  

REFLEX PROJECT

A summary report on the results and findings from the REFLEX project

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https://www.gov.uk/government/organisations/innovate-uk

1 Executive Summary

Flexible packaging is a resource efficient packaging format which utilises a range of materials and is used across numerous markets and applications. In the UK a total of 414,000 tonnes of plastic-based[1] flexible packaging is placed on the market each year[2]. Currently, after use most of this material is disposed of in landfills or incinerated to recover its energy content.

A consortium of companies from across the flexible packaging value chain was established to deliver a collaborative R&D project, the REFLEX project, which aims to understand and address the technical barriers to mechanically recycling flexible packaging in the post-consumer waste stream. The two-year project was co-funded by the UK's innovation agency, Innovate UK.

The REFLEX project undertook compositional analysis of a representative sample of flexible packaging in the post-consumer waste stream. This showed that approximately 40% is polyethylene (PE), 35% is polypropylene (PP) and 20% are non-polyolefin laminates[3]. With nearly 80% of flexible packaging classified as polyolefin material this is a positive finding, as a larger proportion of the current post-consumer waste stream is potentially recyclable than previously believed.

Several practical trials have been conducted to demonstrate and evaluate the sorting and recycling of flexible packaging using existing and established technologies. The trials have generated positive results and confirmed it is technically possible to sort, wash and extrude post-consumer flexible packaging. Near Infrared (NIR) technology has a key role to play in sorting plastic-based flexible packaging for mechanical recycling, being able to identify PP, PE or mixed polyolefin streams as well as multi-material structures.

The REFLEX project has explored opportunities to adapt or redesign current flexible packaging to improve recyclability at end of life where appropriate from a Life Cycle Assessment (LCA) perspective. Samples of flexible packaging currently on the UK market were selected and tested to determine if the structures were suitable for mechanical recycling. The results of the testing were used to identify potential modifications to the packaging structures which would improve suitability for recycling. The modifications considered included moving to an all PE or all polyolefin structure for non or low barrier packaging and by replacing non-polyolefin polymers in the structure.

A key output of the REFLEX project is the development of a set of preliminary 'Design for Recycling' Guidelines. The aim of the guidelines is to provide information to packaging designers and technologists, filling machine manufacturers, brand owners, retailers and convertors to support them in designing and specifying plastic-based flexible packaging suitable for mechanical recycling at end of life. The guidelines provide information on key components of flexible packaging structures, such as polymer type and coatings, and how these influence the suitability of packaging structures for mechanical recycling or energy recovery at end of life. The guidelines are currently in a draft form and by their very nature a dynamic document, subject to changes following further research and testing. The guidelines are not intended to be made available to the public at this stage, and will instead be available for future development work.

A case study, based on an outline business model, has been developed to estimate what is needed to establish a collection, sorting and reprocessing infrastructure for post-consumer flexible packaging in the UK. The analysis has shown there is a viable business case for establishing this infrastructure in the UK, with an estimated investment of £100 million required to achieve full deployment, including costs to modify existing sorting facilities and to construct two purpose-built reprocessing plants.

The REFLEX project has provided a base of knowledge and collaboration on which future projects can be built. The understanding of flexible packaging recycling in the UK is significantly more in-depth because of the REFLEX project. There are plans to merge the REFLEX project with a second project

[1] "Plastic based" is defined as being made primarily from polymers with or without functional barriers (including aluminium foil) and excludes packaging with paper

[2] WRAP 'Plastics Market Situation Report Spring 2016' http://www.wrap.org.uk/sites/files/wrap/Plastics_Market_Situation_Report.pdf.

[3] All percentage figures of composition refer to percent by weight

carried out in Europe, FIACE, to continue addressing the barriers before implementing an optimised circular economy solution for packaging considering the entire lifecycle of flexibles.

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2 Background

The REFLEX project is a collaborative R&D project which aims to understand and address the technical barriers to mechanical recycling of flexible plastic packaging in the post-consumer waste stream, with a focus on the UK case.

Flexible packaging is a resource efficient material which utilises a variety of materials, polymer grades, coatings and adhesives to provide the various functional properties required by the product contained within. Flexible packaging is used across many markets, each one demanding specific performance, resulting in a range of structures being placed on the market. Its versatility and material efficiency have paved the way for a large adoption of this packaging form by brand owners and retailers over the last decades. It is estimated that in 2014 27% of plastic packaging in the UK post-consumer waste stream was flexible, with a total of 414,000 tonnes of flexible packaging being placed on the UK market each year[4]. The infrastructure for the collection, sorting and reprocessing of post-consumer flexible packaging is in its infancy in the UK. Currently only polyethylene (PE) films are collected for recycling in the UK, either through kerbside collection (by some local authorities only) or front-of-store collection scheme. Currently approximately 95% of this material is disposed of in landfills or incinerated.

There are a number of perceived barriers to collecting, sorting and recycling flexible packaging from the post-consumer waste stream. The REFLEX project aims to show that these barriers are either a misconception or can be readily overcome. Barriers include:

- There is a significant amount of currently 'difficult to recycle' packaging structures in the waste stream, which have an impact on the yield which could be achieved by the recycling process;
- It is technically difficult for Material Recovery Facilities (MRFs) to handle and process flexible packaging, primarily due to its lightweight nature and that it is often considered to be a contaminant of other dry recyclable materials;
- Flexible packaging is considered difficult and costly to collect for recycling from householders; and
- It is thought that flexible packaging must be recycled back into film applications so there are limited end markets available.

Experiences from other countries show that collection and recovery of post-consumer flexible packaging is possible under specific technical and regulatory conditions. For example, Germany has been running a separate collection of light-weighted packaging for several years. The collected material is sorted in highly automated facilities into specified fractions and, with respect to flexible packaging, recycling of a proportion of the PE and polypropylene (PP) stream takes place, although there is still scope to increase the recycling of the smaller (<300 mm) flexibles. These European cases show that there is value in flexible packaging at end of life, which presents an exciting and significant opportunity to create a true circular economy for flexible packaging.

[4] WRAP 'Plastics Market Situation Report Spring 2016' http://www.wrap.org.uk/sites/files/wrap/Plastics_Market_Situation_Report.pdf.

3 Project aims and objectives

A consortium of key players across the flexible packaging value chain were successful in obtaining funding from the UK's innovation agency, Innovate UK[5], to deliver a project to increase the opportunity for post-consumer flexible packaging to be mechanically recycled by investigating and proposing a circular economy solution. The consortium consists of Axion Recycling (project leader), Amcor, Dow Chemical Company, Interflex Group, Nestlé UK, Suez, TOMRA Sorting and Unilever.

The overall aim of the REFLEX project is to understand and remove the barriers to creating a mechanical recycling solution for flexible plastic-based packaging in the post-consumer waste stream. The project has a number of key objectives:

- To gain an understanding of the type of flexible packaging found in the post-consumer waste stream in the UK;
- To determine the potential recyclability of flexible packaging currently on the UK market;
- To evaluate the potential to use existing sorting and reprocessing technologies to mechanically recycle flexible packaging;
- To identify and develop techniques for 'marking' recyclable flexible packaging to aid sorting and improve yields achieved by recyclers;
- To explore opportunities to redesign current flexible packaging structures to improve their suitability for recycling at end of life; and
- To develop a set of 'Design for Recycling' Guidelines to provide information to packaging technologists and designers, brand owners, retailers and convertors in designing, specifying and manufacturing flexible packaging that is able to be recycled.

The project objectives were used as a basis to develop and deliver a number of work packages over a two-year period (October 2014 to September 2016). It should be noted the focus of the project was on plastic-based flexible packaging rather than paper or aluminium-based flexible packaging (apart from where the aluminium is used as a functional barrier in a primarily plastic structure).

[5] https://www.gov.uk/government/organisations/innovate-uk

4 Key activities

4.1 Flexible packaging in the waste stream

There is a lack of detailed data on the type of flexible packaging placed on the market and therefore arising in the post-consumer waste stream at end of life. Typically, flexible packaging is primarily manufactured using materials such as PE, PP and polyethylene terephthalate (PET). In addition, polymers such as polyamide (PA), polyvinylidene chloride (PVdC) and ethylene vinyl alcohol (EVOH) are used in some structures and applications depending, for example, on the barrier requirements of the packaged product.

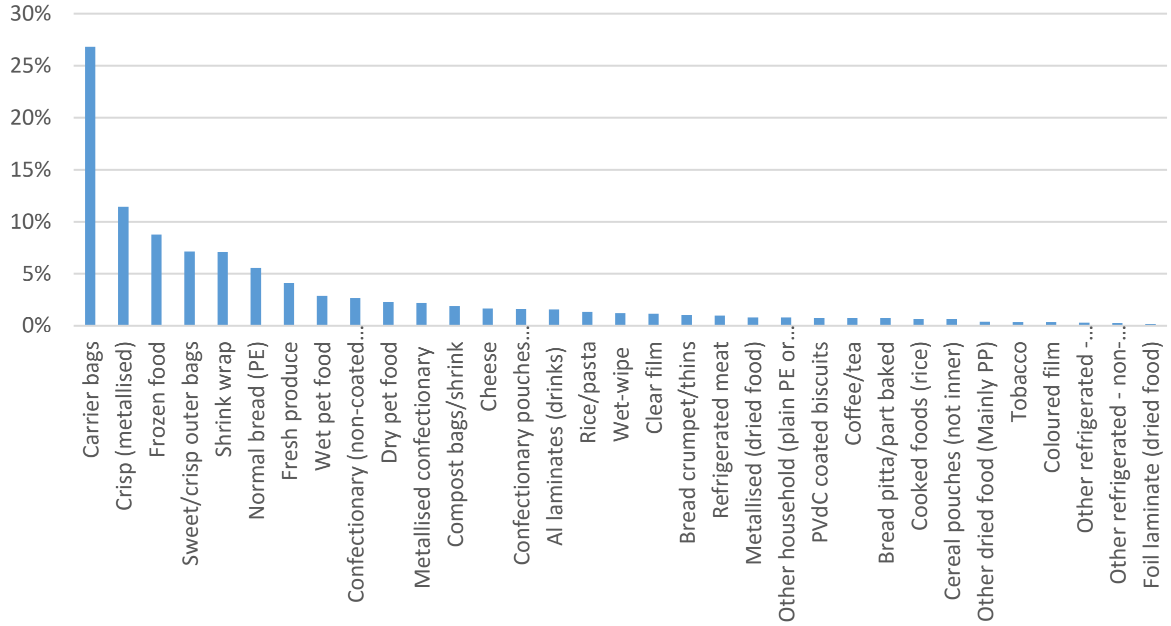
The REFLEX project recognised that it was important to understand the composition of the post-consumer flexible packaging waste stream. This would aid exploring opportunities to redesign flexible packaging structures, allowing them to be acceptable for recycling, whilst still retaining the required functional properties. It is also valuable information for evaluating sorting and processing technologies and considering end market applications for the recycled polymers.

The REFLEX project took a representative sample of household residual waste for compositional analysis[6]. This material was passed through a trommel with a 40mm screen and then the flexible packaging material present in the oversize fraction was manually removed, as can be seen in Figure 1. This fraction was sorted by hand into a number of key product types including crisp packets, pet food, carrier bags, bakery products and confectionary pouches. A total of 143kg of flexible packaging was sorted and analysed as shown in Figure 2.

Figure 1 Example of post-consumer flexibles

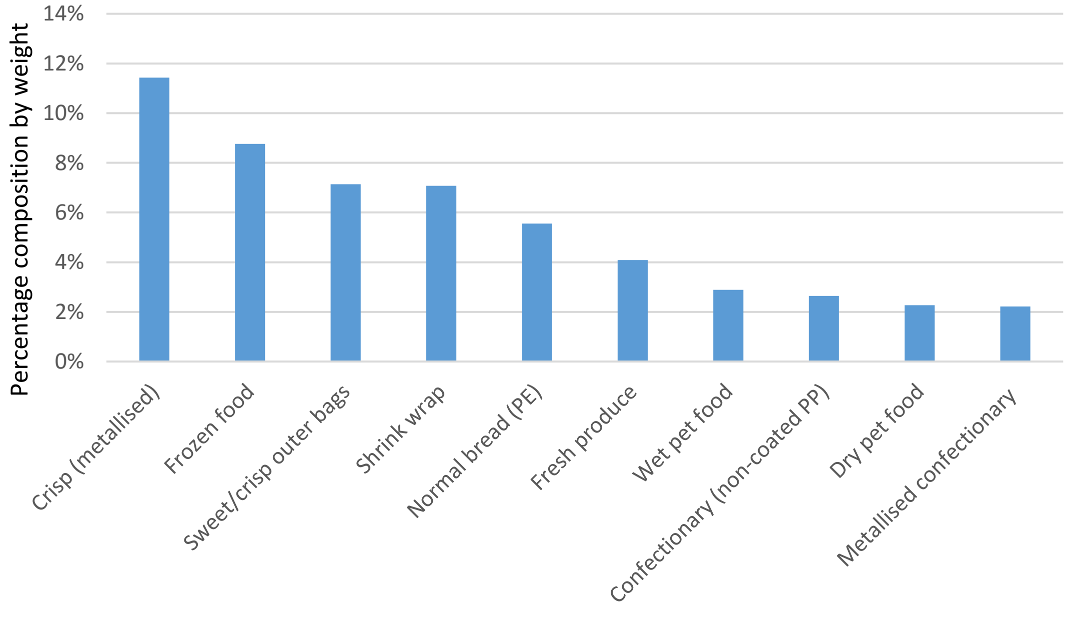
[6] Residual or 'black bag' waste collected from households in the Northamptonshire area by Suez

Figure 2 Ordered composition of post-consumer film by application (percentage by weight)



It is worth noting the analysis was carried out prior to the introduction of the plastic bag charge in the UK[7], with carrier bags making up more than 25% of the sample. The ten most common product categories (excluding carrier bags) are shown in Figure 3.

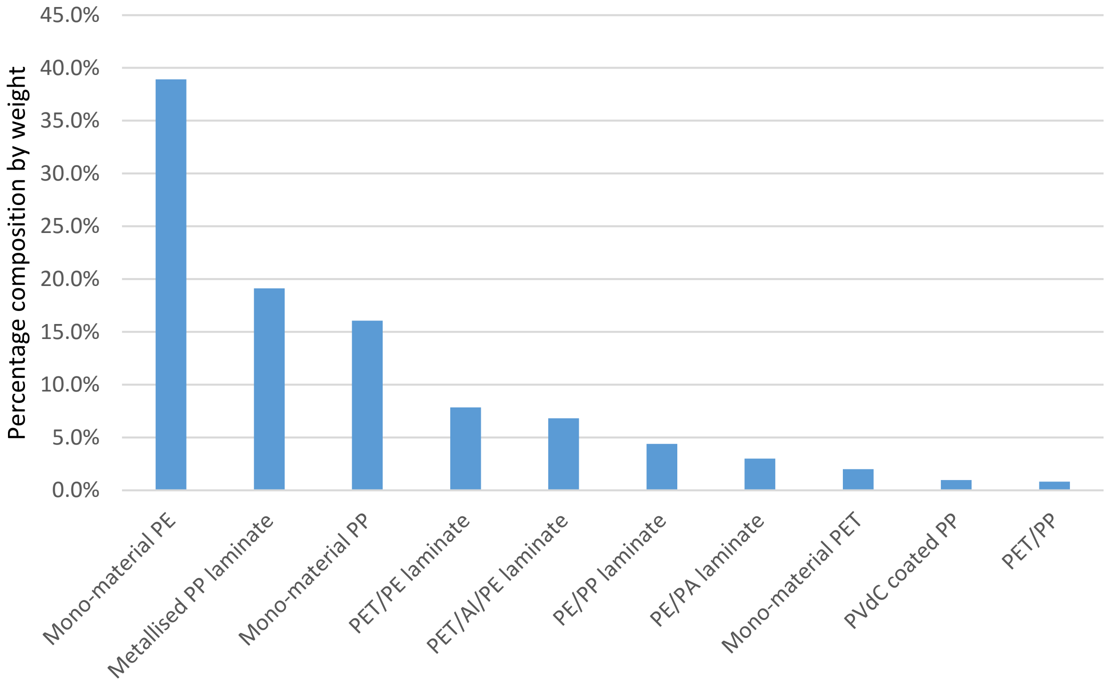
Figure 3 Ten most common product categories (excluding carrier bags)



[7] https://www.gov.uk/government/publications/single-use-plastic-carrier-bags-why-were-introducing-the-charge/carrier-bags-why-theres-a-5p-charge

The compositional analysis by product type was used to estimate the waste by polymer type, by assuming the most likely polymers used in the different product categories. The results can be seen in Figure 4 and includes scaling for an 80% decrease in carrier bag consumption observed after the charge was introduced in 2015.

Figure 4 Composition of flexible packaging in residual waste by polymer structure



This shows that approximately 40% of the post-consumer flexible packaging is mono-material PE, 35% is mono-material PP (both metallised and non-metallised) and 20% is multi-material laminates containing a mixture of polyolefin and non-polyolefin materials. This level of compositional analysis gives a valuable insight into the type of flexible packaging being used and disposed of by households.

Nearly 80% of the flexible packaging waste stream was classified as polyolefin material (PE and PP) which can be recycled together (as demonstrated by the REFLEX project, see Section 4.2). This is a very positive finding as a greater proportion of the current waste stream is potentially recyclable than previously thought. This data is specific to the UK and other nations are likely to have different compositions, reflecting the type of products placed on the market in individual countries.

4.2 Recyclability of flexible packaging

The REFLEX project has tested a wide range of structures and materials currently used in flexible packaging applications to determine if they are suitable to be mechanically recycled at end of life and to evaluate which materials are best used in flexible packaging from a recyclability viewpoint. A methodology to test the 'recyclability' of a packaging structure was developed, consisting of size reducing the material using a laboratory scale granulator and then extruding the shredded material to produce pellets. The pellets were moulded into test pieces and tested to determine the physical properties of the material including tensile strength, yield strength, impact strength, elongation at yield and elongation at break. The results of the testing were compared with virgin PE and PP properties. Other aspects were also noted during the testing such as inhomogeneous mixing of different polymers, degradation of coatings and presence of contamination. Overall more than 50 flexible packaging structures and blends were tested using post-industrial and virgin materials, including packaging examples manufactured by the convertors and brand owners in the consortium. Tests were carried out conforming to ISO test methods.

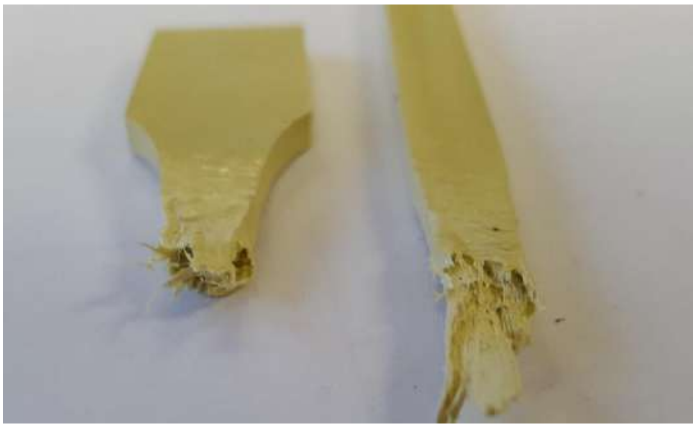
As well as polymer blends, single polymers (i.e. PE or PP only structures, either as films or laminates) were also assessed. Figure 8 shows one of the test pieces made from metallised PP used to obtain qualitative data on the performance of the recycled polymer.

Figure 5 Injection moulded test piece made from metallised PP film

A range of polyolefins (PE and PP) laminated with PA, PET, EVOH and aluminium foil were tested to give an indication of which materials have a negative effect on the ability of the sample to be mechanically recycled. The testing found PE/PP laminates could be reprocessed and produced well-mixed recyclates with physical properties that would allow it to be used for injection moulding applications that are a blend of the properties of PE and PP. This is a key finding of the REFLEX project and suggests that PE and PP can be reprocessed together. This development would simplify the recycling process for flexible packaging considerably, leading to greater yields and allowing brand owners and packaging designers to use PE/PP laminates that are suitable for mechanical recycling at end of life. During the pilot trial (see Section 4.3 for further details), a PE/PP blend of post-consumer film was made and analysed.

PET laminates of varying designs (for example, with 12 µm PET and 58 µm of PE) were also tested and PET/PE laminates were found to produce an inhomogeneous mix of the two polymers, as can be seen in Figure 6. This resulted in poor material properties of the recyclate, with a weaker tensile strength and more brittle structure than virgin PP and PE, with the conclusion being drawn that today PET/PE laminates should not enter the PE/PP mechanical recycling stream, but be repurposed through other routes. The discolouration of the sample comes from the adhesives and ink on the structures.

Figure 6 Inhomogeneous mixing in recyclate from PET/PE laminates

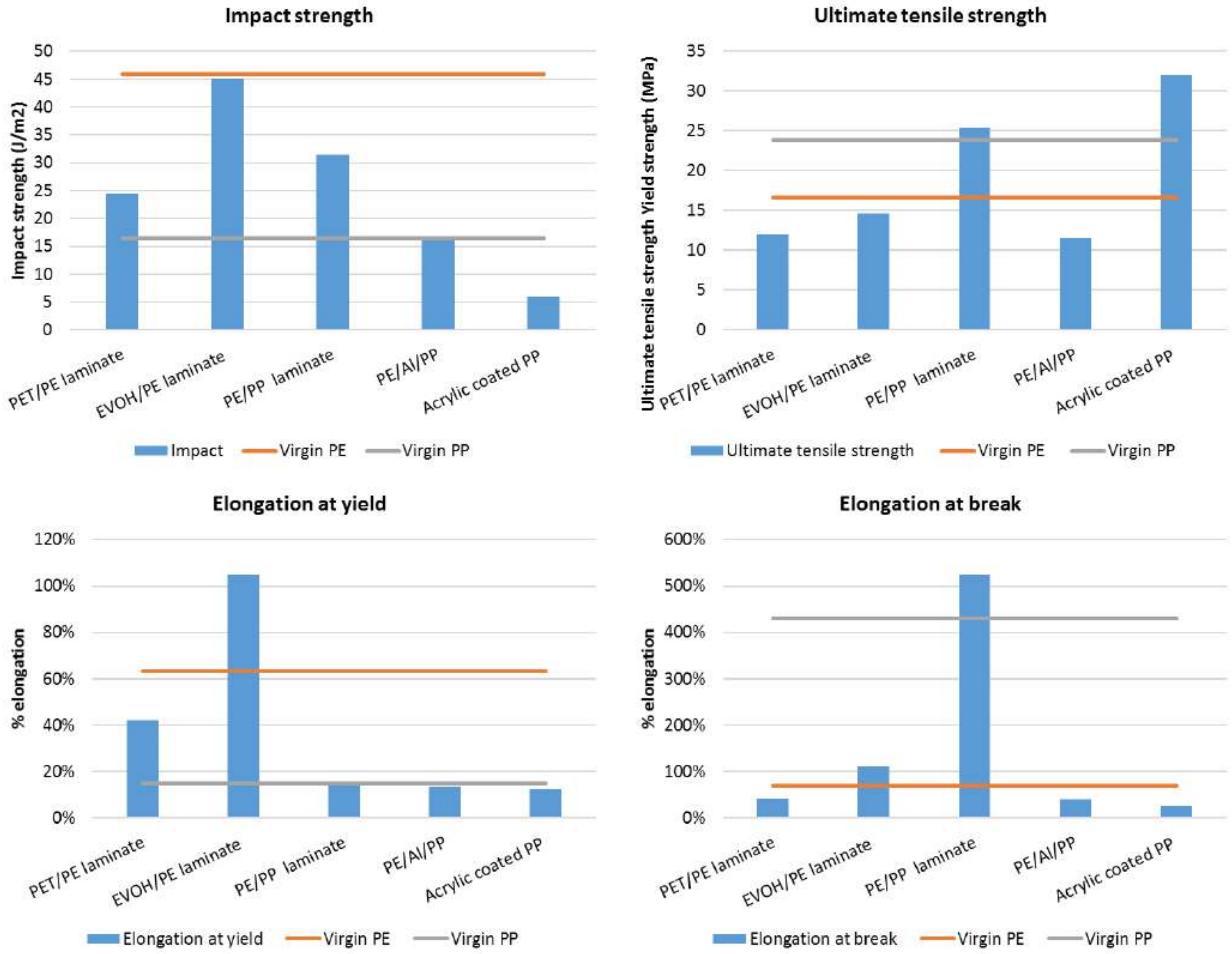


PA laminates were tested and found to be problematic with the material becoming 'fluffy' when shredded due to the toughness of PA and therefore difficult to extrude at levels with >5% PA. As a result further testing is recommended on this packaging type since it is believed that more adequate sizing and extrusion equipment can cope with this material, including the use of an auger to feed materials into the extruder.

A sample of 40µm OPP / 8µm foil / 90µm PE was tested to show the effect of aluminium on a polyolefin recyclate. A twin-screw extruder was used which caused the foil to be ground and blended with the polymer. The presence of the metal in the recyclate did cause a degree of weakening and the material was significantly more brittle, suggesting it should not be considered suitable for mechanical recycling at this time. Recycling foil laminates using a process that converts the polymer to oil and recovers the aluminium content may be more suitable for this type of material, and is becoming more common across Europe.

Figure 7 shows the physical properties of some example structures compared to a PE and PP control sample. The data has been interpreted by the REFLEX consortium and used to draft the Design for Recycling Guidelines.

Figure 7 Physical properties of selected structures



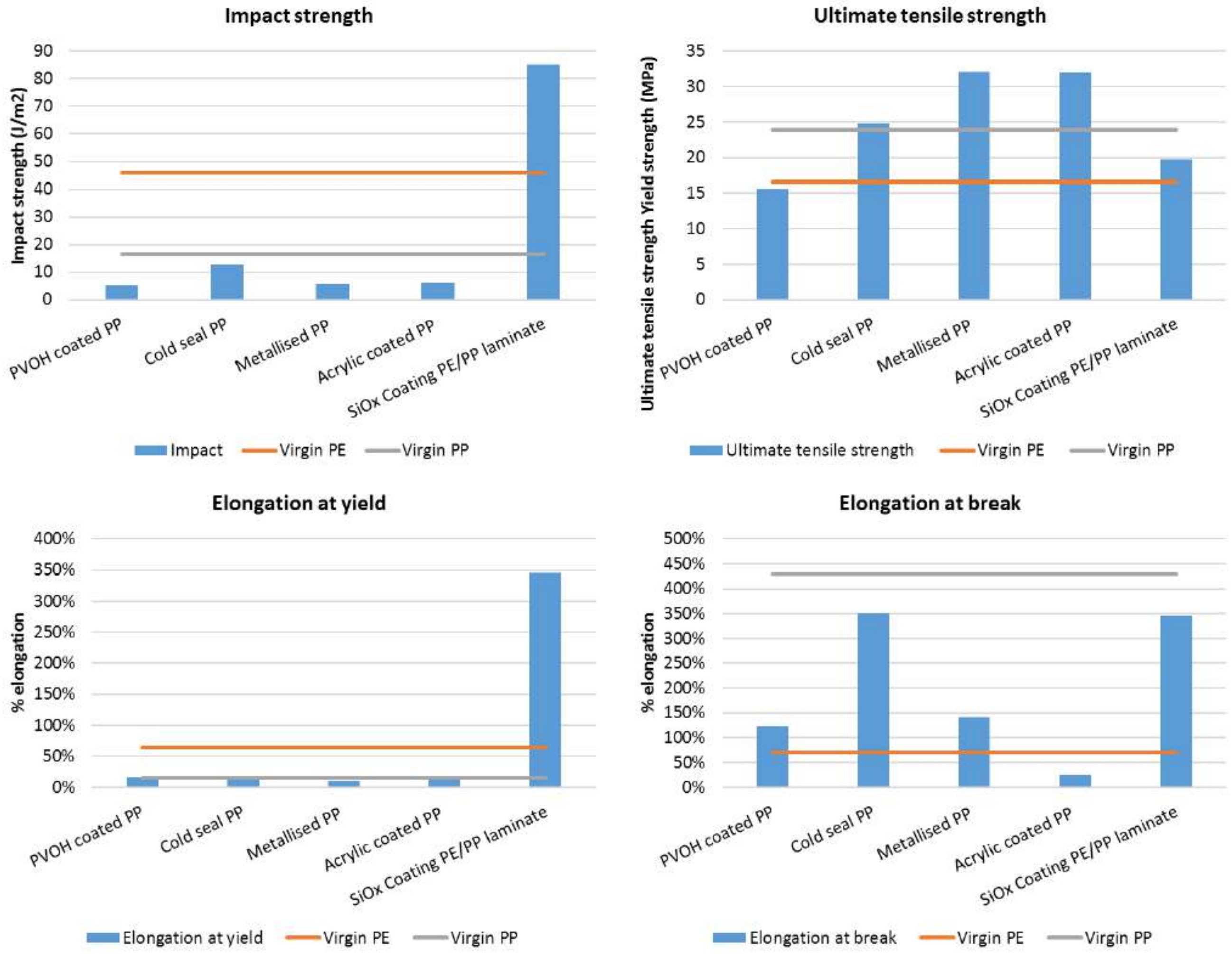
Several different coatings have been tested including polyvinyl alcohol (PVOH), EVOH, PVdC, silicon oxide, PETg and cold seal. In most cases, results have shown that coatings disperse into the recyclate or are removed during the extrusion process as gases. PVdC has been shown to have a detrimental effect on the recyclate quality due to its thermal degradation below the temperatures required to melt the mainstream polymer, as can be seen in Figure 8.

Figure 8 PVdC degradation from extrusion process

Metallised flexible packaging resulted in a recyclate with slightly lower quality physical properties, such as the impact strength but it is thought to still be suitable for rigid plastic applications.

Figure 9 gives the measured properties for some of the coated structures tested. Once again, the results of the testing has been used by the REFLEX consortium to form the Design for Recycling Guidelines.

Figure 9 Example physical properties for coated films



Standard Nitrocellulose (NC) inks have been shown to not have a negative effect on the quality of the recyclate, but do impact the colour of the reprocessed material even when present in very low proportions. Other ink chemistries may be used in flexible packaging, however during the larger scale recycling trial with a mix of unknown packaging, no negative effects caused by the inks were observed.

It is also to be noted that during these experiments described above, no polymer compatibilisers were used to enhance further any properties. The effect of compatibilisers on recycled PE/PP laminate film structures was investigated in the REFLEX project. Compatibilisers are polymers designed to help the mixing of two different polymers when recycled. The compatibilisers used to aid the mixing of PE and PP are co-polymers made from PE and PP.

The effect of compatibilisers when recycling PE/PP laminates back into film was observed. A laminate containing ≈20% PP and ≈80% PE with and without a compatibiliser was recycled into film at the Dow site in Tarragona, and the physical properties measured, which are given in Table 1.

Table 1 Properties of recycled film with and without compatibiliser

	Film type	Standard PE/OPP	PE/PP with compatibiliser built in
	Thickness, µ	50	50
	Dart Drop Impact, g	83 (SD[8] 3)	142 (SD 14)
Elmendorf Tear, g	TD (transverse direction)	884 (SD 50)	570 (SD 63)
	MD (machine direction)	150 (SD 21)	163 (SD 18)
Tensile Strength, MPa	TD	11.1	21.5
	MD	16.6	20.7
Elongation, %	TD	386	564
	MD	343	400

The testing undertaken shows that when recycling flexible packaging back into film, the compatibiliser improves the properties significantly.

4.3 Sorting and recycling technologies

The REFLEX project has demonstrated and evaluated several technologies for the sorting and recycling of post-consumer flexible packaging. There are several technologies that are currently used to sort and reprocess rigid packaging and if these could be used to sort and process flexibles then this would help to encourage the recycling infrastructure to be developed and established.

Near Infrared (NIR) is a well-established technology in the waste and recycling sector and is already commonly used to identify and separate different types of rigid plastic packaging and in some instances used to sort flexible PE. Trials were carried out using TOMRA Sorting's NIR equipment to optimise the detection stage of the NIR sorting process. Flexible packaging is inherently more difficult to sort due to its lightweight nature, causing the material to move around on the belt of the sorting equipment or to get caught up in the air currents and be miss-sorted. Figure 10 shows the NIR sorting belt.

[8] Standard deviation

Figure 10 NIR sorting belt showing the lamps emitting the infrared light

The results of the trials undertaken have shown that NIR can be used to identify a PP, PE or mixed polyolefin stream of material. It is also possible for NIR to detect different types of multi-material structures such as PET/PE and PP/PE at sorting speed. This is a key finding of the project as it shows that NIR can be utilised to sort a wide range of flexible packaging structures. The trials have also demonstrated that NIR technology can be optimised to identify and sort specific types of packaging by the equipment being ‘trained’. Training the NIR involves optimising the detection software to recognise different NIR spectrum as specific structures of packaging.

There are a few limitations to consider with NIR, firstly that the technology cannot be used to distinguish different types of printing (surface printing versus reverse printing for the use of de-inking further in the recycling process) and secondly that thin layers of coatings, such as PVdC, cannot be detected. The separation efficiencies achieved for flexible packaging are acceptable but are lower than would be expected when sorting rigid packaging due to the way in which lightweight material behaves on a sorting belt.

During trials carried out in the test centre, recovery rates were typically >90% for the target film and purity was >95%. When recovering PE and PP together high purity and yield can be achieved.

The REFLEX project has demonstrated that NIR can be used to successfully sort plastic-based post-consumer flexible packaging. This is an important finding as it means that an existing, well-established technology can be used with even more effect in the waste stream. This will help to overcome a number of the technical challenges, that are often perceived as barriers. There will need to be significant investment in technology and facilities to separate and reprocess flexible packaging from the post-consumer stream. Sorting facilities will need to make modifications and invest in additional equipment, such as conveyors and bunkers to enable them to process and separate flexible packaging from other dry recyclables.

The project has also trialled technologies for the sorting of foil laminated flexible packaging. Induction sorters (automated sorting technique using metal detection) and Eddy Current Separators (a method of ejecting non-ferrous metals using rotating magnets) (ECS) are used to separate materials containing non-ferrous metals. It may be desirable to separate foil laminates from other flexible packaging structures to allow the aluminium content to be recovered separately due to its high value.

The trials undertaken suggest that an induction sorter is more likely to give a higher efficiency than an ECS when separating foil laminated packaging. When carrying out test centre trials on an induction sorter, recovery and purity levels of > 90% was observed for aluminium laminates. It was not possible to reach these levels when carrying out trials on an ECS, with typical yields of 50% recorded. Induction sorters do have a higher associated cost, and so the method used to recover flexibles would need to take this into account.

The REFLEX project also conducted a large-scale recycling trial of flexible packaging, taking post-consumer material from the UK residual waste stream all the way through the sorting and recycling process to demonstrate and evaluate the technical feasibility. NIR technology was successfully used to separate a mixed PE and PP fraction, which was then washed using hot washing technology from Sorema[9]. A hot wash process was used to remove contamination such as paper, food and glue. The cleaned material was then extruded using EREMA[10] extrusion equipment. Very positive results were obtained from the trial, with the sorting, washing and extrusion processing stages achieving an overall yield of 75% on a dry basis[11] and the final PE/PP blend being shown to have good physical properties. It is important to recognise that this was achieved by using existing technologies which is a highly valuable outcome of the REFLEX project, which will enable progress to be made in moving towards establishing a sorting and recycling infrastructure for flexible packaging from the post-consumer waste stream. Figure 11 shows the flexible packaging at three different stages during the pilot trial.

Figure 11 Pilot trial for recycling of a PE/PP mix. Mixed film (left), washed and shredded film (middle) and extruded pellet (right)

The REFLEX project has also carried out research of a 'marking' technology. The idea is for packaging that can be classed as recyclable to be 'marked' and sorting equipment to recognise the mark and separate out this packaging from unmarked items. The aim is for the mark to ideally be invisible to the human eye so as not to disrupt branding and product information on the packaging, but to be detected by a sorting and recycling facility. There are several potential options for a marking technology. The REFLEX project has focused on digital watermarking as a technique which shows real promise. A digital watermark is a unique code that can be printed on packaging. The REFLEX project carried out initial trials on the technique which have shown the mark can be detected using a camera although further development work is needed to optimise this before it could be used by the waste and recycling sector.

[9] http://sorema.it/en_US/

[10] http://www.erema.at/

[11] Dry basis means that moisture and contamination have been excluded from the equation as these are characteristic of the material collected from the residual waste stream. Overall yield on a wet basis was 41%, meaning for each tonne of dirty material fed into the process 410 kg of washed, dry flake was produced. These numbers would be improved significantly for an optimised system working on material collected separately from residual waste.

4.4 Removal of ink

Previous projects conducted on recycling flexible packaging have shown that the final recycled polymer is a grey/green colour (as can be seen in Figure 12), which is due to the mix of different inks and primers used in flexible packaging printing. The colour of the final recyclate does not have an impact on the physical properties of the material but can limit the end market applications the recycled plastic can be used in. The REFLEX project carried out research to determine if it would be possible to remove the ink from the flexible packaging during the recycling process, in order to produce a final recyclate that would be clear or light coloured. This recycled material would have a higher financial value and be able to be used in a wider range of end uses.

Figure 12 Recyclate from post-consumer flexible packaging

The REFLEX project considered changing the inks and primers used in the printing process which would be easier to remove and also techniques to remove inks/primers from packaging in the waste stream. Trials demonstrated that water based primers (which would be applied during the printing process) could be 'broken down' by an alkali solution and more easily removed than standard solvent based primers. As a result, inks printed on the primers could potentially be removed more easily. The REFLEX project also identified a patented technology developed by Cadel Deinking[12] in Spain which can deink surface printed packaging. This technology uses a surfactant in an alkali solution to remove the ink. Small-scale trials with Cadel Deinking demonstrated that it was technically feasible to remove NC inks from post-consumer PP and PE flexible packaging and to produce a clear/light coloured recyclate stream.

The recycling of post-consumer flexible packaging is still in the early stages of deployment. So although the REFLEX project has demonstrated that it is technically feasible to remove inks from some types of flexible packaging, at the present time it is not economically viable[13] to remove ink during the recycling process (either through using water based primers during printing or by using an ink removal technology) for post-consumer household films. Unfortunately, the current financial benefit of producing a clear or light coloured recyclate does not compensate for the additional costs involved in removal of the inks. As the sorting and recycling infrastructure for post-consumer packaging becomes established over the next five to ten years it will be worth revisiting this work and to evaluate if ink removal can be commercially viable and consider the environmental impact of the process. As removal of ink is only possible from surface printed packaging there will also be a need to evaluate options to moving towards more surface printing and the associated challenges and benefits.

[12] http://cadeldeinking.com/en/

[13] In this instance, including de-inking lead to a reduced net income in the economic modelling carried out in the REFLEX project

4.5 Redesign of flexible packaging to improve recyclability

A key area of activity for the REFLEX project has been to explore opportunities to redesign current packaging to improve recyclability at end of life without increasing the cost of the packaging. Using the information gained from the compositional analysis exercise (see Section 4.1) and input from the partners in the consortium, a number of packaging examples were selected. These examples were products found in significant quantities in the post-consumer waste stream and also for which there was an opportunity to improve the suitability of the packaging for mechanical recycling at end of life.

Samples of current packaging selected including confectionary pouches, pet food pouches and personal care product packaging were provided by the brand owners and convertors in the consortium. These packaging structures were tested using the methodology described earlier (see Section 4.2) to determine if they could be mechanically recycled. The results of the testing were used to identify potential modifications to the packaging structures which would improve its suitability for mechanical recycling.

Trials were undertaken at both small-scale and production scale to manufacture new packaging structures in order to test material production and processability, production and filling of packaging, as well as consumer and marketing acceptance through internal assessment panels. During this work consideration was given to the technical application performance requirements, visual impact of the packaging, the environmental impact of modifying a packaging structure and the financial implications. The REFLEX consortium recognises that changes to packaging design and manufacture must be taken in the context of overall packaging performance and production and not in isolation. Changes to the packaging design should not jeopardize the primary function of packaging, that is to protect the product it contains, avoid waste along the supply chain and perform consistently on packing lines.

A number of successful trials have been delivered to make packaging more suitable for mechanical recycling processes at end of life. The modifications evaluated include moving to an all PE or all polyolefin structure and the replacement of non-polyolefin polymers in the packaging structure. Work will continue in this area as more testing and trials are undertaken, knowledge is gained and the 'Design for Recycling' Guidelines updated and adopted. Figure 13 shows how a flexible pouch which was previously made from a PET/PE laminate can be redesigned using compatible coated polyolefins.

Figure 13 Pouch redesigned to use only polyolefin material and compatible coatings

4.6 Design for Recycling Guidelines

Currently in order for consumer packaging to be classed as 'recyclable' (as an environmental claim) a significant proportion (>70%) of consumers must have access to a collection route for the packaging and there must be the infrastructure available for the packaging to be recycled. Currently the UK, only 19% of local authorities accept clean PE films for recycling[14], meaning that there are 81% of authorities which offer no film collection and no local authorities offer collection of PP films. Therefore, o plastic-based flexible packaging cannot be considered recyclable. Results from the REFLEX project indicate that collection and recycling of post-consumer flexible packaging is technically possible. In order to stimulate the recycling sector to invest in collection and reprocessing infrastructure there needs to be a common understanding along the whole packaging value chain as to what makes flexible packaging suitable for mechanical recycling processes.

The REFLEX project has worked on a preliminary set of 'Design for Recycling' Guidelines to support this objective. The aim of the guidelines is to provide information to packaging designers and technologists, filling machine manufacturers, brand owners, retailers and convertors to support them in designing and specifying plastic-based flexible packaging suitable for mechanical recycling processes at end of life. The guidelines cover key components of flexible packaging structures including polymer type, coatings, adhesives, inks and lacquers. For each component, there are three categories:

- Desirable for mechanical recycling: packaging that can be used to produce recycled polymers for a film grade PE or rigid grade PP. These are the highest value adding options for flexible packaging;
- Acceptable for mechanical recycling: packaging that can be used to make a rigid grade PE or a rigid grade PE/PP blend; and
- Energy recovery: packaging that can be processed as a Solid Recovered Fuel (SRF) or Refuse Derived Fuel (RDF).

Information is provided for what each component of the packaging should and should not include to be classified as desirable or acceptable for mechanical recycling or for energy recovery.

The guidelines are a dynamic document that will be subject to change following further research, testing and evidence. As further work is required on the guidelines they have not been released for public consumption at this time and will be used as a basis for ongoing work.

4.7 Business case for the UK

The REFLEX project has set a vision that by 2025 there will be an established collection, sorting and reprocessing infrastructure/economy developed for post-consumer flexible packaging across Europe, based on end of life technologies and processes to achieve the best economic, technical and environmental outcome.

A case study has been developed to set out what is required to achieve this vision in the UK. An outline business model has been developed, encompassing waste flows, mass balances, commercial factors and sensitivity analysis for the UK market. This analysis has indicated that there is a viable business case for collecting, sorting and recycling post-consumer flexible packaging in the UK. This will require:

- Local authorities adopting kerbside collection of flexible packaging (estimated to need a further 75 local authorities to start collections);
- Achieving at least 50% participation rate from the householder in each local authority with the required communication activities;
- Further augment the portion of flexible packaging suitable for mechanical recycling by integrating recyclability into the packaging design process where it makes technical and economic sense, supported for example by Design for Recycling Guidelines;

[14] http://www.recoup.org/p/229/2014-uk-household-plastics-collection-survey

- Sorting and processing facilities to make the necessary investments in new equipment required to extract flexible packaging from feedstock streams;
- Provide certainty in feedback and off-take markets to enable recycling plants to be financed and constructed;
- Understanding the life cycle of the proposed value chain to determine the environmental impact and find optimised routes; and
- To lobby for an appropriate policy infrastructure to be in place.

It is estimated that nearly £100 million of capital investment will be needed to achieve full deployment in the UK. These costs will include modifications to existing sorting facilities such as additional conveyors, bunkers and sorting technology and the construction of two purpose-built reprocessing plants. Additional funding may also be required to support local authorities in transitioning into offering collections of flexible packaging.

5 Next steps

The REFLEX project completed in autumn 2016. There is a significant amount of interest from the flexible packaging value chain to continue the work started by the REFLEX project. Already a separate project 'FIACE' has been established to map flexible packaging in the circular economy. It is proposed that the REFLEX and FIACE projects work together to establish a new project to recognise the role of flexible packaging in a circular economy, including measuring and communicating resource efficiency and waste prevention benefits of flexible packaging and to establish collection, sorting and reprocessing infrastructure across Europe.

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