Massimo Serapioni

General Manager Business Unit Recycling I Coperion

Recycling Days

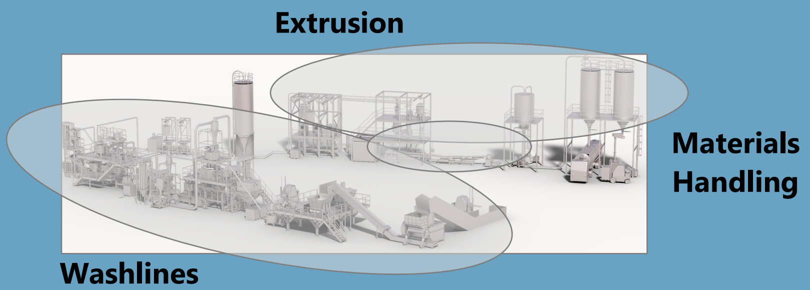
Day 1

Chris Dow

Chris Dow I Business Development Manager, Business Unit Recycling I Coperion

What you can expect…

Coperion presentations about



Application deep-dive
PET Recycling

POLYMETRIX

Application deep-dive
Film Recycling

suez

Turnkey Systems

Service

Industry 4.0

What you can expect…

Tour and live demonstrations

What you can expect…

Guest Speakers

Plastics Recycling - State of Play | Challenges & Opportunities

Prof. Edward Kosior I Founder and CEO I Nextek

Panel Discussion - Recycling seen from different perspectivesx

James Samworth I Partner - Renewable Infrastructure, Private Equity, M&A I Schroders Greencoat LLP

Prof. Edward Kosior I Founder and CEO I Nextek

Christian Crepet I Petcore Board Member – Textile Recycling Specialist

Plastics in Circular Economy - Requirements and Challenges

Prof. Daniel Schwendemann I Institute for Material Science and Plastics Processing (IWK)
OST University of Applied Sciences Eastern Switzerland

What you can expect...

AGENDA | NOV 06, 2024

09:30	**Welcome and Introduction to Coperion** Massimo Serapioni I General Manager Business Unit Recycling I Coperion Chris Dow I Business Development Manager, Business Unit Recycling I Coperion
09:45	**Introduction to Recycling Business Unit** Massimo Serapioni I General Manager Business Unit Recycling I Coperion
10:15	**Plastics Recycling - State of Play | Challenges & Opportunities** Prof. Edward Kosior I Founder and CEO I Nextek
11:00	Coffee break
11:15	**Solutions for Efficient Recycling: Herbold Washlines and Latest Developments in Water Treatment Technology** Achim Ebel I Head of Sales I Herbold Meckesheim Kürşat Başdemir I General Manager I Ekosistem Ltd.
12:00	Lunch

AGENDA | NOV 06, 2024

13:00	**Coperion Extrusion Technology - Innovation for the Recycling Industry** Jochen Schofer I Head of Sales Recycling I Coperion Frank Mack I Head of Process Technology Engineering Plastics I Coperion
14:00	**Plant Tour and Live Demonstration in the Recycling Innovation Center**
15:00	Coffee break
15:15	**Panel Discussion - Recycling seen from different perspectives** Prof. Edward Kosior I Founder and CEO I Nextek Christian Crepet I Petcore Board Member - Textile Recycling Specialist Prof. Daniel Schwendemann I Institute for Material Science and Plastics Processing (IWK) OST University of Applied Sciences Eastern Switzerland Chris Dow I Business Development Manager, Business Unit Recycling I Coperion
19:00	**Evening event**

HERBOLD
MECKESHEIM

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Introduction to Recycling Business Unit

Massimo Serapioni
General Manager Business Unit Recycling I Coperion

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SHAPE WHAT MATTERS FOR TOMORROW™

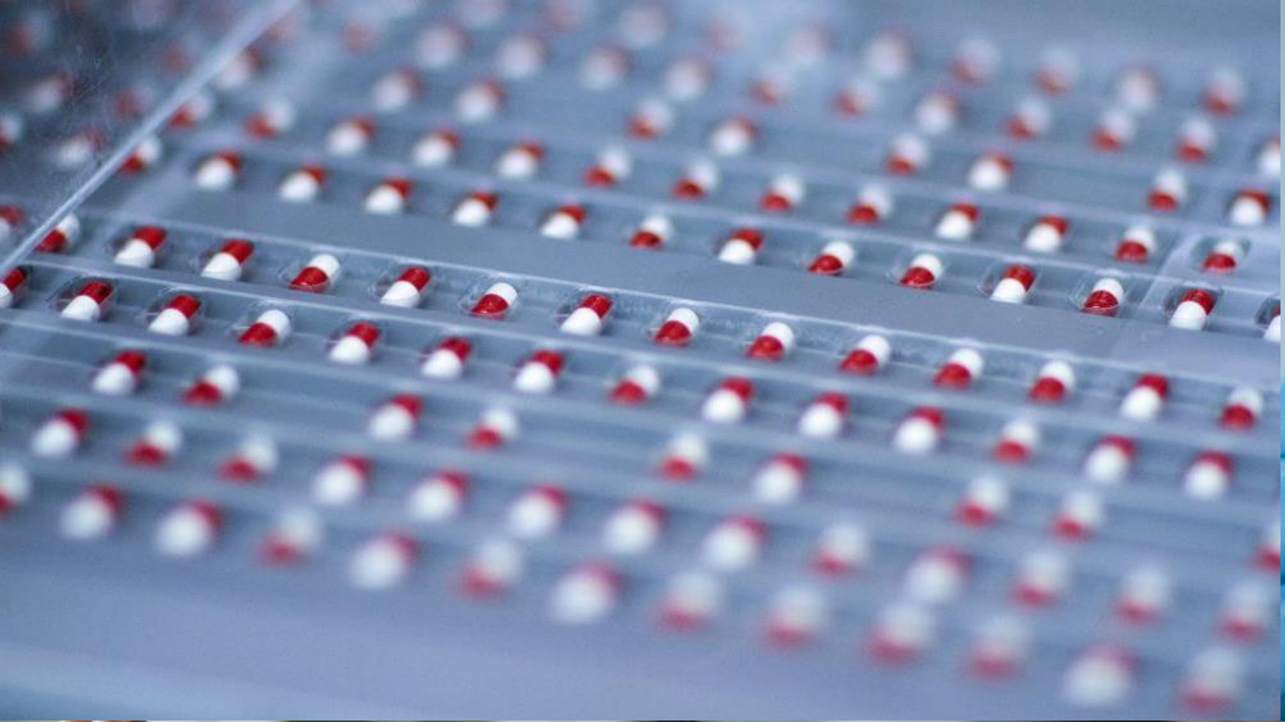
SHAPE

- The world is constantly changing, so are we
- To be able to provide total solutions. For a wide range of challenges

For **more recycling**
of all kinds of plastic

For **powerful batteries** and a rapid mobility turnaround

For **more food safety and sustainability**



For **durability, safety and health**

coperion

We are **5,000 employees** worldwide, combining engineering expertise, quality and reliability

WHAT MATTERS

Every day our experts work on high-quality process technology – optimized for the best end products, highest efficiency and sustainability

All these experts are part of Hillenbrand, Inc.

Herbold Meckesheim

coperion

HILLENBRAND

INC

MILACRON

Mold Masters

DME

coperion
confidence through partnership

ROTEX
HIGH PERFORMANCE SCREENERS

A closer look at Coperion

HERBOLD MECKESHEIM coperion

coperion

Well established brands with up to **140 years** of market experience

coperion K-TRON | HERBOLD MECKESHEIM | GABLER A BRAND OF COPERION | raymond bartlett snow A BRAND OF COPERION | stock A BRAND OF COPERION | baker perkins A BRAND OF COPERION | kemutec A BRAND OF COPERION | mucon A BRAND OF COPERION

BAKON | DIOSNA | PEERLESS FOOD EQUIPMENT | SHAFFER | SHICK ESTEVE | UNIFILLER | VMI

Three divisions for first-class solutions

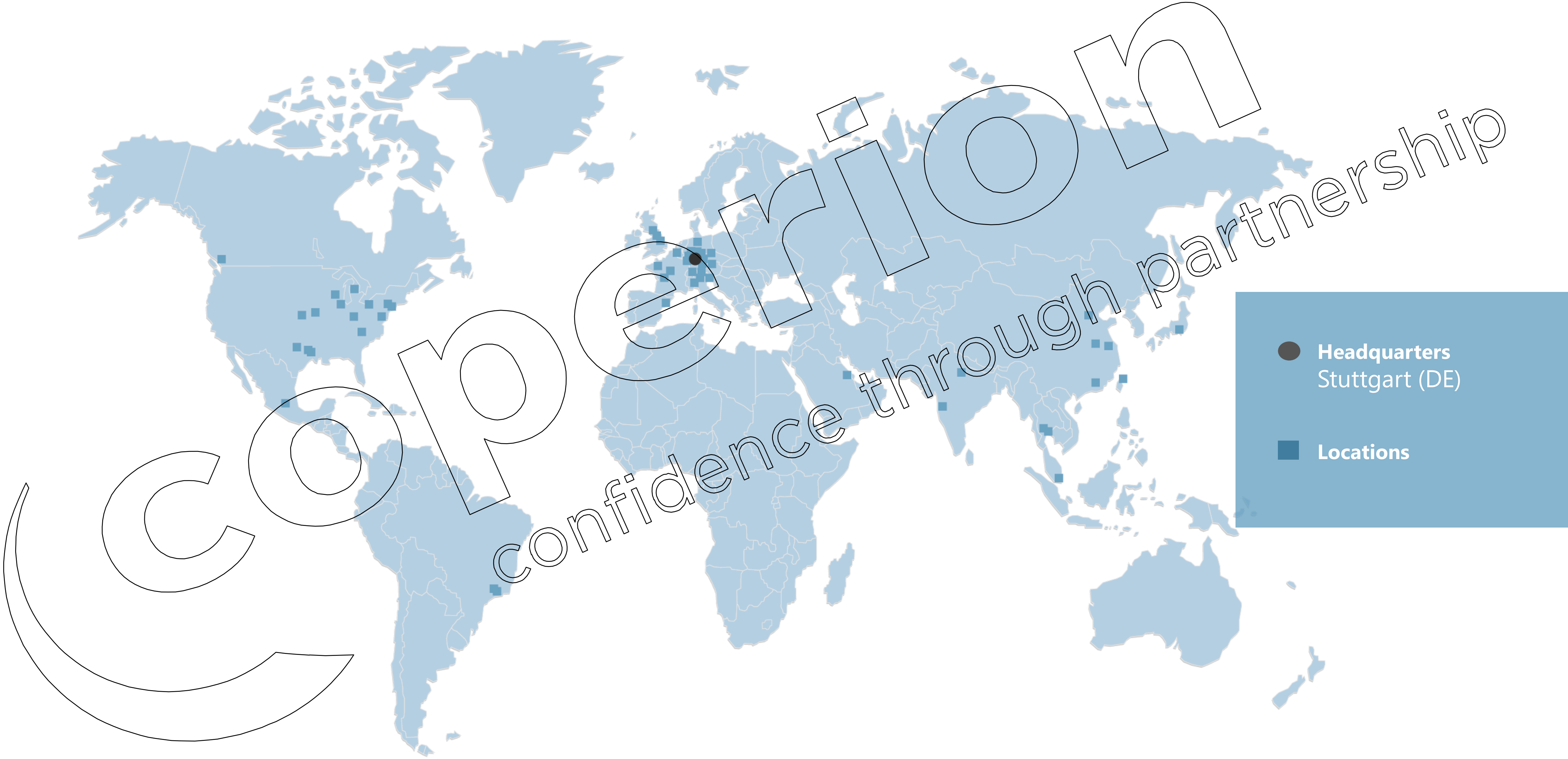
confidence through partnership

Performance Materials
Division

Food, Health & Nutrition
Division

Aftermarket Sales & Service
Division

The Coperion network



Business Unit Recycling

Where we are coming from

Key milestones

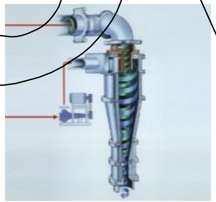
1884
Foundation of Herbold Meckesheim by Adam Herbold – first grain mill built

1978
Change from agricultural equipment to plastics grinding

1985
First wet grinder for simple plastics washing applications

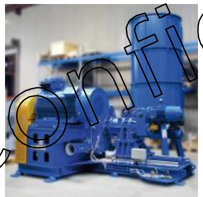
1989

New washline lab with wet grinder, friction washer, mechanical & thermal dryer

1990

Introduction of the hydrocyclone technology, leading to significantly higher yiealds

1992


First ZSK 40 for production of cast film out of undried PET shown at K-Show '92

1996

Intrudoction of the first Herbold Plastcompactor

2003

First PET washline including hot wash and hydrocyclone technology

2020

First FDA-approved PET bottle-to-bottle line sold

2021
First multi-layer recycling line sold

2022

Launch of ZSK MegaFeed

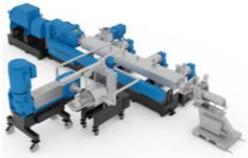
2022

Acquisition of Herbold Meckesheim by Hillenbrand Inc. &

Founding of new Recycling Business Unit

2023

First trials in newly built Recycling Innovation Centre

2024

Launch of ZSK FilCo+

2024


First production-scale chemical recycling line start-up

2024


Largest PET bottle-to-bottle recycling plant in India sold to Magpet

Why are we here

Global Trends

FAST-DEVELOPING COUNTRIES

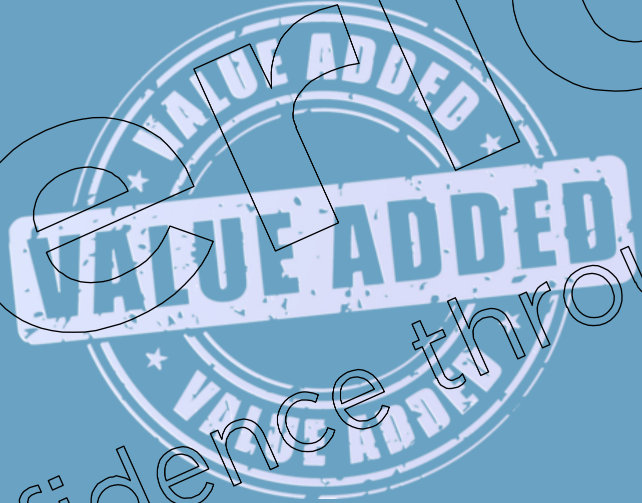
+

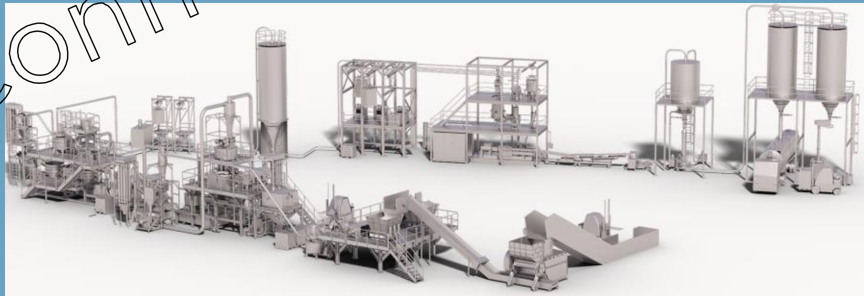
Trends in Plastics Recycling

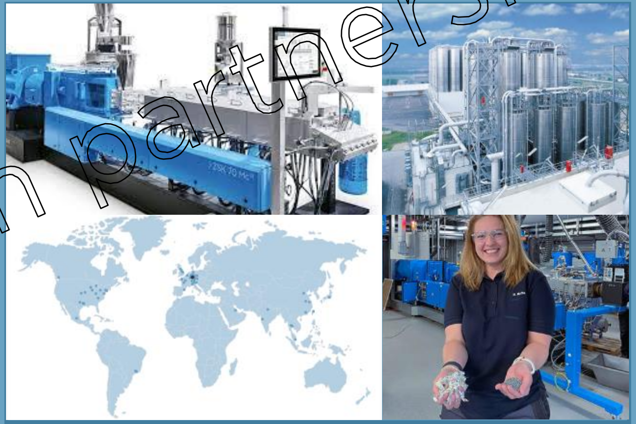
Higher throughput

Chemical Recycling

Increased Quality Requirements







Recycling Business Unit – New common product range

HERBOLD MECKESHEIM

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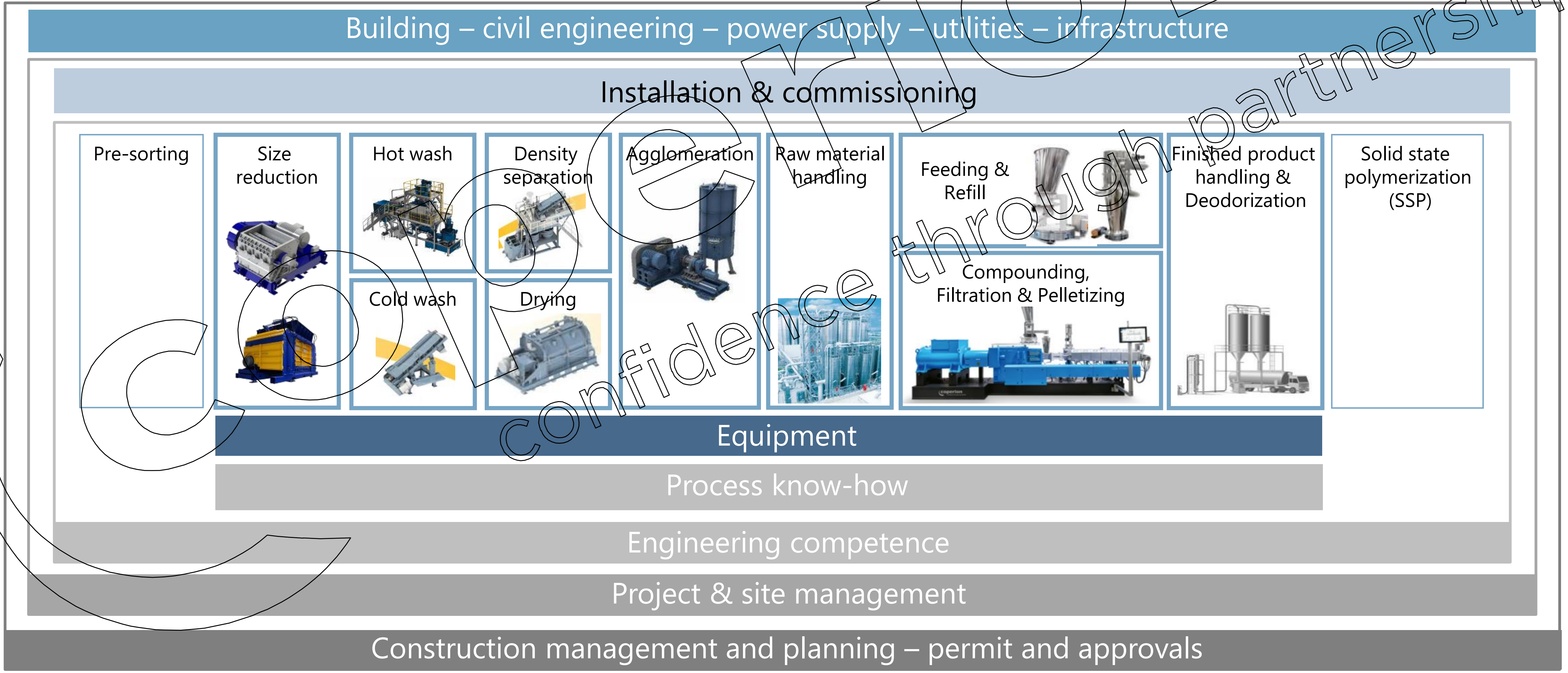
The integration of Herbold and former Schenck Process FPM allow us to offer the Recycling industry best in class equipment as well as full scale Recycling plants by leveraging Coperion's engineering capabilities.



Coperion Recycling – activity spectrum

Post-consumer film

Post-industrial waste

PET bottles

PET trays

Post-consumer HDPE/PP waste

Agricultural film

Post-consumer Big Bags

Car battery cases

Pulper/UBC waste

We offer a wide range of recycling solutions accross a wide spectrum of plastics types, recycling technologies, customer segments and geographic regions.

Business Unit Recycling – Why we are the right partner

Coperion and Herbold – A new level of expertise in plastics recycling

What makes Coperion Recycling unique and the best partner:

- **Bringing strong brands together** – Offering best in class process
- Serving you **globally**
- Targeted product development with **high in-house production rate**
- **Decades of experience and process know-how** in plastics and plastics recycling.
- **One stop shop**
- **Tailor-made solutions** for all recycling processes.
- **Food-grade PET bottle-to-bottle references** with brand approval with our SSP partner (Coca Cola)
- **Recycling Innovation Centers** in Europe and testing facilities around the world to support our customers.

Industry leading technology offering best quality, lower opex, maximal throughput and flexibility

Best Total Cost of Ownership

Worldwide support

Coperion Recycling Unique Selling Points

Turnkey capabilities

Improved quality

High throughput

Worldwide service footprint

FDA / EFSA approved

Reduced opex

Global engineering capabilities

Optimized footprint

Enhanced flexibility

Test centers across the globe

HERBOLD
MECKESHEIM

coperion

Challenges, Innovations and the Circular Economy confronting the recycling of post-consumer plastics

Prof. Edward Kosior
Managing Director | Nextek Ltd and NEXTLOOPP Ltd.

Challenges, Innovations and the Circular Economy confronting the recycling of post-consumer plastics

COPERION RECYCLING DAYS
6&7 NOVEMBER 2024

PROF. EDWARD KOSIOR
Managing Director
Nextek Ltd and NEXTLOOPP Ltd
London UK, Sydney Australia, NY USA and Pune India

nextek

NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP

NEXTEK LTD
WHAT WE DO

Recycling plant design and Feasibility studies.

Strategic advice to Multi-National Corporations and Recycling Co's.

Food-grade recycling of post consumer plastics – process development.

Research and development of novel materials and processes including plastics and bioplastics.

Business support, productivity improvement and problem solving.

Ground breaking projects for governments and major commercial organisations in the EU, UK, India, Malaysia, USA, South America, Middle East, North Africa and Australia/NZ.

Strong ties to Universities and Scientific Centres of Excellence in the UK and Europe.

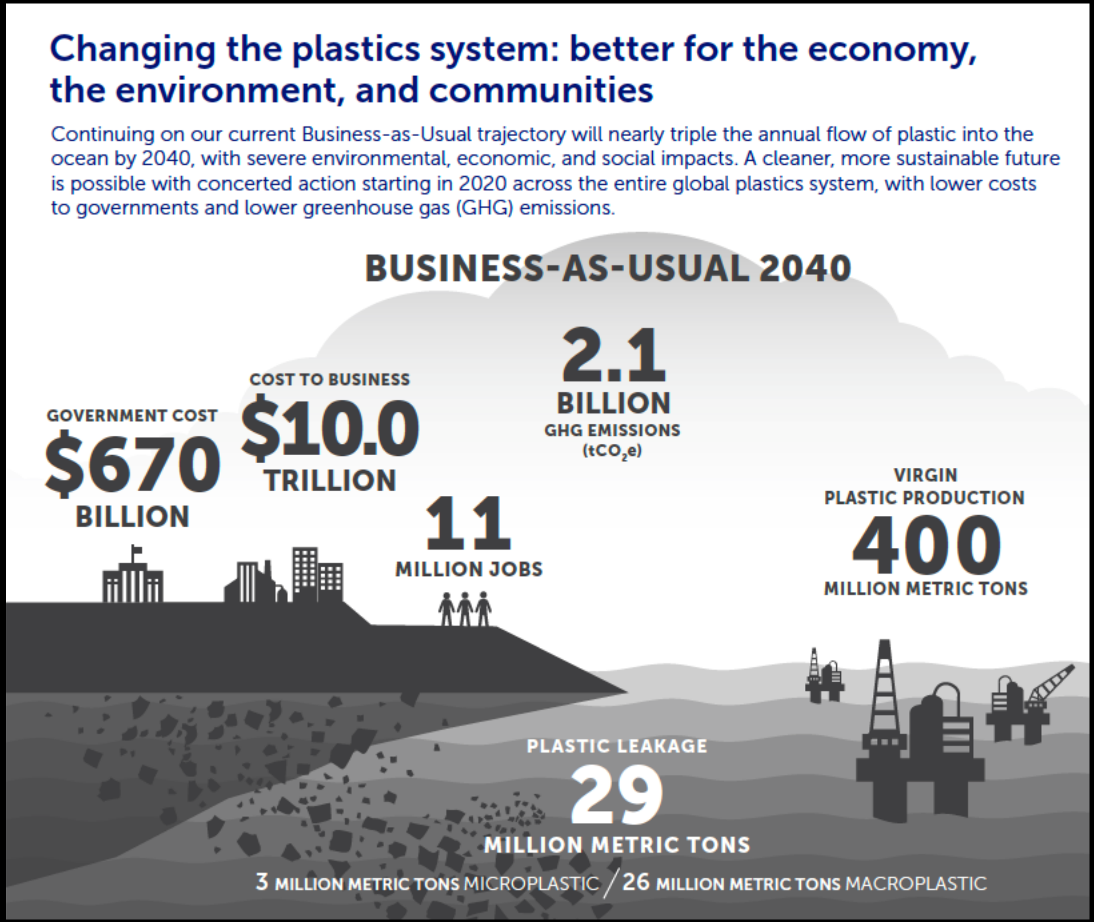
AWARDS

WHERE ARE WE HEADING WITH PLASTICS

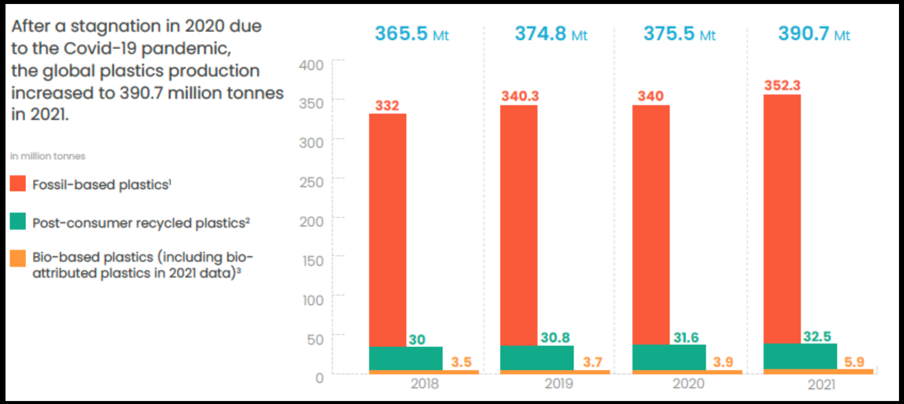
Business as usual- 2040

- On the way to Zero Net Carbon economy
- The tipping point is 2030.
- Plastic production will be 400 million tpa
- Plastic will be 20% of oil production.
- Population 9.2 billion people to be fed.
- Food waste is typically 35%
- 35,500 species on extinction list
- 11.2 billion tpa solid waste (2021)
- Leakage to oceans would be 29million tpa

System Change is necessary to avoid the worst impacts!



Global Plastics Production



WHAT WE CAN EXPECT IN THE FUTURE - with Maximum Intervention

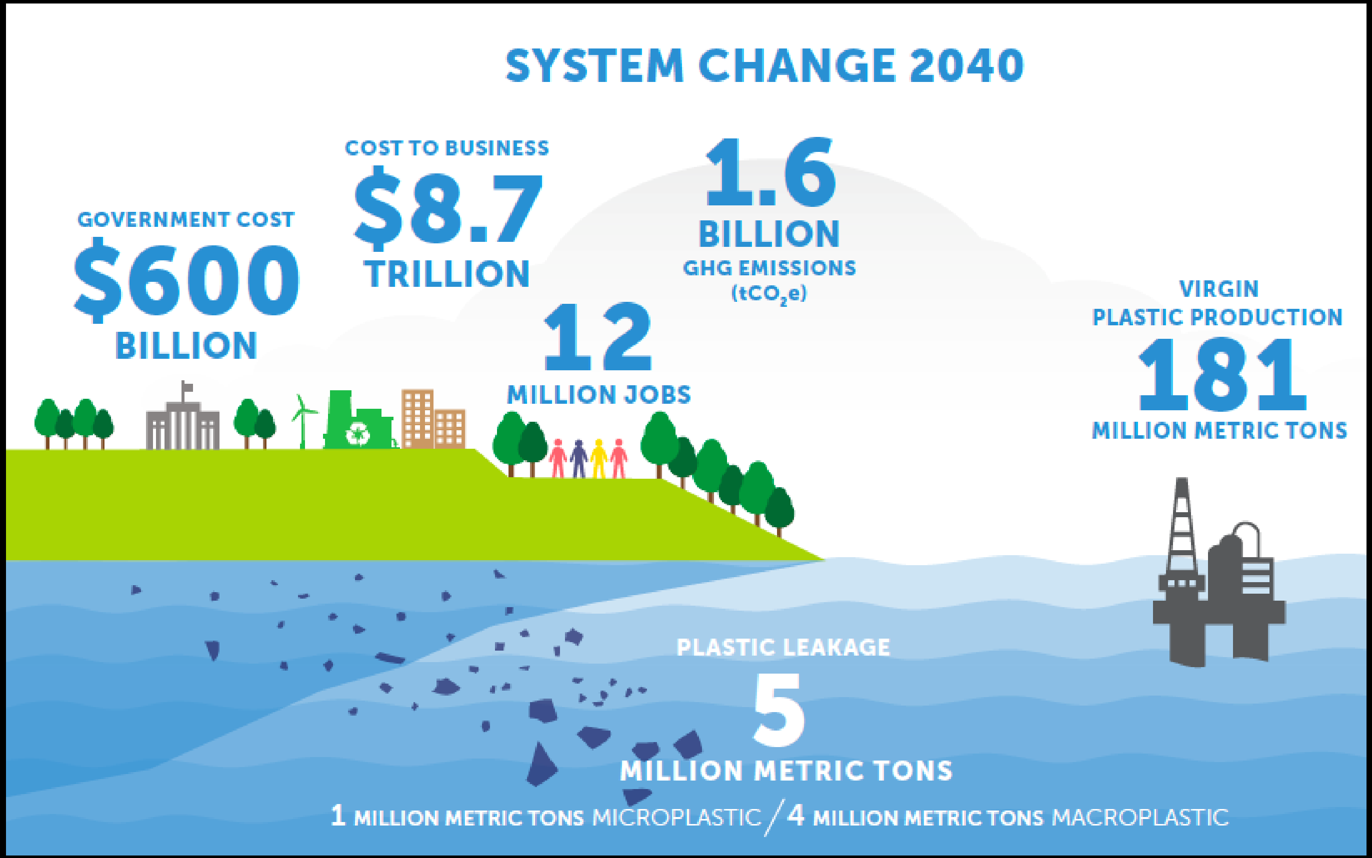
Plastics WILL be an important part of the future (except for single use plastics!).

Plastics will be key in reducing carbon emissions and reducing food waste.

Producers can expect to do MORE with Design, Recycling, Recycled Content.

Improved Sorting and Recycling technologies for packaging will deliver greater circularity and recycled content.

None of this is rocket science!



Progress towards UK Plastics Pact Targets

Target	Progress (2022)	Likelihood of meeting Target
Target 1: Elimination of Problematic & Unnecessary Plastic	• 99.4% reduction in units • 55% reduction in PS/PVC • 8% reduction in total single use plastics	• Further effort on PS/PVC • Loose fresh produce
Target 2: 100% Recyclable, Reusable or Compostable	• 71% recyclable • 73% recyclable or reusable • 94% of rigids are now recyclable	• Could achieve 78% recyclable (kerbside) and 97% recyclable at kerbside or supermarkets
Target 3: 70% Effective Recycling Rate	• 55% recycled	• Will require kerbside collections for films & flexibles and investment in infrastructure
Target 4: 30% Average Recycled Content	• 24% average recycled content	• Will require revisions to the Plastics Packaging Tax, or PET to do the majority of heavy lifting.

Brand Owners requirements for recycled plastics

- Improved colour control
- Improved material consistency
- Odour reduction in recycled plastics for HDPE, PP and LDPE
- Food Grade Recycled Plastics for HDPE, PP and LDPE
- Recycling plant boost in quality and output to brand owner standards

CHALLENGES TO THE CIRCULAR ECONOMY

- The majority of resins and products have been designed to be processed once only – not recycled.
- **Recycling friendly STABILISED formulations and designs are needed.**

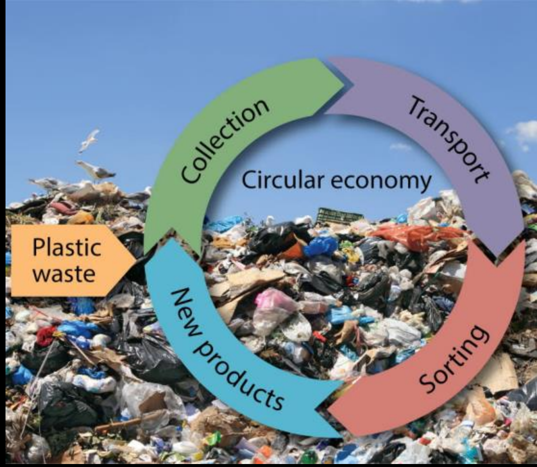
- In the circular economy, you can only recycle what is put out by the retailers.
- **Printing inks and pigmentation limit re-use and yield of most valued resins.**

- Not all packaging is recyclable. (100% recyclable by 2025???)
- **Mono materials are more widely recyclable to high value.**

- Food grade recycling is essential for the circular economy especially for polyolefins and films.
- **EU reg 1616/2022 has new requirements to establish EFSA compliance.**

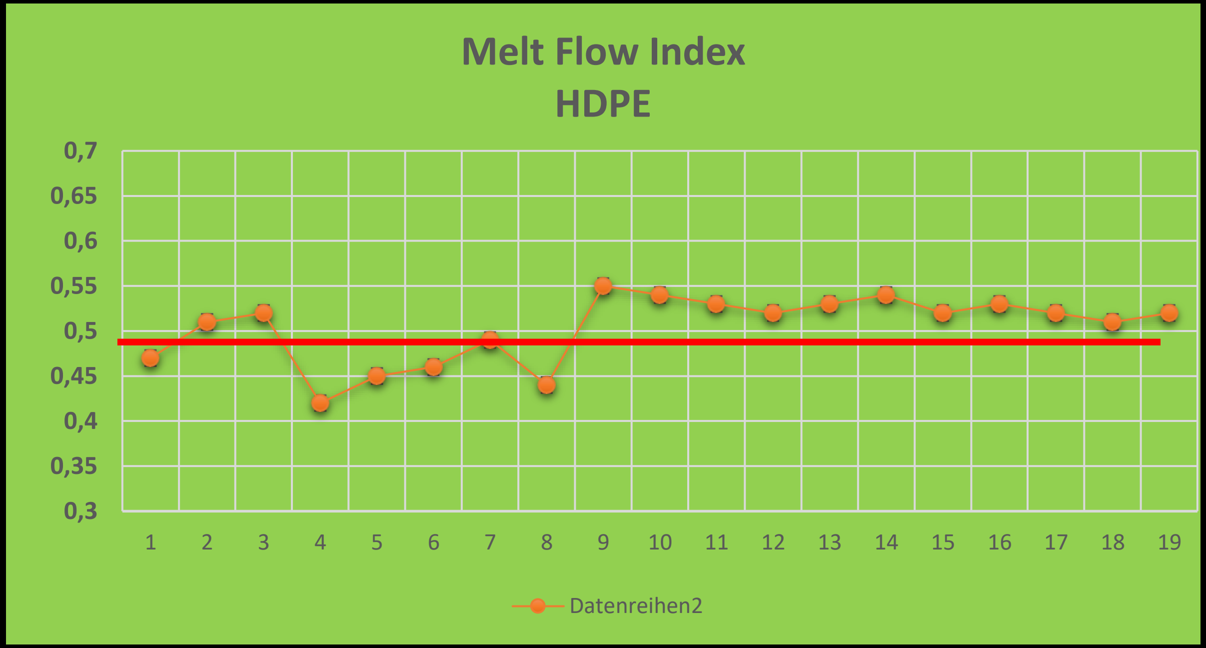
Yield Limitations on collections. (assuming all plastics are available for recycling)

75% **collection** x 95% **sorting** x 85% **recycling** = **60% Recovery**



CIRCULAR RECYCLED PLASTICS – QUALITY ATTRIBUTES

- Recycled Plastics are made from mixtures of grades
- Properties (processing and mechanical) are an average of the inputs so they don't line up exactly with virgin grades
- 100% rPlastic DOES NOT equal 100% virgin Plastic
- Blending with an appropriate grade of virgin polymer will allow re-alignment of the properties close the standard virgin grade.
- Blending minimises colour variation and processing variation
- Manufacturing is more stable when recycled content is spread over more packaging than concentrated into fewer products

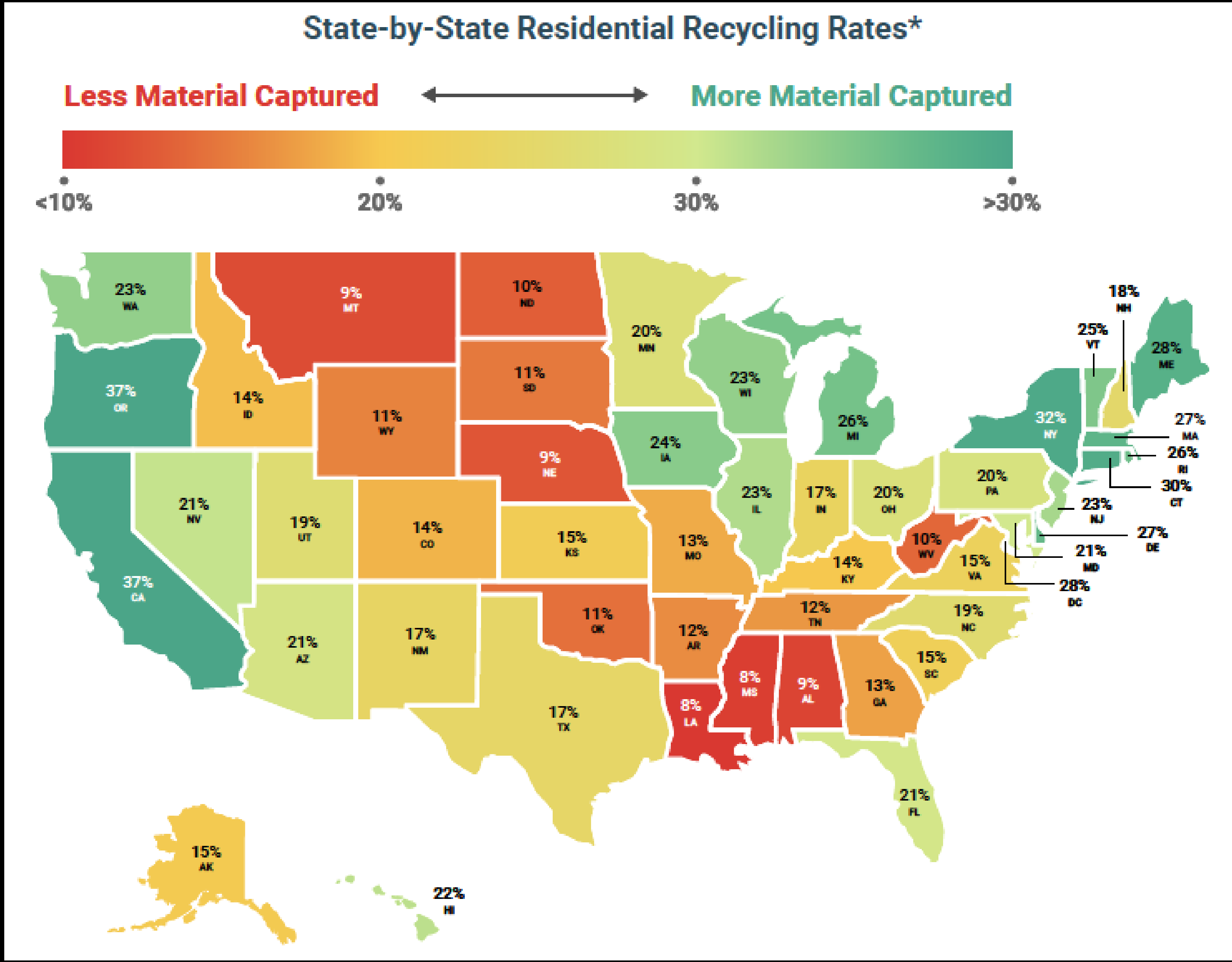


COLLECTION RATES in USA (2024)?

National Residential Recycling Rates by Material Category*
(in Tons Per Year)

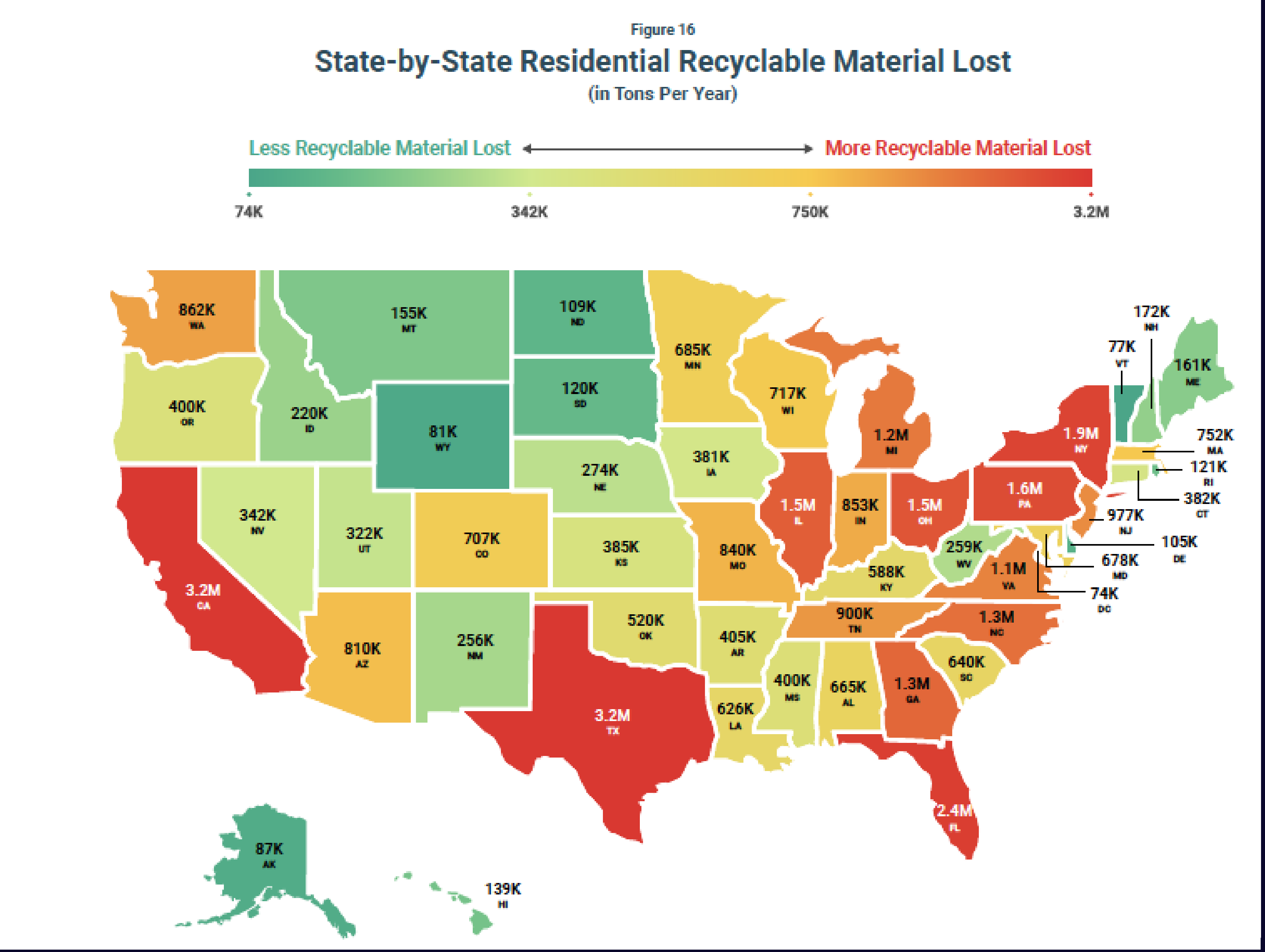
Material	Tons Generated	Tons Recycled	Recycling Rate	Total Tons Lost (homes & MRFs)	% Lost (homes & MRFs)
PET Bottles**	3,412,310	971,215	28%	2,441,095	72%
Non-bottle PET	748,974	58,443	8%	690,531	92%
HDPE Natural Bottles	739,178	188,704	26%	550,474	74%
HDPE Colored Bottles	928,780	208,624	22%	720,155	78%
Polypropylene Containers	1,225,325	94,881	8%	1,130,444	92%
Plastics 3-7 (minus Polypropylene)	754,006	8,909	1%	745,097	99%
Bulky Rigid Plastics	1,516,711	17,231	1%	1,499,479	99%
Film & Flexible	4,787,126	4,569	<1%	4,782,556	>99%
TOTAL	47,366,519	10,138,381	21%	37,228,139	79%

NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP



USA Recycling Rates by state

- The recovery of recyclable post consumer materials varies across the states from 8% to 37%
- Demonstrating presence of infrastructure for recycling



Recyclable materials (all) lost Tons/yr

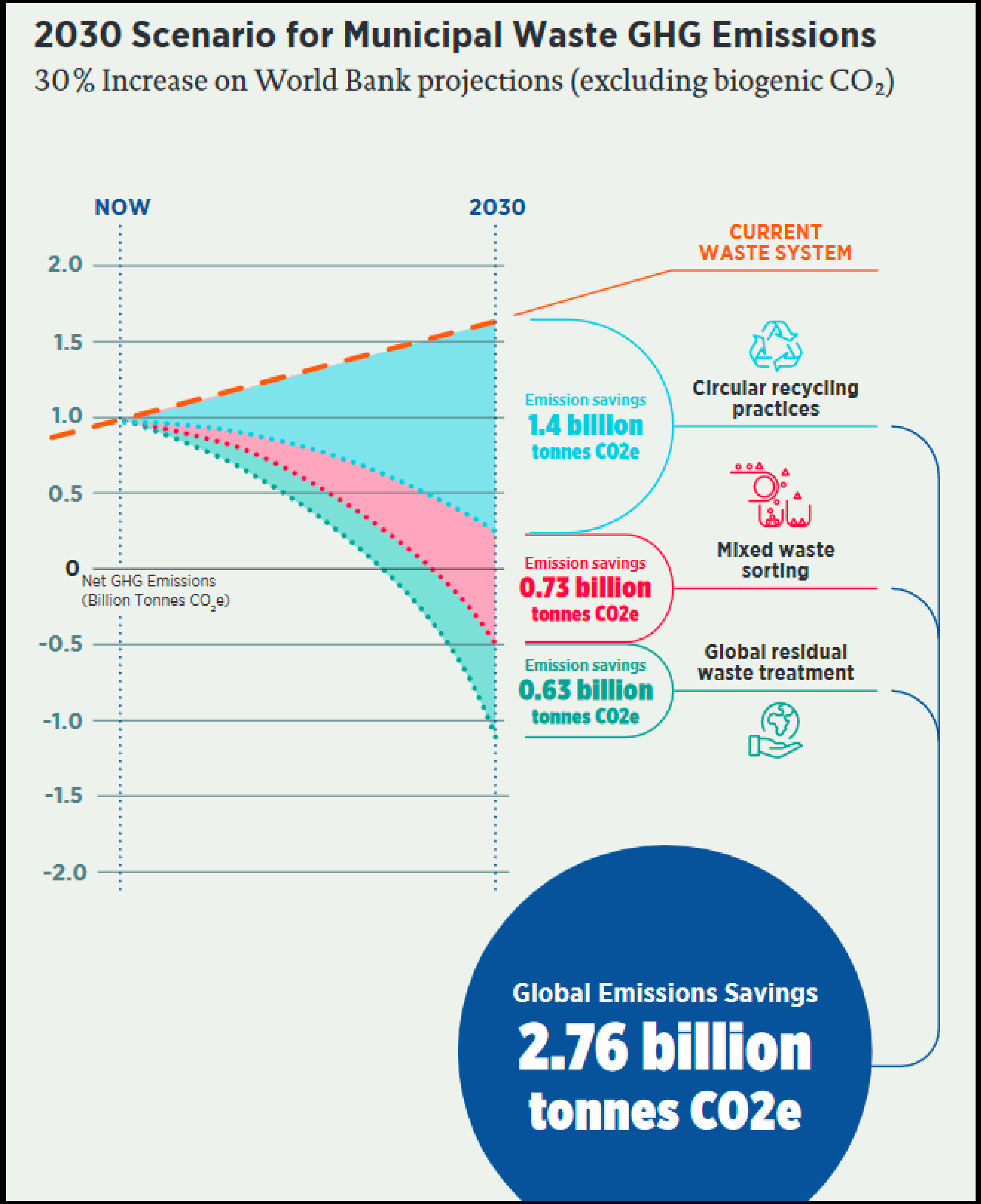
2M+	
1.5M - <2M	
500K - <1.5M	
<500K	

The biggest losses = the best PP growth potential

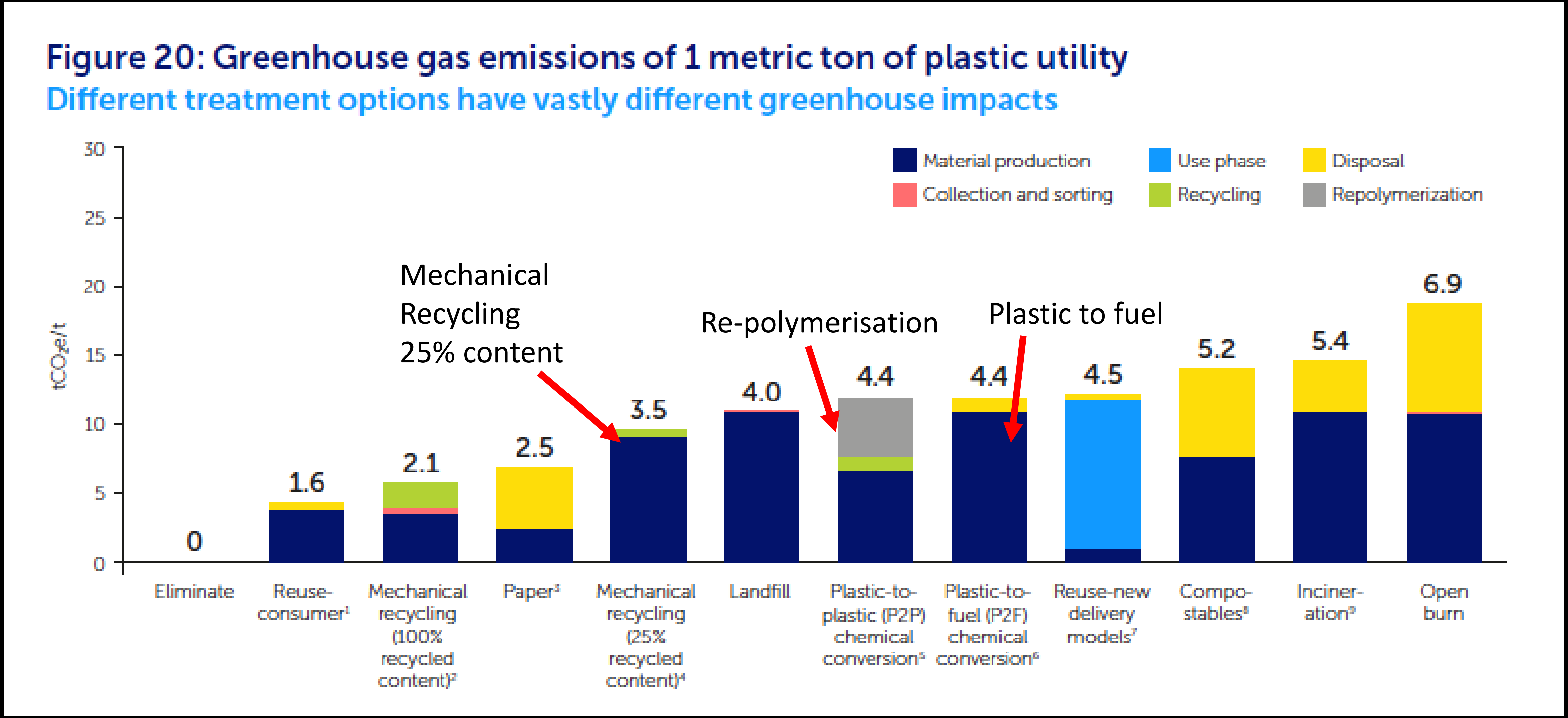
NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP

Circular Economy - NEXT: Red Bin/Black Bag Recycling

- **The "wastestream" destined for landfill or waste-to-energy contains many recyclable materials including Plastics, metals, glass, paper, organics.**
- The World Bank projects that 2.76 billion CO2e savings could be made through residual waste treatment
- Each of these materials have a value and once recovered and recycled will reduce the need for new resources to be dug out of the ground.
- **The technology is readily available and already in practice in countries that have a Zero Waste approach by choice or necessity**
- **Netherlands, Taiwan, Crete,Wales, Kamikatsu (Japan), Vancouver (Canada), Flanders (Belgium), Cappanori (Italy) Thiruvananthapuram (India)**



GHG emissions of Competitive recycling options



100% recycled content

25% recycled content

Chemical recycling

Compostables

Source: Breaking the Plastics Wave - Systemic

Regulation in a Circular Economy (EU)

- The European Commission has changed the **Directive on Plastics and Packaging Waste** to a **Regulation**

has the following mandatory targets i.e it will be illegal to not have:

- All packaging recyclable or reusable by 2030
- Recycled Content targets
    - 30% for contact sensitive packaging made from PET by 2030 and 50% by 2040
    - 10% for contact sensitive packaging made from plastic materials other than PET by 2030 and 50% by 2040
    - 30% for single-use plastic beverage bottles by 2030 and 65% by 2040
    - 35% for other packaging by 2030 and 65% by 2040

Other packaging, including packaging made of biodegradable plastic polymers, must allow material recycling without affecting the recyclability of other waste streams

The biggest market for plastics is food packaging so food grade compliance is crucial to meeting these targets.

RECYCLED PLASTICS & FOOD LAW

Plastics for food contact are always evaluated for any migration that might occur when in contact with food material

Must use food grade packaging as input

Migrating substances are considered to be food additives

Threshold of Regulation – a level which the probable exposure to a potentially toxic substance is a negligible risk (0.5 ppb Dietary Concentration)

Any recycling process must demonstrate its ability to remove potential contaminants due to consumer misuse **via a challenge test**

European Food Safety Authority

Must not endanger human health, deteriorate the organoleptic characteristics of the food, or cause unacceptable change the food

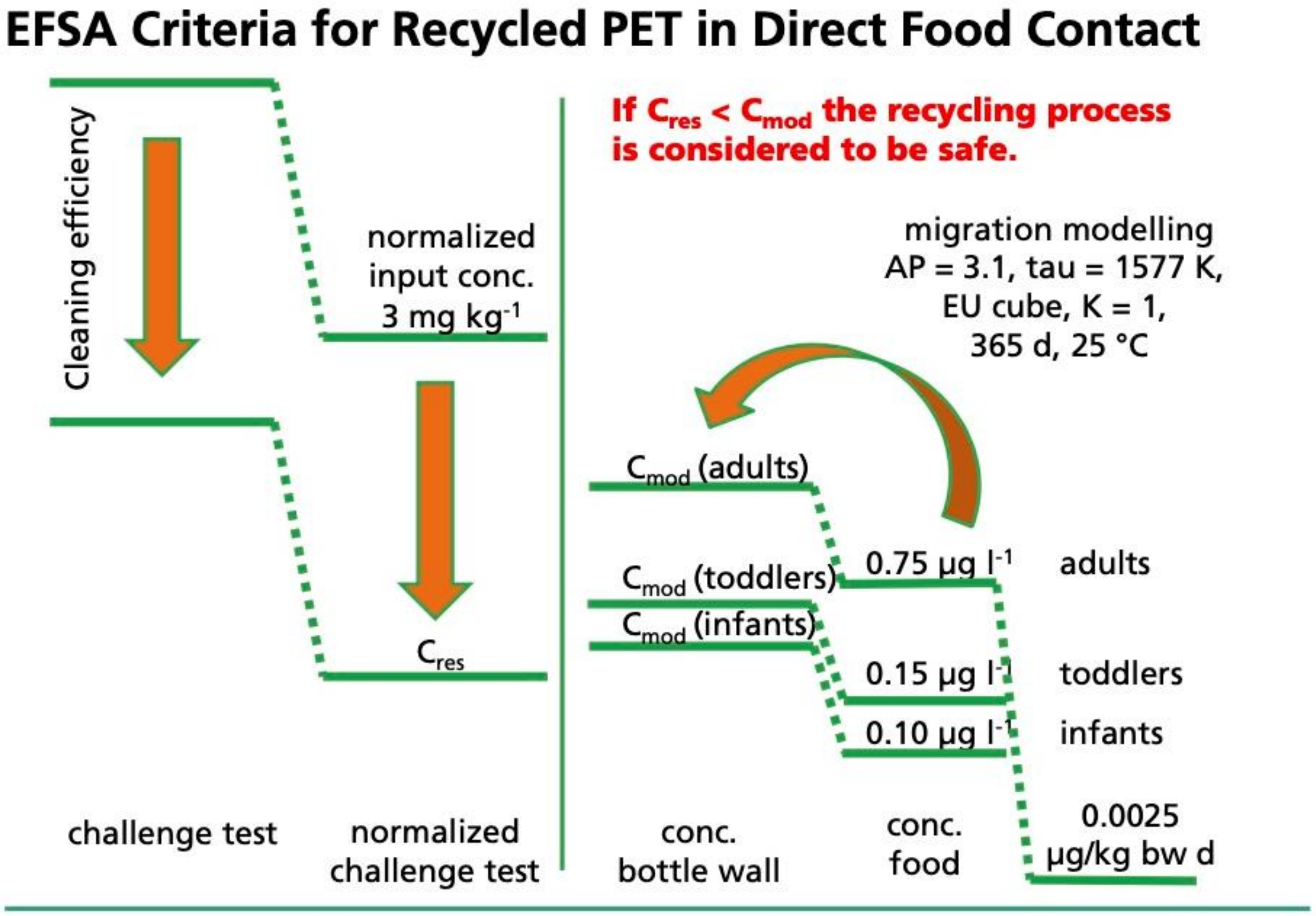
Only materials that have been manufactured compliant to EU Regulation No. 10/2011 can be used in the recycling process

The migration of substances from the packaging into food, must not exceed thresholds of toxicological concern

Any recycling process **must demonstrate its ability to remove potential contaminants** or prevent contamination in a closed-loop system
New regulation 2022/1616 (Oct 2022)

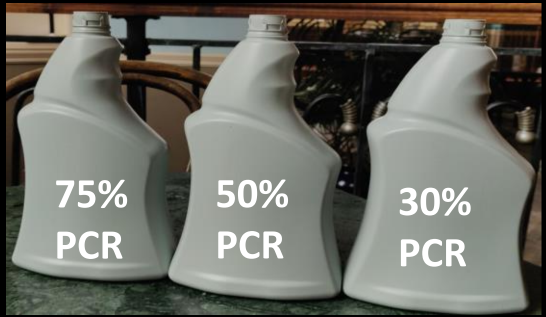
EFSA Scientific Opinion of safe assessment of recycling processes – worst case principles

- Determination of the contamination levels in the input stream (including misused bottles)
- Determination of the cleaning efficiency of the recycling process (challenge test).
- Calculation of the residual concentration of contaminants (Cres) after recycling (based on a normalized input concentration)
- Evaluation of the exposure (infants, toddlers, adults)
- Calculation of the maximum bottle wall concentrations (**C**mod)
- Comparison of **C**res with **C**mod
- The process can be considered as safe if **C**res < **C**mod for all kinds of contaminants



DESIGN FOR FOOD-GRADE CIRCULAR ECONOMY RECYCLING.
REMOVING AND CONTROLLING COLOUR TO BOOST RECYCLING

- The key challenges for food grade recycling are twofold:
    - 1. Recovering the food grade fraction of packaging for recycling
    - 2. Boosting the yield of the most favoured colours (natural and white) to improve economics
- controlled use of pigmentation could be used to improve food grade sorting and increase yield.
- All food products should be preferably free of of pigment where possible; otherwise if opacity is needed, pigmented white.
- Non-food products would be in light pastel colours – thereby using smaller concentrations of pigments.
- Hazardous products would be pigmented in black carbon black or detectable black pigments).
- Sorting by transparent/pastel/black colouration of packaging is very simply achieved by the use of well-established, accurate and relatively low-cost automatic sorting technology using the visible light spectrum and cameras for detection.



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CASE STUDY: Competitive INTELLIGENT SORTING into food use packaging

Globally, Near Infra Red (NIR) and visible signatures are used to identify the polymer type and colour at very high speeds.

No markers are needed for sorting into polymer types such as PET, HDPE, PP, LLDPE etc

The important technologies of marker sorting (Spectroscopic, Neural network (Artificial Intelligence) and Digital product markings will deliver more precise separation for recycling.

No.1 Priority is FOOD-GRADE Prior Use

No.2 Priority is Non-Food Grade Prior Use

No.3 Priority is Toxic products

No.4 Priority is Difficult to Recycle packaging

Fluorescent markers on labels

Digital watermarks Filigrade and Digimark

NEXTLOOPP's mission is to close the loop on food grade post consumer Polypropylene

NEXTLOOPP

CLOSING THE LOOP ON FOOD GRADE PP

NEXTLOOPP Innovation Technologies

Design for Recycling

Post consumer characterisation

Sorting into food and non-food fractions

Cleaning

Decontamination/ deodorisation

Processing into new food grade products

Brunel University London
ORLEN
BEKAERT better together
HENG HIAP
RECOUP
Aptar
EARTH CHAMPIONS Local Heroes, Global Impact.
SHARPAK BY GUILLIN
BOSTIK
greiner packaging
Unilever
mcc iml.mcclabel.com
TotalEnergies
DANONE ONE PLANET. ONE HEALTH
wrap
circular&co.
gneuß
Silver Plastics
HydroDyn
KIEFEL PACKAGING A Member of Brückner Group
TOMRA
SUPER FILM PACKAGING FILMS
extrupet recycling your world (Pty) Ltd
NEXTLOOPP CLOSING THE LOOP ON FOOD GRADE PP
kp
ALMA Products Ltd
Saputo Dairy UK
MANNOK
intraplás
INEOS Olefins & Polymers Europe
LYB LyondellBasell
sorema PLASTICS RECYCLING SYSTEMS
LAVAZZA GROUP
PPG
ALBÉA COSMETICS & FRAGRANCE
OPRL THE ON-PACK RECYCLING LABEL
MIRAGE·INKS
Rubbish reusables
Viridor
adapa
UNIVERSITY of GREENWICH NRI Natural Resources Institute
nextek
CCL
Braskem
ROBINSON
fsg
SEE SealedAir
L'ORÉAL
müller
PFF Group INNOVATION | SUSTAINABILITY | CREATIVITY
Teda Pack thermoforming
TRACING Technologies

NEXTLOOPP ahead of the curve

Since launching NEXTLOOPP Europe in 2020, we have been deploying our technologies to sort and decontaminate post-consumer PP packaging.

NEXTLOOPP TECHNOLOGIES

GAINnext ™ (TOMRA)

Sorting food-grade packaging

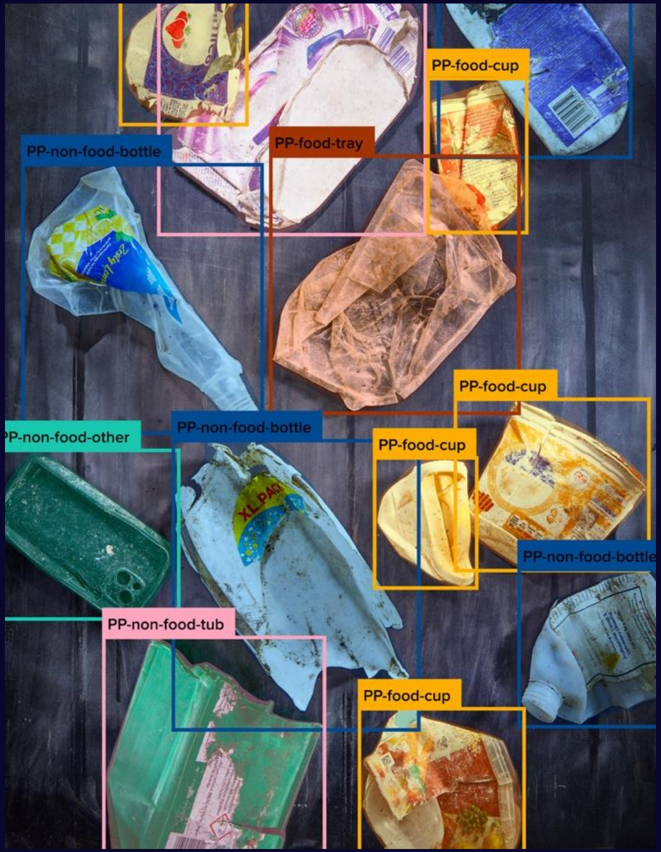
PPristine™

Decontamination technology

Having explored best in class technologies to efficiently separate food from non-food packaging, the project has opted for GAINnext™, TOMRA's AI technology that sorts at > 95% purity, meeting the stringent food safety authorities' standards

Sorting Food Packaging using “deep learning”

Recent trials with TOMRA’S GAINnext^{TM} achieved > 97 percent food contact packs with yields as high as hand sorting.



This sorting breakthrough will dramatically speed up the adoption of food-grade recycling operations for polyolefins.

NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP

NEXTLOOPP

CLOSING THE LOOP ON FOOD GRADE PP

Designing food-grade PP packs for sorting using AI - GAINnext™

Examples-Packs which look similar....

Food √

Non-food √

Non-food √

?

- Non-food brands could adopt coloured opaque packs to not risk being sorted as white food-grade PP
- Ice-cream containers could be selected as non-food.
- Transparent tubs would more likely be selected as food grade.

Sorting alone does not deliver food grade recyclate

NEXTLOOPP PPristine

DECONTAMINATION IN MELT AND SOLID STATE

The next step after sorting is high performance decontamination

Decontamination efficiency achieved by NEXTLOOPP PPristine technology.

Process	Toluene (mg/kg)		Chlorobenzene (mg/kg)		Phenyl-cyclohexane (mg/kg)		Benzophenone (mg/kg)		Hexyl salicylate (mg/kg)		Isopropyl myristate (mg/kg)	
M Wt	92.1	Decon (%)	112.5	Decon (%)	160	Decon (%)	182.2	Decon (%)	222.3	Decon (%)	270.4	Decon (%)
Control*	1049	~	1151	~	970	~	720	~	962	~	843	~
NEXTLOOPP PPristine	<0.5	100%	<0.5	100%	1.7	99.8%	9.0	98.8%	22	97.7%	41	95.1%

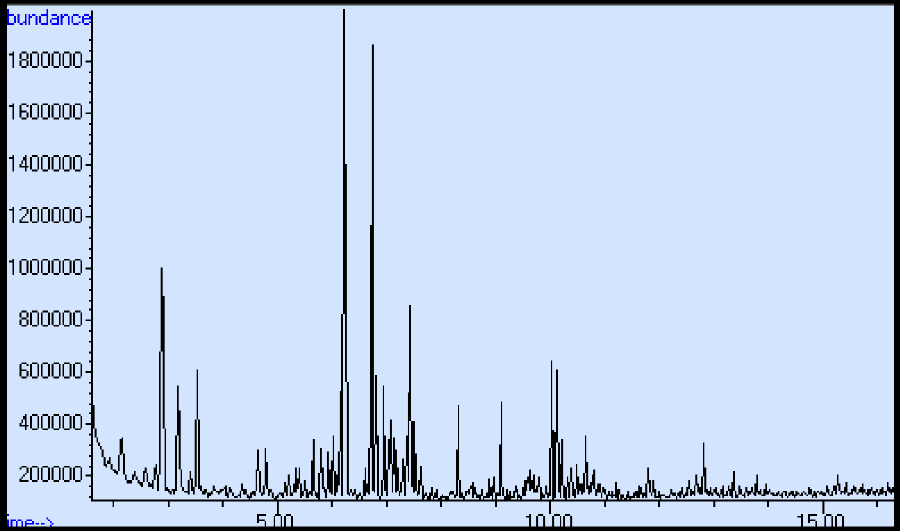
Where 'Control' refers to measured concentration of surrogates in challenge test flake prior to any processing.

NEXTLOOPP
CLOSING THE LOOP ON FOOD GRADE PP

Headspace GC/MS testing of PPristine™ Resin

(Natural FG and INRT™)

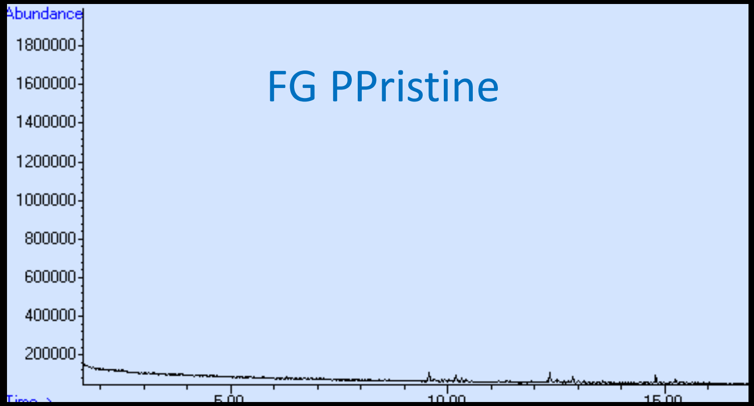
Natural flake

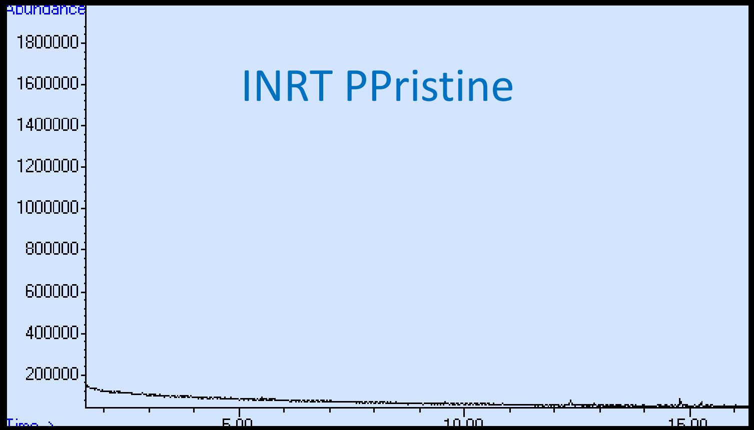


PP Flake after washing

No Odour
Reduced Fuming

NEXTLOOPP





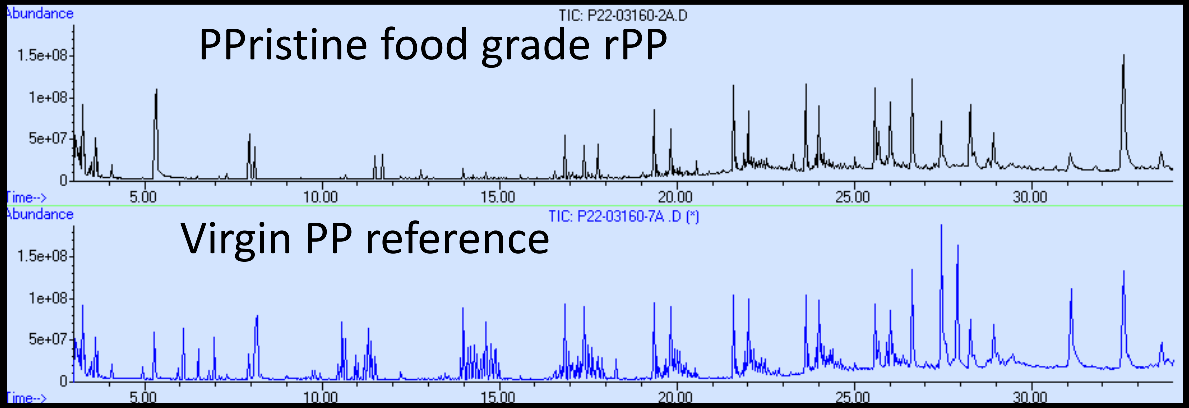
PP pellet after decontamination

PPristine rPP resin - Output characterisation

- Important material properties
- Data showing suitability for food contact
- Organic and inorganic NIAS screening
- Migration/sensory testing
- Ames testing – genotoxicity check

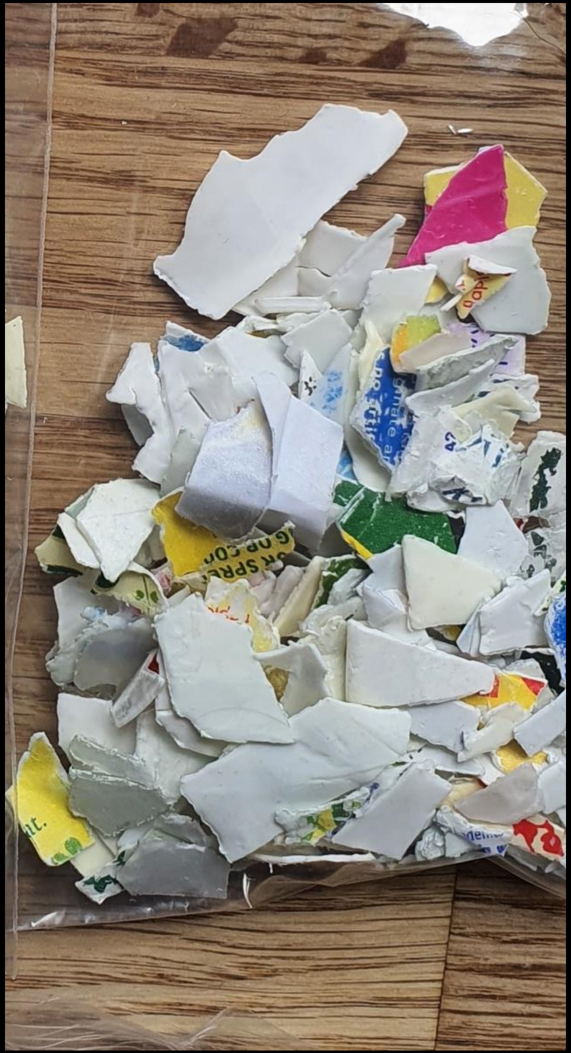
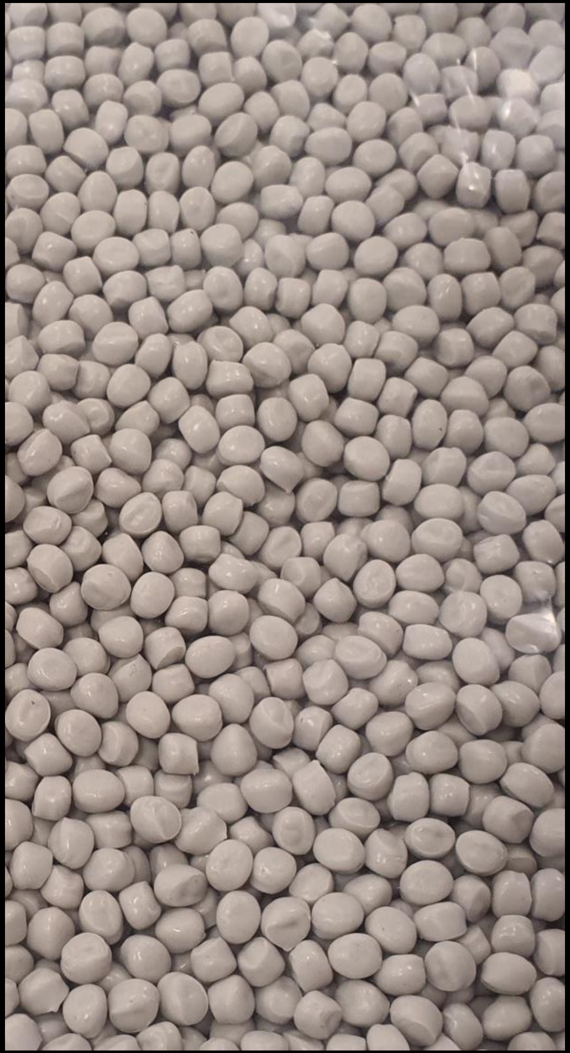
Property	Natural	White	Coloured
Pellets per 5 g	147	136	174
Tensile stress at yield (MPa)	30.5	28.5	28.0
Tensile strain at yield (%)	9.0	6.3	6.1
Tensile modulus (MPa)	1,183	1,255	1,248
Flexural modulus (MPa)	1,379	1,426	1,376
Izod impact, notched, 23 °C (kJ/m^2)	5.1	5.7	5.4
Izod impact, notched, -20 °C (kJ/m^2)	3.0	3.6	3.5
Melt flow rate (g/10min)	14.1	20.2	27.3

Sample name	3% Acetic acid overall migration mg/dm^2	10% Ethanol overall migration mg/dm^2	Olive oil overall migration mg/dm^2
PPristine Natural	1.38	1.30	6.54
PPristine White	2.49	1.09	9.66
PPristine Colour	3.47	1.45	8.70
PPristine IM	0.78	1.04	6.58
PPristine INRT	2.67	1.46	6.59



IML AND PRINT REMOVAL - COLOUR IMPROVEMENT
Mechanical Cleaning during wet washing

Recycling with IML labels left on

Design to Recycle: NextCycle IML from MCC Verstraete

- Removable IMLs - Verstraete's NextCycle IML
- Fully printed (non-bleeding inks) without adhesives.
- These labels are designed to be removed prior to extrusion at the grinding steps or air elutriation stage and separated from the rigid flakes

Design to Recycle: SealPeel from MCC Verstraete

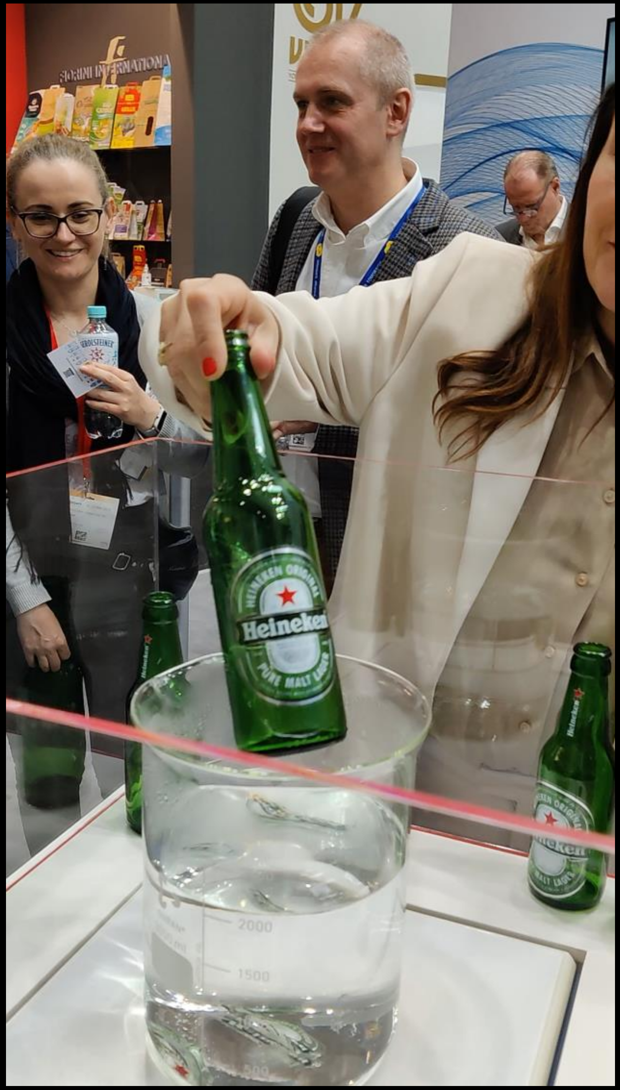
- Foil-lidded containers make recycling less effective due to
    - Al Foil remnants on the lid result in PP tubs ending up in the residue stream
    - Melt filtration is made dramatically difficult causing reductions in throughput and yield
- During trials full mono PP packaging achieved a 14% higher yield during the sorting phase.

- Aluminium seals often get damaged during transport.
- The PP SealPPeel lids are twice as puncture resistant compared with thinner aluminium seals.
- The pack is easy to open and microwavable
- it is also visually appealing and provides higher graphic quality to improve branding.

REMOVABLE ADHESIVES FROM BOSTIK

- Adhesives with phthalate plasticisers
  - Many endocrine disrupting / toxic to reproduction
  - Conflicts - some permitted use with FDA indirect use but excluded from 10/2011
  - MEHP / BEHP / DOTP frequently observed in labels
  - Some alternatives available i.e. adipates (see 10/2011)

- Label removal
  - One long term study finds an average of 2.2 % of HDPE flakes with labels attached after conventional hotwash process
  - Poor delamination = carry over of glues and inks
  - Glues causing gels and black speck impurities
  - Label carry over causing issues with genotoxic activity and circularity
- Should stay with the label when they peel off
- Ideally do not leach plasticisers



NEXTLOOPP - Creating a Circular Economy for rPP

CO TOO CLEAN

Cleaning Plastic Film To Food-Grade Standards using super critical CO_2

Creating food-grade destinations for films.

Alliance Prize
Solutions to Address Flexible Plastics in Household Waste
NY Stock Exchange
29th November 2022

COTOOCLEAN Decontamination of Plastic Films

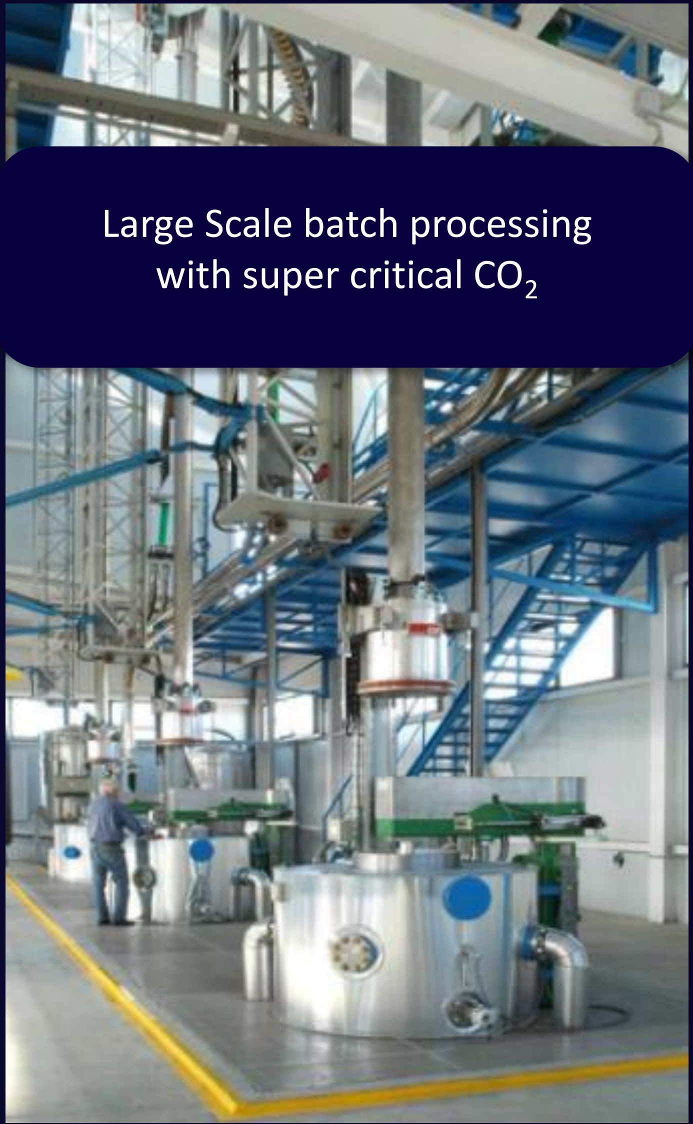
Decontaminates LLDPE, HDPE & PP films and chemical contamination in US FDA and EFSA challenge tests

Removes >99% of oils

Deodorises films – no smell

De-inks with “green” co-solvents - improves colour and quality

De-metallises multi-layer films – boosts yields



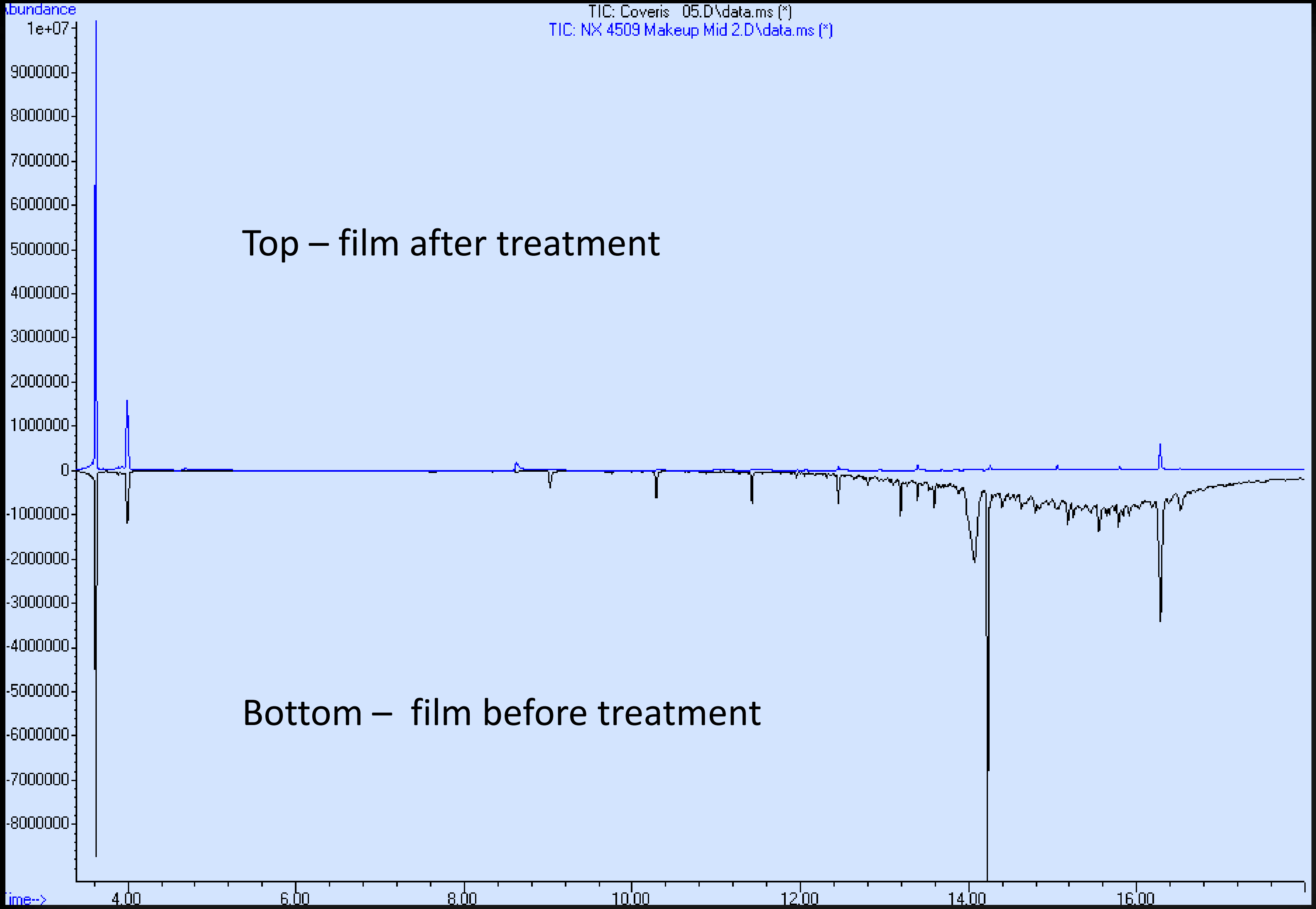
Large Scale batch processing with super critical CO_2

Our Approach- % Decontamination Rates

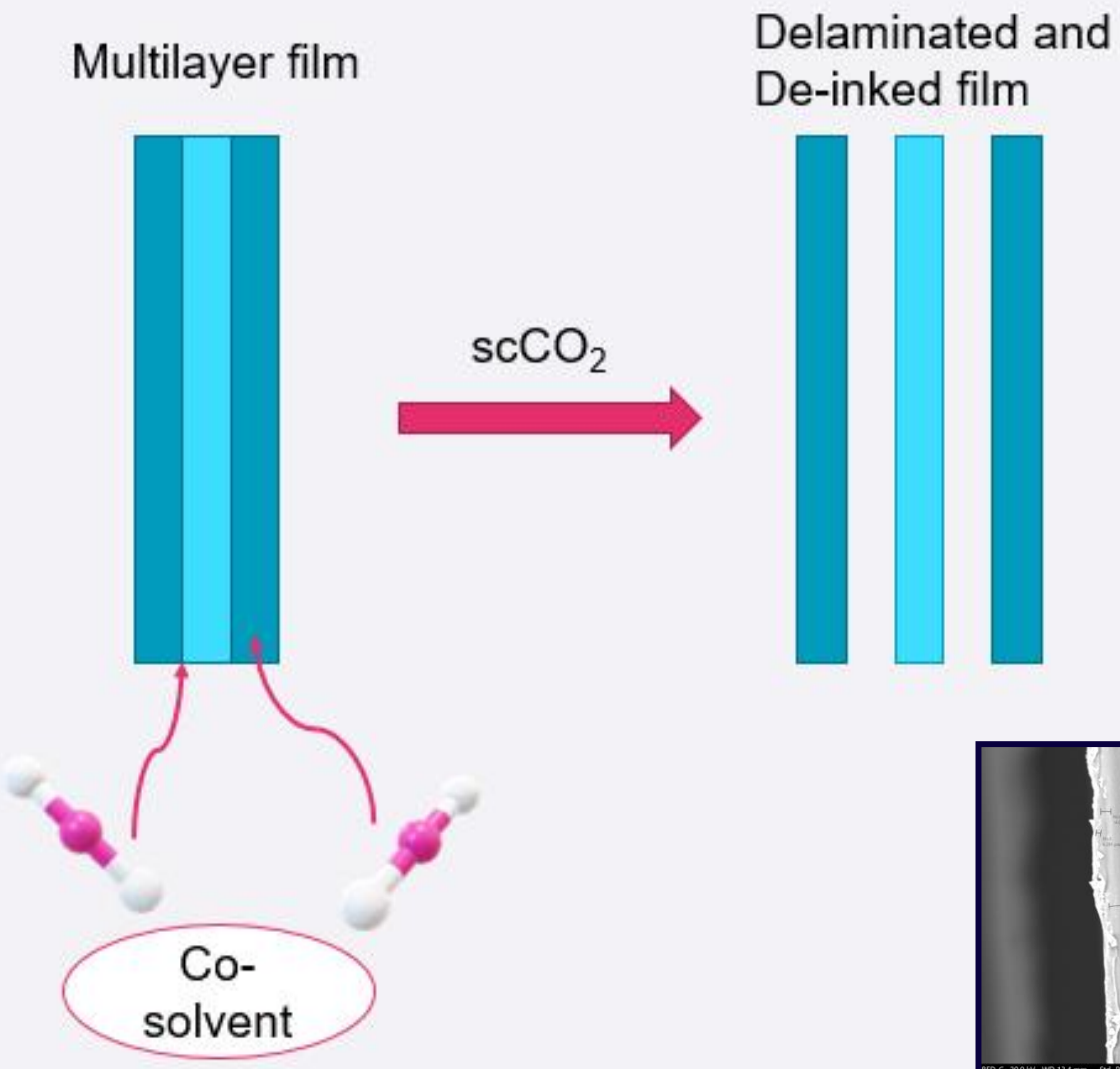
-Based on EFSA "Challenge test" method for food grade recycled polymers.

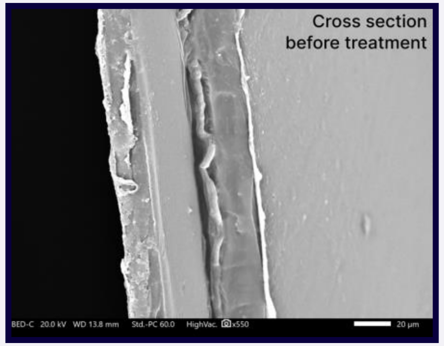
Contaminant	LDPE			PP			HDPE		
	Initial (ppm)	Final (ppm)	% removed	Initial (ppm)	Final (ppm)	% removed	Initial (ppm)	Final (ppm)	% removed
Toluene	**73**	0	**100.00%**	188	0	**100.00%**	42	0	**100.00%**
Chlorobenzene	**201**	0	**100.00%**	507	0	**100.00%**	85	0	**100.00%**
Limonene	**980**	<10	**99.00%**	1549	0	**100.00%**	368	0	**100.00%**
Phenylcyclohexane	**2242**	38	**98.30%**	2366	7	**99.70%**	729	7	**99.10%**
Hexyl Salicylate	**3584**	11	**99.70%**	2725	26	**99.10%**	1046	21	**98.00%**
Benzophenone	**2755**	<10	**99.60%**	2202	3	**99.90%**	800	1	**99.90%**
Isopropyl Myristate	**3926**	9	**99.80%**	2703	27	**99.00%**	1056	17	**98.40%**

Large Scale Challenge Test Analysis



COTOOCLEAN Delamination of multilayer films





COTOOCLEAN De-Inking and Oil removal

De-Inking

BEFORE

Crisp pack, reverse print outer layer

Crisp pack, reverse print mid layer

Surface printed bread bag

AFTER

Oil Removal

BEFORE

Oil saturated film sample, simulation of surface contamination from food.

AFTER

After CO_2 cleaning >99% oil was removed.

What happens to Polyolefins in Recycling

- Polyolefins progressively change colour as it is recycled due to oxidation
- Too high temperatures during decontamination and extrusion can make it worse
- Recycling at high substitution levels can mean higher initial colour and faster change in properties after recycling.
- Running at 100% recycling rate will quickly cause a change in colour and melt index

Number of cycles	Proportion of original material present after a given number of cycles									
	% Recycled rate									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
1	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	90.00%	100.00%
2	1.00%	4.00%	9.00%	16.00%	25.00%	36.00%	49.00%	64.00%	81.00%	100.00%
3	0.10%	0.80%	2.70%	6.40%	12.50%	21.60%	34.30%	51.20%	72.90%	100.00%
4	0.01%	0.16%	0.81%	2.56%	6.25%	12.96%	24.01%	40.96%	65.61%	100.00%
5	0.00%	0.03%	0.24%	1.02%	3.13%	7.78%	16.81%	32.77%	59.05%	100.00%
6	0.00%	0.01%	0.07%	0.41%	1.56%	4.67%	11.76%	26.21%	53.14%	100.00%
7	0.00%	0.00%	0.02%	0.16%	0.78%	2.80%	8.24%	20.97%	47.83%	100.00%
8	0.00%	0.00%	0.01%	0.07%	0.39%	1.68%	5.76%	16.78%	43.05%	100.00%
9	0.00%	0.00%	0.00%	0.03%	0.20%	1.01%	4.04%	13.42%	38.74%	100.00%
10	0.00%	0.00%	0.00%	0.01%	0.10%	0.60%	2.82%	10.74%	34.87%	100.00%

Chemical recycling of Plastics (LDPE, HDPE, PP and PET)

- **Thermal Cracking of plastics (PYROLYSIS) -** decomposes plastics to gas and liquid products that can be filtered and used as part replacement for petroleum oil and re-refined to make new monomers and then polymers.
- **Chemical Recycling - Depolymerisation of Polymers to Monomers** PET & PS) several technologies available but all require a Polymerisation Plant to re-make the polymer.





Decomposition of Plastics to Oils and Naphtha Feedstock – L to R. Plastic Energy, ReNew, Recycling Technologies, Blue Alp, Quantafuel,

How do we accelerate a Circular Economy for Plastics?

1. Infrastructure

- Create greater MRF resources to sort Recyclables and Post-Consumer Household "Waste"

2. Recycled Content in Packaging

- Every product should be designed to be circular
- Recycled plastics should be manufactured locally NOT imported

3. Innovation in the Circular Economy

challenges remain for innovation

- Sorting food grade from non-food grade packaging to implement food-grade recycling technologies
- Recovery of plastics from waste before landfill
- High performance plastics properties in closed loops in existing and new applications

What will help to Make a Difference

- A shared vision in Chemical-Waste-Recycling Industry Associations and buy-in by Brands and Convertors
- Big recycling operations for high quality plastics in every major population centre
- Research that focuses on greater efficiency and participation in the circular economy
- Large Petro-chemical operations that scale up "Chemical Recycling" for difficult-to-recycle plastics.
- Bans on oxo-degradable plastics that distract or damage circularity
- Government taxes on packaging without recycled content to stimulate the timelines

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HERBOLD
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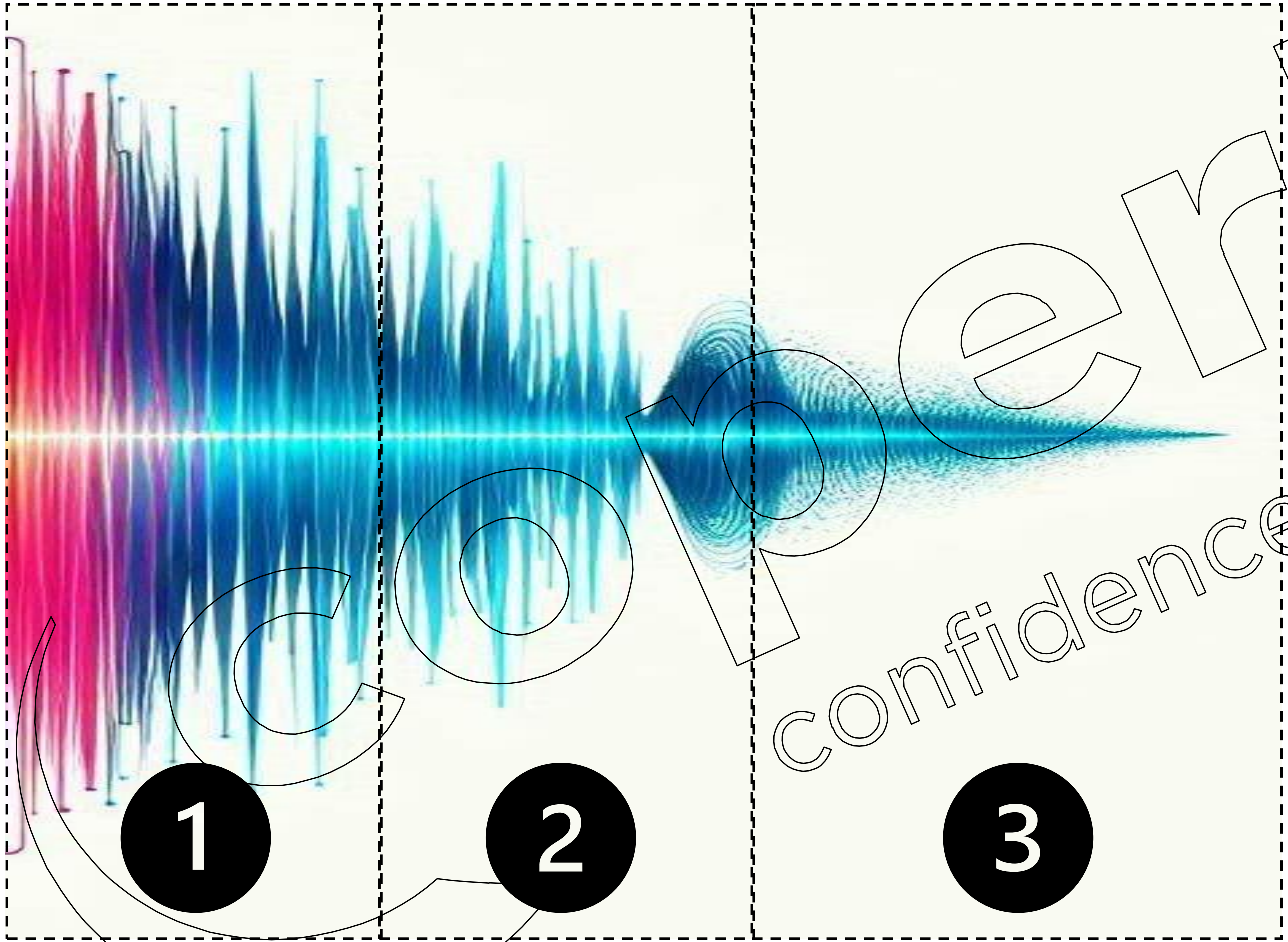
Herbold Washing Technologies Solutions for Efficient Recycling:
Herbold Wash lines and Developments in Water Treatment Technology

Achim Ebel
VP of Sales I Herbold Meckesheim

Kürşat Başdemir
General Manager I Ekosistem Ltd.

Visualization of cleaning in plastics recycling

Main process steps of purification



1 – Transform waste into sorted plastics

Dry treatment using mechanical cleaning and automatic sorting

2 – Transform plastic into purified polymers

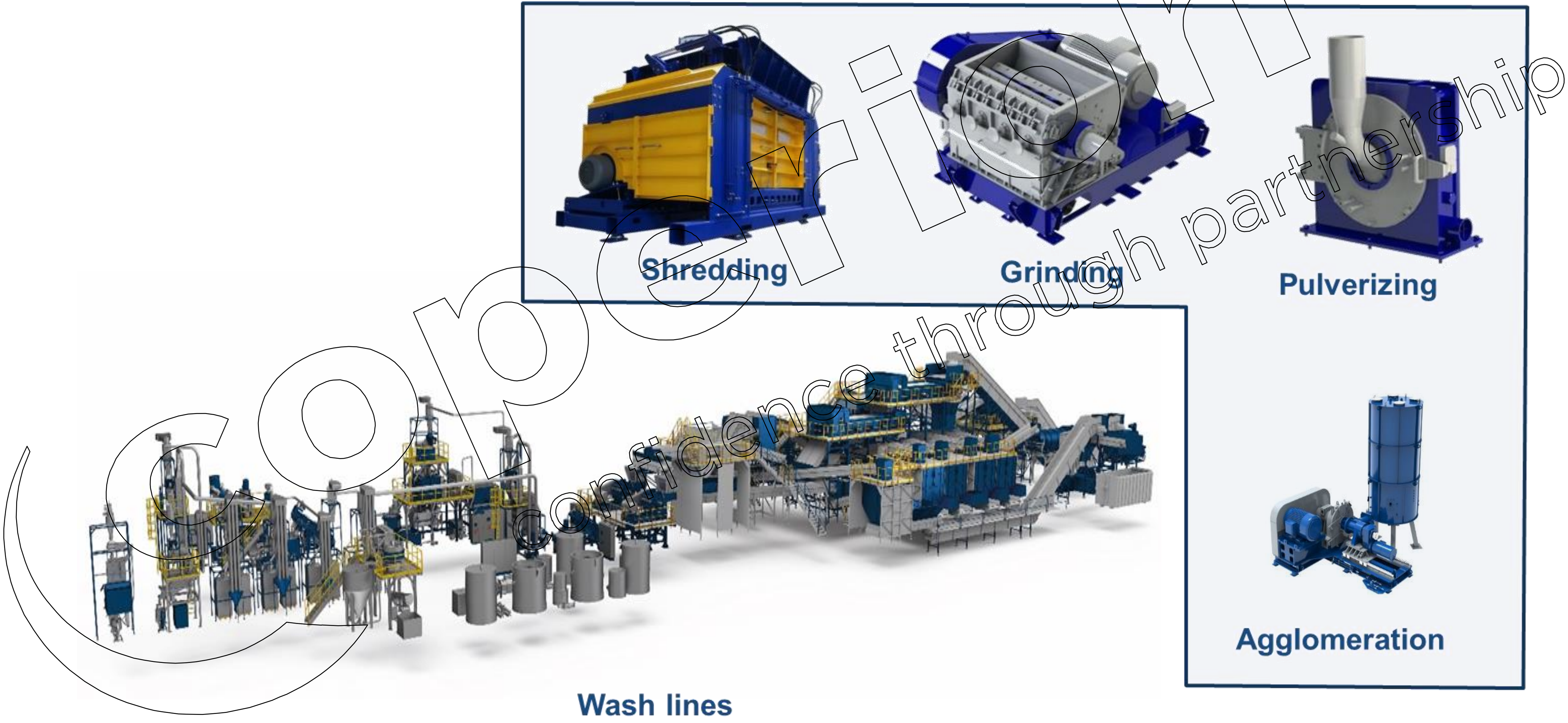
Surface cleaning, density separation, drying and flake sorting

3 – Purify the polymers to super clean and reset the performance

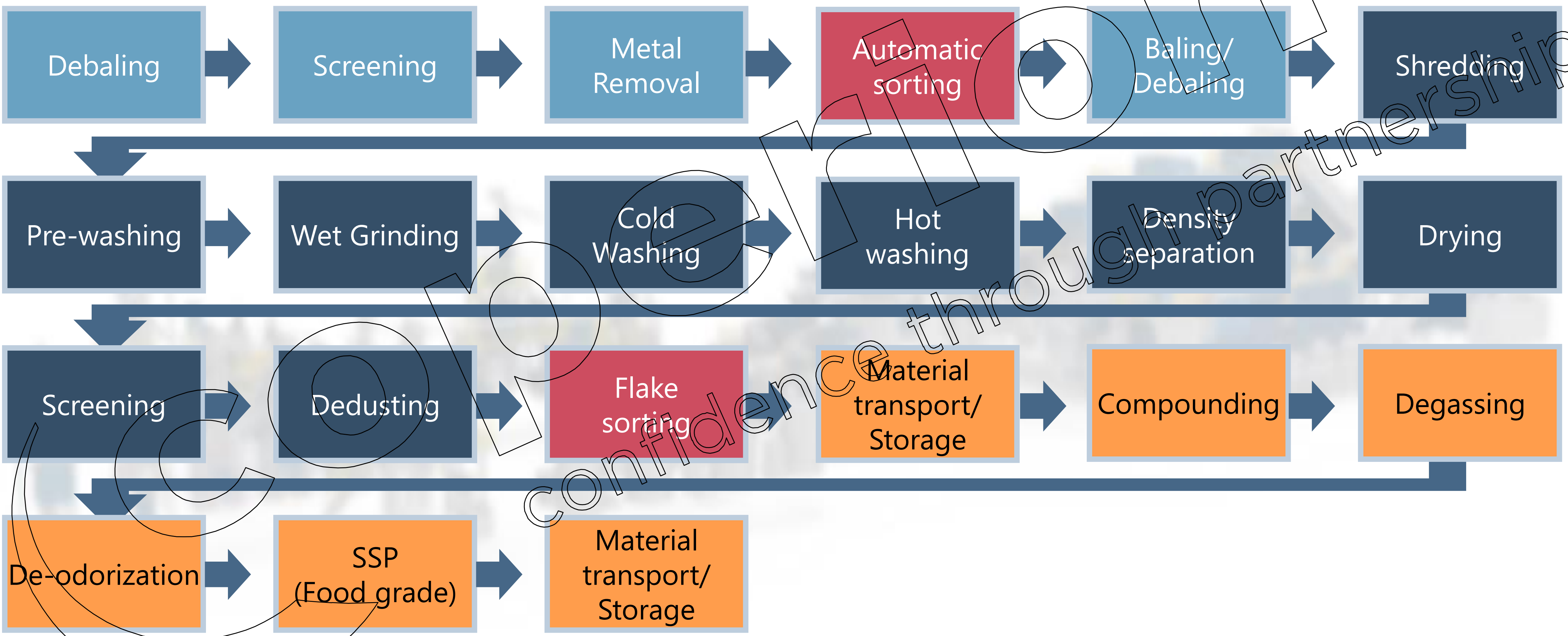
Called compounding and comes later

Product range – Categories

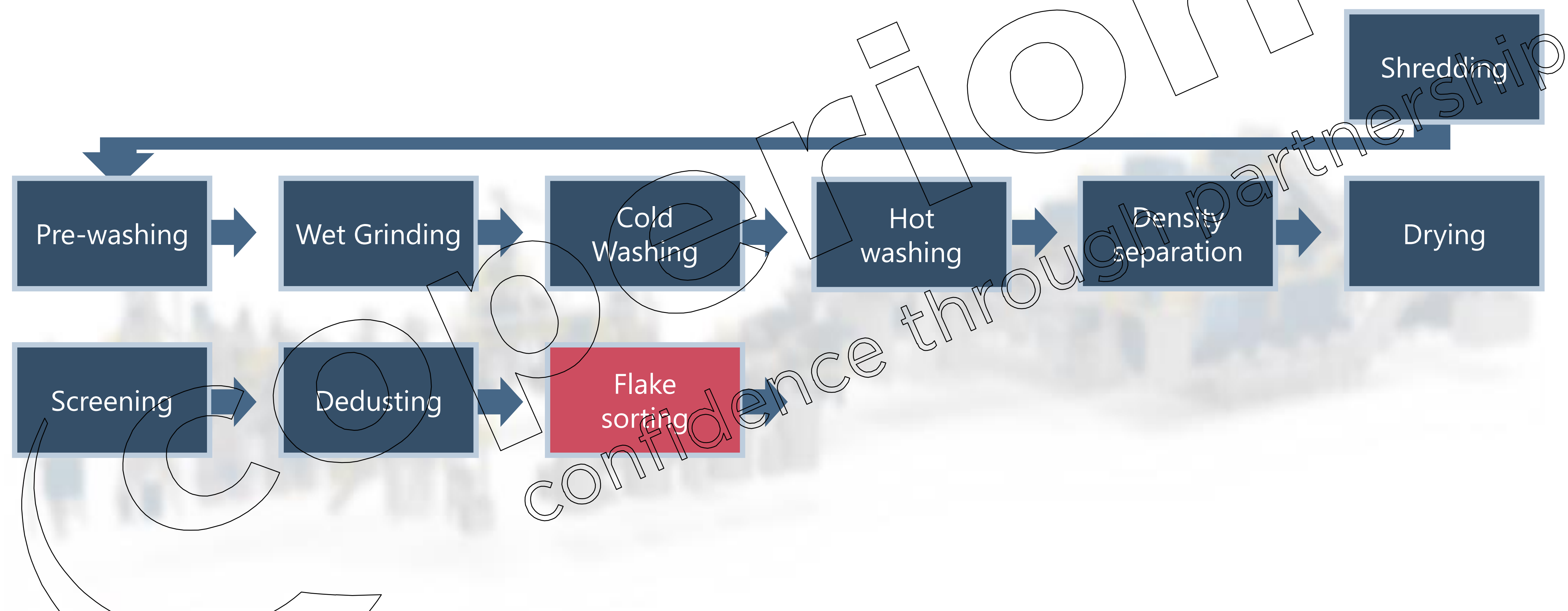
79% of our business are wash lines



The complete chain as process step

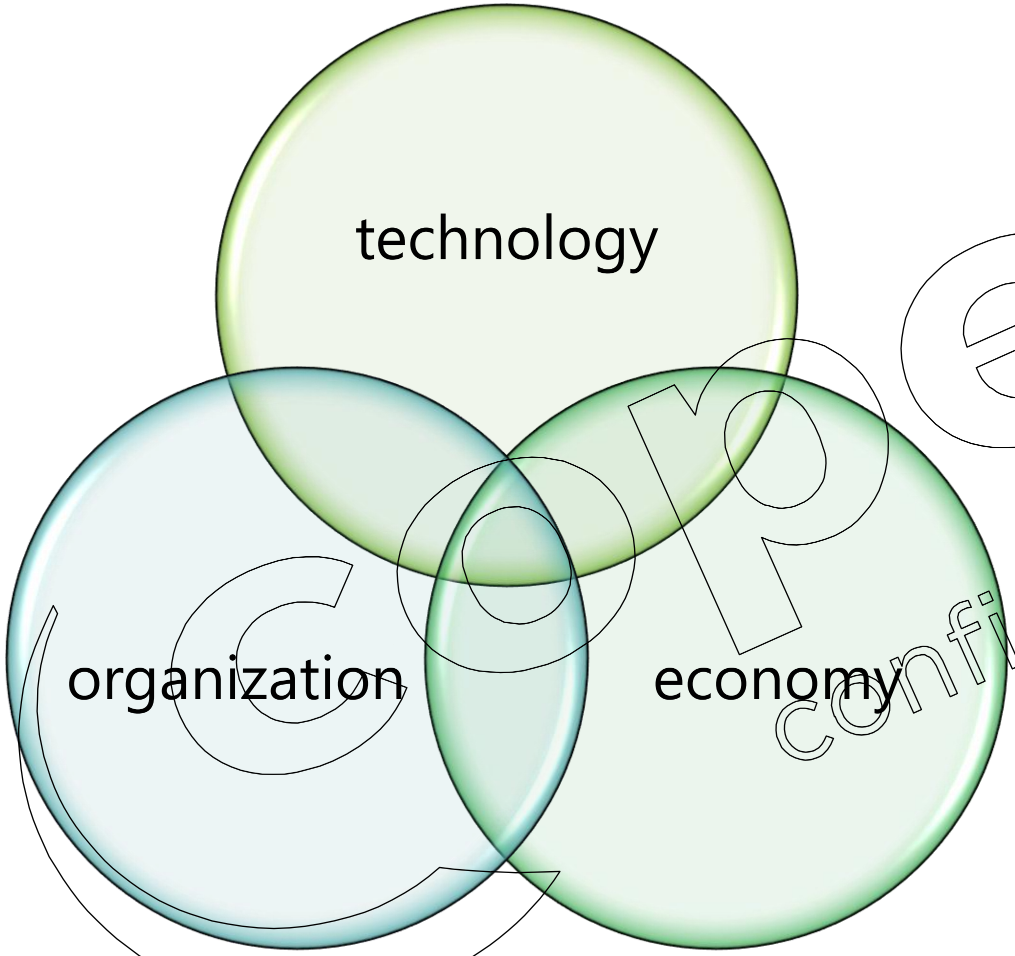


Herbold's contribution to the reuse of plastics



What makes the successful difference

Efficiency = Best result with lowest effort

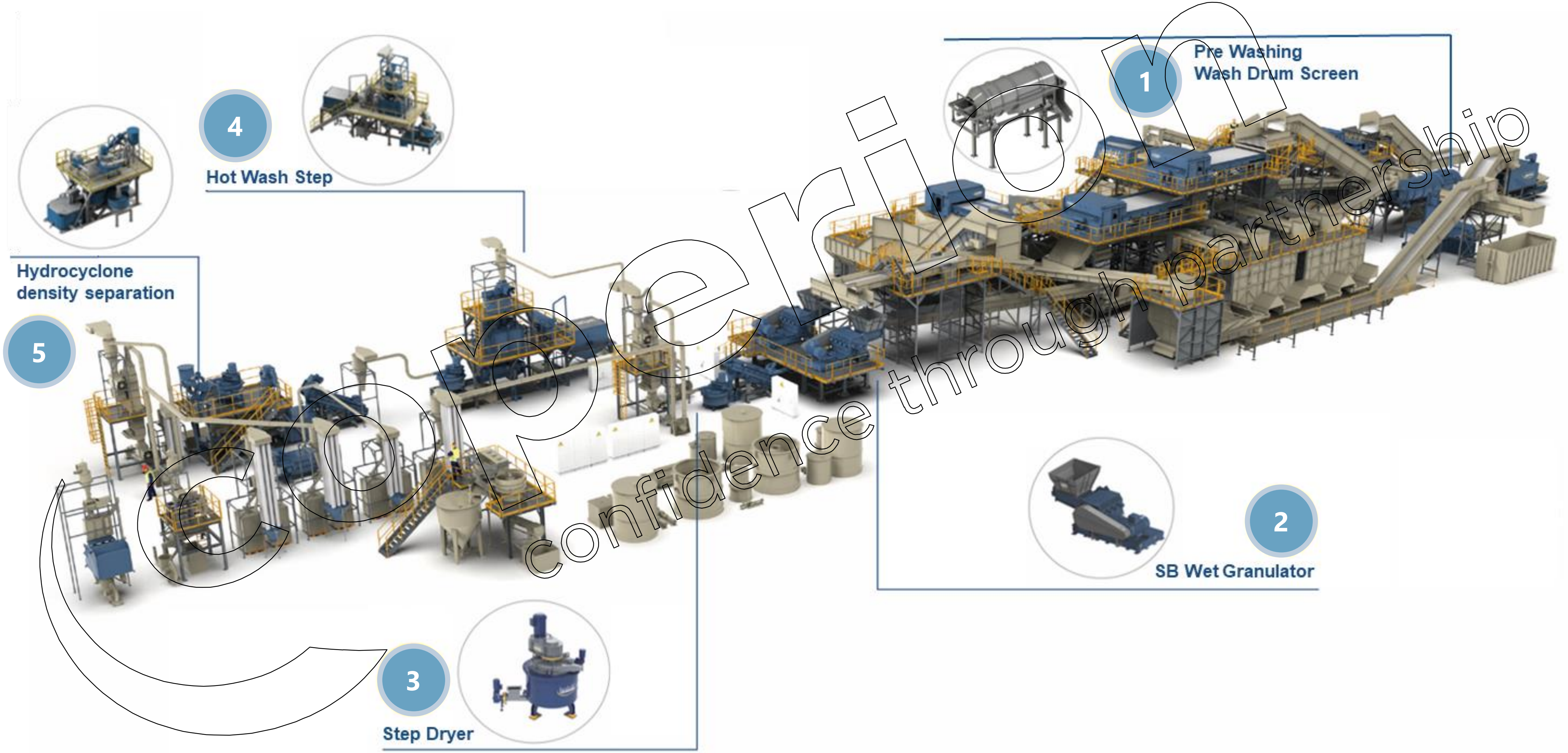


We provide costumer support in organizational processes like:

- Input specification
- Output specification
- Quality assurance
- Preventive maintenance
- Education
- …

Our main impact is best technology at lowest operational cost at highest quality

What makes the successful difference



Efficiency effect of Herbold core technologies

1

PRE-WASH

Operation with cold water
→ lower cost for removing sand and soil

Better sorting result due to cleaner objects to detect

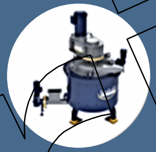
2

WET GRANULATOR

Designed for high wear applications and easy to maintain

Due to screw feeding into the cutting chamber always optimal cutting at lower energy

3



STEP DRYER

1/3 less fines
→ better yield of prime product

Smaller motor
→ less energy

4

HOT WASH

Best tool to remove glue and odors

Optimized water management for high cleaning at low water / chemical consumption

5

HYDROCYCLONE

Better separation
→ Higher yield

Minimal influence of false reject due to turbulent conditions

Efficiency effect of Herbold core technologies

Sustainability 100 KW less
= ~ -100.000 €/a less cost

Prime Grade – Off Grade ratio 2 % more prime grade
= 285.000 €/a more revenue

Yield prime grade: 2 % more fines
= 700 to yield loss

0,5 l/kg water consumption instead of 1 – 4 l/kg that's now the time to hand over

HERBOLD MECKESHEIM

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EKOSISTEM & HERBOLD

CIRCLE OF LIFE STARTS WITH WATER

PRESENTATION

INTRODUCTION

Washing involves removing impurities from a product to ensure cleanliness. Water acts as the medium that carries away these impurities after they have been removed mechanically, physically, or chemically. The more efficient the transportation of impurities, the more effective the cleaning process.

Eko-Save Wastewater Recycling Systems in a plastic recycling wash plant offer several significant environmental and economic benefits. Here’s a breakdown of the key advantages:

COMPARISON

OLD SYSTEM

OLD SYSTEM

1

1.High Water Consumption

- Water consumption per kilogram of product is significantly higher.
- Basic chemical treatment of wastewater leads to an accumulation of organic pollutants (COD), requiring frequent water renewal. The frequency of renewal increases based on the contamination level of the raw material.

2.Increased Chemical Usage

- As wastewater pollution rises, the demand for chemicals also increases, resulting in higher operating costs and environmental impact.

OLD SYSTEM

2

OLD SYSTEM

3

3. Impact on Product Quality

- Fluctuations in the quality of recirculated water directly affect the quality of the final product.

OLD SYSTEM

4

4. Small, Inefficient Water Circuits

- Numerous small circuits with minimal water exchange reduce efficiency and increase operational complexity.

COMPARISON

NEW SYSTEM

NEW SYSTEM

1

1. Water Efficiency at Its Best

- Water consumption is reduced to less than 500 ml per kilogram of product.
- With the majority of fresh water being recovered from treated wastewater, the overall consumption is only one-eighth to one-tenth of that in older systems.

2.Lower Chemical Demand

- Systems supported by biological treatment processes require fewer chemicals for wastewater purification, leading to cost savings and a smaller environmental footprint.

NEW SYSTEM

2

NEW SYSTEM

3

3. Consistent Water Quality, Optimal Cleaning

- The system continuously supplies high-quality water, ensuring optimal cleaning performance and process consistency.
- Water is tailored to meet the specific requirements of each wash stage, with purification extending beyond the DAF unit to achieve RO-quality water.

NEW SYSTEM

4

4. Larger Circuits, Higher Efficiency

- Larger water circuits with significantly higher exchange rates improve operational efficiency by enhancing water flow and quality.

NEW SYSTEM

5

5. High Automation, Low Operator Costs

- Automated systems reduce manual intervention, lowering operational costs and increasing efficiency.

Let's Take a Look at the Advantages of the New System…

EVERY DROP MATTERS FOR THE FUTURE

COST SAVINGS

1

Reduced Water Expenses

The system significantly cuts costs by drastically lowering the need for fresh water from external sources. Treating and recycling water internally proves far more cost-effective in the long term than external treatment or discharge fees, even in regions with less stringent regulations.

Environmental Responsibility

The new system not only reduces operational costs but also minimizes environmental pollution. By treating wastewater on-site, the facility reduces the release of harmful pollutants into the environment. This is especially important when considering the irony of recycling rigid materials while polluting water resources—this approach solves both challenges.

Higher Automation

Eko-Save Waste Water Reuse Plants are entirely controlled by an automation system. The system includes measurement instruments for pressure, conductivity, temperature, flow meter, and oxygen concentration, allowing all data to be monitored in real time via SCADA. The remote access module also lets you view the facility's performance even when off-site. Thanks to the automation systems, operator costs are minimized to the lowest possible levels.

Water Conservation

The reduced reliance on freshwater promotes a more sustainable approach to resource management. This system supports global efforts to conserve water, aligning with sustainability goals and contributing to a circular economy in plastic recycling.

IMPROVED PROCESS EFFICIENCY

2

Enhanced Product Quality

- Consistent use of treated and controlled water can improve the cleanliness of recycled material, leading to higher-quality outputs.

Proven Technology

The First Eko-Save Plant has been operating successfully for the past 4 years, making it a well-established and reliable solution.

Closed Loop System

Eko-Save is especially Customized for Herbold washing lines. A well-designed wastewater recycling system creates a more efficient closed-loop process, minimizing the need for clean water. As a backup water source, wastewater from nearby treatment facilities can be utilized. This approach virtually eliminates the need for fresh water consumption.

WATER CONSERVATION

3

Reduction in Water Usage

Recycling wastewater reduces the need for freshwater, which is often required in large quantities for washing and processing recycled plastic. This conservation is crucial in areas where water is scarce. The water requirement will be eight times less compared to systems without Eko-Save.

Sustainability

Plastic Recycling Factories can significantly reduce their environmental footprint by reusing water, contributing to more sustainable industrial practices. This significantly enhances the reputation of plastic recycling, showcasing it as a more sustainable and responsible industry.

ENVIRONMENTAL IMPACT

4

- **Reduced Effluent Discharge:**

  By recycling wastewater, the volume of effluent (wastewater discharged into the environment) is reduced. This decreases the risk of polluting local water sources with chemicals or microplastics, ensuring the factory adheres to environmental regulations.

- **Drastic Micro Plastic Reduction**

  The regulation regarding removing microplastics in wastewater within the European Union is part of a broader initiative to reduce microplastic pollution. Currently, the EU has adopted several measures to address microplastics, with some specific regulations already in place. Thanks to MBR filtration, wastewater passes through a 0.04-micron filter before discharge, ensuring no microplastics are present.

- **Better Compliance with Environmental Regulations**

  Many countries have strict wastewater disposal laws. Recycling wastewater helps factories stay compliant, reducing the likelihood of fines or penalties.

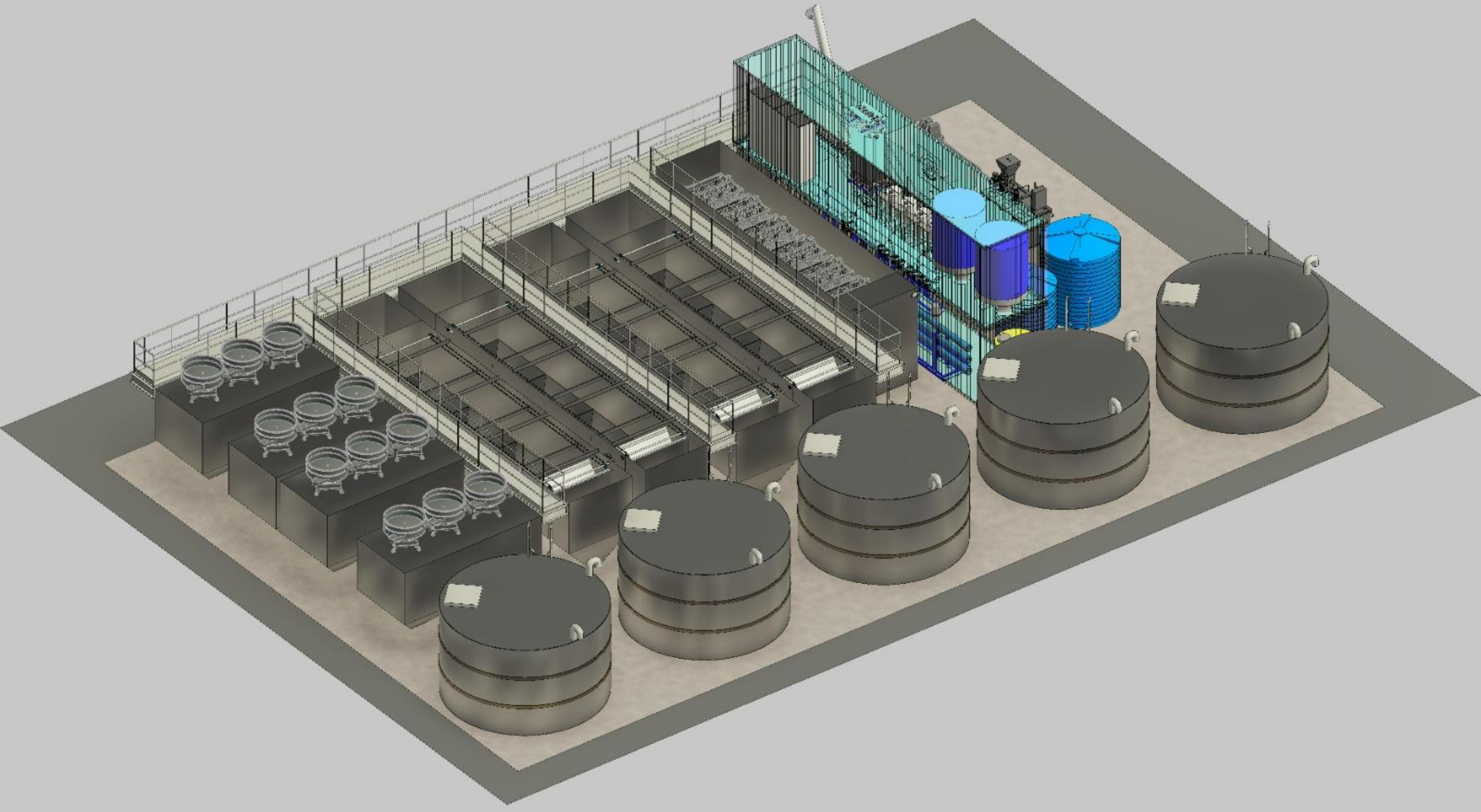
Our Common Ground

WIN-WIN FOR BOTH THE BOTTOM LINE AND THE PLANET

WE SERVE A FINANCIAL EFFICIENCY WHILE PROMOTING ENVIRONMENTAL RESPONSIBILITY. IT’S A WIN-WIN FOR BOTH THE BOTTOM LINE AND THE PLANET, WHICH ALIGNS WITH LONG-TERM BUSINESS SUSTAINABILITY GOALS.

Let’s take a closer look at the system that delivers these benefits…

In a modern plastic recycling facility, the efficiency and sustainability of operations heavily depend on an effective wastewater treatment system. Transforming wastewater into high-quality freshwater begins with a series of carefully designed processes that ensure optimal filtration, reduced maintenance, and the protection of sensitive equipment.



CREATING AN ECO-FRIENDLY DESTINATION

MECHANICAL TREATMENT

The first step in this journey is mechanical treatment, which uses a vibrating screen to filter out large particles. Unlike conventional methods, this vibrating screen provides superior filtration without the risk of clogging. This ensures smooth operation and continuous water flow, essential for the following stages.

EQUALIZATION TANK

Next, the equalization tank steps in, acting as a reservoir that collects and homogenizes all types of waste water. By blending the wastewater, the tank creates a consistent pH level, which means that less acid is needed for pH adjustment. This not only reduces chemical costs but also helps create a more stable and predictable treatment process.

DISSOLVED AIR FLOTATION

The process then moves to chemical treatment, combined with a Dissolved Air Flotation (DAF) unit, the Eko-DAF unit plays a crucial role in removing sand particles and suspended solids by using Nano bubbles from the water. This is particularly important because, without the DAF unit, tiny abrasive particles like sand could enter the granulator, causing unnecessary wear and tear on the blades. If not removed, these particles would gradually erode the blades, leading to frequent maintenance and reduced operational efficiency. The DAF unit, therefore, serves as a protective barrier, ensuring that the water entering the granulator is free from potentially damaging contaminants.

CREATING AN ECO-FRIENDLY DESTINATION

BIOLOGICAL TREATMENT

Following the chemical treatment, the system moves into biological treatment, which is essential for removing organic impurities from the water. This stage relies on activated sludge, a biological agent that naturally breaks down organic matter, transforming the wastewater into a purer form. The biological treatment acts as the heart of the system, restoring the water to near-freshwater quality.

MEMBRANE BIO REACTOR

After the biological stage, the water is passed through Membrane Bioreactor (MBR) units, which provide an advanced level of filtration. These units are highly effective in capturing any remaining particles, ensuring the water is suitable to be fed into the next crucial stage:

REVERSE OSMOSIS SYSTEM

In the RO system, the water undergoes its final purification, emerging as high-quality fresh water that can be reused in hot wash and further systems. RO permeate water is precious in critical operations like the hot wash and other purification steps that require exceptionally clean water. Thanks to the effectiveness of the RO system, key impurities such as hardness, color, odor, and chemical oxygen demand (COD) are reduced to trace amounts, ensuring that the RO product water meets the stringent standards required for these sensitive stages of production.

CREATING AN ECO-FRIENDLY DESTINATION

DECANTER FOR SLUDGE DEWATERING

The decanter is a centrifugal machine used for dewatering sludge, the Output of the DAF Unit and Biological Treatment. In sludge treatment, decanters play a crucial role by reducing the water content of the sludge, making it easier and more cost-effective to handle and dispose of.

THIS SYSTEM REFLECTS THE COMMITMENT TO INNOVATION, EFFICIENCY, AND ENVIRONMENTAL RESPONSIBILITY

THROUGH THESE STEPS—EACH INTRICATELY CONNECTED—THE WASTEWATER RECYCLING PROCESS NOT ONLY PROTECTS THE FACILITY'S EQUIPMENT AND REDUCES MAINTENANCE COSTS BUT ALSO CONTRIBUTES TO A MORE SUSTAINABLE AND COST-EFFECTIVE OPERATION. THIS SYSTEM REFLECTS THE COMMITMENT TO INNOVATION, EFFICIENCY, AND ENVIRONMENTAL RESPONSIBILITY, HALLMARKS OF A MODERN PLASTIC RECYCLING FACILITY.

Thank you!

Achim Ebel
VP of Sales I Herbold Meckesheim

Kürşat Başdemir
General Manager I Ekosistem Ltd.

HERBOLD
MECKESHEIM

coperion

Coperion Extrusion Technology

Innovation for the Recycling Industry

Jochen Schofer
Head of Sales Recycling

Frank Mack
Head of Process Technology Engineering Plastics

1

Introduction.

2

Comparison ZSK and single screw extruder.

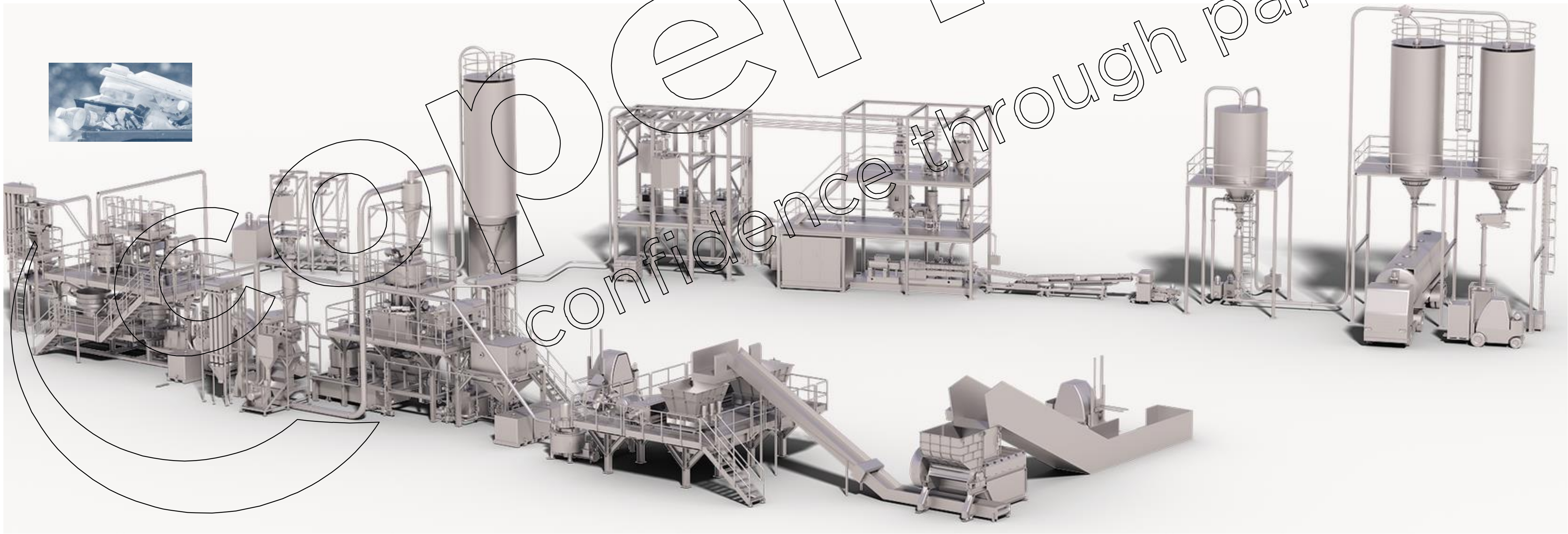
3

Summary and conclusion.

Coperion Material Handling & Processing Plants

Field of Activities for Recycling

Bundled PET bottles all colors and dirt → Sorting → Shredding → Washing & drying → Raw material: Conveying, Storing, Feeding → Com-pounding / Extrusion / Degassing → Filtration and Pelletizing → Degassing / De-odorization → Finished product: Conveying Storing, & Packing



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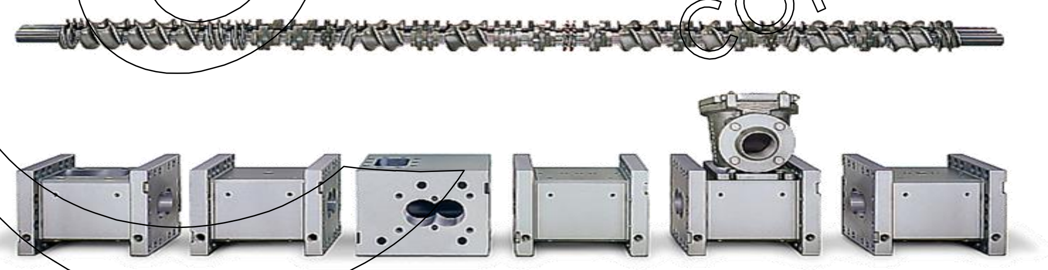
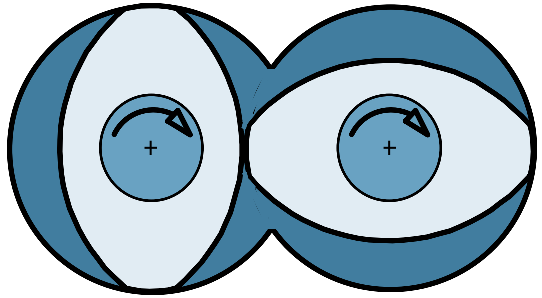
Let's have a closer look!

The ZSK Mc18 twin screw extruder

Modular design and => perfect fit to any process task

Main drive | Coupling gearbox | Process section | Die head



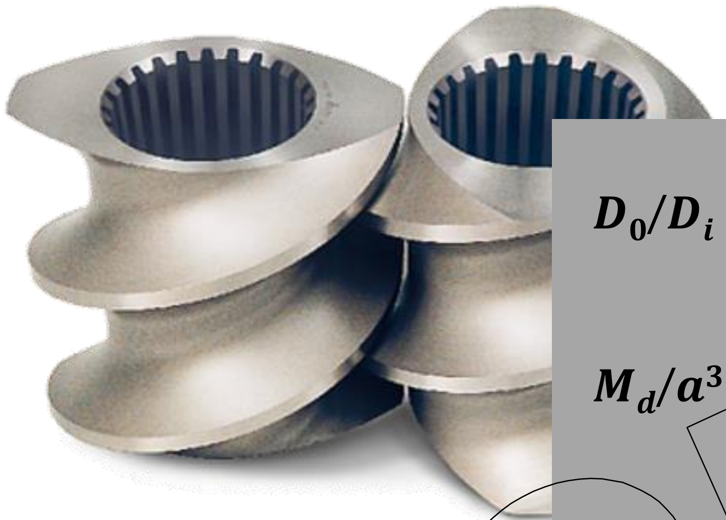


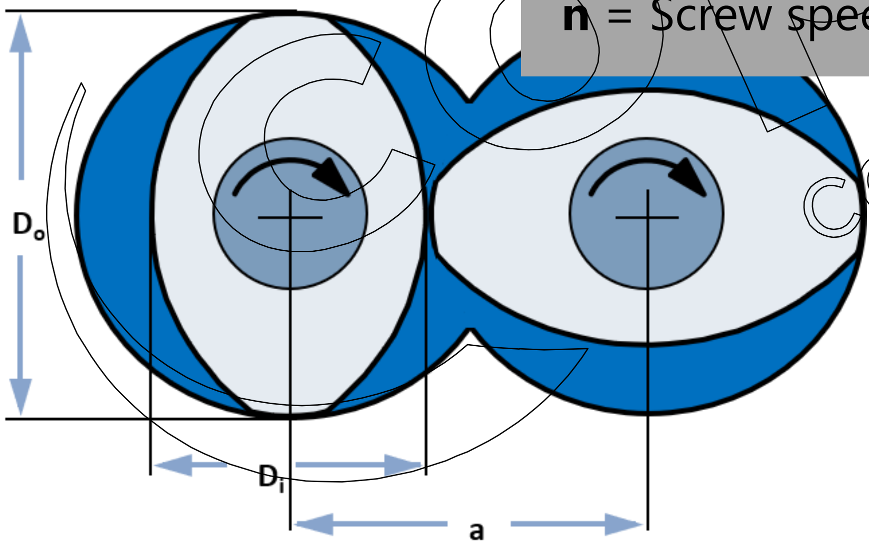
Benefits

- Modular design of barrels and screws
- Intermeshing and self-cleaning

The ZSK Mc18 twin screw extruder

Characteristic dimensions





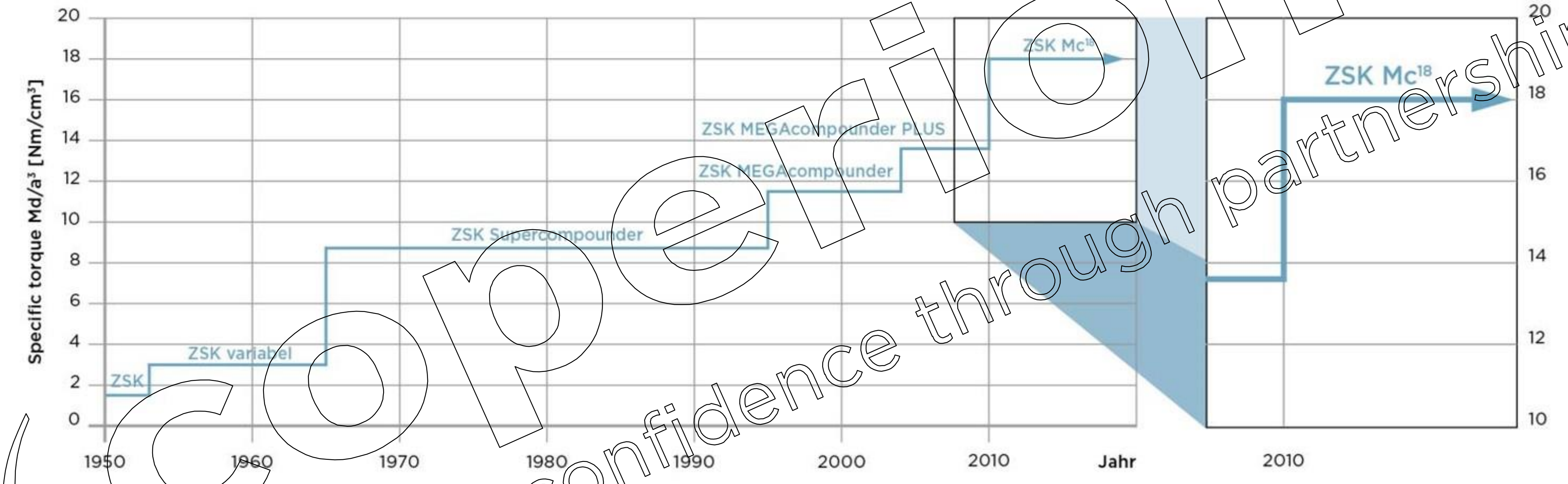
D_0/D_i = Diameter ratio	→ determines free volume
M_d/a^3 = Specific torque	→ determines power density
n = Screw speed	→ determines shear and mixing

Conclusion

Several parameters define a co-rotating twin screw extruder ZSK

The ZSK Mc^{18} twin screw extruder

History and development

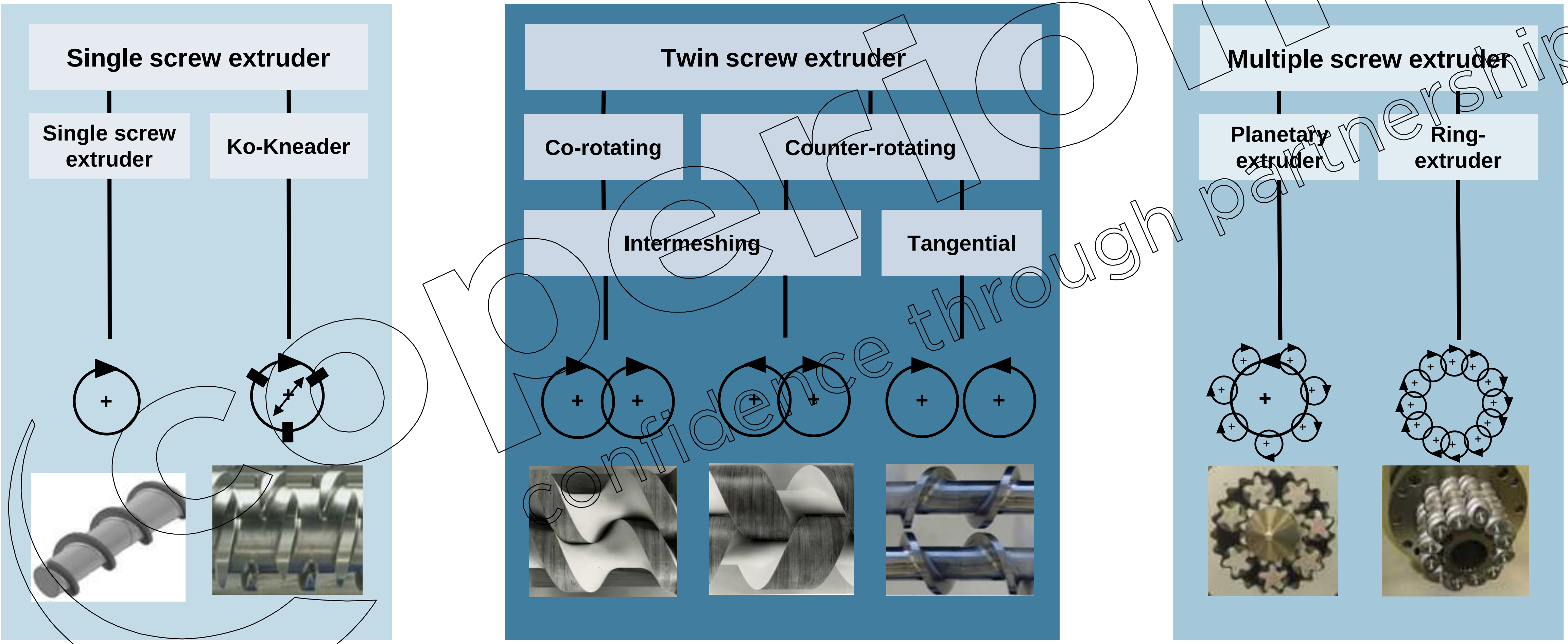


Conclusion

Since the 1950 permanent increase in free volume, specific torque and screw speed

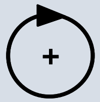
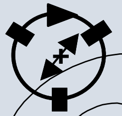
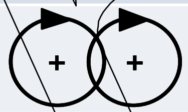
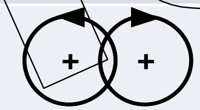
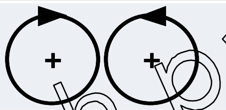
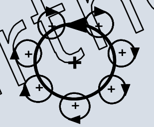
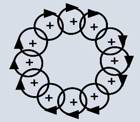
Overview of extruder systems

System comparison



Overview of extruder systems

System comparison

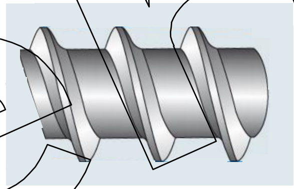
Characteristics		Extruder systems						
		Single screw extruder		Twin screw extruder			Multiple screw extruder	
		Single screw	Ko-Kneader	Co rotating	Counter rotating		Planetary	Ring-extr.
				Intermeshing		Tangential		
								
Feed intake of bulk materials		+	++	+++	+++	++	++	+++
Downstream adding of bulk materials		+	+++	+++	+	-	-	+++
Downstream adding of liquids		+	+++	++	+	+	+	++
Melting capability	Powder	+	++	+++	++	+++	++	+++
	Pellets	++	+++	+++	++	+	++	+++
Distributive mixing	Axial	++	+++	+++	+	+++	++	+++
	Crosswise	++	+++	+++	+	+++	++	++
Dispersive mixing		++	++	+++	++	++	+++	+++
Degassing capability		++	+	+++	+	-	++	+++
Pressure built-up capability		++	+	+	+++	-	+	+
Self cleaning		No	Yes	Yes	Yes	No	In planetary	Yes
Residence time distribution		wide	Narrow	Narrow	Very narrow	Wide	Narrow	Narrow
Modular design	Screws	No	Yes	Yes	No	No	Yes	Yes
	Barrels	No	Yes	Yes	Yes	No	Yes	Yes
Possibility of heating and /or cooling	Screws	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Barrels	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[Quelle: Der Doppelschneckenextruder, VDI-K]

Comparison ZSK and single screw extruder

Feed intake overview

Feed intake



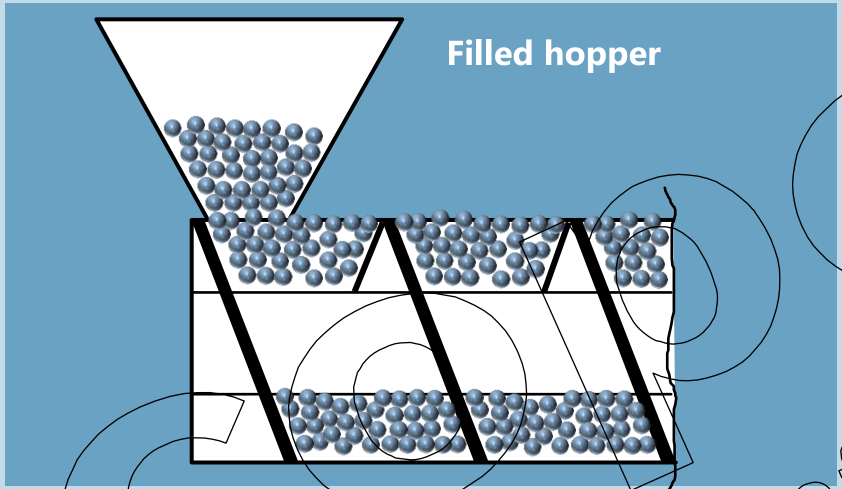
	Single screw	Twin screw
Feed intake of bulk materials	+	++
Downstream adding of bulk materials	+	+++
Downstream adding of liquids	+	+++

Comparison ZSK and single screw extruder

Feed intake overview

Single screw extruder

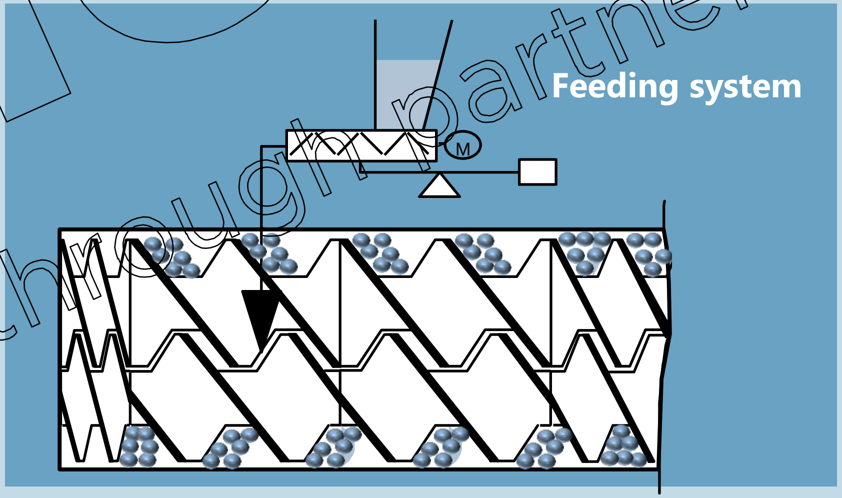
Volumetric



- Product feed from full hopper
- No additional feeder required
- Screw channels are filled
- Output rate = f(screw speed)

Twin screw extruder

Gravimetric dosing systems



- Product feed is controlled by a gravimetric feeding system
- Screw channels are partially filled
- Output rate is independent of the screw speed
- Accurate feeding of additives -> recipe consistency

Comparison ZSK and single screw extruder

Feed intake for challenging recycling materials

Easy Shapes

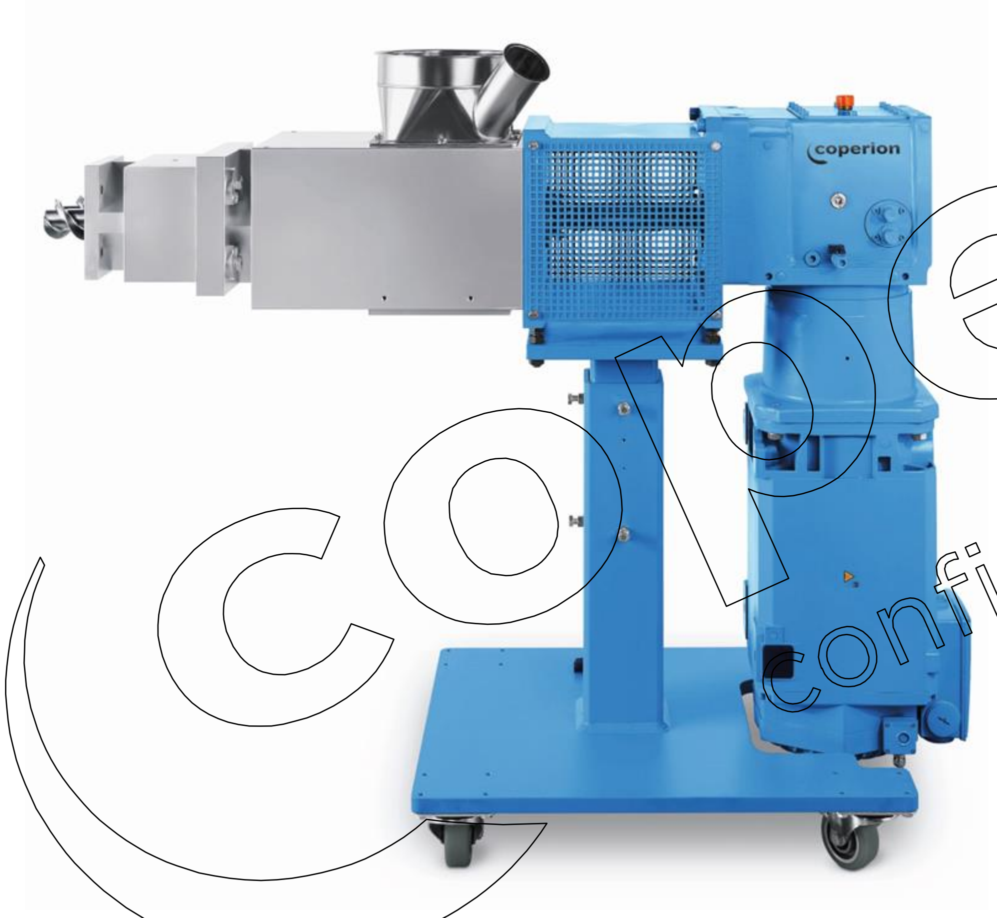
Single Screw
- Pellets
- Homogenous grinded and sorted materials like PET flakes

Shapes with challenges

Twin screw extruder ZSK (ZS-B, ZS-B, FET, ZS-B MEGAfeed)
- Pellets
- Homogenous grinded and sorted materials like PET flakes
- Powder (direct feed as well as indirect feed with ZS-B and ZS-B equipped with FET)
- Film flakes and many kind of fibers (direct feed as well as indirect feet with ZS-B and ZS-B MEGAfeed)

Comparison ZSK and single screw extruder

Feed intake for challenging materials I New side feeder MEGAfeed



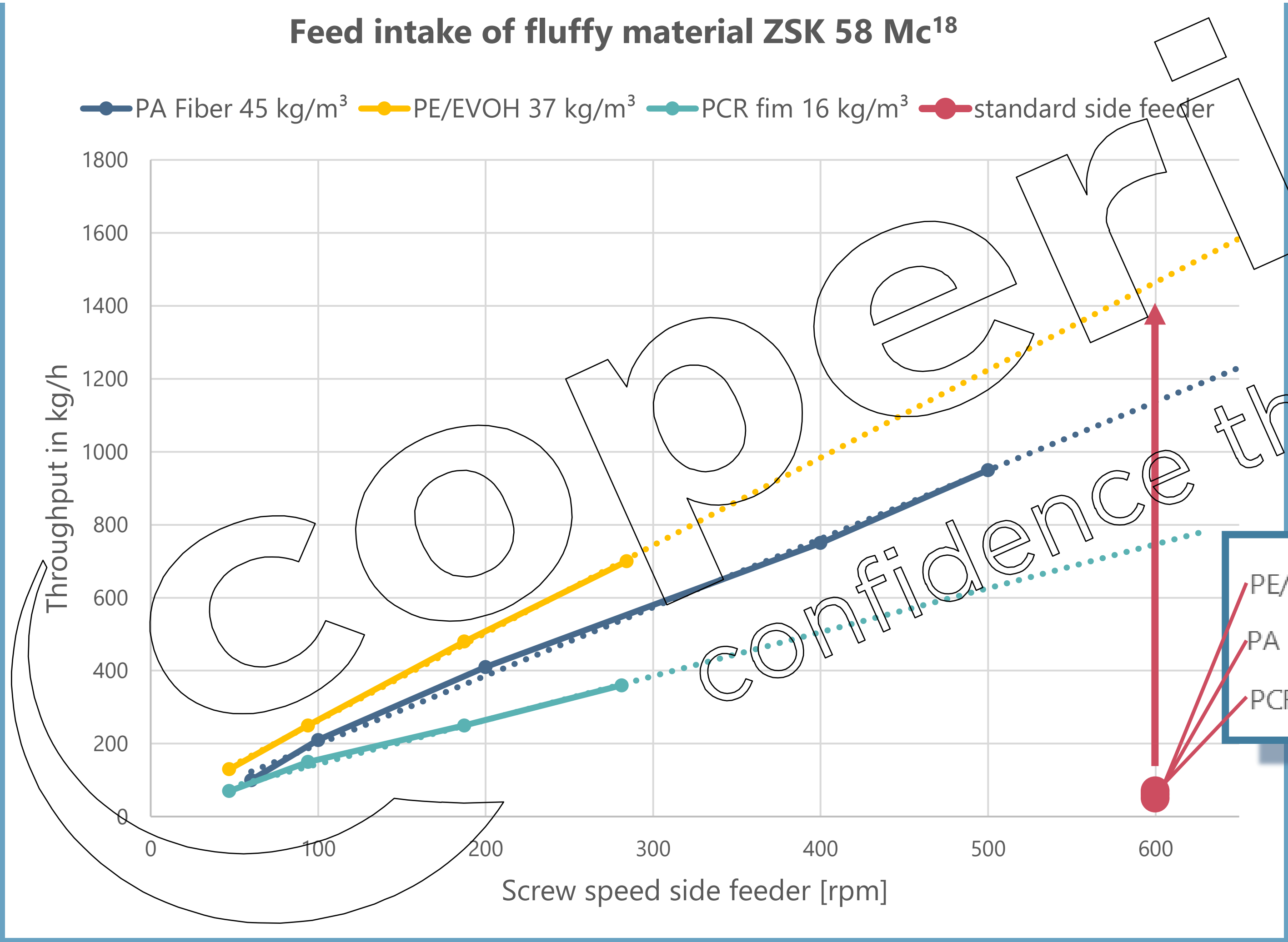
New side feeder **ZS-B MEGAfeed**

- Constant feeding of high volume / low bulk density products as film flakes, fibers, …
- No energy-intensive pre-compacting necessary
- Recycling and compounding in one process step

→ Insights: Presentation of Marina!

Comparison ZSK and single screw extruder

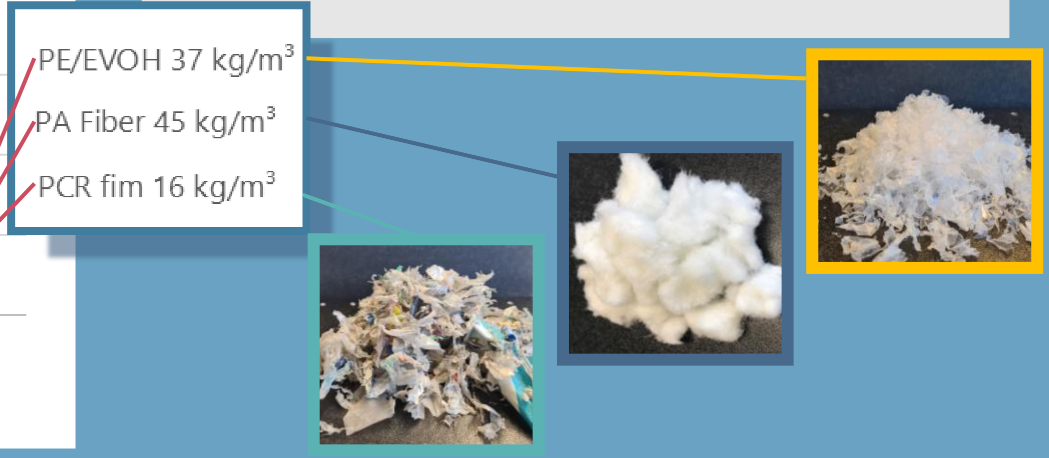
Feed intake for challenging materials I New side feeder MEGAfeed



New innovative feeding device

Even with very low screw speeds at the **NEW side feeder**, higher throughputs can be achieved with very fluffy materials

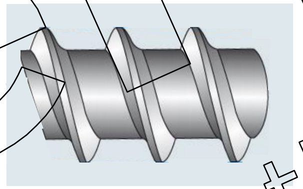
By fully utilizing the screw speed of the side feeder the throughput for very fluffy materials can be increase by **Factor 10-15**!



Comparison ZSK and single screw extruder

Melting capability overview

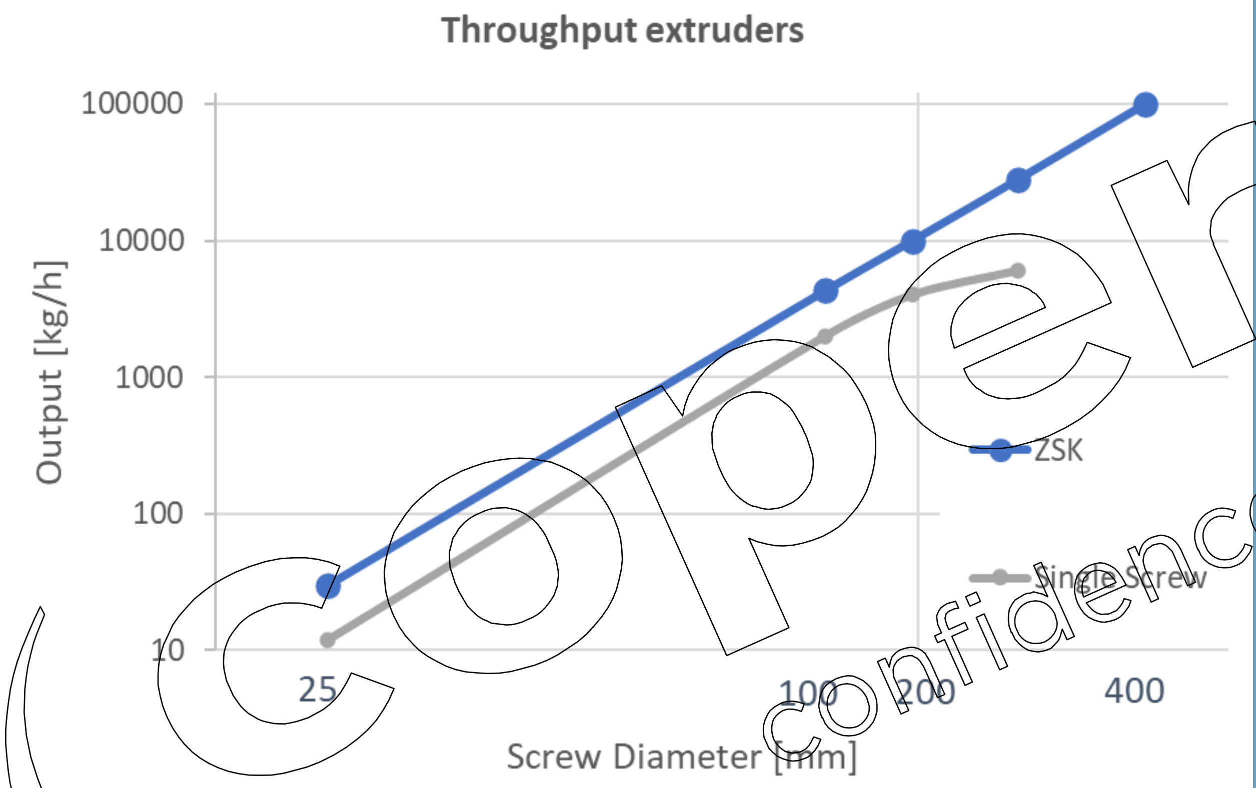
Melting capability



	Single screw	Twin screw
Powder	+	++
Pellets	++	+++

Comparison ZSK and single screw extruder

Melting capability



Max. throughput for recycling applications

	Single Screw	Twin-Screw
Mechanical Recycling of PO	4.000 kg/h	10.000 kg/h
PET Recycling	6.000 kg/h	10.000 kg/h
Chemical Recycling	4.500 kg/h	25.000 kg/h

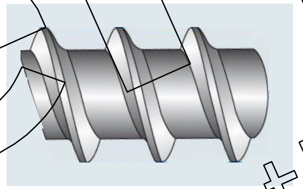
Conclusion

The Twin Screw has a linear correlation between melting capability and throughput due to its highly efficient melting principle by friction
→ no limitations!

Comparison ZSK and single screw extruder

Mixing and homogenization overview

Mixing

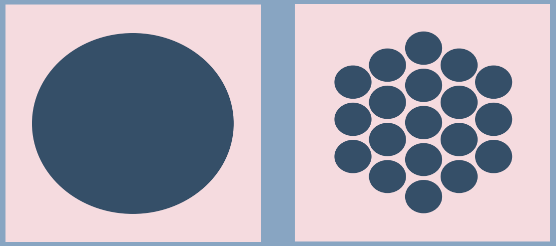


		Single screw	Twin screw
Distributive Mixing	Axial	++	+++
	Crosswise	++	+++
Dispersive Mixing		++	+++

Comparison ZSK and single screw extruder

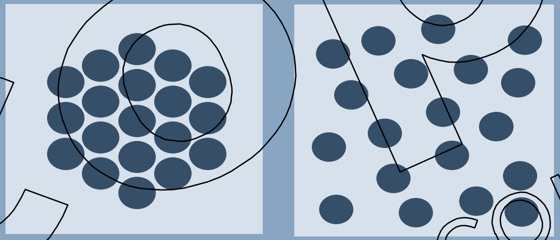
Mixing and homogenization overview

Dispersive mixing = Deagglomeration

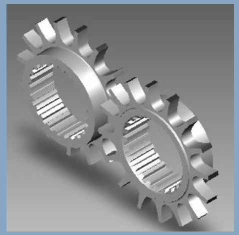


Example: Dispersive Mixing element

Distributive Mixing = Equal concentration



Example: Distributive Mixing element

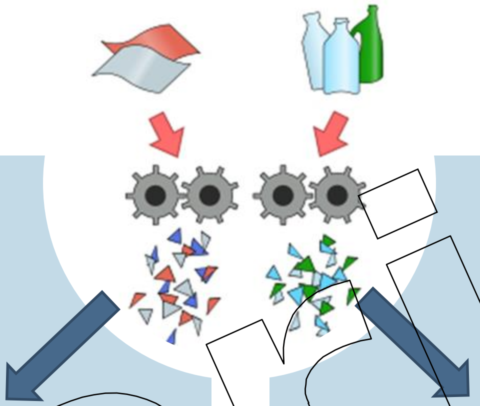


Benefits of ZSK

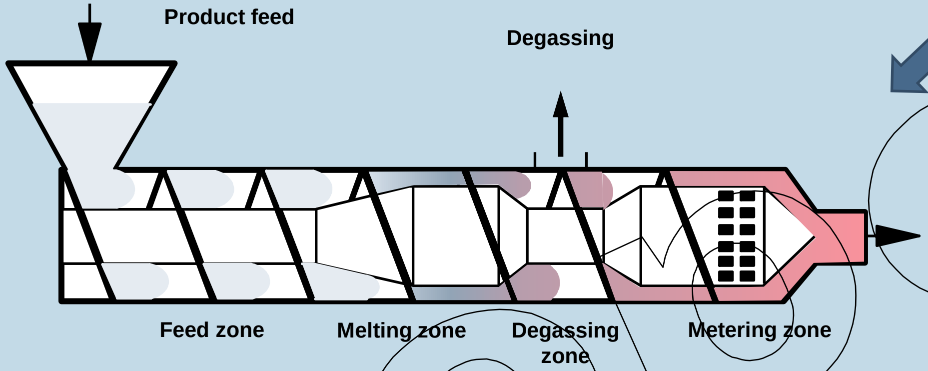
- Very good dispersive and distributive mixing / Flexibility because of modular screw design
- Compounds are made on ZSK with good dispersion (e.g. MB) to be used in single screw extruders

Comparison ZSK and single screw extruder

Mixing and homogenization in recycling

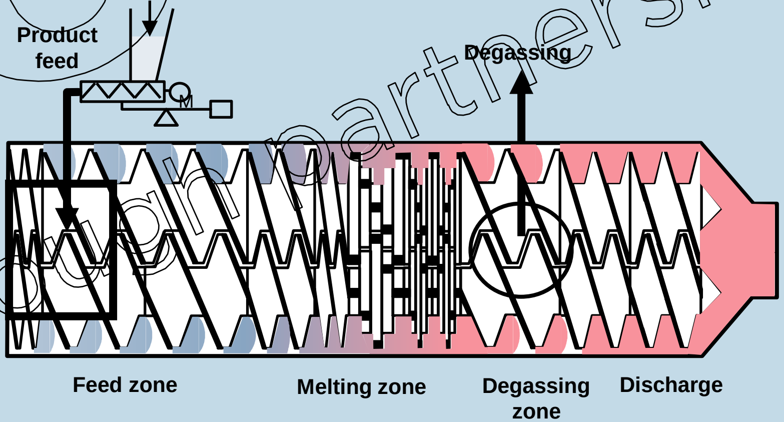


Single screw extruder



Basic recycling

Twin screw extruder

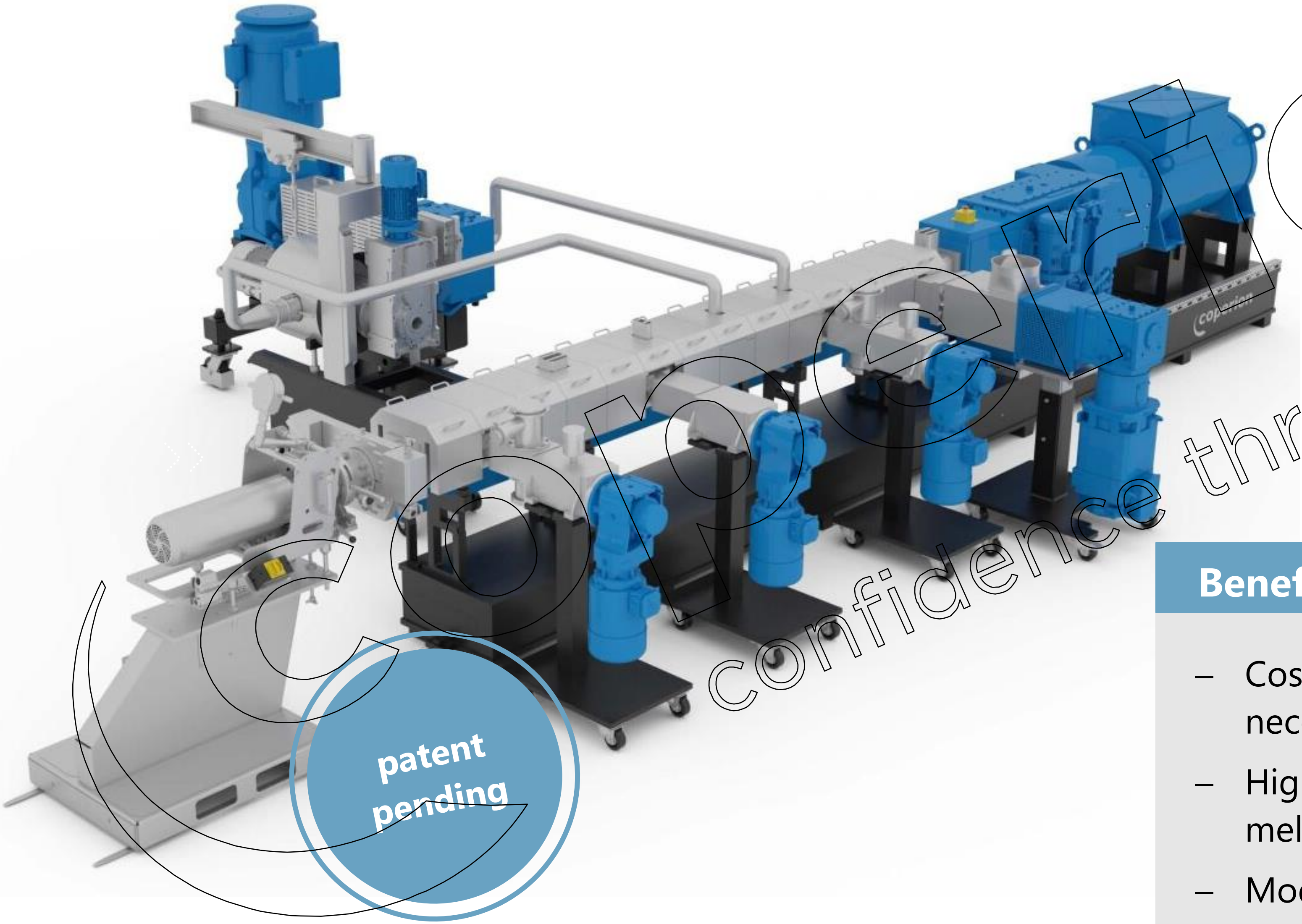


Advanced upcycling

Increased mixing and homogenization

Comparison ZSK and single screw extruder

Coperions new concept: **FilCo** (Filtration Compounder)



Filtration and **Co**mpounding of pre-washed and sorted PCR streams in **one** process step

- Melting and blending of different polymers, **discharging** the melt from the twin screw and **returning** the filtered melt
- **Adding** of coarse fillers, fibers or cross-linking additives such as peroxide after filtration

Benefits

- Cost and energy savings due to reduction of the necessary aggregates (only one extruder required)
- Higher quality of recycled plastics due to one-time melting (low temperature history)
- Modular design offers efficiency and flexibility

Comparison ZSK and single screw extruder

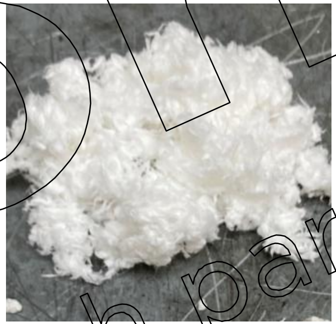
Coperions new concept: **FilCo** (Filtration Compounder)


PP flakes


PCR flakes


Rubber


Carbon fibers


Cellulose


Recycled PA fibers

- Filtration of various polymers with different particle sizes and bulk densities
  - Polypropylen
  - Polyamid 6
  - LDPE
  - Film scrap
  - etc...

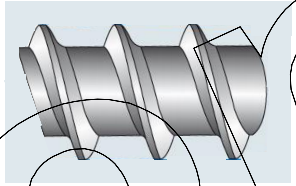
- Adding additives, coarse fillers, tire rubber, fibers (e.g. wood/glass/carbon fiber) or cross-linking additives such as peroxide

Incorporation after filtration leads to gentle processing of the additives and to a higher product quality

Comparison ZSK and single screw extruder

Degassing capability overview

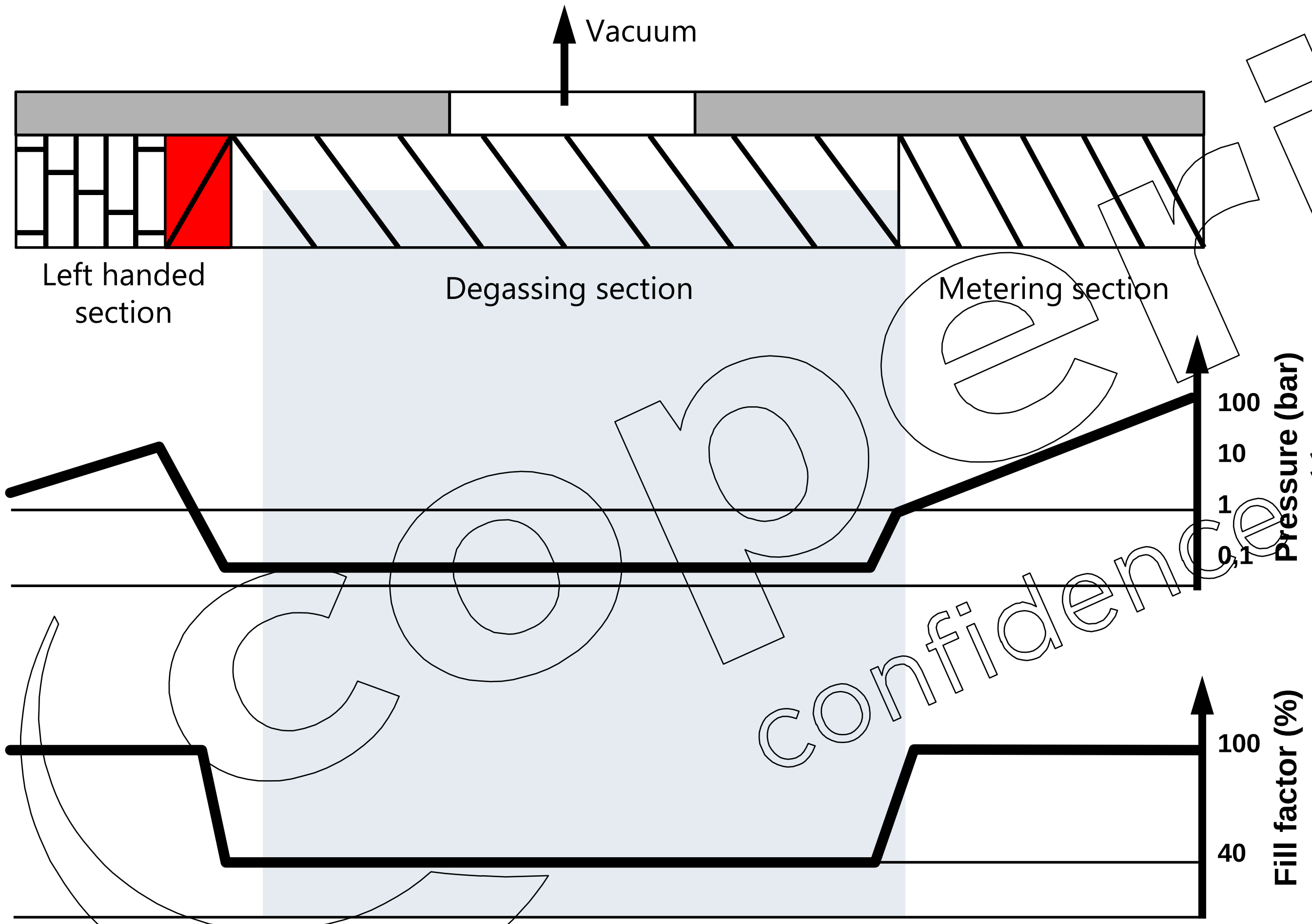
Degassing



Single screw	Twin screw
++	+++

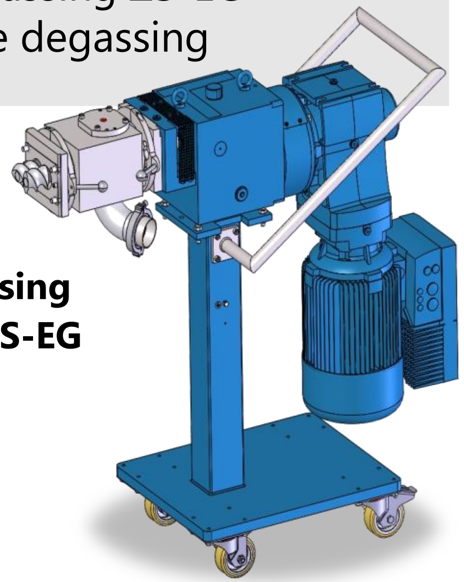
Comparison ZSK and single screw extruder

Degassing capability / Principle of degassing



Benefits of ZSK

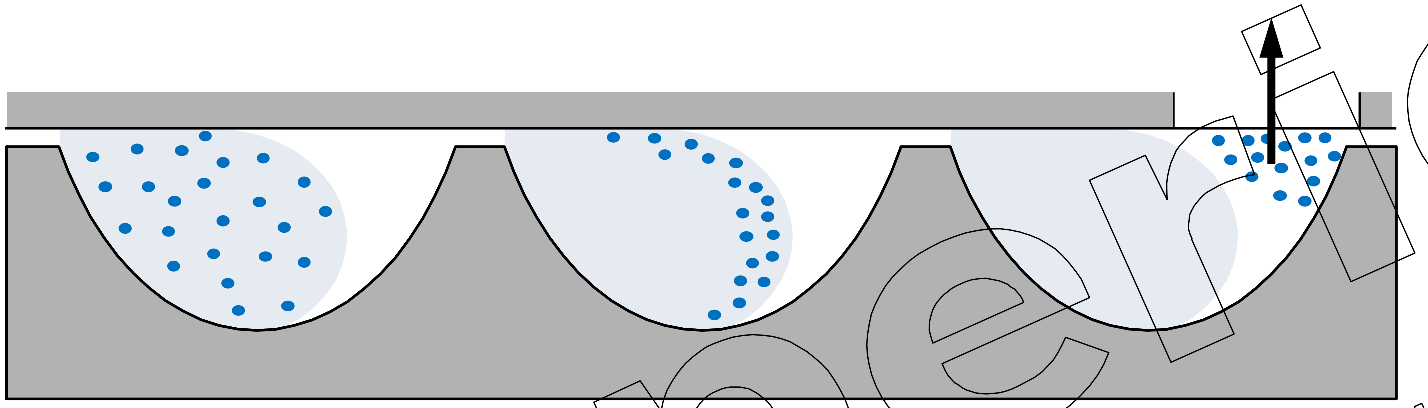
- The polymer melt will also be degassed in the partly filled screw channels in the closed barrel sections upstream and downstream of the vent opening
- Surface renewal because of transition from one to another screw
- Use of side degassing ZS-EG possible → Safe degassing

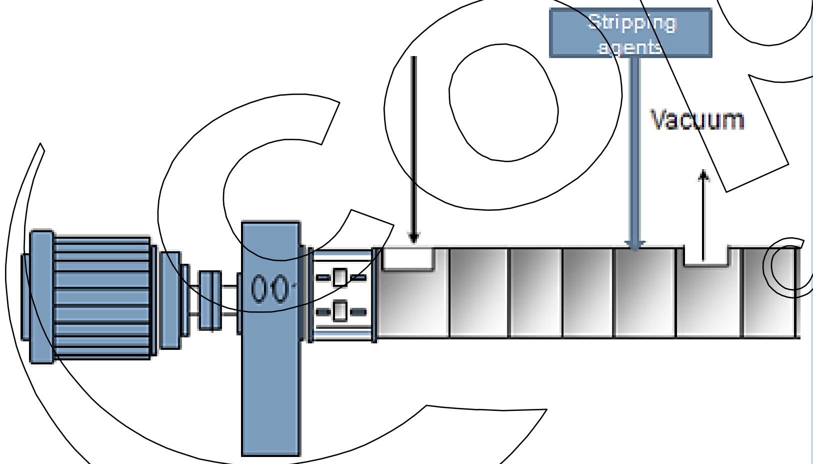


Side degassing unit ZS-EG easy

Comparison ZSK and single screw extruder

Degassing capability → Principle of degassing in a twin screw





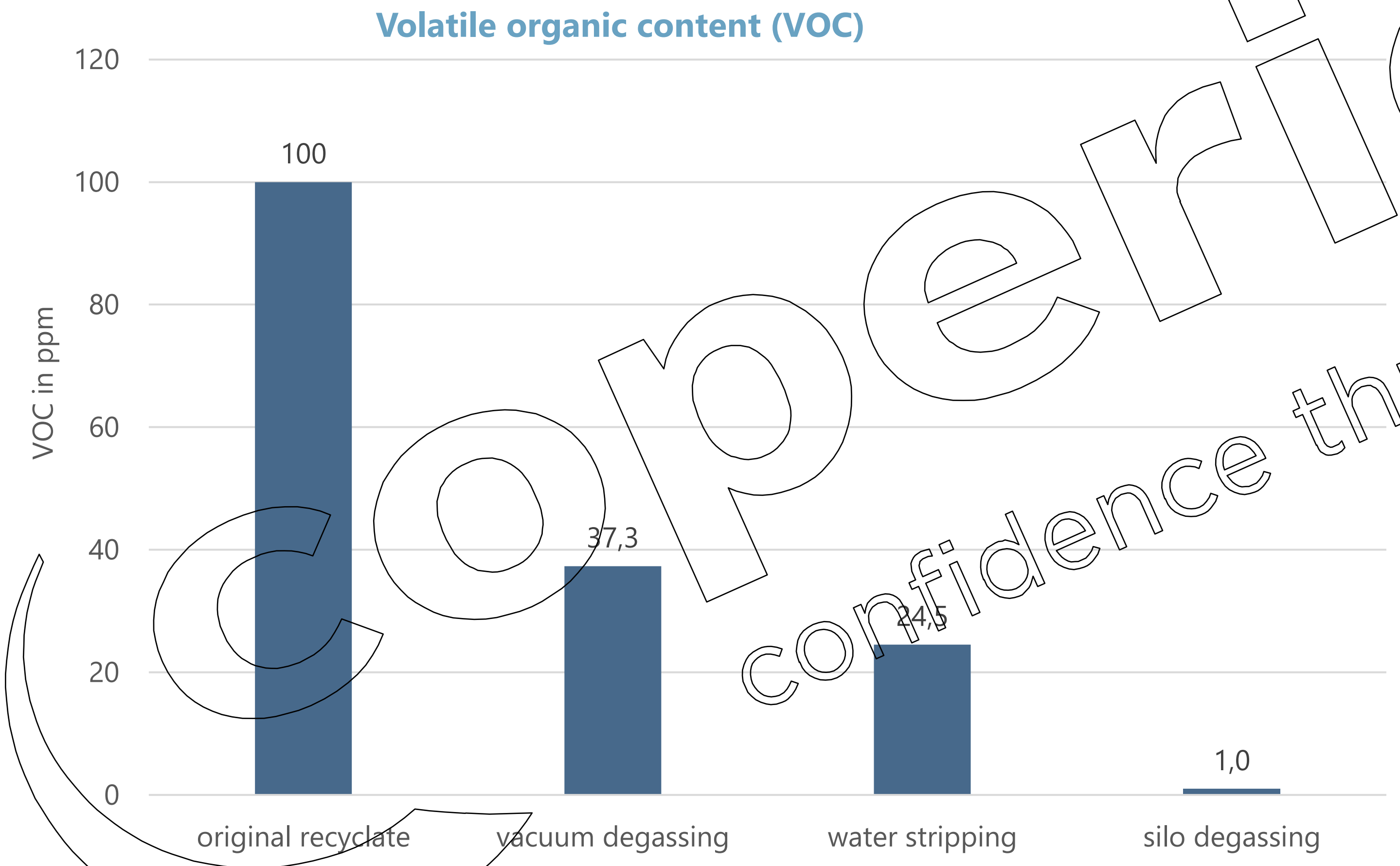
Stripping agents are incorporated into the melt in liquid form shortly before the degassing dome, which entrains short molecular chains and volatiles

The diffusion is influenced by

- **residence time**
- **viscosity of the melt**
- **thickness of the melt layer**
- **renewal of the melt surface**
- **pressure difference**
- **stripping agent**

Comparison ZSK and single screw extruder

Degassing capability, Degassing with stripping agents, VOC reduction



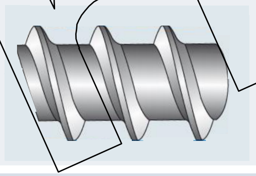
VOC reduction during the compounding step

- Standard vacuum degassing in the ZSK helps to reduce VOCs
- Usage of ZS-EG improves process stability

→ By adding water as stripping agent the VOC content can be further **lowered by 20-35 %**

Comparison ZSK and single screw extruder

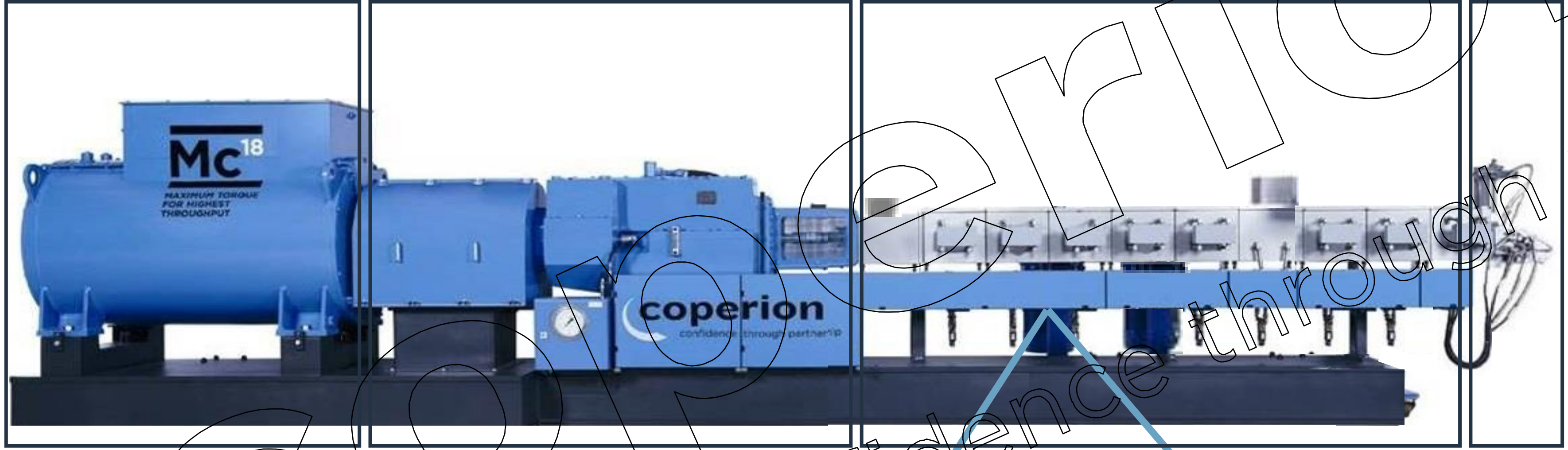
Self cleaning, residence time, modular design

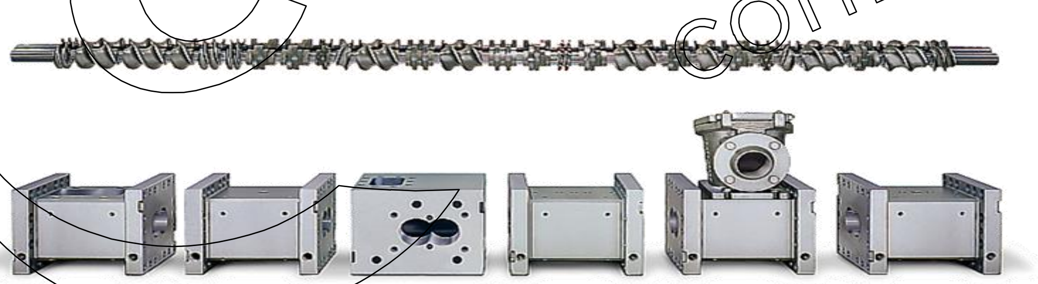
	Single screw 	Twin screw 
Self cleaning	**No**	**Yes**
Residence time distribution	**Wide**	**Narrow**
Modular design of screws and barrels	**No**	**Yes**

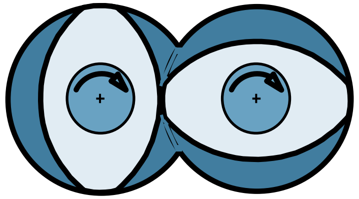
Comparison ZSK and single screw extruder

Self cleaning, residence time, modular design

Main drive | **Coupling gearbox** | **Process section** | **Die head**





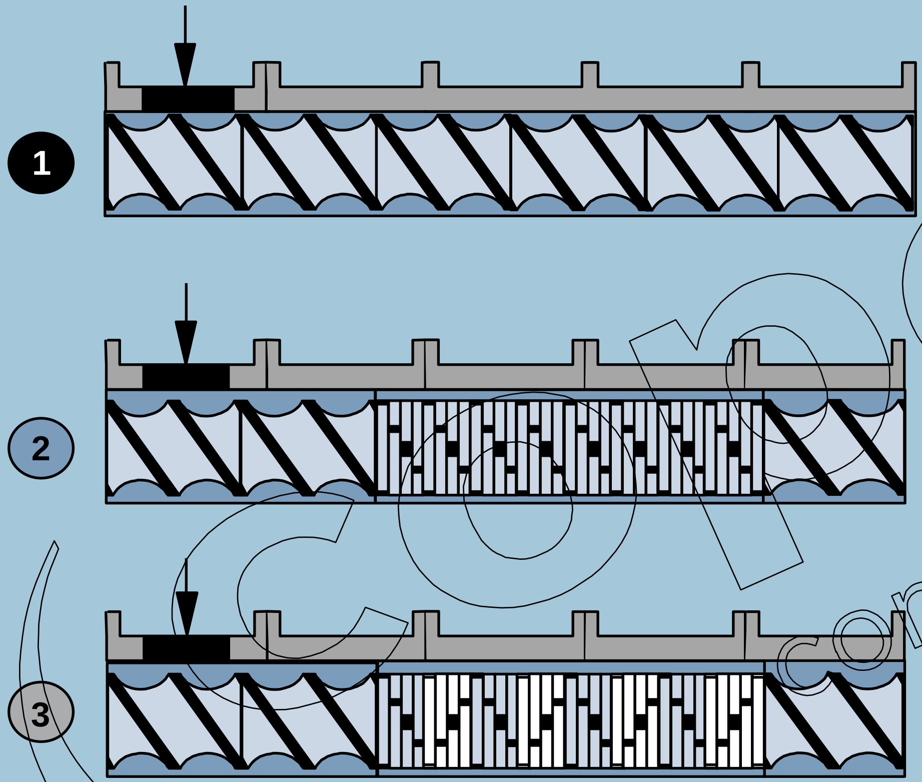


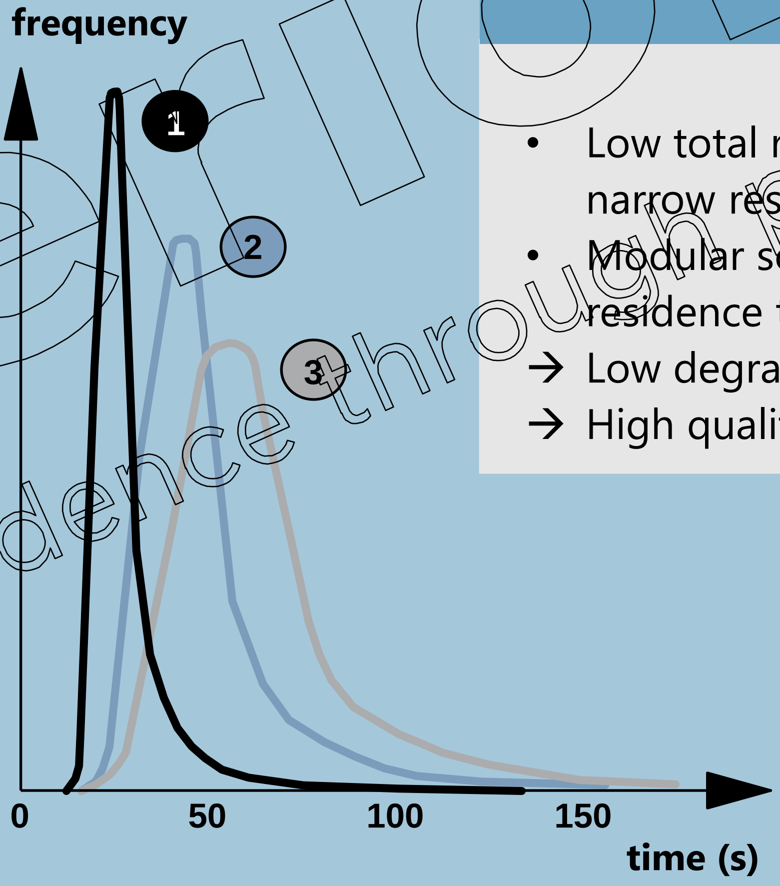
Benefits of ZSK

- Modular design of barrels and screws → fits to all recycling tasks
- Intermeshing and self-cleaning → High Quality of recycled materials and compounds

Comparison ZSK and single screw extruder

Self cleaning, residence time, modular design





Benefits of ZSK

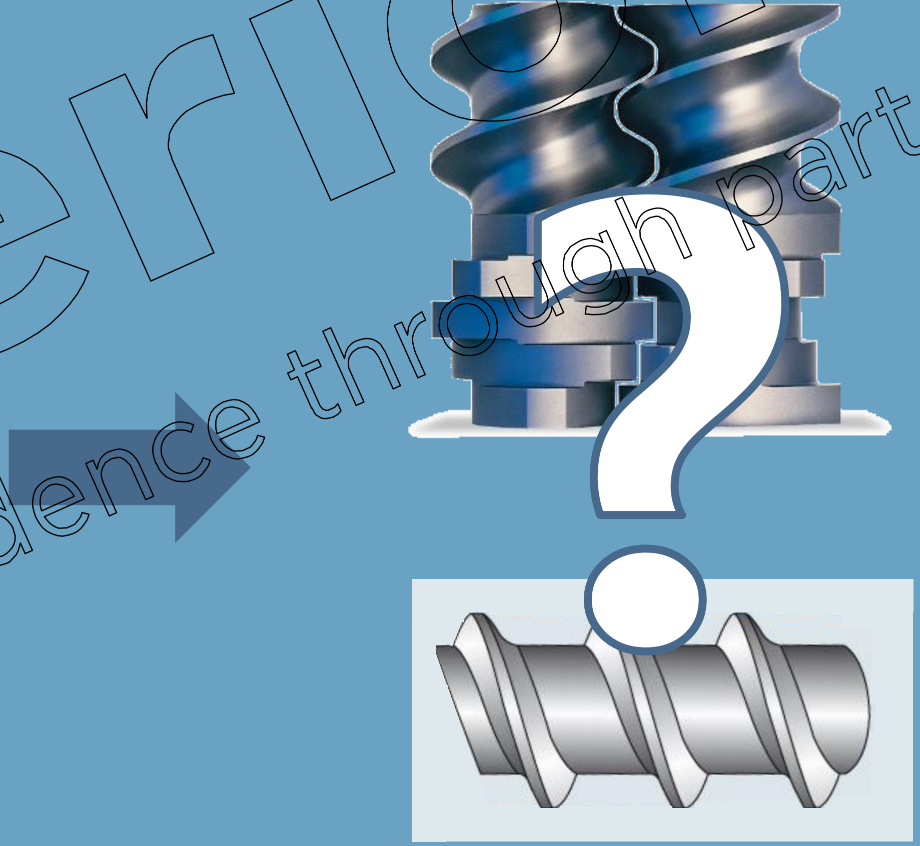
- Low total residence time and narrow residence time distribution
- Modular screw design to influence residence time and distribution

→ Low degradation
→ High quality

System comparison ZSK vs. Single screw extruder

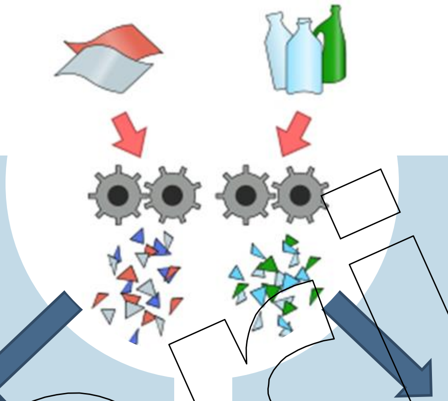
Summary

Characteristics		Single screw	Co-rotating twin
Feed intake of bulk materials		+	++
Downstream adding of bulk materials		+	+++
Downstream adding of liquids		+	+++
Melting capability	Powder	+	++
	Pellets	++	+++
Distributive mixing	Axial	++	+++
	Crosswise	++	+++
Dispersive mixing		++	+++
Degassing capability		++	+++
Pressure built-up capability		++	+
Self cleaning		No	Yes
Residence time distribution		wide	Narrow
Modular design	Screws	No	Yes
	Barrels	No	Yes
Possibility of heating and /or cooling	Screws	Yes	Yes
	Barrels	Yes	Yes

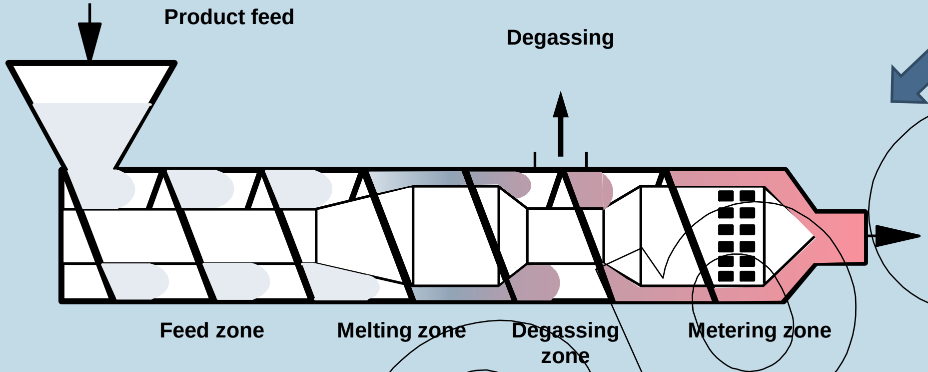


System comparison ZSK vs. Single screw extruder

Overall conclusion



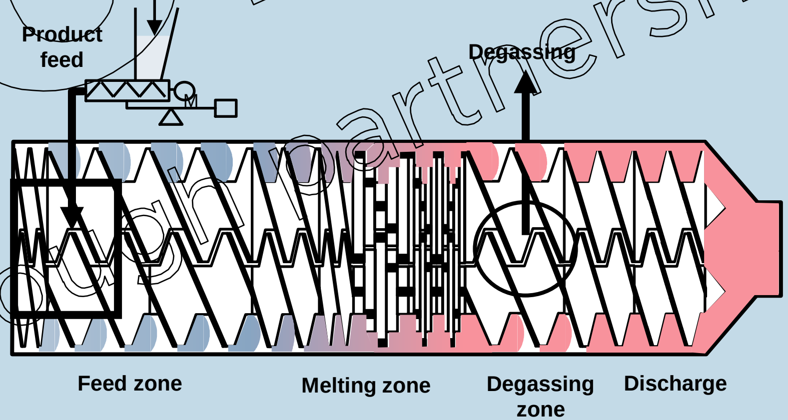
Single screw



Basic recycling

- Reduced mechanical properties
- Mainly filtration of solid contaminations

Twin screw



Advanced upcycling

+ Low energy consumption -> low OpEx
+ Low area consumption / footprint
+ Flexible, modular system

Conclusion

For challenging tasks or high-quality end products, the usage of a twin screw is mandatory

Thank you!

Jochen Schofer
Head of Sales Recycling

Frank Mack
Head of Process Technology Engineering Plastics