ROYAL SOCIETY OF CHEMISTRY

The future of recycling

When thinking about the future of our relationship with plastics, we should start by considering plastic a valuable resource to be conserved. Breaking away from the take-use-waste model and keeping materials in circulation for as long as possible allows us to retain value in products beyond when first manufactured. The resource (previously waste) hierarchy (shown to the right) is a useful framework for thinking about how we approach resource use and disposal, in order of priority.

Recycling is an important component of a well-functioning circular economy and should be as efficient and 'closed loop'* as possible. It should also be easy for each of us to understand our role and be confident in our ability to make a difference.

Moving towards better recycling for plastics not only helps deal with the environmental problems that come from waste but allows us to remove our reliance on fossil resources as the raw materials for plastic production.

There have been some challenges in creating a well-functioning recycling system for the UK, but with a crackdown on exporting plastic, now is the time to focus on our domestic recycling capability.

* A 'closed loop' recycling system refers to a system in which plastic is repeatedly reused and recycled without compromising the quality of the material. 'Open loop' recycling refers to a system where the material is downgraded into lower quality applications, losing value.

Resource hierarchy

SIDE NOTE

It is important to note that we are not just talking about single use plastic packaging. Plastics form many of the longer lasting products that we use every day – laptops, phones, car parts, furniture – and these products also need to be recycled once they can no longer be reused or repaired.

Current goals for recycling

There are many recycling targets specific to plastics, while others look at recycling of all materials.

The UK government has set:

An **ambition** of zero avoidable* waste **by 2050**

A **target** of eliminating avoidable plastic waste by the **end of 2042**[1]

*The term 'avoidable' is defined here as 'when the plastic could have been reused or recycled; when a reusable or recyclable alternative could have been used instead; or when it could have been composted or biodegraded in the open environment.'[1]

The EU has set a plastic packaging recycling target of **50%** by 2025, and **55%** to be reached **by 2030**[2]

The Scottish Government has set out a number of new measures including introducing a **70%** recycling target for all waste (regardless of its source) **by 2025**, as well as matching the EU ambition for all plastic packaging to be economically recyclable or reusable **by 2030**[3]

The Welsh Government has an ambition to become a zero waste nation **by 2050**. It already has high recycling rates, recycling **65%** of waste for the year 2019/2020.[4]

The Northern Ireland Executive had set a general recycling target of **50% by 2020**, which it met.

The WRAP (Waste & Resources Action Programme) UK Plastics Pact brings together business across the UK, and has set the following targets:

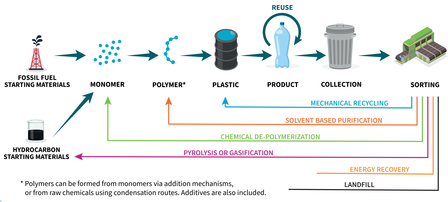
- to eliminate unnecessary single-use plastic packaging;
- for all plastic packaging to be re-usable, recyclable or compostable;
- for **70%** to be recycled or composted by 2025; and
- for **30%** average recycled content across all plastic packaging.

Case Study: How to improve recycling in the UK

- A new national strategy, which sets out targets for improvement of recycling in the UK
- Standardised and easy collection of plastic from kerbside
  - Requires an understanding from citizens of their role, including how to reduce contamination
- Improved sorting, including the potential for further standardisation of outputs
  - Industry-led benchmarks for quality of sorted bales could help remove uncertainty for recyclers
- Better and more transparent data on recycling rates, to allow for evidence-based decision making
- Improved collaboration between stakeholders in the system, to improve understanding of the challenges
- Long term investment in quality recycling infrastructure, for a more consistent and better product
- A rethink of incentives
  - to make the export of plastic waste abroad a less attractive option, and
  - to protect against the use of recycled plastic becoming economically unattractive if oil prices fall significantly

In order to improve recycling in the UK, we need a system-wide view of what is currently happening, what we want to achieve, and how to get there.

An ideal system would have several recycling methods working in concert, with each retaining or improving the value of the waste stream, with minimal environmental impact. Landfill and energy recovery options are included below as the current most commonly used waste management methods, but they are not circular economy solutions.



* Polymers can be formed from monomers via addition mechanisms, or from raw chemicals using condensation routes. Additives are also included.

Sorting is the next big challenge

"In order to decide on the best method of improving sorting outcomes, there needs to be a common goal for the resultant product. For instance, standardising the outputs of collection and sorting infrastructure means more certainty in the recycling system.

A crucial barrier to unlocking the value from plastics is sorting. It is easier for the citizen to put all plastics in one bin, but that means separation of different plastics further down the line. In order to optimise recycling, it is important that sorting processes consistently produce polymers of known purity for recycling. Recent innovations in this area have included:

- Fluorescent tracer technology can help to identify and separate food grade packaging and non-food packaging, even if they are made from the same polymer. This works by including coded fluorescent labels on plastic which can be read by optical sorting machines, complementary to existing near-infrared technology. One example is research by the PRISM (Plastic Packaging Recycling using Intelligent Separation technologies for Materials) consortium who say their technology can be added to existing sorting facilities, and still works if the plastic is contaminated by food, or damaged.[5]
- Sorting could also be improved by automation of the 'picking' of plastic from conveyor belts. For example the Max-AI® sorting robot can identify recyclables and other items, seeing things in a similar way to a human. This information is transmitted to the AI brain, which instructs its articulated arm to select the correct materials.
- Digital watermarks are another potential area for innovation, where the plastic is stamped, or the watermark integrated into printed labels. A European project called HolyGrail uses these digital watermarks which are picked up by cameras on the sorting line, with codes identifying the material.[7]

Other areas for future research and innovation

- Improved labelling for citizens, making it simple for them to decide if and how to recycle. This is also important for plastics that cannot and should not be recycled, like compostable plastics.
- Product design with reuse and repair in mind, and for more efficient eventual recycling. This can be done by simplifying the number of polymers used, and removing composites which are difficult to recycle.[6] Similarly there have been calls to limit plastic bottles to clear plastics for a more consistent recyclate.
- Designing the chemistry of the underlying polymers and processes to make them more easily recycled – either mechanically whilst retaining their structural integrity or chemically to form monomers and chemicals which can in turn be turned into polymers.[7]
- Chemical additives are included in plastic to improve performance, but can sometimes be more difficult to deal with than the polymers themselves. It is important that research considers the complete circularity of the whole plastic.

It is vital that we think carefully about what we want the future of recycling to look like and begin to move towards that vision. Various parts of the system require investment, but without defining a goal, it is difficult to prioritise areas for improvement. Joined up thinking across the plastic production and recycling sector will be crucial to gain a system wide view of the challenge.

Chemistry has an essential role to play in all parts of the system, from designing better plastics to optimising recycling processes. However, there are many areas where further collaboration is needed, for example in behavioural studies on recycling – a better understanding of citizen choices around plastics could allow reuse and reduction of plastics to be implemented, and collection for recycling to be optimised.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693516/25-year-environment-plan.pdf
[2] https://ec.europa.eu/info/news/commission-reviews-implementation-eu-waste-rules-proposes-actions-help-14-member-states-meet-recycling-targets-2018-sep-24_en
[3] https://www.gov.scot/policies/managing-waste/
[4] https://gov.wales/recent-year-wales-recycling-64-target-exceeded
[5] https://researchforlings.files.parliament.uk/documents/CBP-8515/CBP-8515.pdf
[6] https://www.chemistryworld.com/features/the-plastic-waste-challenge/9013454.article
[7] https://www.rsc.org/globalassets/04-campaigning-outreach/campaigning/plastics-debate/
[8] https://wrap.org.uk/sites/default/files/2021-03/WRAP-rigid-plastic-packaging-design-tips-for-recycling-v2-Nov-2020.pdf
[9] https://www.nature.com/articles/d41586-021-00349-9