Written evidence from the Bio-based and Biodegradable Industries Association (BBIA) (ENB0007)

About the BBIA

The Bio-based and Biodegradable Industries Association (BBIA) We unite those working in the bio-based and biodegradable industries, through advocacy, collaboration, and education, to put the industrial bioeconomy at the centre of sustainability and economic growth in the UK.

The BBIA was established by seven founder members in June 2015 and as of today, we represent 48 organisations in this space, with membership growing rapidly. More details about the BBIA can be found on www.bbia.org.uk.

Our Mission: The BBIA exists to champion the industrial bioeconomy to accelerate the development and adoption of bio-based and biodegradable materials and products through advocacy, collaboration, and education.

Our purpose: We do this to reduce the impact of human consumption on the planet.

Our vision: Our vision is for a more sustainable future, where the UK is a global leader in developing, manufacturing, using and exporting bio-based and biodegradable solutions.

Government defines engineering biology as the design, scaling and commercialisation of biology-derived products and services that can transform sectors or produce existing products more sustainably. It draws on the tools of synthetic biology to create the next wave of innovation in the bioeconomy.

For this submission, we are considering Engineering Biology, as organisations working within the industrial bioeconomy, or those utilising industrial biotechnology for the development of bio-based, biodegradable and compostable materials.

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

Key Research Institutes

- **University of York:** Through the Centre for Novel Agricultural Products (CNAP), York has an outstanding track record in industrial biotechnology. This has evolved in recent years to develop expertise in engineering biology, providing solutions to tackle societal needs such as food production, environmental contamination, and using agricultural byproducts.

- **University of Manchester:** is a powerhouse of research and is ranked first in Europe and second in the world for social and environmental impact (Times Higher Education Impact Rankings 2023). Sitting within the University is the Industrial Biotechnology Innovation Catalyst (IBIC), which supports and connects the Northwest of England as a world-leading ecosystem to deliver a transformative bioeconomy. IBIC offers partners access to cutting-edge R&D knowledge, capabilities, talent and facilities. We support our community with skills-training, finance, and business advice so they can realise success. IBIC is led by the University of Manchester, in partnership with the Universities of Liverpool, Salford and Manchester Metropolitan, leading SMEs and corporate businesses, regional R&D organisations, accelerators, investors, and specialist skills providers, united by a culture of ethics, diversity, and openness and drive to deliver a R&D intensive bioeconomy.

- **Biorenewables Development Centre:** is an open-access research, development and demonstration biorefining centre and a subsidiary of the University of York. They apply technologies derived from both biology and chemistry to optimise and process biorenewable raw materials for the production of chemicals, materials and fuels.

Key projects

- **BBSRC NIBBs:** In 2014, UKRI funded 13 Networks in Industrial Biotechnology and Bioenergy (NIBB) across a range of industrial biotechnology and bioenergy (IBBE) relevant areas. These networks were setup to foster collaborations between academia, industry, policy makers and non-governmental organisations (NGOs) in order to find new approaches to tackle research challenges, translate research and deliver key benefits in IBBE and also look for international opportunities. In 2019, an additional £11 million was committed to fund six Phase II NIBBs from 2019 to 2024. The second phase builds upon the success of the first phase NIBBs and continues to build capacity and capability in the UK by supporting research and translation into sustainable bio-based manufacturing. The six Phase II NIBBs are: Algae-UK: Exploiting the algal treasure trove; BBNet: Biomass Biorefinery Network; Carbon Recycling – Converting waste derived GHG into chemicals, fuels and animal feed; E3B: Elements of Bioremediation, Biomanufacturing & Bioenergy: Metals in Biology; EBNet: Environmental Biotechnology Network; HVB: High Value Biorenewables Network.

- **UKRI Engineering Biology Mission Hubs:** (1) Professor Katherine Denby with the John Innes Centre and the University of Cambridge: 'Engineering gene regulatory networks to design disease resistant crops.' (2) Dr Liz Rylott with the University of Kent: 'Environmental processing and recovery of metals: from contaminated land.'(3)Professor Luke Alphey with Fera Science: 'Advanced strains of black soldier larvae for low-carbon waste management and food/feed production.'

- York has also recently been awarded UKRI BBSRC Prosperity Partnership awards to work with industry to develop bio-based solutions that require engineering biology:

    - Professor Ian Graham is working with the specialist chemical company, Croda Europe Ltd to co-develop new sustainable technologies to improve the performance of new medicines, increase food production and help reduce the use of ingredients in cosmetic formulations from unsustainable sources.

    - Professor James Chong is working with Yorkshire Water Services Ltd to understand how groups of microorganisms respond to design and process engineering in wastewater treatment. In addition, York runs two UKRI-funded Networks in Industrial Biotechnology and Bioenergy – Biomass Biorefinery and High Value Biorenewables. Both networks have interests in engineering biology.

Key innovative companies, start-ups, or spin-outs

AQUAPAK is a specialist polymer manufacturer and pioneers in the design and development of innovative planet-friendly materials that are helping to accelerate the move toward a circular economy. Working in partnership with paper and packaging companies and major consumer brand owners around the world we provide scalable

solutions to their recycling and sustainability challenges. Our R&D teams recently launched the ground breaking new polymer Hydropol™ which can deliver in terms of performance and functionality as well as provide a more environmentally responsible end-of-life for product.

BASF have been creating chemistry for 150 years. As the world's leading chemical company, we combine economic success with environmental protection and social responsibility to offer customers intelligent system solutions and sophisticated products. Through science and innovation we enable our customers in nearly every industry to meet the current and future needs of society. We have summed up this contribution in our corporate purpose: We create chemistry for a sustainable future.

BIOME BIOPLASTICS is a leading UK-based developer of bioplastics. Serving a global customer base from its headquarters in Southampton, the company's mission is to produce materials to challenge the dominance of oil-based polymers. The main focus is on the development of novel bio-based and biodegradable hetero-aromatic polyesters for a variety of end-uses. Over the last four years Biome and its partners have invested over US$7 million in research and development funding. Now proven robustly at laboratory scale and with appropriate patents filings, the next challenge is to scale up for a pilot on the path to commercial production. Meanwhile, other work continues to expand the range of feedstocks, broaden the pathways used and refine the products offered our customers.

BIOPAK products are designed for the circular economy, and our mission is to produce packaging that puts the planet first. We strive to offer the most sustainable and innovative packaging on the market and we're dedicated to reducing any negative impact we have on the environment. Our food packaging solutions are designed to minimise the environmental impact, whilst delivering an unforgettable dining experience. Our products are certified carbon neutral and can be either home composted, industrially composted or recycled – ensuring a no-waste-to-landfill solution.

BIOTEC is a leading company that develops and produces sustainable bioplastics made from plant-based renewable resources. The film and rigid application range stretches from refuse and shopper bags to pharmaceutical capsules, including food industry blisters, cosmetics packaging and many other requests from our clients. BIOTEC produces and sells a new generation of customized thermoplastic materials with various functional properties under the brand name BIOPLAST. All products made from BIOPLAST grades are 100% biodegradable.

CHEMIAN TECHNOLOGY LIMITED was founded in 1996 as a freelance Business Development service, helping companies develop new technologies, product ranges or introducing production projects. We launched our Citrepel (naturally derived insect repellent active) in the late 2000's. Our initial hurdle was proving that a natural material could perform as well as a synthetic. Today that is firmly established. Since then, we developed/patented a second-generation version (our Citrepel 75) and we now sell everywhere there are mosquitoes.

COMPOST BAG COMPANY In 2001 Harold Naylor and his colleague Christopher Marsden set up a joint venture to bring BioBags to local authorities across England Wales and Northern Ireland. Part of the BioBag International group, BioBag Ltd's aim was to develop their successful Norwegian model of using compostable liners and associated products in food waste recycling schemes. By working closely with both the waste collection and the waste treatment industries BioBag Ltd became a highly respected, responsive and trustworthy supplier to public and private sector operators across the waste industry. In 2019, the company changed its name to The Compost

Bag Company to reinforce that the company's bags are compostable and to disassociate itself from 'bioplastic' bag products that are partly derived from bio-based sources but are not compostable.

CENTRAL PLAINS GROUP promote and facilitate regenerative farming practices and high quality potato starch based polymers that contribute as much to a healthy ecosystem as they do to nourishing populations. Since 2019, we've been working successfully in some of the most productive, low-cost farming regions in the world to develop a vertically integrated agricultural and biopolymer refinery business. Our purpose? To develop a low-carbon, zero-waste, circular bioeconomy that nurtures people, plants and planet.

CRODA We create, make and sell speciality chemicals that industries and consumers everywhere depend on. Established in 1925, we are driven by a focus on our customers, collaborative working, a proactive attitude and the ability to think differently. We encourage our people to work as a unified global team and alongside our customers to find new and sustainable ways to satisfy unmet needs. This means over 6,100 passionate employees in manufacturing sites, laboratories and offices worldwide work with a shared Purpose: using Smart science to improve lives™.

CROMWELL POLYTHENE Since 1983, Cromwell Polythene has committed to supplying polythene and compostable products that capture, contain and secure. Cromwell continues to grow organically and now occupies its fourth purpose-built distribution facility near Leeds and a manufacturing plant in Derbyshire, strengthening our UK recycling and manufacturing capacity.

ECO-CRAFT was established in 1992 as a specialist mail order manufacturer of recycled paper products and craft materials. The company moved online in 2000 and following growing customer feedback, by 2007 the decision was made to stop selling conventional plastics and adopt a plastic-free approach to all products. This led to eco-craft becoming an e-commerce only company, with compostable packaging a focal point of the business.

ERTHOS INC is actively transforming bio-based inputs into plant-powered alternatives for traditional plastics. Erthos is building a massively scalable platform for better materials, for a planet free from plastic pollution. Single-use products made with erthos materials are not only compatible with existing plastic manufacturing systems, but are also sustainably manufactured, and compostable at their end of life.

FUCHS is the world's largest independent lubricants manufacturer. We manufacture and supply innovative lubricating products and bespoke support packages – providing a complete service to our customers. We have expertise and experience in developing lubricants for a wide variety of applications, including: engine oils, food grade lubricants, agricultural oils, cutting fluids, greases, hydraulic oils and much more. We have a full range of support services to help customers choose the right lubricant for their application and get the most from their lubricants.

FUTAMURA is a leading global manufacturer of plastic and cellulosic materials including Cellophane™ films, renewable and compostable NatureFlex™ films, casings and non-wovens. Our films are sold to converters, brand owners and end-users in over 100 countries worldwide. They become part of the packaging, labelling or overwrap solution for some of the world's best known brands across a wide variety of everyday consumer goods.

FLEX SEA develops novel biomaterials derived from red seaweed, with the potential to replace single-use plastic packaging in various applications, such as cosmetics, pharma food and non-food. Our material is truly home compostable and in the

process of receiving certifications and undergoing testing with major regulatory bodies. We have recently relocated to a larger laboratory and industrial space in the Midlands, where we will have the capacity to replace up to 2500kg of plastic each week. Additionally, we are fully circular, setting us apart from all other biomaterial producers in the sector. We use the waste derived from seaweed biopolymer extraction and put this through our patented bio-digestion process that allows us to turn valueless waste into high value compounds and polymers with applications in the pharma and cosmetics/personal care industry.

FLOREON is an award-winning biomaterials technology company, with patents granted both in the UK and internationally for greener, safer plastics which are high performing, environmentally friendly and fully compostable. The materials come from renewable sources, the production processes use less energy, the end product is stronger and lasts longer . When it does reach the end, Floreon lends itself to recycling , composting, or use for energy or even feedstock , leaving landfill behind and completing a circle of sustainability.

FABBRIGROUP Established 70 years ago, Fabbri Group is a global packaging company with headquarters in Italy, several subsidiaries in Europe and a global network of distributors. Producing machines and films, predominantly for the food sector, Fabbri Group's key focus is protecting fresh food and reducing food waste. They are driven by creating eco-friendly packing solutions that have minimum impact on the planet.

HOLIFERM a spin-out from the University of Manchester, develops processes for the sustainable manufacture of biosurfactants which eliminate the need for harmful petrochemicals. Based in the Northwest of England they have an R&D facility in Manchester and a commercial biosurfactant plant in Wallasey. The plant currently produces 1.1KTA, with ambitious scale up plans for 2024 and beyond. The biosurfactants Holiferm produces can be used in a variety of applications including cosmetics, home care, personal care and agriculture. Holiferm's products are sold and distributed worldwide including to the Americas, Asia, Europe, New Zealand and Australia.

INGEVITY is a leading provider of specialty chemicals, high-performance carbon materials and engineered polymers. These products are used in a variety of demanding applications, including asphalt paving, oil exploration and production, agrochemicals, adhesives, lubricants, publication inks, coatings, elastomers, bioplastics and automotive components that reduce gasoline vapor emissions.

KCC PACKAGING As an experienced food packaging specialist, for the last 15 years KCC has focused on sustainable solutions, and has become 'a company of our time', with all its products made either from low-carbon, recyclable materials or compostable plant sources. Its riji® product is currently its most notable innovation. riji ® packaging provides a compostable, natural alternative to CPet that cannot be recycled in the ready meal and food-to-go industries. Its uniqueness is the application of a natural barrier coating, which renders the natural fibre base non-porous, and thus suitable for foods with a high moisture content, such as curries and lasagnes. riji ® also performs better than CPet in both microwave and traditional ovens, remaining rigid at higher temperatures. The product carries a food migration certificate to 240C.

LEADERGRAIN has been working in the international grain market since 2013 and now is also a world-leading biopolymers supplier and innovator with products of naturally advanced materials made from renewable, abundant feedstocks with performance and economics that compete with oil-based intermediates, plastics, and fibers. Our goal is to make economically competitive and scalable chemicals and

materials that are produced based on renewable feedstocks, fully recyclable, with a significantly lower carbon footprint, and with superior performance to the petroleum-based alternatives.

NATUREWORKS is an independent company invested in by Cargill and PTT Global Chemical, offering a family of commercially available biopolymers derived from 100 percent annually renewable resources with cost and performance that compete with petroleum-based packaging materials and fibres. The company apply its unique technology to the processing of natural plant sugars to create the proprietary polylactide polymer marketed under the Ingeo brand name. NatureWorks represents one of the largest efforts ever in green chemistry and biorefinery.

NOVAMONT is the world's leading company in the sector of bioplastics and biochemicals obtained through the integration of chemistry, environment and agriculture. It promotes a new model of bioeconomy in the logic of the circular economy, not only based on efficiency and sustainable use of renewable resources, but also as a factor for territorial regeneration. Under the brand name MATER-BI it produces an innovative family of proprietary bioplastics, which are biodegradable and compostable according to the European standard EN 13432.

OCEANIUM is developing food and nutrition products and marine-safe, home compostable bio-packaging materials from sustainably-farmed seaweed. Utilizing an innovative green chemistry, Oceanium will produce a home compostable, marine-safe bio-packaging material to replace current food packaging which has no end of life solutions. Oceanware will be 100% natural and its end of life solution is to be disposed of with food waste which will then be composted for soil health or for anaerobic digestion for energy. Unlike competing feedstocks for packaging, such as fossil fuels or corn, Oceanware will be processed close to seaweed farms. Seaweed does not require land/water/fertiliser, it sequesters carbon and removes excess nutrients from surrounding waters.

PARKSIDE is a pioneer in the development and commercialisation of a leading range of industrial and home compostable packaging solutions that provide a credible alternative to landfill for traditional flexible packaging. The high barrier packaging and lidding designs are suitable for a wide range of market sectors, including snack, confectionery and ambient food applications such as coffee and dried goods. Developed under the Park-2-Nature brand, Parkside's compostable laminates are robust and durable, just like traditional plastic packaging, and are rigorously tested for eco-toxicity and a host of other criteria against EN 13432. They are also accredited from TUV (formerly Vincotte) and are available in a range of aesthetic options including white, matt, clear, metallised and kraft and can be fully colour flexographic printed.

PUJING CHEMCIAL INDUSTRY CO., Ltd (PJCHEM) established in 2005, is a high-tech enterprise mainly focused on investment, development and authorization of chemical process and advanced material technology. PJCHEM polymer business division, composed of a consolidate team with skilled and experienced experts, is mainly engaged in the cutting-edge polymer business, including new biodegradable material development, manufacture and distribution. We deliver industry-leading products and a full range of technical support service to help our customers and partners using our products. By staying closely with our customers, we keep developing innovation technology in response the needs and requirements from our customers. Our vision is to use our self-developed technology and knowhow to become a leading supplier of new biodegradable polymer in global market.

PLANGLOW For more than three decades, multi-award-winning Planglow has been a leading supplier of catering labels, compostable packaging and food labelling software. In 2011 we introduced our first environmentally-friendly packaging range, today we offer five branded collections of compostable packaging and labelling for grab-and-go and hot takeaway foods. All of our packaging is made from compostable materials, even the clear window film is derived from renewable plants rather than oil-based plastic. The plant based laminate is fully certified to the European (EN13432) norms for compostable packaging and is also certified as home compostable. Working with bio-processing experts, we are able to offer our clients a closed-loop solution for disposing of food and packaging waste on site.

PROMATERIAS is a leading European manufacturer of sustainable products and solutions for the circular economy. With a history of more than 60 years in packaging manufacturing, Promateris has gained regional leadership and top manufacturing expertise in packaging production. Promateris Group invests in developing sustainable packaging products and solutions for the circular economy, R&D and end-of-life solutions. The company also operates a plant dedicated to manufacturing specialty compounding for technical applications, and is active in Bucharest, Valencia and Warsaw through commercial offices and distributors in more than 10 countries. We are dedicated to offering highly customised solutions for retailers, HoReCa and waste management companies.

SHELLWORKS Vivomer is a completely vegan, compostable material, made with a little help from friendly microbes. Once disposed of, it will fully break down in any soil and marine environment, leaving behind zero microplastics.

SONICHEM Sonichem, a biorefinery technology company, is pioneering ultrasonic technology to advance green chemical production. Our proprietary process efficiently transforms low-value forestry by-products into high-value, sustainable bio-based chemicals. Specialising in the production of lignin, cellulose, and hemicellulose sugars, we offer viable bio-sourced alternatives to traditional petrochemicals with diverse applications in materials, resins, personal care, and cosmetics. Demonstrated at our industrial-scale pilot plant, Sonichem is actively preparing to scale operations to a commercial biorefinery, driving the shift towards sustainable chemical solutions.

SOLUTIONS4PLASTIC is a U.K , Lincolnshire manufacturer of home compostable, water soluble, biodegradable plastics.

TIPA Sustainable Packaging was founded in 2010 to create viable compostable, flexible packaging options. TIPA's vision is for flexible packaging to have the same end-of-life organic matter has, while also offering consumers and brands the same durability, transparency and shelf life they have come to expect from conventional plastics. Even though the volume of flexible packaging is smaller by weight and space, most flexible packaging cannot be practically recycled. Flexible packaging isn't made of pure plastic polymers but rather made by blending several materials. These blended materials make flexible packaging complicated for separation and recycling.

VEGWARE is the UK's first and only completely compostable food packaging firm, manufacturing since 2006. We are pioneering the development and manufacture of eco friendly catering disposables and food packaging that can all be recycled along with food waste. Our products are stylish, functional, economic and sustainable. The Vegware range of 250+ compostable products spans cutlery through to tableware, napkins, hot and cold drink cups, and takeaway packaging. We work with a network of distributors across the UK to deliver our range of eco disposables to our clients.

WOOLCOOL® aims to unleash the true potential of wool as a bio-material through the application of science, thereby making a significant impact on human health and wellbeing. Woolcool® serves the Pharmaceutical Cold Chain Industry. Along with other temperature sensitive medicines, it is used to send life-saving vaccines, insulin and cancer drugs around the world, keeping them in temperature and safe to use on arrival. It is also one of the leading Insulated Packaging solutions of choice within the Online Food Industry in the UK and Europe, supplying a number of large, medium and small online food companies. Woolcool® is used to send fresh chilled foods from raw milk and meat to chocolate and cakes, direct to the customer's door.

What are the key applications for engineering biology?

Climate change is one of the largest challenges for modern day society. In terms of climate change, Engineering Biology (EB) and Industrial Biotechnology (IB) are key enablers of defossilisation and decarbonisation and the driving force for a strong and vibrant bioeconomy[i]. Its transformative enabling technologies have the potential to change our relationship with the resources we use and to develop inspiring solutions that improve our lives. EB and IB can reroute our unsustainable extraction, manufacture, and consumption.

The UK manufacture of petrochemicals results in direct GHG emissions of 6.1 million tonnes of CO_2eq per year (average 2012-2021). When the manufacture of all chemicals and chemical derived products (paints, inks, basic pharmaceuticals, rubber, plastics etc) are included, emissions increase to 18.6 million tonnes CO_2eq per year (average 2012-2021)[1].

It is estimated that the global chemical industry currently generates around $4.7 trillion in annual revenue, representing approximately 4% of global GDP, and it is responsible for the employment of over 15 million people worldwide. The global chemical market is expected to grow considerably in the coming years as developing economies continue to advance and society places greater demand on the production of affordable functional materials and products to improve the quality of lives around the world. A growth in demand for petrochemical products will mean that petrochemicals are set to account for over a third of the growth in oil demand by 2030, increasing to almost a half by 2050.

The chemicals and materials sector is a vital component of the UK economy. In 2023, the Chemicals Industry Association (CIA) used Standard Industrial Classification (SIC) codes to estimate that there were 4,415 chemicals businesses in the UK. In 2023, these businesses:

- Employed approximately 151,000 people.
- Contributed an estimated £31bn in Gross Value Added (GVA) – equivalent to almost one sixth of all UK manufacturing GVA.
- Exported approximately £54bn of manufactured goods.
- Were responsible for around one sixth of total UK business R&D expenditure.

Given the significant contribution of the current chemicals and materials sector to the UK economy, it is clear that:

a) converting even a fraction of that activity to become bio-based could offer considerable economic opportunity, and that;

b) the talent and skills required to grow bio-based chemicals and materials activity exist in the UK.

[1] Office of National Statistics, Residence (production) emissions.

Economic and Environmental benefits of biomass for biochemicals

The unpublished DESNZ study 'Environmental benefits of biomass for biochemicals' concludes that with the right investment, by 2050, the UK bio-based chemicals industry has the potential to significantly grow, producing over 2 million tonnes of bio-based chemicals, contributing to 5.2 million tonnes CO2eq GHG savings and £1.6bn in value to the UK economy.

In 2021, renewable fuels supplied under the RTFO saved 5.07 million tonnes of carbon dioxide (CO_2), equivalent to 58 million car journeys from London to Glasgow[2], demonstrating that the potential CO_2 savings from biochemicals warrants policy intervention and investment.

Opportunities for growth

Opportunities for growth lie in: Bio-based chemicals, Bio-based plastics (that are conventionally recyclable and/or chemically recyclable), biodegradable materials for biodegradable non-packaging products designed to biodegrade in part(s) of the natural environment, and compostable materials for compostable packaging and non-packaging products (designed to biodegrade in industrial composting facilities, and, for some products, additionally in home composting units/heaps/set-ups). Examples of polymers synthesised only 'in nature' are wood, hemi-cellulose, cellulose, those synthesised by fungi or by algae; some of these 'natural polymers' have so far tended to be used in compostable products and mulch films designed to biodegrade in agriculture/horticulture after crop harvest. Below is an overview of how engineering biology plays a role in the development of biobased, biodegradable and compostable materials and products:

- **Microbial Engineering:** Researchers use engineering techniques to modify microorganisms, such as bacteria and yeast, to produce specific polymers. For instance, bacteria like *Escherichia coli* or *Cupriavidus necator* can be engineered to produce bioplastics like polyhydroxyalkanoates (PHAs) by introducing genes responsible for polymer synthesis. Genetic engineering can also be used to modify microorganisms like bacteria and yeast to produce enzymes that can break down specific types of plastics. For example, researchers have engineered microorganisms to produce enzymes capable of degrading polyethylene terephthalate (PET) and polyethylene (PE), common types of plastics.

- **Metabolic Engineering:** Metabolic pathways within microorganisms can be engineered to redirect their natural processes toward the production of precursor molecules needed for bioplastics. This involves manipulating enzymes and metabolic reactions to increase the production of specific compounds. Microorganisms can be engineered to produce enzymes that break down plastics as part of their metabolic processes. This can involve introducing new pathways or modifying existing ones to enable the breakdown of plastic polymers into smaller, more easily degradable molecules.

- **Enzyme Engineering:** Enzymes involved in polymer synthesis can be engineered to enhance their efficiency and specificity, leading to higher yields of desired bioplastics. This can involve modifying enzyme structures through techniques like protein engineering. In addition, enzymes that naturally degrade plastics are identified from microorganisms that have evolved the ability to break down plastic

[2] https://www.gov.uk/government/consultations/supporting-recycled-carbon-fuels-through-the-renewable-transport-fuel-obligation/outcome/supporting-recycled-carbon-fuels-through-the-renewable-transport-fuel-obligation-government-response#executive-summary

waste. These enzymes can then be further engineered to enhance their activity, stability, and specificity for different types of plastics. In addition, we can use enzymatic routes to novel high value pharmaceuticals.

- **Plant Engineering:** Some bioplastics can be produced in plants by introducing genes responsible for natural polymer synthesis. Plant engineering can lead to the production of bioplastics within the plant tissues, which can then be extracted and processed.

- **Synthetic Biology:** Synthetic biology approaches involve designing and constructing new biological systems or modifying existing ones to achieve specific goals. This can include creating novel pathways for bioplastic production or optimizing existing pathways for higher yields. In addition, synthetic biology techniques are employed to design and construct biological systems that can efficiently degrade plastics. This involves assembling genetic parts and pathways to create synthetic microorganisms with enhanced plastic-degrading capabilities.

- **Enhancing Biodegradability:** Through genetic engineering, researchers can modify the structure of bioplastics and other persistent polymers to make them more susceptible to microbial degradation. This involves designing plastics that contain specific bonds that are easily broken down by enzymes produced by microorganisms.

Engineering Biology in the bioeconomy in action

Compostable materials to drive food waste recycling and fertile UK soils

WRAP estimates food and drink waste in the UK in 2021 to have been 10.7 million tonnes[3] (Figure 1). 1.9 million tonnes were estimated as having gone to disposal (some to sewer, other to landfill), so this would be better managed if separately collected and organically recycled using AD, composting or integrated AD-composting treatment, as too would be the food/drink waste tonnage that was thermally treated in EfW facilities. Decomposition of food waste in landfill accounts for 8% of all UK greenhouse gas emissions, and 31% of methane emissions.

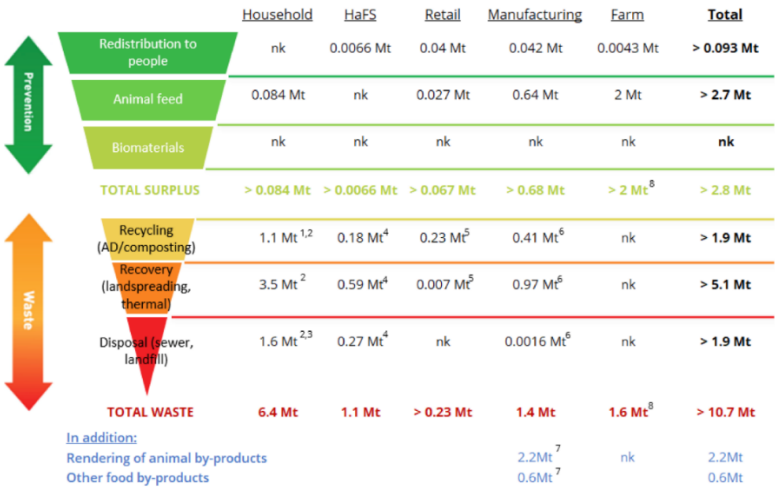

Figure 1. Food waste in the UK and preferred uses

A higher percentage of annual UK food and drink waste arisings could be put to better use if managed higher up the waste hierarchy - being utilised for biomaterials - than landfilling them, sending them to sewer or sending them to EfW facilities (Figure 2).

[3] https://wrap.org.uk/sites/default/files/2024-01/WRAP-Food-Surplus-and-Waste-in-the-UK-Key-Facts%20November-2023.pdf

There is a huge opportunity to prevent these emissions by organically recycling a higher percentage of food wastes and using the derived digestates and composts to replenish agricultural soils. For the treatment stage of organic recycling, options include commercial scale anaerobic digestion, composting and integrated AD and composting processes.

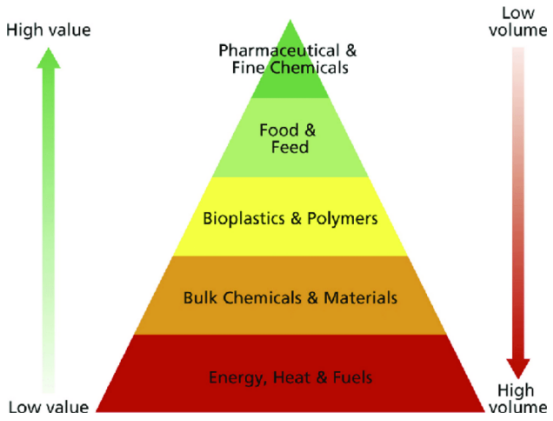

Figure 2. Biomass utilisation hierarchy

For effective household food waste collection, each house needs a food waste caddy, and the use of compostable bin liners has been shown to significantly increase household participation. Other packaging that is contaminated with food waste and hard to recycle by mechanical recycling, should also be compostable and collected with food waste, for example., coffee pods, fruit labels and teabags.

Biodegradable agricultural mulch film

Plastic mulch films are often used in agriculture to cover the soil around plants. While they have several benefits, such as weed suppression, moisture retention, and temperature control, the use of plastic mulch films has detrimental environmental consequences, as when not removed, they contribute to plastic pollution.

This has spurred the development of certified biodegradable mulch films, which, in contrast to conventional mulch films, do not need to be removed, but are ploughed under after the harvest, where they will completely biodegrade in the soil.

This has many benefits for farmers and for society. Above all, it reduces the amount of persistent microplastics in agricultural soil caused by remains of conventional plastic mulch films and thus contributes to a sustainable food production that keeps agricultural soil healthy and productive for a longer time.

Bio-based novel packaging materials to reduce plastic pollution

Plastic packaging generates the most plastic waste of any sector, and its production produces 1 billion tonnes of carbon dioxide annually. As of 2015, more than 3.1 billion tonnes of plastic packaging waste have been generated – yet only 9% of that has been recycled, 12% was incinerated, and 79% has accumulated in landfills or the environment. Novel packaging materials, made from non-fossil resources, such as seaweed, plants and waste materials, are already making a positive contribution to achieving Net Zero, and reducing microplastic accumulation in the environment.

Barriers to commercialisation of bio-based, biodegradable and compostable materials

Currently ~88% of chemicals and plastics are made from virgin-fossil resources (Nova-Institute-2023), with only ~8% from biomass. Transitioning from fossil resources to biomass will require rapid innovation and deployment of new Bio-based

and Biodegradable materials, necessitating a whole-of-government approach that tackles petrochemical "lock-in" (DOI:10.1016/j.erss.2022.102729).

Bio-based and Biodegradable materials are not being afforded a level playing field with their fossil-based counterparts (Nova-Institute-2024). Barriers and challenges being faced by bio-based innovators include:

- **Regulation:** Regulations favour fossil-based incumbents, slowing market entry of alternatives. Legislation around chemical safety, plastics, waste management, and licensing/permitting creates financial barriers and hinders commercialisation of Bio-based and Biodegradable materials.
- **Standards, certifications, and labelling:** Standards and guidelines for LCA and end-of-life labels for BB-materials are inadequate and misleading. Labelling is inconsistent and confusing for consumers.
- **Communication:** Research shows the average person spends <10 seconds interpreting a product label. Terminology for Bio-based and Biodegradable materials is often unclear or misleading, obstructing consumer choice and proper end-of-life disposal.
- **Policy:** There is a disconnect between government departments policies, hindering commercialisation of Bio-based and Biodegradable materials, with UK taxpayers' money funding the development of Bio-based and Biodegradable materials, but the contradictory Biomass Strategy, Simpler Recycling guidance, and the EPR scheme blocking commercialisation.

Policy	Current Policy Barriers
UK Biomass Strategy	Inadequate detail on chemicals sector in the strategy.
Climate Change Agreements (CCA) scheme	The CCA scheme does not have a formal method to account for the increase in energy that a site could expect to use if it switches to alternative feedstocks.
Plastic Packaging Tax	No accepted mass balance accounting method to calculate the proportion of recycled content in plastic packaging.
Standards and labelling	No standardised system for the labelling of recycled content.
UK Emissions Trading Scheme	The UK ETS does not consider biomass used in a product as carbon stored, nor as usefully cycling carbon that does not go through a fossilised stage. This means there is no incentive to use bio-feedstock over fossil feedstock.
Industrial Energy Transformation Fund	Scheme does not support alternative feedstock investment as it focuses on scope 1 emissions.
Renewable Transport Fuel Obligation	Renewable Transport Fuel Obligation encourages biomass to fuel over biomass to chemicals.

How can Government policy support the development of engineering biology?

The drive towards a more environmentally-friendly economy is not an option, it is an obligation. The bioeconomy and bio-based materials offer the ability to dramatically reduce our reliance on fossil resources. However the sector faces significant challenges, which need interventions to be overcome.

1. We ask that UK government develop a unified cross-departmental biomass utilisation hierarchy and associated joined up policies and regulatory environment that ensures biomass and biowastes are prioritised for high value materials and products, to derive the maximum value from our bio-resources.
2. Recognise the benefits of the bioeconomy, and bio-based materials and products, with a dedicated and coherent policy and regulatory framework.
3. Introduce investment frameworks for biomanufacturing of bio-based materials and products, including access to risk capital, enabling multi-scale biorefining facilities.
4. Elevate the role of organic recycling in the waste management hierarchy, and invest in organic recycling infrastructure, allowing certified compostable products to be collected with food waste, to be composted or treated via Anaerobic Digestion with one or more composting phase.
5. Establish innovation principle-applied R&D priorities for bio-based materials and products, digital and AI advancement, intellectual property and innovation protection, plus skills development to support the transition away from fossil resources.
6. Ensure sustainable government procurement, by implementing a bio-preferred procurement scheme, where the use of bio-based products is incentivised over fossil-based incumbents, for example, in the NHS, by requiring bio-based plastics replace fossil-based incumbents.
7. Remove the Plastic Packaging Tax from certified bio-based and certified compostable packaging products containing more than 30% biomass content.
8. Restrict the use of the term biodegradable to specific applications e.g. agricultural plastics, forestry products and bio-lubricants, and incentivise their use though inclusion in the sustainable farming incentives agreement.

Where should funding be focused?

Biomass process technologies: Biomass processing technologies can involve mechanical, chemical or biological processes for the fractionation, pretreatment and conversion of feedstocks into valuable components downstream. Key biomass processing technologies for the conversion of feedstock into chemicals includes: fermentation, pyrolysis, gasification, combustion, carbonation, thermal decomposition, and hydrothermal liquefaction technology etc.
Engineering biology for chemical production: Engineering biology has a key role to play in the production of bio-based chemicals and chemicals through CCU using industrial biotechnology. The Government's 'Engineering Biology Vision' aims to create a vibrant engineering biology ecosystem, it is important that chemicals production is given sufficient considered within this vision alongside medical and other engineering biology applications**.**
Low carbon agriculture: The environment impacts of bio-based chemical production are to a large extent determined by the choice of biomass feedstock and how it is cultivated. Optimising the planting, cultivating and harvesting of biomass can reduce GHG emissions and reduce other environmental impacts

thereby improving the sustainability of bio-based chemical production. The manufacture, transportation and use of inorganic / artificial fertilisers is a significant source of GHG emissions. Consequently, if nitrogen-use efficiency is increased in combination with meeting a larger percentage of fertiliser needs by using non-fossil-derived fertilisers (e.g. biowaste-derived digestates) and soil improvers (e.g. biowaste-derived composts), and without using fossil-derived energy to produce them, this would dramatically reduce emissions. The Biomass Feedstocks Innovation Programme represents an important initiative to support the sustainable production of biomass resources.

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[i] d390c237-04b3-4f2d-be5e776124b3640e.pdf (bioindustry.org)