



## ➤➤➤ Plastics Recycling

How can plastics processing operations increase the proportion of recycled material used in compounds while maximizing quality?

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# »» Executive Summary

The plastics industry has recognized that it has to produce more sustainably if it is to meet the needs of end users' changing consumption behavior and ever stricter environmental legislation worldwide. Recycling plays a key role in achieving this goal. Many plastics processing operations are facing the question of how to implement recycling on an industrial scale at the highest quality.

This white paper looks at the current state of the technology involved, including technical challenges in production, and explains why **better results can be achieved in many recycling applications by using twin screw extruders** rather than the more commonly used single screw extruders. Moreover, specific solutions will be presented, showing how the plastics

industry efficiently implements recycling - from pneumatically conveying the receipt of raw materials to feeding, compounding, pelletizing, and conveying end products - and can increase the quality of recycle-based compounds across the entire manufacturing process.

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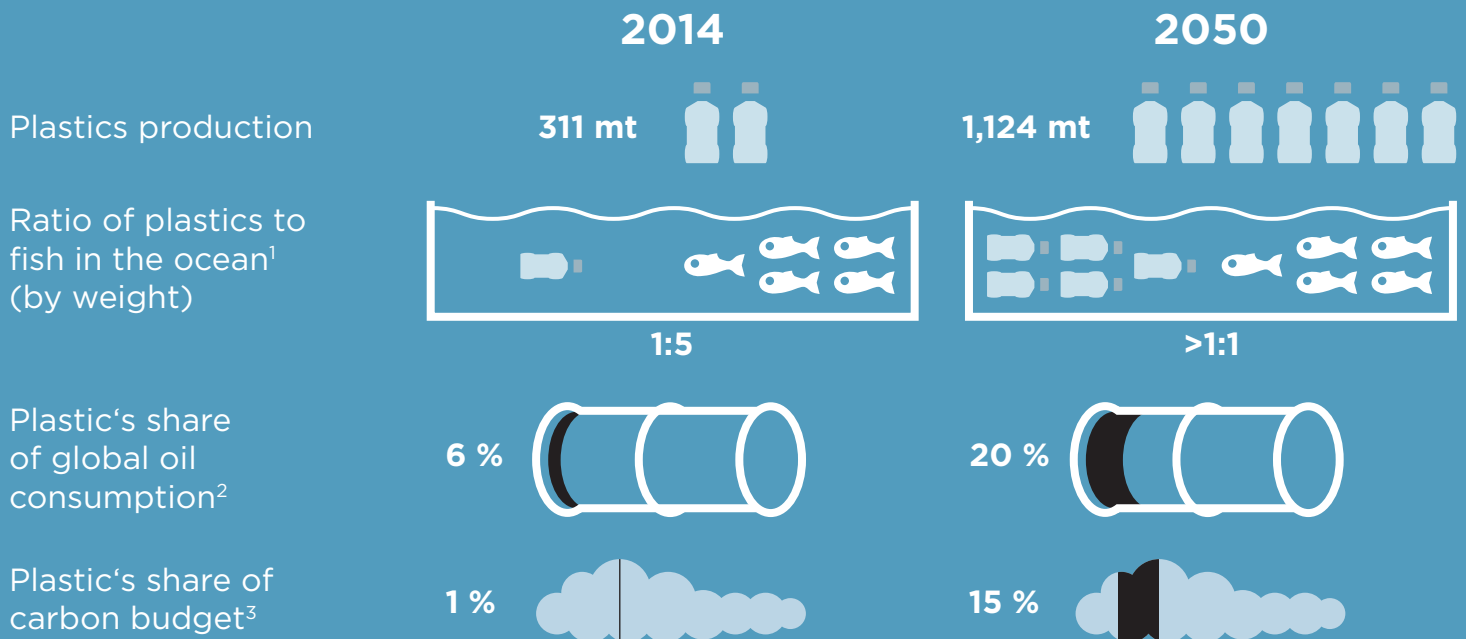
# 1. 1. The Plastics Industry en Route to a Circular Economy

Today, industry alone can no longer determine the life cycle of plastics: Society is speaking up and politicians are listening.

Industry experts such as economist Martin Stuchtey warn: For plastic that is not recycled properly but instead ends up one way or another in the ecosystem, the limits of the populace's acceptance have been reached.<sup>i</sup> The provocative topic of garbage in the oceans stands out in particular. While the quantitative ratio of plastic to fish in the sea was 1:5 in 2014, according to prognoses from the Ellen MacArthur Foundation<sup>ii</sup>, for every kilogram of fish, a kilogram of plastic will float in the oceans if current practices are not altered.

While in 2014 manufacturers and processors could long rely on the position that plastics constituted only 6% of the total use of petroleum, this argument's effectiveness has faded as a result of the changes in energy policy over the long term. By 2050, the share of petroleum used for plastics manufacturing will have reached 20%.<sup>iii</sup>

## With an expected surge in consumption, negative consequences related to plastics will multiply



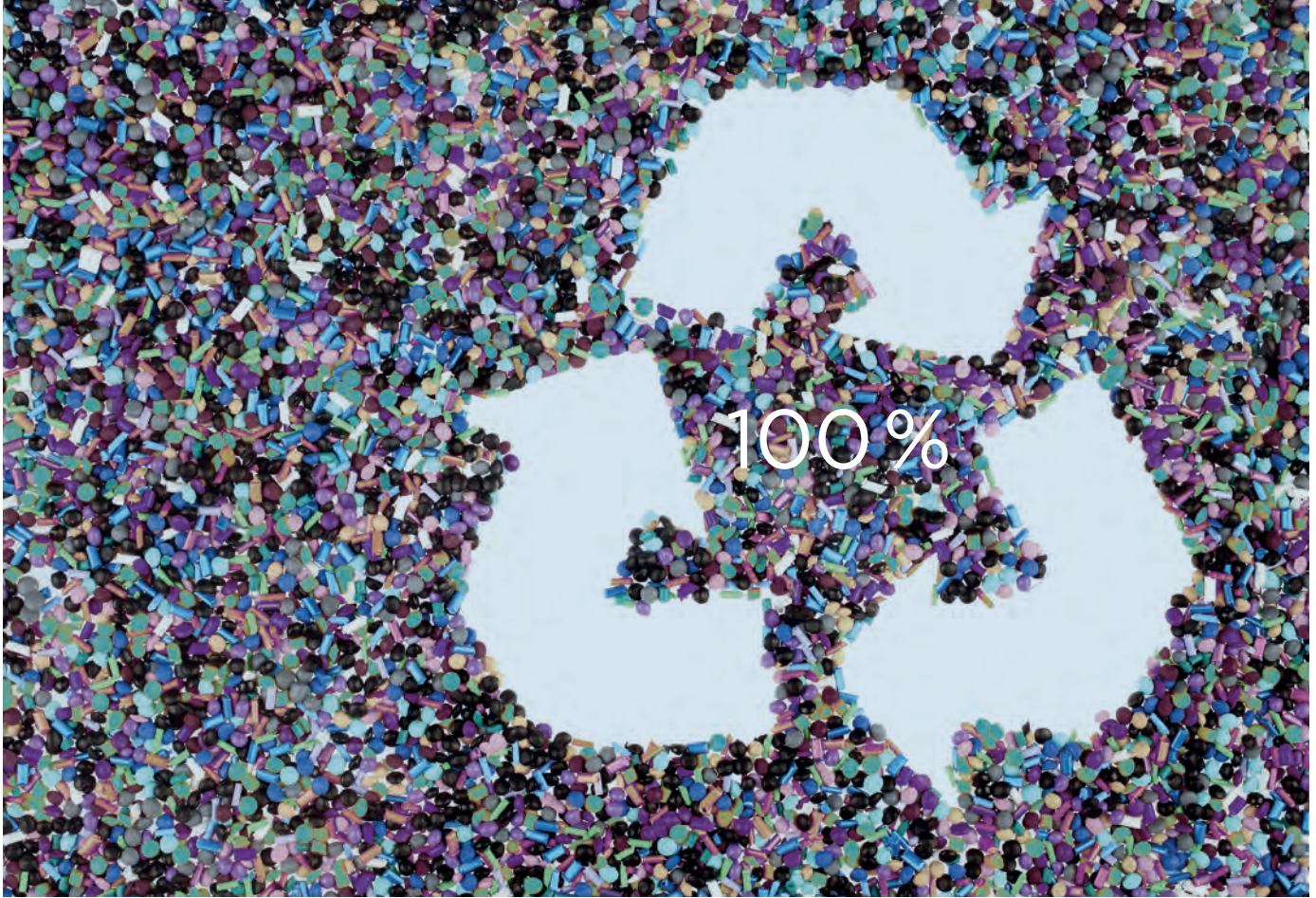
World Economic Forum, Ellen MacArthur Foundation, McKinsey & Company, A New Plastics Economy: Rethinking The Future Of Plastics (2016). [ellenmacarthurfoundation.org/publications](http://ellenmacarthurfoundation.org/publications)

<sup>1</sup> Fish stocks are assumed to be constant (conservative consumption)

<sup>2</sup> Total oil consumption expected to grow slower (0,5 % p. a.) than plastics production (3,8 % until 2030 then 3,5 % to 2050)

<sup>3</sup> Carbon from plastics includes energy used in production and carbon released through incineration and/or energy recovery after use. The latter is based on 14% incinerated and/or energy recovery in 2014 and 20% in 2050. Carbon budget based on 2 degrees scenario.

Source: PlasticsEurope; ICIS Supply and Demand; IEA World Energy Outlook (2015) (Global GDP projection 2013-2040 and central 'New Policies' Scenario oil demand projection 2014-2040, both assumed to continue to 2050); Ocean Conservancy and McKinsey Center for Business and Environment, Stemming the Tide: Land-based Strategies for a plastic-free ocean (2015); J.R. Jambeck et al., Plastic waste inputs from land into the ocean (Science, 13 February 2015); J. Hopewell et al., Plastics recycling: Challenges and opportunities (Philosophical Transactions of the Royal Society B, 2009); IEA, CO<sub>2</sub> emissions from fuel combustion (2014); IEA World Energy Outlook Special Report: Energy and Climate Change (2015); Carbon Tracker Initiative, Unburnable Carbon (2013).



### **The Long Road to a Circular Economy**

At this point, new hopes such as biodegradable plastics cannot meet the high expectations placed upon them. The plastic products will only degrade under very specific conditions. Educating consumers on proper disposal is proceeding sluggishly, and the waste industry is struggling to properly exploit this new material stream, especially when it comes to packaging, conventional plastics such as PET, PE, or PVC will remain without competition for the foreseeable future. In order to consistently reduce effects upon the environment caused by the use of plastics, the plastics industry has no choice but to become circular. To that end, there is still plenty of room for improvement. In Germany, e.g., the share of recyclate used in plastics processing in 2017 only achieved a bit more than 12%.<sup>iv</sup>

### **Plastics Industry Accepts Responsibility**

Manufacturers have grasped the demands placed upon them and are assuming responsibility. For this reason, 250 organizers of the “Our Ocean 2018” Conference in Bali committed to ensuring that by 2025, **100% of all plastic packaging** for which these companies are responsible will be able to be **recycled or composted** simply and safely.<sup>v</sup>

### **Recycling Must Be Learned**

The mere possibility that packaging can be recycled is still far from a guarantee that it will actually happen. In order to ensure that plastic is recycled in practice as a matter of course, many factors must add up: from product design to collection to sorting and processing. Many companies that want to use recycled material in processing plastic lack the necessary technical knowledge and the appropriate machinery to increase the proportion of recyclates used.

This white paper will provide those responsible for production, purchasing and decision making in plastic processing operations with information about the necessary prerequisites and technical procedures to increase the percentage of recycled material in their products and to **improve the quality of compounds made from secondary raw materials** in the process.

### **Recyclate and Quality Must Go Hand in Hand**

In order to increase the percentage of secondary raw material for processing as much as possible, it is preferable from the perspective of the recycling company that waste plastic be as easy to process as new material. Of course, the final product must also fulfill every customer requirement – independent of the recyclate proportion. This must be taken into account in every area of production. Specifically, the areas of greatest importance are feeding, compounding, pelletizing, and conveying.

## ❖ 2. Plastics Recycling in Practice

Before recyclate can be processed, the waste plastic must first be broken down, cleaned, and then separated according to type. From this, regrind and ground product result which then can be delivered via conveying lines and feeders, together with other recipe components, to the compounding process.



## » 2a. Feeding

One notable difference between primary and secondary materials is especially important during feeding. Like practically any recycling material, waste plastics are heterogeneous in size, form and bulk density. Therefore, the correct choice of feeding technology is very important in ensuring optimal bulk material flow.

Single screw extruders, ubiquitous in plastics recycling, are operated primarily using volumetric feeders, which are only suited for feeding bulk materials with consistent density. When handling secondary raw materials, the bulk material characteristics described above can quickly lead to irregularities in flow behavior.

In contrast, **twin screw extruders** are usually operated with gravimetric feeders, which operate **far more precisely** and, thanks to the weight signal, **can react better to fluctuations** in bulk density and material flow. Moreover, their feeding performance is precisely documented.

» Coperion K-Tron gravimetric feeders ensure highly precise feeding of materials into the compounding process.



### The Application Determines the Technology

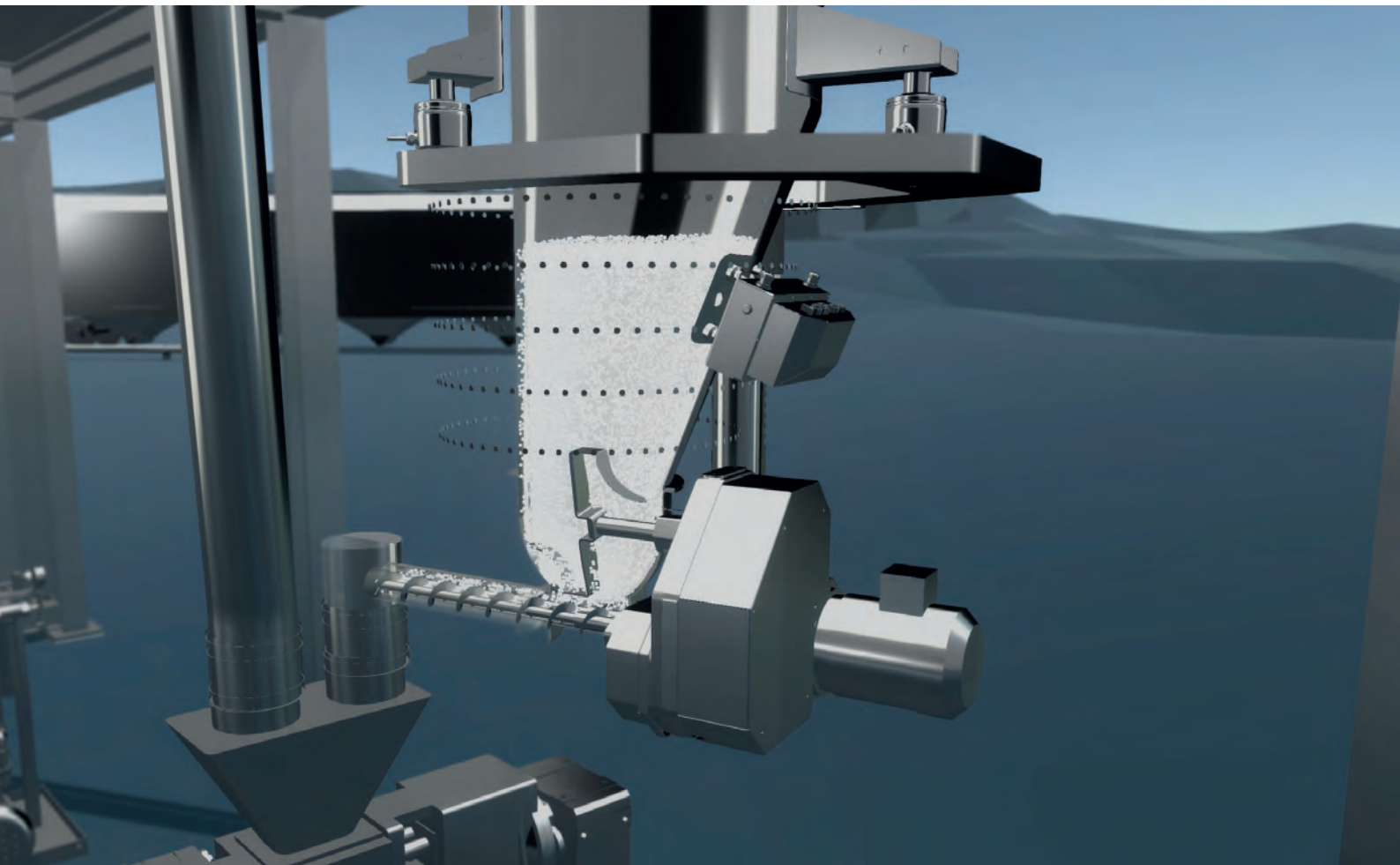
Finding the most appropriate feeding technology for the application in question that is both technically suitable and at the same time economically efficient in terms of investment and operation can pose challenges for decision makers. It is helpful to rely on providers who have mastered various technologies and can thus offer the right feeding system for any case. Coperion K-Tron offers, for example, weigh belt, vibratory and screw feeders, in addition to others. Each technology has its own advantages – what is decisive is the process know-how that brings operational requirements and processes together.

### For Accurate Feeding

As comparatively simply constructed components, **weigh belt feeders** are reliable, gravimetric feeders that offer **high precision** and **efficient process control**. They can reliably feed large volumes of bulk material and materials with varying flow properties, since they weigh the bulk material prior to discharge and actively adapt belt speed. As such, the Coperion K-Tron Smart Weigh Belt feeders are suited, for example, for **processing recyclates** with fluctuating bulk density. In many applications the weigh belt feeder is combined with a screw feeder as a pre-feeding system in order to smooth out the mass flow or to reliably transport materials that tend to form bridges onto the belt. One further advantage is that, depending upon the situation, weigh belt feeders, even with pre-feeders, often require less vertical clearance than other fixtures. Weigh belt feeders from Coperion K-Tron are also available with optional heat-resistant silicone belts for applications where the bulk material is coming from a heated process upstream.



> The new Coperion K-Tron vibratory feeder is especially suited for gentle gravimetric feeding of friable products.



### For Bulk Materials of All Kinds

If smaller recyclates or flakes are being fed, or if glass fiber is added into compounding processes, **vibratory feeders** are an ideal solution. These feeders are available in various sizes with a selection of tray configurations to choose from, appropriate for the application in question and for conveying a wide range of bulk materials. The absence of mechanical parts that are subject to wear is advantageous for continuous operation – vibratory feeders are practically **maintenance-free** as a result. The bulk material experiences no mechanical impact, either.

However, in particular for companies who are dedicated to using the largest recyclate quantities possible, these feeding technologies are insufficient. If the material presents very irregular sizes or forms, under certain circumstances a **screw feeder** must be used – generally with a single screw. The feeder's rotating screw conveys and feeds the material from a hopper into the process below. Using the screw and the horizontal agitator, a **uniform mass flow** is ensured. Screw feeders are available in various sizes

and configurations. One must differentiate between single and twin screw feeding. Both forms are available in gravimetric and volumetric designs.

### For Quality That Remains Consistent

**Twin screw feeders** in particular are also implemented at a later point in time along the value chain, for example, in **compounding**. Here, the technology distinguishes itself through the precise feeding of finer bulk materials, which is primarily suitable for additives. Thanks to the high precision of the corresponding weighing technology and precise control algorithms, additional materials are **fed precisely into the process according to the recipe**, and the end product's **quality** is constantly optimized.

### Complete Feeding Systems

As a specialist in the plastics processing industry, Coperion K-Tron offers other components alongside the feeder types presented here, including bulk solid pumps, liquid feeders and mixing stations.



## 2b. Compounding

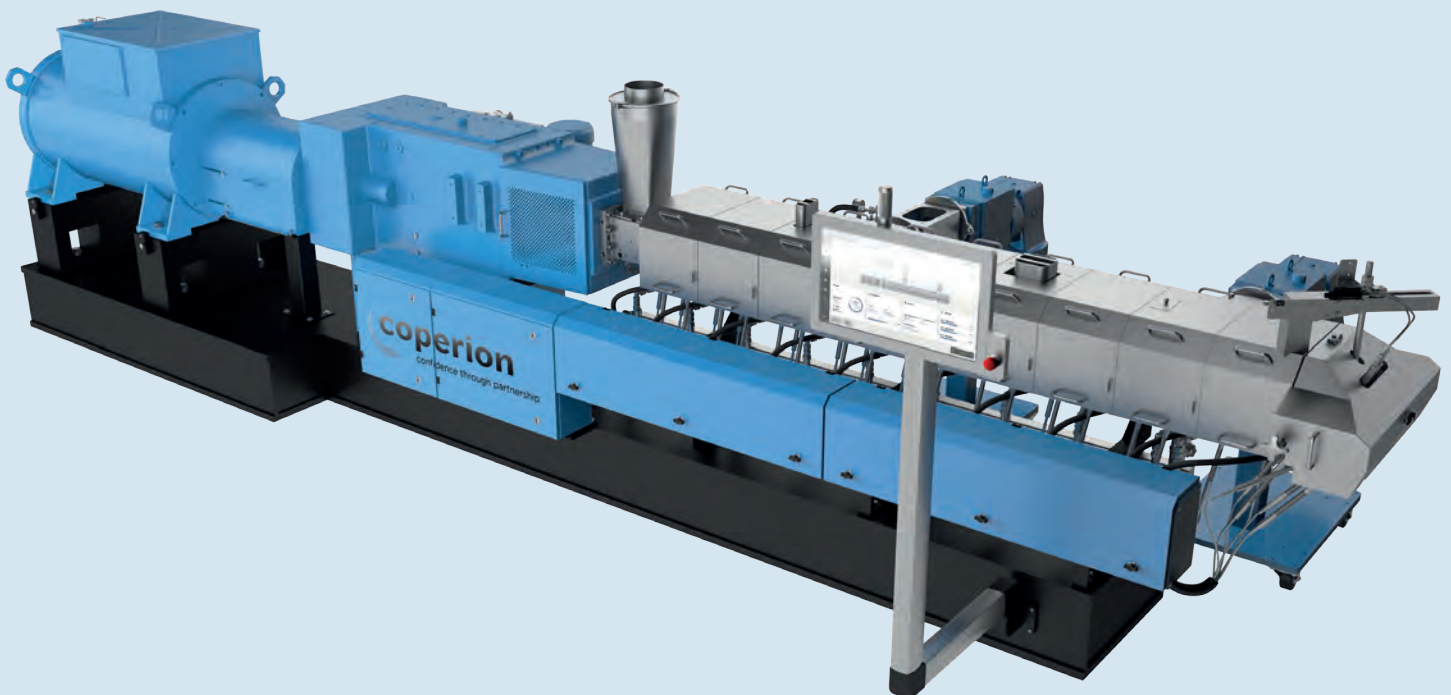
In compounding, the screw melts the raw materials and mixes them. The melt is devolatilized and conveyed toward the discharge. Usually, material is fed continuously to the screw via feeders and hoppers from above.

With the general trend towards rising throughputs, however, the fact that single screw extruders are fed volumetrically limits their processing capacity. Moreover, an additional problem is encountered in processing waste plastics: Single screw extruders exhibit relatively low dispersion and devolatilization output. Depending upon the available raw material, this can lead to inadequate compound quality. If the secondary raw material is too heterogeneous, then the percentage of recyclate must be reduced or 100% primary raw material must be used. If the customer has defined expectations of the end product, under certain circumstances it may no longer be possible to meet them.

### Twin Screw Extruders Increase Compound Quality

Here, the solution lies in using a twin screw extruder for com-

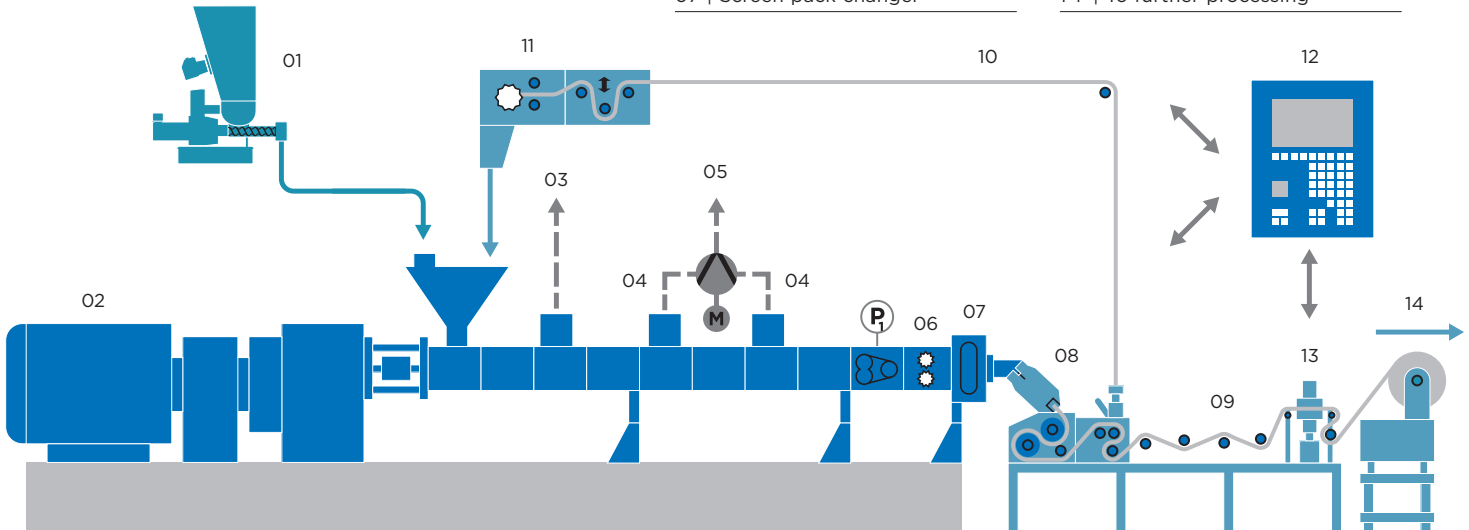
pounding. Coperion offers two different series that are suited for applications that include a percentage of recyclates: the **high-end ZSK type** and the **STS series**. For both series, feeding of additives, filler and reinforcing materials into the process section takes place using feeders. The extruders are able to **process high percentages of calcium carbonate, talc, glass or natural fibers**, thanks to the extruders' high torque and optimally adjusted process parameters. Homogenization and devolatilization take place, moreover, with markedly higher intensity than with the single screw extruder - this also has a positive effect with regard to odors that may be present in the secondary raw material, which are effectively removed. Using the twin screw extruder, **compounds with the precise characteristic profile stipulated by the customer can be manufactured at a constant high level of quality.**



> The Coperion ZSK Mc<sup>18</sup> twin screw extruder, with its high torque and gentle processing, is especially well-suited for manufacturing high-quality recycling compounds.

> Typical set-up for direct extrusion of non-pre-dried PET to flat film

01   Pellet feeding	08   Film die
02   ZSK twin screw extruder	09   Chill-roll-plant
03   Venting	10   Edge trim
04   Degassing	11   Pelletizer
05   Vacuum pump	12   Control
06   Melt pump	13   Film thickness control unit
07   Screen pack changer	14   To further processing



### Compounds Must Satisfy Customer Requirements

This technology can be implemented for various applications in the manufacture of recycled plastics: for regrinding of plastics such as HDPE, PP, ABS, PS and PVC, for manufacturing films, PET recycling, and for upcycling of various materials. The latter in particular is sought after by compounders: in order to be profitable, they must be in a position to generate pellets of **consistent and high quality** in accordance with the specifications and quantities required.

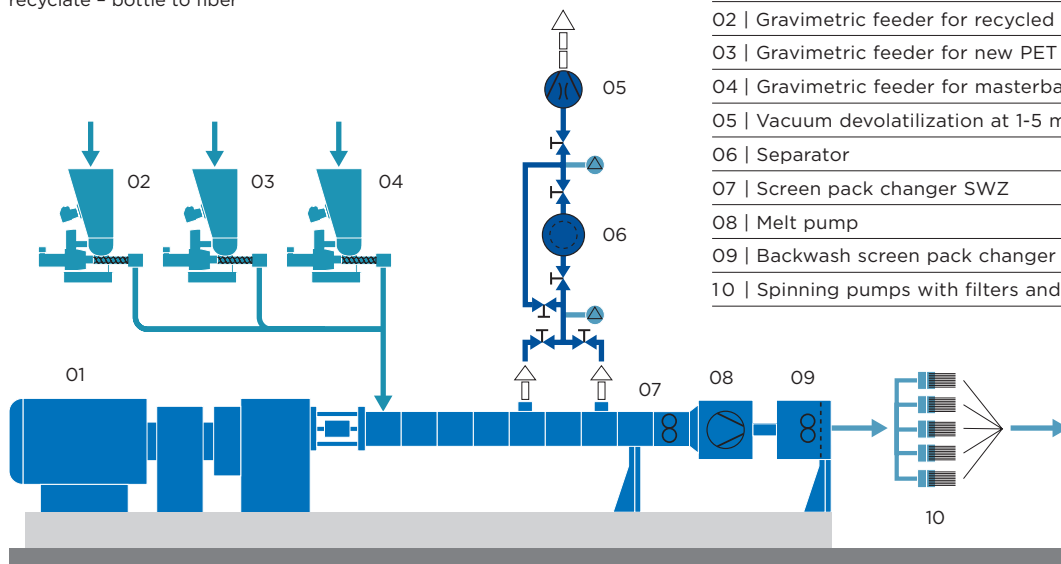
### As Good As New

Upcycling is the **optimization of recycling plastics** in their characteristics such that their quality equals that of primary material. For this purpose, machines that combine a single screw extruder with a twin screw extruder from Coperion, for example, are appropriate. In an initial recycling step, plasticizing and filtering takes place in a single screw extruder with a cutter compactor. Compounding takes place immediately thereafter in a co-rotating twin screw extruder from Coperion without cooling the melt. It is here that the recyclate's property profile is precisely optimized as needed. Recycling plastics processors thus acquire the ability to manufacture and market high-quality pellets with specific properties for demanding applications.

> Extruder assembly at Coperion's Stuttgart site



> Typical set-up for devolatilization of recycle - bottle to fiber



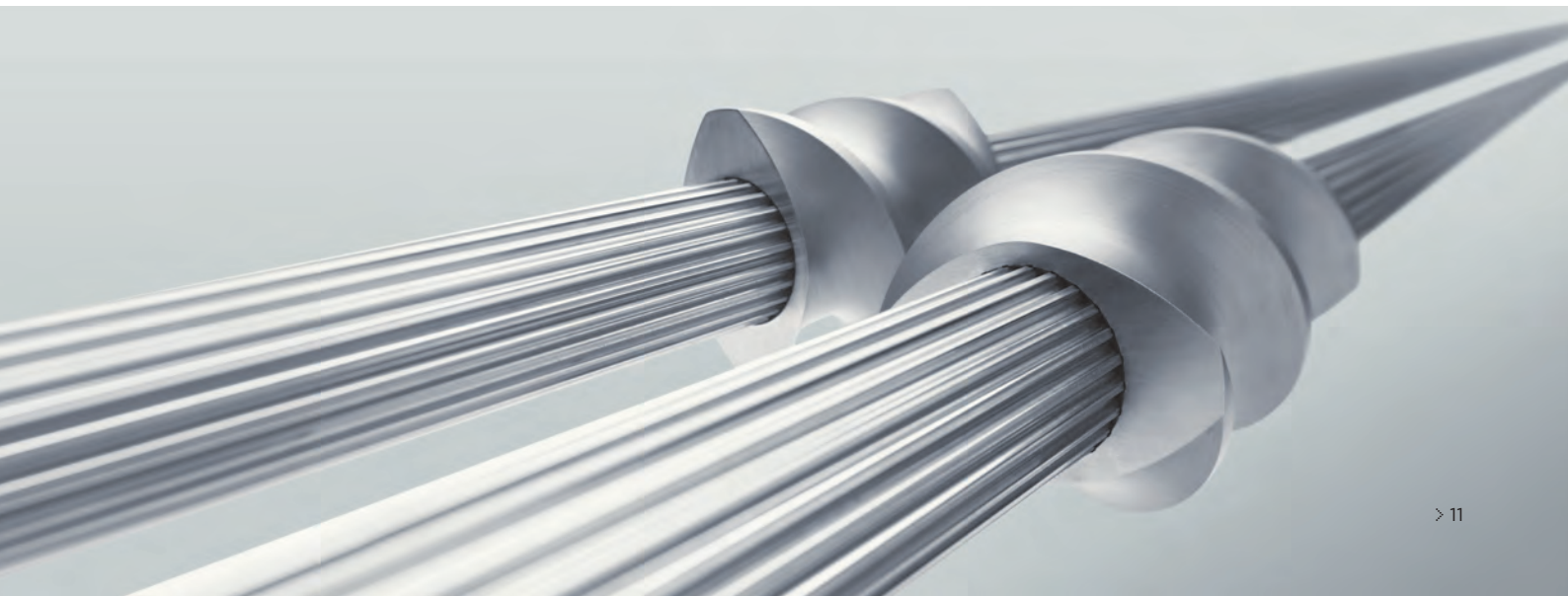
- |   |
|---|
| 01   ZSK Mc <sup>18</sup> twin screw extruder             |
| 02   Gravimetric feeder for recycled PET bottles (flakes) |
| 03   Gravimetric feeder for new PET product               |
| 04   Gravimetric feeder for masterbatch                   |
| 05   Vacuum devolatilization at 1-5 mbar (absolute)       |
| 06   Separator  |
| 07   Screen pack changer SWZ                              |
| 08   Melt pump  |
| 09   Backwash screen pack changer                         |
| 10   Spinning pumps with filters and spinnerets           |

### Direct Compounding of PET

Especially in the large market segment of packaging, PET plays an ever greater role – particularly due to the growing expansion of single- and multi-use bottles made from PET. Accordingly, it can be lucrative for recycling companies to focus on this material. The twin screw extruder’s advantages are useful in processing PET, for example, in the form of bottle flakes, due in large part to the hygroscopic property of the plastic. Prior to compounding, recyclates must normally be predried, crystallized, or agglomerated using single screw extruders. In contrast, using a specialized technology from Coperion, shredded PET can be compounded directly – predrying, crystallization and agglomeration of the recycle are necessary only to a limited extent. This direct processing into films, fibers, or bottles increases product quality. At the same time, it leads to savings in operational costs and energy use as well as reduced logistics expenditures. This procedure has proven its value especially at very high throughputs of 500-6,000 kg/h.

### Gentle Product Handling

PET processors profit from **consistently high and defined end product quality, great flexibility**, rapid recipe and color changes afforded by the use of a twin screw extruder, from simpler logistics and, moreover, from **energy savings** by foregoing predrying and crystallization. With their wear and corrosion protection, these machines ensure high profitability, regardless of material. Users can thus profit from long uptimes and high reliability, even at high throughput rates. However, the gentle processing speaks above all for the use of twin screw extruders in PET processing. Despite short residence times in the extruder, dispersion is very high. The Coperion machines’ high torques enable processing at low temperatures and with almost no viscosity loss. The process’ optimized devolatilization options remove volatile components such as monomers, oligomers and water, thus contributing to high end product quality as well.



## » 2c. Pelletizing

In pelletizing, process know-how is also sought after – especially when processing recyclates.

Depending upon the level of preparation quality, processors can be faced with high contamination by different product qualities. This can also cause increases in strand breaks and unstable behavior. Under certain circumstances, products to be processed may be highly abrasive. These factors can be measurably reduced using the process optimizations described in previous sections.

### Automated Pelletizing

One process that is especially well-suited for recycling applications is strand pelletizing. It is used to process melted polymer into cylinder-shaped, dry, easy-to-handle plastic pellets. Coperion offers this process step as well – from drying and pelletizing to screening. The operating principle corresponds fundamentally to those of other systems: cooling using water, drying, evaporation into the atmosphere, and pelletizing. The difference lies in the fact that Coperion offers **both a fully as well as a semi-automatic strand conveying system to the pelletizer**. In both cases, the water bath is replaced by a combination of a water-flooded chute and a conveyor belt. The strands are contained above the flooded water chute, cooled, and led onto

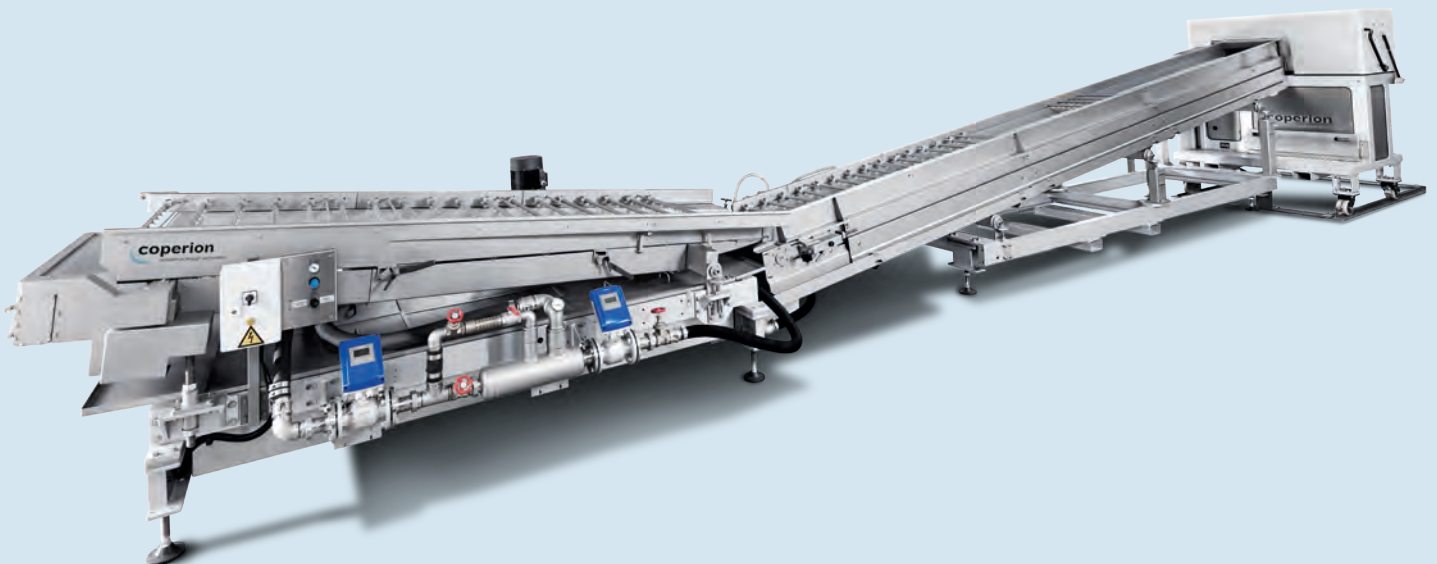
a conveyor belt that takes the strands to the pelletizer. The conveyor belt can be sprayed with water or air to cool the strands. Air suction units are integrated over the belt section for dewatering the process.

For users, this technology adds a higher degree of automation to the process in comparison to a conventional water bath. Moreover, the semi- or fully automatic process start-up function, as well as the strand break monitoring, **reduce the use of manpower required and increase productivity**, as the process can be started more easily and broken strands are automatically rethreaded into the pelletizer. Additionally, the quantity of waste is decreased and product quality is increased. Like twin screw extruders, pelletizers are equipped with effective wear protection.

### High Flexibility

Providing additional support to manufacturers of recycled plastics, strand pelletizers are equipped with adjustable cooling length and quick-change conveyor belts, enabling processing of a broad spectrum of products on one line and, when needed, quick maintenance.

>For the automatic transfer of extruded strands from the extruder's die head to the pelletizer, Coperion offers the fully automatic ASC strand conveying system which markedly increases the productivity of recycling machines.



## » 2d. Conveying

In the bulk handling of recycling products, such as ground products, flakes or fibers, and in conveying ready-to-sell recyclates, there are particulars which must be heeded in order to satisfy the required standard of end product quality.

Thus, the handling of recycling products represents a challenge, based on the differing and fluctuating qualities of the materials received, as well as the often difficult-to-handle particle shapes and properties. Moreover, the discharge from containers and silos is critical when conveying ground products, flakes or fibers. Because the material tends to form bridges, the selection of the appropriate discharge device is just as critical as use of appropriate systems for upstream process stages.

### Well Mixed

When manufacturing recyclates, **homogenization of the incoming material** is of primary importance. For this step, a mechanical mixer such as the Coperion MIX-A-LOT can be provided to transform batch mixing to a continuous process. If homogenization of the finished product is required to achieve uniform quality, use of Coperion's Combiflow® mixer is recommended.

### Conveying Technology Influences Product Quality

Users have a choice of various conveying processes for pneumatic transport. Coperion builds systems using both dense phase and dilute phase conveying processes. Both versions are available as vacuum- and pressure conveying.

Coperion specifies, based upon comprehensive corporate experience, which bulk material handling method is a precise match for the recyclate to be processed. Factors that are taken into account include the product's tendency toward dust and fiber formation as well as pipeline wear. Moreover, product-specific customer requirements are important, for example, with regard to residual dust content, as this can significantly influence product quality as well as machine availability.

For the pneumatic transport of salable recyclates, Coperion offers components, partial and complete systems that are tailor-made especially for their handling. As with bulk material handling, Coperion also takes into account the precise conveying properties of the granules in order to maintain their high product quality.

### Process Expertise is Critical

If devolatilization or deodorization of the end product is required for reasons related to safety, odor reduction or increase in quality, customer-specific solutions are likewise available. Be it product cleaning, heating, or cooling – users can find all process steps under one roof. Here, it is precisely the know-how regarding every process step that ensures the appropriate solution for manufacturers and processors.



> The MIX-A-LOT bulk materials mixer from Coperion mixes individual components for compounding cost-effectively, quickly, and gently at the same time.

# » 3. From Recyclate to Application-Optimized Quality Compound

Politicians and the public expect the industry to manufacture and use more secondary raw materials to move closer to the goal of a circular economy. As a result, manufacturers and processors face the challenge of reconciling the demands placed upon them with technical and economical feasibility.

For companies wishing to use recyclates for the first time, this step can be complex, and even for processors who already use regrinds, increasing the proportion of recyclate quickly creates problems, because only with the appropriate process technology and the right expertise will increased processing of waste plastics be economically possible.

### Recycling on Industrial Scale

Manufacturers who rely upon application-specific components and machinery can produce end products of consistently high quality at high throughput capacities, even when processing recyclates. Thanks to its process know-how, the variety of its products and their sizes, Coperion can cover **throughputs of up to 10 t/h** using its own technology – depending on the processed material. End products are implemented, among others, in the demanding automotive industry and by packaging manufacturers, some of whom supply to the food industry where especially high demands are placed upon material purity.

### Broad Spectrum of Applications

With technologies from Coperion, who covers the entire plastics

recycling process chain, companies who process post-industrial and post-consumer waste plastics acquire appropriate solutions for the demands that customers place today on sustainable products. The spectrum of waste plastics that are recyclable using these technologies begins with household packaging waste and extends to films and containers from specific applications and parts from automobile recycling up to homogenous waste from industrial production.

### Focus on the Entire System

Coperion's years of experience **ensures comprehensive expertise across all process stages and components**. In so doing, a seamless interplay of raw material handling via conveying, feeding, compounding, pelletizing, up to conveying the finished product can be ensured. These systems offer continuous productivity and efficiency. Using Coperion twin screw extruders can **achieve markedly better results and significantly increase the quality and marketability of products**. Processors can thus manufacture ready-to-use quality pellets on their own for high-quality applications, thus achieving a markedly greater share of the value created.



## » Find out more now!

In this white paper, we aim to provide important information and helpful suggestions for sustainable composition of your products and for economical manufacturing of qualitatively high-value plastics from recyclates.

Would you like to learn more about processing used plastics and the production of defined compounds? **Write to us at** [info@coperion.com](mailto:info@coperion.com) and discuss your options with an expert partner for increasing the share of recycling material and the quality of your products!



<sup>i</sup> „Jenseits von Angst und Abarbeiten“, Recycling Magazin 06/2019, S. 34

<sup>ii</sup> „The New Plastics Economy: Rethinking the future of plastics“, Ellen MacArthur Foundation, Januar 2019 (<https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics>)

<sup>iii</sup> *ibid.*

<sup>iv</sup> „Stoffstrombild Kunststoffe in Deutschland 2017“, Conversio Market & Strategy, September 2018 ([https://www.bvse.de/images/news/Kunststoff/2018/181011\\_Kurzfassung\\_Stoffstrombild\\_2017.pdf](https://www.bvse.de/images/news/Kunststoff/2018/181011_Kurzfassung_Stoffstrombild_2017.pdf))

<sup>v</sup> „A line in the sand“ – Global Commitment to eliminate plastic pollution at the source“, UN Environment, Oktober 2019 (<https://www.unenvironment.org/news-and-stories/press-release/line-sand-global-commitment-eliminate-plastic-pollution-source>)

<sup>vi</sup> Schönfeld, S.; Elsässer, R.; Wiedmann, W.: Polykondensation, Aufbereitung und Recycling von Polyester ohne Vortrocknen. Technische Mitteilungen Krupp, 2/1998, S. 33 - 38

<sup>vii</sup> Rieg, W.: A-PET Folienherstellung ohne Vortrocknung. In: Handbuch zur 3. Fachtagung Kunststoffverarbeitung der Kreyenborg Gruppe, Münster/Westfalen, 3. - 5. Juni 2003

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