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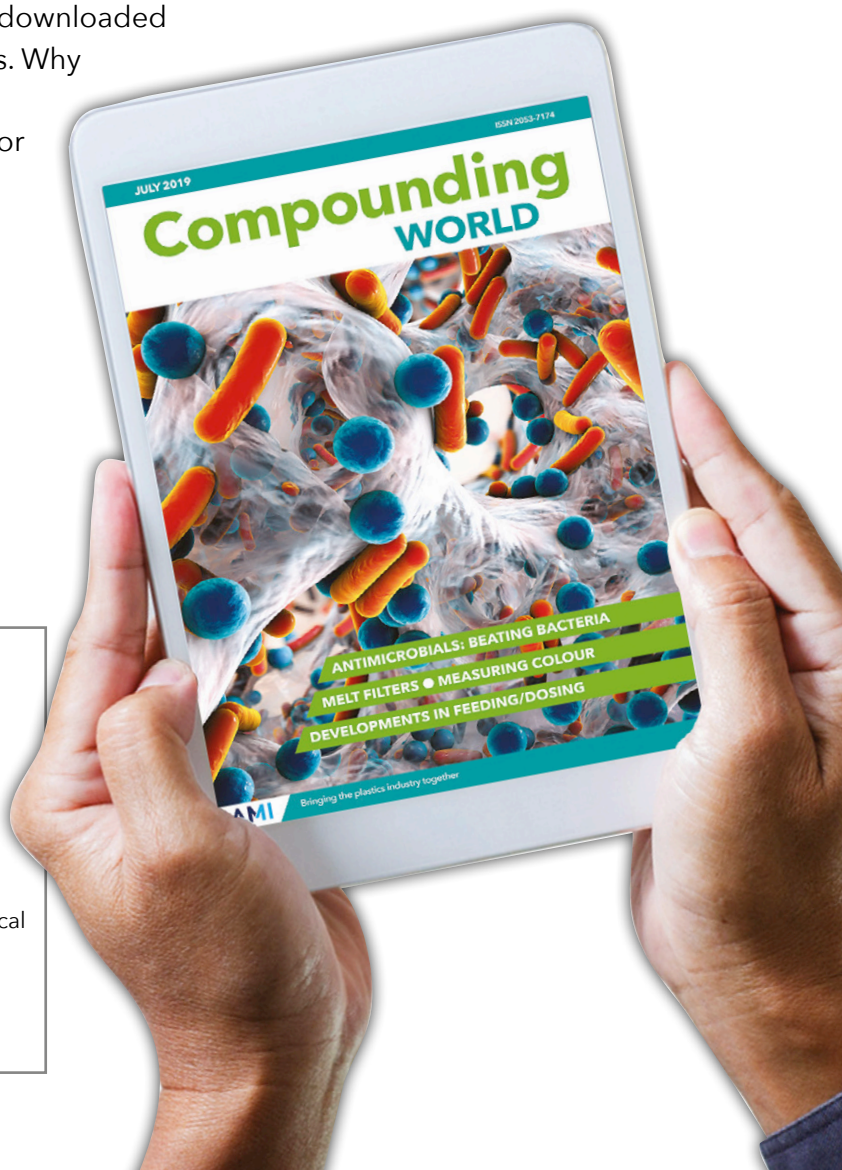

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Chemical recycling presents new opportunities for dealing with plastics waste but what does the technology involve? Who are the key players? And how does it fit in the established recycling hierarchy? Produced by AMI's Magazines and Consulting teams, Chemical Recycling Global Insights 2022 presents an easy-to-digest introduction to this rapidly-evolving sector.

COMING NEXT ISSUE

› Electrically conductive compounds › Additives for polyamides › Surface modification

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Ascend/BASF invest in PA66

Ascend Performance Materials and BASF both announced investments to increase global capacity for production of the PA66 feedstock hexamethylenediamine (HMD) at the beginning of this year.

Ascend said it had committed investment to build a previously announced new HMD and specialty chemicals plant at Lianyungang in China. Construction will start later this year with production expected to begin in the second half of 2023.

According to Ascend, the plant will be its first chemical production operation and its largest investment to date outside of the US.

"Our growth is driven by increasing market demand and growing collaboration with our customers globally," said Phil McDivitt, Ascend's President and CEO. "The materials we produce are helping drive technological transformations across markets, from e-mobility to automation. Our new HMD plant positions us to continue supporting these transformations well into the future."

Meanwhile, BASF announced it is to build a new 260,000 tonne/yr HMD plant at its Chalampé facility in France. Production is expected to start in 2024.

The company also said it is to expand production capacity for PA66 polymer at its site at Freiburg in Germany during this year.

The investments expand the PA66 business that BASF acquired from Solvay in 2020. "With this new HMD plant in Chalampé and the expansion of the polymerisation in Freiburg, BASF ensures that customers can be reliably supplied with HMD and PA66 while also addressing increasing demand in the market," said Dr Ramkumar Dhruva, President of BASF's Monomers division.

› **www.ascendmaterials.com**
› **www.basf.com**

Reagens grows in stabilisers

Reagens USA is to buy the Evans Chemetics' Thioester business, which includes the Evanstab family of secondary antioxidants and stabilisers.

As part of the deal the parties have agreed a transition period, during which Evans will supply Reagens with thioesters from its manufacturing plant at Waterloo in New York state. Over that period, Reagens said it will invest in additional production capabilities for the acquired products at its site in Pasadena, Texas.

As well as thioesters, Reagens USA produces tin and calcium-zinc stabilisers, as well as a range of lubricants. Its Italian parent also produces thioesters at its headquarters facility in Italy.

› **www.reagens-group.com**

Clariant to make FRs in China

Clariant is to invest around CHF60m (€58m) to build a first Chinese production facility for its Exolit OP range of aluminium diethyl-phosphinate (DEPAL) flame retardants. The plant will be located at Daya Bay in Guangdong province and will open in 2023.

The company said establishing local capacity for its Exolit OP products will enhance speed of delivery in China and other Asian markets, where there is growing demand for the flame retardant additives particularly from the electrical and electronic equipment industries.

Clariant is to build its first Exolit OP FR capacity in China

IMAGE: CLARIANT

Clariant said the move follows several other investments in China. It expects the country's share of its global sales to grow from 10% in 2020 to around 14% by 2025.

› **www.clariant.com**

Ampacet adds capacity in Europe

Masterbatch producer Ampacet is doubling capacity at its plant at Dudelange in Luxembourg with the addition of new colour production lines.

The company said the investment will reduce lead times and offer additional product delivery flexibility. "This colour investment is part of the overall strategy to better respond to customers' needs with respect to both quality and service," said Ampacet Europe Managing Director Marcello Bergamo.

The move follows previous expansions in 2017 and 2019 at the Dudelange site, which houses Ampacet's European headquarters, Colour Centre of Excellence, and European R&D lab.

› **www.ampacet.com**

Neste trial validates chemical recycling

Neste has concluded the first series of large scale trials, which it commenced last year, to process liquified (chemically recycled) waste plastics at its Porvoo refinery in Finland. To date, it has processed about 800 tonnes, with larger-scale trials planned for 2022.

"The tests validate that Neste is already able to process significant quantities of recycled raw materials to drop-in products for petrochemical use, while developing the capabilities to upgrade even larger quantities of waste plastic into even higher quality feedstock for petrochemical uses," the company said.

› **www.neste.com**

Akro Plastic and Highsun establish Chinese JV

German technical compounder Akro Plastic, part of the Feddersen Group, is to establish a joint venture compounding operation in China in partnership with Fujian Highsun Engineering Plastics.

Under the agreement, Highsun – a fully integrated producer of PA6 resins – will acquire a 51% stake in Akro Plastic's existing Akro Engineering Plastics (Changzho) business. Assuming regulatory approval is granted, the JV will begin operation early in Q2 of 2022 under the new name of Highsun Akro Engineering Materials (Changzhou).

Akro Plastic said it will provide Highsun Akro with research, development and engineering support. It will also license the JV company to use its ICX production technology and to manufacture and market all products the German company manufactured in China. It will retain exclusive rights to its brands, formulations and technologies outside of China.

IMAGE: AKRO PLASTIC

Above: Akro Plastic and Fujian Highsun executives celebrate signing the new JV agreement

Akro Plastic, together with its AF-Color and Bio-Fed divisions, has a global compounding capacity of around 180,000 tonnes and is a leading player in compounding of PA, in particular. It said the JV arrangement with Highsun will give its customers in China a secure PA6 supply and set the Changzhou business up to become a leading player in the country's engineering compounds market.

› **www.akro-plastic.com**
› **http://en.hscc.com**

Multi-phase solution for conductive 3Dprint

LATI3Dlab – a division of Italian compounder Lati – has developed a novel electrically conductive multi-phase compound for production of 3D print filaments for use in electronic, robotic and medical sensor applications.

The compound technology is being used by Filoalfa to produce its Alfaohm filament. It comprises a multi-phase material formulation of conductive PLA, containing multi-wall carbon nanotubes (CNTs) and structured carbon black, together with a dispersed elastomer.

This multi-phase approach allows an electrically conductive network to be achieved without compromising flexibility and 3Dprinting characteristics, according to Lati.

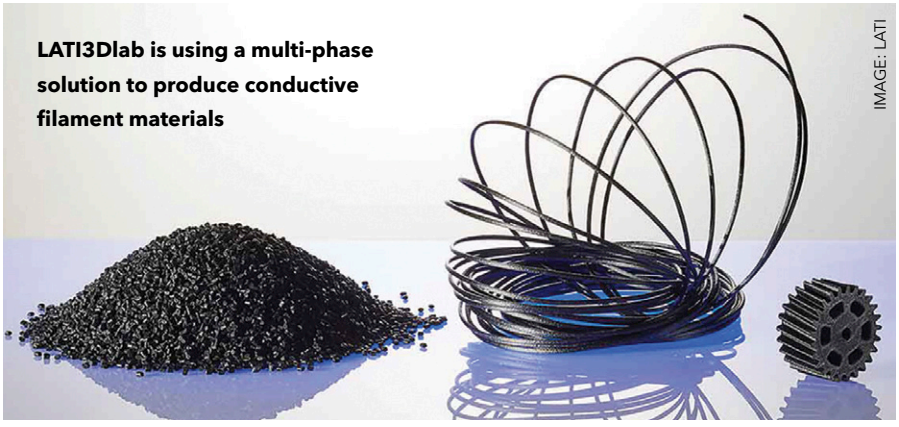

IMAGE: LATI

LATI3Dlab is using a multi-phase solution to produce conductive filament materials

The company said the Alfaohm filament has been successfully used at the Instituto Tecnológico y de Estudios Superiores de Monterrey in Mexico to 3D print a prototype electroanalytical conductive sensor for point-of-care medical applications.

› **www.lati.com**

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Benvic ups US presence with Trinity acquisition

European compounding group Benvic has extended its North American presence with the acquisition of Ohio, US-based Trinity Specialty Compounding from Ravago Americas.

Trinity is a custom compounder specialising in flame-retardant, cross-linked and specialty additive compounds for industries including wire & cable, appliances, and construction. The purchase was made through Benvic's US Chemres business, a medical compounds specialist it acquired last year in its first move in the US market.

Luc Mertens, CEO of Benvic Group, said: "We are thrilled that Trinity is joining the Benvic Group. This acquisition is part of Benvic's ambition to accelerate its development in the USA, initiated in 2021 with the acquisition of Chemres."

According to Benvic, the Trinity acquisition will allow Chemres to consolidate its presence in the US specialty compounds market and expand its current product portfolio. The company said it plans to grow compounding activities at the Trinity site at West Unity and strengthen the relationship with Ravago and its portfolio companies.

IMAGE: BENVIC GROUP

Above: The Trinity Specialty Compounding site at West Unity in Ohio in the US

"With Chemres, we were able to enter the US market and strengthen our exposure to the medical sector," Mertens said. "With Trinity, we are adding unique assets to our portfolio, helping us to better serve the needs of our international customers and forge new partnerships," he added.

Ravago Holdings America CEO, James Duffy said many of its portfolio companies, including Ravago Manufacturing, have long-standing relationships with Chemres. He said he expected to grow those relationships with Chemres and the Benvic Group in the future.

› **www.benvic.com**
› **www.chemres.com**

Graft Polymer lists on LSE

Slovenian compounding venture Graft Polymer has listed on the London Stock Exchange Main Market, raising £5m to expand and upgrade its research and production facilities, enable future IP registration, and increase inventory.

Founded in 2017, the company specialises in development of polymer modification and drug delivery systems to improve performance, reduce raw materials consumption, and enhance physical values of finished products.

Products include graft/block copolymers, reactive solid super-concentrates for polyolefin rheology modification, and high-temperature nano-structured PO/PA alloy elastomers for PA modification and cable applications.

› **www.graftpolymer.com**

Upcycled PP meets appliance demands

Below: A dishwasher base produced using upcycled PP in a Bosch/Fraunhofer project

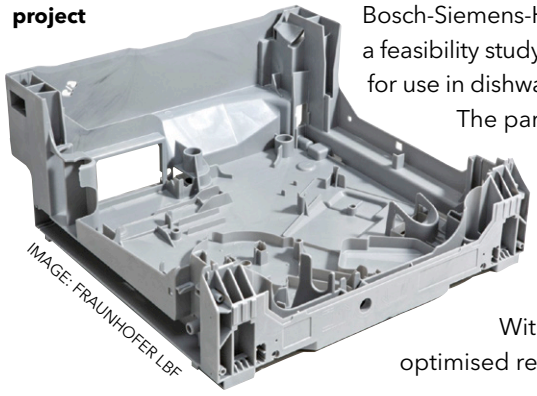

IMAGE: FRAUNHOFER LBF

Researchers at Germany's Fraunhofer Institute for Structural Durability & System Reliability (LBF), working together with Bosch and Bosch-Siemens-Hausgeräte, have completed a feasibility study to upgrade recycled plastics for use in dishwasher base supports.

The parts weigh around 2kg and form the basic structure of the dishwasher, holding the side walls and accommodating ancillary components.

Within the study, Bosch optimised recycled PP from car battery cases, using additives to enhance strength and aesthetic properties. Fraunhofer said that tests were then carried out to ensure the recycled material met the typical application requirements of large household appliances.

The recyclate was shown to provide similar stiffness as virgin plastic, albeit with 15% lower strength. Deformability tests simulating the loads and typical dishwasher thermal exposure of up to 50°C showed it would be feasible to use the recyclate in this application.

› **www.lbf.fraunhofer.de**

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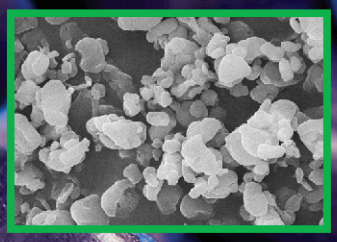

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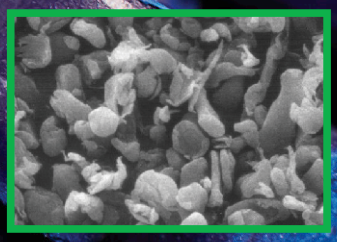

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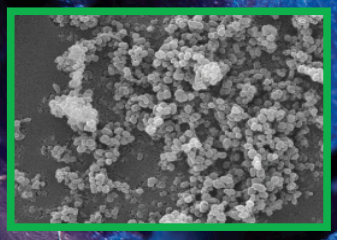
Natural Prime PTFE



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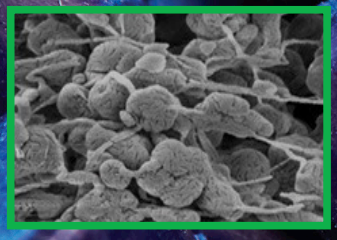

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IN BRIEF...

German pigment producer **Heubach** has completed the previously announced acquisition of Clariant's colorants business. Renamed Heubach Group and headquartered in Vienna in Austria, the company now has 19 manufacturing and sales of around €1bn.
www.heubachcolor.com

Spanish engineering plastics compounder **Repol** has commissioned a new Coperion ZSK 58 Mc18 extruder. The machine will increase production capacity and improve final quality, the company said.
www.repol.com

Huber Engineered Materials (HEM) completed the acquisition of RHI Magnesita's 50% stake in their Austrian-based Magnifin Magnesiaprodukte joint venture at the end of 2021. Magnifin produces coated and uncoated magnesium hydroxide flame retardants for use with thermoplastics and elastomers requiring processing temperatures above 300°C.
www.hubermaterials.com

Cargill buys Croda PTIC businesses for €915m

Croda International is to sell most of its Performance Technologies & Industrial Chemicals (PTIC) business to a wholly-owned subsidiary of US agri-products group Cargill for €915m.

The deal includes Croda's wholly-owned production facilities located at Gouda in the Netherlands and Hull in UK, as well as 100% of the Croda Sipo JV in China (in which Croda currently holds a 65% stake). Croda said if full ownership of the Sipo business cannot be achieved it will be excluded from the sale, reducing the deal value by €140m.

Together, the divested businesses accounted for 77% of PTIC's 2020 revenues of £470m. The transaction includes production and laboratory facilities supporting activities in smart materials, energy technologies, and industrial chemicals.

Croda said the deal is expected to close in the summer of 2022, subject to usual regulatory approvals and consultation with employee representatives. It is part of Croda's plan to focus its activities on sciences and consumer care; it had announced it was reviewing options for PTIC in May last year.

According to Cargill, the acquired business will "dramatically expand" its bioindustrial footprint. "Aligning with Cargill's commitment to sustainability, more than two-thirds of the raw materials used to manufacture these solutions are bio-based and renewable," the company said.

› **www.croda.com**
› **www.cargill.com**

Festool selects Wipag PA66

Industrial vacuum cleaner maker Festool is using a PA66 compound from Germany's Wipag containing 30% recycled carbon fibre content to produce its suction module pre-separators.

The WIC PA66 compound is electrically conductive, which prevents static build-up and discharge, and offers good impact resistance. Wipag, part of Otto Krahn Group, said it worked closely with Festool to ensure its sustainability, performance, safety and durability requirements were met.

WIC products are made using Wipag's carbon recycling technology, which sources carbon fibre from lightweight composite production waste.

› **www.wipag.de**

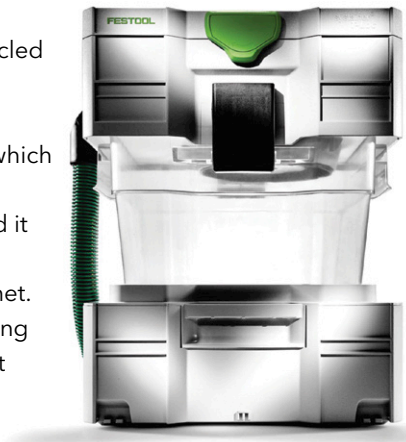

IMAGE: FESTOOL/WIPAG

Ineos joins food grade PP recycling project

Ineos Olefins and Polymers has joined the NextlooPP project, a UK technology collaboration aiming to manufacture food-grade PP from post-consumer recycled (PCR) packaging.

The Ineos/NextlooPP project aims to validate the manufacturing process and assess its commercial viability, with the aim of securing approval from the UK Food Standards Agency and EFSA in the EU. Carried out at the Ineos site at Grangemouth in Scotland, project results will feed into longer term plans to build a 10,000 tonnes/yr demonstration plant.

Currently, PP food packaging is produced from virgin material; the UK uses more than 210,000 tonnes/yr in this application alone. "This isn't unique to the UK but a large global issue that Ineos and its partners are determined to change," said Graham MacLennan, Polymer Business Manager at Ineos O&P UK.

› **www.ineos.com**
› **www.nextloopp.com**

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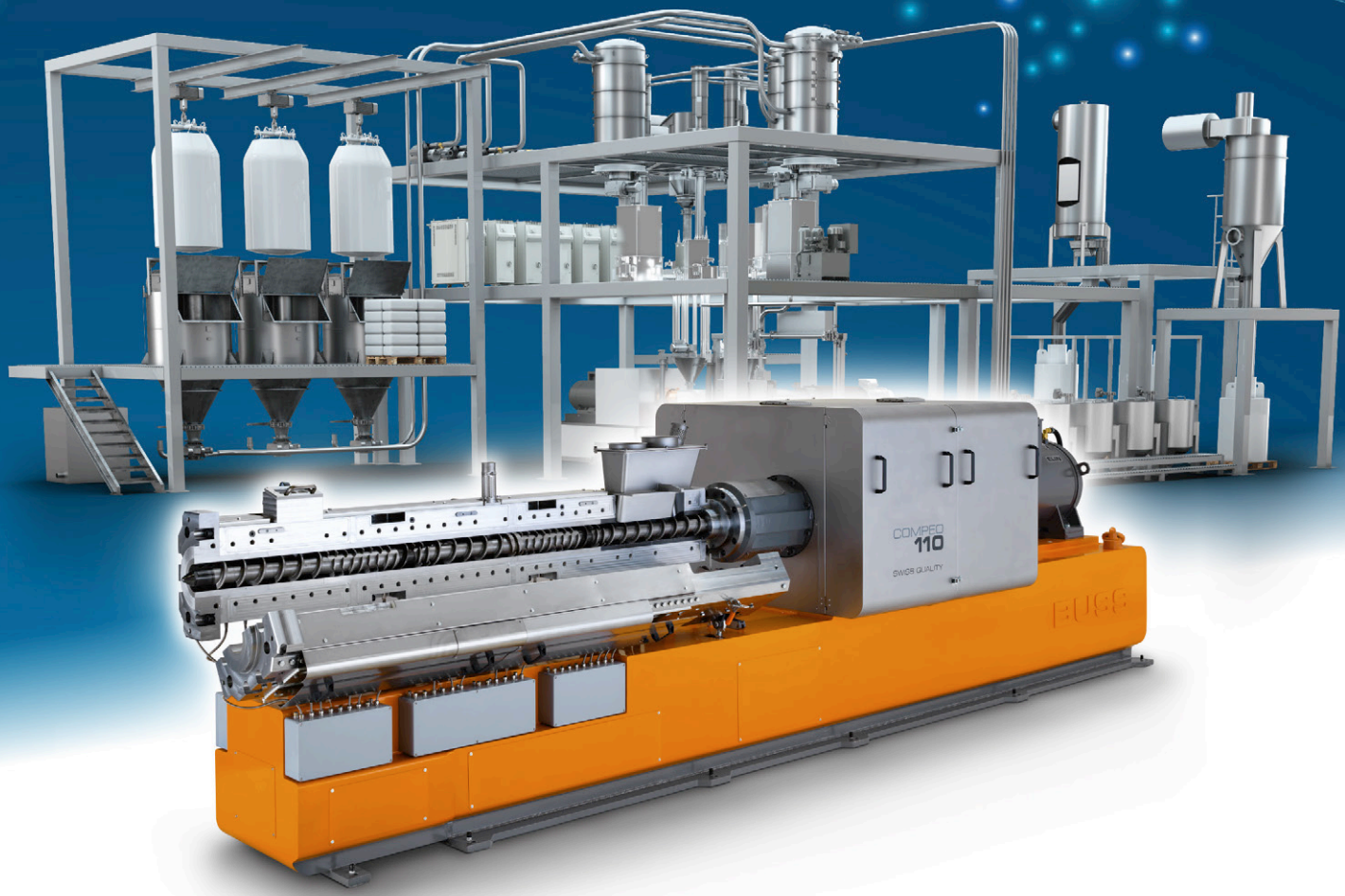

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Business calls for global UN treaty on plastics pollution

A group of multinational businesses has given support to a global treaty to tackle plastic pollution, which is set to be discussed at a meeting of the United Nations Environment Assembly (UNEA) next month.

"A new UN treaty is crucial to set a high common standard of action for all countries to abide by, and to drive the transition to a circular economy for plastics globally and at scale," said the group, which includes polymer producer Borealis and several plastics packaging converters: Alpla, Amcor, Berry Global, Evertis, Flexfilm, Greiner, Minipak, Mondi and Selenis.

The group said a global plastic pollution treaty would need to include upstream and downstream policies, reduce virgin plastic production and use, and decouple plastic production from consumption of fossil resources.

At the UNEA 5.2 meeting, due to take place in Nairobi in Kenya from 28 February to 2 March, an Intergovernmental Negotiating Committee is scheduled to discuss treaty proposals from various UN member states.

A resolution from Peru seeks a treaty encompassing circular economy objectives, while another to be tabled by Japan focuses on a treaty covering plastic pollution and waste management.

Information about UNEA 5.2 proposals was presented by Tim Grabiel from UK-based NGO Environmental Investigation Agency (EIA) at AMI's Plastics Recycling Technology conference in October. He said he was optimistic there would be enough support for a treaty to move ahead.

In January, the EIA published a report in which it said that "only a robust global treaty for plastics can address the problem".

› **www.plasticpollutiontreaty.org**

Entek bolts on materials handling with AEF deal

US-based twin screw compounding machinery maker Entek has acquired Adaptive Engineering & Fabrication (AEF), a specialist supplier of difficult-to-handle materials handling systems located at Placentia in California.

Entek has worked together with AEF on projects for many years and described combining the companies as a natural next step in the relationship. "Together we will be able to leverage our teams to better serve our customers," said Entek Manufacuring President Kim Medford.

"We will be even better positioned to share resources and deploy systems that will make building a plant or buying equipment solutions from the combined Entek AEF teams an even better experience," she said.

AEF will remain at its current location with its current workforce. Entek said as it expands manufacturing capabilities at its new plant at Henderson, in Nevada, it will build both extrusion and material handling equipment there to support the growth of the combined companies.

› **www.entek.com**
› **www.aef-inc.com**

Bolder acquires Pyrolyx plant

Colorado, US-based Bolder Industries has acquired the former Pyrolyx tyres-to-chemicals facility at Terre Haute in Indiana, which closed in March 2020.

Bolder plans to retrofit the plant, which has 6,000 m^2 of space, with its own technology for manufacture of BolderOil feedstock and BolderBlack recycled carbon black. It will invest some $40m in the initial phase, which is expected to be completed in early 2023.

The company claims its process uses 98% of the tyre material, with 75% of the solids and liquids going back into new tyres, manufactured rubber goods and plastics.

› **www.bolderindustries.com**

Coperion targets fuel cells

Coperion has joined the University of Stuttgart's Institute for Plastics Technology (IKT), Robert Bosch, and Matthews International/Saueressig in a joint project to develop bipolar plates for proton exchange membrane (PEM) fuel cells.

Coperion said the extremely high fill levels of more than 85% by weight "pose challenges upon the process technology, the likes of which have not been seen before". It aims to improve addition of fillers using its ZSK twin-screw extruder to avoid creation of agglomerates and degradation of the polymer during compounding.

› **www.coperion.com**

Moulding expo dates moved

Compounding World publisher AMI and Crain, publisher of *Plastics News*, have rescheduled the newly-launched Injection Molding & Design Expo (IMDE), which was due to be held in March in Detroit in the US, to 25-26 May 2022.

"Since launching the event, we have received widespread industry support for the format and location," said Andy Beevers, Events Director at AMI. "However, a number of companies have asked us to consider moving it from March to later in the year, when the plastics industry events calendar is less crowded".

Close to 50% of the booths at the free-to-attend expo have been sold, with participants including Absolute Haitian, Accede, Ampacet, Cavalier, Chroma Color, Conair, DME, EAS, iMFLUX, Incoe, KraussMaffei, M Holland, Mastip, Milacron, PCS, Progressive Components, StackTeck, Star Plastics, and Wittmann-Battenfeld.

The Injection Molding & Design Expo also features three free-to-attend conference and training theatres. View the programme **HERE**. Register your ticket **HERE**.

› **www.injectionmoldingexpo.com**

NanoXplore buys Canada's Canuck

Graphene producer NanoXplore has acquired Canuck Compounders in a deal worth around $9.3m, subject to post-closing adjustments. Both companies are located in Canada.

Canuck compounds engineered recycled plastic compounds for use in transportation, building and construction, agriculture and packaging at its facility at Cambridge in Ontario. It has a capacity of around 18,000 tonnes/yr and 40 employees. CEO and founder William Dickinson will continue in the role of General Manager.

NanoXplore CEO Dr Soroush Nazarpour said the acquisition "is strategically aligned with our growth initiatives and significantly increases our graphene compounding capability, especially in recycled plastics, and will enable us to form strategic partnerships with end customers".

The combination will also, Nazarpour said, enhance the firm's technical expertise in recycled plastic compounds and increase its revenues by about $20m annually. He said he expects revenues of about $85m for the fiscal year ending 30 June 30 2022.

› **www.nanoxplore.com**

› **www.canuckcompounders.com**

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Film additives target sustainability goals

Developments in additives for packaging films are increasingly focused on meeting the environmental and sustainability requirements of users. Peter Mapleston reports

IMAGE: SHUTTERSTOCK

Main image: Additive technologies can improve film performance and processing while enhancing recyclability

Performance and processing certainly remain important requirements in terms of film modification but it is very clear that many of the latest developments are responses to growing calls from both producers and users for improved sustainability. These developments address sustainability in different ways: they may make the film easier to process and recycle, or they may offer a more sustainable production chain through the use of renewable feedstocks or less energy-intensive manufacturing systems.

Regulation is a key driver. In the European Union, for example, all plastics packaging must by law be either reusable or recyclable in a cost-effective manner by 2030. And by that date, 55% of plastics packaging should actually be recycled. That is a challenging goal as flexible packaging can be deceptively complicated. Flexible packaging films frequently rely on a combination of multiple layers of diverse materials – PE, PP, PET, PLA, PA, EVOH, and aluminium, among others – to achieve the necessary balance of physical and chemical properties required to protect the packaged contents.

While highly effective in achieving their primary objective of product protection, these multi-material constructions present serious challenges when it comes to recycling. As a result, there is increasing pressure from various players involved throughout the supply chain to utilise mono-material structures whenever possible. Over the past few years, various solutions have been proposed. These mostly involve commodity polymers with improved physical characteristics – biaxially oriented polyethylene (BOPP) for example – or extremely thin barrier coatings rather than internal barrier layers.

Additives could provide an alternative route to the same end point. Additive supplier **Milliken** has developed its UltraGuard Solutions line of tailored

IMAGE: MILLIKEN

Above: Milliken's UltraGuard additives can improve moisture barrier and recyclability of polyolefin packaging films

masterbatches to enhance barrier properties in polyethylene. Milliken says the products have the potential to help film producers eliminate the need for metalized layers and to enable recyclable multilayer structures with good barrier to moisture.

In polyethylene-based structures, HDPE often is favoured over LDPE or LLDPE when higher levels of moisture barrier are required. Milliken says UltraGuard can enable HDPE to achieve a WVTR (water vapour transmission rate) below 2g/m^2/day in a 25-micron film.

HDPE is not always the best solution in terms of toughness and mechanicals, however, which is why monolayer films may require the use of blends of different types of PE – LDPE may be mixed with HDPE to achieve a more stable bubble or to reduce wrinkling, for example. According to Milliken, the reduction in barrier caused by the use of LDPE can be compensated for using UltraGuard.

Another option open to converters is to create a multilayer PE film with a core layer of HDPE inside outer layers of LDPE or LLDPE. In such constructions, the use of UltraGuard is claimed to help minimise the thickness of the HDPE layer needed to achieve the required level of barrier, so minimising the loss of other physical film properties.

Milliken says that UltraGuard functions by altering the orientation of the polymer crystals in the film to create a more tortuous path for permeation of molecules. So, in principle, it can be used to improve barrier not only to water, but also to oxygen, carbon dioxide, alcohols, fragrances, and other migratory chemicals.

Anti-fog agents are instrumental in maintaining consumer appeal, extending shelf-life and preventing wastage of food packaged in transparent film products. However, according to **Palsgaard**, which specialises in a wide range of additives for foods and also plastics, the use of additives in food packaging films has become a target of concern with regard to potential harmful effects on human health.

"There is good reason for this, since anti-fogs normally work by migration, and it is important to make sure that no traces of them will compromise the safety of the food," the company says. "This is why many synthetic fossil-based anti-fogs are subject to strict migration and concentration limits, which can be difficult to meet with innovative film structures for thin-wall packaging."

Renewable sources

Palsgaard's Einar anti-fogs are based entirely on renewable plant sources, which are also widely used in food additives. The company says they are not restricted by any migration limits and have full food-contact, kosher and halal approvals. "Moreover, as they migrate and increase the surface tension of the film, they develop outstanding anti-fog performance even at reduced concentrations, which maximises their cost-efficiency," according to Ulrik Aunskjær, the company's Global Industry Director, Non-Food Business Development, Polymer Additives.

"We are experiencing a fast-growing demand for our sustainable polymer additives among plastics and masterbatch manufacturers," says Aunskjær. "As highly effective and renewable solutions, they offer responsible choices to meet strict regular and high-performance requirements especially in ever thinner multi-layer film applications without compromising mechanical and barrier properties."

Einar anti-fogs are derived from polyglycerol esters, monoglycerides and other vegetable sources. The portfolio comprises migratory solutions tailored to PE, PP, EVA, and PVC packaging films. Grades are available in pellet, paste and liquid form, enabling dust-free blending in film extrusion compounds and masterbatches.

IMAGE: PALSGAARD

Right: Einar additive pellets from Palsgaard are plant-based and available in an easy-to-handle pellet form

Even the general-purpose paste product Einar 211 has been shown to work well in various types of PE as well as PVC mono-layer film formulations for both cold-fog and hot-fog applications at recommended loading levels of

IMAGE: AMPACET/SHUTTERSTOCK

Above: Ampacet's Fresh+ 1032AF masterbatch delivers antifog performance with improved FFS processing

0.3-0.6% and 0.2-0.4%, respectively. Other grades offer similar efficiency in coextruded and laminated polyolefin packaging films. These include Einar 422 for demanding hot-fog conditions in the packaging of hot food and microwave-ready meals in PP film structures, and the Einar 632 custom-made ester blend for PE greenhouse films.

For other packaging materials – such as PET, PS and some grades of BOPP – where internal migration is hindered by the crystallinity of the polymer or its chemical bonding to the additive, Palsgaard has developed Einar 1124. This is a solvent-free, water-based and thermally stable anti-fog coating, which can be applied by spray or roller and shows good performance in layers as thin as 25nm with surface concentrations from 50 to 150 mg/m².

Slip performance

Masterbatch specialist **Ampacet** has introduced Fresh+ 1032 AF (1001032-E), a new speciality antifog masterbatch for polyethylene flexible applications. Ampacet says it also offers very good slip performance and machinability on packaging equipment.

Applications for the new masterbatch are foreseen in grocery packaging for washed, pre-cut and ready-to-eat vegetables and fruit. In this type of packaging, fog and water droplets can form on interior surfaces of the film, affecting both shelf appeal and product shelf life. Fresh+ 1032 AF (1001032-E) is said to provide an attractive shelf appearance while its low coefficient of friction makes it highly suitable for the manufacturing of form, fill and seal (FFS) packaging. The additive can also be used in lidding applications.

"Fresh+ 1032 AF (1001032-E) demonstrates excellent antifog performance in barrier and non-barrier single wrap films as well as in laminated film structures and provides outstanding slip properties (COF < 0.25) without the use of a migrating slip additive," claims Ampacet.

Slip additives have been a speciality at **Croda** for more than 50 years. The company recently created a number of externally-verified case studies to illustrate the sustainability benefits that can be achieved by using its slip products. One among them investigates the carbon footprint of the company's Crodamide ER grade and the in-use sustainability benefit the additive can bring when used in LDPE film.

"The externally verified Life Cycle Assessments (LCA) of Crodamide ER shows that Crodamide ER has a negative carbon footprint, which means more CO_2 is removed from the atmosphere than is created during production," the company says. "These results are possible due to the use of bio-based raw materials and more sustainable manufacturing processes. The raw material supply is also back integrated which means there is full transparency of the supply chain."

Downgauging gains

The thinner a film is, the more difficult it is to process and handle. To enable further down-gauging, more slip additive needs to be added to ease handling. "In our example, Crodamide ER enables the LLDPE film to be made 33% thinner, while maintaining the same slip performance and

IMAGE: EVONIK

Above: Images show the surface quality of PP films without a processing aid (left), with 1% of a fluorine- based masterbatch (centre), and with 1% of Evonik's Tegomer 6850

handleability," says Croda. "This means that up to 33% less polymer is used to make a film that meets the same performance requirements, which also leads to a 33% reduction in transport emissions as less film is needed."

Over the past two years, **Evonik** has been boosting its portfolio of film additives a part of its ongoing sustainability efforts. It recently launched two new halogen-free processing aids (PPAs) – Tegomer 6810 and Tegomer 6850. These are based on the company's organo-modified siloxane (OMS) chemistry and are intended as alternatives to conventional fluorine-based elastomer PPAs. The company says an advantage of OMS PPA products is that they act as a permanent slip enhancer. In addition, it says they present no concerns in respect of recyclability labelling.

For films containing recyclate, Evonik also offers its Tego Sorb line of odour suppression additives. These include a 100% active odour absorber additive, Tego Sorb PY 88, intended for use by masterbatchers and compounders, as well as the Tego Sorb PY 50 PE and Tego Sorb PY 50 PP grades, which are already in masterbatch form.

The additives are based on zinc ricinoleate chemistry, which Evonik says reduces and eliminates odours evolving from various chemicals. "Differently from other odour control additives in the market, the Tego Sorb series work in accordance with the 'lock and key' principle by irreversibly binding odour-causing molecules rather than covering up or masking odours with a scent," says Ido Offenbach, Americas Segments Manager at the company and whose brief includes Specialty Additives.

Last year, the company also launched two new compatibiliser additives, Tego XP 21024 and Tego XP 21025, intended for mixes of recycled PE in PP and PP in PE. They act as process stabilisers and reduce the incidence of gels. Moreover, they are claimed to enable higher film production speeds by lowering viscosity and providing lubrication to prevent melt fracture and shark skin.

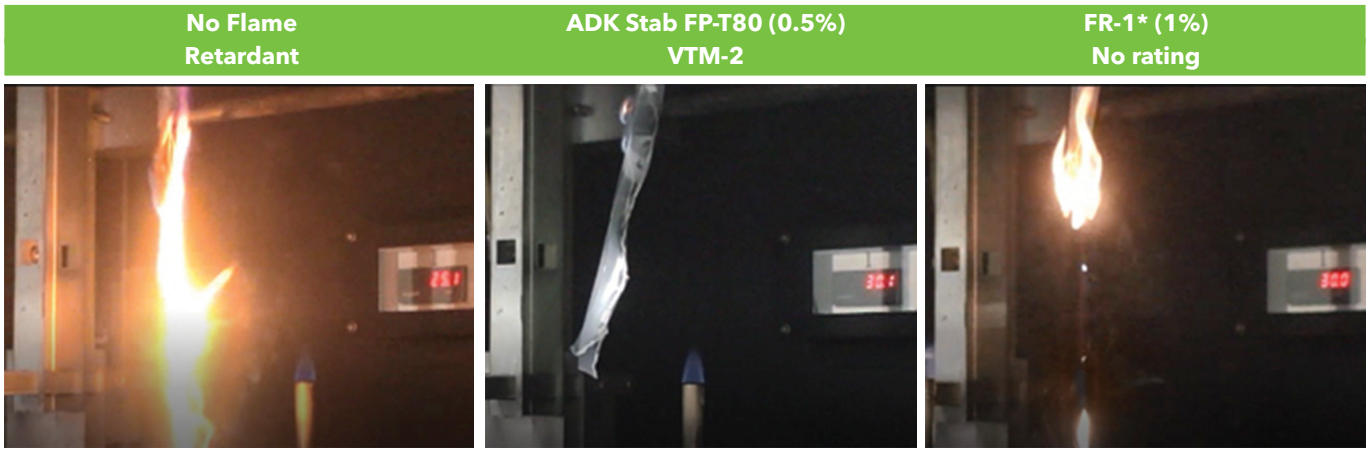
The Accurel direct and Accurel XP lines are two examples of the company's highly filled masterbatch technology. Accurel direct additives contain up to 80% by weight of active liquid ingredients used as antifogging agents, slip agents, antistatic agents, and antiblock agents. They are intended for use in mostly polyolefinic polymers. Accurel XP is an organic porous carrier technology based on thermoplastic polymers that allows customers to convert their own liquid additives into solid masterbatches.

"This technology allows a reduction in logistic costs," says Offenbach. "For example, to deliver 7.5 tonnes of additives in conventional masterbatch with 15% active ingredient, 42.5 tonnes of resin are needed and five shipping containers need to be used for transport; if an Accurel technology is used, with 75% active ingredient, only 2.5 tonnes resin is needed and one shipping container." Both product lines are said to be free-flowing and easy to dose.

A new addition to the film additive line up is anorthosite, a multi-functional additive that Canada's **Hudson Greenland** has recently started mining in Greenland. Branded as "Greenspar," this white mineral is a calcium aluminium silicate sourced from a high-purity deposit (at White Mountain in Greenland) and is said to hold potential for use in antiblock applications in polyethylene film. The company is also optimistic over finding uses in other areas as well, predominantly in combination with non-polar polymers.

Hudson Greenland says several customers are currently sampling the mineral. In polyethylene film, Greenspar matches the refractive index of the polymer to provide very good clarity as well as highly efficient anti-blocking performance, according to company CEO Brian Hanrahan.

Flame retardancy is not a property generally associated with packaging films but it is an



Above: Images showing UL94 VTM (Vertical Thin Material) fire resistance testing of a 200-micron MFR 2 LLDPE film with no flame retardant, ADK Stab FP-780, and a competitive traditional NO-Alkyl FR *Source: Adeka*

increasingly common requirement in highly technical applications, where the direction of development is towards halogen-free types.

Halogen-free flame retardants such as P-N (phosphorus-nitrogen) intumescents and metal hydroxides are found in electric and electrical devices, including wire & cable, where they offer the benefit of low smoke emissions alongside 'green' credentials. But they are considered less suitable for films due to the high loadings typically required to obtain the desired fire performance, which makes processability of the compounds a critical issue.

Tackling fire

One of the latest halogen-free flame retardants from **Adeka** that is suitable for use in films is ADK Stab FP-T80, which is based on NO-Alkyl chemistry. This liquid additive is said to have proven high flame retardant performance at loadings as low as 0.5-1.0% while also providing good processability in applications such as polyolefin films and fibres. The additive acts as a radical generator during combustion and prevents fire spread by avoiding dripping as well as contributing to the gas-phase radical reaction.

Adeka highlights the example of a 200-micron LLDPE film containing 0.5% of ADK Stab FP-T80, which achieves a VTM-2 flammability rating according to the UL94 VTM (Vertical Thin Material) test method. The company says that in its tests the novel structure of ADK Stab FP-T80 enabled it to offer performance superior to that of an alternative NO-Alkyl type FR product. "Furthermore, results from horizontal test methods such as FMVSS 302 show that ADK Stab FP-T80 substantially suppresses the rate of flame spread," says the company. It adds that the additive preserves translucence of polyolefins and allows coloration.

NO-Alkyl compounds also act as light and heat stabilisers. "Therefore, ADK Stab FP-T80 may be considered for exterior applications including tents and sheets for building & construction applications," Adeka says. According to the company, a test sample of a 200-micron PP film incorporating 1% of ADK Stab FP-T80 exhibited self-extinguishing behaviour and achieved a B2 rating under the German DIN 4102 standard covering fire behaviour of building materials and elements.

Another company offering a novel development in flame retardants for films is **Inovia Materials**, with its ionic liquids (covered in more detail in the December 2021 flame retardants feature in *Compounding World*). Ionic liquids containing elements such as phosphorus, nitrogen, and sulphur can be used as halogen-free flame retardants. Structures can be tailored to work with different plastic materials so that processability can be improved, while optical and mechanical properties can be maintained.

When used in combination with traditional flame retardants, ionic flame retardants are claimed to improve compatibility between the additives and the plastic, further enhancing flame retardant performance and mitigating negative effects on physical properties. Inovia has registered its products in various key markets and registration in others is said to be ongoing.

CLICK ON THE LINKS FOR MORE INFORMATION:

- **www.milliken.com**
- **www.palsgaard.com/polymers**
- **www.ampacet.com**
- **www.croda.com**
- **www.evonik.com**
- **https://hudsonresourcesinc.com/**
- **www.adeka.co.jp/en**
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Compounders face testing times

IMAGE: SHUTTERSTOCK

Supply chain pressures and increased use of recycled materials will see a shift of quality control from lab to production and put more emphasis on polymer testing and analysis in compounding operations, write Mark Holmes

The need for simple and accurate product characterisation of polymers is gaining in importance to ensure that compounds continue to meet required quality and performance requirements. Increased use of recycled polymers, with their inherent higher levels of variability, together with demand for high performance compounds for emerging markets such as electric vehicles are just two examples driving demand for rapid, reliable and accurate testing and analysis. In line with the parallel trend to 'close the loop' on quality testing, results are increasingly being required on the production shop floor as well as in the laboratory.

International testing, assurance, inspection and certification group, **Intertek** sees a number of factors driving today's demand for polymer testing and analytical services. "Supply chain disruption has been a major issue driving the market," says Julie Mason, Delivery Manager at Intertek Wilton in the UK. "Against a background of already complex global supply chains, which have been impacted by Covid-19, businesses have had to look at alternative materials or ingredients, such as additives or for new suppliers. This has driven the need for analytical testing to ensure that materials are of the same quality and meet the same performance specifications."

Meanwhile, Chantal Haarmann, Business Unit Manager Polymers at the Intertek Polychemlab in the Netherlands, says: "Another important driver we have observed is the need for polymer testing to support the development and applications of post-consumer recycling. To make a circular economy for plastics a reality, the recycling processes, the 'recyclability' of materials and the quality and performance of resulting materials must be assessed through robust materials evaluation programmes."

There are a number of important points plastics compounders and masterbatchers need to consider when selecting polymer testing services, according to Intertek. "When considering recycled polymers and where recycled materials are mixed with virgin polymer, plastics compounders and masterbatchers are facing challenges in identifying

Main image: Changing supply chains and more variable recycled materials are likely to lead to more material testing by compounders

Right: Increased use of recycled resins means additional testing to manage inherent variability

and measuring the amount of recycled polymer that has been added," says Malcolm Beckett, Senior Experimental Scientist & NMR Specialist at Intertek Wilton.

"It may be possible to measure masterbatch composition using Nuclear Magnetic Resonance (NMR) if all constituents are known, it is soluble, and the constituents can be detected; however, it cannot measure recycled polymer content," he says. "Currently, the industry does not have methods to identify or measure the amount of recycled material in a product. This is mainly because, for example, polyethylene 'looks' like polyethylene to techniques traditionally used for identification such as NMR, regardless of whether it is recycled or virgin polymer. Further research is required to fully understand the impact of polymer quality on recycling. For example, how many times can a polymer be recycled before it is unfit for purpose?"

Haarmann adds that another challenge in analysis of recycled products is making a comparison with virgin materials - it is known that recyclate can vary according to origin and cleaning processes, for example. This applies to both the physical and mechanical properties, as well as the chemical safety where the materials could include potential hazardous impurities that may migrate out in particular use scenarios.

Pandemic effects

Covid-19 is also driving new developments in polymer analysis. Mason says that an interesting result of the pandemic is that it has brought together new groups of stakeholders with different expertise. She cites, for example, engineering companies, materials specialists and testing experts that may have been pulled together to solve problems related to supply and production of critical polymer components for products such as respirators or PPE. She says these new networks are playing a key role in ongoing innovation and partnership in the polymer sector.

In general, Covid has demonstrated that more flexibility and agility in polymer supply chains is required, according to Haarmann. She says having a Plan B covering materials and suppliers has become more important than ever before, particularly across the automotive, packaging and medical devices sectors. A core part of an agile supply chain is the ability to be able to deliver materials which meet the required specifications, which she says is simpler when working with polymer testing partners that can drive insight into material evaluation and validation with application-specific knowledge. As a consequence, many

IMAGE: SHUTTERSTOCK

organisations are using strategic outsourcing of laboratory services to help them remain competitive.

Recycling certainly ranks high among opportunities for new solutions in polymer analysis. "Considering materials where post-consumer recycled content (PCR) has been incorporated, new analytical approaches are required to help understand how long these new materials can be kept in productive use," says Mason. "These approaches could drive insight into how many times they can be recycled whilst still meeting performance specifications and criteria for quality and safety. This is a challenge that is further compounded by the fact these materials may not be produced consistently of the same quality."

Haarmann says another question regularly asked by potential clients is how 'processable' is a particular recycled compound. She says Intertek has developed programmes to assess if materials can be processed by injection moulding, cast moulding, or as blown films that include subsequent evaluation of key physical and mechanical properties. Such studies can help drive insight into the recycling process and the functional properties of the recycled materials and support decision-making on end-use applications.

Other key areas of development in polymer analysis include increased digitalisation and the use of big data and modelling techniques, according to Haarmann. "Enabling production continuity, meeting compliance with environmental legislation such as stack emissions and wastewater, as well as ensuring value of feedstocks and polymer products are all areas which can benefit from big-data tools and process-analytical technologies," she says.

"Analytical technologies are improving, and this

Selecting the most appropriate testing techniques depend on various factors, including the purpose of the test, the point in the manufacturing chain it will take place, ease-of-use, sensitivity and level of automation, says PerkinElmer

What am I testing?	Most used by	When am I testing?	Technologies
Identification	• All	• On arrival • During recycling sorting process	• FT-IR, IR microscopy • DSC
Mechanical and thermal attributes	• Compounder • Converter	• Throughout research and development • Final product and packaging	• DSC, DMA, TMA, TGA
Impurity testing	• Raw material supplier	• End of raw materials production	• FT-IR • ICP-OES, ICP-MS
Residual monomers and contaminants	• Resin producer • Compounder • Recycler	• Pre-shipping • On arrival • Production checkpoints • End of the recycling process	• IR microscopy • GC, GC/MS • ICP-OES, IC-MS
Crystal orientation	• Compounder	• End of manufacture • Pre-shipping	• FT-IR
Toxins	• Converter • Recycler	• Final product and packaging	• GC, GC/MS, HPLC, LC/MS • ICP-OES, ICP-MS
Leachates and volatile emissions	• Converter	• Final product and packaging	• FT-IR, IR microscopy • GC, Headspace, GC/MS, HPLC, LC-MS/MS • ICP-OES, ICP-MS • Hyphenation TG-IR, TG-GC/MS, TG-IR-GC/MS
Failure anaysis and reverse engineering a material	• Compounder	• Throughout research and development	• FT-IR, IR microscopy • GC, LC • DSC, DMA, TMA, TGA • ICP-OES, ICP-MS • Hyphenation TG-IR, TG-GC/MS, TG-IR-GC/MS

Source: Perkin Elmer

leads to new opportunities to apply portable application testing (PAT). We are increasingly working with our clients to develop bespoke PAT solutions to enable measurement of chemical components or physical properties directly in process streams. This allows real-time insight into the process and products, allows detection of problems such as low or high levels of substances and early awareness of potential production issues," she says. "Having the right PAT in place for critical processes that delivers accurate data can drive confidence in the ability of the plant to deliver first-class product and performance goals where margin pressure and cost control are constant issues."

Assuring quality

According to **PerkinElmer**, the need for testing and assessing the quality of polymers is growing alongside manufacturers' moves to deploy comprehensive polymer quality assurance programmes. "There are many factors to consider when deciding on the best method for polymer testing applications," says Gerlinde Wita, Global Market Manager, Materials, Energy & Petrochem. "These include the purpose of testing and the point in production when it will take place, as well as the scalability, ease of use, sensitivity and automation potential of the instrument."

Wita says, for example, that while testing for identification purposes might require the use of infrared spectroscopy (FT-IR) solutions, testing for toxins may require the use of gas chromatography-mass spectrometry (GC/MS).

"In addition to testing considerations, the production of polymer compounds and masterbatches also requires labs to gain a competitive edge at all stages from research and development (R&D) to quality and safety. The key to this is often hyphenated equipment - the coupling of two or more instruments to increase the power of analyses and throughput," she says.

"To ensure maximum safety both in labs and for those further down the supply chain, there is a separate set of features regarding the ease-of-use of equipment that must also be considered. These include the robustness, size, portability, automation capability and a common shared software platform between instruments to ensure a smooth operation within the lab. Combined, this guarantees the best possible sensitivity and resolution capabilities to best assure the quality of the final product," says Wita.

According to PerkinElmer, one of most pressing drivers in testing equipment innovation is the need

to safeguard consumer health by assuring the quality of polymers. This is evidenced by the number of areas that are tested for quality assurance, from impurity testing of raw materials to examining final products and packaging for leachates, volatile emissions and toxins.

The other significant influence is the increasing global awareness of our environmental footprint, says Wita. To assure the highest possible quality of recycled polymers, it is important to pre-sort plastics. This means testing and analysis is critical and may often take place before the recycling process even begins. This allows for classification of plastic types, measurement of the crystallinity of semi-crystalline polymers and material characterisation, all of which are vital in assuring the quality of the material output.

At present, PerkinElmer says that there are two primary problems that the industry is working to solve. "Firstly, there is the need to support the move towards a circular economy and to improve the recyclability of polymers," says Wita. "To do so, we need to improve the speed at which the sorting and analysis of recyclable waste materials can be performed, in addition to improving our understanding of how specialist analysis improves the quality of the final materials, allowing for them to be put to the best possible use as they return into the cycle. FT-IR deployed through systems such as the Spectrum Two is presently the most common choice for analysis of polymers for quality assurance and control due to its high-speed, ease-of-use and ability to perform non-destructive analysis."

The second problem the industry is working to tackle is how to simulate accurately the thermal conditions a polymer may experience when it is implemented in a product, such as when it is used in injection moulding. Wita says the solution usually offered for determination of thermal properties such as melting point and glass transition temperature (T_g) is differential scanning calorimetry (DSC). However, the most common type of DSC, heat flux DSC, typically uses heating rates below 50°C/min. Considering the injection moulding process often takes place in less than 30 seconds, she says this does not accurately simulate the conditions a polymer will experience.

Perkin Elmer argues that Hyper DSC analysis using instruments such as PerkinElmer's DSC 8000/8500 allows for controlled heating rates up to 750°C/min, providing a more accurate simulation of the process.

Hyphenated options

Wita says another way the company is aiming to meet the expanding needs of industry is through its expansion of hyphenated solutions. For example, hyphenated Thermogravimetric – Infrared Analysis (TG-IR) provides powerful insight by pairing a thermogravimetric analyser with an infrared spectrometer for evolved gas analysis. When further hyphenated to TG-IR-GC/MS, this can present a very powerful combination that provides separation, identification and trace-level quantification all within a single workflow. Using hyphenated workflows such as these provides more information in less time.

"The future of polymer testing lies in the development of solutions that allow for great speed and ease-of-use, helping labs to keep pace with the growing demand for high-quality polymer solutions," says Wita. "I believe that through hyphenated analysis and software which is consistent across instruments, labs of the future will be better optimised to run the barrage of tests to meet their needs, making the ease of recycling and innovating in the polymer industry easier than ever before."

Seeking answers

Analytical polymer testing equipment touches every aspect of the plastics process chain, from resin polymerisation to compounding and conversion. "At each step, scientists and engineers in R&D and Quality Control need answers to understand and control key parameters such as melting point, crystallinity, melt stability, processability and blend compatibility, for example," says Dr Bharath Rajaram, Senior Market Development Manager, Chemical & Materials Science at **TA Instruments**, a division of Waters Corporation. "Analytical testing provides these answers, allowing them to make time-sensitive decisions

IMAGE: PERKINELMER

Right: The Spotlight IR infrared microscope from PerkinElmer allows detailed exploration of a polymer sample's structural composition

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IMAGE: TA INSTRUMENTS

Right: DSC equipment such as TA Instruments' DSC X3 can reveal small variations in crystallinity in recycled and virgin plastics

in product development and product environments. As companies accelerate their product development timelines, the demand for analytical testing equipment and services continues to grow."

Rajaram identifies a number of factors that plastics compounders and masterbatchers need to consider when selecting polymer testing and analytical equipment. "The first and foremost factor is around the data quality and equipment reliability," he says. "Data quality is driven by the analyser's sensitivity and resolution – instruments with greater sensitivity allow the user to pick up on subtle signatures that can make the difference between good and bad batches. Next, precision and accuracy are important since analytical data are used to establish limits for go/no-go criteria – for compounders, confidence in their analyser's data allows them to stand by their products when it is shipped to their customers. Finally, analysers that are easy-to-use and offer a straightforward test setup with integrated data analysis greatly enhance the lab's productivity, increasing sample throughput and driving profitability."

The plastics industry is responding to heightened consumer awareness around the environmental cost of plastics waste, says Rajaram. In addition, brand owners have made public commitments to incorporate minimum percentages of post-consumer recycled (PCR) content in their packaging. For plastics compounders, this requires combining waste plastic feedstocks with virgin material to meet their customers' – the brand owners – commitments.

Compared to virgin resins, waste plastic feedstocks are inherently variable and often contain contaminants, such as incompatible polymers. A common example is the presence of polypropylene (PP) in bales of recycled post-consumer polyethylene (PE). In addition, it is critical to screen the recycled resin for banned additives and substances, since the presence of these contaminants can relegate the resin into lower value applications. Compounders need to be able to identify and understand their incoming feedstock to mitigate downstream effects using appropriate additives.

Determining the variability in an incoming feedstock requires testing additional samples in each batch to ensure statistical validity of the results. For analytical labs, easy-to-use reliable equipment is required that can provide rapid results that meet their planned project timelines and production schedules. In particular, equipment that can simultaneously screen multiple samples offers labs a competitive advantage by significantly reducing their test time. Labs can also benefit from equipment that can directly combine two or more techniques, providing scientists and engineers access to additional information that is not available through stand-alone testing.

Rethinking testing

Polymer testing labs are also applying existing techniques in new ways in response to the shift towards sustainability and recycled resins. "For example, differential scanning calorimetry (DSC) is traditionally used to study the melting point and crystallinity of polymers," says Rajaram. "With recycled resins, the DSC's trace can reveal small differences in the crystallinity of the recycled

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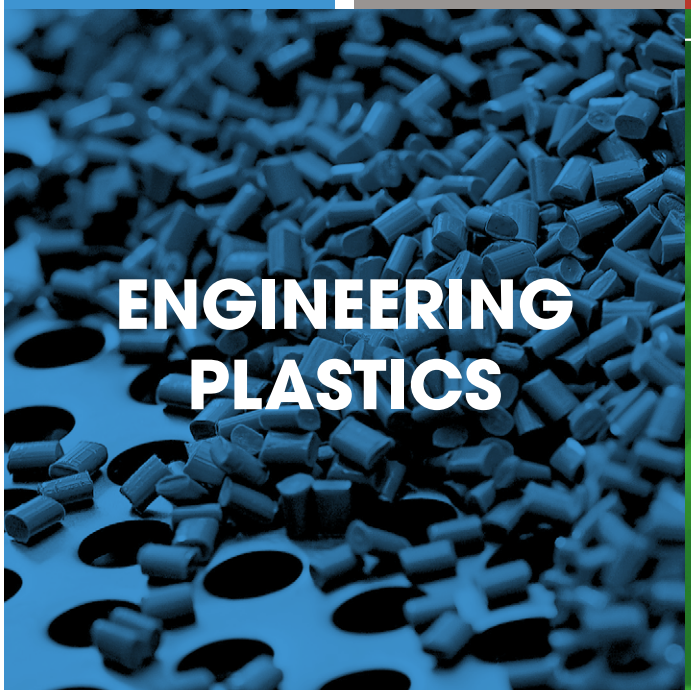

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feedstocks compared to virgin resin, which can affect the final product's flexibility and optical clarity.

"Another popular technique, thermogravimetric analysis (TGA) reports the weight change in polymers on heating and can provide information about polymer degradation and stability. When TGA is combined with complementary techniques like mass spectrometry (MS) or Fourier transform infrared (FTIR) spectroscopy, labs can obtain detailed insights into the chemical identity of the decomposition products, such as additives and fillers."

TA Instruments offers a comprehensive range of thermal analysis, rheology and mechanical testing equipment that directly provide solutions for the polymer industry. These include the Discovery Series DSCs, multi-sample X3 DSC, and TRIOS software platform.

According to the company, its Discovery Series DSCs provide the flat baseline performance required to identify the weakest thermal transitions that might be present due to trace quantities of additives or contaminants. The new Multi-Sample X3 DSC provides the ability to test three samples simultaneously on the same instrument, accelerating productivity at every level of materials testing and allowing replicate testing and statistical analysis to be carried out in a single test.

The TRIOS software platform, used across TA Instruments' suite of thermal analysis and rheology equipment, offers a combined instrument control and data analysis package. It is said to eliminate the need to learn multiple programs, decreasing training time and increasing efficiency, while its TRIOS AutoPilot feature allows users to create automated routines to further reduce training requirements.

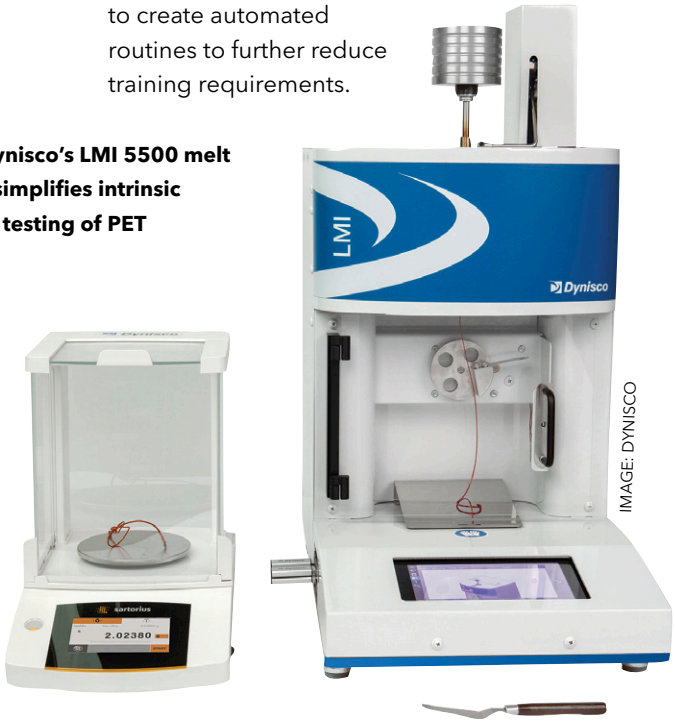

IMAGE: DYNISCO

Right: Dynisco's LMI 5500 melt indexer simplifies intrinsic viscosity testing of PET

Crystallinity concerns

One of the areas where its DSC equipment is being employed is in quantifying and controlling the crystallinity of recycled PET (rPET) resins. TA Instruments says this is especially important when rPET is used to produce parts for automotive and aerospace applications, where crystallisation behaviour can be affected by differences in molecular weight and impurity content in the rPET feedstock. DSC tests only require a few milligrams of material per run, which it says is a real positive for compounders, masterbatchers and converters.

Waters Corporation and TA Instruments says that many of its future developments will support the compounding and masterbatch industry as it transitions from virgin resins to PCR materials, which will require analytical solutions that support the increased need for routine chemical identification of polymer samples as part of quality control. The newly introduced RADIAN ASAP mass detector from Waters Corporation offers rapid, easy, low-cost mass spectrometry analysis of polymer samples within a compact benchtop footprint. Further, evolved gas analysis (EGA), achieved by combining TGA with techniques such as FTIR/MS/GC-MS, will continue to gain importance due to the increased variability and contamination present in incoming feedstocks.

According to Johannes Lorenz, Sales Manager, **Dynisco Europe**, global initiatives for recycling and the circular economy have proved to be significant drivers for polymer testing and analytical equipment. "The market is growing in its need for tools that will improve quality and throughput," he says. "The demand for more recycling content requires dealing with various raw material sources, which makes stringent quality control along the process chain a key factor. In addition, the equipment needs to provide accurate results over a large range of products and applications. Ease-of-use and a quick understanding of method and operation also becomes increasingly important as quality control moves towards the production floor."

Lorenz highlights a number of further development trends in polymer analysis. These include quick adaptation for product changes so that analytical services and quality control can follow a flexible production schedule, as well as making results accessible quickly, if not in real time. Training on methods and equipment also need to be tailored to customer needs and be accessible regardless of the location through e-learning, remote learning, case studies and white papers, for example. In addition, solutions are being developed for increased recycled content and new

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IMAGE: C-THERM

Above: Testing thermal conductivity of a carbon fibre composite using C-Therm's Trident equipment

types of materials, such as biodegradable and renewable plastics.

Cloud-based solutions

With these demands in mind, Dynisco has extended its range of inline rheometers to make the technology more accessible for the mass market, including applications in recycling and toll compounding. It has also developed cloud-based solutions to improve visibility throughout the production chain and across remote locations, as well as making results accessible anytime and anywhere. Melt indexers and some of the inline rheometers are now based on an Industry 4.0/IoT platform to improve usability, making them more flexible for new developments in cloud-based services. These include sharing analytical results but also enabling remote servicing and learning, for example.

The company highlights its melt indexer LMI5500 , which offers accuracy to standards such as ISO1133-2. It provides a reliable correlation between melt index and intrinsic viscosity of PET, which eliminates the need to work with dangerous solvents. Meanwhile, the ViscoIndicator is an inline rheometer offering easy installation and operation. It is especially useful for new users of inline viscosity measurement, allowing them to monitor quality in real-time easily and minimise off-spec production and waste.

In terms of recent applications, Lorenz cites the company's involvement in studies covering inline measurement of viscosity of starch-based polymers. "These materials are very difficult to analyse off-line because the process conditions cannot be replicated in a lab environment," he says. "Inline viscosity measurement helped to understand the flow behaviour better, which then helps to design better machinery for these types of materials."

Inline viscosity measurement can also greatly improve production efficiency in PET recycling by providing a more accurate and real-time process insight compared to traditional temperature and pressure measurements. While in PE and PP recycling, it provides options to control and monitor viscosity in production in real time, such as dosing of viscosity modifiers, blending of different sources, or classifying product.

Thermal characterisation

A new and growing area of interest in testing technology is in understanding thermal behaviour of plastics, according to **C-Therm**. "With the rapid growth of innovation in the electrification of transportation, battery technologies and plastic injection moulding, better understanding of a materials' thermal conductivity, particularly those with novel composition and anisotropic thermal behaviour, has been a critical performance attribute," says Jarett Nickerson, Vice-President, Sales & Marketing.

"As polymers continue to replace traditional materials for heat transfer, such as ceramics and metals, altering their thermal behaviour and understanding its effects has become a common issue driving the market," he says. "In addition, compounders and masterbatchers have seen a growth in demand for properly understood thermal properties of their materials by their customers. As a supplier, it is critical that the reported and claimed characteristics of the material, particularly thermal conductivity, is accurate and representative for buyers to understand its effects on their thermal models and the end-user scenarios. A proper understanding of thermal conductivity, in all relevant axes for anisotropic materials, is of critical importance to improve thermal models and ensure thermal runaway will not occur in the end design."

Nickerson says that testing of polymers in their melt phase, or in the case of plastic injection moulding their processing phase, is a challenge due to the volatile temperatures and pressures that traditional thermal conductivity testing methods cannot replicate. C-Therm's recent release of a high temperature/high pressure needle probe was developed to address this problem directly, allowing for accurate thermal conductivity analysis in these unique environments.

Other current technical areas of interest in thermal conductivity testing of polymers include understanding anisotropy. "When materials have different properties in different axes, this cannot be overlooked," says Nickerson. "Our Trident thermal conductivity instrument with the Modified Transient Plane Source (MTPS) and Flex Transient Plane

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Source (TPS) methods allows unbiased exploration if a material exhibits these properties."

He says the ability to replicate environments that affect thermal transport properties is also important. "From harsh environments of a cold winter (-50°C) to the melt phase of a polymer (200-300°C) there can be drastic changes in thermal conductivity. With environmental control chambers and speciality testing cells, real-world testing of thermal conductivity in these environments can be accomplished."

There are also particular challenges in measuring and characterising the thermal properties of thin films. "As a material enters the range below 0.5mm, its inherent thermal properties can change – meaning traditional test methods that require larger or thicker samples do not present relevant data. With the TPS thin film module on Trident, understanding of a material's thermal conductivity at this thickness can be developed," Nickerson says.

C-Therm's flagship instrument, Trident, was introduced to provide a thermal conductivity testing solution that brings together the most prominent methods for polymer testing - MTPS for rapid testing, double-sided TPS for testing thin films, and TLS (Needle Transient Line Source) needle probes for testing of polymers in their melt phase.

The company says that MTPS is fast, easy and highly accurate, using a single-sided, 'plug & play' sensor suitable for testing solids, liquids, powders and pastes. Applications include pure and composite polymers, rubber and 3D anisotropic samples. TPS uses a flexible double-sided sensor that can provide greater control over experimental parameters, making it suitable for more advanced users. Applications include anisotropic polymers and thin films. The TLS Needle sensor offers maximum robustness and can be applied in polymer melts and plastics injection moulding.

Composite standard

Testing systems maker **Instron** has recently participated in a collaborative test programme led by the National Physical Laboratory (NPL) in the UK to support development of a new ISO standard for through-thickness testing of polymer composite materials. The new standard, ISO NP 20975-1 (Fibre-Reinforced Plastic Composites - Determination of Laminate Through-Thickness Properties, Part 1: Specimen Designs for Direct Tension and Compression Tests), covers both tension and compression testing in the through-thickness direction.

Composite materials are most commonly tested to determine their in-plane properties. However, there is an increasing demand for measurement of their through-thickness properties in the development of reinforcements.

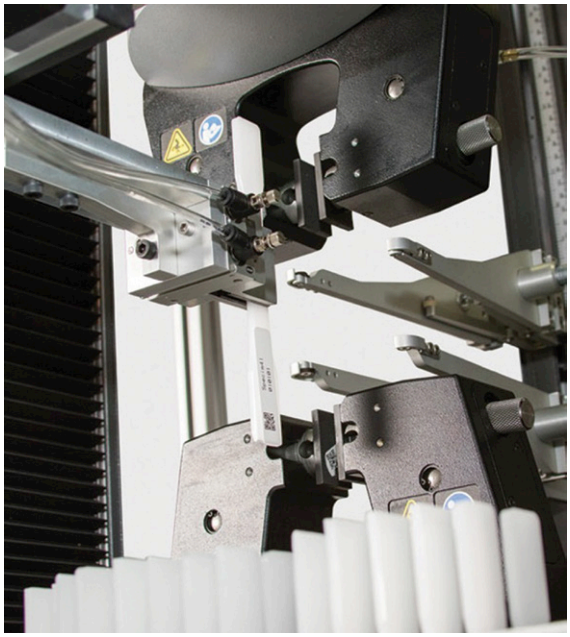

IMAGE: INSTRON

Right: Instron has supplied a testing system from its 5900 series to NPL in the UK to develop a new through-thickness composite testing standard

The test programme involved the use of an Instron 5985 electromechanical testing system with 250kN capacity. The tensile test specimens were supplied with bonded metal studs, which were gripped between a pair of Instron hydraulic grips, which had been precisely aligned using an AlignPRO fixture and checked using a strain gauged alignment specimen. The compression test specimens were tested between a pair of compression platens mounted on the hydraulic grips. The upper compression platen incorporated a lockable spherical seat which allowed the alignment of the platens to be adjusted.

For strain measurement, four axial and four transverse strain gauges were used (for determining Poissons ratio). The gauges were connected using Instron strain gauge adapters and an expansion channel module. Test control, data collection and analysis were performed using Bluehill Universal software. Successful tests were carried out on both carbon and glass fibre specimens. The company says the data will help to validate and establish the precision of the new test method.

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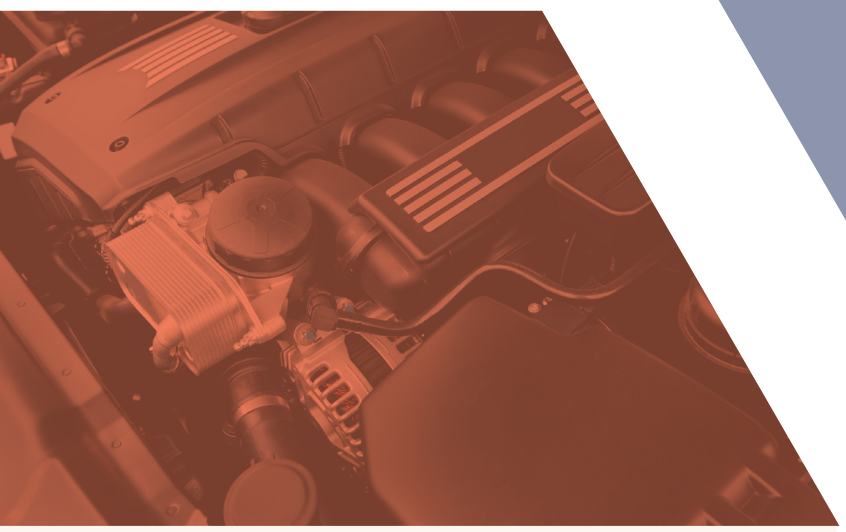

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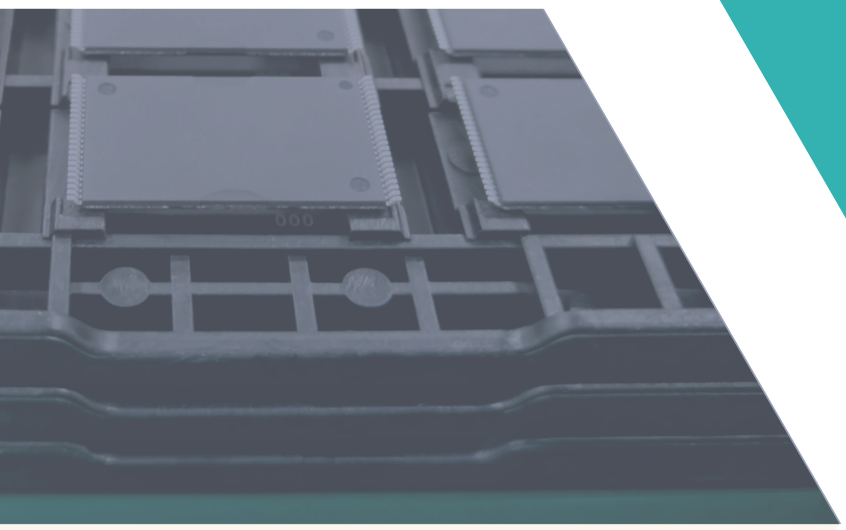

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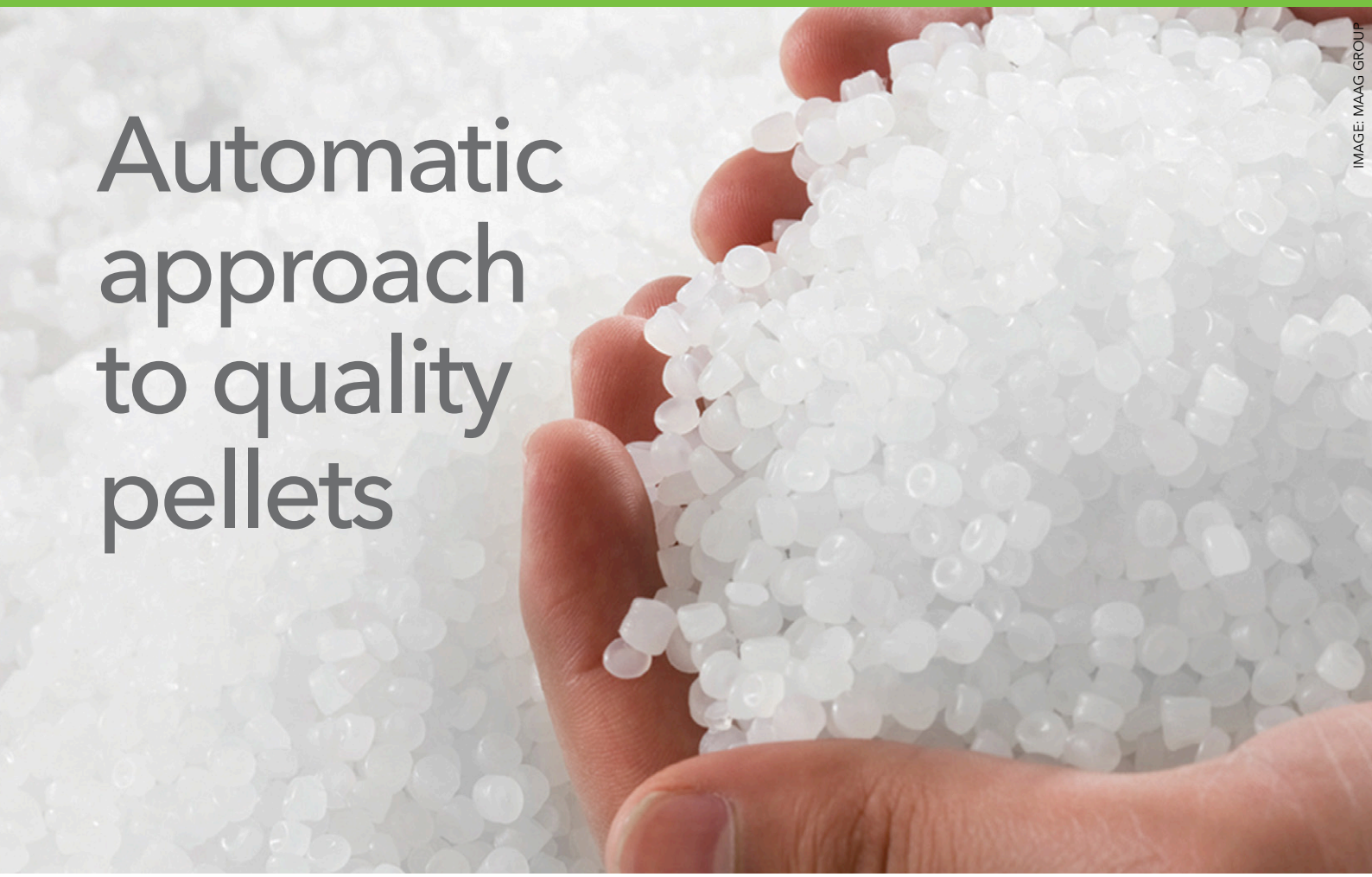

IMAGE: MAAG GROUP

Compounders worldwide are looking to pelletiser automation to improve quality, efficiency, flexibility, and safety, as well as deal with a shortage of skilled workers. Jennifer Markarian reports

Today's plastics industry, including compounders and recyclers producing pelletised materials, is responding to a new operating environment characterised by the challenges of fluctuation in the economy, availability of employees, and material supply. Current supply-chain issues are making production planning more difficult and are driving an increasing need for flexibility in operations, which must be supported by both personnel and machinery.

Faced with such challenges, compounders should consider taking a holistic view of downstream equipment with a focus on systems providing easy changeover, cleanability, accessibility and flexibility, according to Alexander Helm, Product Manager Dry Cut at **Maag Group**. In addition, and he says this is especially important given personnel shortages, automated machines should be sought to help minimise operator attendance.

Recent Maag Group pelletiser developments include completing the combination of the Automatik-Scheer product line into a new generation of strand pelletisers, as well as the introduction of its Zero-Gap system for cutting very fine fibres on strand pelletisers. The latter is being used, for example, for a specialty PP fibre used as reinforcement in construction materials.

"In traditional strand pelletising applications, a minimal cutting gap must be maintained between the rotating cutting rotor and the fixed cutting bar. The Zero-Gap system allows the cutting rotor to touch the fixed knife during operation, with the result that even very thin fibres can be cut accurately," says Helm.

Maag has also further optimised its Pearlo underwater pelletiser technology, which is designed to process spherical pellets at high capacities of up to 36,000 kg/hr (79,200 lbs/hr). This flexible system can be used to pelletise virgin materials, compounds, masterbatches, engineering plastics, wood and natural fibre-filled polymer composites, and thermoplastic elastomers, as well as for varied recycling applications.

Helm says the Pearlo pelletiser integrates moveable and flexible components on one frame to ensure increased uptime. "The combination of

Main image: Fast product changeover, flexible operation, and automated setup and operation are becoming priority requirements in pelletiser selection

IMAGE: MAAG GROUP

Right: A P-JSG400 dry cut strand pelletising system from Maag

die design and turbine style cutter hub allows one cutter hub to be used for multiple jobs, resulting in a cost advantage of up to a factor of eight, while operator safety has improved and operational duration doubled," he says.

"Thermally, this combination widens the operational window, while heat losses have been reduced by 25%. In combination with the Heat Flux die plate design, the production window is further enlarged and operation improved for many sensitive materials." The Pearlo system is available with either manual or automated blade-advance capabilities. In the fully automated Pearlo-EAC version, the blade advances during operation.

Also new from Maag is the eXso centrifugal pellet dryer, which is claimed to offer higher throughputs in a more compact and easier to clean format. The eXso pellet dryer is suitable for use with both underwater and wet cut pelletisers and has been tested at production rates up to 8,200 kg/hr.

A key feature of the eXso design is the three-door housing, which is said to allow improved access and visibility to the interior of the unit to provide faster and more effective cleaning to minimise risk of cross-contamination. The design reduces floor space requirements by around 20% and is quieter in operation (down to 80dB depending on the selected option).

Digital solutions

Helm says the company is also seeing growing demand for digital pelletising solutions. "Our technology is focused on machine condition and wear monitoring, communication between the individual functional units of the system, and comprehensive documentation," he says.

Combining Maag's XANTEC controls with systems to analyse data in real-time provides in-line pellet quality features, while the application of artificial intelligence results in improved procedural insight that can be used to optimise pelletising lines. "We are making progress towards our customers having more stable and transparent processes," Helm says.

Automation is a key requirement for pelletising systems used in almost all application areas, according to **Coperion**, whether that be high performance compound production or pelletising of recycled polymers. Frank Lechner, General Manager Process Technology and Research & Development in the Polymer Division at the company, cites automatic strand conveying as one example, providing the ability for safe start-up of the pelletising process without the need to touch or pull the strands.

"A high degree of automation in [strand] pelletising results in no unnecessary production interruptions due to strand breaks. This increases the efficiency of the entire compounding system," Lechner says.

Coperion recently commissioned a turnkey system for Lanxess constructed around the company's high-performance ZSK 92 Mc^{18} twin screw extruder equipped with an SK92 die head and automated ASC strand conveying system from its Coperion Pelletising Technology division. The combination of the die technology with a high level of pelletising process automation is said to have enabled Lanxess to achieve higher throughputs in production of its polyamide compounds.

Lechner says the SK92 die head incorporates an intelligent heating/cooling concept, which results in a homogeneous temperature distribution that ensures strands discharge uniformly across the entire width of the die head, even at high throughput rates. Optimised flow geometry in the die head further improves compound quality by reducing stress in the melt.

The fully automatic strand conveying system takes the strands from the die head and guides them

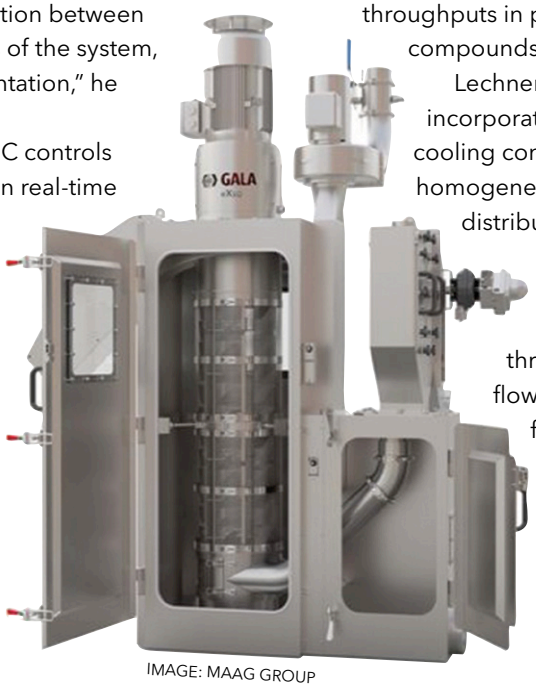

IMAGE: MAAG GROUP

Right: Maag Group's new eXso pellet dryer is designed to save space and be easy to clean

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Coperion's fully automatic ASC strand pelletising system reduces product loss and downtime

IMAGE: COPERION

over a cooling water chute and downstream conveyor belt to the SP 700 HD strand pelletiser's intake. Startup is fully automatic, as is conveying and rethreading of any broken strands. As a result, Lechner says there is no product loss or production interruptions.

Streamlining trend

The growing interest in automated production equipment is also identified as a significant trend at US-based pelletising systems maker **Bay Plastics Machinery**. "Companies are trying to streamline their existing process with the goal of reducing the number of operators. This includes automation of repetitive tasks to where a single operator can be responsible for multiple pelletising lines without being overwhelmed," says Vice-President of Sales James Forgash.

However, he sees pelletising system automation offering more, citing improved safety through the elimination of the need for operators to interact with hazardous pieces of equipment as well as gains in efficiency and quality. Automation combined with measurement and data collection, for example, opens potential for improved process control and tighter adherence to quality specifications. Such an approach could include monitoring the melt upstream of the die (in the case of an underwater pelletiser) or the strands coming out of the die (in the case of a strand pelletiser), as well as in-line measurement of pellets.

Forgash says BPM is working with several partners to develop vision systems that will allow more autonomous pelletising lines. "The systems would monitor and control strands coming out of the die to determine if several key quality issues are being maintained (strand diameter, temperature, strand separation, dropped strands, etc). This system will detect quality issues as they are happening and make adjustments or signal alarms to prevent or reduce scrap downstream," he says.

Data collection is another key step to improved control. Forgash says BPM is working to give equipment users the ability to store product recipes or to enter a pellet-per-gram requirement that the system can then use to automatically adjust pelletising line variables to achieve target specifications.

Tackling dust

One of the latest BPM equipment developments aims to provide a solution to the long-standing issue of dust created during pelletising. "Whether the pellets were fractured at the time of cutting or sharp corners are 'knocked off' during conveying, this dust is a potential problem with downstream operations and needs to be removed efficiently," says Forgash.

The company's pellet evacuation system transfers cut pellets from the cutting chamber, which initially reduces the amount of dust generated by preventing pellets from being cut twice. "A double cut generates a pellet that is now a fraction of the intended size and out of spec. Evacuating the pellet immediately reduces the

IMAGE: BAY PLASTICS MACHINERY

Above: Dust is commonly produced during pellet cutting and conveying (left). BPM's pellet evacuation system and dedusting cyclone results in a marked reduction (right)

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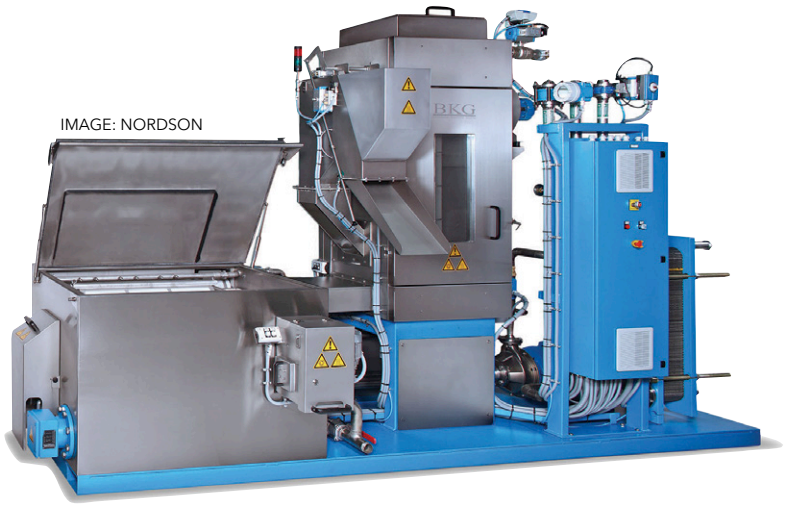

IMAGE: NORDSON

Above: Nordson's BKG Optigon water filtration system eliminates fines from underwater pelletising systems

chance that it could bounce around the cutting chamber and be cut twice," explains Forgash.

Pellets are then conveyed to a separate area where any remaining dust, or any dust generated after the cut, can be removed with a secondary dedusting cyclone. "This cyclone uses a proprietary ratio of counterflow air in the right areas to remove a controllable amount of unwanted materials sizes from the end product as it is spread thinly in the dedust phase," he says.

Fines are also a concern in underwater pelletising. "Significant fines generation decreases the end-product quality and increases maintenance efforts," says Ralf Simon, Director, Special Projects at **Nordson**. The company addresses this issue with its BKG Optigon automated water filtration system, which incorporates a self-cleaning Polygon filter that is cleaned automatically depending on the differential pressure in the water tank.

Another challenge for compounders is handling materials with high residual moisture. Nordson offers multiple solutions for this challenge, including high efficiency dryer designs to achieve the desired moisture levels, die plates with optimised insulation, flexible bypass systems that can control residence time, and automated control of key process parameters, says Business Development Manager Frank Asmuss.

Highly filled compounds can lead to high pressures that are also challenging for the pelletising process. Nordson offers its BKG melt pumps, which feature adapted clearances for pressure build-up, and carefully designed die plates with precise and material-adapted borings to overcome this challenge, according to Asmuss.

Fillers and other abrasive additives cause wear, which can be managed using protective coatings and metallurgy at the die plate. Another solution is automatic blade adjustment, which provides constant compensation for wear, as well as inline grinding tools that provide automated grinding of the die plate to increase the lifetime of plate and blades.

Recycling demands

Processing of reyclates is becoming increasingly commonplace. It places additional demands on the compounding and pelletising process as the incoming material tends to be more variable and more contaminated than virgin polymer. Asmuss says Nordson's BKG HiCon V-Type 3G system melt filter uses a power-backflush technology that provides an effective backflush with minimal losses.

"Even with an efficient backflush screen changer, the screens will be quickly blocked with contaminants so screen changes are required more often than in other applications. As every screen change comes together with a pressure loss, even if it is a slight one, a booster pump might be required between screen changer and pelletiser," he says. "Nordson's BKG gear pumps ensure a constant process pressure so that the melt stream that is fed into the pelletising system is even and smooth, which is key to a high-quality end-product."

Austrian pelletiser maker **Econ** is also focusing on high level automation. Its ECONia fully

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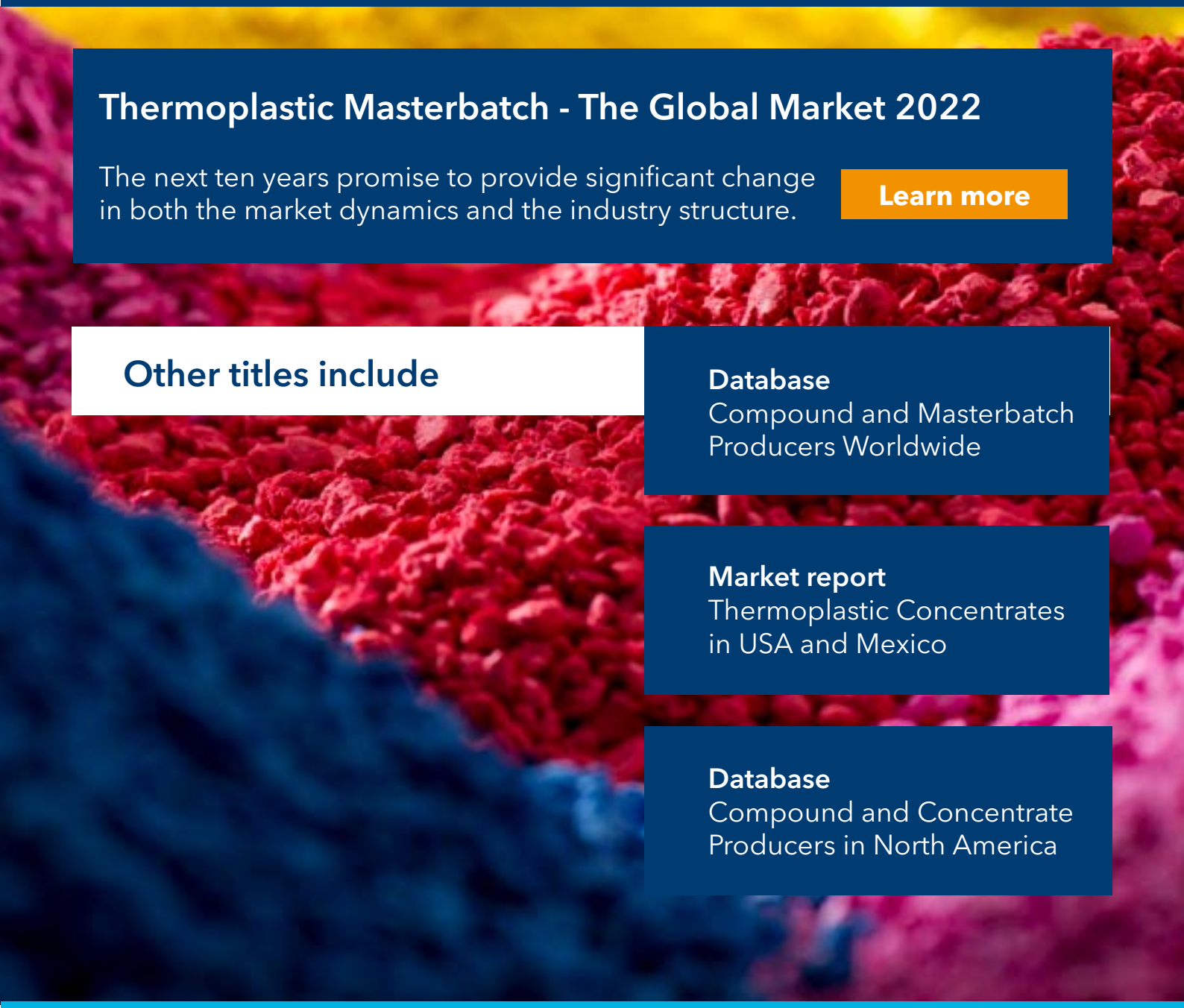

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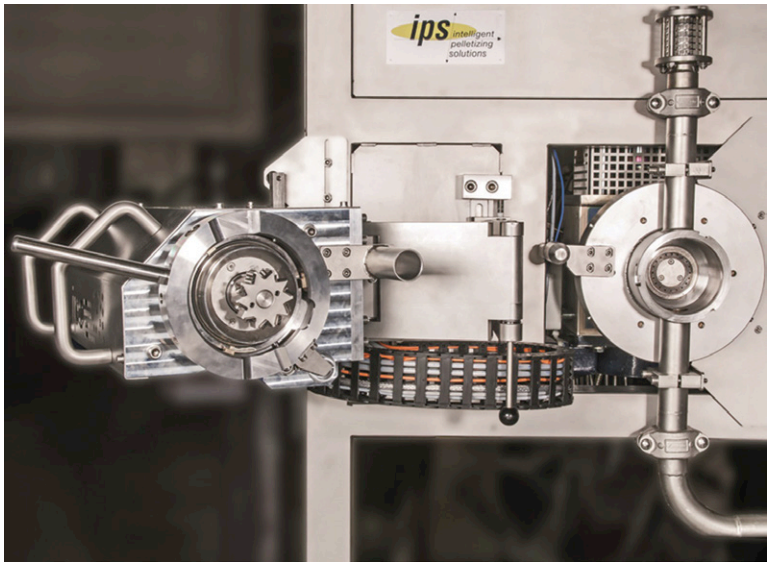
IMAGE: INTELLIGENT PELLETIZING SOLUTIONS



Above: A UWG 75 S underwater pelletiser from IPS is being used at bioplastics compounder Tecnaro

automated underwater pelletiser is equipped with its Pellet Vision system to monitor the pellets and, where deviations are detected, automatically adjusts process parameters. The company says the system reduces off-spec material and results in high process stability.

The ECONia line also features an integrated robot that eliminates manual start-up processes and manual knife changes, which Econ says is safer for the operator and reduces production downtimes. The company claims that one operator can efficiently operate and control up to 10 lines from a central control.

Early last year, Germany's **IPS** (Intelligent Pelletising Solutions) supplied both an SG 220/2 strand pelletising plant and ips-UWG 75 S underwater pelletising system to bioplastic producer Tecnaro. The new equipment is part of an expansion of Tecnaro's biopolymer production, which includes bioplastic and biocomposite compounds for markets such as automotive, construction, solar, packaging, and furniture.

The UWG 75 S underwater system is said to be particularly suitable for production of spherical pellets and, due to its modular design, can be tailored specifically to the applications and requirements of the customer. In this case, IPS optimised the system to Tecnaro's sustainable material portfolio. This included a specially-adapted perforated die plate that allows bioplastics reinforced with natural fibres to be pelletised without damage.

According to IPS, the UWG 75 S provides a throughput of up to 700 kg/h. It is equipped with a frequency-controlled process water pump that allows energy-efficient setting of the volume of process water. Water temperature is regulated by means of a plate heat exchanger.

Pellet inspection

In-line inspection of pellets is increasingly being used for quality control purposes, especially in areas such as medical and HV power cables, according to Germany-based **Sikora**. Its Purity Scanner Advanced system uses both optical cameras to detect and sort contaminants or discoloration (including black specks) on the pellet surface and X-ray technology to detect metal impurities on the surface or inside the pellet in-line. "We see a strong demand for highest material purity among all plastic manufacturers and processors worldwide, as well as in compounding," says Ralf Kulenkampff, Head of Sales at the company.

Sikora also offers two offline laboratory systems, the Purity Concept X with an X-ray camera and the Purity Concept V with an optical camera. These are typically used for quality control, incoming inspection, or for material release before delivery.

Israel-based **Inspection Technologies** also offers systems to detect and identify pellet quality problems - including contamination, size and shape change, or colour shift - in real time during pellet production. "Most pelletising lines, in either compounding or recycling, are not using in-line pellet inspection systems," says Gilad Roter, Business Development Manager at the company. "More often, producers take samples to a lab for evaluation of contamination, size and shape. If a problem is detected, troubleshooting can be delayed. Taking inspection into the production line enables an immediate change to be made if a problem is found."

Another potential concern when using sampling and off-line testing is that the sample may not represent the entire production flow, so problems

IMAGE: INSPECTION TECHNOLOGIES

Right: Inspection Technologies offers an inline system for monitoring and classifying pellet quality

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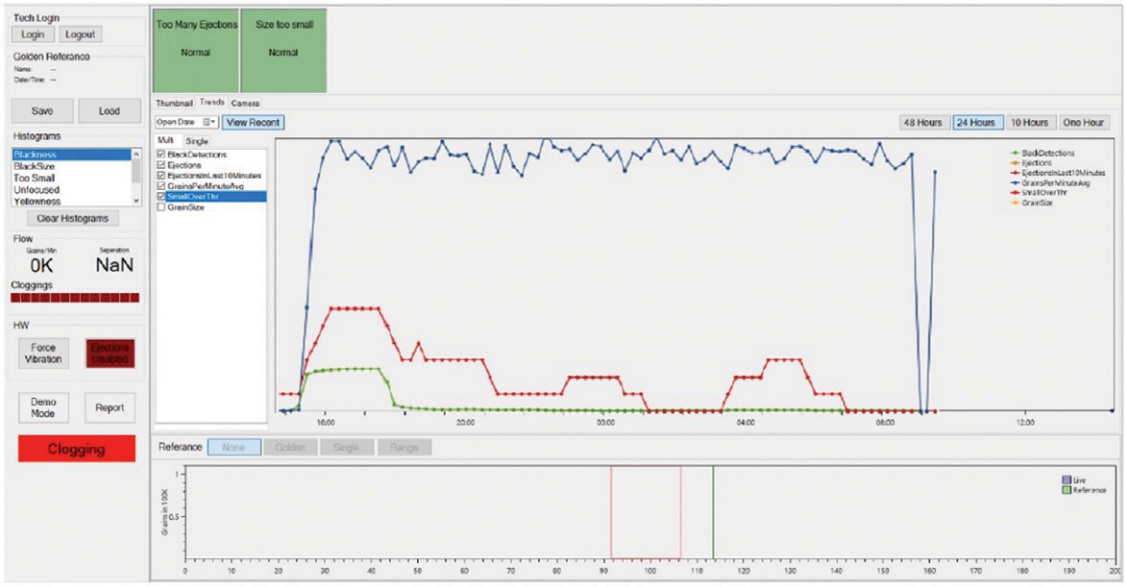

The Inspection Technologies system software provides comprehensive trending analysis

Image: Inspection Technologies

can be missed, according to the company. Continuous in line monitoring, by contrast, gives an immediate alert of any problems.

Roter says Israeli compounders such as Tofrat, Kafrit and Polyram have implemented the company's technology in some of their operations in Israel and several major global compounders started implementing the system in their production lines in Europe and in the Far East during 2021.

Recycling variation

The inline inspection system is also beneficial for pelletising recyclate, which is more prone to contamination, according to Nadav Leshem, founder and CEO of Inspection Technologies. "A major constraint of using recycled material is quality of product and variability of quality; online inspection systems can help narrow down the quality variation," he says.

The Inspection Technologies vision system is designed to withstand the harsh environments of plastics production, which can include high temperatures, dust from antiblock additives, and abrasive or corrosive materials such as glass-filled masterbatches and coupling agents.

The equipment uses area cameras (rather than linescan cameras). These incorporate a matrix, rather than a line, of pixels that allows different illumination to be used in different parts of the image frame. "You can have several inspection tasks in one frame with different illumination types in the upper and lower parts," says Leshem. "For example, for size you need to see good contour, so you need a high contrast with the background. For impurities such as black specks detection, the system will use a different type of illumination."

The smallest system is designed for a throughput of 1,000 kg/hr but the company has customers using the technology at up to 2.8 tonnes/hr. A system offering twice that capacity is also available, with equipment capable of three times that capacity available soon.

Aside from impurities detection, the system also analyses pellet size and pellet contour to detect improper cuts such as 'tails'. "The system shows the distribution of size and shape, and it indicates if this distribution is changing. You can see immediately if you're beginning to get angel hairs or tails, and you can set up a real-time alert if a control limit is exceeded," says Roter. When inspection tasks related to pellet colour are needed, colour cameras can be added to the system.

In addition to in-line continuous monitoring, a sorting unit can be added to sort out poor quality pellets. Leshem says that application of both monitoring and off-line sorting can be used to help better plan and implement maintenance. "You don't need to do preventive maintenance at predefined time, but instead you can do it if and when the monitoring gives you a heads up that there is a problem," he says.

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- **www.coperion.com**
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- **www.nordson.com**
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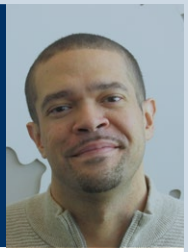

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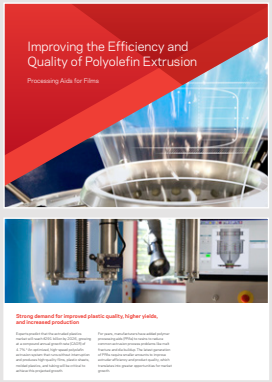

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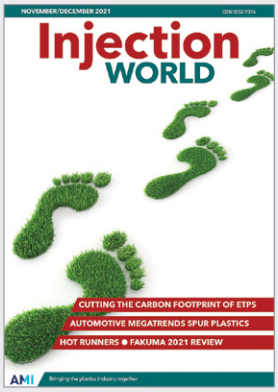

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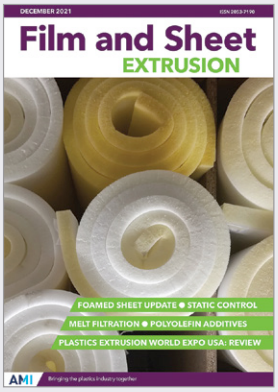

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Chemical Recycling
GLOBAL INSIGHT 2022

Letter from the Editor

Welcome to Chemical Recycling Global Insight 2022, a special publication written and produced by AMI Magazines, with support from AMI Consulting. The development of chemical recycling is a response to the global problem of waste plastics in the environment. Its advocates see chemical recycling as complementary to mechanical recycling which is itself growing in importance.

In this publication, we look at the market prospects for chemical recycling and how the industry is taking shape.

The articles cover not just the scope of the waste plastics problem, but also influencing factors such as legislation and targets for use of recycled content. There is an article on the various technologies that come under the chemical recycling umbrella term, offering a guide to their differences and relative advantages.

You will find our article on what's new in chemical recycling projects very helpful in staying up-to-date with the many facilities being built around the world. Some of the players in this fast-moving industry are featured in a series of company profiles.

We hope you find this publication informative and useful.

David Eldridge – Editor
AMI Magazines

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The need for more plastics recycling

The problem of plastics waste has come to dominate the outlook for the plastics industry. Many polymer producers and technology companies are now turning to chemical recycling as a possible solution

IMAGE: SHUTTERSTOCK

Main image: Mixed plastics waste is the source of feedstock for many plastics recycling companies

The circularity of plastics has risen rapidly up the agenda for the global plastics industry. It is now the top talking point at any conference, forum and exhibition at which industry companies gather. Campaign groups have tried to highlight the problem of plastic waste in the environment for many years, but it only cut through to the public as a mainstream issue in 2018. The blanket media coverage of plastic pollution in oceans and on beaches has receded since then, but the problem of what to do about waste plastics remains just as strong.

The European Union responded quickly with actions to tackle plastic packaging waste, including its Plastics Strategy, setting medium-term targets for reducing plastics waste, and more immediate action to ban plastics in certain single-use items. But it's not just in Europe that the issue has achieved such prominence. The challenge has been recognised in all regions of the world and many countries have implemented or are planning to implement regulations, notably China's ban on most plastic waste imports, which was followed by other Asian countries imposing similar import bans.

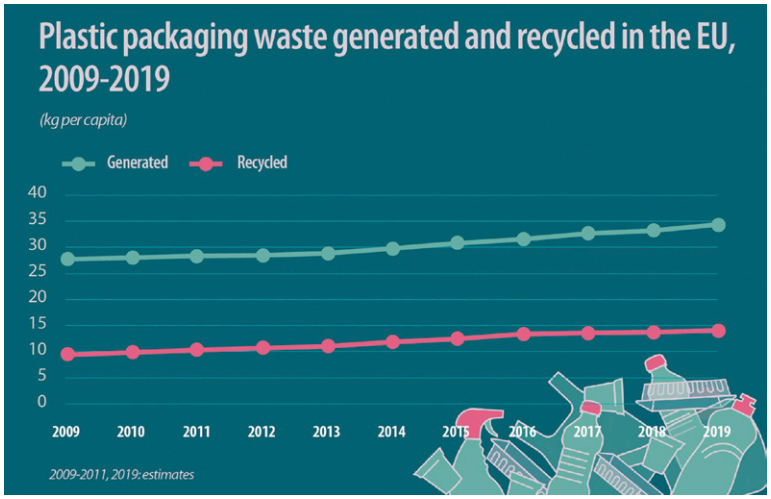
A key approach to the problem is circularity, which encompasses reduction in material usage and the recycling of materials so that loops are created in material production and use, thereby cutting the amount of waste. Multinational brand-owners have become active in reducing virgin plastics and increasing recycled plastics in packaging of their products.

Ellen MacArthur Foundation has been at the forefront of the drive towards a circular economy in plastics packaging, along with other areas such as fashion and food. In November 2021, it published the third annual progress report on its New Plastics Economy Global Commitment. It said signatory businesses, accounting for 20% of all plastic packaging produced globally, have progressed towards their 2025 targets to create a circular economy for plastics.

The report was nonetheless critical of companies in terms of reducing packaging: "There is very little evidence of ambitious efforts to reduce the need for single-use packaging in the first place."

Chemical and mechanical recycling can be used for plastics waste that arises in all sorts of industries, including automotive, electronics and others. But it is plastics packaging that is the major focus for many companies in the plastics industry, because of the huge volumes of packaging waste and because this is where social concern is the greatest.

Plastics packaging recycling has actually been increasing in the EU for more than a decade. A study published by Eurostat in October 2021 indicated a 41% EU recycling rate for plastics



SOURCE: EUROSTAT

packaging waste in 2019. Between 2009 and 2019, the recycling volume of this waste increased by 50%. However, a burgeoning plastics packaging market in the decade meant that the volume of waste generated per inhabitant over the decade increased by 24%.

Recycling of plastics packaging waste has not kept pace with the growth in the EU packaging market. So the pressure is on the plastics industry to deal with the problem and plastics producers have turned to chemical recycling as a solution.

Mechanical recycling is a more established transformation route for waste plastics, and it has the advantages of being a cheaper and less energy-intensive process than chemical recycling. But current small capacities for mechanical recycling are not enough to deliver the huge tonnage of recycled plastics that are necessary to meet regulatory and corporate targets. This is where large-scale polymer producers believe they can step in and help.

In May 2021, PlasticsEurope, the representative body for polymer producers in Europe, announced a significant increase in planned chemical recycling investment, from €2.6bn in 2025 to €7.2bn in 2030. Its member companies are aiming to increase their investment in chemical recycling to produce 1.2m tonnes of recycled plastics in 2025 and 3.4m tonnes in 2030. Advocates of chemical recycling state that this growth will not impact on the further development of mechanical recycling, as the focus would be on mixed plastics waste and other types of hard-to-recycle waste streams.

PlasticsEurope said: "Chemical recycling allows us to recycle plastic waste which is otherwise incinerated or sent to landfill. It delivers significant quantities of recycled material with virgin plastic properties. It is complementary to mechanical recycling and has a huge potential for creating quality jobs and contributing to a climate neutral and competitive Circular Economy in Europe."

The American Chemistry Council is supporting US-based polymer producers involved in projects to increase capacity for chemical recycling, or advanced recycling as it is more commonly called in the USA. A chemical recycling report from ACC in 2019 estimated the US could support investment in 260 new facilities converting plastics waste to products such as feedstocks for new plastics and chemicals.

ACC's polymer producing members have set a goal for 100% of US plastic packaging to be reused, recycled or recovered by 2040. To help reach that goal, ACC has drawn up its Roadmap to Reuse which highlights six key areas for plastics makers and the value chain to focus on to help solve plastic waste challenges.

Increased plastics recycling capacity will certainly be needed as plastics usage is set to grow over the next decade in all regions of the world. According to a forecast by AMI Consulting, China accounted for almost one-third of commodity polymer demand in the world in 2019. By 2030, China is forecast to account for 38%. This contrasts with slower virgin polymer demand growth in Europe (0.2% annually to 2030) and in North America (1.1% annually) and South America (also 1.1% annually). South East Asia and the Middle East/Africa are both forecast to grow by 3% per year. The Indian Subcontinent will be a hotspot with its polymer demand forecast to grow by 5.3% per year up to 2030.

In its *Chemical Recycling Global Status 2020* report, AMI Consulting presents its expectations for the global chemical recycling market in 2025 and 2030. It is forecasting a compound annual growth rate (CAGR) for global chemical recycling of 28.0% up to 2030. Europe is expected to grow fastest and have a lead over North America by 2030 due to the more advanced legislative agenda of the European Union. But North America will not be far behind, and Asia is likely to also experience good growth.

Of the four types of chemical recycling technologies – pyrolysis, gasification, depolymerisation and dissolution – pyrolysis will be the dominant one in terms of total waste recycled (also see separate technology article). This is due to a few factors: the greater number of pyrolysis projects currently being developed; less complexity than other processes; fewer concerns about the scale required to achieve commercial viability.

Mixed polyolefins can readily be recycled in large amounts using pyrolysis. Depolymerisation technologies will mainly be used for PET waste types, such as coloured material, that mechanical recycling is not targeting. Polystyrene waste will be recycled by different technologies, especially dissolution and depolymerisation. ■

IMAGE: SHUTTERSTOCK

Explaining chemical recycling processes

Chemical recycling is an umbrella term that includes a variety of technologies, each with their own process characteristics, input requirements and outputs. We explain the technologies

Few in the plastics industry will not have heard of chemical recycling but that simple term covers a huge range of quite different technologies. Today's chemical recycling technologies can be classified into three broad concepts: dissolution, depolymerisation, and thermal cracking. These three approaches differ, at a conceptual level at least, in the type of materials they can handle, the amount of "chemistry" involved, and the product that results.

Dissolution technologies use carefully selected solvents to dissolve the polymer from the mixed waste, allowing insoluble contaminants such as fillers and pigments to be filtered out. The dissolved polymer can then be precipitated and recovered from the solvent, which is reused. This is a physical process – the chemical composition and structure of the polymer is unchanged. As a result, many of its proponents consider it to be closer to mechanical than chemical recycling and promote it accordingly, using terms such as solvent-based purification or physical or material recycling.

The key to success in dissolution is the selection of a solvent that recovers only the target polymer. This means it is best suited for use with relatively homogenous waste streams. A number of pilot projects are already well advanced – Purecycle Technologies in the US, for instance, is targeting polypropylene with a technology licensed from P&G while Canada's Polystyvert is focusing its efforts on polystyrene.

The need for a relatively homogenous waste stream does not necessarily mean that dissolution technologies are suitable only for mono-material plastic waste. Germany's APK, for example, is developing its technology to recover LDPE and PA from multi-layer films. ›

Main image: Some chemical recycling involves changes in chemistry, but not in the case of dissolution

In theory, at least, dissolution exposes the polymer to less thermal and physical stress during the recovery process than conventional mechanical recycling. However, the recovered polymer is likely to require compounding or pelletising to make it suitable for further use, which may mitigate that benefit to some extent. In addition, the cost of the numerous processing steps – pre-treatment, dissolution, filtration, precipitation, solvent removal and reformulation – is likely to make dissolution most attractive for processing of mono-material waste streams with a relatively high level of contaminants that would be difficult to remove mechanically otherwise.

Depolymerisation is certainly a chemical recycling process, typically using heat (and often a catalyst) to convert a polymer back to its building block monomers – for this reason it is sometimes referred to as monomer recovery. It is most suitable for use with step-growth polymers such as PET, which are polymerised by polycondensation.

A number of companies are developing various processes to depolymerise PET, with pilot projects underway at Carbios in France, CuRe Technology and Ioniqa in the Netherlands, Rittec in Germany, and BP Infinia, Eastman and Loop Industries in North America.

Depolymerisation of polycondensation polymers typically involves reintroducing the molecular component that was eliminated during the original polymerisation process. Several solvolytic processes are being investigated to do this, including hydrolysis, glycolysis, methanolysis and transesterification. These are all multi-step processes that include pre-treatment of the waste, followed by depolymerisation, monomer recovery, repolymerisation, and finally extrusion and pelletising.

Solvolytic depolymerisation techniques are not suitable for use with polymers produced by chain-growth or polyaddition reactions, such as PE, PP and PS. However, some companies – including Pyrowave in Canada and Agilyx in the US – are working with alternative thermal depolymerisation technologies that are capable of converting PS polymer back to styrene monomer.

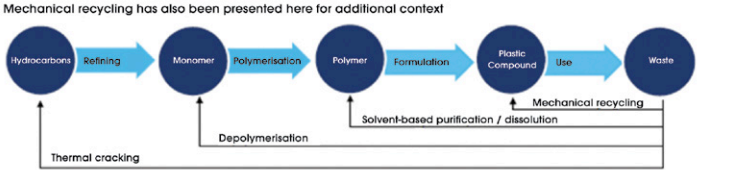
By converting polymers back to the original monomers, depolymerisation can lead to new polymers of virgin quality. However, it uses highly specific chemical processes so the incoming waste stream has to be consistent in terms of polymer composition, meaning considerable cost may be incurred in pre-sorting. Energy requirements can also be quite high.

Thermal cracking converts waste plastic – and many of the contaminants the waste may carry – back to basic feedstock components such as hydrocarbons and syngas (a gaseous mixture of CO, CO_2, H_2 and CH_4). Two processes are used to thermally crack – or feedstock recycle – polymers: pyrolysis cracks the polymer chains at high temperature in the absence of oxygen; gasification heats the polymer with a controlled but limited amount of oxygen. Both yield a different mix of end products with targeted applications ranging from fuels to chemical feedstocks.

Conventional pyrolysis thermal cracking is a relatively simple technology. Waste goes through a pre-sorting and shredding process and is then pyrolysed at high temperature – typically 400-600° – to create vapour and gas, which is then purified to create a range of hydrocarbons. These hydrocarbons can include gas, wax, oils and char. Yields of each can be controlled to some extent by adjusting temperature, pressure, and residence times, as well as through the use of particular catalysts and thermal profiles.

As pyrolysis occurs in the absence of oxygen, the process is only really suitable for polymers with a limited oxygen content, such as PE, PP and PS. Polymers containing high levels of oxygen or halogens – particularly PVC and compounds containing brominated flame retardants – must be sorted and removed from the waste input stream.

Oxygen and halogen concerns aside, pyrolysis can handle waste streams with a mixed polymer composition that would be highly challenging for either mechanical or dissolution and depolymerisation chemical recycling methods. That said, it is an energy intensive process and the quality and mix of the output materials is still dependent to some extent on the input materials. In addition, much of the gas and oil output from pyrolysis plant is likely to be burnt as fuel, either to provide energy for the process itself or because of the need for additional purification steps to upgrade it to be used as a cracker or chemical plant feedstock. Under most regulatory and accreditation regimes, the use of



	Mechanical recycling	Solvent-based purification / dissolution	Depolymerisation	Thermal cracking
Feedstock	PET, POs, PS, PVC, mixed plastics	POs, PS, PVC, PET	PET, PS	Mixed plastics, POs, PS
Output	Plastic compound	Polymer	Monomer, oligomer	Hydrocarbon mix
Status	Industrial scale	Pilot stage	Pilot stage	Pilot, industrial

Four types of plastics recycling
Source: AMI Consulting

outputs as a fuel is not recognised as recycling.

Major players in the development of pyrolysis-based technologies include Luxembourg-headquartered Clariter, Enval, Recycling Technologies, Renew ELP and Plastic Energy in the UK, Fuenix Ecogy in the Netherlands, OMV in Austria, Quantafuel in Norway, Brightmark, Encina, Nexus Fuels and Alterra Energy in the US, GreenMantra Technolgies in Canada, and Licella in Australia.

Gasification thermal cracking differs from pyrolysis in that the process takes place in the presence of a controlled but limited amount of oxygen. It can handle almost any organic material – including plastic waste and biomass – and can take on polymers containing oxygen and halogens. The end result is syngas that, depending on its composition and purity, can be used as a production feedstock.

The gasification process involves fewer steps than pyrolysis: pre-treatment of the waste (including water removal); gasification; and cleaning of the gas to remove tars and other contaminants. That final purification step is required to remove impurities such as ammonia, H_2S, alkali metals, NO_x and tars.

Gasification is not a new technology. Texaco developed and licensed its TCP (Texaco Gasification Process) technology back in the 1980s to handle hazardous waste organics. It is a non-catalytic, partial oxidation process capable of converting organics to syngas and chars. However, the TCP process does not produce feedstocks suitable for reintroduction into plastic-to-plastic or other value-added chemical synthesis chains.

A number of companies are investigating gasification processes to crack plastic waste to heavy oil and non-condensable gases and condensable gases. The non-condensable gases are used as process fuel while condensable gases and heavy oils can be gasified with oxygen and steam. These processes typically involve use of high temperature gasification at more than 900°C, which is energy intensive, followed by additional purification steps.

Gasification thermal cracking technologies are under development by a number of companies, including Enerkem in the Netherlands, Eastman in the US, and Showa Denko and Sekisui/Sumitomo in Japan.

Chemical recycling is still a very young technology. However, it seems clear from the work carried out to date that hopes that it will solve the challenge of handling mixed waste streams may be misplaced. The reality is that most of the technologies currently under development will need some level of homogeneity in waste feedstock. That means that, initially at least, chemical recycling is likely to draw on the waste sources and supply infrastructure developed for mechanical recycling.


IMAGE: BASF

Above: BASF's Andreas Kicherer holding a jar containing pyrolysis oil

Drawing on the same collection and sorting infrastructure does not necessarily mean that chemical recycled material will compete directly with mechanical recycled material. Compared to mechanical recycling, all chemical recycling processes are more complex and are likely to be more costly. So, where high quality waste streams are available, mechanical recycled polymer is likely to win out simply on economics.

Chemical recycling, on the other hand, begins to look a lot more attractive where waste streams are less homogenous than is preferred for mechanical recycling, or where volumes of recycled material exceed the capacity for reuse in new applications (either for reasons of regulation or for deterioration in material properties).

There may be some competition for feedstocks, but even that is likely to be limited. In its most recent *Chemical Recycling Global Status* report, AMI Consulting says that while the potential exists for competition to develop between the two recycling technologies in some areas – it cites the example of PET bottles and trays – it is also quite conceivable that separate markets may emerge. PET waste with the lowest levels of contamination, for example, could be sought out by mechanical recyclers while PET waste streams with higher contamination levels may be processed by depolymerisation, the report authors say.

Looking at feedstocks for the thermal cracking processes – either pyrolysis or gasification – that are expected to account for the majority of chemical recycling in volume terms, the AMI consultants say the fact that mechanical recycling can only offer a "downcycling" solution for mixed plastics waste makes it a prime stream for the chemical route. The study authors conclude that the likelihood of feedstock competition "is minimal for the vast majority of chemical recycling." ■

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IMAGE: GR3N

What's new in chemical recycling projects

The number of companies getting involved in chemical recycling of plastics waste has been growing rapidly. This article provides an update of recent developments in projects around the world involving chemical recycling of mixed waste, plus ones focussed on PS and PET

Announcements of new plastics chemical recycling projects have been coming out regularly in recent months, along with progress reports on previously announced projects. Most operations are set for the 2022/23 time frame. What follows is a non-exhaustive review of projects in various states of construction and operation around the world, mostly related to mixed plastics waste but also for individual polymer streams (PET and polystyrene).

Plastic Energy, probably the most prominent independent technology company operating in chemical recycling, already has two commercial chemical recycling plants in operation, in Almeria and Seville, Spain. They have been running since 2015 and 2017 respectively. Each has a capacity of 5,000 tonnes/yr. The technology uses a thermal anaerobic conversion (TAC) process to produce what Plastic Energy brands as Tacoil. The Spanish facilities take waste, mostly film, collected by a waste management company that would normally send the material to landfill.

Main image: Swiss company Gr3n has constructed a demonstration plant for its PET recycling technology

Plastic Energy says it is continuing to increase its portfolio of European projects, with a 20,000 tonnes/yr plant currently under construction in the Netherlands with partner **SABIC** in a joint venture called SPEAR (SABIC Plastic Energy Advanced Recycling), and a 25,000 tonnes/yr plant that has recently started construction in France, along with a collaboration offtake agreement with ExxonMobil.

The company also has a joint venture with **TotalEnergies** (previously Total) for a 15,000 tonnes/yr recycling plant at the latter's Grandpuits "zero-crude platform" site in France, with construction expected to start soon. This will be France's first chemical recycling plant using pyrolysis to produce Tacoil.

The plant in the Netherlands is expected to become operational in 2022, with SABIC building a treatment facility to purify the pyrolysis oil coming from this joint venture, before feeding the oil into its own processes. Both plants in France should be operational in 2023.

This October, Plastic Energy also announced a partnership with Freepoint Eco-systems and its first recycling project in the US, with plans to build a 33,000 tonnes/yr plant in Texas, and a collaboration offtake agreement with TotalEnergies; it should be operational by mid-2024. In addition to this, Plastic Energy has an MoU with Petronas for a recycling project in Malaysia, and says it is working towards expanding in other parts of Asia.

SABIC is also exploring opportunities in other regions. It is for example working with Saudi Investment Recycling Company (SIRC). The two companies are cooperating in Saudi Arabia to build the first chemical recycling facility in the country, producing feedstock for SABIC's local polymer units. SABIC is also doing something similar in Asia and in the Americas, but no announcements have yet been made.

In March, **BP** and SABIC signed a new agreement to work together to drive a circular economy in the petrochemical activities at the Gelsenkirchen chemical complex. The two companies have a long history of cooperation on the site, dating back to when the SABIC operations were owned by DSM.

Below: BP and SABIC are working to drive a circular economy in petrochemical activities at the Gelsenkirchen chemical complex

IMAGE: SABIC

Pyrolysis oil will be processed at BP's Gelsenkirchen refining site and then used by SABIC in its Gelsenkirchen polymer plants to produce certified circular products, which SABIC brands as Trucircle. After successful trials in December 2020, polymer production using the alternative feedstock started at the site early this year.

BP and **Brightmark**, a global waste solutions company that has proprietary chemical recycling technology, have signed a Memorandum of Understanding (MoU) to jointly evaluate opportunities for development of the next generation of plastic waste renewal plants in Germany, the Netherlands, and Belgium. BP is already the offtaker for Brightmark's 100,000 tonnes/yr pyrolysis plant in Ashley, Indiana, USA, which is currently undergoing final commissioning. The Ashley facility produces plastics-to-fuel and waxes. "Moving forward, all facilities will be designed for circular end products," says a representative.

In January, Brightmark and **SK Global Chemical**, headquartered in South Korea, signed an MoU to create a partnership to build a commercial scale pyrolysis plant in South Korea with a 100,000 tonnes/yr capacity. Both parties are currently carrying out a feasibility study. By the end of this year, they should have completed evaluation of the most optimal methods to operate, scale and develop the technology within South Korea.

In September, Shell Ventures and BlueAlp Holding announced a strategic partnership to develop, scale and deploy BlueAlp's pyrolysis technology. Shell has taken a 21.25% equity stake in BlueAlp as part of the agreement.

Shell and **BlueAlp** will form a joint-venture company to build two new conversion units in The Netherlands, which are forecast to convert more than 30,000 tonnes/yr of plastic waste. The units are planned to be operational in 2023 and will supply 100% of their pyrolysis oil as feedstock to Shell crackers in The Netherlands and Germany. Shell is exploring licensing a further two units for deployment within Asia to supply the Shell Energy and Chemicals Park Singapore.

In October Shell Chemicals Europe also announced a strategic cooperation and offtake agreement for pyrolysis oil made by Rotterdam-based company **Pryme** from recycled plastic waste. Pryme will supply Shell from its first plant located in Rotterdam. Currently under construction, the plant

is scheduled to become operational in 2022 and is forecast to convert 60,000 tonnes/yr of plastic waste into pyrolysis oil by 2023.

The agreement also includes provision for future supply to be delivered from Pryme's proposed second plant in the region. This will have an estimated annual pyrolysis oil production capacity of 350,000 tonnes.

Eastman has two chemical recycling technologies that tackle different feedstock streams. Polyester Renewal Technology processes polyester feeds (see section on PET below), while its Carbon Renewal Technology can recycle most other thermoplastics, with the exception of PVC. In late 2020, Eastman said it expected to use up to 50m pounds (close to 27,000 tonnes) of waste plastic in Carbon Renewal Technology operations in 2020, with projects underway to significantly expand that amount. No update was available at the time of writing.

In early November, **Aduro Clean Technologies**, a Canadian developer of patented water-based technologies to chemically recycle plastics and transform heavy crude and renewable oils into new resources and higher-value fuels, announced a pending partnership with Brightlands Chemelot Campus in Limburg, The Netherlands.

Aduro says the objective of this partnership is to complete an installation that applies Aduro Hydrochemolytic technology (HCT) to demonstrate, on a tonnes per day scale, the conversion of polyethylene waste to useful feedstock for chemical processes, including production of new PE.

Ofer Vicus, CEO of Aduro, says: "This year we plan on doing our proof of concept. This is nearly done and we are working on the data to submit it to a third party," says Vicus. "Our next step in the road map is to work on the pilots – this is happening now with Brightlands and possibly others."

He says: "Traditional methods rely on high temperatures from 400°C to as high as 1,100°C, and on hydrogen produced by conversion of fossil fuels at between 700°C and 1,000°C. Aduro Hydrochemolytic processes operate at only 240-390°C."

Marc van Doorn at the Brightlands Chemelot Campus says: "We are at the early stages and it still needs quite a lot of development, but lab results were quite interesting. Aduro is planning to scale the process up to pilot plant level at our campus, where we have a number of other things going on in chemical recycling."

Another chemical recycling process that relies on water – super-critical steam in this case – has been developed by **Mura** in the UK. In April, it announced a partnership with Dow Chemicals to support the rapid scaling of its HydroPRS (Hydrothermal Plastic Recycling Solution) process. Dow will also take recycled materials from the first plant, in Teesside, UK. The first of four 20,000 tonnes/yr lines is expected to be operational in 2022. Dow and Mura are looking to co-operate on offtake at a number of additional European projects, currently in Mura's development pipeline.


IMAGE: EASTMAN

Above: Eastman has two chemical recycling technologies that tackle different feedstock streams

Alongside its first plant in the UK, Mura also has four 100,000-tonnes/yr sites under development in Germany and four of the same capacity in the US – Washington State has just been announced as the first location. It also recently announced the sale of the first HydroPRS licence to Mitsubishi (MCC), which has plans to develop the process to commercial operation by 2023 at its Ibaraki site, Japan. It will have the capacity to handle 20,000 tonnes of plastic waste per year – with MCC studying the possibility of increasing capacity in the future. Initially, the project will aim to use post-industrial plastics.

"Our ambition is to have 1m tonnes of plastic recycling capacity in operation or development by 2025," says a representative.

Dow says it is actively pursuing a number of commercial partnerships with customers and brand owners to scale chemical recycling technology. Two years ago, for example, it announced its partnership with Fuenix Ecogy Group for the supply of pyrolysis oil feedstock made from recycled plastic waste, to be used in the production of new polymers at Dow's production facilities in Terneuzen, The Netherlands. It has since announced additional investments in Fuenix to help scale this advanced recycling technology further. Most recently, in October 2021, Dow and Fuenix announced the construction of a second plant in Weert, which will process 20,000 tonnes of waste plastic.

As well as its partnership with Mura Technology, Dow has also established a multi-year agreement with New Hope Energy, based in Tyler, Texas, USA to supply it with pyrolysis oil feedstocks derived from plastics recycled in North America, which Dow


IMAGE: RENASCI

Above: Renasci's ISCC PLUS-certified recycling centre in Oostende, Belgium

will use to produce circular plastics.

BASF is working with several partners to further develop pyrolysis technology. In 2019, it invested €20m in **Quantafuel**, a Norwegian company specialised in the pyrolysis of mixed post-consumer plastic waste and the purification of the resulting oil. In September 2020, Quantafuel started up its first pyrolysis plant with a capacity of approximately 20,000 tonnes/yr in Skive, Denmark. "Together, we are also working on further developing and improving the process," says BASF. "Developing suitable catalysts for the new process technology is an important aspect of this. These catalysts aim to ensure that high-purity pyrolysis oil is always produced, even when the composition of the plastic waste varies."

In late August, Quantafuel said the Skive plant would undergo upgrades before the end of the year, allowing for stable, long-term commercial production. "We are working on removing the last known obstacle," said Quantafuel's interim CEO Terje Eiken. In September, it announced plans to expand into the UK, with a plant in Sunderland that could be up and running "in a few years." Additional sites are also being considered by Quantafuel UK. The Sunderland plant will be designed to process more than 100,000 tonnes/yr of waste plastics, to be sourced from across the north of England.

In June, **Borealis** announced an exclusive agreement with **Renasci** which has enabled Borealis to offer commercial volumes of chemically recycled base chemicals and polyolefins since May. (Borealis has a10% share of Renasci.) Borealis obtains chemically recycled material from Renasci Oostende Recycling in Belgium. Projected output is 20,000 tonnes/yr. Feedstock will be subsequently processed in the Borealis steam crackers, initially at its production location in Porvoo, Finland.

Earlier, in April, Borealis announced a feasibility study for a chemical recycling unit to be established at the Borealis production location in Stenungsund, Sweden is being carried out with project partner Stena Recycling, and could lead to operations beginning in 2024. Borealis will also co-operate independently with Fortum Recycling and Waste on a project involving the sourcing of plastic waste to the chemical recycling unit.

In October, **ExxonMobil** announced plans to build its first, large-scale plastic waste advanced recycling facility in Baytown, Texas, USA, which is expected to start operations before 2023 with a planned capacity of 30,000 tonnes/yr. A smaller, temporary facility, is already operational and producing commercial volumes of certified circular polymers that will be marketed by the end of this year.

ExxonMobil's initial trial of its proprietary process recycled more than 1,000 tonnes of plastic waste and has demonstrated the capability of processing 50 tonnes per day.

The company says it is developing plans to build approximately 500,000 tonnes/yr of chemical recycling capacity globally over the next five years. As mentioned earlier, it is collaborating with Plastic Energy on a plant in Notre Dame de Gravenchon, France, which is expected to process 25,000 tonnes/yr of plastic waste when it starts up in 2023, with the potential for further expansion to 33,000 tonnes/yr. ExxonMobil is also assessing sites in The Netherlands, the US, Canada, and Singapore.

At the beginning of November, **Honeywell** announced the commercialisation of its UpCycle Process Technology, which incorporates pyrolysis. Sacyr, a Spain-based global engineering and services company with operations in more than 20 countries worldwide, will be the first to deploy the Honeywell technology. The two companies will form a joint venture to operate a facility in Andalucía, Spain, with a capacity of 30,000 tonnes/yr of mixed plastics waste. Production is expected to begin in 2023.

Arcus Greencycling uses a pyrolysis process that can handle a wide range of polymers found in mixed waste, from PP, PE, and PS to more difficult polymers like PVC and ABS. The company has a co-operation agreement regarding pyrolysis technology with Karlsruhe Institute of Technology.

Arcus is currently building a 4,000 tonnes/yr industrial-scale pilot plant in Frankfurt am Main, Germany. The company expects this to start operations in the second quarter of 2022. "This plant will offer customers a highly robust process at an industrial scale to either test the suitability of a wide variety of waste streams for chemical recycling and/or utilise the facility to produce commercially usable pyrolysis oil," it says.

Clariter says its chemical recycling technology

enables it to make end products, not a feedstock like pyrolysis oil. The company has developed a three-stage process for recycling mixed plastics waste. First it uses thermal cracking which generates a wide range of hydrocarbons. Stage two is a hydro-refining process developed to remove impurities and form naphthenic and paraffinic hydrocarbons. The third distillation stage results in three product families, waxes, solvents and oils for industrial and consumer use which are sold to its customers.

Clariter's technology has been proven through an operational pilot plant in Gliwice, Poland, and a demonstration plant in East London, South Africa. In 2021, it has announced collaborations with DSM and Mitsubishi. In addition, South African chemicals group AECI has made a €2.5m investment in Clariter and is exploring construction of full-scale plants in South Africa, Germany and USA.

Recycling Technologies, in Swindon, England, has developed thermal cracking technology that it says can be installed at existing waste sites anywhere. Its RT7000 machine produces pyrolysis oil branded Plaxx. A demonstration plant and testing facility has been operating at Swindon Borough Council's recycling facility since 2017. The first commercial-scale unit will be installed at Binn Eco Park in Perth, Scotland, in collaboration with Binn Group and Zero Waste Scotland.

Polystyrene

Chemical recycling of polystyrene is well-advanced. This April, Recycling Technologies was selected by **Ineos Styrolution** as the technology provider for commercial scale recycling of PS back to styrene monomer. Prior to building the commercial scale recycling plant, a PS recycling pilot plant will be built in Swindon, UK. It uses the same basic technology as the RT7000 but the machine to recycle polystyrene will have a different name.

Ineos Styrolution plans to build its full commercial scale recycling facility in Wingles, France, but has not given a date; capacity should be 15,000 tonnes/yr. **Trinseo** has said it plans to build a dedicated 15,000 tonnes/yr plant at its Tessenderlo, Belgium location, to come into operation in 2023.

In May, Trinseo announced that it could supply recycled polystyrene (rPS) for food contact applications with the launch of the first yogurt pot integrating rPS (again from Yoplait), now on shelves in France. Styron CO2RE CR55 contains 55% recycled content resulting from depolymerisation.

In September, Trinseo and Indaver, a leader in sustainable waste management in Europe, signed an offtake agreement for recycled styrene monomer. Trinseo said it would buy a minimum of 50% of the monomer produced at Indaver for a 10-year period, following start-up of the plant planned in 2023.

Indaver will collect post-consumer polystyrene, such as yogurt pots and single-use packaging, and produce new styrene monomer through a proprietary depolymerisation technology at its Antwerp, Belgium site, for repolymerisation at Trinseo's Tessenderlo, Belgium site.

At the end of last year, Total (now TotalEnergies), sheet extrusion company Intraplás, and yoghurt producer Yoplait said they had successfully run a pilot test aimed at using certified chemically recycled polystyrene in yogurt pots. Total said that by converting mixed plastics waste in its steam cracker in Antwerp, it can produce certified chemically recycled polystyrene.

Canadian technology company **Pyrowave** is involved in a major polystyrene chemical recycling project in a partnership with Michelin in Europe. Pyrowave manufactures modular equipment that uses microwave technology to depolymerise polystyrene and it licenses its use. Michelin will operate the equipment at a location yet to be decided. It will acquire several units from Pyrowave. Michelin will use the styrene monomer as a feedstock to make rubber for tyres.

At the end of last year, the two companies said they would work together to fast-track the industrialisation of Pyrowave technology with a view to a certification and commercial roll-out in international markets. The joint development agreement will ultimately account for an investment of more than €20m. Michelin and Pyrowave are working together to develop an industrial demonstrator, funded and operated by Michelin, by 2023.

PET

Eastman is building the world's largest polyester chemical recycling facility at its site in Kingsport, Tennessee, USA, employing its Polyester Renewal Technology (PRT) which uses methanolysis. Eastman expects the facility to be mechanically complete in late 2022. "Our goal is to recycle 250m pounds (around 113,000 tonnes) annually by 2025 and 500m pounds annually by 2050," says a representative.

"We pioneered the technology decades ago when we were formerly part of Eastman Kodak and used methanolysis to recycle polyester including Kodak films. We've retained that R&D knowledge and actually improved on it in the decades since."

Aquafil Engineering designs polyamide and polyester polymer plants based on its own patented technology and production know-how. It also offers several recycling solutions under the brand

IMAGE: CARBIOS

Abve: The Carbios demonstration plant

name EverPET for internal, industrial or post-consumer waste. It has recently been building a recycling unit to produce 100% PCR PET on a small scale for customer and test samples for different PET customer applications (bottle, film, yarn, multi-layer packaging).

In the chemical EverPET process, the raw materials (oligomers, monomers and BHET) are recovered from previously cleaned polyester wastes, which can be re-processed into a high-quality polyester by downstream polycondensation.

Carbios, which has developed an enzymatic recycling technology (C-Zyme) for depolymerising PET using hydrolysis, brought its first demonstration plant onstream in September. The plant includes a 20 m^3 depolymerisation reactor capable of processing 2 t of PET per cycle, which is the equivalent of 100,000 bottles. It is co-located with a Michelin tyre production plant in Clermont-Ferrand, France; Michelin is a major shareholder in Carbios, and is interested in using various recycled or renewable materials in its tyres.

Martin Stephan, the company's Deputy CEO, says Carbios will also build and operate a 40,000 tonnes/yr reference unit, the first industrial plant. Its intention is to start up the plant in 2025 and that the plant will be adjacent to an existing PET production line. Carbios has Expressions of Intent with at least one PET supplier.

Swiss company **Gr3n** has another technology that uses alkaline hydrolysis. A demonstration plant should be fully operational early next year. Fabio Silvestri, Head of Marketing and Business Development, says the first industrial plant, with a capacity of 30,000 tonnes/yr, could start up before the end of 2024. He says the company has had confirmation that its technology can depolymerise textiles. Gr3n has an MoU with Kolon Industries to accelerate the commercialisation and the implementation of its technology throughout Asia.

Ioniqa, a clean-tech spinoff from the Eindhoven University of Technology in The Netherlands, has a 10,000 tonnes/yr plant producing BHT monomer from bottles using glycolysis, which it currently supplies exclusively to Indorama. Maarten Stolk, the company's Business Developer, says that it plans also to use fibre as a feedstock. The company is currently in discussions with a plant engineering firm so that it can sell licensed packages.

In June, **Loop Industries** in Terrebonne, Quebec, Canada, announced a strategic partnership and equity investment from SK Global Chemical (now called SK Geo Centric); Loop and SKGC intend to form a joint venture with exclusivity to build recycled PET resin and polyester fibre manufacturing facilities using Loop's depolymerisation technology throughout Asia. SKGC currently has a 10% shareholding in Loop. In August, plans were announced for the first Infinite Loop Asian facility in Ulsan, South Korea, to begin preparation in 2022.

Loop recently completed the conversion of its Terrebonne, Québec pilot plant to a small production facility. In September of this year, together with French mineral water company Evian, Loop unveiled the Evian Loop bottle, made from Loop's 100% recycled PET coming from waste plastic and fibre. The bottles will be rolled out at commercial scale in South Korea in 2022, with the goal of launching in other markets later. ■

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Aquafil

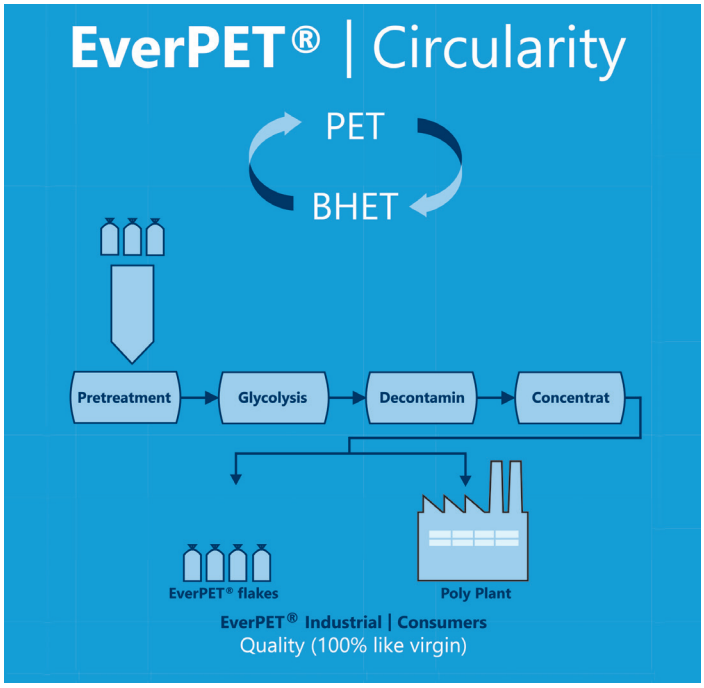
Aquafil Engineering: Experts in polyester and polyamide recycling plants

Aquafil Engineering, an independent company of Aquafil Group, is located in Germany, and is one of the worldwide leading companies in technology and equipment design for polyamide, polyester and recycling plants. The plant design is based on patented technology and production know-how which provides customers with state-of-the-art technology combined with high quality, flexibility, efficiency and sustainability.

Aquafil Engineering understands itself as provider for customised solutions for fibre, film, technical and bottle applications.

The EverPET™ technologies are the newest developments in polyester recycling. EverPET™ is the brand name for a collection of different recycling systems and includes solutions for mechanical (extrusion) as well as for chemical (glycolysis) recycling.

› **www.aquafileng.com**



Arcus

Leading the way to recycle mixed and dirty plastic waste
Arcus leads the way in providing a chemical recycling solution for currently non-recyclable mixed plastics waste streams with as little as possible prior sorting or cleaning of the waste. Our process successfully handles a wide range of polymers from PP, PE, and PS to difficult to process PVC, ABS, or PET.

First industrial scale plant of its kind in Germany
Arcus is currently building a fully authorised (BImSch approved, REACH registered, end-of-waste status acknowledged as well as ISCC, RedCert2, and EfbV certified) 4,000 tonnes per year industrial-scale pilot plant in Frankfurt am Main, Germany, which will go live in the second quarter of 2022. This plant will offer customers a highly robust process at an industrial scale to either test the suitability of a wide variety of waste streams for chemical recycling and/or utilise the facility to produce commercially usable pyrolysis oil.
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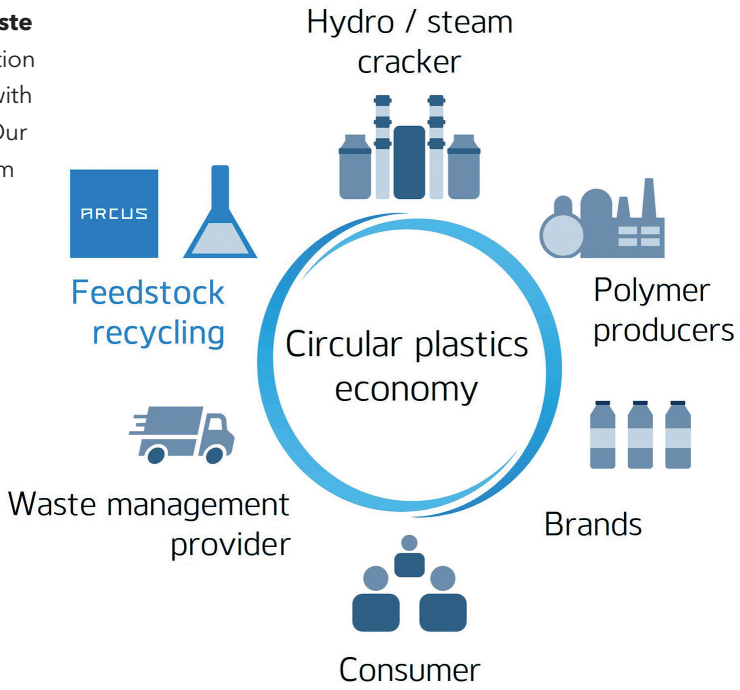

The ARCUS Greencycling solution: Closed loops are the model for a world without plastic waste and lack of resources

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- High-value feedstock for the petrochemical industry (incl. REACH registration)
- Longstanding operations and research track record
- Fully approved and certified testing plant in Germany

Greencycling ...

Recovers raw materials | Closes the material loop | Is eco-nomical | Preserves natural resources

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Clariter

clariter
A Clean Slate

Clariter takes plastic waste no one wants and transforms it into products everybody needs. While the recycling industry is turning plastic waste into new plastics, fuels, or intermediates that require further processing and blending, Clariter's innovative technology transforms most plastic waste streams, even those with the lowest value, into pure, ready-to-use industrial products: aliphatic solvents, mineral oils, and snow-white waxes.

According to the latest Life-Cycle Analysis, Clariter's process is preferable to landfill, incineration, and other pyrolysis-based solutions. This is a real paradigm shift and a resource efficient approach to meet circularity standards in the EU and beyond.

The company unlocks the value of the circular economy without compromising on profitability or sustainability. Clariter's short-term plan is to build and operate full-scale plants in Israel, Poland, and the Netherlands.

Each plant will recycle 60,000 tons of plastic waste and produce 50,000 tons of clean products annually.

Clariter's solution bridges the world of recycling and the petrochemical industry by replacing crude oil with upcycled plastic waste, thus saving significant amounts of CO_2, cleaning the earth of plastic waste, and making sustainable products for the market with 1000+ end applications, e.g. paints, shoe polishes, degreasers, detergents, inks and even ski waxes.

› **https://clariter.com**

Watch the video Clariter in Brief

Above: Clariter's Industrial-scale plant has been in operation in East London, South Africa since 2018

Left: Clariter's technology transform plastic waste into aliphatic solvents, mineral oils and paraffinic waxes

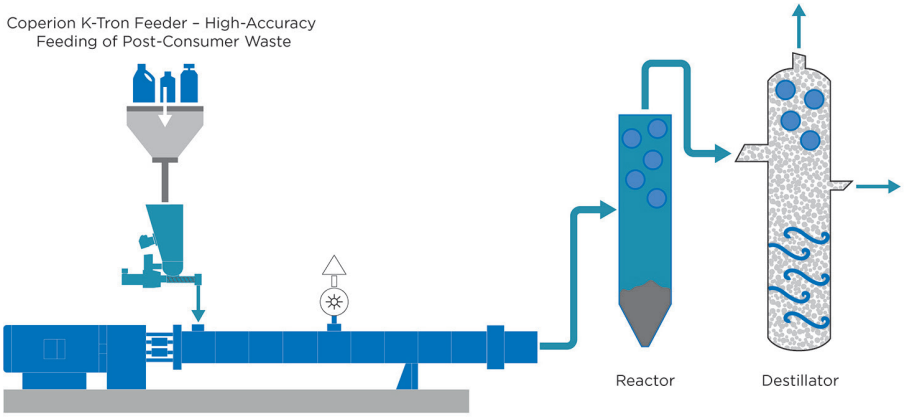
coperion
confidence through partnership

First class technology for chemical recycling

Chemical recycling is a promising process for recycling mixed plastic waste into chemicals, waxes or liquid energy carriers. Coperion provides process know-how and superior technologies for chemical recycling.

Coperion K-Tron feeders ensure high-accuracy feeding of raw materials into the extruder. Coperion's ZSK twin screw extruders enable a very efficient energy addition to the material in shortest time. Within 30 seconds, ZSK extruders produce a homogeneous, highly devolatilised melt with high temperatures. Throughputs of up to 20 tonnes per hour can be realised.

COPERION PROCESS FOR CHEMICAL RECYCLING



Next the melt is further processed to the reactor and destillator to transform it into marketable products such as oil, heavy fuel, or waxes.

Contact: Jochen Schofer
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MAAG Group

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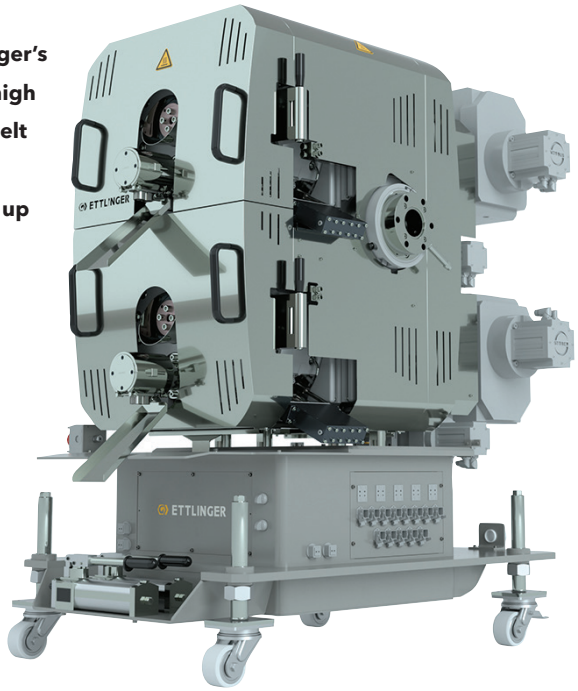
Next level solutions for recycling applications
MAAG Group systems play a key role in enabling a more circular economy for plastics. Our equipment and solutions cover the entire plastics value chain and help to introduce used plastics back into high quality products.

As a specialist for polymer filtration and recycling systems, we have developed custom melt filtration and pelletising systems that meet the strict requirements of our customers. Our systems provide solutions to process the most demanding material streams and turn them into valueable resources.

Our goal is to preserve material properties and produce pellets that are equal in quality to virgin materials when processing post-consumer and post-industrial plastic materials.

› **https://maag.com**

MAAG Group company Ettlinger's new ECO 500 high performance melt filter achieves throughputs of up to 4,000 kg/h



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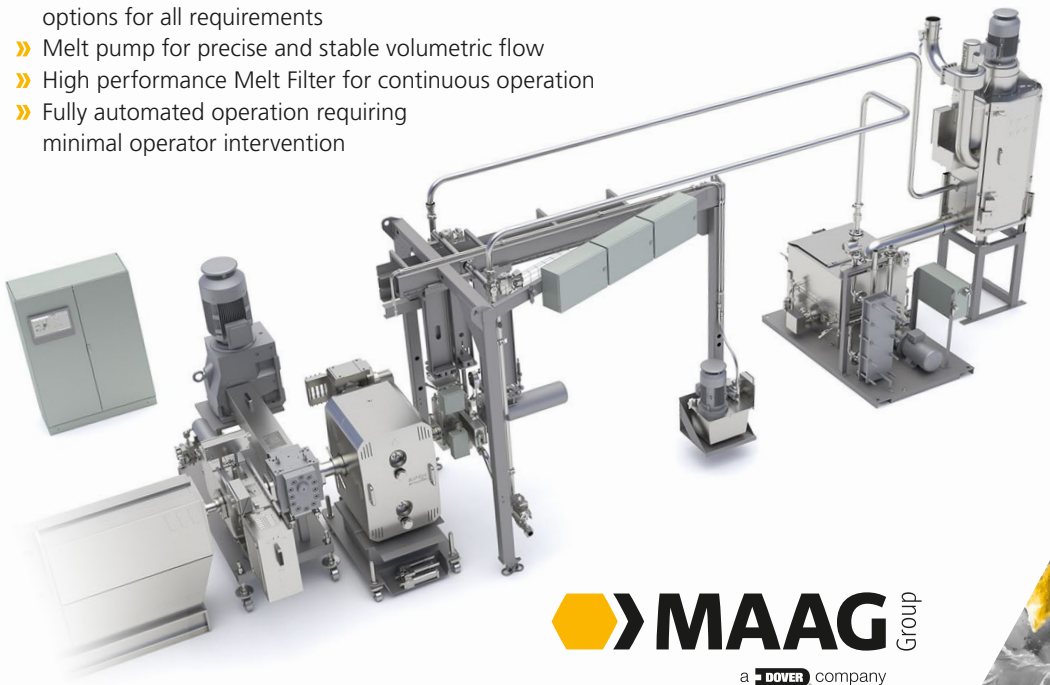

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Pryme

Pryme contributes to a meaningful solution to the global plastic waste problem by enabling the circularity of plastic. We convert plastic waste into valuable petrochemical products using a proven pyrolysis process that is enhanced with proprietary characteristics and has a low carbon footprint.

Our R&D team has worked long to take the pyrolysis process to a higher level, so we teamed up with a reactor manufacturer that boasts over 80 years of experience in this area. As a result, our reactor ensures a very precise and controlled application of heat at lower temperatures, which makes the recycling process more energy-efficient.

In addition, we have enhanced the process in order to remove contaminants such as chlorine, which we know oil majors don't want in recycled oil because it is highly corrosive. Moreover, we can process more waste than our competitors do, giving us an extremely high conversion rate: 100% of the plastic waste that we treat is converted to value-added streams.

Thanks to our tweaks to the process and installation, we can ensure a high input and output capacity and can rapidly scale the technology, which is key for market feasibility. Pryme's first plant will start production in 2022 in Rotterdam. This plant will have an initial intake capacity of 40,000 tons of plastic waste per year and produce 30,000 tons of feedstock in its first year. That tonnage will grow by 50% by 2023.

Pryme is an ambitious and innovative company, so if you're interested in our business, technology or job opportunities, be sure to contact us via our website.

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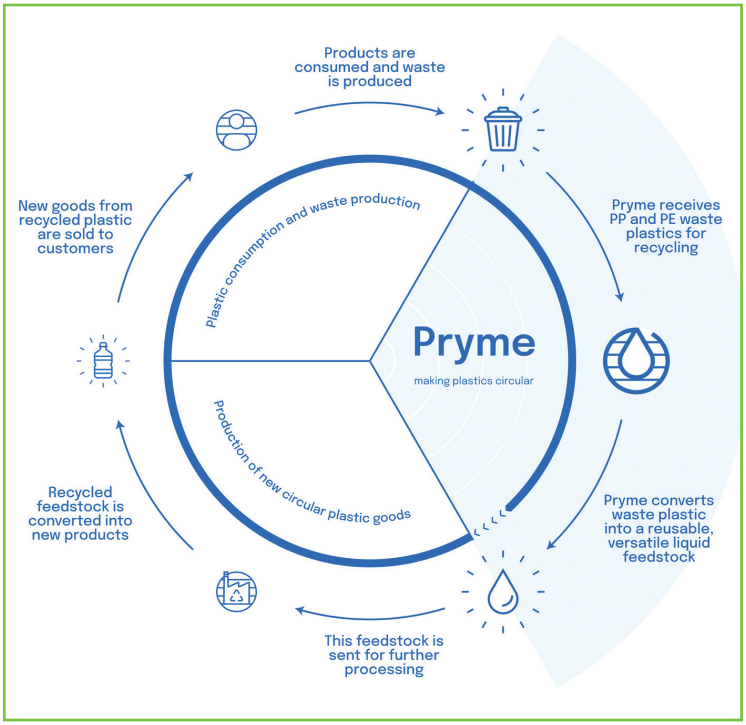
Above: Sander Schiereck, Michiel Kool and Joeri Dieltjens at the site of the new Pryme plant



Above: Pryme provides a sustainable, circular solution to converting waste plastics into valuable feedstock

IMAGE: SHUTTERSTOCK

Realising the opportunity

How will the chemical recycling industry develop? We look at factors that have a major influence on the industry's progress, including legislation and the mass balance concept

The chemical recycling industry has started on a growth path as the drive for greater plastics recycling volumes stimulates demand. As well as supply-demand dynamics, there are other important factors that are helping to shape the chemical recycling industry, such as legislation.

In Europe, regulatory impetus in plastics recycling comes from the European Union's Strategy for Plastics in a Circular Economy which the European Commission announced in 2018. This set out a series of targets focussed on packaging recycling: a target for recycling 65% of packaging waste by 2025 and 70% by 2030, and a specific target for plastic packaging recycling of 50% by 2025 and 55% by 2030.

Another aim is for all packaging to be recyclable by 2030, which would not only help grow mechanically recycled volumes but would also benefit chemical recycling by reducing contamination in waste feedstock.

Going hand-in-hand with legislation is funding support from the EU. Among collaborative R&D projects is Demeto, in which 13 partners are developing a PET depolymerisation process using microwave-based process intensification, and which receives funding from the EU's Horizon 2020 research and innovation programme. Other EU projects are not looking at packaging but focus on other areas, such as the Plast2BCleaned project in WEEE plastics recycling, and the Circular Flooring project which is investigating the CreaSolv process as a means for recycling PVC flooring.

Associations have been set up to provide collaborative platforms as the chemical recycling industry grows. The European Coalition for Chemical Recycling was founded in early 2019 by Cefic and PlasticsEurope, which supports the work of the EU Circular Plastics Alliance and its aim to ensure that 10 million tonnes of recycled plastics find their way into new European products by 2025. Chemical Recycling Europe's members are companies fully focused on chemical recycling technology rather than production of plastics, although it does hope to involve petrochemical companies as well.

Voluntary commitments are also acting as a focal point for mechanical and chemical recycling companies. Many polymer producers are among the corporate signatories of the Global Alliance set up by Ellen MacArthur Foundation, which has also led the way for individual countries to formulate specific recycled plastics content targets within its Plastic Pacts initiative. Sector-specific recycling is supported by Extended Producer Responsibility (EPR) schemes in different countries. But the extent to which EPR schemes proliferate remains to be seen after some poor results and scheme failures.

The chemical recycling industry in the USA is also being influenced by legislation. In the past couple of years, federal bills formulated by often cross-party sponsors have targeted aspects of plastics waste, recycling and environmental improvement. The Break Free from Plastic Pollution Act envisages a producer responsibility scheme involving a 10-cent beverage container deposit

Main image: Mass balance aims to measure the waste plastics contribution from chemical recycling in a much larger manufacturing process and allocate that to the end product

IMAGE: RECYCLING TECHNOLOGIES

Above: Recycling Technologies makes its Plaxx pyrolysis oil from waste plastics at its plant in Swindon, UK

program to operate nationally, minimum recycled content targets, phasing out some single-use plastics items, and a temporary halt to new polymer production plants being built. The RECOVER Act focuses on allocating federal grants to states and municipalities to invest in improving their recycling programs and infrastructure.

In addition to federal and state legislation, the Environmental Protection Agency has developed a National Recycling Strategy with a goal of achieving a 50% recycling rate for all materials by 2030. The American Chemistry Council, representing petrochemical and polymer producers, has been proactive and developed its own Roadmap to Reuse to support its members' aim for all US plastics packaging to be reused, recycled or recovered by 2040.

In the ACC's opinion, crucial to the US achieving its plastics sustainability ambitions is the need for official recognition of chemical recycling and its contribution to the country's efforts. Placing chemical recycling on a par with mechanical recycling is also desirable for plastics producers working in Europe. The risk for the chemical recycling industry is that its processes are not defined as recycling if the European Commission holds the position that the waste plastics input can be converted to fuel either for processing purposes or in the creation of new fuel products. After much lobbying of the European Commission, it has still not officially announced if its definition of plastics recycling includes chemical recycling processes.

Mass balance

A counter approach is being followed by chemical recycling companies with regard to the input-output of their plants and its use in the production of new plastics: it's called the mass balance approach. Tracking use of recycled material is relatively straightforward in the mechanical recycling supply chain but not so easy in chemical recycling, where outputs typically take the form of basic hydrocarbons that subsequently make their way through multiple and complex cracking and polymerisation processes. The solution for the chemical recycling industry is to follow the principles of mass balance.

Already applied in sectors as varied as electricity marketing and Fair Trade agriculture, the mass balance concept aims to determine and measure the contribution of a particular component in a much larger manufacturing process and allocate that accordingly to each unit of end product. In the case of chemical recycling, it aims to ensure that the amount of recycled feedstock entering a production plant equates to any claims made about the recycled content of a product leaving it.

While this may sound a simple task, the reality is much more complex as different approaches can be taken with regard to what and where to allocate. For instance, the entire output of a chemical recycling process could be allocated as a contributor to any polymer or chemical production process – so called free-attribution. Alternatively, it may be decided to allocate only the non-fuel components. Or, at its strictest, only those components used as a non-fuel contributor to production of a polymer.

Chemical Recycling Europe leans toward the free-attribution approach. In a recent white paper it said: "Our position is that all mass-balance interpretations should ensure that the full recycled output from chemical recycling finds a credible value and recognition though the system."

Others, however, favour more restriction. Zero Waste Europe, together with several other environmental NGOs, this year published 10 recommendations to ensure that mass balance does not undermine circularity goals. These include only allowing post-consumer waste streams, not allowing trading of recycled content credits, and ensuring allocations are restricted only to processes where there is a direct link between feedstock and final product (an approach being followed by Sweden's Perstorp with its traceable mass balance scheme).

Mass balance will be essential in the development of chemical recycling as an industrial process and to that end must be seen to be transparent and trusted – consumers, for example, must understand the claims made and, more importantly, have confidence in them. A number of organisations are already running certification programmes, of which the best known are International Sustainability and Carbon Certification (ISCC)and RedCert (both headquartered in Germany). In addition, last year the International Organisation for Standardisation (ISO) announced it had started work on a global mass balance standard. ■

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