



RECYCLING TECHNOLOGY **FOR PET FLAKES**

Decontamination for food-contact packaging, rPET with characteristics like resin, IV increase through solid state polycondensation, reduction of AA content, engineering and supply of turn-key projects

PET recycling: *Resource conservation through upcycling*

PET is one of the few thermoplastics that can be upcycled to achieve resin-like quality through SSP treatment. Today, post-consumer bottle flakes are successfully used for food-contact packaging, high-IV strapping bands, and filaments. Bottle-to-bottle recycling requires the highest standards in terms of decontamination.

Due to its favourable characteristics, the use of PET (polyethylene terephthalate) for food-contact packaging is a success story. But it also causes more PET waste, which in turn raises public interest in this issue. Recycling contributes significantly towards a positive perception of PET packaging: It increases ecological awareness and induces collection of post-consumer waste and obligatory reuse of recycled PET (rPET). Also major brand-owners jump on the bandwagon and promote low carbon footprint and resource conservation.

Be part of the solution

It is projected that within the next ten years the worldwide consumption of PET bottles will double. Even assuming ambitious collection rates, the major share of PET waste will end up in land-fills. Washed and processed PET bottles are a valuable secondary resource. In this context, it is the consumers' responsibility to contribute to recycling efforts and to welcome products with rPET content – bottles that are turned into fibres, filaments and nonwovens, sheet, strapping, and, most prominently, into bottles again.

Safety first for the whole value chain

The various stakeholders in a recycling project have different expectations:

- The authorities have to make sure that laws for food-safety are observed.
- The recyclers need efficient and flexible recycling equipment to ensure competitiveness in a volatile industry. Process stability and automatization guarantee the production of food-contact safe pellets.
- The preform producers demand resin-like quality in terms of viscosity (IV), flow characteristics and processability.
- Bottlers and brand-owners require high rPET content without jeopardizing the visual appearance.
- And finally, all stakeholders including the consumers need to be absolutely certain that the packaging is safe.

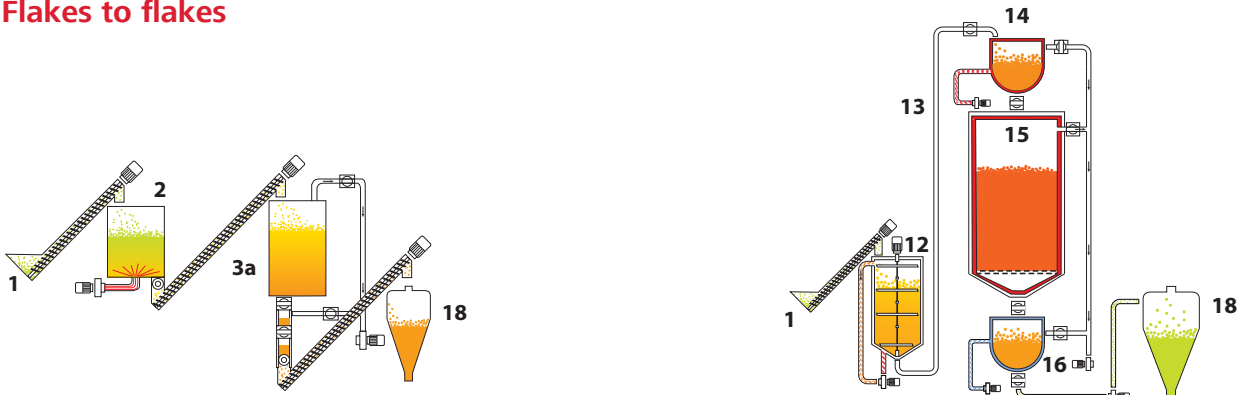


Starlinger recycling equipment has proven its high decontamination capability in a series of challenge tests. The rPET produced on Starlinger recycling machinery can be used at a rate of up to 100 % for direct food-contact packaging.

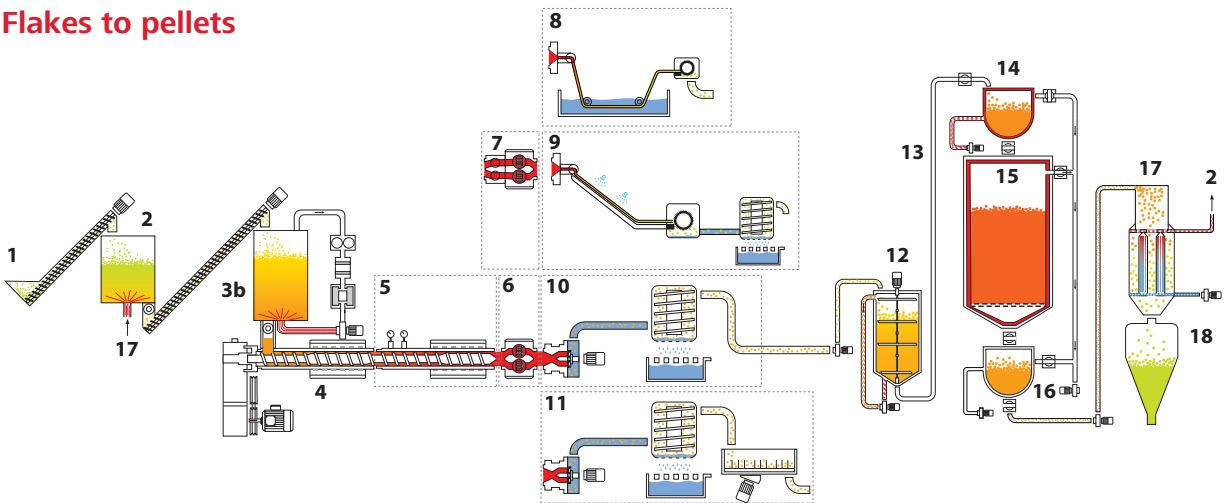


Flexibility through modular design: PET flakes are decontaminated and IV-increased stand-alone or inline. In combination with the recycling extruder and pelletising system the downstream vacuum SSP reactor ensures outstanding rPET quality. Inline applications combine energy saving and value-adding in one step.

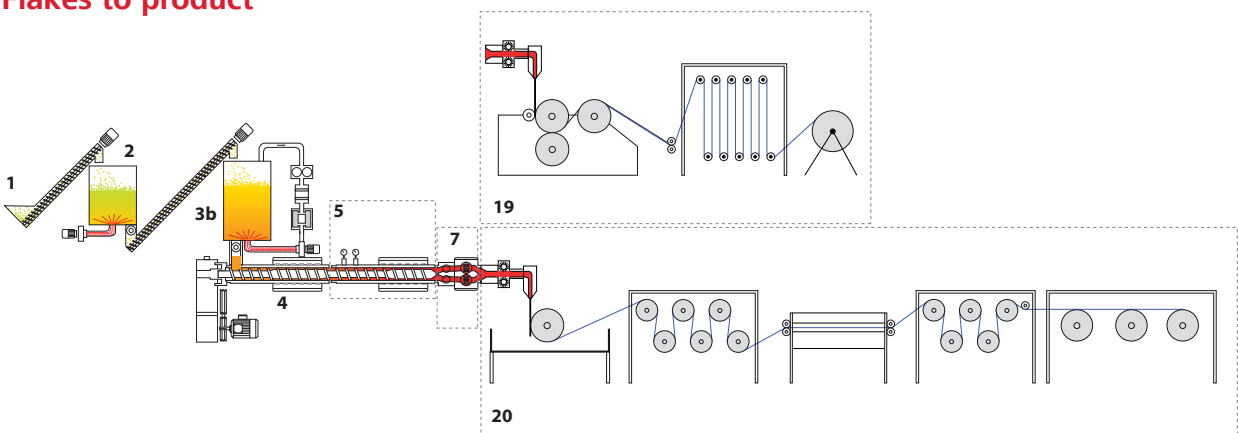
Flakes to flakes



Flakes to pellets



Flakes to product



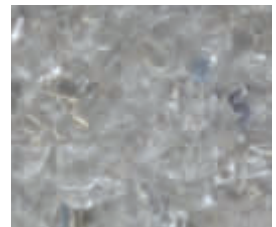
- | | | | |
|----------------------------------|-------------------------------------|--|------------------------------------|
| 1. Conveyor screw | 5. High-vacuum degassing extruder | 10. Underwater pelletiser (UWP) | 15. SSP reactor |
| 2. Hot air drying unit | 6. Melt filter without backflushing | 11. UWP with inline crystallisation | 16. Cooling unit/vacuum sluice |
| 3a. Pre-drying unit under vacuum | 7. Melt filter with backflushing | 12. Crystalliser/post-crystallisation unit | 17. Energy recovery kit |
| 3b. Pre-drying unit | 8. Strand pelletiser | 13. Vacuum transport | 18. Storage silo |
| 4. Extruder | 9. Automatic strand pelletiser | 14. Preheating unit | 19. Thermoforming sheet production |
| | | | 20. Strapping band production |

Flakes from production scrap and post-consumer waste of preforms, bottles and sheet can either be recycled to pellets or processed inline into a final product. Depending on the application, the input material is decontaminated and/or its IV increased.

	Food contact	FDA/EFSA	Bottle-to-bottle	Brand-owner approved	Decontamination	Low AA level	IV increase with full output
Flakes to flakes	✓	✓			✓✓	✓	✓✓

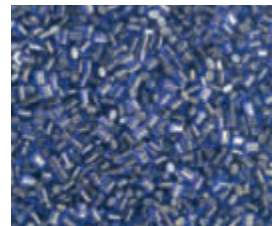
A variety of applications such as sheet or strapping bands allow the use of post-consumer PET flakes. For inline applications, the vacuum SSP reactor can be installed before the production extruder instead of a conventional dryer. A stand-alone SSP unit is used for increasing the IV of washed post-consumer flakes and decontamination for direct food-contact packaging.

The design of the patented reactor outlet ensures first-in/first-out-flow and a consistent treatment time of the material in the reactor. The large surface area of the flakes allows fast IV increase (0.01 – 0.03 dl/g/h) and efficient decontamination. State-of-the-art technology guarantees highest efficiency, quick product change and low maintenance.



	Food contact	FDA/EFSA	Bottle-to-bottle	Brand-owner approved	Decontamination	Low AA level	IV increase with full output
Flakes to pellets	✓	✓	✓	✓	✓✓✓	✓✓	✓✓✓

Starlinger's state-of-the-art recycling technology turns post-consumer PET flakes into pellets that meet the highest requirements. Decontamination and IV increase can be carried out upstream and/or downstream of the recycling extruder. The modular design of the equipment ensures flexibility and adaptability to different input materials and the changing requirements of rPET users. The whole system works continuously on a FIFO (first-in/first-out) basis with a defined residence time. Consequently, every particle receives the same treatment, which ensures food-contact safety and adjustable IV increase. AA, imparting a fruity-aromatic taste to water if migrating from wall to content, is reduced to less than 1 ppm – the same level as in virgin resin.



	Food contact	FDA/EFSA	Bottle-to-bottle	Brand-owner approved	Decontamination	Low AA level	IV increase with full output
Flakes to product	✓	✓			✓✓	✓	✓✓

The Starlinger inline recycling process for extrusion lines combines value-adding, energy saving and flexibility in one step. Flakes are heated and dried in a two-stage process upstream of the recycling extruder, first by means of hot air, subsequently either with dried air or vacuum. In this process, post-consumer flakes are decontaminated and their IV is increased.

The advanced technology offers a wide processing latitude for post-consumer flakes and ensures constant throughput even with varying bulk density. It is also possible to process skeletal scrap and coloured material; quick material changeover allows for high product versatility. The combination of recycling steps and production steps results in competitive investment costs and helps to reduce energy consumption and maintenance while remaining user-friendly.



Traceability and quality control for food safety

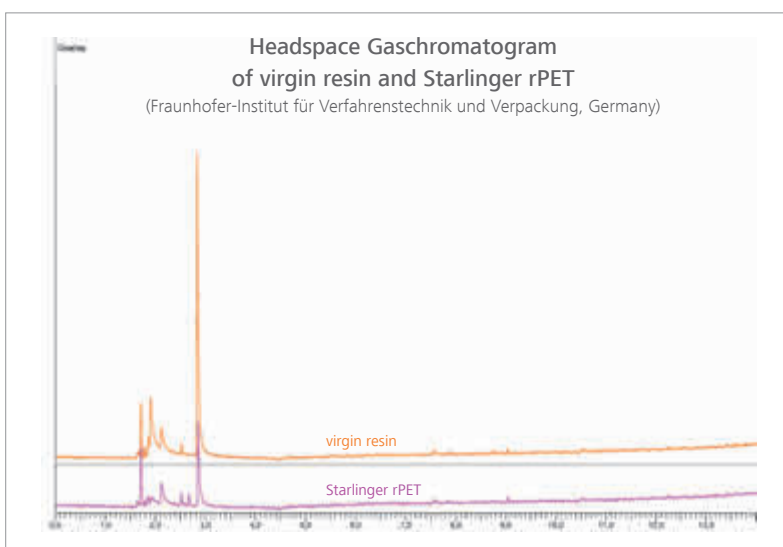
Cleansing efficiency of post-consumer PET is, beside others, the most important aspect to secure food safety for rPET in packaging for direct food contact. Food safety is guaranteed mainly by operating the appropriate equipment with proven cleansing efficiency, continuous process data, rPET quality control, and protocol archiving for traceability.

Recyclers are obliged to strictly comply with the prescribed process parameters and to monitor them – a task which is ensured by the automatic process monitoring system offered by Starlinger. For the protection of the end users, authorities and marketers furthermore require that a reproducible quality must be maintained and documented. These requirements are fulfilled through analysing flakes and pellets along the recycling process, archiving of hand samples,

and keeping of test records. It must be possible to trace back each batch that has been supplied to converters to an archived sample and the corresponding process parameters.

To prove decontamination efficiency for national authorities and brand-owners, Starlinger recycling technology has performed several challenge tests. Flakes, highly contaminated on purpose with specific organic chemicals, were stored in a

sealed vessel for a given time at a defined temperature. Subsequently, the contaminated flakes were processed on production-scale equipment without adding clean flakes (“worst case scenario”). When the output material was subjected to measurements of contaminant concentration and migration tests, the results demonstrated that the system has excellent cleansing efficiency. This fact shows that it is possible to use up to 100 % rPET for packaging with direct food contact.



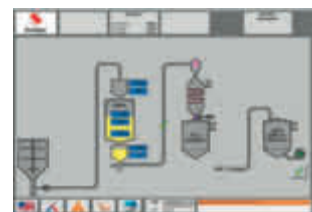
Frequent gas chromatography tests with rPET deliver better VOC results than virgin resin. Starlinger recycling technology guarantees adequate decontamination of rPET for reuse in direct food contact: The AA content is lowered to less than 1 ppm, other unwanted substances such as limonene are also reduced.

Various proofs for food contact safety such as the FDA Letter of Non-Objection, Austrian and French approbations, conformity to EFSA, ILSI and German BfR requirements have been achieved. In addition, brand owner approvals underline the superior quality of rPET produced on Starlinger recycling lines.



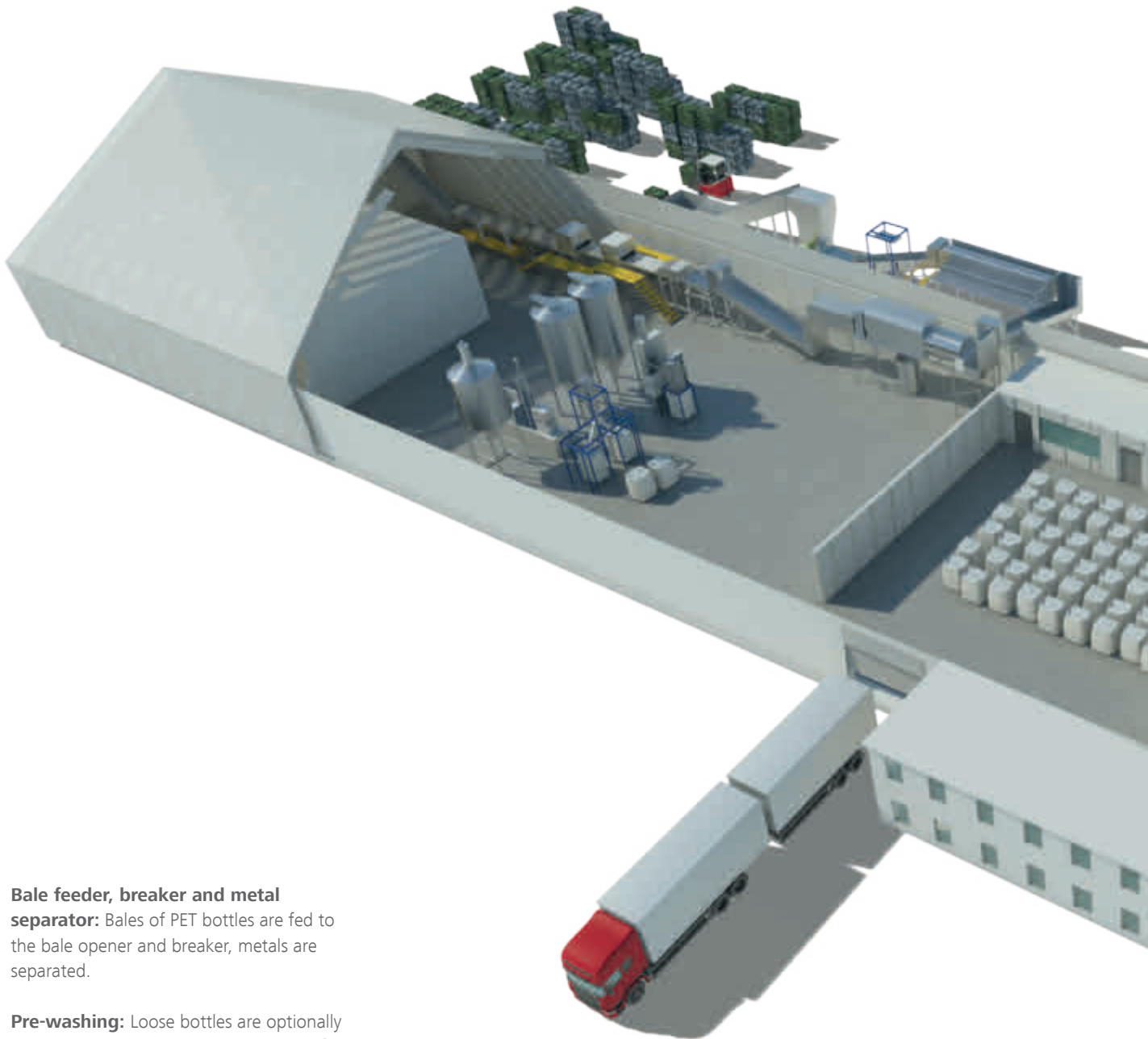
recoSTAR PET with Starlinger iV+ technology features the following advantages:

- Careful treatment of flakes, avoiding dust, high IV loss and degradation
- FIFO principle for flakes and pellets ensures defined residence times
- Increased efficiency by using gas, steam or the residual heat of previous process steps to optimise electrical energy consumption
- IV increase is adjustable and consistent (variation rate similar to virgin resin)
- The SSP units have a small footprint, convenient height and can be quickly installed on standard industrial floors
- The modular system allows simply adding another SSP unit in case higher IV is needed or the IV of the input material decreases over time
- Flake treatment, extrusion and solid-stating can be used both stand-alone or inline
- Equipment is designed for high automation and is user and service friendly
- The visualisation panel features archiving, maintenance list, alarm list, etc.
- And the most important point: rPET produced using Starlinger recycling technology enables preform producers to replace virgin material without having to change the production process or materials handling.



Compliance with process parameters is documented by means of an advanced control system with food-contact monitoring. Only if all relevant process parameters are met is the material transported into the "food-grade" silo.

Standard PET Bottle Recycling Plant



Bale feeder, breaker and metal separator: Bales of PET bottles are fed to the bale opener and breaker, metals are separated.

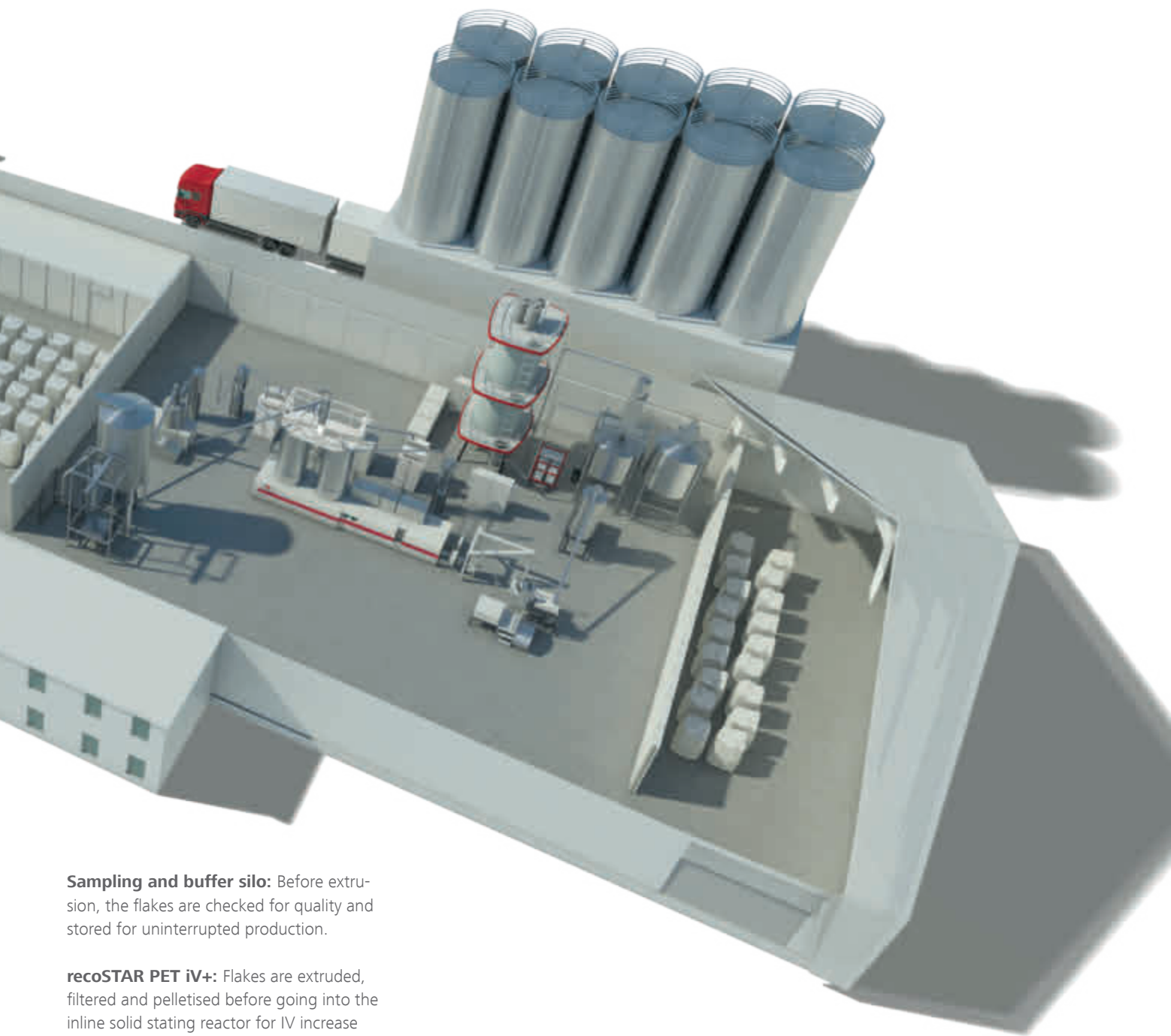
Pre-washing: Loose bottles are optionally pre-washed to improve the separation of PVC bottles and to remove labels.

Automatic and manual sorting: Depending on bale composition, a series of sorting systems are installed. Off-spec material is compacted for selling.

Grinding: Bottles and caps are ground to flakes.

Washing: PET flakes are separated from other thermoplastics in the sink/float tank before hot washing and rinsing. Caustic soda is applied to dissolve the glue from the labels.

Flake sorting: After drying, the flakes go through a series of sorters to improve final flake quality.



Sampling and buffer silo: Before extrusion, the flakes are checked for quality and stored for uninterrupted production.

recoSTAR PET iV+: Flakes are extruded, filtered and pelletised before going into the inline solid stating reactor for IV increase and decontamination.

Logistics: Food-grade pellets are filled into big bags or storage silos before truck loading; optionally, they can be fed directly into the production line while still hot.

Laboratory and office: Flakes and pellets are tested for food safety on a regular basis and archived for traceability.



***PET Recycling -** combining ecological and economic advantages*

Product packaging plays a major role in brand creation. When marketing a new product, bottlers and brand owners can choose from various types of packaging. Besides fitting in well with the current consumer lifestyle, PET offers a variety of unique features and consequently is going to replace other materials for packaging.

Higher usage of PET packaging leads to a considerably increased waste stream, but also to a higher demand of rPET for food contact applications. The growing amount of available material has to be split up between different applications such as fibre, filament, film, sheet, strapping and bottles. Also, the rPET content in packaging is increasing due to requirements of authorities and brand owners.

rPET – a step towards a smaller carbon footprint

Authorities increasingly encourage carbon footprint reduction. Although it depends on a variety of factors, using rPET instead of resin can cut down the carbon foot-

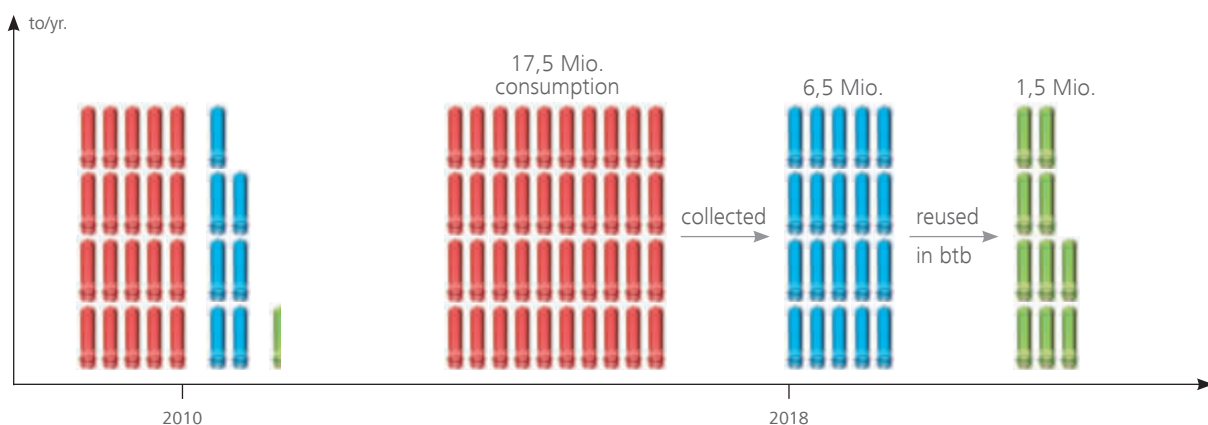
print considerably. The results: reduced energy consumption, less greenhouse gas emissions and lower transportation costs. Besides convenience, consumers prefer packaging that helps to conserve the environment.

Value adding through recycling

As prices for rPET and collected bottles fluctuate, it is important to use efficient and reliable recycling equipment. Pellets produced on Starlinger recycling lines lead to superior quality and achieve high selling prices on the market.

The in-depth know-how of Starlinger engineers on the processes along the PET value chain, combined with effective quality management, contribute to increase the efficiency of the recycling equipment.

Only superior recycling technology, process know-how and thorough understanding of the requirements of the involved stakeholders will pave the way for the increased use of rPET in food-contact packaging. Providing the best solutions for the applications at hand, Starlinger is the right partner in this endeavour.





Demand for PET packaging has been on the rise since 2010. PET bottles are an increasingly popular type of packaging for carbonated soft drinks, bottled water, ready-to drink tea and functional drinks.

	Million tonnes 2013	Million tonnes 2016
PET bottles for beverages	12.50	16.68
Bottled water	5.45	6.18
Carbonated soft drinks	5.17	6.13
Other drinks	1.88	4.37

Source: Smithers Pira

Starlinger recycling technology
Furtherstrasse 47a
2564 Weissenbach, Austria
T: + 43 2674 808 3101
F: + 43 2674 86328
E: recycling@starlinger.com
recycling.starlinger.com

Starlinger Head Office
Sonnenuhrgasse 4
1060 Vienna, Austria
T: + 43 1 59955-0, F: -180

Starlinger & Co. Gesellschaft m.b.H.
A member of Starlinger Group

recoSTAR® is a registered trademark of Starlinger & Co. Gesellschaft m.b.H.