Sustainable Growth

Acrylonitrile-Butadiene-Styrene (ABS)

Because of its good temperature resistance, impact resistance and aesthetics appearance, acrylonitrile-butadiene-styrene is often used in household goods and in the automotive industry. The development of a circular economy also shows successes. More and more ABS materials used in a range of applications are containing a contribution of recyclates.

Acrylonitrile-butadiene-styrene (ABS) is the largest-volume engineering thermoplastic resin, offering an excellent balance of heat, chemical, and impact resistance with superior processing versatility. ABS resins are produced by the polymerization of styrene, butadiene and acrylonitrile. Typically, the proportion of styrene is between 50 and 60%, while 20 to 30% is acrylonitrile. In blends with polyamide or polycarbonate, ABS resins are frequently used in order to combine high end properties with affordable prices.

ABS consumption is primarily driven by household appliances (40%) and electrical/electronic applications (26%). During the last five years, demand for ABS resins in appliances and electrical/electronic applications (E&E) grew at average annual rates of 4.9% and 5.3%, respectively. This trend is expected to continue and these two industries will drive ABS resins demand growth. The transportation sector, followed by building and construction, will be the next-largest markets for ABS resins

Northeast Asia is the major market for ABS, accounting for more than three-quarters of global capacity and more than two-thirds of global consumption in 2019 (**Fig. 1**). Mainland China is the largest supply and demand center – it accounted for about 37% of global ABS capacity and 57% of consumption in 2019.

Over the past five years (2014–19), global ABS consumption grew at an average annual rate of 4.4% to reach 9.3 million t in 2019. The Asian ABS demand scenario is robust, particularly in mainland China, as a result of government incentives. Growing internal consumption was one of the major focus areas of mainland China's 12th Five-Year Plan (2011–15), which has enhanced durable goods consumption. With support from its automotive and construction sectors, the North American ABS markets did well over the same period, registering an average annual growth rate of 2.3%. European markets also registered growth during the past five years; Western Europe registered an average annual growth rate of 2.6% and Central Europe grew at 2.4% per year.

During 2019–24, global ABS consumption is forecast to grow at 3.6% per year to reach 11.2 million t in 2024, representing an increase of 1.8 million t. Mainland China is expected to represent about 76% of the additional volume; the Indian Subcontinent and Southeast Asia are also expected to witness strong growth.

Global capacity increased during 2009–19 at 3.1% per year compared with consumption growth of 3.5% per year (**Fig. 2**); this resulted in a nearly 3% increase in operating rates. However, lower demand prospects and a strong capacity addition rate (5.1% per year) during 2019–24 are expected to lower operating rates by 2024 (**Table 1**). The global operating rate was more than 80% in 2019, and with more than 3 million t of capacity »

More than half of the world's ABS consumption is accounted for by household and E&E equipment © Shutterstock

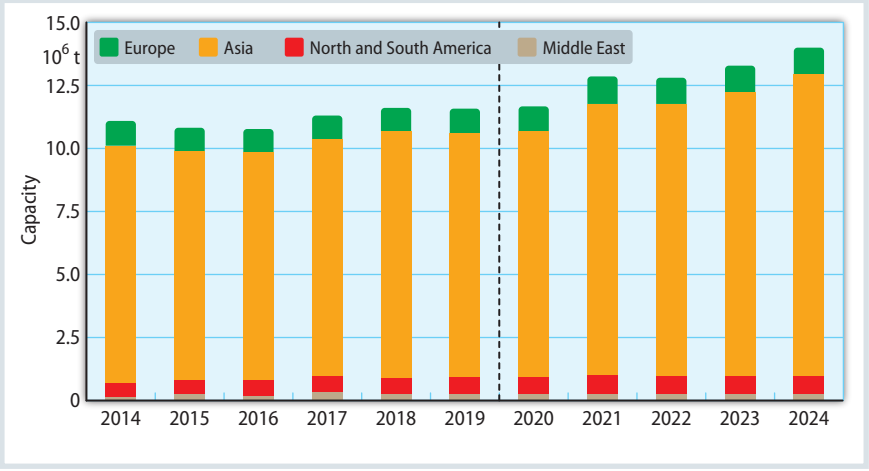

Fig. 1. ABS capacity by region (as of July 2020): Asia is by far the largest producer Source: IHS database; graphic: © Hanser

additions planned in the next five years, the global operating rate is expected to decline slightly in 2024. In the interim, the global ABS market is moving from tight to balanced.

The majority of new capacity in the next five years is coming online in Asia (primarily in mainland China) and the Middle East. Chi Mei Corporation, Tainan City, Taiwan, and LG Group, Seoul, South Korea are currently the largest ABS producers. Northeast Asia is the largest export region of ABS resins. In 2019, South Korea and Taiwan together accounted for 68 % of global exports; this is expected to continue for the next five years. Despite capacity buildup in mainland China, the country continues to be the largest importer of ABS resins, accounting for about 46 % of global imports in 2019.

Backed by a positive volume outlook, Ineos Styrolution announced plans to build a world-scale ABS plant in Ningbo, China. The new production site will be adjacent to the recently acquired polystyrene plant in Ningbo. Its annual capacity is planned to be at 600,000 t. Construction is planned to start in 2020, completion is expected in 2023.

The success of ABS in so many applications is based on its unique combination of properties. With a temperature resistance on the order of 100 °C, an unmatched impact to stiffness ratio, extremely pleasing esthetics and the processing advantages of an amorphous material ABS is clearly the material of choice for designers, converters and final customers even though the latter not always realize the high gloss parts of their daily use items are actually made from this versatile material. But ABS producers are still pushing the boundaries of the application space by tuning the properties

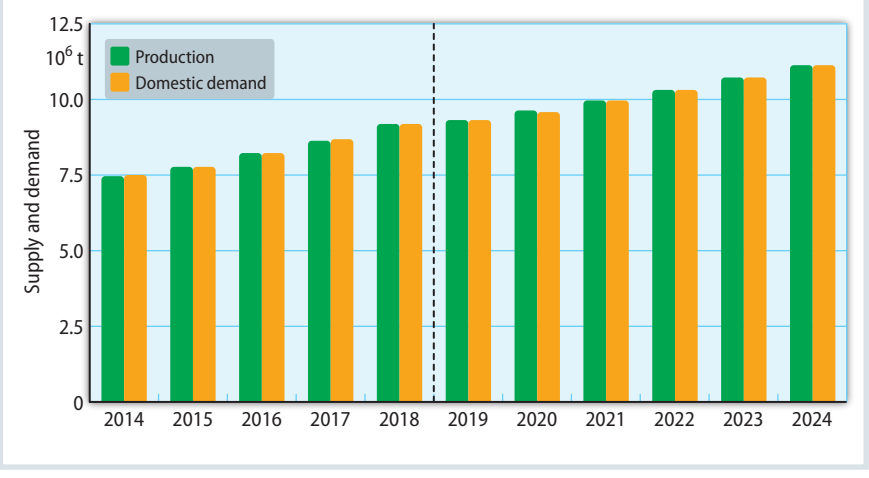

Fig. 2. Supply and demand for ABS develop very evenly Source: IHS database; graphic: © Hanser

in many aspects. For instance, ABS is a material with a long history in a wide range of exterior and interior automotive applications. The announcement of Minda Industries Limited – Lighting Division (an Indian automotive lamp manufacturer) to use Ineos Styrolution's Novodur HH-112 for the rear lamp housing application of a leading 4-wheeler model in India is a typical example for the use of ABS in the automotive sector.

Novodur HH-112 enjoys a track record of more than ten years being the material of choice in terms of performance and process ability for rear lamp and housing applications and is currently used by leading global automobile brands. This material provides high heat resistance, high dimensional stability and excellent stiffness. In addition, it also offers great performance in metallization and welding processes. With its Vicat B-50 temperature of 112 °C this grade significantly enhances the application space of ABS and represents about the highest reachable temperature resistance of a pure ABS that is technically achievable. For Minda, the molding and metallizing performance of Novodur HH-112 were the key criteria to select this material for its rear lamp housing application. Novodur HH-112 offers excellent mechanical properties with overall balanced thermal and rheological properties.

Even Large E&E Components Can Be Produced

In the E&E sector, the production of large parts, e.g. for air conditioning devices, vacuum cleaners and coffee machines, traditionally is a challenging task for application providers. A step forward was made with a new ABS grade in Ineos Styrolution's family of Novodur ABS specialty copolymers. The new material grade, Novodur P4XF, excels with a high flowability and at the same time offers an attractive balance profile between flowability and impact strength. Its product properties make the new grade the material of choice for large and complex applications in the household and electronics industries and contributes to improving their carbon footprint.

The plastics industry as a whole and individual materials like ABS in particular have a strong focus on sustainability. At

last year's K-fair in Düsseldorf, Germany, this trend became very visible. There was no vendor who ignored this topic.

Several vendors started projects to explore new solutions, others were already more advanced and brought sustainable solutions to market.

An example is Ineos Styrolution that introduced an entire new family of sustainable styrenics solutions. Their new ECO products are the result of the company's unmatched R&D expertise combined with extensive collaboration with leading-edge technology companies, with Ineos Group, and with the styrenics value chain.

With the Terluran ECO GP-22, the company brings its first mechanically recycled ABS products to market. The two new grades Terluran ECO GP-22 MR50 and Terluran ECO GP-22 MR70 contain 50 and 70% of recycled post-consumer waste electrical and electronic equipment (WEEE), respectively. Both grades are available in black. The recycled material matches the mechanical property profile of its non-recycled counterparts.

The new material is developed in collaboration with Austrian recycler Bage Plastics. The collaboration resulted in ABS recyclates allowing for true recycling, not downcycling. These recycled grades are available in commercial quantities as a drop-in solution for customers.

Mechanical Recycling Remains the Best Choice

While mechanical recycling of ABS (**Fig. 3**) currently remains the best choice for a more circular ABS application space as other techniques like dissolution or a controlled thermal breakdown (pyrolysis) are still in its infancy, the larger and older styrenic sibling polystyrene turns out to be even more versatile in terms of its potential to enable a circular plastics economy and is also suitable for chemical recycling (**Fig. 4**). In a sense, polystyrene is a unique plastic made for the circular economy. This is due to the very nature of this material, being successful on the market since 1930. Due to its moderate ceiling temperature (the temperature where polystyrene fully converts back to styrene) it is possible to generate high value styrene monomer in relatively high yields, without creating major issues with unwanted by-products

Polystyrene has a glass transition temperature well above the temperature of use. As a result, the molecular mobility of polystyrene chains is "frozen" and as such the migration of (unwanted) trace impurities from or through polystyrene is minimized. This effect makes PS very suitable for as well for mechanical recycling to highly pure, food quality packaging materials

In 2019, Ineos Styrolution announced its successful test run in producing polystyrene from recycled material. Six months since, the company produced its first small batches of depolymerized polystyrene at its laboratory in Antwerp and provided sheets containing 50% of recycled GPPS to Unternehmensgruppe Theo Müller, Luxembourg, a manufacturer of dairy products. The Group has now produced yoghurt cups from this recycled material. (**Fig. 5**)

Ineos Styrolution and Unternehmensgruppe Theo Müller are collaborating on a joint project to develop a circular solution for polystyrene based on chemical recycling. The two companies had agreed on a phased approach with a lab-scale »

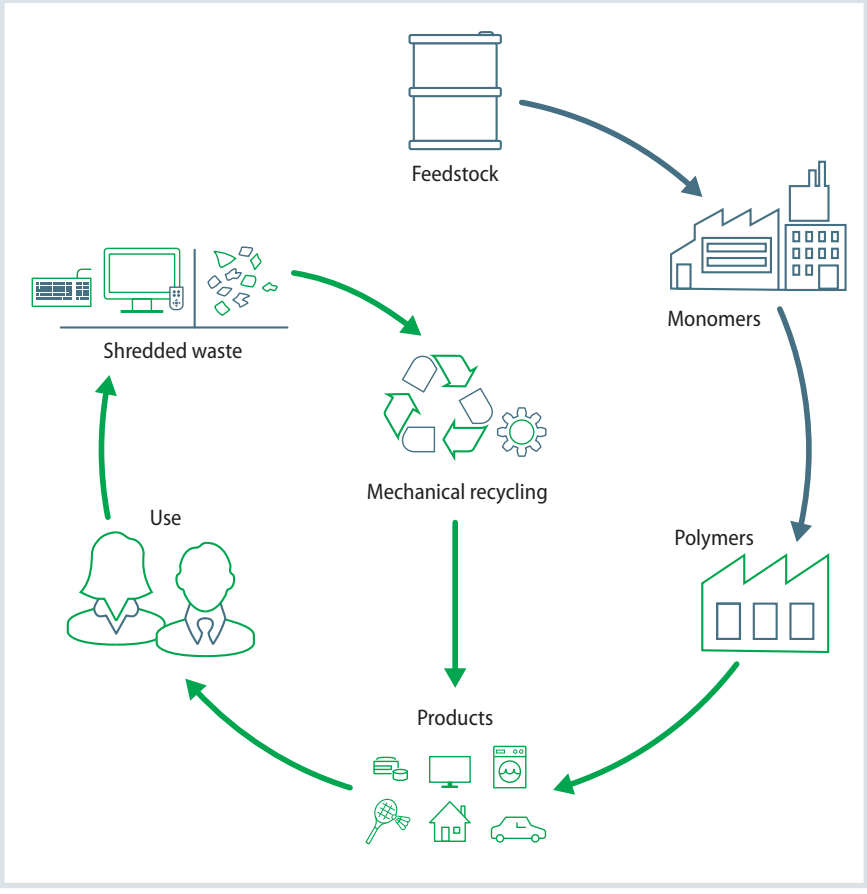

Fig. 3. Mechanical recycling is currently the best way to reuse ABS Source: Ineos Styrolution; graphic: © Hanser

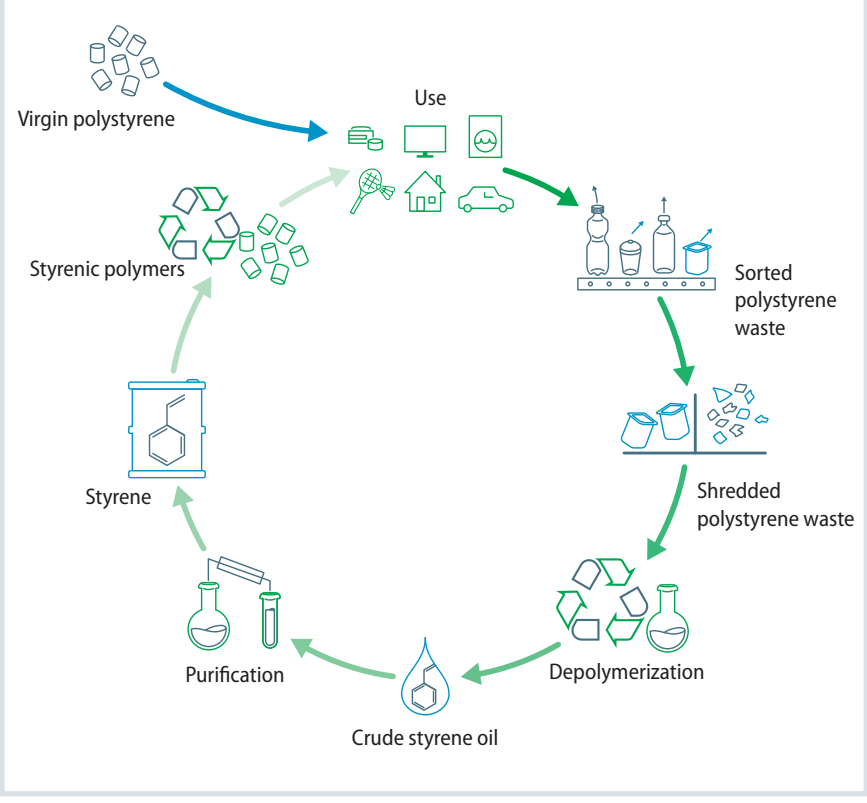

Fig. 4. Various chemical recycling processes for PS are currently in the industrial test phase

Source: Ineos Styrolution; graphic: © Hanser

phase to start this year, a pilot-scale phase starting in 2020 and a commercial-scale phase in 2022.

The developments in chemical recycling have been recognized with Ineos Styrolution being chosen joint winner of the ICIS Innovation Awards in the category "Innovation with Best Benefit for Environment and Sustainability". The company's demonstration of a closed loop solution by polymerizing styrene from depolymerized polystyrene was selected as it showed a distinct benefit to the environment and to the sustainability of the company and its customers.

Sirap, Gmbh, Bergheim, Germany, an international manufacturer of food packaging (particularly of XPS based food containers), is another vendor focusing on developing packaging solutions based on chemically recycled polystyrene. Ultimately, the solution aims at achieving circularity for polystyrene reducing post-consumer waste, saving valuable resources with a reduced environmental footprint.

The joint project between Ineos Styrolution and Sirap focuses on the use of polystyrene that is recycled through depolymerization, a process that converts post-consumer polystyrene waste back to its monomers. Polystyrene recycling plants are currently planned or under development in multiple locations around the globe.

One example is Agilyx's development of a chemical recycling facility in Channahon, IL/USA. The facility will be capable of processing up to 100 t per day of post-consumer polystyrene and converting it into a styrene product that will go into the manufacturing of new polystyrene products. The facility will leverage Agilyx's proprietary chemical recycling technology, which breaks polystyrene down to its molecular base monomers that will be used for the creation of new styrenic polymers. Agilyx completed a successful development program for Ineos Styrolution that qualified the styrene product to Ineos Styrolution's specifications and the identified post-consumer polystyrene feedstock for the process.

Joint Recycling Projects

A range of projects are driven forward under the umbrella of Styrenics Circular Solutions (SCS), the joint industry initiative

to increase the circularity for styrenic polymers. The organization was formally incorporated in December 2018. SCS welcomes committed partners from the supply chain, other styrene- and expanded polystyrene producers, converters, recyclers, brand owners and trade associations. SCS also promotes a close collaboration with other diverse stakeholders who are as committed to the circular economy.

Examples include an in-depth evaluation of the decentralized proprietary depolymerization technology of Pyrowave, Oakville, Ontario/Canada. It is based on a catalytic microwave technology. Another project is with Tomra, Leuven, Belgium, a company in waste collection via deposit systems and sorting. Tests revealed that polystyrene is not only made for recycling, but also made for sorting.

With Tomra's near-infrared (NIR) sensor technology, post-consumer plastic waste was sorted in a multi-step process including initial sorting from post consumer waste, grinding into smaller flakes, washing, drying and flake sorting. The resulting purity of polystyrene turned out to be higher than 99.9%. Tomra's findings prove that today's sorting technologies achieve a purity level beyond what is required to successfully recycle polystyrene through both mechanical as well as advanced recycling processes.

A first life cycle assessment analysis has also been completed for depolymerized styrene according to the ISO 14040 and ISO 14044 standards. Results were presented for the first time by Ineos Styrolution. A laboratory scale project shows greenhouse gas savings of 37%, while upscaling and optimization of by-products allow for savings of up to 50%.

	2017	2018	2019	2020	2021	2022	2023	2024
Europe	0.95	0.95	0.95	1.02	1.07	1.03	1.03	1.03
Asia	9.43	9.79	9.77	9.81	10.78	10.85	11.30	12.03
America	0.62	0.66	0.64	0.64	0.78	0.71	0.71	0.71
Middle East	0.35	0.28	0.28	0.28	0.28	0.28	0.28	0.28

Table 1. While capacity in Europe and America is expected to increase only moderately, a significant expansion is expected in Asia Source: IHS database

The lab scale LCA analysis was done in the framework of the ResolVe project, a research project funded by the German Federal Ministry for Education, in collaboration with InVerTec, a non-profit organization associated with the University of Bayreuth, Germany. InVerTec is specialized in providing pilot plants for conceptual and lab-scale research. Upscaling and optimization of by-products allow for GHG savings up to 50%. The detailed study at commercial scale was completed by Ineos Styrolution together with a commercial recycling partner and experts from the University of Manchester. »

Fig. 5. PS from chemically recycled PS waste is already tested in yoghurt cups from Theo Müller Group © Ineos Styrolution

The above mentioned ResolVe project also proved the feasibility of post-consumer waste becoming a valuable feedstock, thus creating a circular economy for polystyrene. The project concludes that depolymerization – an enhanced process breaking polystyrene up into its building blocks – is a very appropriate recycling solution for polystyrene in combination with distillation of the output for further polymerization. The process promises to produce recycled polystyrene meeting food contact standards.

The research has shown that up to 75 % of the output can be fed into the purification step and subsequently back into the production of new polystyrene. Key of the project was the investigation of waste composition and the effect on styrene yield. This was done in a perfect collaboration between the IKV (Institut für Kunststoffverarbeitung), the Institute for Processing and Recycling (Institut für Aufbereitung und Recycling, I.A.R.) and Neue Materialien Bayreuth GmbH (NMB), Germany. The most relevant process parameters temperature, mass flow rate, residence time and vacuum pressure, were systematically permutated and the best process conditions were identified. IKV Aachen, Germany, transferred these basic process/properties relations to a larger scale and successfully de-polymerized polystyrene to styrene oil. As part of the research, the feasibility of additional processes including steamcracking of process residues is assessed, together with Ineos O&P as project partner.

The research has shown that a stable depolymerization process is possible with a broad variety of feedstock material. Lightweight packaging and expanded polystyrene (EPS) waste have proven to be most suitable feedstock for the depolymerization process. While the process tolerates polyolefin contamination, a "legacy" flame retardant HBCD (hexabromocyclododecane) could be removed to a large extent, however bromine containing traces remain.

Depolymerization Removes HBCD

The results demonstrate that polystyrene and depolymerization fit perfectly to the concept of a circular economy. While more work will be required and done on the chemical recyclability of styrenic copolymers like ABS and the family of styrenic specialties like SAN, SMMA or SBC copolymers in the near future, the production of such materials can be rendered more sustainable when the styrene monomer available from the polystyrene depolymerization will be used. Therefore, the commercialization and upscaling of polystyrene depolymerization can become a key enabler to make all styrenics significantly more sustainable at no compromise in terms of performance and application ranges. ■

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Service

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