Mechanical recycling

Plastics are useful materials for a wide variety of applications, but the quantity of waste produced from using them in an unsustainable way is creating an environmental problem globally.

In the UK we use around five million tonnes of plastic every year.[1] In 2018, 1.2 million tonnes of post-consumer plastic waste in the UK was sent for recycling.[2]

But what actually happens to your plastic once it leaves the recycling bin? Can we go further in optimising the infrastructure we already have?

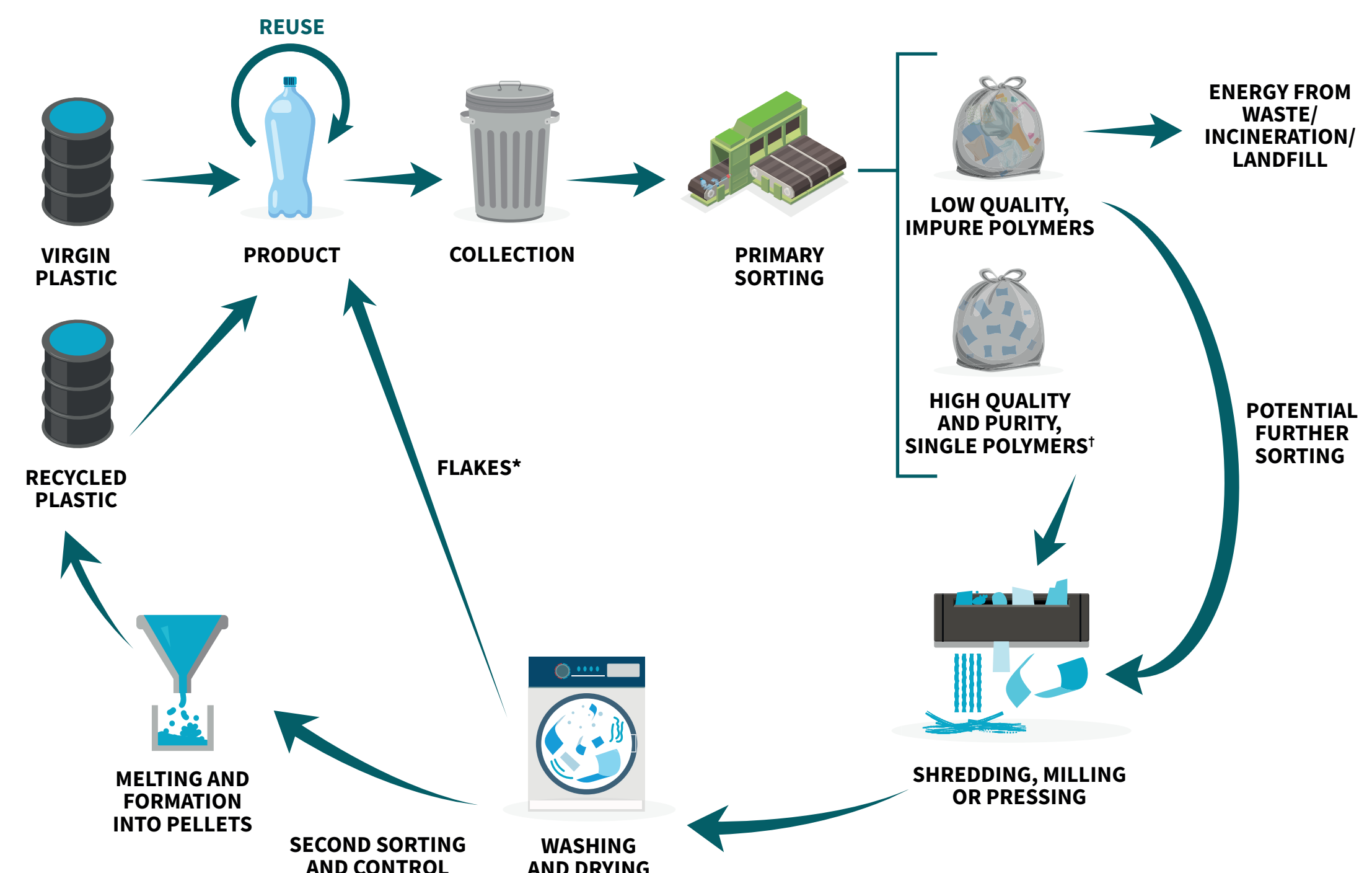
What is mechanical recycling?

Mechanical recycling refers to the processing of plastics waste into secondary raw material or products, without significantly changing the chemical structure of the material. In other words, the polymer chains are not chemically disrupted in the process.

It is currently almost the sole form of recycling in Europe, representing more than 99% of the quantities recycled.[2]

Currently, the scope of what can be recycled is limited by collection and processing at a local level. Most Local Authorities collect plastic bottles and other plastic packaging, and from 2023 under the proposed 'Consistency in Household and Business Recycling in England' regulations this will be made consistent across England. Up to this point the variation in material content between Local Authorities and contamination levels of the plastic have made it difficult for recyclers to produce consistent, high-quality recycled plastic.

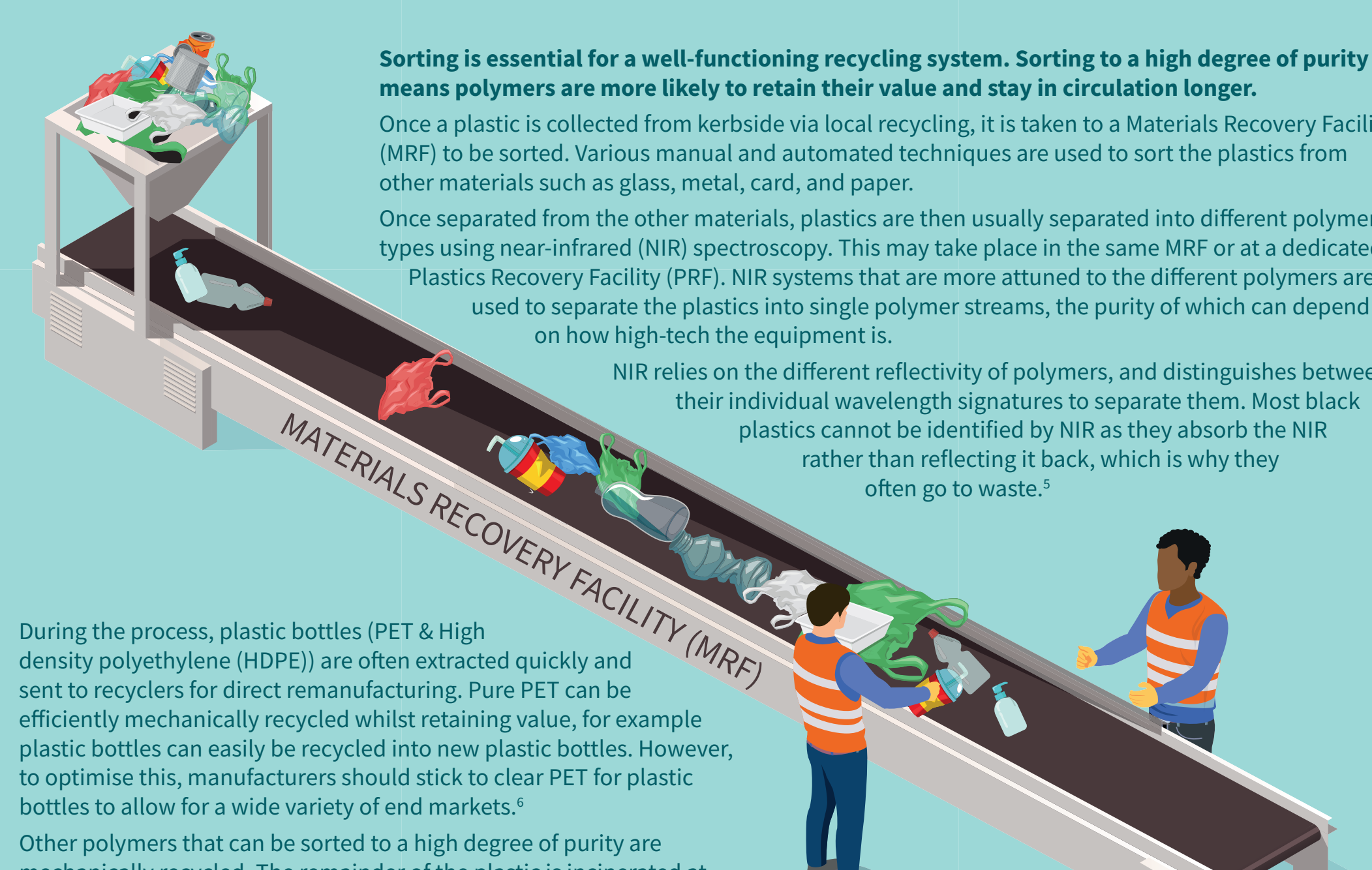
Diagram of the mechanical recycling system[3]



*After further sorting and controls, washed flakes can be used directly in the manufacture of new products. This is particularly the case in Polyethylene terephthalate (PET) bottle recycling where the 'flake to bottle' process eliminated the pelletising stage thus reducing thermal damage to the PET polymer.

†Clean films and rigid plastics not requiring washing can go straight to the melting and formation into pellets stage, and are processed using specialist recycling extruders.

Current sorting methods[4]



Sorting is essential for a well-functioning recycling system. Sorting to a high degree of purity means polymers are more likely to retain their value and stay in circulation longer.

Once a plastic is collected from kerbside via local recycling, it is taken to a Materials Recovery Facility (MRF) to be sorted. Various manual and automated techniques are used to sort the plastics from other materials such as glass, metal, card, and paper.

Once separated from the other materials, plastics are then usually separated into different polymer types using near-infrared (NIR) spectroscopy. This may take place in the same MRF or at a dedicated Plastics Recovery Facility (PRF). NIR systems that are more attuned to the different polymers are used to separate the plastics into single polymer streams, the purity of which can depend on how high-tech the equipment is.

NIR relies on the different reflectivity of polymers, and distinguishes between their individual wavelength signatures to separate them. Most black plastics cannot be identified by NIR as they absorb the NIR rather than reflecting it back, which is why they often go to waste.[5]

During the process, plastic bottles (PET & High density polyethylene (HDPE)) are often extracted quickly and sent to recyclers for direct remanufacturing. Pure PET can be efficiently mechanically recycled whilst retaining value, for example plastic bottles can easily be recycled into new plastic bottles. However, to optimise this, manufacturers should stick to clear PET for plastic bottles to allow for a wide variety of end markets.[6]

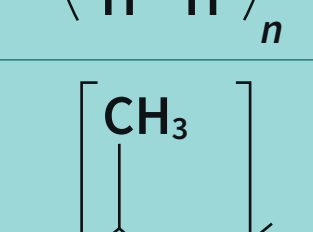
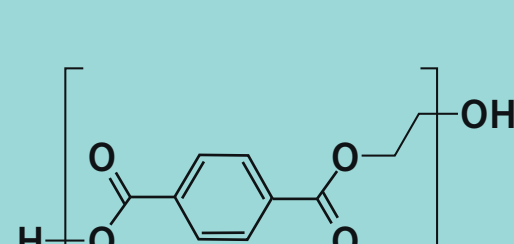
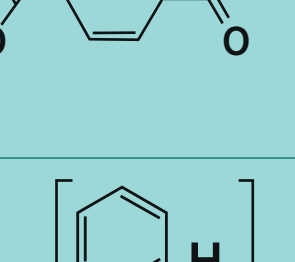
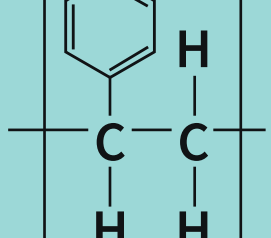
Other polymers that can be sorted to a high degree of purity are mechanically recycled. The remainder of the plastic is incinerated at Energy from Waste facilities.

The sorted plastic may be exported for recycling overseas. Such exports must legally comply with the requirements of the Waste Shipment Regulations (WSR). Exports should only ever be done if there is certainty that the material is actually recycled (rather than incinerated as is sometimes the case), and the energy costs of exporting the waste are outweighed by this.

Some plants still use manual picking lines where employees identify the different materials and sort by hand. This is an area where robotic technology could make big efficiency gains. As recycling volumes are set to increase following government incentives, more efficient sorting techniques will be needed to ensure high quality waste streams can be created quickly.

What different polymers are there?

One of the benefits of plastic is its suitability for different applications; however, the diversity of polymers on the market is also a drawback, since it makes sorting and separation a challenge:

NAME	SHORTENING	STRUCTURE*	USES
Polyethylene – can come in high density (HDPE) and low density forms (LDPE & LLDPE)	PE		HDPE is used for milk bottles, containers, and water pipes. LDPE is used for rigid containers, and LLDPE for a variety of films such as plastic bags.
Polypropylene	PP		Wide array of uses, from bottle tops, to furniture, to piping systems.
Polyethylene terephthalate	PET		Most plastic drinks bottles are PET, also used for clothing, and other packaging
Polystyrene	PS		Can be solid or as an expanded foam (EPS), for use in packaging, cutlery and containers
Polyvinylchloride	PVC		Can be rigid or flexible. Rigid forms can make pipes and windows. Flexible vinyls can be used to make flooring, clothing, and cables.

*In the chemical representation the brackets and 'n' denote the chain continuing 'n' number of times, potentially in both directions.

What do we mean by 'food grade'?

There are standards governing the type of plastic that can be used in applications where it will be in contact with food. Usually polypropylene (PP), high density polyethylene (HDPE), or PET are used for this type of packaging. When using recycled versions of these polymers, they need to be high purity (around 99% for EU regulations) to make sure there are no potentially harmful substances that could get into the food.

What kind of products are made from mechanically recycled plastic?

Aside from direct bottle to bottle recycling, there is a wide range of products (usually non-food-grade) made from recycled plastic including:[7]

- refuse sacks and carrier bags
- flower pots, seed trays, watering cans and water butts
- damp proof membranes, guttering and window profiles used in construction
- reusable crates and pallets
- wheelie bins and food caddies
- shampoo or detergent bottles
- polyester fabric for clothing

In 2018, close to half of plastic recyclates used in new products in Europe went into building and construction materials.[2] This usage is often categorised as 'open-loop recycling' as the material goes to make a different product than its original form. It is often viewed as a less beneficial option compared to closed-loop recycling, where the material goes to make a similar product, ie bottle to bottle. However, as most applications in the building and construction sector are long life this open-loop recycling can be seen as desirable.

Where mechanical recycling really works

Mechanical recycling is still the top option for many plastics as it has the lowest carbon footprint and is the best in terms of minimising overall environmental impact. For instance, the resultant stream from the upcoming deposit return scheme – which will selectively collect plastic drinks bottles – could provide a very efficient recycling loop where the material is recycled back into plastic bottles with minimal reduction in quality.

Limitations of mechanical recycling

The price of making plastic is currently closely linked to the price of oil – its main ingredient.

Recycled plastic should be a valuable commodity with the potential to replace raw materials in production, and in fact for some polymers this is the case.[8] However, experts say that the UK system falls short of working for all plastics, and often recycled plastic is of worse quality than the virgin material. This is due to gradual degradation of the material with each cycle, or the introduction of impurities to the plastic, often due to poor quality sorting.

It is the value of the product which can limit mechanical recycling. The price of making plastic is currently closely linked to the price of oil – its main ingredient. As the price of oil goes up and down, the economic incentives for using recycled plastic get bigger or smaller. The disincentives when oil is especially cheap could become larger in the future as other industries move away from fossil fuels (eg the move to electric vehicles). There are future policy incentives, such as the Plastic Tax on packaging with less than 30% recycled plastic, which aim to address this and increase pull through.

Product design can also be a critical blocker for mechanical recycling, which struggles with films or layered materials. It could be that complementary chemical recycling technologies deal with these, but, as in the resource hierarchy, the first step should be to re-think and re-design to ensure the most sustainable option that fits within the recycling system.

Mechanical recycling can still be the most energy efficient and sustainable option for dealing with our used plastic. However, in order to ensure the system can improve in the years to come, sustained investment in quality infrastructure needs to be implemented. The UK should aim to be a world leader in domestic recycling capability.

When looking to increase the value of recycled plastic, sorting is often the weakest link. If we can set a goal for the desired output of sorting, we can design a system to create that. Standardisation of recycling collection will go some way towards improving the consistency, but some say there should be a move towards industry-led benchmarking of the purity of sorted waste stream, which would remove uncertainty for those processing it. Chemistry can also provide solutions – such as innovative marking systems – to improve the efficiency and selectivity of sorting.

CASE STUDY

Plastics often contain additives: chemicals that improve particular properties, such as colour, stability, flexibility, and being flame retardant. These improve the performance of the plastic in use, but can make them more difficult to recycle. For instance, colour pigments are used to make individual products stand out, but once melted and mixed together the colour of the resultant recycled plastic has traditionally been regarded as unappealing by manufacturers.

> *Waste Management must be optimised and considered holistically. We must ensure plastics aren't lost to the environment, they are recycled optimally, and fulfil the requirements of the 2nd generation packaging item.*
>
> DR SAM HILL, BRIGHT GREEN PLASTICS

On the other hand, it is also possible to add additives that help stabilise the recycled product, ensuring it is fit for purpose and/or improving its value. These are sometimes antioxidants, which protect the polymer chains from degrading during their lifetime, or 'chain extenders', which repair breakages.[9]

One company which uses additives to improve the quality of recycled plastic is Bright Green Plastics. Polypropylene and Polyethylene polymers are challenging to fully separate with Near-infrared sorting or by density. Their BrightFusion™ additive can help improve the performance of recycled mixed polyolefins, allowing incompatible polypropylene and polyethylene to be processed and recycled together. This action improves the physical characteristics of the resultant recycled plastic, meaning it can be incorporated into products at higher proportions than previously.

[1] https://researchbriefings.files.parliament.uk/documents/CBP-8515/CBP-8515.pdf
[2] https://www.plasticseurope.org/en/resources/publications/4312-plastics-facts-2020
[3] https://www.sciencedirect.com/science/article/pii/S0921344920305085, https://www.plasticseurope.org/en/resources/publications/4312-plastics-facts-2020 (pg 56)
[4] https://www.sciencedirect.com/science/article/pii/S0921344920305085
[5] https://www.chemistryworld.com/features/the-plastic-sorting-challenge/4011434.article
[6] https://wrap.org.uk/sites/default/files/2021-03/WRAP-rigid-plastic-packaging-design-tips-for-recycling-v2-Nov-2020.pdf
[7] https://www.recyclenow.com/recycling-knowledge/how-is-it-recycled/plastics
[8] https://www.chemistryworld.com/features/the-plastic-sorting-challenge/4011434.article
[9] https://onlinelibrary.wiley.com/doi/10.1002/marc.202000415