LEEDS BECKETT UNIVERSITY
LEEDS BUSINESS SCHOOL

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MEMBERS PLATFORM WHITE PAPER

CHEMICAL RECYCLING & THE CIRCULAR ECONOMY OF FILM

THE RETAIL INSTITUTE

Introduction

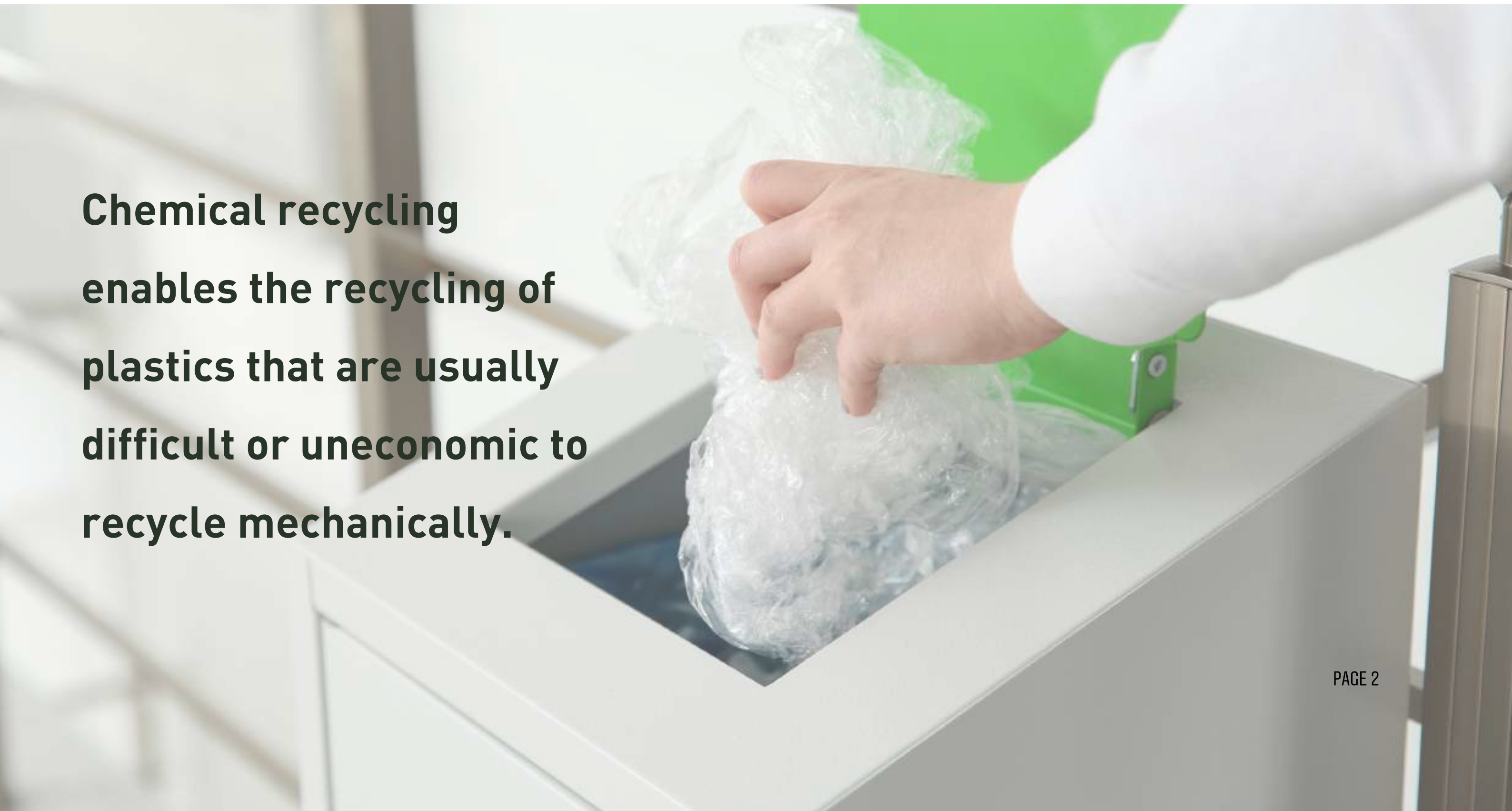
Systemic change is necessary to enable the transition to a circular economy. There are many complexities with no single solution that works across multiple settings. High level stakeholders across industry, government and society must collaborate to ensure changes achieve sustainable goals. This is true for all environmental interventions, including chemical recycling and developing a circular economy of film, the themes of this Members' Forum White Paper. It summarises presentations and discussions by colleagues working within the retail packaging supply chain, and representatives of leading chemical recycling organisations, who came together to share knowledge about these issues and identify future actions.

Hard to recycle materials, including flexible films, create a challenge for businesses with internal recycling targets or enforcement through plastic taxes. According to Plastic Recyclers Europe (PRE), 15 mega metric tons (Mt) of flexible films are placed annually on the EU market, of which 9 Mt are polyethylene (PE) films and 2.5 Mt are polypropylene (PP) films. At a current recycling rate of 23%, PE films are seen to have significant potential for increased collection and recycling, especially for films from household waste streams that make up 40% of all PE film waste generated in the EU. Current limitations to the recycling of films come from design issues such as the use of multilayer materials and a limited infrastructure for collection, separation, and recycling.

Chemical recycling is the broad term used to describe a range of emerging technologies in the waste management industry. They enable the recycling of plastics that are usually difficult or uneconomic to recycle mechanically. Several pilot plants demonstrating the viability of various chemical recycling processes are currently in operation at the time of writing. Commercial plants range in size from large-scale centralised plants with 30-200kt of annual throughput to much smaller, modular, distributed units with capacity from 3-10kt per annum. The technologies fall into three distinct categories based on the position of their outputs in the plastics supply chain. These categories are:

- Purification
- Depolymerisation
- Feedstock (thermal conversion) recycling [1]

Recycling Technologies' research for Project Lodestar suggests that, compared to mechanical recycling alone, an advanced Plastics Recycling Facility (aPRF) offers significant uplifts in recycling rates [2].



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1. The Value of Chemical Recycling

The size of the challenge is clear and stark. Just 12% of the 260 million tonnes (Mt) of global plastic waste was recycled in 2016, while the amount of plastic waste is predicted to almost double within the next decade, reaching 460Mt by 2030 [3]. While this adds pressure on companies to do more, McKinsey's projections also visualise a scenario in which 50% of plastics worldwide could be reused or recycled by 2030, representing a fourfold increase from today's 12% global figure. Whether such visions turn out to be realistic depends on the success of interventions by individual companies, improvements in infrastructure and huge upscaling of new technologies [4].

As an example of the pressures that packaging companies face, in 2018 Amcor made a pledge that 100% of its products would be recyclable or reusable. The implication of that pledge is the need to significantly increase the use of the recycled materials. This involves ensuring there is a market for that recycled product to be, ideally, put back in into the exact packages that it came from. That can only be achieved by working with other companies, recyclers and legislators to develop a standard system across Europe.

McKinsey's projections visualise a scenario in which 50% of plastics worldwide could be reused or recycled by 2030.

The context for achieving these changes includes the forthcoming UK packaging tax. From 2022, there will be a £200 per tonne tax on packaging that does not contain at least 30% recycled content. This creates a challenging timescale for increasing recyclability and ensuring recyclable content. In addition, flexible packaging needs third party accreditation to be considered recyclable. This involves considerable collaboration to develop standards across many countries. There are currently major differences in international recycling practices, meaning that packaging manufacturers often use different materials to package the same products in different countries. In addition, continuing efforts to reduce plastic can encourage greater use of more sophisticated laminate structures to maintain shelf life. This means that despite using less plastic there is a proportion that is actually less recyclable.

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According to the McKinsey report, an increase in both collection and scope could help global mechanical recycling rates increase from 12% to 22% of the plastics waste market by 2030. WRAP has suggested that, "Non-mechanical technologies may be vital in achieving not only the 70% effective recycling rate but also enabling the average 30% recycled content of packaging." [5]

Recycling Technologies [6] is developing technology to enable the waste industry to turn 'liability plastic' back into a profitable material. During the last decade, plastic production has increased from 250 million tons a year to 368 million tons a year.

Despite its advantageous properties, plastic is not a sustainable material unless recycling rates improve and plastic pollution stops. Current estimates (from McKinsey) suggest that 40% of plastic waste goes to landfill, 25% is used to produce energy from waste and 19% ends life in the environment.

Plastic comes from oil and gas. There is an extensive supply chain, including refineries, monomer manufacture, polymer manufacture, and compounders. Mechanical recycling is, and continues to be, vital in taking end of life plastic and post-consumer plastic back to the compounder. Although, all plastic might be mechanically recyclable, the qualities of plastic degrade each time it is recycled this way. Therefore, other tools are important to maximising circularity. For example, polymer purification helps to remove some colours and contaminants and other additives to ensure a purer form of recycled plastic end-product. Also, monomer recycling includes turning materials like polystyrene back into styrene.

Non-mechanical technologies may be vital in achieving not only the 70% effective recycling rate but also enabling the average 30% recycled content of packaging.

With around a billion tons of plastic likely to be produced annually in the World by 2050, about one third would come from mechanically recycled plastic and 40% continuing to come from virgin feedstock[7]. The remaining c25% would come from monomer recycling and feedstock recycling and there is significant potential for growth in chemical recycling. Between now and 2050, there is also likely to be a significant shift away from using virgin oil and increasing use of bio-derived fuels.

BASF has been active in chemical recycling (or chemcycling) for many years, having put work on hold in the past due to lack of progress. However, having renewed interest a few years ago, the company is reporting its first commercial successes. Following investment and collaboration in a range of industries and securing a supply of pyrolysis oil, BASF is trying to increase momentum to scale up chemcycling, using a mass balance approach. This means offsetting for every tonne of chemical recycled products produced. Partners convert the plastic waste into pyrolysis oil and, via a thermochemical process, BASF then purifies it. This acts as a feedstock at the beginning of a production process. It is an alternative to fossil fuels and, as everybody is concerned about use of fossil fuels, this is a really good way of offsetting that.

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While the use of traditional mechanical processes means that the plastics economy is often more like a downward spiral (as much plastic is going back into the market as is being taken out), it is possible to make anything from chemical recycling, which supporters claim make it potentially a more circular approach. In many countries, there have been issues relating to recycling of films for decades. Therefore, chemical recycling promises a significant and, potentially, very important piece of technology.

Image Courtesy of BASF: Quantafuel and REMONDIS want to cooperate on chemical recycling of plastic waste, April 21

3. Limitations of Chemical Recycling

Despite the many promising aspects of chemical recycling, several questions and uncertainties must be resolved. These include issues relating to the potential carbon footprint of the process, in comparison to mechanical recycling, and the impact it may have on moving away from a reliance on fossil fuels and plastics in general. WRAP has observed that:

> *Whether or not the impact, across any or all Life Cycle Analysis (LCA) categories of nonmechanical recycling, is in fact higher than producing virgin polymer from crude oil is unknown at this stage. It is a real possibility that from an LCA perspective, an approach of making packaging from virgin polymer and mechanically recycling waste polymers into both packaging and non-packaging applications has a lower impact than nonmechanical recycling. [8]*

In addition to concern about the high energy use needed to break the chemical bonds during pyrolysis and gasification, WRAP has also questioned whether each type of non-mechanical recycling meets the definition of recycling. The output product must be usable as a secondary raw material. This is the case for chemical depolymerisation and solvent dissolution, which can achieve high yields of new polymer. However, pyrolysis processes might only achieve low yields of secondary raw materials providing the naphtha is converted into new polymer.

The members forum acknowledged that the amount of energy needed to break down recycled materials back to monomers is an issue because of the potential increase in carbon footprint. Therefore, it must be considered as part of an end of life hierarchy that recognises reduction and reuse as optimum approaches with other levels of intervention still valuable circular approaches. Mechanical recycling is preferred for its lower carbon footprint. However, the need for purity in recycled materials means that chemically recycled materials outperform mechanically recycled outputs.

Those involved in the development of chemical recycling processes have done a considerable amount of life cycle analysis and acknowledge the energy intensiveness. However, there is still great value if used in a balanced way. For the difficult to recycle plastics and materials, it remains a preferable solution to alternatives such as landfill.

Some problems are simply hurdles to overcome rather than fundamental flaws. Work will continue to improve quality and efficiency. A massive amount of pyrolysis oil is needed to feed the steam crackers and getting enough at the right quality is still a challenge. Although progress is being made, considerable scaling up is required. Another question concerns the collection of both post-consumer and post-industrial waste. Collection of flexible materials such as shrink wrap and stretch wrap must grow considerably to achieve the volumes that make it commercially and environmentally viable. Legislation would also help to resolve issues relating to the definition of waste and recycling. While a chemical recycler has the capacity to process waste plastic and put it back out on the market as 100% recycled content, current regulations might still define those materials as waste, which cannot be used commercially.

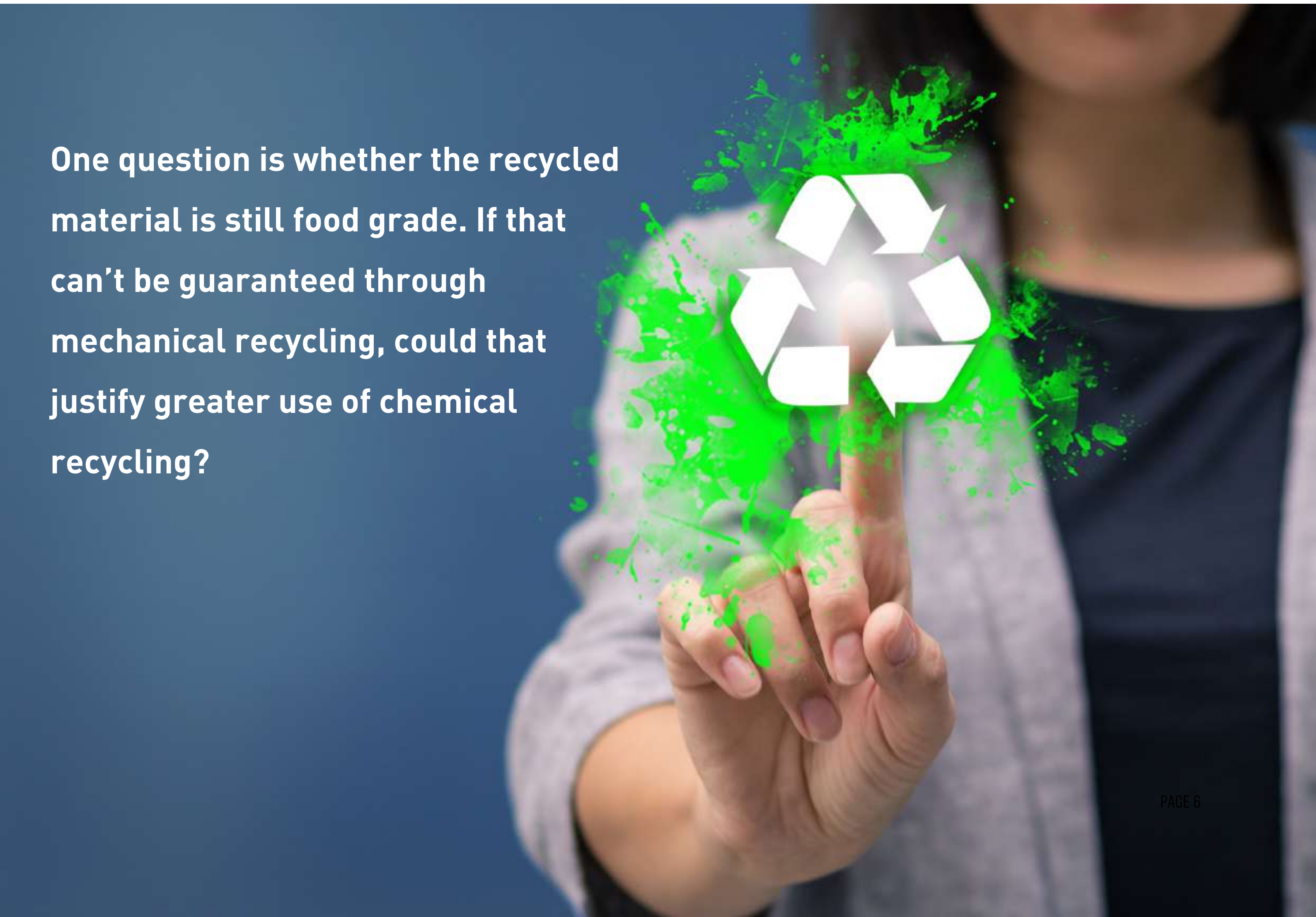
Further issues raised in our Members Forum discussion included tackling waste from the chemical recycling process, materials that are more difficult to process than others and systems for tracing plastic so that it is sent to the most appropriate waste process.

Collection of flexible materials such as shrink wrap and stretch wrap must grow considerably to achieve the volumes that make it commercially and environmentally viable.

Waste from the chemical recycling process is determined by which materials are input. For example, where there is a high proportion of polyesters, there will more a higher amount of oxygen within the system. Other waste comes from pigmentation. The ash that comes out of the process can have a relatively high metal content and work is in progress to develop the capability of stripping away heavy metal which has its own value. Other issues include managing PVC content and creating value for other extracted materials. Some materials take greater effort at the chemical level to remove unwanted molecules from the stream, adding cost and complexity. These include PVC, PTFE and anything containing halogens. There are other challenges around bioplastics and chemical recycling. Although bioplastic and plastic are closely related, if there is a significant increase in the industry's use of bioplastic, it could create a significant fall in the yield quality, due to additional oxygen input.

Finally, with multiple forms of recycling available, including mechanical recycling, monomer recycling and feedstock recycling, it can be difficult to determine the best outcome for individual items of plastic. One question is whether the recycled material is still food grade. If that can't be guaranteed through mechanical recycling, could that justify greater use of chemical recycling? An ideal future development would involve digital watermarks for recycling for identification of where to direct plastics. This raises the question of whether the waste industry is prepared to invest in technology to detect tracers that plastic manufacturers can include.

In summary, much work still needs to be done, not only in increasing the scale of chemical recycling capacity but also in terms of spreading understanding among all industry stakeholders. Collaboration between different sector could help to improve waste collection as well as the planning, lobbying and design activities needed to achieve the full potential of this technology.



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4. Future Developments

Probably the most pressing question for the Members' Forum related to when chemical recycling will be available at sufficient scale. Investment will be critical. Global investment in chemical recycling is estimated at around $500 million in the last decade. In comparison, the same period has seen $60 to $70 billion a year worth of investment into new plastic production. It was suggested at the forum that all investment into plastic production should be accompanied by a proportionate investment (e.g. one quarter to one third of the amount) into the capacity to turn it back into oil.

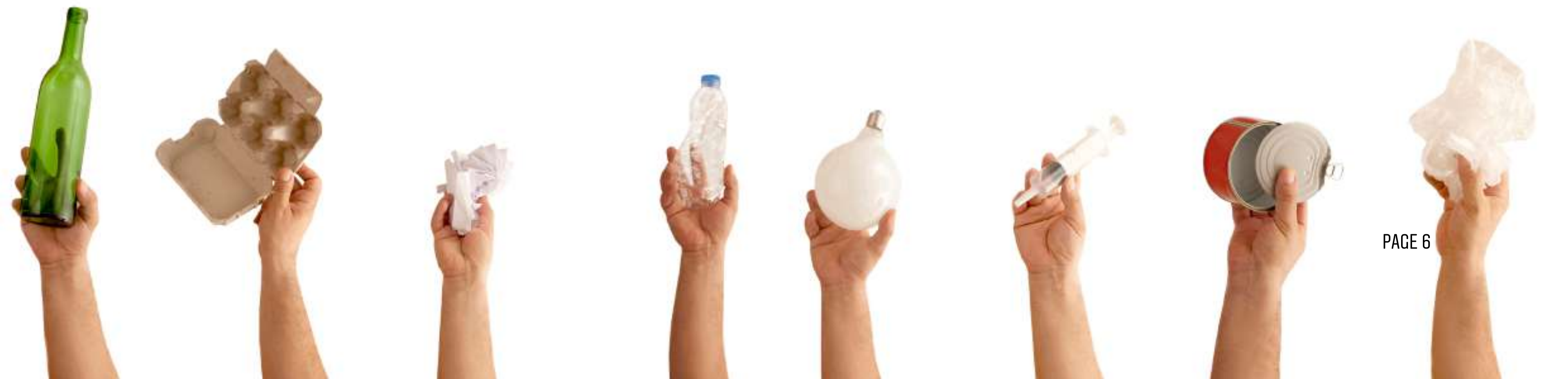
The current reality is that the chemical recycling industry is tiny compared with associated industries such as waste, retail and petrochemicals. It was noted that the UK's forthcoming packaging tax of £200 per ton of plastic is much lower than the EU tax of €800 and, therefore, is not enough to a) make it more expensive than the cost of compliance and b) to ensure there is sufficient investment into recycling infrastructure. The situation was likened to the automotive industry in which investment in a new platform must be accompanied by investment in deconstruction of cars at end of life. An equivalent practice is needed for plastics.

Greater scale is also necessary to ensure the collection of sufficient feedstock. Chemical recyclers and other stakeholders are frustrated about the slow pace of progress in this area. Knowing that the technology will generate income, and that mass production will help costs to fall significantly, these companies are keen to encourage investment to make that happen. Money from extended producer responsibilities and other incentives can enable that investment.

UK's forthcoming packaging tax of £200 per ton of plastic is much lower than the EU tax of €800 and, therefore, is not enough to make it more expensive than the cost of compliance and to ensure there is sufficient investment into recycling infrastructure.

In terms of learning from other countries, in Germany BASF are working with the German government on different waste streams and many countries are starting to scale up, facing the same challenges with regulation, such as how to define chemical recycling as a waste product or a raw material.

In general, the forum noted that government awareness and knowledge must improve to inform effective policy making. While there has been some communication with the UK Government through general advocacy and the Plastics Waste Directive, there is a tendency for industry, waste processors, government and other stakeholders to see investment as someone else's responsibility.



Non-governmental organisations (NGOs) are another communication target to enhance awareness of the benefits of chemical recycling among the public. There have been discussions with NGOs about chemical recycling to explain its value. This includes addressing concerns about burning waste and demonstrating how chemical recycling can help to take waste out of the environment. It requires an open dialogue to find ways to tackle concerns and meet CO2 reduction commitments.

Packaging supply chain companies also must change to incorporate the advantages of chemical recycling. For example, Amcor is working with partners to use advanced recycled materials via the mass balance approach. It hopes to produce food contact grade materials for a range of products on the market using polyester, OPP and polyethylene.

Alongside the anticipated improvements in capacity and use of chemical recycling, packaging companies continue to improve the properties and recyclability of flexible plastics. There is currently a push to move away from laminated packaging and towards flexible packaging made from a single material that still has all the same protective properties. For some large companies, nearly every new structure they are working on are mono-material structures, such as mono polypropylene and mono polyethylene. These are replacing laminates, with at least the same shelf life and the same protection, and where possible, the same production efficiency (using the same machinery). With the limited infrastructure at the moment, these products are recyclable mechanically and downcycled. The recyclate cannot go back into food packaging, although it can go into other products such as bags for life, bin bags or for use in the automotive industry.

However, chemical recycling can turn those products back into food grade materials, which can now be produced as a mono material. This helps to reduce the noncircular disposal of plastic films, to maximize the collection of plastic and bring it back into the recycling loop. It will also simplify the plastic recycling process for both consumers and waste collectors as they will no longer have to sort non-recyclable plastic from their other recyclable waste.

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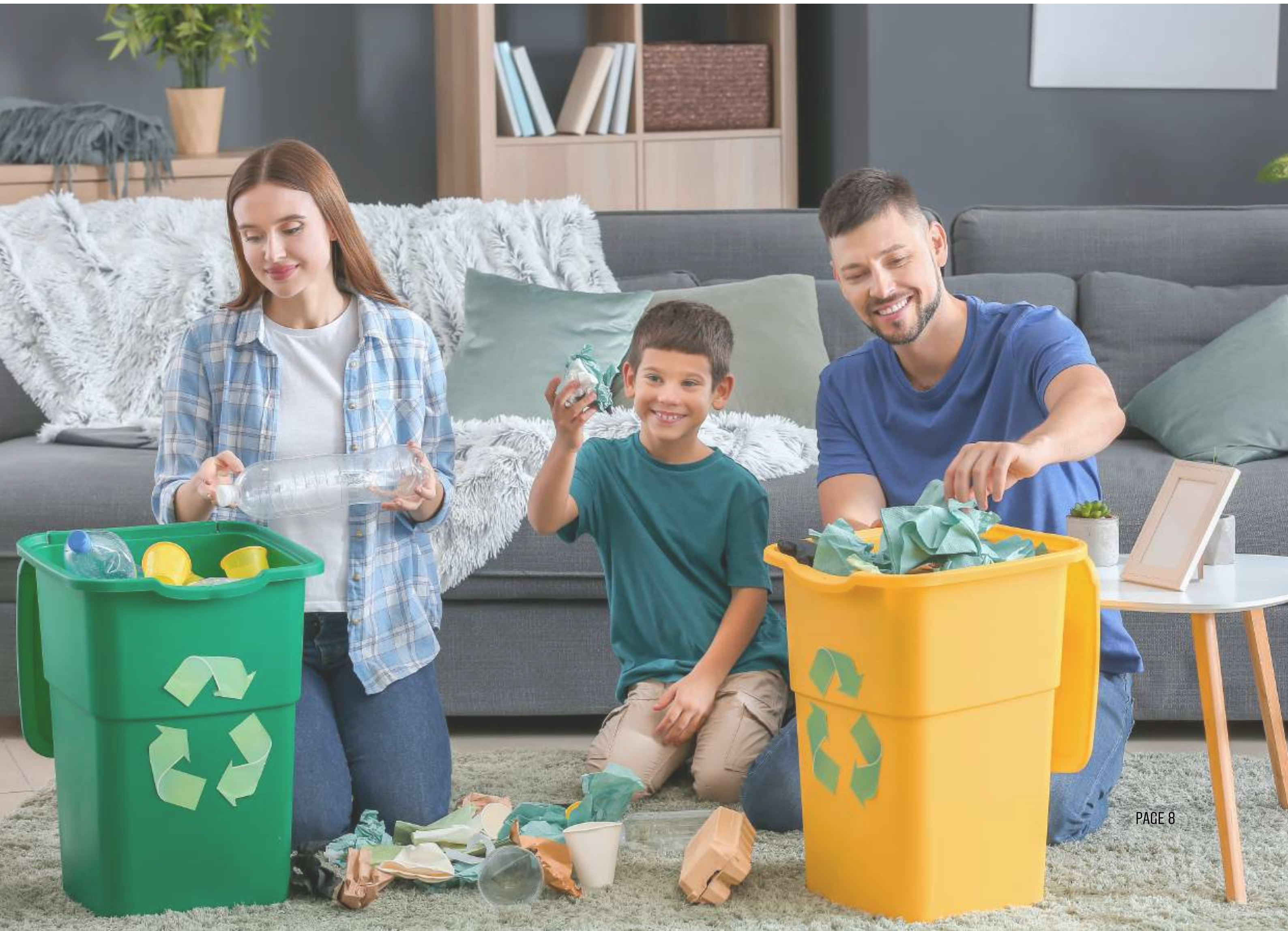
5. Conclusion

There is considerable interest among packaging manufacturers and retailers in chemical recycling as a solution for boosting recyclability. This forum demonstrated the potential value of the technology while acknowledging that there are still some significant challenges to overcome. It is an enterprise that can only work on a very large scale. That means large scale technological investment, collaboration, waste collection, communication and legislation. A paper from the European Chemical Industry Council (CEFIC) states:

To be successful, chemical recycling must be supported by a holistic enabling policy framework, an open investment environment and a competitive economic model. [9]

Addressing the various challenges will require partnerships to boost innovation and investments, the development of uniform standards for a mass balance approach and further quality standards for waste sorting and treatment. In addition, chemical recycling must be comparable from a lifecycle perspective to other systems and feedstocks.

It would be misleading to present chemical recycling as the solution to the plastic waste crisis. However, its potential value in helping to reduce the problem and significantly increase recycling rates means that it deserves serious consideration and investment. This forum of practitioners from the retail packaging supply chain calls for action to make this happen.



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LEEDS BECKETT UNIVERSITY
LEEDS BUSINESS SCHOOL

THE RETAIL INSTITUTE
LEEDS BECKETT UNIVERSITY
LEEDS LS1 3HE
TEL: 0113 8123309
RETAILINSTITUTE@LEEDSBECKETT.AC.UK