive innovation and contribute to the advancement of Engineering Biology in the UK.

- Does lack of land (e.g. for biofuels or growing GM crops) or dedicated lab space inhibit the growth of engineering biology? If so, what should the Government do to address this?

Allocating funding for the establishment of dedicated laboratory facilities equipped with state-of-the-art equipment for engineering biology research and development. This includes pilot-scale facilities for environmental applications like bioleaching and bioremediation, enabling researchers to conduct truly replicated experiments and scale-up processes efficiently. There is also a need for ensuring equitable access to research infrastructure and facilities across England, Wales, and Scotland to promote regional development and collaboration. This may involve establishing satellite facilities or providing funding incentives for institutions in underserved regions to upgrade their infrastructure.

07 May 2024