Reducing plastic Waste

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Published: 31/07/2024

Publisher's PDF, also known as Version of record

Cyswllt i'r cyhoeddiad / Link to publication

Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):
Courtene-Jones, W. (2024, Jul 31). Reducing plastic Waste. UK Parliament. https://post.parliament.uk/research-briefings/post-pn-0724/

UK Parliament
POST

POSTnote 724

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31 July 2024

Reducing plastic waste

Overview

- Plastics are versatile and inexpensive, and are used widely across different sectors. However, the resulting plastic pollution may pose risks to human, animal and environmental health globally.
- In March 2022, United Nations Member States agreed to develop an international legally binding agreement to end plastic pollution by 2024. The UK governments set out ambitious plastic waste plans in 2020 and 2023. However, these may need to change if the UN targets are to be achieved.
- The UK's plastic waste management system is complex. Challenges include the contamination of plastic waste streams, inconsistent waste management strategies, and inadequate reprocessing infrastructure. The design of products containing plastics also pose further challenges to recycling.
- A circular economy for plastics aims to promote design for plastic re-use and recycling and to minimise waste. However, achieving this this would require a whole systems approach including wide range of policy interventions and other changes in society. For example, this may include changes in the design of plastic products to enhance their recyclability, implementation of environmental product policies to manage plastic lifecycle impacts, and Plastic Packaging Tax reforms. A revised Extended Producer Responsibility (EPR) scheme for packaging is due to be implemented in 2025.

Background

Plastic is a versatile and inexpensive material that has a wide variety of applications in products used in most sectors.[1] However, its extensive use over decades has been associated with accumulation of plastic objects in the natural environment.[2,3]

Plastics enter the environment in multiple ways, including littering, wastewater, wind dispersal, during product use (such as tyres) or run off from landfill.[4–6] Once in the environment, plastics are broken into smaller fragments.[2] Depending on their size, plastics can be classified in four main classes: macroplastics, mesoplastics, microplastics and nanoplastics (Table 1).

In 2019, the Royal Society stated that "little is known about the effects of long-term low-level exposure to microplastics, or what their effects might be to the wider food chain".[a,7] It also stated that "there is not yet conclusive evidence that microplastics affect human health, or cause significant harm to people." However, studies since have suggested that endocrine-disrupting chemicals[b] leaking from plastics may cause adverse health effects.[9]

Animals and other organisms can interact with or ingest plastics found in the environment, which some studies suggest may result in adverse effects.[10–12] Some studies have also demonstrated the presence of microplastics in commonly consumed food, including table salt, meat and seafood.[13] A 2021 study published in the scientific journal Environmental Science & Technology revealed that microplastics were 50% more prevalent in faeces of humans with inflammatory bowel disease.[14]

Other studies suggest that plastics may be related to a range of public health issues.[15–17] This may be linked to harmful chemicals present in plastic products which can be released into the natural environment.[c,20,21]

[a] The 2019 Royal Society evidence synthesis 'Microplastics in freshwater and soil' states: "Microplastics have only recently been identified as an environmental pollutant and their effects on animals are not yet fully understood".[7]

[b] Endocrine-disrupting chemicals are substances known to interfere with the endocrine system of organisms, that can mimic, block or change the function of hormones or related biomolecules, causing adverse developmental and health effects[8].

[c] According to a report published by PlastChem Project in 2024, more than 16,000 chemicals were found to be present in plastic materials.[18] Moreover, 10,000 of these associated chemicals were found to lack detailed hazard information, with PlastChem Project report highlighting "a large global governance gap".[18,19]

Table 1: Size and degradation of plastics		
Macroplastics	**Meso- and microplastics**	**Nanoplastics**
Greater than or equal to 2cm[22]	Meso-: 5mm - 2cm Micro-: Between 1mm – 5mm	Smaller than 1mm[22]
Macroplastics (e.g. water bottle, car bumper) fragment to smaller sizes due to weathering, such as by sunlight, chemical degradation and biological degradation by micro-organisms. [16] Some properties (e.g. shape, low polymer resistance, previous weathering) can accelerate their fragmentation.[24]	Microplastics are fragments of meso- and macrocroplastics, derivatives from mechanical wear & tear or tyres, paint, clothing (PN 528).[25,26] Microplastics have similar weathering stability as macroplastics, and they can further degrade to smaller fragments such as nanoplastics.[27]	Fragments of microplastics, paints, adhesives, electronics.[16] Nanoplastics can further degrade into water-soluble organic materials at detectable levels.[27]
May leach chemicals that are released in the environment[28]	Microplastics are found in air, soil, bottled water, sewage effluent and human blood.[29–31] Mesoplastic distribution is less well reported in literature.[22]	The same environmental distribution as microplastics[16]

UK statistics on plastic waste

A 2020 research study ranked the UK second globally in terms of plastic waste generation per person in 2016.[32] However, a 2021 study investigating global plastics in the oceans, suggested that Asia accounted for 80% of global plastic waste accumulating in the oceans and Europe only 0.6%.[34,35] A WWF report stated that total plastic waste generation in the UK was around 4.9 million tonnes in 2014.[36] A 2024 report from Greenpeace indicated that 17% of all UK plastic waste is recycled, 11% landfilled, 58% incinerated, and 14% exported.[37,d]

[d] UK official statistics on waste only record plastic packaging waste.[38] Many other uses of plastic are longer term with differing lifecycle considerations.

According to the Waste and Resources Action Programme (WRAP), nearly 70% of all UK's annual plastic waste is plastic packaging.[39] In 2021, Defra reported that 44.2% of plastic packaging waste was recycled in the UK (see also CBP 8515).[38]

Official UK recycling rates comprise both this domestic reprocessing and data on plastic packaging exported for recycling. In 2023, Turkey received the highest amount of this exported plastic waste, accounting for 25% of UK's total plastic recycling exports.[40e] However, UK plastic waste exports to Turkey have been previously associated with mismanagement practices.[43,44]

Challenges in reducing plastic waste in the UK

Constraints to adopting a circular economy approach

After the UK's exit from the European Union (EU), the Government has largely adopted the EU's Circular Economy Package into UK regulations in 2020.[45,46] This includes a legislative framework aimed at reducing waste and creating a viable path for waste recycling, with further plans for a UK circular economy set out in 2023.[47,f] However, reducing plastic waste in the UK has been associated with several challenges that constrain the widespread implementation of a circular economy framework[g] for plastics.

Plastic waste management and infrastructure

In the UK there are 123 material recovery facilities (MRFs) and 7 dedicated plastic recovery facilities (PRFs). MRFs receive and separate dry mixed recycling from households, using magnetic, ballistic[h] and near infra-red technology. Once sorted, the

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[e] In 2017, China banned imports of plastic waste including from the UK and EU, which had a substantial impact on global flows of plastic waste.[41] The EU banned the export of plastic waste to non-OECD countries in 2024, but an expected government consultation on a similar export ban for England has not taken place. More than 26% of England's plastic waste was sent to non-OECD or developing countries in 2023.[42]

[f] This sets out 3 main policy approaches: designing out waste, including ecodesign and consumer information requirements, and Extended Producer Responsibility schemes; systems and services including collection and take-back services, encouraging reuse, repair, leasing businesses and facilities; data and information: including materials databases, product passports (sets of data, unique to the specific product that can be accessed online and give detailed information on, for example, contained materials, components and history, to support improved outcomes such as higher quality recycling) and voluntary corporate reporting. Plastic and packaging are one of the plan's seven focal sectors.[47]

[g] A circular economy framework is a model of production and consumption that aims to extend the life cycle of a product for as long as possible, by means of sharing, reusing, repairing and recycling.[48]

[h] Ballistic separation of waste is a stage during the sorting process that typically occurs after materials have been classified according to their size and density.[49]

material is wrapped into a bundle and is transported to either a PRF, a reprocessor or exported. PRFs facilitate further sorting of plastic materials to increase the quality of the recyclates.

At the reprocessing stage, pre-sorted plastics are shredded and washed to remove unwanted items or contaminants while polymer types are also separated. The resulting grinded material is then sold or converted into a pellet through melting.[50]

Although existing MRFs and PRFs can facilitate the sorting of plastic waste at large scale, commentators argue the UK's reprocessing capabilities are insufficient in terms of sorting ability and capacity.[51–53] According to RECOUP's 2022 report "Plastic Packaging Sorting & Reprocessing", existing reprocessing infrastructure in the UK is not sufficient to reach the 30% plastic packaging recyclate targets outlined in the HMRC's Plastic Packaging Tax and WRAP's UK Plastics Pact.[54,55]

In May 2024, the then UK Government also announced that planning permission for the development of new incinerators in England was paused to allow "sufficient time for the Department to consider the outcome of the piece of work being carried out by Defra officials to consider the role of waste incineration capacity in the management of residual wastes in England".[56]

Differing recycling policies within the UK

Waste management in the UK is a devolved matter where approaches differ across local authorities and government administrations.[57,58]

For example:

- In 2021, the Scottish Government introduced a ban on the manufacture and supply of a range of single-use plastic items under the Environmental Protection Regulations.[59] These include plastic cutlery, plates and expanded polystyrene drink and food containers.
- The Welsh Government has introduced bans on the supply of some single-use plastic items under its Environmental Protection (Single-use Plastic Product) regulations in 2023.[60]
- England's Environmental Protection (Plastic Straws, Cotton Buds and Stirrers) Regulations, introduced a ban on the supply of specific single-use plastic items, including plastic cutlery, plates and expanded polystyrene drink and food containers between 2020 and 2023.[61]
- The EU's restrictions on single use plastic items were added to the (amended) Northern Ireland Protocol to the UK/EU Withdrawal Agreement.[62]

These bans vary as to whether they are on the supply (provision or sale) or manufacture of items (CBP 8515). The UK Government also committed itself in 2023 to implement a Deposit Return Scheme (DRS) for drinks containers by 2025.[63,64] However, in April 2024 Defra announced that the implementation of the DRS was to be delayed. In a joint policy statement, the UK Government and devolved administrations announced the implementation of a common DRS scheme scheduled to launch in October 2027.[i,65] Environmental NGOs have called for the scheme to be in place before 2027.[66]

Academic commentators argue that existing policies for reducing all types of plastic waste have limitations.[67] For example, the Plastic Packaging Tax and the existing Extended Producer Responsibility (EPR) scheme (reviewed in CBP 8515) have been shown to increase recycling rates[68] and promote data transparency on plastic packaging across the supply chain.[69,j] However, commentators criticise the policies for restraining technological innovation,[71] and focusing on recycling plastics rather than their reuse in a circular economy.[72,73] A revised strategy for the forthcoming EPR scheme is currently expected to be introduced from October 2025.[k]

WRAP state similar limitations for targets on reusability, recyclability, or compostability of plastic packaging set by the UK Plastics Pact (see page 9), which are not on track to be met by 2025.[55,74–76] Commentators have also criticised such voluntary agreements for allowing relevant parties to divert focus away from implementing more comprehensive policies through their optional participation.[74–76]

Types of polymers used in plastic manufacturing

Polymers, such us polyethylene, are made by chemically linking multiple monomers together.[77,78] To meet functional requirements for strength or barrier capacities for products, plastics are often made using combinations of multiple polymers[l] and other additives, including stabilisers, colorants or plasticisers.[81–83] This combination of chemicals can make plastics challenging to recycle. To lessen this challenge, eco-design requirements can be established.[84]

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[i] The Scottish Government has been working towards establishing a DRS for several years (CBP 8515). In June 2023 the Scottish Government said that its scheme will be delayed further, until at least October 2025, "as a consequence of the UK Government's refusal to agree a full exclusion from the Internal Market Act."

[j] Under EPR, producers fund the collection, recycling and disposal of post-consumer goods, in line with the 'polluter pays' principle. The EPR for packaging places a legal obligation on businesses over a certain size which make or use packaging, to ensure that a proportion of the packaging they place on the market is recovered and recycled. Packaging Recovery Notes (PRNs) or Packaging Export Recovery Notes (PERNs) are issued by accredited businesses and provide the evidence for compliance (CBP 8515).[70]

[k] The main change will be that the full cost of collecting, sorting, recycling and disposing of household packaging waste will be placed on packaging producers rather than through local authorities. These businesses will need to meet recycling targets and label packaging to show its recyclability (CBP 8515).

[l] The industrial blending of two or more polymers can result in the development of novel polymers that have tailor-made properties.[79] This process is usually referred to as "polymer blending".[79] However, a common disadvantage of this approach is the development of non-homogenous and unstable polymer mixtures where particles of the less abundant component often predominate.[80] Challenges in the process may arise where the original structure and stability of the polymer composition will need to be restored to recycle them.[80] Although chemical practices for restoring some polymer compositions exist, these are often incompatible with many other polymer combinations.[80]

Recycling of polymer compositions might also be affected by the potential degradation of the original mixture due to the presence of other components.[m] In some instances, different polymers within the mixture might have varying degradation rates affecting the overall degradation behaviour of the materials during recycling.[80] This degradation within the polymer composition may lead to loss of quality of the recycled product, reducing their economic value and limiting re-use.[81]

Fossil and bio-based plastics

Plastics are made from either fossil-based or bio-based materials. Fossil-based plastics contribute to the release greenhouse gas emissions[n] at every stage of their life cycle. [87] New plastics with biodegradable qualities may reduce packaging waste (PN 606).[88–91] However, a systematic review has found these do not extend product life or reduce food waste (PB 60).[92]

Although bio-based plastics derive from biological resources, negative impacts on the environment may need to be assessed.[o] For example, the biomass needed to produce bio-based plastics may result in extensive land use, which will have a range of direct and indirect impacts, such as GHG emissions arising from use of fertilisers[p] (PN 710).[96,97]

Biodegradable plastics

Biodegradable plastics can be either fossil-based or bio-based. They are designed to break down into natural substances, mainly under specific industrial conditions.[q] Biodegradable plastics are often confused with bio-based plastics by consumers,[98] and bio-based but non-biodegradable plastics often end up in food waste bins contaminating waste for composting or anaerobic digestion (PN 387).[98] Some

[m] The degradation of additives present in polymer blends may also result in the release of various hazardous substances in the environment, contributing to environmental pollution. Hazardous substances from polymer blends that are released in the environment include phthalates and polycyclic aromatic hydrocarbons (PAHs).[81]

[n] In 2019, plastics generated 3.4% - 5.3% of the global greenhouse gas emissions.[85,86] This figure is expected to increase to 17-22% by 2050.[86]

[o] A Life Cycle Analysis (LCA) can measure the environmental impacts of products or services throughout their life cycle.[93] However, some bio-based plastics may be characterised by higher carbon footprint than traditional fossil-based plastics.[94]

[p] The then UK Government stated in its 2023 Biomass Strategy that would work "to better understand how the bio-based chemicals and materials sectors can form part of the long term priority use of biomass".[95]

[q] Biodegradable plastics are designed to biodegrade in soil, water or compost under specific conditions and differing periods of time. Compostable plastics are designed to biodegrade in either industrial conditions, or in conditions of well-managed home composter at controlled temperatures.[98,99] The responses to a recent government consultation on standards for biodegradable, compostable and bio-based plastics highlighted that more research was required to determine whether in practise biodegradable plastics do not simply accelerate the fragmentation of plastic into microplastic.[100,101]

biodegradable plastics do not degrade in the environment if they are inappropriately disposed of or released[r].

Contamination of plastic waste streams

Mismanagement of all plastic waste can result in the contamination of the recyclate feedstock.[104] This is mainly caused by the practices followed during the disposal, collection and management of plastic waste streams, that are often mixed with different types of waste such as food, textiles, or other materials ("created attributes", Table 2).[104]

Contamination of plastic waste streams can also be caused due to "designed attributes" (Table 2).

Table 2: Types of contamination in plastic waste streams

Designed attributes (arising in manufacture)[s]	Created attributes (arising in the waste stream)[t]
Adhesives found in polymer compositions[105]	Mixed with organic waste at collection[105]
Additives found in polymer compositions[105]	Mixed with paper, metal or other materials at collection[105]
Labels included in the packaging[105]	Mixed with fragments of polymer contaminants at collection[105]
Items composed of multiple materials[106]	Incorrectly disposed household waste[106]

[r] A 2023 study found that a bio-plastic material releases nine times less microplastic than conventional plastic under seawater exposure conditions.[102] However, a 2024 review revealed that more research is needed to understand the degradation differences between conventional and biodegradable plastics.[103]

[s] "Designed attributes" are defined as the characteristics of plastic waste that derive during the manufacturing stage of a plastic product (e.g. colour, hardness, density).[104]

[t] "Created attributes" are defined as the characteristics of plastic waste that derive from human based activities (e.g. contamination of waste stream with non-compatible materials).[104]

Consumer plastic disposal behaviours

The disposal and recycling of plastic products are also affected by consumers' disposal practices. A 2022 systematic review, investigating the drivers behind plastic waste prevention, found that consumers often do not understand packaging materials and are confused about how to sort waste, leading to ineffective recycling and waste reduction.[107] Research has also shown that clear messaging in plastic packaging can influence positive behaviour.[108]

Labelling of some plastic packaging regarding their disposal is often misleading. For example, certain household products such as synthetic wet wipes that are labelled as "flushable" are in fact not designed to be flushed down the toilet.[109] Consequently, when these products enter wastewater treatments, their microscopic synthetic polymers are released along with wastewater effluents.[110]

UN Member States: End Plastic Pollution by 2024

In March 2022, United Nations (UN) Member States agreed to adopt an international legally binding agreement to "end" plastic pollution by 2024.[111] The UN Plastics Treaty is intended to foster investment and innovation, as well as to promote circular economy measures that accelerate upstream changes in the design and use of plastics.[112]

The second-to-last round of negotiations was conducted in Canada in April 2024 and the final round of negotiations is expected to be completed in South Korea, in December 2024. However, nations remain divided on the treaty's goals. Some countries are advocating for reductions in plastics manufacturing, while others focus on recycling and reusing plastics.[113]

Depending on the outcomes of the treaty, existing plastic waste regulations in the UK may need to change if the targets agreed are to be achieved. Insights from April's 2024 round of negotiations indicate that plastic production may be constrained through a "life-cycle approach".[u,115] This would consist of changes in the extraction, production, design, as well as the usage and disposal of plastics.

Over the years, the UK has committed to tackling plastic waste through various targets. These include eliminating all avoidable plastic waste by 2042,[116] as well as increasing the recycled content in plastic packaging[54] while improving recycling rates.[117]

In 2018, the voluntary agreement "UK Plastics Pact" brought together businesses from across the entire plastics value chain, with UK regulators and NGO's, setting further targets to reducing plastic waste.[55]

[u] A "life-cycle approach" evaluates the effects of a product at every stage of its life cycle, from the extraction of raw materials, to the production, design, usage and disposal.[114]

Although these efforts have achieved some success, the UK approach to reducing plastic waste has been characterised by academic commentators as "complex, inefficient and decentralised".[1]

Whole systems approach to reducing plastic waste

In linear economic models, products once used become waste, the disposal of which may damage the natural environment through pollution and GHG emissions.[118,119] By contrast, in a circular economic system, materials are designed to be re-used as many times as possible.[120]

A linear economic framework is a system where people purchase a product, use it, and then dispose it.[121] UK's economy is predominantly based on a linear economy framework with a national circularity metric of 7.5% in 2023. Consequently, the UK's circularity gap[v] is 92.5%, which means that most material inputs to plastic products in the UK are not from recycled sources.[122]

Existing policies, such as the Plastic Packaging and landfill taxes, or forthcoming policies, such as EPR and DRS, promote sustainable practices. However, they target different parts of the system without effectively integrating sustainability across the entire supply chain.[1]

Some commentators suggest a circular economy for plastics across supply chains presents an opportunity for innovative approaches and policies for managing plastic waste, to benefit society, the environment and economic growth.[120, 45,46] However, the transition towards a circular economy presents financial, cultural, and technological challenges.

Plastic waste is a multi-dimensional problem. A growing body of evidence suggests that it needs a whole-systems approach to address these challenges, which encompass material-based interventions, social-based interventions, policy interventions as well as investments and developments in research innovations (Figure 1).[1,123–125]

[v] The Circularity Gap Report aims to provide recommendations on how to build and strengthen a circular economy. The circularity gap refers to the difference that exists between a linear economic model and a circular economic model.[122]

Material-based interventions

Recycling plastics is a complex process that requires mechanical, chemical and design interventions.

Mechanical recycling

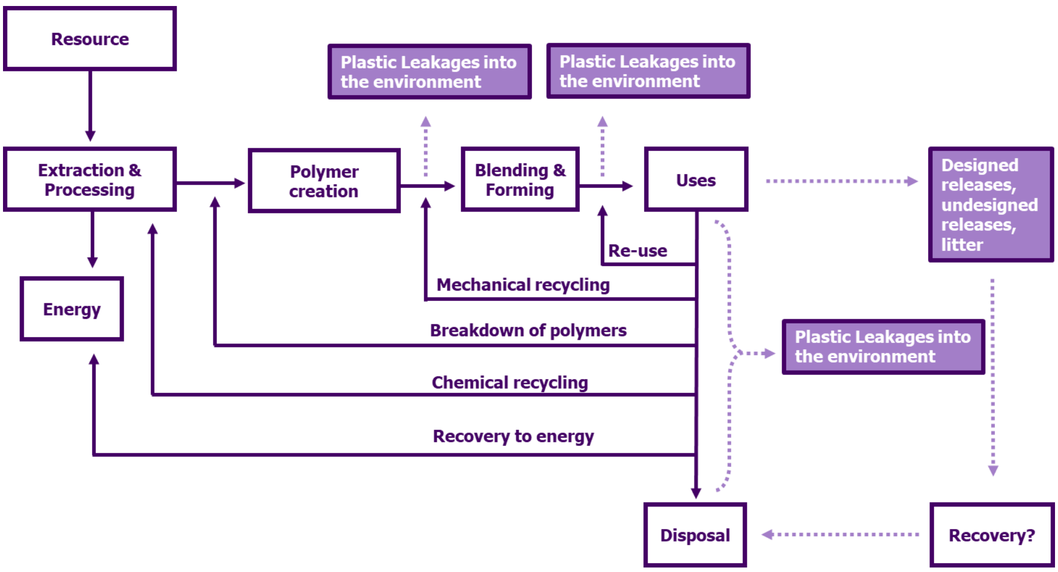
Mechanical recycling, which involves melting and reforming plastics into new products, is popular, cost-effective, and environmentally friendly (Figure 1).[126] However, this process requires highly segregated plastic feedstocks and works only with certain types of polymers.[51]

Chemical recycling

Chemical recycling is a category of recycling technologies that converts polymer waste into smaller molecules and consists of two main approaches: thermochemical recycling and chemical depolymerisation (Box 1).[127]

Although chemical recycling technologies offer an attractive approach for achieving a circular economy for plastics, their use is often limited due to small commercial investment, variabilities in the chemical structure of the polymers used in plastic design (Figure 1), and highly segregated feedstocks and energy requirements.[51,81,128] However, chemical recycling can be complementary technology to mechanical recycling.

Figure 1: A "closed-loop" approach for recycling plastics



Source: Adapted from Clift et al., 2019[129]

Design for recycling

Keeping high-quality recyclable monomers in the value chain for longer can extend the life of plastics, reducing the production of virgin plastics.[127] The concept of "Design for Recycling" employs a range of parameters in the design of products to increase their recyclability.[130]

Designing for recycling requires reducing the number of different polymers used in plastic production.[131,132] It may also involve re-evaluating the types of additives, product accessories, and composite materials used during the manufacturing stage.[131]

Box 1: Chemical recycling approaches

Thermochemical recycling (pyrolysis):

Uses high temperatures to break down polymers into smaller molecules or fuel-type products.[127] This process can yield gaseous, char or liquid products that can be used to produce new plastics or in other chemical processes.[127]

Chemical depolymerisation (solvolysis):

Uses combinations of chemical reagents and temperature treatments to separate mixed plastics into monomers. These monomers are then used to create new plastic products of similar quality with those made from fossil-based materials.[122,127]

Social-based interventions

Governments, businesses, and organisations can minimise the effort or cost to individuals of taking more circular approaches by taking a systems approach to adapting physical and regulatory environments (PN 714). Waste can be minimised and the associated emissions if the repair and reuse of products is increased rather than buying new and recycling (PN 646, PN 714).

Some research suggests that consumer behaviour can be influenced by structural and market dynamics, highlighting the need to consider the roles of various actors in the plastic provision system.[134] However, other studies consider the role of consumers to be pivotal in the transition to a circular economy. For example, current global consumer trends increase waste generation and reduce the value of recycled and reused resources.[135]

Another study examining the use of whole-systems approach for the circularity of plastics argues consumption choices are affected by consumer's cultural, social and educational background, which link to environmental attitudes.[124] It suggests the number and rate of products placed on the market depends on human behaviour and businesses may prioritise the attractiveness of their products over their recyclability, to increase their market competitiveness.[124]

Other studies argue choices are the interaction of social and structural factors,[134,w] and that changing supply chains may facilitate behaviour change.[136] Shifts in consumer habits and changes in human behaviour can also be achieved via financial reimbursement, such as the DRS scheme. Incentives or charges that give the right information to consumers may influence changes in product purchase, use, and disposal,[137] including plastics.[124,138]

This can include an increased consumer awareness of using plastics as a resource and that the recovery and reintroduction of plastics in the system can create environmental, economic and social benefits.[124]

Research interventions to reduce plastic waste

The UKRI's Smart Sustainable Plastic Packaging (SSPP) challenge is the UK's largest government-funded initiative for sustainable plastics research.[139] The SSPP's goals include reducing single-use plastic packaging, increasing the use of reusable and refillable systems, and supporting new recycling technologies.

To achieve these goals, the SSPP has funded several research projects (Box 2) that focus on:[x]

- commercialising reuse and refill processes
- eliminating single-use plastics by exploring new materials
- innovating recycling processes and improving recycling infrastructure

Box 2: Outcomes of the SSPP-funded projects

- **The Many Happy Returns** project led by the University of Sheffield found that successful reuse systems rely on social, behavioural, technological, material, and environmental factors.[141] Barriers to repeated reuse include poor communication, wear, and existing disposable packaging practices of both businesses and consumers.

- **Reath** is an Edinburgh-based start-up that has created a "digital passport" which collects and standardises data of re-usable packaging. The passport can track the life cycle of the packaging, including dates on when it was created as well as what it has been filled with. This digital platform is now used by several businesses that need to collect all the legal information required for making a packaging reusable.[139]

- **Notpla** is a London-based start-up that developed seaweed based-coatings for paper and board packaging products.[142] The coating is grease-proof and water resistant, an ideal alternative for conventional food packaging. Notpla

[w] This includes factors such as social and economic shifts, how cities and their infrastructure are arranged as well as business models.[134]

[x] The UKRI's Smart Sustainable Plastic Packaging challenge included both commercial and academic research projects in making plastic packaging more sustainable, with 10 university-led projects funded through the enabling research programme.[140]

seaweed-lined boxes are used by several Just Eat restaurant partners and have been adopted across eight European markets.[139]

- **Xampla** is a University of Cambridge spin-out that engineered a new class of biodegradable, plant-based materials.[143] Their soluble films can dissolve in water without leaving harmful residues. The firm is now scaling up the production of their innovative materials and has secured a partnership with a large manufacturing company.[139]

- **ReNew ELP/Mura Technology** is an innovative recycling plant that uses hydrothermal technology to convert difficult-to-recycle plastics into raw materials.[144] The first recycled hydrocarbon products from ReNew ELP/Mura Technology are expected to be placed on the market in 2024.[139]

Other UK-based research projects

Several UK-based research projects, outside the SSPP challenge, relate to developing the circularity of plastics:

- Researchers have demonstrated a way to enhance the performance of an enzyme that is used to break down a commonly used type of plastic.[145] This strategy allows the complete degradation of the plastic into monomers within 24 hours, which can be reused for the production of new plastic. If it can be scaled up this technique could be used to enhance existing recycling processes.

- Another group of researchers has developed a quick and simple method to break down various types of plastic waste into hydrogen and valuable carbon materials.[146] This method uses microwaves and inexpensive iron-based catalysts to initiate the breakdown. Within 30 to 90 seconds, this method turns commercial plastic waste into 97% hydrogen gas.

Policy interventions

Governments, through appropriate decision-making processes, could retain plastic materials within the economy, but only if a number of key challenges are addressed (Table 3).

There are plans to establish the world's first United Nations-backed centre for circular economy research in the UK.[147] The negotiations at the UN Plastics treaty are currently ongoing, but reducing plastic waste will depend on national sustainability policies and regulations.[148–150]

In 2024, the Sustainable Plastics Policy Commission, which included experts from the University of Birmingham alongside multiple stakeholders drafted a series of recommendations for the UK Government in relation to reducing plastic waste.[148,150] Other UK-based experts in materials science, sustainability, and waste management have also published a series of policy recommendations for the Government to help transition to a more circular economy for plastics. [1,124,148,104-107] Amongst others, their recommendations include:

- Expanding the scope of the EPR scheme beyond packaging to include textiles and construction products,[148] which are known to contain plastic materials.[152,153] An updated EPR scheme is expected to be introduced from October 2025, which will mainly consist of reforms to place the costs of collection, sorting and recycling of packaging waste on producers.[61].

- Stronger regulations of compostable and biodegradable plastics. An appropriate recovery system for recycling compostable and biodegradable plastics is required to prevent contamination in existing recycling streams. A stronger regulation on marketing statements regarding compostable and biodegradable plastics can also help tackle the public's confusion regarding the term "biodegradable".[148] In 2021, the Government published an independent review of standards for biodegradable plastics that highlighted public understandability issues and consulted on changes.[100,101]

- Policies could also implement greater consistency in waste management and recycling practices, to help tackle plastic waste. Standardised practices throughout the supply chain, including bin colours and collections, polymer grades with precise technical information, data transparency as well as waste sorting techniques and infrastructure can not only maintain, but also create new value for recycled plastics.[1,151] In 2018, the Government published its Resources and Waste Strategy, which included proposals for achieving greater consistency in waste collections in England to be implemented in 2025.[154]

- Plastic waste management strategies may also require the implementation of product-specific policies that entail regulatory controls on product design. This approach has been referred to as "environmental product policy" and emphasises the need to regulate via law, the environmental impacts that arise throughout the lifetime of a plastic product before it is launched onto the market.[155] This policy will aim to address the leakage of plastics[y] into the environment as waste but also ensure that plastics are designed to be recovered and reused using the available recovery systems (Figure 1).[155]

- The UK's plastic packaging tax which mandates a 30% recycled content in the manufacture of plastic products may also need to change. For example, rewards for companies that surpass the 30% threshold could be introduced to target the most-difficult to recycle plastics.[148] Policy interventions to enable businesses to implement circular and sustainable strategies that aim to prolong the useful life of plastic products, including reforms to encourage investment in research advancements for tackling plastic waste.[z,124]

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[y] Plastic leakage can be defined as the escape of plastic products from the economy into the environment. "Leakage" differs from "waste", as the former refers to items that were released uncontrollably into the environment, whereas the latter refers to items that have been used and discarded[129].

[z] Some products are not able to include recycled content due to regulatory constraints, such as contamination with food waste (PB 60), and those mentioned in the "Challenges in reducing plastic waste in the UK" section.

Table 3: A summary of key challenges for reducing plastic waste in the UK

Regulating product design	To meet functional requirements, plastics are often produced by combining multiple polymers and additives such as stabilisers, colorants, and plasticisers.[81–83] This process, known as polymer blending, often reduces the quality and economic value of recycled products.[81] Regulatory controls on product design, such as "environmental product policies", may help regulate via law the environmental impacts of a product throughout its lifetime before it is launched onto the market.[155]
Sufficient recycling infrastructure	Despite the presence of 123 material recovery facilities (MRFs) and 7 plastic recovery facilities (PRFs), the UK's reprocessing infrastructure was reported to be inadequate in meeting the 30% plastic packaging recyclate targets required by the HMRC's Plastic Packaging Tax and WRAP's UK Plastics Pact.[54,55] Policy interventions can introduce reforms to encourage business to invest in research advancements including infrastructure.[124,139]
Consistency of waste management practices	Waste management in the UK varies across local authorities and government administrations, creating inconsistencies in the implementation of plastic regulations, including bans on problematic single-use plastic products.[58,156] Policies can implement standardised practices throughout the supply chain to help tackle plastic waste.[1,151] These may include consistent collections of items which are currently being pursued, sorting of items for recycling as well as standardised bin colours.[1,88,151]

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Contributors

POST is grateful to Konstantinos Panagiotidis for researching this briefing, to the Natural Environment Research Council for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Jonathan Wentworth.

POSTnotes are based on literature reviews and interviews with a range of stakeholders and are externally peer-reviewed. POST would like to thank interviewees and peer reviewers for kindly giving up their time during the preparation of this briefing, including:

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https://doi.org/10.58248/PN724

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