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Market Perspective

Bio-based & Biodegradable Plastic in the UK

April 2018

Background

This perspective was compiled using third party data (public market research and industry statements) and NNFCC knowledge and market insight. Supporting information is available on request and NNFCC consultants are available for further discussion.

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Funding Declaration

This perspective, produced independently by NNFCC was supported by a financial contribution from Biome Bioplastics Limited.

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Contents

1 Summary

Plastics are cheap and easily processed, they are low in weight but high in strength making lifting and transporting easy. They are also highly functional, providing many benefits including a hygienic and safe method of packaging.

Despite the many positive attributes of plastic, it does have negatives. The plastic industry is essentially an oil and gas based industry, generating fossil greenhouse gas emissions during plastic production, and when plastics are incinerated after use. It is also a highly visible cause of litter and serious source of pollution on land and in the sea.

A paradigm shift from oil based durable plastic to plastics produced from renewable materials and designed to be recyclable or biodegradable, offers the potential to address the issues with plastics while retaining its many benefits.

Bio-based plastics, produced partly or wholly from renewable raw materials e.g. plants, provides an opportunity to move away from oil-based materials. Furthermore, biotechnology can be the basis for clean manufacturing processes and used to produce new materials with properties superior to current plastics.

Although nearly all types of plastics can be recycled, the majority are not. The introduction of biodegradable plastics provides a solution to the dilemma of how to treat hard to recycle products unsuitable for incineration. As such, biodegradable plastics have a key role to play in the circular economy. Biodegradable plastics also provide a solution to the pollution caused by plastic products designed for use in the wider environment such as agricultural mulch films and fishing gear.

Plastic production is a strong and productive UK industry. It is the UK's third largest manufacturing sector in terms of employment, has a turnover of £25.5bn per year and exports products and materials worth over £8bn each year.

The UK is renowned for its academic excellence and the recent investments made in bioscience and building a biotechnology and synthetic biology research community means the UK is well poised to take a leading role in bio-based technology innovation.

The UK has the expertise, facilities and incumbent industries to realise the economic opportunity and, in line the Government's 25 Year Environment Plan, gain from the social and environmental benefits of bio-based and biodegradable plastics. With appropriate strategic investments, policy support and forward thinking, the UK can realise the ambition of being a world leader in the production of innovative, low carbon and environmentally friendly plastic.

Delaying action will only result in ongoing issues for the UK and global ecosystems and a need to tackle even greater problems in later years with higher environmental remediation costs.

2 Introduction

Plastic products and packaging are a ubiquitous part of the global economy. The cost and performance benefits of plastic over other materials has allowed plastic production to grow from a mere 1.5 million tonnes per annum in 1950 to 335 million tonnes in 2016.

The UK plastics processing industry consumes around 3.5 million tonnes of raw material a year, around half of which is produced in the UK, the remainder being imported. The industry is sizable representing the 15th largest consumer of plastics in the world and the 4th largest in Europe.[1][2]

The charity WRAP estimates that 59% of all UK plastic is used in packaging applications; bottles, trays films etc, accounting for around 2 million tonnes.

3 The importance of plastic

There are many reasons why, over the last 60 years, plastic has increasingly replaced other materials such as glass and metal. Plastics are cheap and easily processed allowing a large amount of design freedom including shape and colour. They are low in weight but high in strength making lifting and transporting easy. Plastic provides a hygienic and safe method of packaging food and pharmaceuticals, allowing the production of shatter-proof and tamper-proof containers.

Pixabay

[1] www.bpf.co.uk
[2] http://www.wrap.org.uk/sites/files/wrap/Plastics_Market_Situation_Report.pdf

Another important benefit of plastic to society and the environment lies in the performance of plastic during its use.

It has been calculated that throughout its life-cycle, a typical plastic will save 7 times more greenhouse gas emissions (e.g. through material light weighting or avoided food waste) than emitted during its production. If plastics, where feasible, were substituted by traditional materials in the EU, greenhouse gas emissions would increase by 61% and energy consumption by 57%.[3]

For example, on average 15-20% of materials used in the construction of cars are plastics, saving around 5% in emissions compared to the use of alternative materials. The situation is even more stark for aviation, 22% of the Airbus A380 is made of plastics, helping to reduce fuel consumption by 15% over its life cycle.[1]

Plastic packaging helps preserve food for longer – thus minimising waste – and reduces weight compared to traditional packaging. The weight of traditional material packaging represents 36% of an overall product weight, whereas plastic pouches only contribute 3.6% to the total product weight. This significantly reduces transport emissions. If plastic packaging was not used to preserve food and drink, retailers would make at least 50% more truck journeys within the EU.[3]

It's not just the food chain and the consumer that benefits from plastic packaging. In the UK, around 0.7 million tonnes of packaging is used in non-food applications including construction, agriculture and other industrial sectors.

In the UK, 2 million tonnes of household food is discarded because it is not 'used in time', half of which is thrown away whole or in unopened packaging, costing consumers around £2.4bn a year.[4] Without plastic packaging to prolong the shelf life of food, UK consumers would certainly discard a greater proportion of purchased food.

Without plastic packaging, the environmental impact of producing packaging, transporting goods and wastage of perishable products would be greater.

4 The plastic challenge!

Despite the many positive attributes of plastic, it does have negatives. Two important negatives are the greenhouse gas emissions resulting from production and incineration after use, and the degradation of the natural environment due to plastic pollution.

To date the majority of plastics have been designed to deliver the benefits described earlier without consideration of their impact after use. The positive featured of the strength and durability of plastic becomes a problem when it contaminates the open environment with plastic persisting as a problem for 100's of years.

[3] Plastics Europe, Plastics' contribution to climate protection, https://www.plasticseurope.org/download_file/force/1089/181

[4] WRAP, Household Food & Drink Waste – A Product Focus, http://www.wrap.org.uk/collections-and-reprocessing/organics/reports/household-food-and-drink-waste

The issue of marine plastic pollution, often referred to as the plastic soup problem, has been widely publicised - brought into critical focus in the recent BBC Blue Planet 2 programme.

4.1 Fossil fuel raw materials

The plastic industry is predominately based on petrochemical inputs and is inexorably linked to the consumption of fossil fuels. Around 6% of every barrel of oil is consumed by the plastic industry, roughly around the same volume as is used globally to fuel aviation. Due to the strong growth of the plastic industry, a rate of growth far outstripping the overall demand for oil, it is estimated that the sector will be responsible for 20% of oil consumption by 2050.[5]

The industry's reliance on fossil fuels results in significant greenhouse gas emissions being released in both the production of plastic and after its use. In 2012, these emissions amounted to approximately 390 million tonnes of CO_2.[3]

4.2 Over consumption and low recycling rates

Although nearly all types of plastics can be recycled, the majority are not. This is due to logistics of collection, contamination of mixed plastic preventing recycling, and the costs of collections and processing. Although not nearly enough, in 2016, Europe (EU28+NO/CH) collected, through official schemes, 27 million tonnes of plastic for recycling and for the first time, the volume of recycled material exceeded that sent to landfill.

There is clear need to reduce the volume of plastic use and dramatically increase the recycling rate of plastic waste. However, this won't provide the complete answer.

In a recent study, the Ellen McArthur Foundation[5] found that over 50% of plastic packaging items don't have viable recycling pathways. These items require a fundamental redesign with innovation required in materials development and use. Items considered hard to recycle in existing and future systems include; small format items (lids, tear-offs, caps and sachets), laminated packaging made with inseparable layers of different materials, uncommon plastic packaging materials (such as PVC, EPS and PS) and food contaminated packaging (such as coffee capsules, organic waste bags and takeaway food packaging).

[5] Ellen MacArthur Foundation, The New Plastics Economy – Rethinking the Future of Plastics, https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf

4.3 Natural leakage into the environment

Despite best efforts to promote recycling and discourage littering some plastic items continue to enter the natural environment, e.g. The Marine Conservation Society have described cotton buds as one of the most prevalent types of plastic pollution found on UK beaches. Other plastic items, such as plastic agricultural mulch films widely used to aid crop cultivation, are designed for use in the open environment but if not recovered effectively contribute to the pollution problem.

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5 Putting the bio into the plastics

A paradigm shift from oil based durable plastic to plastics produced from renewable materials and designed to be recyclable or biodegradable, offers the potential to address the issues with plastics while retaining its many benefits.

Increasing recognition of plastic issues goes hand in hand with moves from producers and users to introduce new biodegradable and bio-based plastics.

Well-known brands including, Coca Cola, Heinz and PepsiCo; car manufacturers such as Mazda and Ford and toy producer Lego are all introducing plastics produced from renewable resources. Although current global production capacity is estimated at a mere 2 million tonnes (<1% of total plastics), the biodegradable and bio-based plastic industry has the potential to grow at a significant rate.

The terms biodegradable and bio-based are becoming increasingly used and recognised by consumers, they are however often misunderstood.

5.1 Bio-based

Bio-based plastics are plastics partly or wholly produced from renewable raw materials e.g. plants. The use of renewable materials for plastic production allows producers, brands and retailers to move away from oil-based materials.

A notable example of a bio-based plastic is the Coca-Cola PlantBottle®. The PlantBottle® is a bio-based version of the common plastic PET drinks bottle. Under the PlantBottle® brand, Coca-Cola have distributed over 35 billion packages and have the ambition to convert all new PET plastic bottles, to PlantBottle® packaging by 2020. Another visible example is bio-based polyethylene produced by the Brazilian company Braskem. Petrochemical polyethylene is the world's largest volume plastic and is used in numerous applications from plastic bags to shampoo bottles. Braskem's bio-based polyethylene came to prominence recently through Lego's decision to use the plastic in the production of its moulded trees and plant bricks.


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As bio-based products are produced from plants which have sequestered atmospheric carbon dioxide during their growth, they can help reduce CO_2 emissions associated with fossil-based plastic and contribute to fighting climate change. For example, bio-based polyethylene resin produced by Braskem sequesters 2.15 tonnes of CO_2eq for every tonne of resin produced i.e. it acts as a carbon sink. In comparison, the production of traditional oil-based polyethylene emits 1.83 tonnes of CO_2eq.[6]

Bio-based plastics have the same product characteristics as their traditional oil-based equivalent i.e. bio-based PET is identical to oil-based PET. It is, however, worth noting that just because a bio-based plastic is made from natural resources doesn't mean it is biodegradable. Bio-based plastics can be just as durable as oil-based plastic.

However, the use of renewable raw materials in combination with biotechnology-based processing allows the production of new plastics with novel properties and better performance.

Examples of new 100% bio-based plastics include the PET analogue, PEF, and the biodegradable plastic, PLA. PEF is an alternative plastic to PET; offering superior plastic performance in packaging applications. Using PEF means less plastic is needed to make packaging, thus reducing plastic consumption, and extending the shelf life of packaged products such as carbonated drinks, reducing wastage in the food chain. PLA is produced from lactic acid; a molecule often used as a preservative in food. Lactic acid is produced from sugars through a fermentation (brewing) process. Increasingly fermentation, a biotechnology, is being used to produce molecules that are difficult or expensive to produce from oil. Increasing accessibility to these molecules will allow the production of new and improved plastics and products.

5.2 Biodegradable

Whereas a bio-based plastic is defined by the carbon it's produced from at the beginning of its life, a biodegradable plastic is a plastic that undergoes biodegradation at the end of its life. In this process, degradation results from the action of naturally-occurring micro-organisms such as bacteria, fungi, and algae.

The biodegradation of a plastic is fundamentally based on its molecular structure and physical characteristics. The necessary structure and characteristics can be achieved using either fossil or renewable raw materials.

[6] E4Tech and LCA Works, Environmental assessment of Braskem's bio-based PE resin, http://www.braskem.com/Portal/Principal/Arquivos/ModuloHTML/Documentos/1204/20131206-enviro-assessment-summary-report-final.pdf

The adoption of biodegradable plastics is important to address the challenge of non-recyclable plastic waste. Not only the hard to recycle plastic packaging waste identified by the Ellen MacArthur Foundation, but also those plastic products designed for use in the wider environment such as agricultural mulch films.

Food packaging, even if recyclable, needs to be cleaned before recycling. In many situations, such as fast/street food, sports events and music festivals, cleaning food contaminated packaging prior to collection isn't an option and increases the cost of post collection processing. Biodegradable plastic in combination with clear labelling and available disposal bins allows packaging to be collected with food waste and treated in an industrial compost facility. European and US standards exist to ensure packaging materials are suitable for collection and industrial composting. Compostable foodservice packaging is widely available from UK companies like Vegware, Biopac and London Biopackaging.

The use of biodegradable plastic packaging and co-collection with food waste would also alleviate problems with other food packaging. Grease and oil spoilt paper and cardboard, such as pizza boxes, contaminate paper recycling streams making the pulp unusable. This is also an issue when oil or grease is transferred from plastic to paper in co-mingled recyclables collection systems.

The collection of compostable waste needs to develop hand in hand with the availability of composting facilities, ideally through coordinated local authority action.

The use of biodegradable plastic offers a solution to those products with a tendency to leak into the environment or designed for use in the open environment, for example biodegradable mulch film for agricultural use and fishing gear.

The role of biodegradable plastics remains an area of debate for addressing marine plastic pollution, with critics pointing to the slow biodegradation rates of current biodegradable plastics in marine conditions. However, this view neglects the scope to develop new plastic combinations designed specifically for the marine environment. Polyhydroxyalkanoate (PHA) plastic has been shown to be similar in marine biodegradation to cellulose and shows the potential to development new products which, if lost into the marine environment will degrade within a number of years rather than decades or centuries.[7]

Ghost fishing remains a notable pollution issue and occurs when fishing gear is lost into the marine environment but continues to trap prey. Clearly, the use of gear specifically designed to have a limited life in the marine environment, would result in the decline of ghost fishing. Trials of fishing gear produced using biodegradable plastic are limited but do show the potential for further development.[8]

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[7] CalRecycle, PLA and PHA Biodegradation in the Marine Environment, http://www.calrecycle.ca.gov/publications/Documents/1435%5C20121435.pdf

[8] UNEP, Biodegradable Plastics & marine litter -misconceptions, concerns and impacts on marine environments, https://europa.eu/capacity4dev/unep/document/biodegradable-plastics-and-marine-litter-misconceptions-concerns-and-impacts-marine-environ

5.3 An opportunity for new plastics

Although there may appear to be a wide range of plastic types the industry is dominated by a small number of large volume plastics, their dominance being based on a combination of performance and low cost of production from oil.

The plastic PEF is just one example of the potential to use renewable raw materials to produce new plastics with improved performance. Biomass contains an array of molecules, which are inaccessible from oil due to prohibitive economics, and can be converted, often using green chemistry or biotechnology to intermediates to produce novel plastics.

Biodegradable shouldn't be seen as synonymous with single use. As demonstrated by the recycling of the NatureWorks PLA based carpet at the 2009 UN Conference on Climate Change in Copenhagen, biodegradable plastic can be recycled.[9,10] Building on this idea there are industry players considering the potential to develop a new set of plastics, combining recyclability and biodegradability. These new plastics would be sufficiently durable to deliver the required performance over the lifetime of their use, robust enough to undergo a specified set of recycling cycles and biodegradable if lost to the environment. While these plastics wouldn't negate the short-term issues of plastic pollution e.g. digestion by marine animals, they would offer a solution to the long-term persistence of plastic in the environment.

6 A UK opportunity

The UK is the birthplace of the plastic industry and it remains a key sector within UK manufacturing.

6.1 UK plastic industry

The plastics industry is the UK's third largest manufacturing sector in terms of employment, with 6,200 companies employing over 166,000 people. It is also a UK success story with industry turnover increasing by over 16% since 2010, now standing at £25.5bn per year.

The UK is home to innovative end user markets for plastics such as the aerospace and automotive sectors and a sophisticated and highly evolved retail sector. The UK is the 15th largest consumer of plastics in the world and the fourth largest in Europe, demonstrating the importance of addressing plastic issues. The abundance of companies covering all aspects of plastic production and vibrant end user markets creates an excellent opportunity to develop novel materials and products and build new manufacturing value chains.

The UK plastics industry has a global outlook, it exports products and materials worth £8.2bn each year and 80% of the members of British Plastics Federation are exporters. This exporting experience and the existing international networks of the UK plastics industry provide an excellent platform to develop new bio-based products and processes for a global market.

[9] Natureworks, https://www.natureworksllc.com/News-and-Events/Press-Releases/2010/01-14-10-COP-15-loopla

[10] LoopLA by Galactic, http://www.loopla.org/cradle/cradle.htm

To address the challenges created through the use of plastic, the industry needs to develop new materials and work with designers to produce new product concepts which allow for easier product reuse and material recycling. Increasing the sustainability of plastic production and use requires a high degree of creativity, and innovation is required across the entire plastic value chain.

In its 25 Year Environment Plan, the UK Government has set out a long-term strategy to create a cleaner, greener country. An important aim is to achieve the goal of zero avoidable plastic waste by the end of 2042. It has recognised both the benefits of, and issues caused by plastics and has laid out several commitments including an acceleration of the pace of research and to encourage the use of environmentally friendly bio-based and biodegradable plastic.

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6.2 Bio-based Innovation

Fortunately, the UK is a highly innovative nation and in 2017, the UK was ranked fifth on the Global Innovation Index. The UK is home to many world leading universities and academic groups and sits at the cutting edge of innovative technology developments such as biotechnology.

The UK Government has made several important investments over the last 10 years to ensure its research base is ready and prepared to capitalise on the commercial opportunities presented through the use of Industrial Biotechnology to manufacture products including bio-based and biodegradable plastics.

As examples, through the Integrated Biorefining Research and Technology Club and Industrial Biotechnology Catalyst programme, Innovate UK, the Engineering and Physical Sciences Research Council (EPSRC) and the Biotechnology and Biological Sciences Research Council (BBSRC), committed over £80M to support biotechnology projects building a foundation of knowledge and expertise to support the growth of a bio-based industry in the UK.

Synthetic Biology applies engineering principles to the development of microorganisms for use in fermentation processes that can be used to manufacture chemicals and plastics. The UK is considered world leading in this area, a position achieved through the investment of £102M in the Synthetic Biology for Growth programme. The programme includes the creation of 6 centres of excellence across the UK and the creation of a £10M capital funding, available through the Rainbow Seed Fund, to support synthetic biology start-up companies.

Over the last 10 years there has been considerable investment and effort placed in ensuring the UK has the facilities in place to allow novel academic research to be translated into commercial bio-based plastic manufacturing processes. Through BioPilots UK, the UK's open access pilot centres are collaborating to ensure that UK companies and academic groups have access to the wide range of know-how, expertise and equipment required to pilot, demonstrate and ultimately commercialise new technology and processes.

An early recipient of Government support was Professor Timothy Bugg at the University Warwick. Professor Bugg received a grant from the Integrated Biorefining Research and Technology Club to investigate the breakdown of lignin, a polymer found in plants and an important source of aromatic chemicals, into chemical building blocks. The scientific foundations laid by the project ultimately led to a close collaboration with Biome Bioplastics, one of the UK's leading developers of bio-based and biodegradable plastics. Several projects later, the technology has now progressed to a point where large-scale trials, earmarked to take place at BioPilots UK member the Centre for Process Innovation, can be envisaged. Although there is further development and scale-up work to do; the initial research performed within IBTI has evolved to a point where a real commercial opportunity can be envisaged and demonstrates the UK's ability to drive academic research towards commercial processes.

The UK is renowned for academic excellence and its inventive nature. The recent investments made in fundamental bioscience and growing a research community focussed on biotechnology and synthetic biology means the UK is poised to take a leading role in bio-based technology innovation.

6.3 Feedstock

Although the UK may not be the most biomass feedstock rich country in the world, it does have sufficient primary resources to support a significant bio-based plastic industry.

The UK's biomass potential has been widely studied in the context of potential bioenergy supply. Although estimates vary considerably depending on the sustainability constraints applied and assumptions made on crop improvements and, agricultural and forestry market dynamics, even conservative assessments demonstrate the large availability of resources.

Taking into consideration crop products, agricultural residues, forestry residues and industrial/municipal wastes, forecasts for biomass potential in 2030 range from 12 to over 60 million tonnes per year.[11] Higher estimates would require that all constraints are removed or overcome and clearly come with significant sustainability concerns. However, even conversion of the lower estimates of biomass to bio-based plastics would result in a production volume of millions of tonnes and would exceed the 2 million tonnes of packaging waste currently produced in the UK.

To place this potential into context, were the UK's two world scale wheat to bio-based ethanol plants convert their ethanol capacity to polyethene, the UK could produce over 350,000 tonnes of polyethylene per year. Switching production from ethanol to an alternative molecule with higher yields e.g. lactic acid for PLA, bio-based plastic production from UK wheat grain could surpass 1 million tonnes.

The UK has the potential to adapt its crop output, e.g. sugar beet is a high yielding crop with considerable environmental and biodiversity benefits when grown as part of the arable rotation. Sugar

[11] UK ERC, The UK bio-energy resource base to 2050: estimates, assumptions, and uncertainties, http://www.ukerc.ac.uk/asset/238DB40D-7CED-462B-8ABE1F5AB3E9573A/

beet is a highly productive crop allowing 4 times more bio-based plastic to be produced on a piece of land when compared to wheat grain. The closure of several of the UK's sugar factories in the 2000's curtailed the cultivation of sugar beet in several regions. Creating a demand for bio-based plastic could provide the stimulus for new investment in sugar beet cultivation and processing.

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The bulk of the estimated 12 million tonnes of available biomass is made up of residues from agriculture e.g. straw, forestry residues and biogenic industrial/municipal wastes. The collection and processing of this underutilised material could result in the production of over 2 million tonnes of polyethylene and upwards of 6 million tonnes of PLA.

Beyond the ability to process UK biomass, the potential to utilise the UK's significant port potential to import biomass resource shouldn't be overlooked. The UK currently imports several million tonnes of wood pellets to generate bioenergy, converting a fraction to bio-based plastic would result in a significant production capacity.

It is clear that the UK has the feedstock capacity to support the growth of an indigenous bio-based plastics industry. Demonstrating production in the UK at commercially relevant scales would provide the platform for a UK industry to export innovative technology. Furthermore, the developing use of agricultural residues such as straw for bio-based plastic production means production can work in synergy with the food production creating a more resilient and robust agricultural industry.

6.4 The current UK bio-based and biodegradable plastic industry

Despite the UK's strong plastics industry and the potential for bio-based innovation, the UK remains an immature market with incomplete value chains. For example, in 2014 three quarters of demand for bio-based finished goods were met through European imports.

In 2014, UK demand for bio-based plastics as finished goods was estimated to be 4,000 tonnes, of which three quarters was imported from Europe. The industry supported around 1,000 jobs and added £50.5 million of gross value added (GVA) to the economy (including direct and multiplier impacts). This represents less than 0.2% of the UK's plastic consumption and demonstrates the enormous potential for industrial development.

Given the right circumstances, i.e. Government policy creating conditions conducive to investment, bio-based plastics industry representatives believe domestic production could reach 120 thousand tonnes over a period of 5-10 years. An industry of this size would create over 5,000 jobs in primary plastic manufacture while supporting a total of 34,000 jobs and contributing £1.92 billion of gross value added across the wider UK economy.[12]

7 A call to action

The UK Government's Industrial Strategy describes its plans to build a Britain fit for the future. It is a strategy based on building on strengths and extending areas of excellence.

The UK has a rich history of plastic production and retains a strong and productive industry; maintaining this position requires innovation and forward thinking. Producing bio-based plastics presents an opportunity for industrial development. The UK has the expertise, facilities and incumbent industries to realise the economic opportunity and, in line the 25 Year Environment Plan, gain from the social and environmental benefits of bio-based plastics.

The introduction of biodegradable plastics provides a solution to the dilemma of how to treat hard to recycle products unsuitable for incineration. As such, biodegradable plastics have a key role to play in the circular economy.

With appropriate strategic investments, policy support and forward thinking the UK can realise the ambition of being a world leader in the production of innovative, low carbon and environmentally friendly plastic.

Addressing the dual challenge of plastic pollution on land and sea, and climate change, requires immediate actions and multiple approaches. Bio-based and biodegradable plastics have a significant role to play.

Delaying action will only result in ongoing issues for the UK and global ecosystems and a need to tackle even greater problems in later years with higher environmental remediation costs.

[12] CEBR, The future potential economic impacts of a bio-plastics industry in the UK, http://bbia.org.uk/wp-content/uploads/2015/11/BBIA-CEBR-Report.compressed.pdf

8 Glossary

Bio-based: derived from biomass, biomass can have undergone physical, chemical or biological treatment(s). (derived from EN 16575:2014)

Bio-based product/plastic): A product wholly or partly derived from biomass. The bio-based product is normally characterised by the bio-based carbon content or the bio-based content. The product can be an intermediate, material, semifinished or final product. "Bio-based product" is often used to refer to a product which is partly bio-based, in in case the claim should be accompanied by a quantification of the bio-based content. (derived from EN 16575:2014)

Biodegradable plastic: A plastic that can be broken down by microorganisms (bacteria or fungi) into water, naturally occurring gases like carbon dioxide (CO_2) and methane (CH_4) and biomass. Biodegradability depends strongly on the environmental conditions: temperature, presence of microorganisms, presence of oxygen and water. The biodegradability and the degradation rate of a biodegradable plastic product may be different in the soil, on the soil, in humid or dry climate, in surface water, in marine water, or in human made systems like home composting, industrial composting or anaerobic digestion. (www.ows.be)

Biomass: material of biological origin excluding material embedded in geological formations and/or fossilized. E.g. (whole or parts of) plants, trees, algae, marine organisms, micro-organisms, animals, etc. (derived from EN 16575:2014)

Biotechnology: The use of living systems and organisms to develop or make products, or "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use". (derived from UN Convention on Biological Diversity)

Polyethylene furanoate (PEF): A developmental polyester polymer produced from monoethylene glycol and 2,5-furandicarboxylic acid, an alternative polymer to PET.

Polyethylene terephthalate (PET): A transparent polyester polymer produced from monoethylene glycol and terephthalate, used to produce bottles and film.

Polylactic acid (PLA): A biodegradable polyester produced from lactic acid, used in wide range of serviceware products and as filament for 3D printing

Polyhydroxyalkanoate (PHA): A naturally occurring family of biodegradable polyesters

Synthetic Biology: The design and construction of new biological entities such as enzymes, genetic circuits, and cells or the redesign of existing biological systems.

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