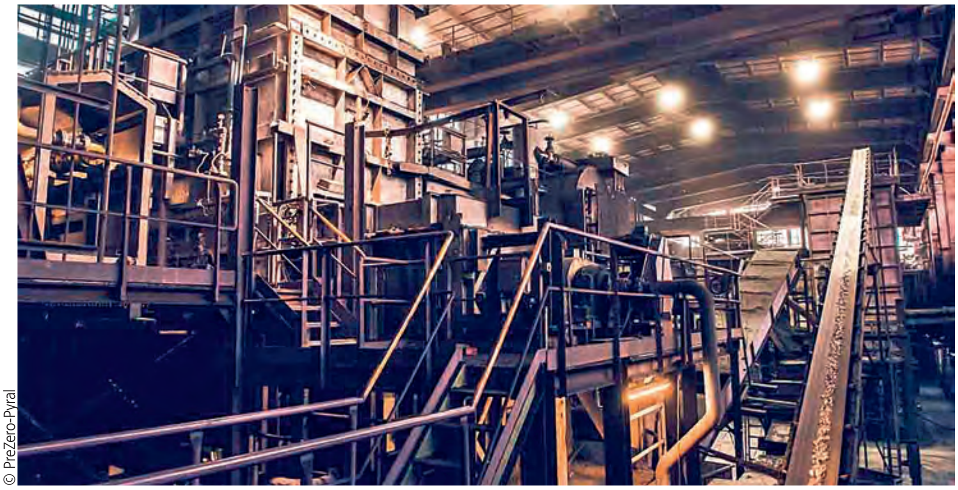
Sorting and recycling of alufoil – technologies and new developments

Recently, the Global Aluminium Foil Roller Initiative (Glafri) organized the first *Alufoil Sorting and Recycling Webinar*, focussing on thin foil-based laminates. With more than 130 participants from Europe, Middle East, North and South America, China, India, Japan, South Korea and South Africa – representing foil rollers, converters, a globally leading brand owner as well as recycling organizations – the coverage was beyond expectations. „Thanks to our excellent speakers on modern sorting and alufoil recycling technologies we could attract an amazing global audience – in line with the Glafri objective to share knowledge and best practices on foil sustainability worldwide and along the supply chain," said Stefan Glimm, director general of Glafri. „So we could make transparent that alufoil-based flexible packaging can be circular if collection, sorting and recycling is set up accordingly."

The five speakers on sorting and recycling technologies summarized their presentations, which are published below.

PreZero Pyral – 15 Years of Cyclic Economy

Andreas Reissner, managing director of PreZero Pyral GmbH



In PreZero Pyral's pyrolysis process the resulting thermal energy is fed back into the process cycle

Resource-efficient recycling of mixed aluminium packaging including aluminium foil, and energy recovery by pyrolysis.

The aluminium recycler PreZero Pyral GmbH in Saxony, Germany, has a real success story behind it. Founded a little more than 15 years ago, today the company is a joint venture between PreZero and the Reikan Group, recovering over 60-65% of all the light aluminium packaging in Germany. And that, by means of a unique pyrolysis process which reprocesses aluminium-bearing 'waste' by thermal and mechanical means in an efficient and environmentally friendly manner which makes use of the gases produced in the process. This unique, synergistic composite concept makes an exemplary contribution to the recycling economy and the ambitious aims that on the basis of the packaging legislation updated in mid-2021 should be achieved by 2025. In that context PreZero Pyral has long been regarded as a model, even internationally, for resource- and energy-efficient aluminium recycling.

Since 2005: aluminium recycling by means of high-tech pyrolysis

As one of the first aluminium recyclers, PreZero Pyral was established at the Freiberg industrial research facility. For the installation of the innovative pyrolysis process, which ensures 100% recovery of the valuable raw material aluminium from packaging and composite materials, there has always been close collaboration with the Technical University of Dresden and the Technical University of Bergakademie Freiberg. Both partners are as always benefiting from the conjoint research and technological results and will continue working closely together in the future as well.

Pyrolysis is a thermal process in which organic substances can be sparingly separated from aluminium without the use of oxygen. For this, only relatively low temperatures between 500 and 550 °C are needed. At those temperatures all of the aluminium present is preserved, while it is freed from substances such as paint, foils, paper and plastic labels or food residues. What is left is a valuable recycling raw material, which can flow back into the economy.

The really special feature of the pyrolysis by PreZero Pyral is the further utilization of the thermal energy produced. The organic material burned onto the aluminium due to the heat is converted into a synthetic combustible gas which, after purification, is returned back to the process circuit as a source of energy. The drum is driven by the heat produced. Flue gas produced during this is passed through a boiler and cooled. The steam generated thereby in turn serves to produce current for supplying the mechanical equipment of the plant. This constantly repeated cyclic principle produces clean aluminium granulates by an environmentally friendly and resource-sparing process, which can be re-melted for use in many new products.

The patented Pyradec process and S.A.A.L.T.

With the unique Pyradec system, which is based on the fluidized bed system, PreZero Pyral set up the next milestone. A fluidized bed is produced when a quantity of a stable particulate substance behaves like a fluid due to the introduction of compressed air. The material to be purified is transported through the 'bath' of this substance. Otherwise than in the pyrolysis process, which works under oxygen-free conditions and in which the material is heated indirectly by flue gas, the Pyradec system purifies its material directly. A thermal reaction takes place when the material comes into contact with the 'fluid substance' at 500 °C.

In 2018 the Freiberg site was enlarged with a new sorting process, which has also remained unique until now. With the S.A.A.L.T. (Sorting of Aluminium Alloys using LIBS Technology) plant, PreZero Pyral can now sort aluminium fractions into alloy types by means of a sophisticated sorting system that uses laser-based plasma spectroscopy (LIBS). This highly modern technology meets the needs of industry always to use more differentiated and special aluminium alloys.

What next for Pyral?

That this utilization of resources must establish itself as a daily feature in the future, is a central concern of the innovative family enterprise. The joint venture PreZero Pyral, which has existed since 2020, invests in new technologies and in research. Thus, it is now working on EcoloopAL, a recycling certificate of its own for aluminium packaging. And the field of activity can also be extended to other types of waste, such as plastics.

Advanced Mechanical Recycling of Aluminium Barrier Flexible Packaging Materials

Thorsten Hornung (CEO) and Sebastian Kernbaum (CTO); saperatec GmbH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saperatec has developed a process for the delamination of polymer and metal films in flexible packaging materials

The Advanced Mechanical Recycling solution of saperatec – a young German recycling technology company – offers a solution to delaminate polymer and metal films in flexible packaging materials, thereby separating these materials into secondary raw materials without substantially changing the material properties.

Plastics are an important material for our economy, and modern daily life is unthinkable without them. Every year approx. 29 million tonnes of plastic waste are generated in Europe with a packaging waste share of approx. 60% which is posing huge challenges to the community.

There is a rising expectation in our community that the industry tackles this waste challenge. Companies representing 20% of all plastics packaging produced globally have committed to the New Plastics Economy Global Commitment under the leadership of the Ellen MacArthur Foundation. They have committed themselves to eliminate problematic plastic packaging and to ensure that the plastics packaging we do need is reusable, recyclable or compostable. In fact, many leading brand owners and packaging converters have committed to achieve this goal by 2025.

One key industry action aiming to facilitate this objective is the Ceflex initiative for a Circular Economy for Flexible Packaging. Under Ceflex the industry is developing design guidelines for a circular economy for flexible packaging materials. These guidelines rate the compatibility of polyolefin-based flexible packaging materials for mechanical recycling depending on aspects of packaging design. The currently published guideline rates the compatibility of aluminium barrier layers in polyolefin-based packaging for mechanical recycling as "to be determined" as the commercial mechanical recycling of such materials has yet to be demonstrated.

Aluminium is still one of the best performing barrier materials in polyolefin flexible packaging with many key advantages. It facilitates lightweight packaging alternatives over more resource-intense rigid packaging options. It achieves superior product protection and shelf live, while simplifying supply chain requirements. Finally, aluminium facilitates the sorting of this type of packaging through established sorting technology (eddy current sorting) to separate aluminium from polymer packaging waste fractions. Consequently, established technology in packaging waste sorting centres can be leveraged to facilitate the recycling of polyolefin-based aluminium barrier flexible packaging materials in the future.

The main challenge today is that even in advanced recycling environments, only the aluminium content of this high-performance packaging material is recirculated. The plastics share – often more than 70% – is at best used for energy. In view of the New Plastics Economy Global Commitment, better recycling options that recover the plastics from this packaging waste is needed before 2025. The alternative is the replacement of aluminium barrier materials with mono-polymer solutions – often at the cost of a poorer packaging performance.

The Advanced Mechanical Recycling solution

The Advanced Mechanical Recycling solution of saperatec offers a solution to this challenge. The company has developed a process for the delamination of polymer and metal films in flexible packaging materials thereby separating these materials into secondary raw materials without substantially changing the material properties.

Specifically designed separation fluids are used to de-bond the metal and polymer layers. These separation fluids are water-friendly chemical formulations circulating in the process to minimize chemicals consumption. The overall recycling process is based on four main steps:

- In a pretreatment stage the incoming waste is pre-sorted and shredded before contaminants such as paper fibre or other foreign materials are removed.
- In the next step the saperatec separation fluid is used to de-bond polymer and metal films. The chemicals are recirculated while the resulting metal/polymer mix is washed to extract residual chemicals and organics.
- Then the material mix is fractionated using a combination of density-based and other advanced sorting technologies to produce polyolefin, aluminium and other polymer fractions.
- The aluminium is delivered to aluminium recycling partners for recirculation, while the polyolefins are mechanically treated to produce film-grade recycled polyethylene, polypropylene and mixed polyolefin pellets.

saperatec also develops pathways for the material recycling of other polymers in aluminium barrier flexible packaging such as PA, PET and PVC in collaboration with partners.

After extensive development and testing in their own labs and pilot plant the company now sets out to build the first commercial recycling plant for aluminium barrier flexible packaging waste in Eastern Germany. The plant will have a delamination capacity of approx. 18.000 tonnes a year and is scheduled to start operations in late 2022.

By means of this industrial scale operation, saperatec is committed to demonstrate the material recyclability of aluminium barrier flexible packaging materials on a commercial level before 2025.

About saperatec: Founded in 2010, saperatec develops technical solutions for the recycling of multilayer materials such as those found in the packaging, automotive and/or electronics industry. The expertise is, firstly, in the development of specifically designed so-called separation fluids – able to act as an agent for delamination, debonding or segregation, thus providing access to materials valuable as secondary raw materials, and secondly in the engineering capabilities to transform ideas into industrial processes for exploitation. To complete the customer demands, saperatec consults in design for recycling, material composition as well as secondary raw materials strategies.

Recycling of Aluminium Foil Thanks to the War on Plastics

Carlos Ludlow-Palafox, CEO of Enval

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Enval's proprietary process is based on a technology known as Microwave Induced Pyrolysis

Enval is a company dedicated to the development and commercialization of recycling and environmental technologies. The company was spun out of the Department of Chemical Engineering at the University of Cambridge and aim is to develop unique recycling processes that provide financially lucrative and environmentally beneficial alternatives to landfill. Enval's proprietary process is based on a technology known as Microwave Induced Pyrolysis.

To date, Enval has focused primarily on the commercialization of its patented solution for fully recycling flexible packaging including plastic aluminium laminates which other companies are not capable of treating. Its proprietary process is the result of more than 15 years of research and development and is based on a technology known as Microwave Induced Pyrolysis.

In general, pyrolysis is a process in which an organic material (e.g. paper or plastic) is heated up in the absence of oxygen, therefore causing the degradation of the material (effectively shortening its molecules due to high temperature), but without any combustion or incineration. Microwave induced pyrolysis is a pyrolytic process in which the energy to heat up the material is provided by microwave energy. Everyday experience in domestic kitchens shows that plastics do not heat up using microwaves (e.g. a plastic dish stays relatively cool even if the soup inside heats up), so how does Enval use microwaves to heat plastics to achieve the high temperatures needed for pyrolysis?

The secret is to use carbon, a highly efficient microwave absorber to absorb the energy and then transfer it by conduction to the plastic, thereby providing a very efficient heat exchange. The presence of the carbon and the conductive heat transfer mechanism also offer some other advantages, such as a chemical environment which prevents undesirable oxygenated compounds forming during the process and a fast reaction time, which enables high material throughput to be achieved in a compact and affordable piece of equipment.

When used on flexible packaging, the Enval Process degrades the plastics present in the material to form useful products (pyrolysis oils) that can be employed as feedstock for new plastics or speciality chemicals. If the packaging is a plastic aluminium laminate, the valuable aluminium remains after processing and is extracted, clean and ready to reintroduce in the aluminium supply chain.

The Enval Process is robust and can treat most flexible plastic packaging systems, whether they are in the form of post-consumer waste contaminated with foreign matter and residual product or relatively clean industrial waste from the packaging production and filling processes. It is efficient, low-cost, requires modest levels of capital expenditure and closes the recycling loop for flexible packaging materials. It offers an economically and environmentally viable route to enable the almost complete recycling of flexible packaging waste by separating and extracting the high value materials contained within.

Furthermore, the rapid heat transfer enabled by the Enval Process permits the construction of compact, modular units which are economically viable at relatively modest throughputs. This allows the ideal recycling scenario to be realized: installing plants to treat locally generated waste and thus avoiding the huge costs and environmental impact that would otherwise be incurred by moving thousands of tonnes of low density waste to a centralized treatment facility. The core of an Enval module, with a processing capacity of 2,500 tonnes of feedstock per annum, is built within three standard shipping containers. By using multiple module plants the process has the flexibility to cater for larger capacity requirements.

The process is also genuinely environmentally effective: for example, for flexible packaging containing aluminium, it is well-known that the production of primary aluminium is a large scale, energy intensive process. The Enval Process is capable of reclaiming all of the aluminium contained in that packaging, which otherwise would end up in landfill sites. Enval has carried out rigorous life cycle assessment (LCA) studies, which demonstrate that metal recovered using the Enval Process reduces CO_2 emissions by more than 75% when compared to the production of primary aluminium. Moreover, LCAs have also demonstrated that the process reduces by up to 90% the carbon footprint for a typical laminate tube when compared with landfill, due to the recovery of the aluminium.

Enval has one commercial plant, located in Huntingdon UK, with more than 5,000 hours of operation and is currently building its second commercial unit. The company also has several advanced projects to install at least five new modules within the next 18 months.

In short the Enval Process is an enabling technology that if implemented and adopted widely could allow the FMCG brand owners to adopt a 'business as usual' approach to the environmental sustainability question surrounding flexible packaging.

Sorting – Effectiveness and Technologies from a Foil Perspective

Michael Langen, managing director of HTP

The article is based on HTP's recent study 'The Ideal Aluminium Packaging Sorting Model', commissioned by the European Aluminium Packaging Group (EAPG) in Brussels.

Reference and packaging types

The aluminium content of aluminium packaging types in source-segregated post-consumer packaging waste varies from rich to poor. Generally, packaging with high aluminium content, such as beverage and aerosol cans, menu trays and food cans are easy to sort. Sorting becomes more difficult when it comes to composite packaging with low aluminium content, such as pouches, sachets, laminated tubes and blisters. The composites contain aluminium layers that perform a barrier function which is especially important for food containing packaging.

Nevertheless, the above-mentioned study has shown that applying eddy current separators across the whole size range of aluminium and aluminium composite packaging leads to a significant gain in sorting efficiency. Moreover, the study has shown that even most ambitious recycling targets for aluminium composite packaging can be met by applying advanced sorting technologies, such as multi sensor or robot sorting technologies. It must be mentioned that successful sorting of aluminium composites is not feasible from mixed household waste. Consequently, the best way to achieve the recycling targets is to collect all type of aluminium packing separately from mixed household waste.

Processing routes and technical challenges

In modern sorting centres with a basic setup, the source-segregated packaging waste is classified according to its particle sizes in a first step. Screening generates different material

Aluminium foil in composite packaging

Statement by Gunda Rachut, chair of the Central Agency Packaging Register in Germany.


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Can aluminium foil in composite packaging be recycled with an appropriate infrastructure?

The use of aluminium in composite packaging often serves to protect the product and is mainly intended to enable a long shelf-life of the product by acting as a gas barrier. Related to this, with the barrier layer of aluminium the other materials can be kept very thin, saving packaging materials. This in turn is in line with the waste hierarchy. As regards recovery, all composites have the disadvantage that only one of the materials can be usefully recovered. In the case of aluminium containing composites it is usually the aluminium component that is recycled, while the other materials such as paper or plastic are used to generate energy.

How can the recycling for aluminium foil from composite packaging be further optimized?

As of today the problem with all material composites is basically the same: only one of the materials is recycled, while the other constituents are often only used for producing energy. In principle, aluminium is a material that can be recycled effectively. Optimization efforts should focus on ensuring efficient separation and the recycling of the various material components. There are already innovative solutions that are currently still in the start-up phase and must then establish themselves in the future sorting and recycling infrastructure.

At present there is much discussion about alternatives to composites involving paper systems, often coated with plastic in order to achieve the required barrier properties. Can these alternatives, which frequently wrongly give the impression of being single materials, be recycled in the paper flow?

The issue of composite packaging is also encountered with these packaging materials: only one constituent of the packaging can be recycled – in this context the fibre fraction. However, another factor is that the recovery capacities are limited. On 1 September each year the Central Agency Packaging Register publishes the minimum standard for determining the recyclability of packaging. With this minimum standard, it is easy to determine quickly whether packaging can be classified as highly recyclable or not. It is important that the product manufacturer examines at an early stage of packaging design the question of how he can best conform with the waste hierarchy in relation to prevention and recovery. This is always an overall consideration of filling product and packaging alternatives. The aim is a resource-sparing cyclic economy. To that, everyone should contribute.

streams with particle size ranges as for example super fine (< 20 mm), fine (20-80 mm), medium low (80-200 mm), medium (200-320 mm) and 2D material. In a second step the material is sifted and undergoes ballistic separation to separate the 2D fraction mainly consisting of film. The aluminium packaging types end-up in the material streams super fine, fine, medium low and medium depending on their dimensions.

Focus on foil-based aluminium composite

For smaller or less modern sorting centres aluminium packaging is commonly sorted by applying eddy current separators (ECS) in the medium-low and the medium stream. This technical configuration enables an overall yield for aluminium packaging of nearly 60% but for foil-based packaging the yield is below 20%. When an additional ECS is installed in the fine stream the total yield increases by approx. 30% and the yield for foil-based packaging by approx. 16%. Provided that all aluminium packaging is collected via a well performing extended producer responsibility scheme, the payback period by adding a ECS in the fine stream is less than six months.

Since 2020/21, in addition to ECS the newly designed sorting centres implement inductive sensor sorting machines and robots. In the case of inductive sensor sorting machines the total yield (average for all type of Al packaging) increases by approx. 4%. When sorting robots are implemented the total yield rises by approx. 6%. Considering foil-based packaging only, adding inductive sensor sorting machines or sorting robots rise the yield by approx. 30% in comparison to the technical configuration applying ECS only.

Outlook

The challenge in recycling the aluminium fraction produced by modern sorting centres is the ever-decreasing aluminium content due to the increasing share of Al composites. In Germany, the so-called Al fraction DSD 420 is mainly recycled via pyrolysis which enables the energetic usage of the polymers and the production of an aluminium concentrate which can be refeed to remelting plants. Since a couple of years, emerging technologies like valorization routes for pyrolysis gas, de-lamination of Al composites and solvent-based processes offer new opportunities to enhance the recycling of foil-based packaging.

On behalf of Glafri and EAFA, HTP will investigate the readiness of these emerging technologies. The objective is to better recycle the aluminium fraction, eventually by separating it into aluminium-rich packaging and foil-based aluminium packaging which could lead to recycling routes enabling mechanical recycling also for the polymer component.

About HTP: HTP GmbH & Co. KG is an independent, owner-managed engineering and technical consulting office for the recycling and waste management sectors. Independency, flexibility and dedication, combined with more than 30 years of experience and expertise, have made HTP the leading engineering service provider in the field of process technology and plant design for waste management and recycling.

HTP's core competencies of cover the entire range of design, engineering and technical consultancy for the treatment of solid waste, such as residual and packaging waste, and mono waste like plastics, paper, etc. Again, the main fields of activities are technical consulting, engineering, and certification and expertise.

Recovery of Aluminium and Polymers from Flexible Al-Foil Laminates

Andreas Mäurer, Fillip Göbel, Martin Schlummer;
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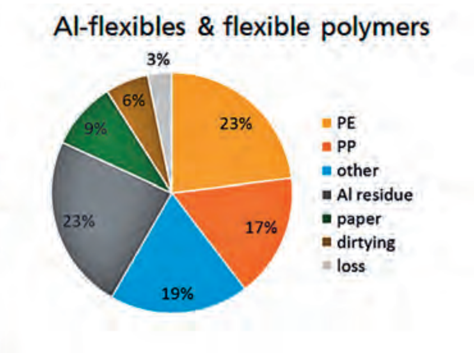
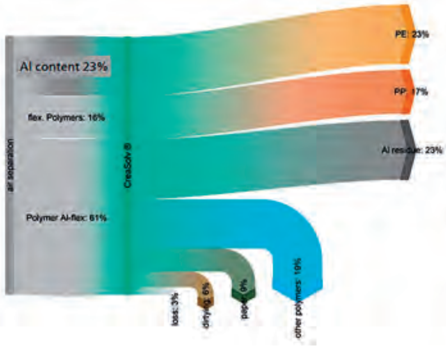


In close cooperation with Creacycle GmbH, the Fraunhofer IVV has developed the 'CreaSolv' process, a solvent-based technology capable of separating multi-layer-composites.

Plastic packaging solutions are of high value to the consumer market. Their set of intrinsic properties leads to a plastic share of 64% in the European packaging market. From this amount, more than 70% are used in flexible packaging applications. Flexible packaging often combines different materials, like plastic films, aluminium and paper, to achieve even more functionality. Such multi-layer-composites (MLC) grew significantly over the last decades due to their outstanding functional excellence, cost efficiency and sustainable use of resources.

However, at the end-of-life, MLC materials cannot be separated by industrial recycling technologies and hamper any material recycling from waste fractions that contain MLC. This concerns plastic recycling on the one hand and aluminium recycling on the other. MLC contaminate mechanical recycling streams of flexible packaging and cause significant losses along the circular plastics value



chain. Sorted aluminium fractions derived from waste packaging contain significant MLC shares and dilute the total aluminium yield from this fraction. Thus, the lack of industrial separation technologies limit yield and quality of sorted and recycled plastics and aluminium as well as economic benefits.

The 'CreaSolv' process, a solvent-based plastic recycling technology that is also referred to as dissolution or solvent-based purification, may serve a tailor-made solution to the MLC and aluminium issue. This technology physically dissolves a target polymer from a plastic containing waste mixture or composite, cleans the dissolved macromolecule from undissolved and dissolved contaminants and recovers a pure recycled polymer. It has been developed by Fraunhofer IVV in close cooperation with Creacycle GmbH, a supplier of tailor-made selective solvents, and applied to many different waste plastic including PE, PP, PLA, PET, PVC, ABS, PS, EPS, PA, PBT as well as their composites with fibres and metals including aluminium.

In 2020 Fraunhofer started a Glafri initiated and co-funded research project to investigate the benefit of solvent-based recycling for the recovery of polymers and aluminium from sorted Al fractions in detail.

The study started with laboratory scale CreaSolv trials on post-industrial waste of aluminium foil laminates and demonstrated its potential of separating a quadruple laminate into four pure target fractions: aluminium, PE, PA and PET. Purity analysis by FTIR and DSC revealed an excellent separation efficiency.

Thereafter, the purification challenge was increased and a non-ferrous metal waste fraction was derived from a standard packaging sorting line and was selected as infeed material. A detailed study with mechanical separation and cleaning steps as well as related composition analysis revealed a mixture of flexible aluminium composites and other flexible polymers as the most promising feedstock for the CreaSolv based separation and purification. This fraction was well separated from organic waste, solid aluminium, rigid plastics and contains amongst others 23% of aluminium, 23% of PE and 17% of PP.

Two strategies were tested to treat this material in a small technical scale CreaSolv procedure. The first strategy targeted at two separated and cleaned polyolefin fractions, PE and PP, to release an aluminium concentrate for subsequent pyrolytic cleaning and aluminium remelting. The second approach focused on production of a cleaned aluminium fraction, applicable to direct remelting, using a multistep extraction of PE and PP, followed by extraction of other polymers considered for disposal. Practical trials demonstrated the technical feasibility of both strategies.

For both strategies, initial business case calculations were based on the small technical scale results, which did not yet consider optimization potential or energetic synergies of CreaSolv and pyrolysis. The studies indicated a payback within three to five years for large-scale installation of >10.000 tonnes a year.

Overall, the recycling study clearly demonstrated both, technical and economic feasibility of the CreaSolv recovery of polymers and aluminium from post-consumer non-ferrous metal fractions. Thus, further upscale activities are planned and will in detail investigate process synergies, since the proposed technology unequivocally improves the circular economy of aluminium-laminate materials. ■