Written evidence submitted by ReNew ELP (PW0038)

1. What measures should the UK Government take to reduce the production and disposal of single-use plastics in England? Are the measures announced so far, including a ban on certain single-use plastics and a plastic packaging tax, sufficient?

A ban on single use plastics will inevitably lead to the development of alternative products made from materials other than plastic, such as wood or paper. These are unlikely to be included in collections of dry recyclables and may have a significantly higher carbon footprint that the plastic that they are replacing.

Instead, there needs to be a focus on increasing the rates of recycling and the scope of materials collected for recycling whilst ensuring that the UK has the infrastructure to process more of its own generated plastic waste (see answer to question 5). The Plastic Packaging Tax is focusing companies' attention on using more recycled content which will create a greater demand for this material. However, it is important that we drive up recycling rates as a whole at the same time, so there is more recycled content available.

In addition, it needs to be recognised that without further investment into UK recycling infrastructure, a large proportion of plastic packaging will be unable to use recycled content due to a combination of issues including regulatory barriers, technical barriers and lack of supply. A recent round table convened by WRAP UK Plastics Pact identified a range of barriers to investment by venture capital or pension funds and issues included the long term requirements for investors versus the short-term nature of waste recycling contracts. This mis-match means, with the uncertainty over the effectiveness of the new Government measures (including Plastics Tax, new EPR and Deposit Return Schemes), that waste management companies and reprocessors are carrying substantial risk around business cases for investment.

New infrastructure also includes innovation and commercial development of new technologies. New ***chemical recycling*** technologies are able to provide the recycled raw materials necessary for the manufacture of new plastic packaging with recycled content. For this reason, to support the development of a world-class domestic plastic recycling infrastructure, monies raised from the Plastic Packaging Tax should be reinvested into new recycling processes. WRAP UK Plastics Pact recently undertook a review of the chemical recycling industry for Defra, including an overview of the technologies, challenges and regulatory barriers faced by the industry, opportunities for development and recommendations for the Government. This is appended to this submission.

We recommend that the Committee appraises itself of chemical recycling as a new sector that can deliver multiple benefits on waste plastic recycling and contribute to Net Zero ambitions of both the waste and chemical production sectors. As a leading member of the UK chemical recycling sector, ReNew ELP would be pleased to present evidence to a future Committee hearing.

The reformed Extended Producer Responsibility (EPR) proposals aim to ensure that packaging producers cover the cost of downstream reprocessing and disposal. It is currently unclear how the system will work in its entirety. The measures for ensuring traceability of material and monetary flow through the system are not defined; critically it is unclear how revenue will flow down to reprocessors and therefore how reprocessors will be able to expand, innovate and increase recycling capacity. A transparent system is needed to ensure that plastic reprocessing capacity is available.

We would strongly recommend the Committee enquire of Defra officials how the scheme will operate to deliver the outcomes expected of Government.

The most common polymer types in plastic packaging are PE, PP and PET and these materials are all easily recyclable. Materials used in the manufacture of SUPs (single use plastics) should be restricted to these three common polymer types to enhance recyclability.

Disposal of SUPs can be eliminated by including these products in collection and recycling schemes for all plastic packaging. Improved collection across public and private sector industries (e.g improved efforts within the NHS to segregate non-hazardous waste plastics and improved kerbside collection schemes) could also help drive up plastic recycling rates.

2. How should alternatives to plastic consumption be identified and supported, without resorting to more environmentally damaging options?

All materials have an environmental impact, but moving from plastics to alternative materials could have adverse impacts. For example, a 2020 study by Imperial College[1] concluded that compared to alternative materials, plastic packaging is often the least damaging when it comes to carbon emissions.

It is essential that Life Cycle Assessments (LCAs) are undertaken to ensure the best material is used for each function.

LCAs should include the full end-to-end product life cycle, including disposal or recycling. New chemical recycling technologies are being introduced into the UK, with significant operational capacity available from 2022. LCA assessments for chemical recycling processes[2,3] have shown significant CO_2 savings in comparison to the alternative disposal methods, i.e. landfill or incineration of plastics that are currently considered 'unrecyclable', and also the savings compared to the use of fossil sourced feedstocks for the chemical industry. Chemical recycling will provide a pathway to Net Zero for both the waste and chemical manufacturing industries, providing low carbon alternatives to disposal by EfW (Energy from Waste) for hard to recycle plastics, including SUPs.

Currently, the chemical recycling industry is undertaking a number of collaborative LCAs for various parties, including the EU Commission.

3. Is the UK Government's target of eliminating avoidable plastic waste by 2042 ambitious enough?

The technology exists to recycle all of the UK's plastics waste without resorting to the export of waste to countries with lower environmental standards and less-developed infrastructure. With full support from the UK Government, it will be possible to construct sufficient new, UK-based plastic recycling infrastructure to meet the Government's target to eliminate avoidable plastic waste well ahead of the stated aim of 2042; a realistic target would be 2030. Recycling all of the plastic waste in UK plants will deliver the greatest environmental benefit and prevent the export of a ready-resource, jobs and investment. The UK can create the world's leading waste management environment, with clear social, environment, commercial and economic benefits.

Although nearly 50% of UK plastic packaging waste is recycled (source NPWD), a large proportion of this is commercial and industrial waste. Household plastics are commonly collected but the recycling

[1] Voulvoulis. N., et.al (2020) Examining Material Evidence The Carbon Fingerprint. Imperial College London. Veolia-Plastic-Whitepaper.pdf (imperial.ac.uk)

[2] Life Cycle Assessment of Plastic Energy Technology for the Chemical Recycling of Mixed Plastic Waste, September 2020 Plastic Energy LCA Executive Summary

[3] BASF Project ChemCycling™ Environmental Evaluation based on Life Cycle Assessment, September 2020. Life cycle assessment (LCA) for ChemCycling™ (basf.com)

of these is dominated by PET beverage containers and HDPE milk cartons. Pots, tubs and trays (PTT) are collected by some local authorities, but there is insufficient UK infrastructure in place to process all of the material collected. Few local authorities collect films and flexibles.

New chemical recycling infrastructure for the processing of hard to recycle plastics will be available in the UK from 2022. Investment into these technologies is critical to help provide a solution to recycling the remaining 50% of unrecycled plastic packaging currently in the UK waste stream. Chemical recycling processes will provide the base chemicals used in the manufacture of new plastic packaging (including food contact), thus replacing fossil sourced chemicals in the production process. Also, more processing plants for the traditional mechanical recycling of plastics are being constructed.

As the reformed EPR system, improved collection proposals and tighter controls on exports are implemented, there will be significantly more plastic waste available in the UK for recycling. Investment in chemical recycling and mechanical technologies will be required to meet the additional demand, ensure the reforms are effective and that material is diverted from EfW and landfill into recycling. There is the opportunity to harness a huge value from the waste stream which is currently lost.

The UK Government should support the development of new UK recycling infrastructure, which will allow all of the UK's plastic waste to be recycled and will provide tax revenue, high-value jobs and prosperity across the whole country.

This will place the UK on the map as world-leaders in the development of effective plastic recycling.

4. Will the UK Government be able to achieve its shorter-term ambition of working towards all plastic packaging placed on the market being recyclable, reusable or compostable by 2025?

With new chemical recycling plants coming online in the UK from 2022, the technology exists to recycle all plastic packaging waste produced in the UK.

Chemical recycling can process contaminated, post-consumer plastics, including those recovered from residual waste and multi-layer barrier films, such as meat packaging. Development of the chemical recycling industry and therefore increasing recycling capacity for films, flexibles and other plastic waste which cannot be mechanically recycled will be critical to ensure that UK plastic recycling targets are met. Provided that the chemical and wider recycling industry receives sufficient support from the Government, the 2025 target mentioned above should be achievable.

It should be noted that investors want long term security of returns. Recycling contracts tend to be short term (3-5years), unlike EfW contracts which are significantly longer. Efforts should be made to provide security to recyclers and provisions to ensure traceability of funds to recyclers under EPR.

It is vital that this Government ambition does not have unintended consequences on existing recycling streams. Compostable materials need to be used in applications where it can be kept in a closed system. If there is a danger of compostable material getting into the mechanical recycling stream, it can prevent some longer-life end markets such as the construction industry from incorporating recycled plastic. Compostable materials should only be used in applications where there is a clear benefit in using them. Applications include compostable plant pots, liners for food caddies, coffee capsules, food service items and packaging that is highly contaminated by food and currently poses significant challenges to recycle economically; or in applications that prevent conventional plastics contaminating the composting stream such as fruit labels. The use of compostable products should always be accompanied by Life Cycle Analysis to determine whether or not they are the best environmental choice.

5. Does the UK Government need to do more to ensure that plastic waste is not exported and then managed unsustainably? If so, what steps should it take?

The UK is currently too reliant on export markets for the recycling of its plastic waste. In 2020, 59% of plastic packaging was exported for recycling [4]. In January 2021, the BPF released a Recycling Roadmap which sets out how plastic exports could be reduced by over a half and the exporting of plastic waste no longer being a route for low quality material. This would result in over a threefold increase in waste plastic material remaining in the UK for domestic recycling. To achieve the roadmap, a key requirement is investment in UK infrastructure and recognising that waste management infrastructure is critical. There also needs to be no financial advantage for material to be exported rather than kept in the UK, which is currently the case with the PRN/PERN scheme. 16 other key requirements are set out in the roadmap, which include consistent collections of all plastic packaging from all households and businesses, a legislative framework supporting domestic recycling and increasing the use of recycled materials wherever practical.

Keeping material within the UK would help ensure the traceability of material and ensure greater confidence that material collected is recycled.

It needs to be recognised that the dumping of material is waste crime and this needs to be tackled. There needs to be a sufficient deterrent in place to discourage criminals from undertaking this activity which affects the reputation of the whole industry. There would be a merit to considering suspending accreditation whilst investigations are in process and, if fraud is revealed, cancelling the accreditation for a meaningful length of time.

One area of concern is that material is moved from the original export destination to another country and then the outcome of the material is unknown. Exporters need to be to prove material has been recycled and where this took place, to ensure movement of plastic waste from its intended destination does not happen.

In summary, there needs to be investment in plastic recycling infrastructure within the UK to reduce our reliance on exports, whilst also ensuring there are sufficient deterrents to prevent waste crime and ensure all our exports are recycled to relevant standards.

[4] PackFlow Covid-19 Phase I: Plastic (wrap.org.uk)

Appendix

UK Plastics Pack Non-Mechanical Recycling Review

Introduction

Non-mechanical recycling has an important role to play in helping the UK Plastics Pact reach its targets, specifically *'70% of plastic packaging effectively recycled or composted by 2025'* and *'30% average recycled content across all plastic packaging by 2025'*.

In 2019 members of the Pact formed a group to explore and evaluate the different non-mechanical recycling technologies available. It identified what opportunities the technology brings, what challenges and barriers there are and how non-mechanical can work alongside the existing mechanical recycling infrastructure. The group included members from the whole value chain including retailers, brand owners, waste management, mechanical recyclers, non-mechanical recyclers and non-governmental organisations (NGOs).

Dialogue with Defra was recognised as essential to deliver an understanding of the government's position on the various technologies and after several meetings with Defra representatives it became clear that the position of government made in the Resources & Waste Strategy didn't necessarily reflect its true position. Subsequently WRAP was asked to provide more information on the opportunities and challenges facing the non-mechanical recycling sector to help better inform government.

This report aims to:

- Give a broad overview of the key non-mechanical recycling technologies;
- Outline the opportunities that non-mechanical recycling is offering the UK as it moves towards a circular economy;
- Highlight the challenges faced and knowledge gaps within non-mechanical recycling;
- Demonstrate the role non-mechanical recycling has to play alongside traditional methods of recycling; and
- Suggest priorities and recommendations for industry and government to help non-mechanical recycling technologies become part of UK recycling infrastructure.

Overview & state of play

Non-mechanical recycling, often referred to as chemical recycling, is a general term used to describe a range of technologies and processes which convert plastic waste into more basic and valuable chemicals which can be used to replace virgin polymers. In contrast to mechanical recycling, which uses physical processes to separate different polymers and extrudes plastics into granulate which can be directly reprocessed into new products.

There are many categories of processes; the three main non-mechanical processes can broadly be described as:

- Feedstock Recycling
- Depolymerisation
- Solvent based Purification (also known as dissolution)

There is no 'one-size fits all' approach to non-mechanical recycling and each technology is suited to different polymer types and challenges.

Feedstock recycling technologies

Feedstock recycling is any thermal conversion process which converts plastic into simple molecules, these are then used as 'feedstock' by processors to create new products and packaging. The most common type of processes which fall under this term is Pyrolysis, Hydrothermal and Gasification. These processes are intrinsically creating a new feedstock that enable the creation of recycled content suitable for high grade level applications including food grade materials.

Pyrolysis

Pyrolysis is the thermal degradation of polymers at temperatures between 400°C and 1000°C in the absence of oxygen. The result from this process is that the polymers' complex molecules are broken down into simple short-chain hydrocarbons like those found in crude oil.

The pyrolysis process produces three products; gas, liquid and a solid char. There are numerous variables which can affect the ratio of these three outputs, including: the method of pyrolysis, the rate of heating, condition of the reactor and residence time within the reactor.

An illustration of a typical pyrolysis process is shown below (figure 1).

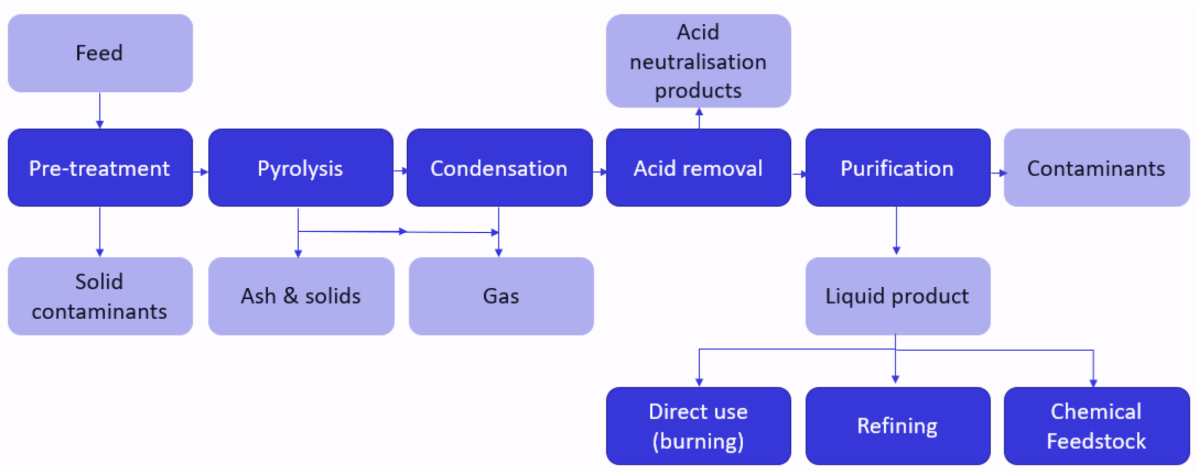

Figure 1 Process flow diagram of a typical pyrolysis process

Pyrolysis is best suited to work with polyolefins, such as polypropylene (PP) and polyethylene (PE). Polystyrene can be tolerated in low levels, however polyethylene terephthalate (PET) should be strictly limited due to the levels of oxygen within the polymer. Polyvinyl chloride (PVC) should be avoided.

Currently there are several large-scale commercial pyrolysis plants in operation globally though historically these have been plants that convert plastic waste into oil/fuel and are not currently processing household/post-consumer material into feedstocks for new polymers production. There are however several notable trials with the technology providers and their petrochemical off takers, to convert plastics to plastics

Hydrothermal

Whereas pyrolysis involves the direct heating of plastics to high temperatures, hydrothermal processes use steam under high pressure and temperature to dissolve the plastics. The end of life plastic is cleaned to remove non-plastic contaminants. The plastic is then melted and mixed with 'supercritical' steam, passed through reactors, and then depressurised and passed into a distillation column where the products are separated.

The supercritical state of the water defines the process, where the water at the 'critical point' co-exists as a liquid and a gas and exhibits properties of both, acting as an organic solvent and as a donor of hydrogen. The vapour is cooled in a distillation column and the condensed liquids are separated to produce the hydrocarbon liquids and oils. The range of products includes naphtha, distillate gas oil, heavy gas oil, and heavy wax residue, all of which can be taken as feedstock for further processing into products including plastics, wax and base oils and bitumen-like materials. The process also produces process gas which is recycled back into the process as a fuel for the boiler to generate supercritical steam.

An illustration of a typical Hydrothermal process is shown below (figure 2)

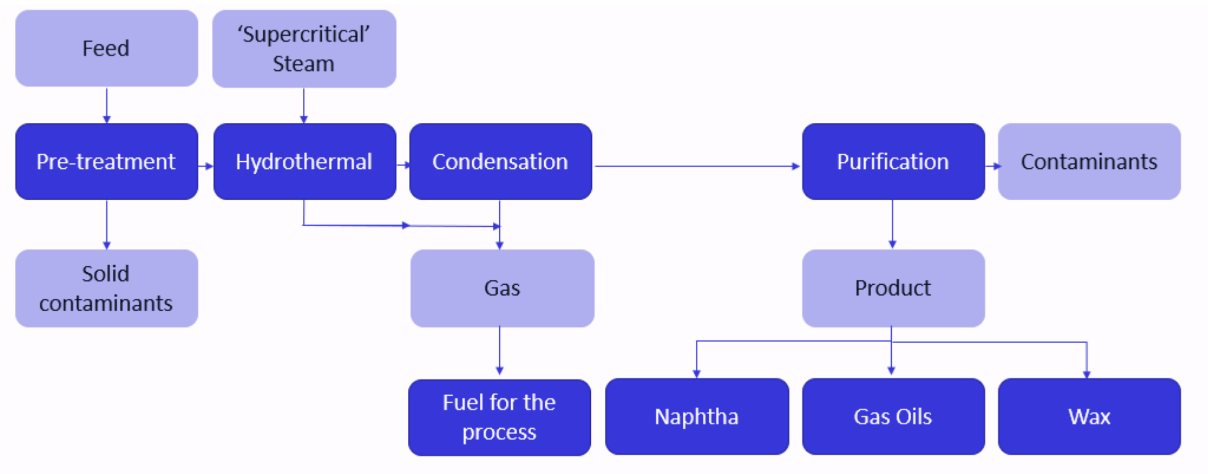

Figure 2 Process flow diagram of a typical hydrothermal process

Gasification

Gasification is less sensitive to the input material than pyrolysis, however it requires more energy and a larger scale of operation. The process heats mixed material plastics to between 1000°C and 1500°C in the presence of a limited level of oxygen. The result of the process is the near total decomposition of the feedstock into 'Syngas', a gas predominantly made of hydrogen and carbon monoxide, as well as carbon dioxide, water and methane. The composition of all the output is determined by the feedstock material as well as operating temperature of the reactor. Cleaned Syngas can be combusted in its current form or converted into fuels, or into basic chemicals to make new products.

An illustration of a typical gasification process is shown below (figure 3).

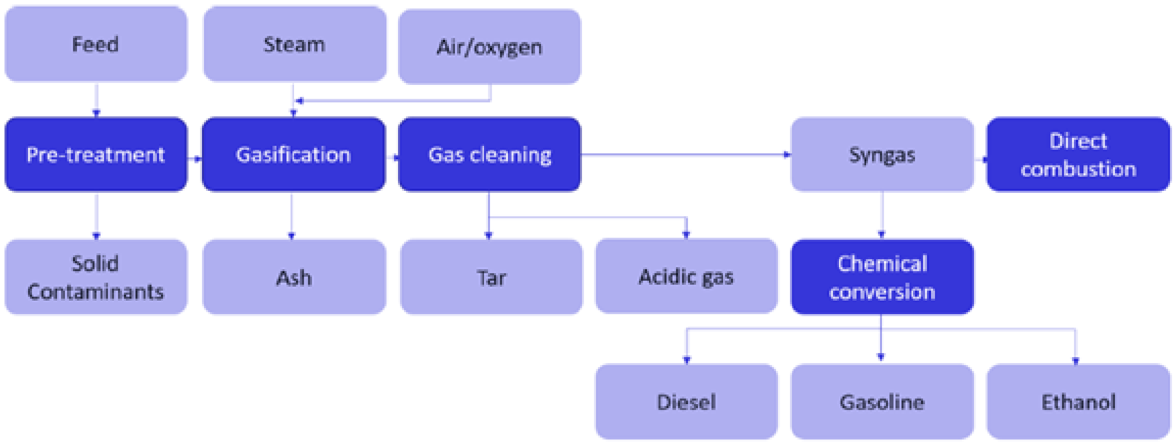

Figure 3 Process flow diagram of a typical gasification process

Gasification for recycling has been developed with not only mixed polyolefin (PE and PP) material in mind as it is less sensitive to the feedstock material than pyrolysis (for example the process can tolerate a presence of oxygen containing polymers such as PET). However, the process does not cope well with feedstock containing PVC as these materials will generate increased levels of undesirable gasses (such as hydrogen chloride) which require additional cleaning to be removed.

Depolymerisation

Depolymerisation is designed to reverse the polymerisation process in order to isolate monomers that can be repolymerised to produce a better-quality polymer. The process uses an agent or catalyst to promote a reaction with the polymer and since the process breaks the polymer into its original 'building blocks', the output can be reformed separately or together with virgin monomers to create a virgin-grade material.

Depolymerisation is more tolerant to contamination than feedstock recycling as the process targets the desired polymer(s) leaving the remaining materials within the feedstock material intact. However, it is possible that the agent/catalyst may react with unforeseen contaminants and therefore inhibit the process.

An illustration of a typical depolymerisation process is shown in Figure 4

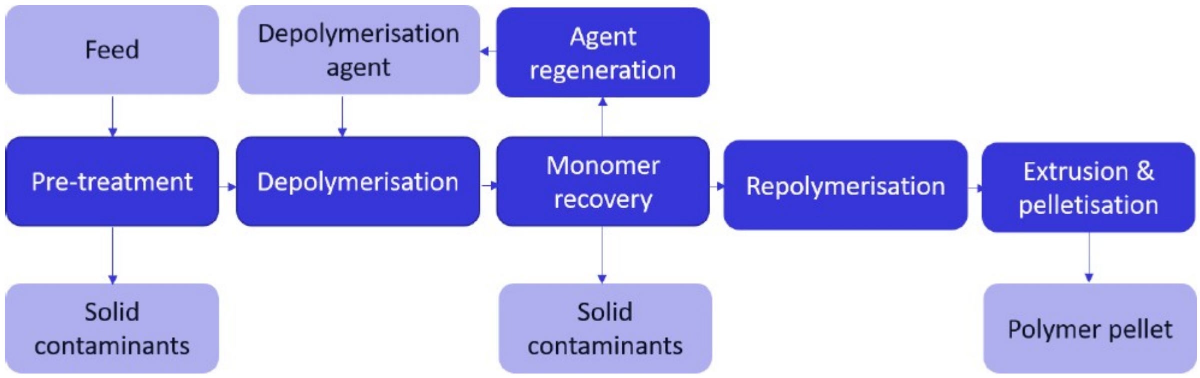

Figure 4 Process flow diagram of a typical depolymerisation process

PET is the most widely researched polymer for depolymerisation as it is the highest volume polymer on the market accounting for 18% of global production. Whilst most proposed processes for PET depolymerisation are still at laboratory level there has been significant attention from the non-mechanical recycling sector.

Solvent-based purification

Solvent-based purification (also known as Solvolysis and solvent dissolution) involves introducing the polymers to a solvent based solution and then recovering the polymer chains. The solvent used depends on which polymer is targeted, the polymer can then be separated from the undissolved solid material, then precipitated and extruded. As the polymer bonds are not broken during the process repolymerisation is not required. Solvent-based purification also allows the removal of additives and contaminants but does not affect the polymer structure. As with depolymerisation, the solvent dissolution process can be tailored to target a specific polymer so the presence of additives and contamination is less problematic, however, there is the possibility of solvents reacting with unexpected contaminants

An illustration of a typical dissolution process is shown in Figure 5

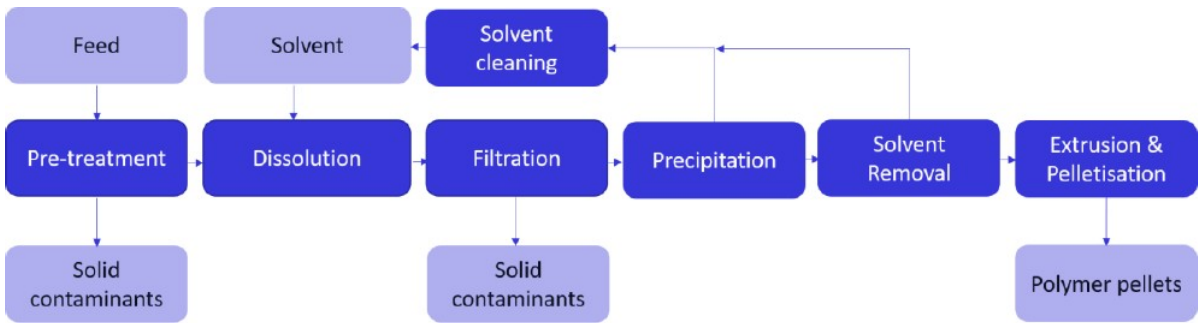

Figure 5 Process flow diagram for a typical dissolution process

Availability and Capacity

There is approximately 2.4 million tonnes of plastic packaging placed on market (POM) in the UK every year, (table 1). According to the 2019 UK Plastics Pact Report approximately 65% (1.5million tonnes) is deemed ‘recyclable’ using current mechanical technologies. This leaves approximately 779,350tn (excluding PVC and ‘other’ polymers) of plastic packaging which has the potential to either be redesigned for mechanical recycling or treated through non-mechanical recycling.

	HDPE	LDPE	PE	PET	PP	PS	PVC	Other	Grand Total
Film	98kt	363kt	103kt	31kt	133kt	2kt	9kt	19kt	**759kt**
Bottles	485kt	0kt	1kt	443kt	17kt	0kt	0kt	0kt	**947kt**
PTTs	26kt	1kt	12kt	168kt	161kt	57kt	13kt	2kt	**441kt**
Other	63kt	23kt	2kt	41kt	79kt	5kt	2kt	0kt	**214kt**
Grand Total	671kt	388kt	118kt	683kt	391kt	64kt	25kt	22kt	**2361kt**

Table 1 UK plastic packaging POM composition (2017)

The UK has the potential to be a world leader in non-mechanical recycling. One UK operator has a forecast of 378kt/yr of capacity in the UK by 2030 with an overall UK and EU combined capacity of 3.3million tn/yr within the same time period. Meanwhile other operators have estimated at least 130ktn/yr capacity in the UK by 2025.

Initiatives such as the UK Plastics Pact, Extended Producer Responsibility as well as developments in new packaging formats and design are likely to have an impact on what capacity for both mechanical and non-mechanical recycling is needed. It is important that this should be considered when planning new recycling capacity.

Costs

Discussions with various non-mechanical technology providers suggests that a plant of ~20,000tn/yr would cost between £35-£45million to build[1]. It should be stressed that true costs will vary widely depending on numerous variables, such as: technology type, process, location, material availability, planning and the size of plant. This cost can be broken down roughly into different categories:

	Cost	Percentage
Material for plant	£3.5-£4.5m	10%
Equipment for plant	£14-18m	40%
Design of site	£7-£9m	20%
Construction costs & contingency	£10.5-£13.5m	30%
	£35-£40m	100%

Table 2 estimated breakdown of costs for building a non-mechanical plant

Commercial plants range in size from large-scale centralised plants with 30-200kt annual throughput to much smaller, modular, and distributed units with capacity from 3-10kt per annum. A key part of any business case for non-mechanical recyclers is the payback period of the plant itself. This means that non-mechanical recyclers need to ensure that they have long-term contracts for feedstock to help build in stable business costs and mitigate against a drop in price of fossil fuels and low price of virgin resin.

Opportunities

The UK government has proposed targets for recycling of post-consumer plastic packaging (55% by 2030) as well as a tax on consumer plastic packaging that contains less than 30% recycled content. For the UK to reach its targets there needs to be immediate investment in plastic recycling infrastructure for both mechanical and non-mechanical recycling. Without investment in non-mechanical recycling it is highly unlikely that industry will be able to achieve 30% recycling content in some packaging due to it being technically or legislatively impossible.

Mechanical recycling of rigid HDPE is a success story in the UK, with two plants able to produce food grade rHDPE which is supplied into the dairy industry as well as cosmetics. MRFs and PRFs are also well adapted to sorting HDPE into natural (generally food grade material) and jazz (generally used for non-food grade). End markets for HDPE are wide ranging, with 30% used in packaging, 30% construction, 20% horticultural and outdoor applications, the remaining being a variety of uses such as railway sleepers, boxes and garden furniture. Similarly, there is existing infrastructure for PET recycling providing high quality food grade materials used to make both new bottles and trays for the food and drinks sector.

Non-mechanical recycling presents the opportunity to make new materials at scale, and to have a profound impact on plastics recycling. Focusing on polymers and formats not widely

[1] Information gain via telephone interviews and anonymised into 'ranges' due to commercial confidentiality.

recycled mechanically and in particular film, pouches and laminates could significantly improve the recycling rates in the UK and critically, produce food contact grade material where this is not technically possible from mechanical recycling. For example, feedstock recycling has input flexibility over other technologies and is particularly promising for recycling film and flexible packaging. As such non-mechanical recycling should be considered as a key approach in meeting current and future recycling targets.

New pilot technologies and modular units have the potential to be better suited to being implemented alongside current recycling infrastructure. The market demand for high quality recycled content for consumer packaging from brands and retailers is also a driving force that has the potential to create a favourable economic environment for these technologies.

Whilst this report does not compare environmental impacts against traditional mechanical recycling technologies, it is widely accepted that any development of new technologies and plants should be supported by an accompanying life cycle analysis (LCA). Mechanical recycling will always be the preferred route due to economic costs and environmental impacts. However non-mechanical technology can be compared against recovery options (EfW) and landfill for material that isn't processed via mechanical recycling. CE Delft[2] carried out a study which looks at the impact on climate change compared to EfW and Landfill disposal. Their findings show that non-mechanical recycling can reduce the carbon footprint by around 2tn CO2 eq./tn input.

To date there has been a lack of clarity for non-mechanical recycling as to if and when a process can be formally classified as 'recycling'. However, Directive 2008/98/EC, Article 3, Waste Framework Directive defines recycling as:

'recycling' means and recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

It is understood that this definition will be transposed into UK law post UK leaving the EU and subsequent transition period ending on 31st December 2020.

The above definition is backed up by The Environment Agency and the Scottish Environment Protection Agency as it is suggested that for an operator to claim Packaging Recovery Notes (PRNs) they much be able to demonstrate either of the following:

- Produce a material with the same properties and functions as the packaging waste material it processed, or
- That material must be used instead of a raw material from a natural source. To produce new products or packaging, or
- Demonstrate that its process results in a beneficial output that does not need further reprocessing, i.e. it must pass an end of waste test.

[2] https://www.cedelft.eu/en/publications/2173/exploratory-study-on-chemical-recycling-update-2019

The point in the process at which the above criteria are reached will differ from one technology to another, and it is not possible to say that recycling is achieved at the same point for all technologies but will need to be evaluated on a case by case process.

The technologies discussed in this paper all offer the opportunity to tackle a range of recycling challenges (polymer degradation, mixing of plastics and polymer types, contamination etc.) that are currently faced in achieving a circular plastic economy. However, although many of the technologies are not currently operational at scale within the UK and not expected to be for another 3-5 years it is anticipated that approximately 40,000tn of capacity will be online by 2022.

There is a growing demand for recycled content in plastic packaging, not just in the UK but throughout Europe and across the world. The introduction of a tax on packaging with less than 30% recycled content, as well as the proposed introduction of Extended Producer Responsibility (EPR) potentially creates a more favourable market for non-mechanical recycling technologies in the future. Since non-mechanical processes can offer recycled content in packaging of up to 100% without having to compromise on quality, this may increase demand for material and create a fertile environment for investment. It is important that non-mechanical recycling is included within the definition of recycling with respect to a future EPR system for packaging and that it continues to be considered a recycled plastic for the purpose of the proposed plastics tax.

The role the technologies can play within the current infrastructure.

Non-mechanical recycling should not be seen as a 'silver bullet' where all material can be processed through one type of plant. The different technology types can be largely split into polyolefin recycling and PET recycling and therefore a level of pre-treatment in order to sort material will always be required. Therefore, the continuation of improved collection and sorting infrastructure and capacity will should be made to ensure the capture rate and quality of feedstock material.

The development of non-mechanical technologies is motivated by the need to process materials which are difficult or not possible to process through traditional mechanical recycling infrastructure.
Mechanical technology is not able to effectively and efficiently remove additives and contamination from waste plastics. Due to the mixing of different additives and contaminants from various sources of material when processed mechanically, the knowledge of the plastics composition and performance is lost along with a significant proportion of the material value. This underpins the need to ensure that material that is being placed on market is being designed, where possible, with mechanical recycling in mind. Furthermore, having a standardisation for plastic bales as in the UK to align with the EU specifications would help reduce the need for pre-treatment and increase the treatment opportunities for post-consumer material be it mechanical recycling of mechanical recycling.

Mechanical processes also degrade the polymer over time lowering the properties of recycled resin, as a result the integrity of recycled resin will always be of a lower quality than that of virgin resins. Non-mechanical technologies offer a pathway to overcome these constraints as they are able to 'clean' material by repurposing the chemical building blocks of the polymer and effectively making 'virgin-like' grade material.

Infrastructure and transport costs for mechanical recycling of plastics can be expensive due to the lightweight nature of the material and non-mechanical infrastructure will face the same challenge, so having regional non-mechanical plants or even modular units alongside mechanical recycling plants may help keep costs down. Other considerations around location of facilities include the geographic chemical off takers (refiners and plastic producers) as well as transport infrastructure for the import and export of materials.

Figure 6 shows how non-mechanical recycling could be used in the UK to facilitate packaging to packaging recycling, with modifications to collection and sorting capabilities (such as digital or fluorescent watermarking), to achieve higher rates of recycling. This diagram does not consider yields and by-products of the processes and it must be noted that efficiency rates do vary dependant on process as well as feedstock material quality.

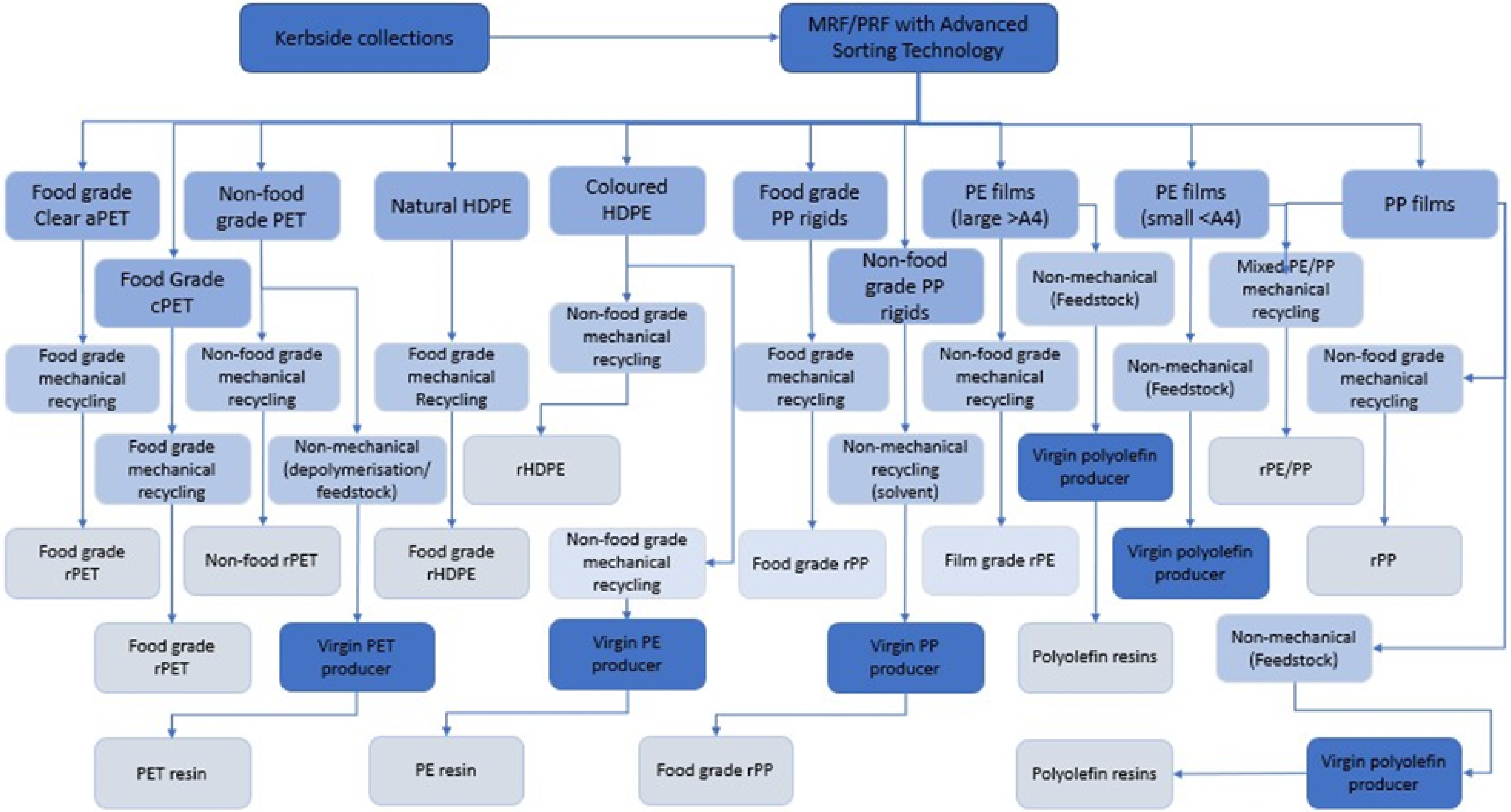

Figure 6 Example of how Non-mechanical recycling could fit alongside mechanical infrastructure in the UK

Challenges & Knowledge Gaps

There are several challenges that need to be overcome to help support the non-mechanical recycling sector reach its potential in working alongside mechanical recycling to help deliver a circular economy for plastic packaging. These challenges have been separated into the following areas; Economic, Investment and Technological Challenges.

Economic Challenges

At a time when fossil fuel prices are low, it is uncertain whether non-mechanical recycling can be competitive on its own. Non-mechanical processes are costly as a result of their high energy and operational costs. Due to the high-quality end products created from non-mechanical recycling, end products are able to demand a premium compared to mechanically recycled products. As long as the virgin materials are cheap to produce as a result of low fossil fuel prices it will be difficult for recycled produced materials to compete on price alone, and this will be particularly challenging for non-mechanically produced material. The HMT tax on plastic packaging that does not contain 30% recycled content will however assist in overcoming this challenge.

Output chemicals from feedstock recycling are generally in scope for use as fuels and/or fertiliser, this means that that output materials run the risk of being used as fuels when demand for recycled content drops or if mechanical processes fulfil the market requirements.

Investment Challenges

Uncertainty surrounding the future demand for recycled plastic is creating a barrier to new investment in capacity. Even with strong early signs of increased demand in quality recycled resin, there is a great deal of uncertainty for the sector. Non-mechanical recycling often involves significant investment to reach the scale needed to make a plant financially viable, with such high uncertainty around future demand for end-product as well as support from government it is difficult for operators to invest in building new capacity.

There is no clear government position on non-mechanical recycling, and this is adding to the challenge. The current Resource and Waste Strategy for England suggests that government supports the technologies on a short-term basis and does not see it as part of the waste and recycling infrastructure long term. This stance means that technology providers are not able to make a business case to investors to build a plant which may only financially pay back in the long term.

Collection infrastructure of appropriate feedstock is needed. Plastic films will very likely be the biggest feedstock however post-consumer films do not have a widespread developed infrastructure with only 18% of local authorities collecting film at the kerbside, equating to approximately 17000tn (around 2% of material placed on market). For non-mechanical recyclers to be able to make a strong economic business case for investing in a new facility, there needs to be a stable and consistent feedstock being collected for them to process.

As previously stated, packaging initiatives that push for better packaging design, as well as an introduction of Extended Producer Responsibility, will impact on the required capacity of both mechanical and non-mechanical recycling. These should be modelled when considering new investment in capacity.

Technological Challenges

Some non-mechanical technologies have high energy requirements and necessitate further refining after the process of breaking down the polymer has been completed. The output from these processes also includes by-products such as char which will either need further treatment to be of use to other industries, or a suitable disposal route found.

There are issues around the measurement of recycled content in new products and packaging made with feedstocks and outputs from non-mechanical recycling. As such there needs to be a standardised methodology for not just measuring recycled content in new products and packaging but also a standardised classification criterion for when a polymer has been recycled within a non-mechanical process.

The approach outlined in the Ellen MacArthur Foundation (EMF) white paper on Mass Balanced Approach to calculating recycled content[3] should be adopted by industry to ensure a standardised methodology, especially when considering implications around taxation on recycled content.

Although certain processes, have been around for several years, many other non-mechanical recycling technologies are still in development and are either in small pilot/demonstrator scales or even only being carried out in lab conditions. As a result, little is known about the potential environmental and social impacts, both positive and negative. If more was known about the positive impacts and unintended consequences, then this might incentivise investment and support.
As such these technologies need further development with increased time and investment in order to ensure that they can work on a large commercial scale.

Priorities & Recommendations for Industry and Government

Industry is keen to engage with government, and with some difficult challenges to be overcome there is a significant need for collaboration in order to support the development of non-mechanical recycling in the UK. The below is a list of priorities that have been identified for industry and government to investigate and develop. These actions would help enable non-mechanical recycling to play a significant part in the UK's move to a circular economy for plastics.

- The Resources and Waste Strategy for England is unclear in its position for non-mechanical recycling, currently suggesting that it is a short-term solution until the packaging industry can design out complex and/or difficult to recycle materials. Discussions with individual Defra officials suggest this is not necessarily the case. Providing public clarity on its position may encourage outside investment and support a strong business development case for the sector.

[3] https://www.ellenmacarthurfoundation.org/assets/downloads/Mass-Balance-White-Paper-2020.pdf

- A Review and update of waste legislation to acknowledge the latest recycling technologies, ensuring consistency across policy initiatives would be welcome. The adoption of a standardised definition and legal status (i.e. end of waste criteria) for non-mechanical recycling will provide clarity on the nature of the output as well as how they relate to other technologies within the waste hierarchy. This action would not just benefit non-mechanical recycling but also advances in mechanical recycling technologies. Implementation of technical standards that allow virgin-grade recycled resins to be used in the same applications as virgin polymers would also support the use of non-mechanically recycled polymers in food grade and medical packaging applications.
- Industry and government need to work together to develop a holistic vision for a recycling system throughout the UK which incorporates both mechanical and non-mechanical recycling, this would help in the delivery of much needed infrastructure. Such a plan should include clear and detailed information around how scaled up non-mechanical recycling will help the UK reduce its dependence on traditional fossil feedstocks and achieve its targets, contributing to the delivery of a circular economy and creating a circle where higher-quality materials lead to further increases in recycled content
- Non-mechanical recycling sector to collaborate and agree a set of non-mechanical recycling guidelines covering the design of materials for non-mechanical processes.
- Industry needs to develop test protocols to verify higher grades of recycled content and what their uses are applicable for, to help preserve the quality and value of materials.
- The development of a suite of regulatory measures to incentivise and boost recycled content within consumer packaging. These regulatory measures could be time-bound targets for recycled content, for example those within the UK Plastics Pact. The government tax on packaging with less than 30% recycled content is a key example of this.
- Any fees paid as a result of EPR to be ringfenced and spent on investments in infrastructure for the collection, sorting and recycling of packaging, including non-mechanical technologies. While it is recognised that the recycled content tax is a central tax, funding should be made available to support and enable the inclusion of recycled content.
- Through the EPR system provide financial incentives for innovation to redesign products and materials that improve the efficiency and effectiveness of mechanical and non-mechanical recycling. The EPR system would need to consider the costs of non-mechanical recycling compared with landfill or energy from waste, which would help to stimulate investment.
- Joint funding for industrial scale piloting of non-mechanical recycling technologies.

Summary & Conclusions

Non-mechanical recycling offers the UK an opportunity to deal with material that does not currently have positive end of life scenarios and would be highly challenging/impossible to achieve through mechanical recycling for challenging post-consumer and post-industrial plastics. It should be seen as a tool that works alongside traditional mechanical infrastructure, to generate value and prevent material from being sent to incineration or landfill. The potential to be able to produce post-consumer food grade film at a near virgin quality opens up the ability to include recycled content in food packaging where currently not possible. Food packaging is the biggest market for plastic film, and while end markets outside of this need to be developed, without the ability to recycle food plastic packaging into food plastic film packaging, circularity will not be achieved.

Non-mechanical technologies offer the opportunity to increase recycled content as well as recycling rates within the UK to help reach national targets. But there are still a number of challenges to overcome such as low fossil fuel prices , lack of suitable legislation and regulations, the availability for suitable feedstock and the high level of investment required (being hampered by a perceived lack of support of the technology by government).

Table 3 gives an overview summary of the broad non-mechanical technologies, the opportunities and challenges faced and recommendations on how to develop the industry further in order to reach UK recycling targets.

	Feedstock Recycling (Pyrolysis)	**Feedstock Recycling (Hydrothermal)**	**Feedstock Recycling (Gasification)**	**Depolymerisation**	**Solvent Dissolution**
Feedstock	Polyolefins (PE & PP), with a focus on films due to the challenges with mechanical recycling	Polyolefins, PET & PS	Polyolefins (PE & PP)	Polyesters & polyamides.	PP and multilayer films with PE
Product	Wax, oil & gas	Wax, Oil & Gas	Syngas	Polyester and polyamide monomers	Recovered polyolefin resin
Cost of plant[4] *(~20,000tn yr plant)*	**Material for plant**			£3.5-£4.5m	10%
	Equipment for plant			£14-18m	40%
	Design of site			£7-£9m	20%
	Construction costs & contingency			£10.5-£13.5m	30%
	Total			**£35-£40m**	**100%**
Estimated/planned capacity (Europe)[5]	460,000tn/yr			11,000tn/yr	20,000tn/yr
Challenges	Economic challenges • Low fossil fuel prices keeping virgin material at a cheaper price • Risk being in a linear locked in system and output being used as fuel • Difficult to change current infrastructure to produce the high quality needed to replace virgin polymers Investment challenges • Uncertainty around the demand for recycled plastic • No clear support from government on non-mechanical recycling • Lack of collection infrastructure for suitable input materials Technological challenges • High energy requirements of some of the technologies				

[4] Indicative estimate only. Actual cost can depend on numerous variables, such as: technology type, process, location, material availability, planning as well as the size of plant

[5] Industry estimates for the next 5-7 years.

	• Need for further refining on some technologies to produce the right quality • No standardised methodology of calculating recycling content or at which point in the process material is 'recycled' • Most modern technologies are still in a lab or pilot/demonstrator scale.
Priorities & Recommendations for industry and government	• Create a clear governmental position supporting the long-term development of non-mechanical recycling to work alongside mechanical infrastructure. • Review and update current legislation to include the advancements in recycling technologies. This should include standard definitions. • Set out a vision of how non-mechanical and mechanical recycling technologies work and complement each other in the UK • Development of standards to verify higher grades of recycled content and what there uses are applicable for, to help preserve the quality, value and safety of materials. • Creation of guidelines to include non-mechanical processes. • A suite of regulatory and fiscal measures to incentivise recycled content and help drive demand for processes that produce high quality recycled polymers. • The provision of incentives for product redesign with end of life in mind. • Funding of industrial scale piloting on non-mechanical technologies. • Government and industry to explore opportunities to work together, this can be done through the UK Plastics Pact group on Non—mechanical recycling.

Table 3 Summary table of the main technologies discussed

The UK Plastics Pact see non-mechanical recycling as playing an important role in achieving its targets as well as national targets and these are highlighted in the actions and tasks in the 'Creating a Circular Economy for Flexible Plastic Packaging' roadmap. The UK Plastics Pact's 'Non Mechanical Recycling group' are keen to explore recommendations outlined above and welcomes further discussion with government how to do this.

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