# Recycling of Polymer Materials

Dipl.- Ing. Günther Höggerl, MEng

Project PolyRegion
19.02.15.

# Topics

- General Introduction
- Polymer Overview
  - Global role of polymers
  - End of life (waste) situation
- Creating high grade recycled polymers
  - Crushing /Cleaning
  - (Separation and sorting)
  - Granulation (Modification)
- Processing of recycled polymers

# Topics

- General Introduction
- Polymer Overview
  - Global role of polymers
  - End of life (waste) situation
- Creating high grade recycled polymers
  - Crushing /Cleaning
  - (Separation and sorting)
  - Granulation (Modification)
- Processing of recycled polymers

| | |
|---|---|
| since 2011 | **Müller Guttenbrunn GmbH** (www.mgg-recycling.com)<br>Recycling Industry, Head of Research & Development<br>**HEC**<br>Engineering&Consulting |
| 2005 – 2011 | **MBA Polymers Austria** (www.mbapolymers.com)<br>Recycling Industry, Head of Quality management |
| 2004 - 2005 | **Harreither Intelligente Energiesysteme** (www.harreither.com)<br>Home energy systems, Head of Research & Development |
| 1996 - 2003 | **EKB GesmbH - Dräxlmaier Austria** (www.draexlmaier.com)<br>Automotive Supplying Industry, Head of Product Development |
| 1988 - 1995 | **Studies in Polymer Engineering and Science** |

# Topics

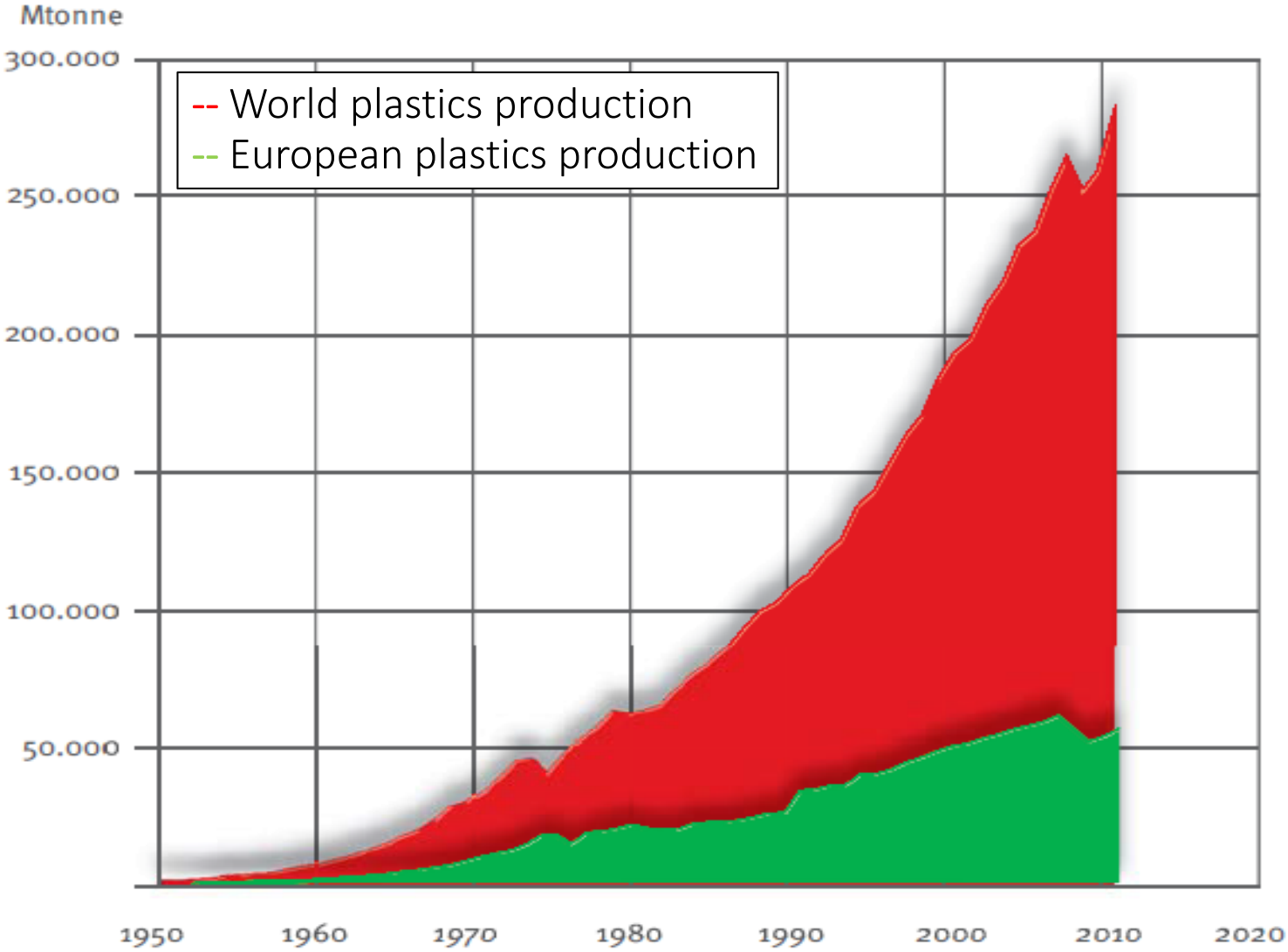
- General Introduction
- Polymer Overview
  - Global role of polymers
  - End of life (waste) situation
- Creating high grade recycled polymers
  - Crushing /Cleaning
  - (Separation and sorting)
  - Granulation (Modification)
- Processing of recycled polymers

# *Global demand of raw materials*

| | 2000 | 2005 | 2010 |
|---|---|---|---|
| | [Mio. to/a] | [Mio. to/a] | [Mio. to/a] |
| Iron& Steel | 848 | 1.144<br>+34% | 1.428<br>+24% |
| Polymers | 180 | 235<br>+31% | 265<br>+12% |
| Aluminum | 53 | 65<br>+22% | 85<br>+31% |
| Copper | 13 | 16<br>+23% | 19<br>+18% |

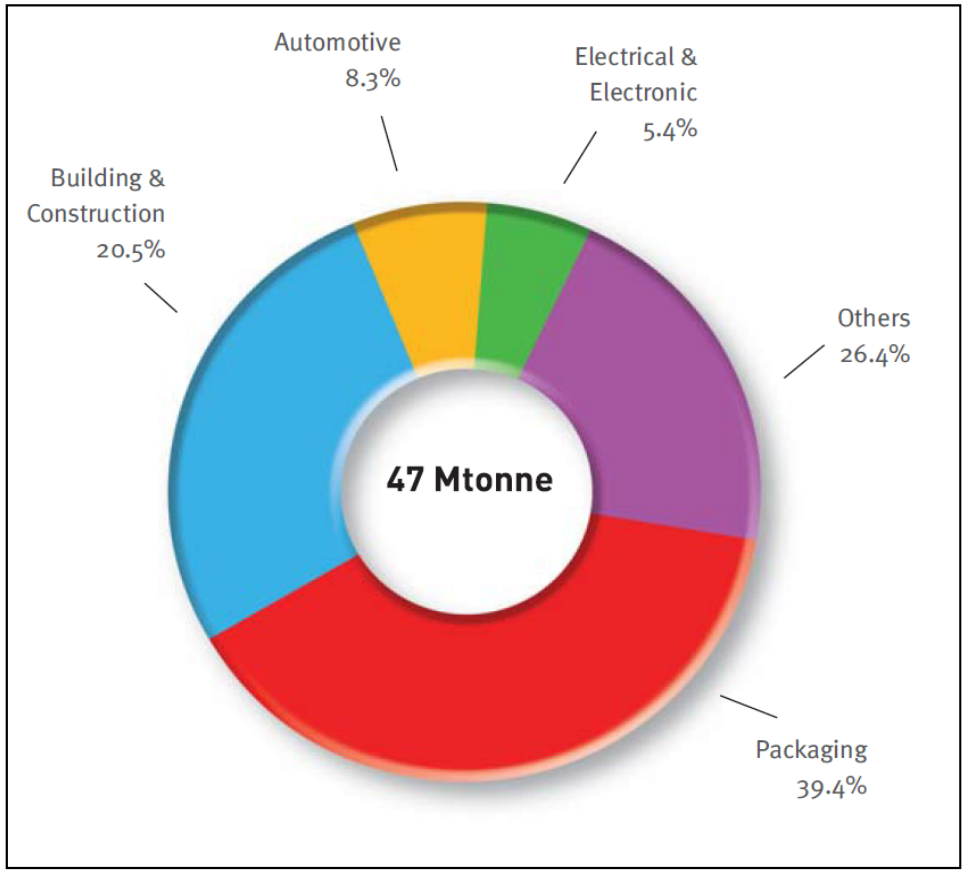
Source: Plastics Europe, Wordsteel.org, world-aluminium.org, www.copper.org

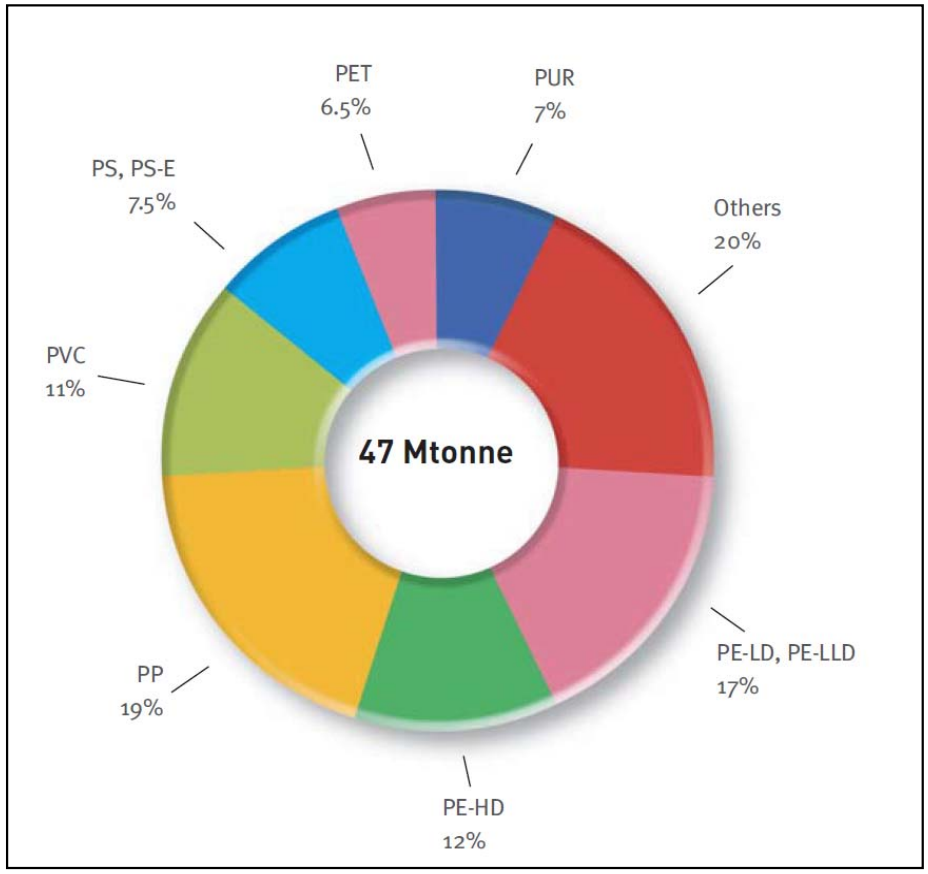
# *Increasing global need of polymers*




Source: Plastics Europe

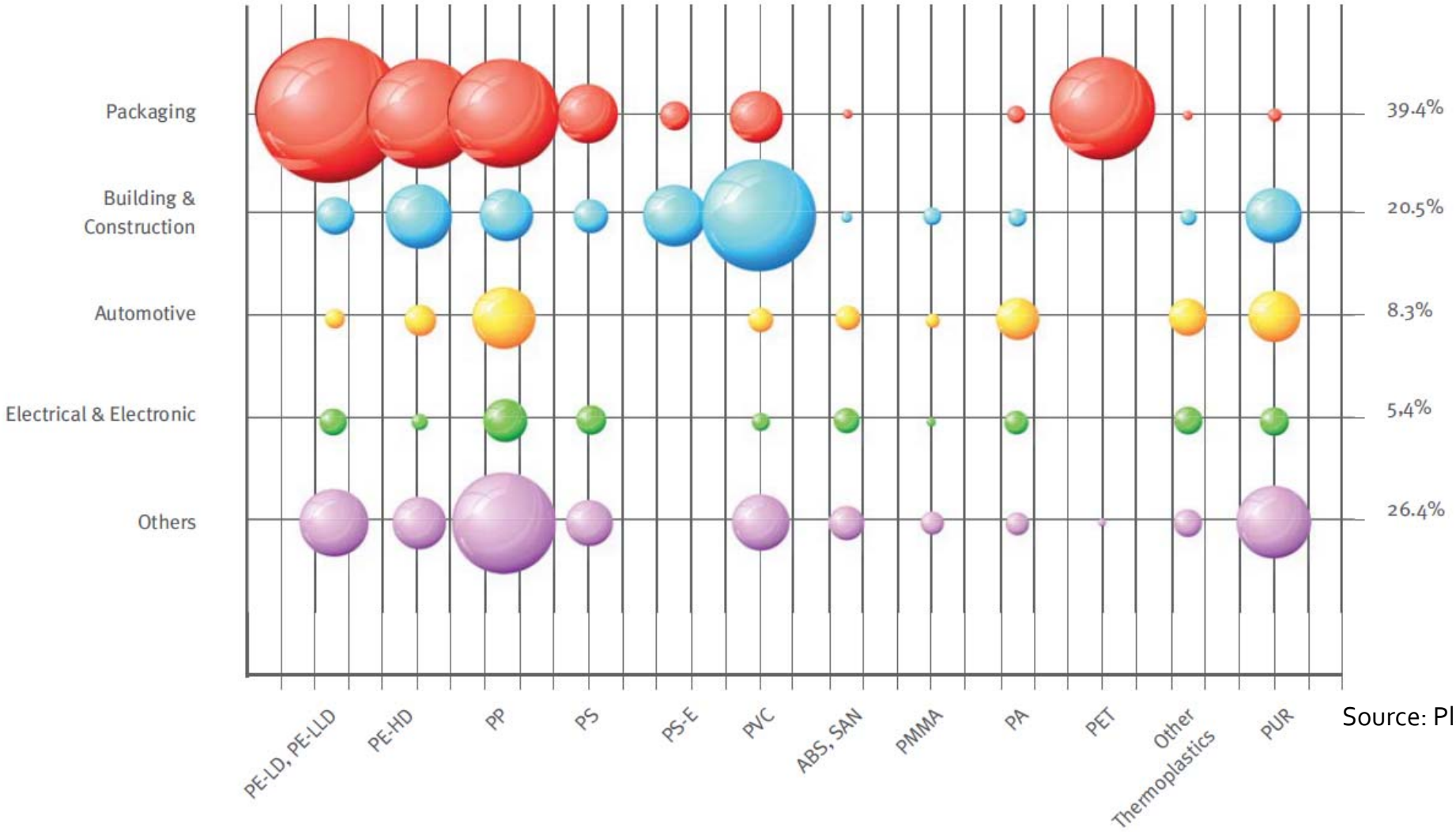
# *European demand by segments/polymers*




Source: Plastics Europe

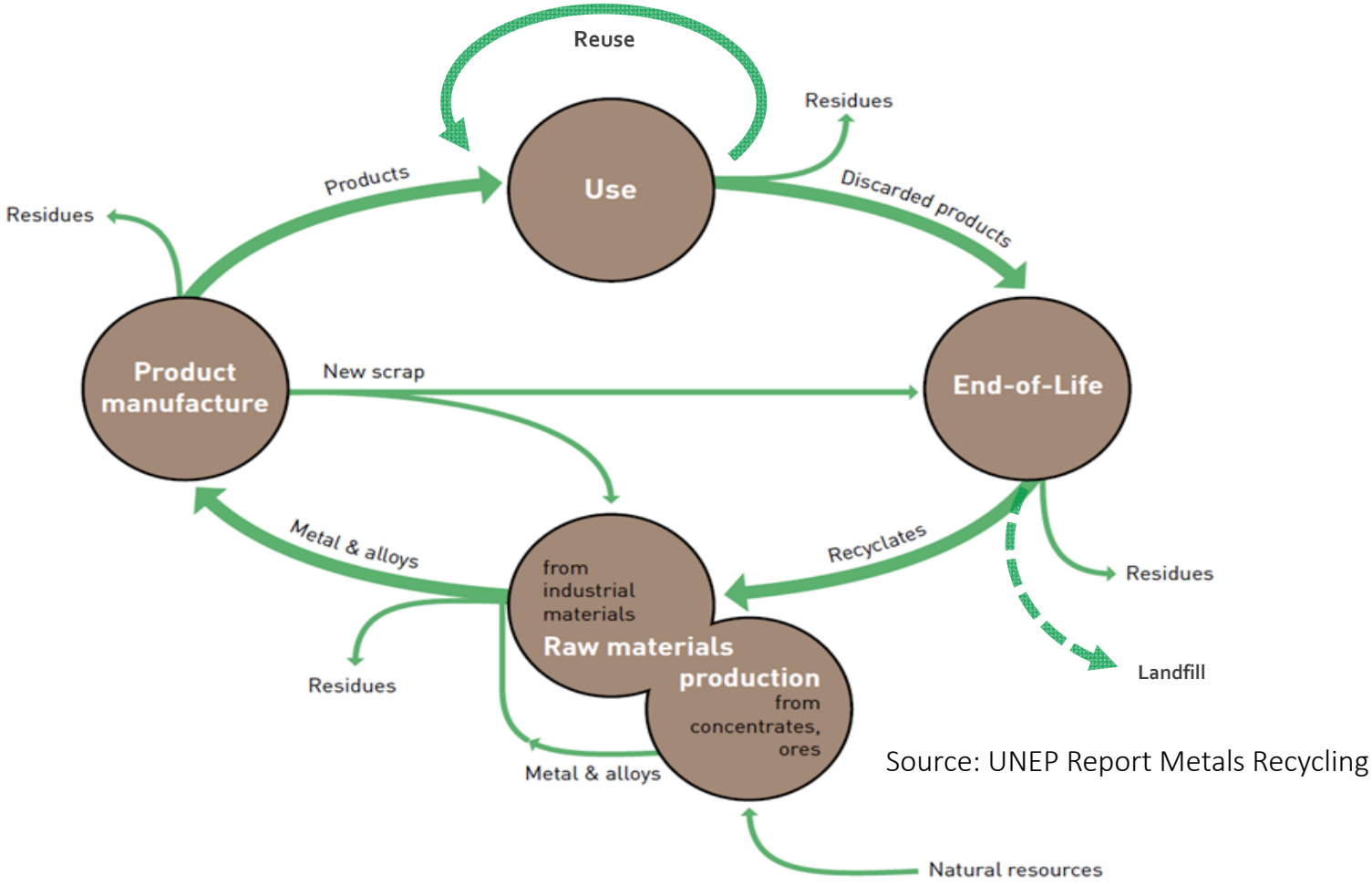
# *European demand of polymers within segments*




Source: Plastics Europe

# Unique features of polymer materials

- Low density
- High spec. Strength/stiffness
- Low heat conduction
- Low electrical conductivity
- Chemical resistance
- Modifiability – „tailor made properties“
- Low processing costs
- High energy content

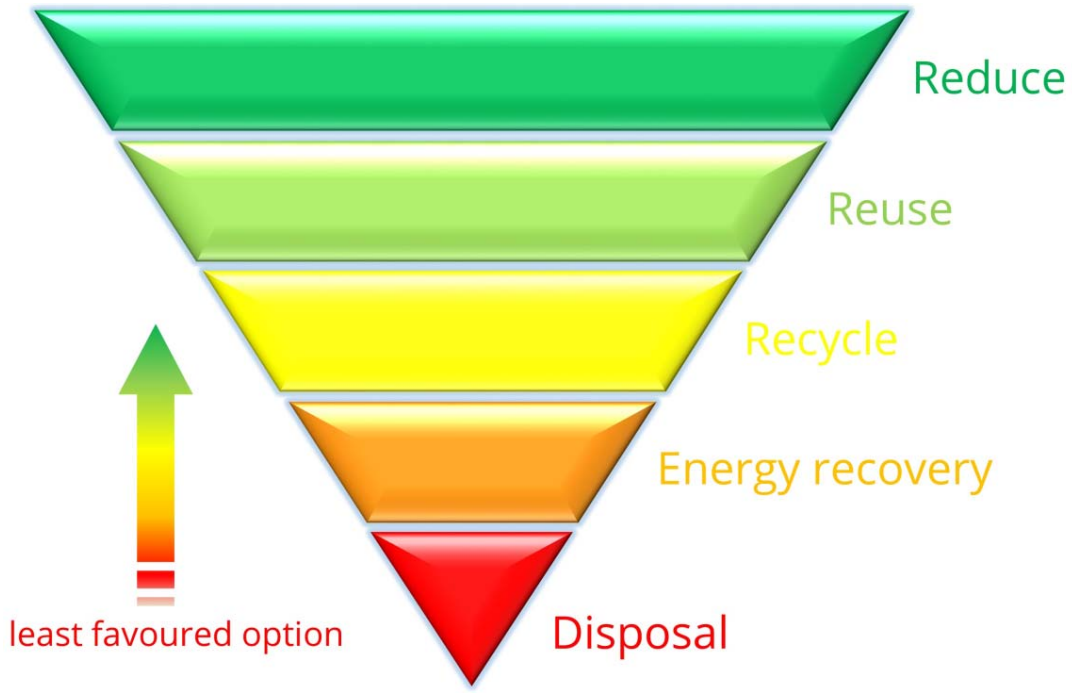



Source: UNEP Report Metals Recycling

- Increasing cycle speed in developed countries
- Increasing interest in antropolical reservoirs = Waste („urban mining“)
- Functioning cycle of materials essential for competitiveness

# *European waste management*

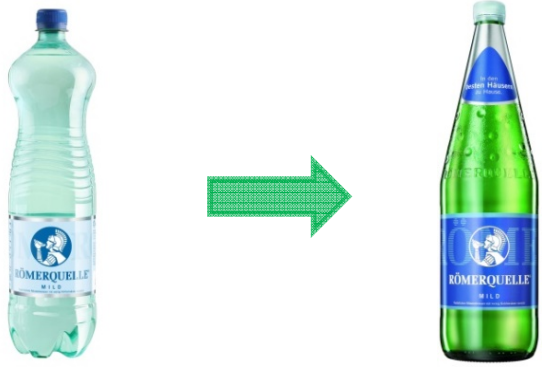
- European Frame Work Directive (EU RL2008/98/EG) defines strategic playing field
- Important: „Five steps waste hierarchy“



# *European waste management*

Example: PET Bottle

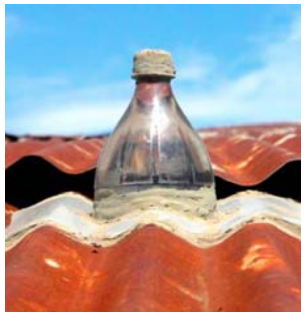
- Reduce
- Reuse
- Recycling
- Energy recovery
- Disposal



# *European waste management*

- Reduce
- **Reuse**
- Recycling
- Energy recovery
- Disposal



# *European waste management*

- Reduce
- Reuse
- **Recycling**
- Energy recovery
- Disposal

# *European waste management*

- Reduce
- Reuse
- Recycling
- Energy recovery
- Disposal


# *European polymer recovery overview*

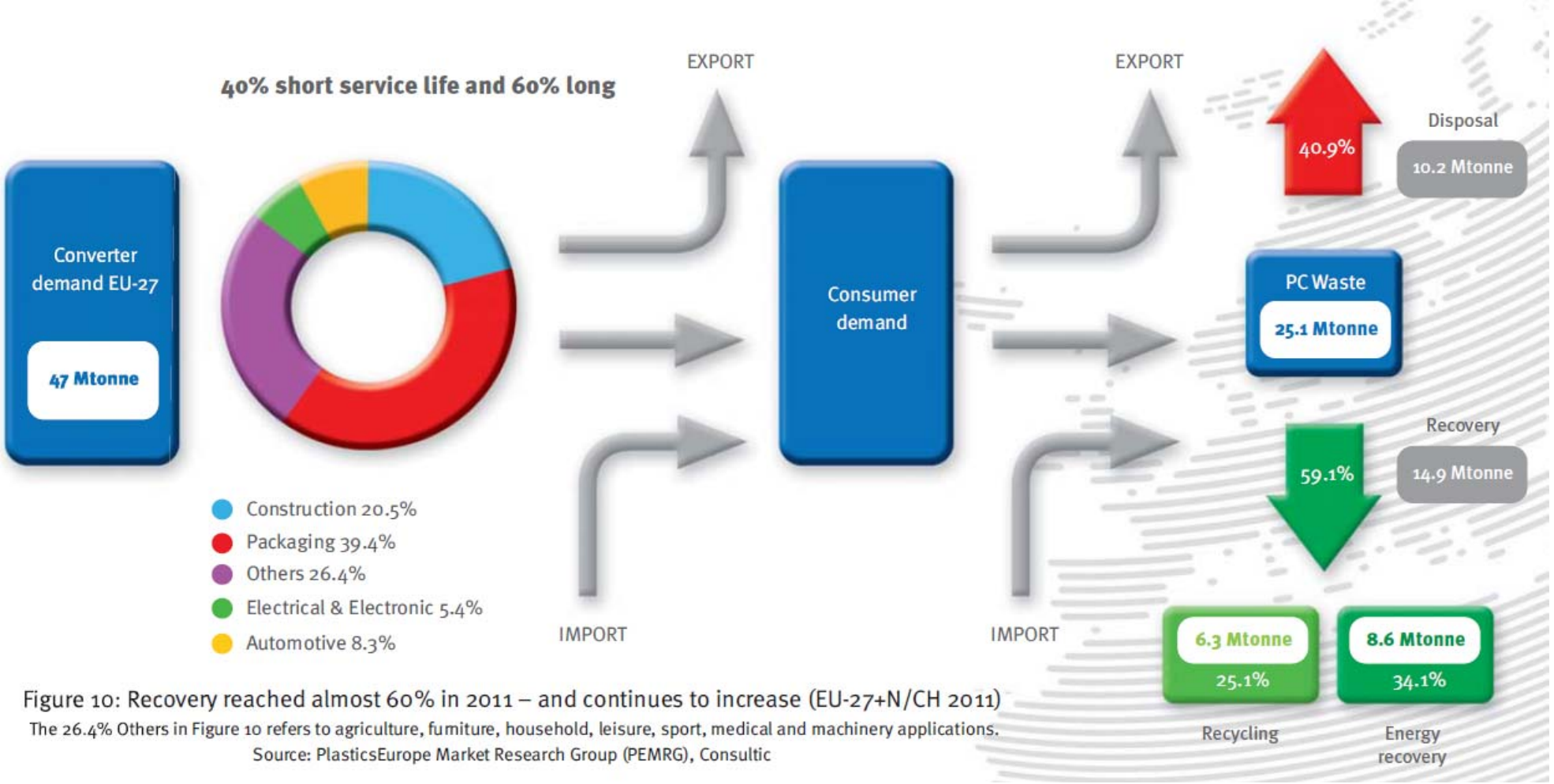
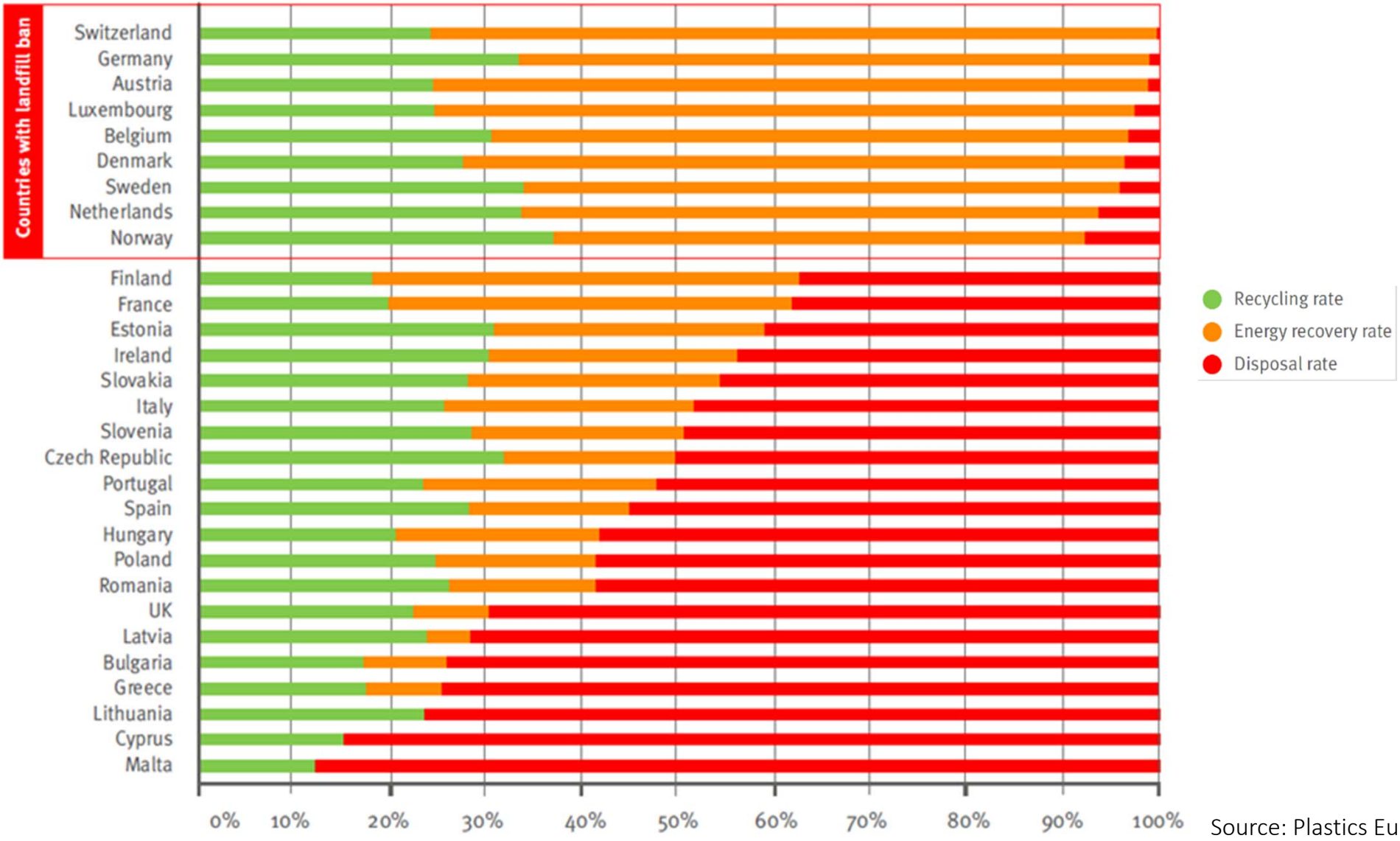



Figure 10: Recovery reached almost 60% in 2011 – and continues to increase (EU-27+N/CH 2011)
The 26.4% Others in Figure 10 refers to agriculture, furniture, household, leisure, sport, medical and machinery applications.
Source: PlasticsEurope Market Research Group (PEMRG), Consultic

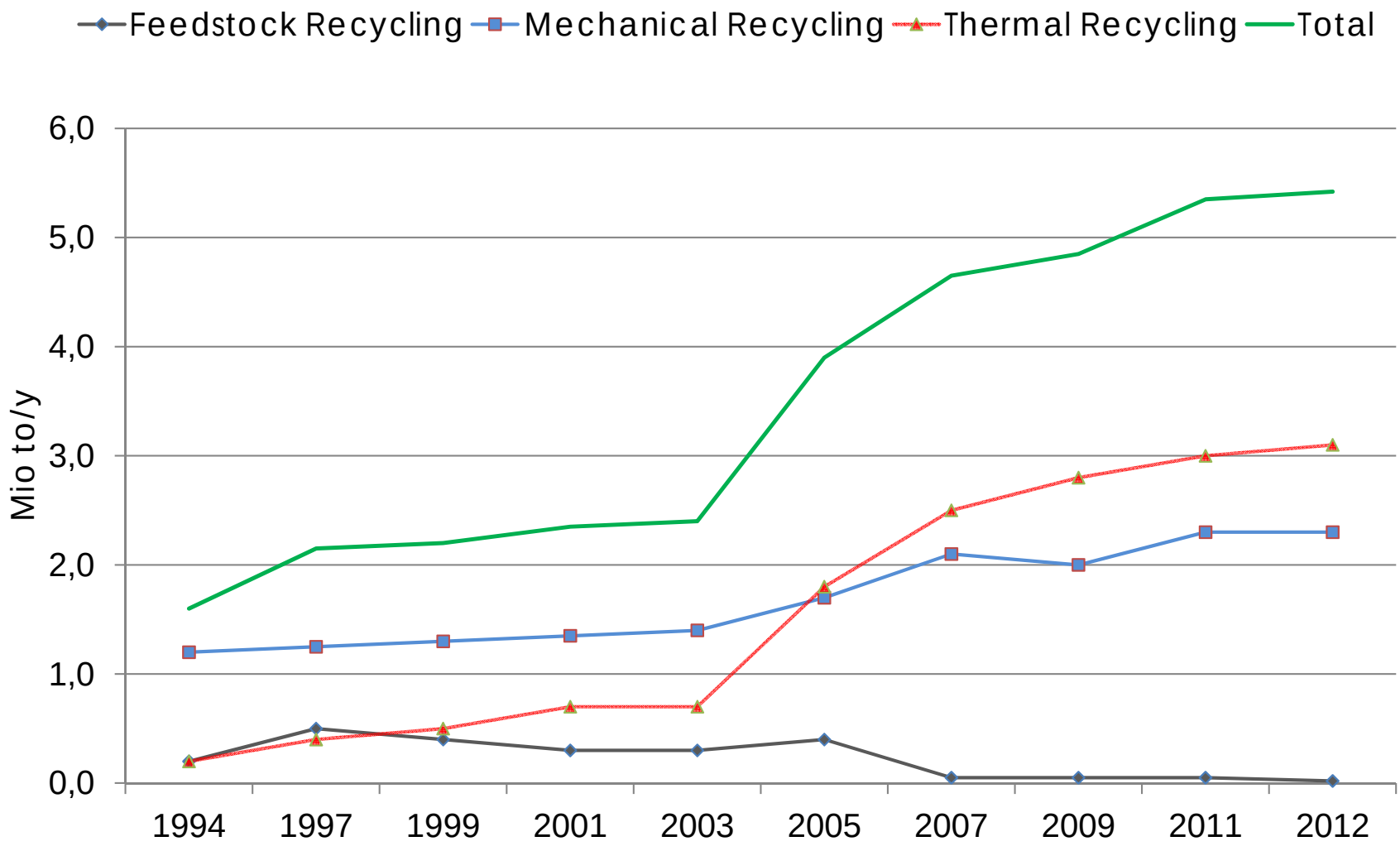
Source: Plastics Europe

# *European polymer recovery overview*

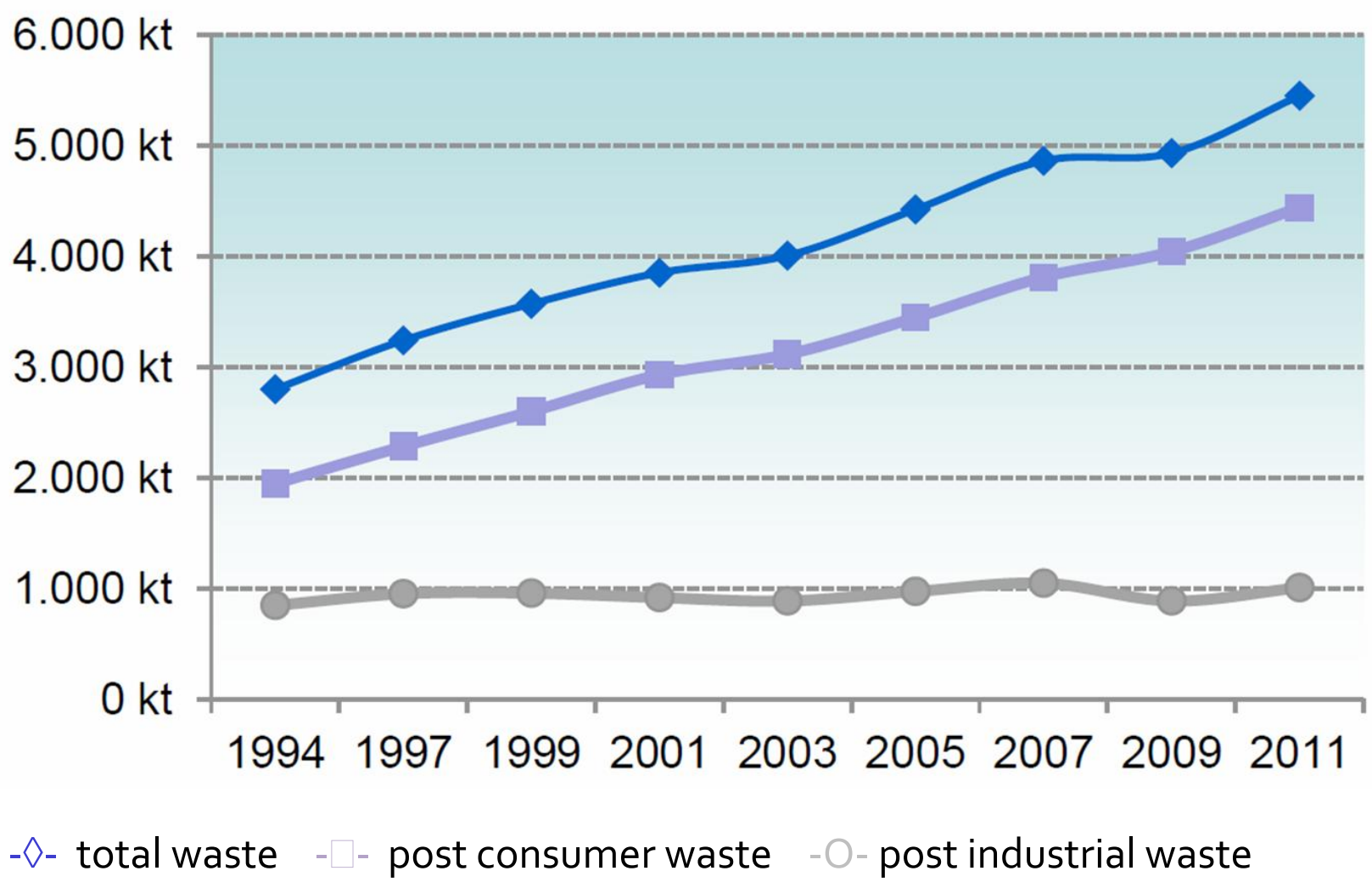



Source: Plastics Europe

# *European polymer recovery overview*



# *Post consumer vs post industrial polymer waste* (Germany)



# *Post consumer polymer waste….*

# *Post consumer polymer waste….*

# Topics

- General Introduction
- Polymer Overview
  - Global role of polymers
  - End of life (waste) situation
- Creating high grade recycled polymers
  - Crushing /Cleaning
  - (Separation and sorting)
  - Granulation (Modification)
- Processing of recycled polymers

# *Recycling paths for polymers*

| | Mechanical Recycling | Feedstock Recycling | Energetic Recycling |
|---|---|---|---|
| Method | No change in molecular structure | Cracking of molecular structure | Oxidation with oxygen |
| Processing | Extrusion/Injection molding | Hydrolysis<br>Gasification<br>Pyrolysis | Incineration |
| Products | Regenerate | Monomers | Heat |
| Side products | Strands, Lumps | Non crackable material | Ash, slag |

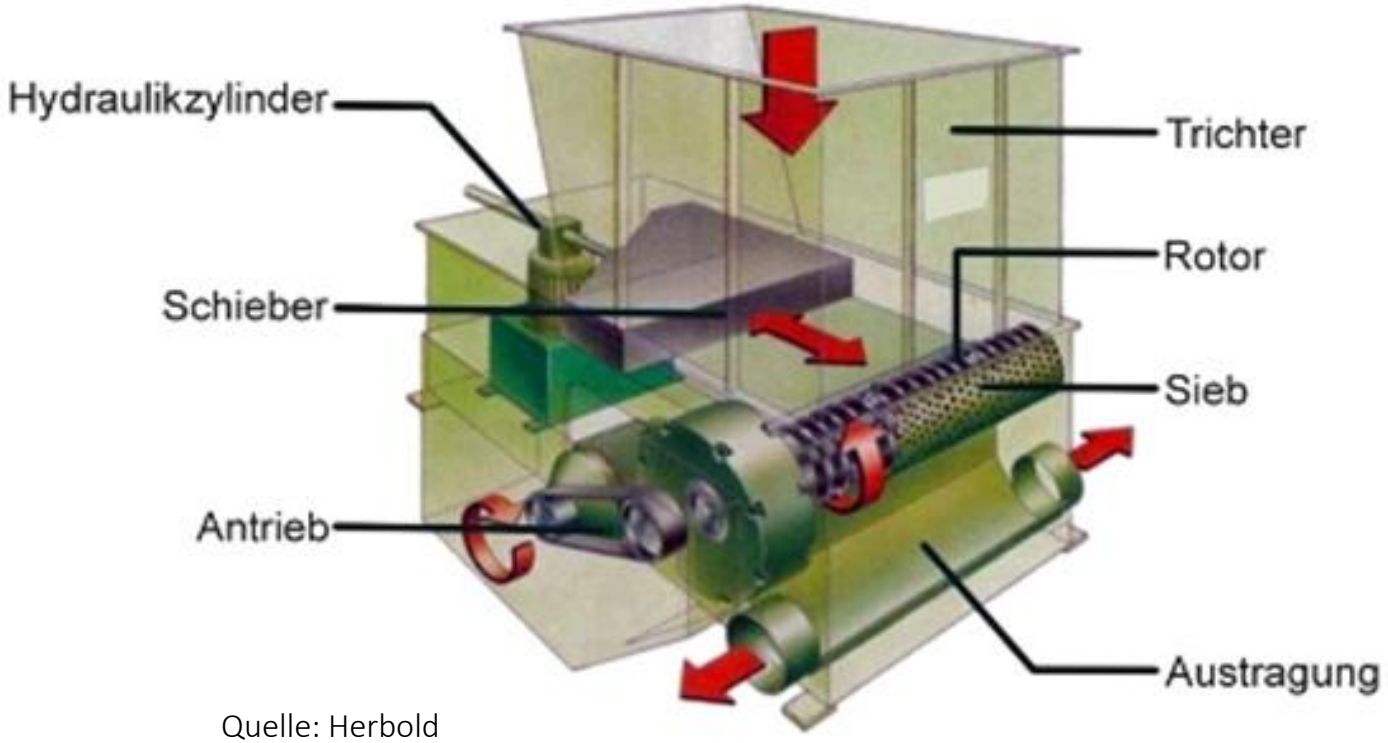
# *Recycling paths for polymers*

| | Mechanical Recycling | Feedstock Recycling | Energetic Recycling |
|---|---|---|---|
| Method | No change in molecular structure | Cracking of molecular structure | Oxidation with oxygen |
| Processing | Extrusion/Injection molding | Hydrolysis<br>Gasification<br>Pyrolysis | Incineration |
| Products | Regenerate | Monomers | Heat |
| Side products | Strands, Lumps | Non crackable material | Ash, slag |

# *Crushing / Cleaning*

# *Crushing - Single shaft shredder*

- Simple Design
- Robust
- Material feed necessary




Quelle: Herbold

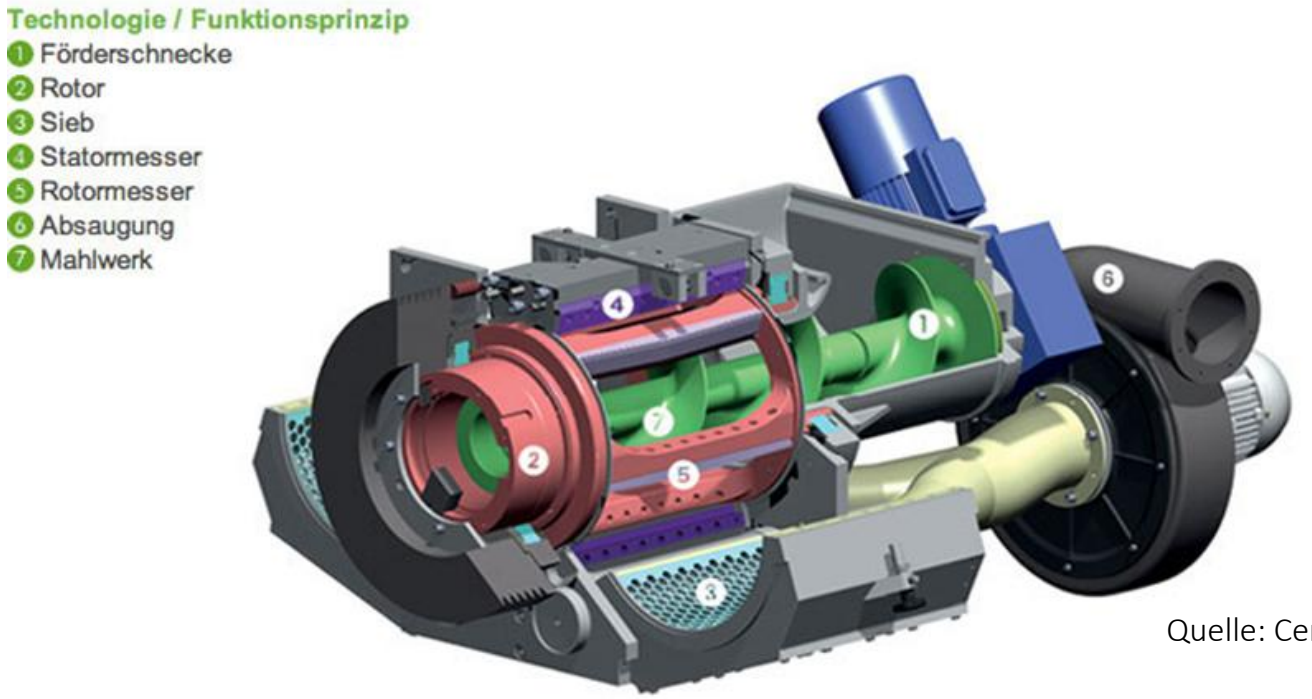
# *Crushing - Multi Shaft Shredder*

- Complex Design
- Robust
- Self feeding – no material feed necessary

Quelle: Lindner

# *Crushing - Grinder*

- Simple Design
- Defined output material (particle size distribution)
- Sensitive to non plastic material




Quelle: CentriCut

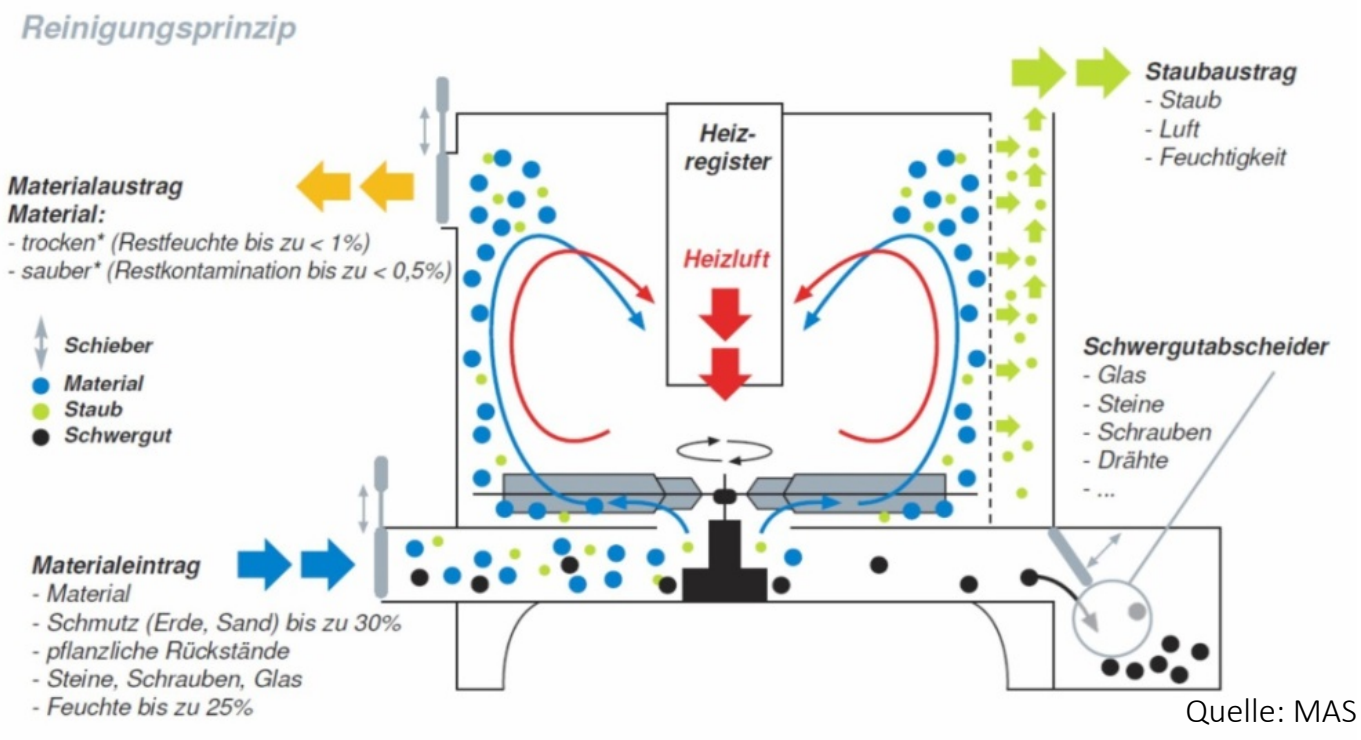
# *Cleaning - Wet processing*

- Cleaning in combination with conveying
- Process water treatment
- Waste water

Quelle: Navarini

# *Cleaning - Dry processing*

- Centrifugal forces do cleaning and drying
- No process water
- Low energy consumtion




Quelle: MAS

# *Separation and sorting*

- Manual sorting
- Sorting by density
- Sorting by reaction to elektromagnetic oscillation (Color, Infrared, X-ray)
- Sorting by triboelectrical reactions
- …

# *Granulation / Modification of recycled material*

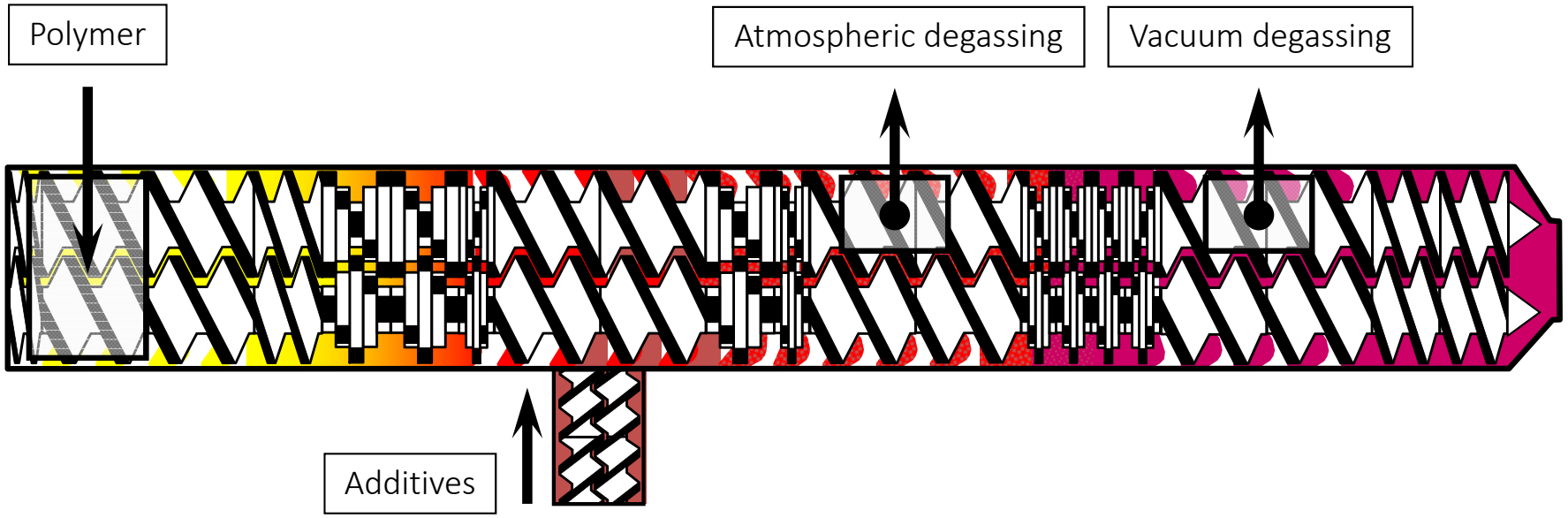
General material requirements:

- Low dirt/mud content
- Less „hard“ contaminations (metal parts, glass, etc.)
- Low  fines content (particles <1mm)
- Pure polymer material without crosscontaminations
- Dry Material

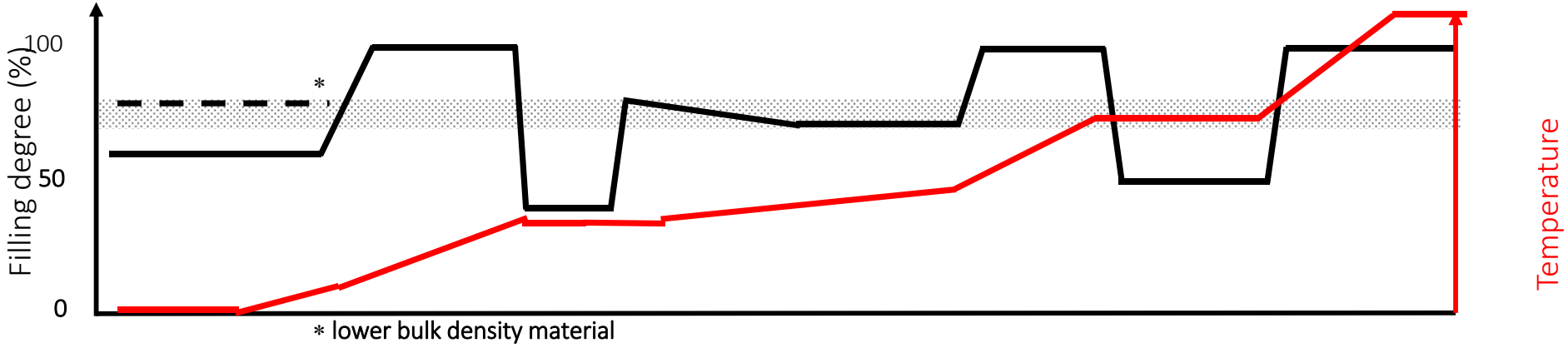
# *Granulation / Modification of recycled material*

## *General equipment requirements*

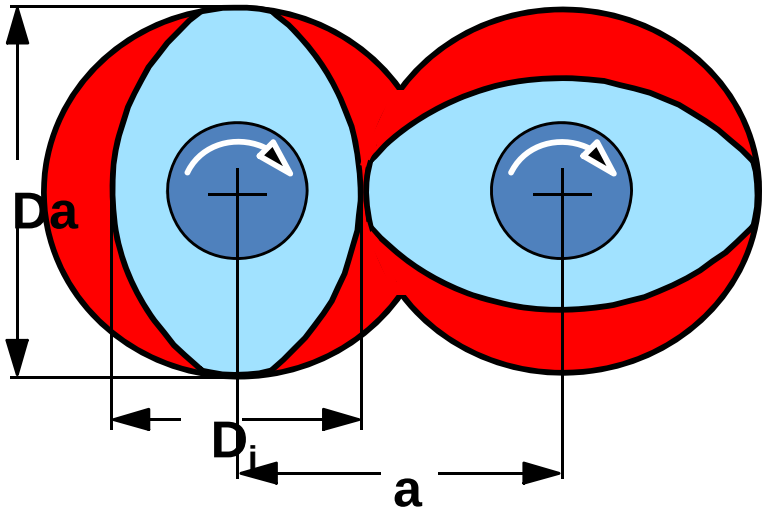
- Material predrying system
- Wear protected Extrusion lines
- Twin screw extrusion systems preferred
- Dosing of additives
- Efficient degassing system
- Continious melt filtration system




| Infeed zone | Melt zone | Feeding | Mixing | Degassing | Homo genizations | Degassing | Pressurization |
|---|---|---|---|---|---|---|---|



# *Basic design parameters of a twin screw extruder*




$D_a$ = outer diameter

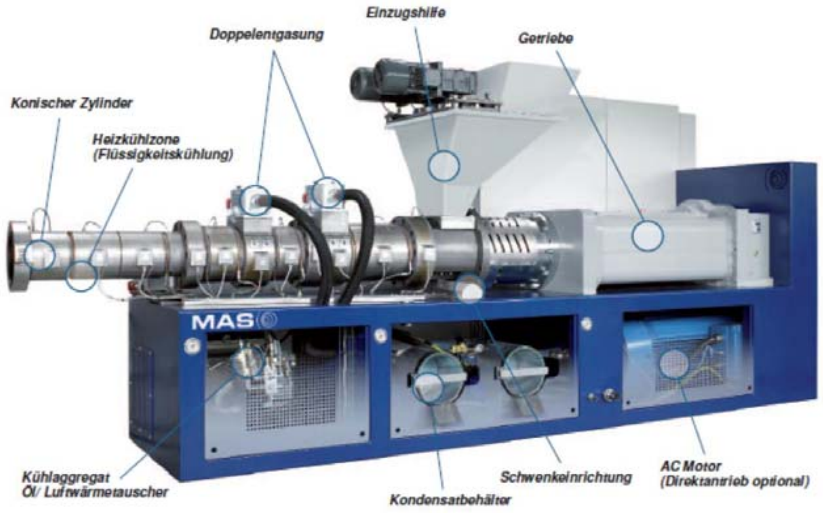
$D_i$ = inner diameter

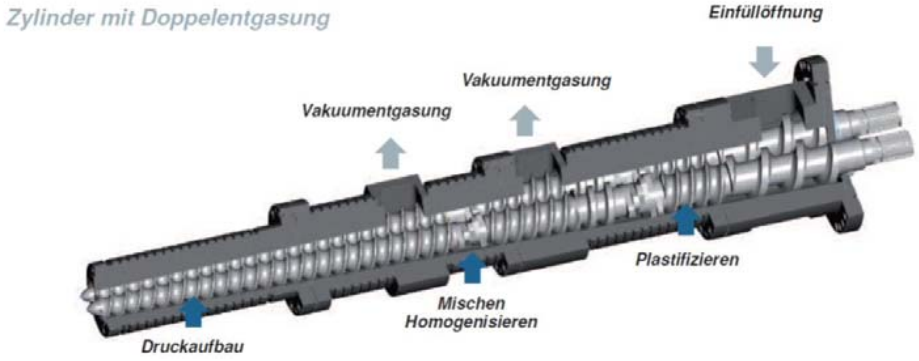
a = distance between axes

- Diameter ration $D_a$ / $D_i$ defines shear stress, degassing and dosing performance
- Specific torque $M_d$ / $a^3$ defines filling degree and troughput performance
- Rpm **n** defines shear stress and mixing performance

# *Extrusion lines – specialized Layouts*

- Conical co-rotating twin screw layout
- Increased feed volumina due to bigger feed opening
- Increased torque due to increased srew diameter
- Higher pressure => lower melt temperatures

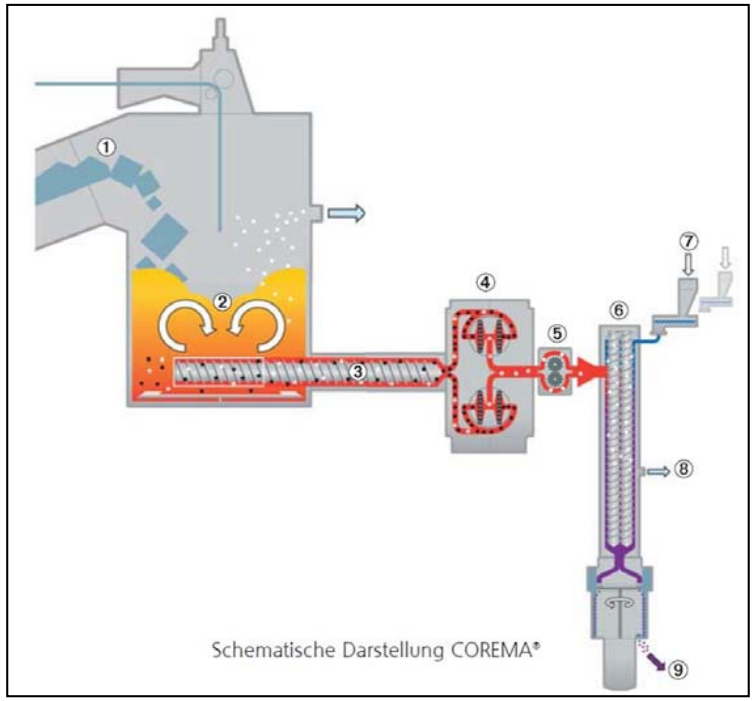



Quelle: MAS

# *Extrusion lines – specialized Layouts*

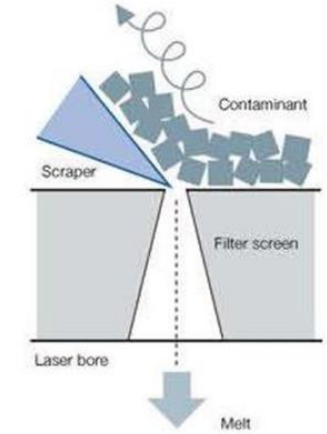
- Homogenisation (single screw) separated from Compounding (twin screw)
- High pressure generation (single screw) with advantages in melt filtration
- Effective degassing and dosing of additives in twin screw extruder

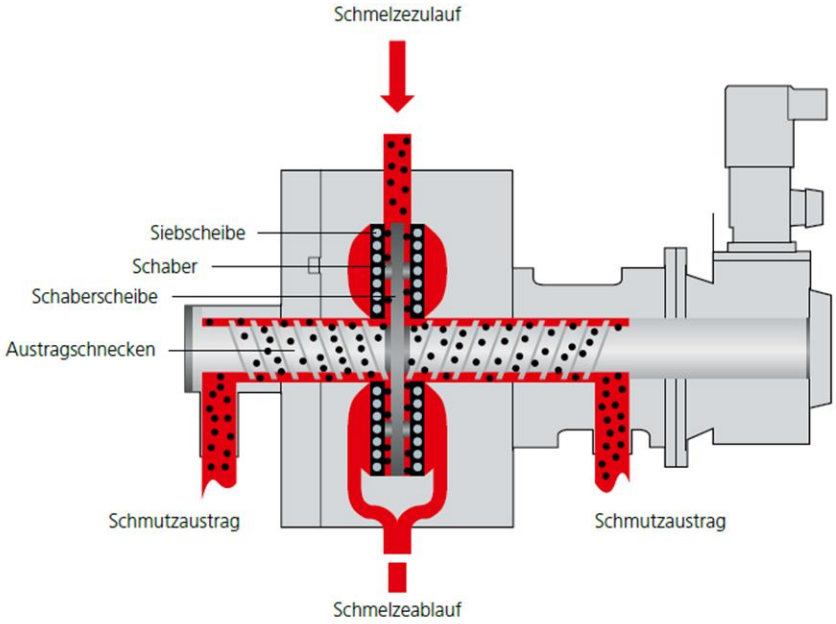


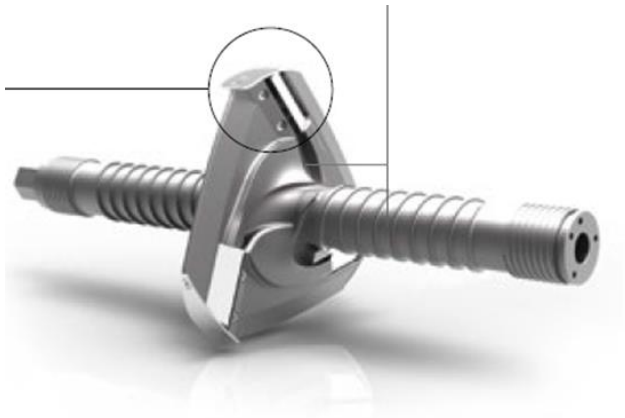

Quelle: Erema

# *Polymer melt filtration (Extrusion)*

- Filter screen designed as a disc
- Filter holes drilled with laser
- Continiously self cleaning filtration system
- Automated operation

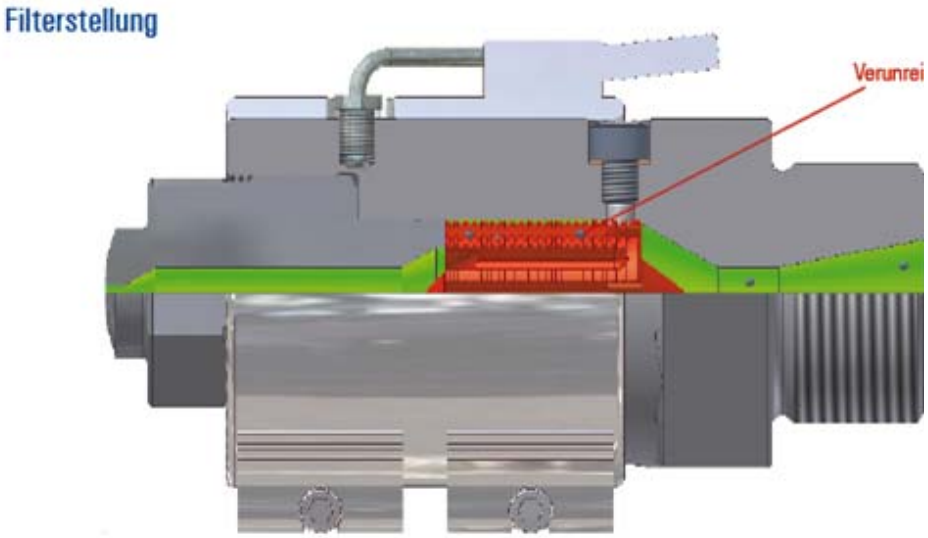


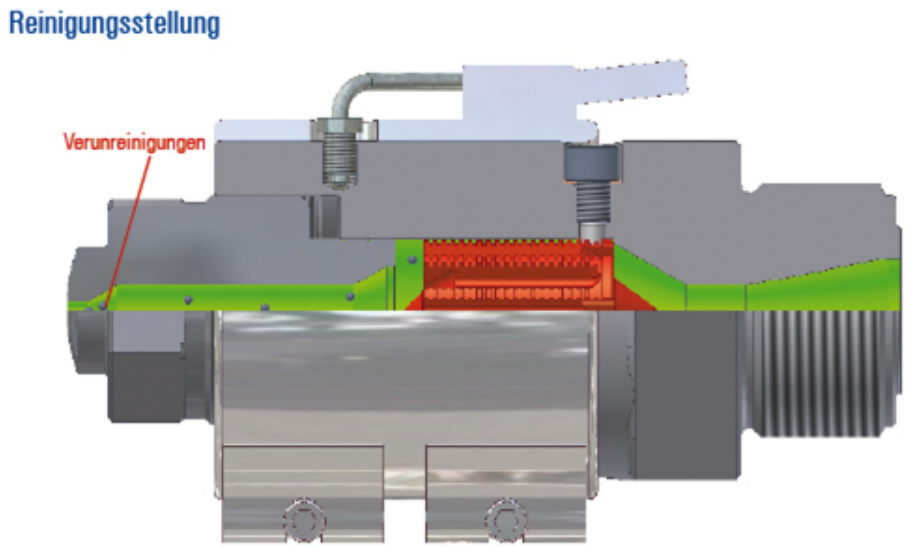



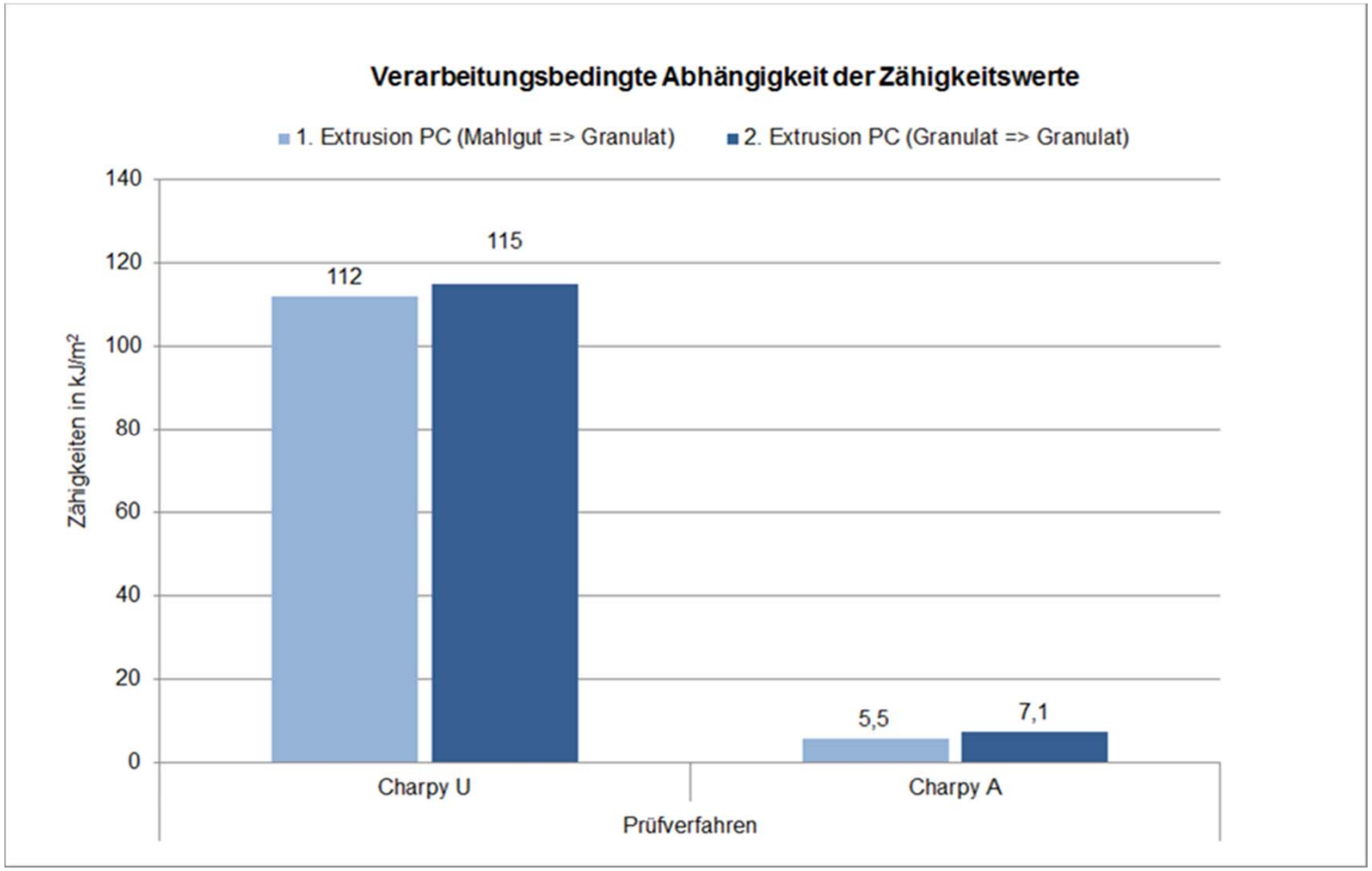
Quelle: Erema

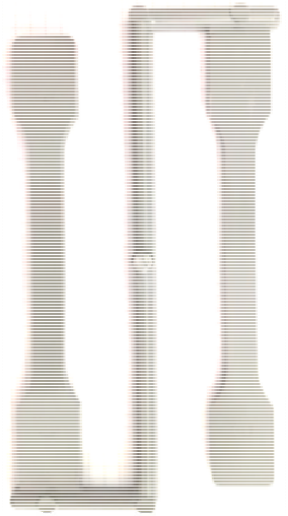
# *Polymer melt filtration (Injection molding)*



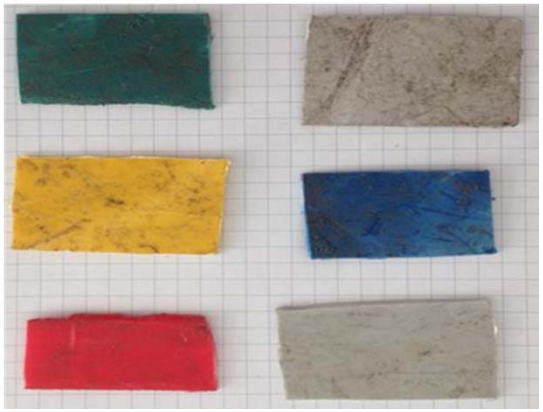



# *Effect of proper extrusion on mechanical properties*



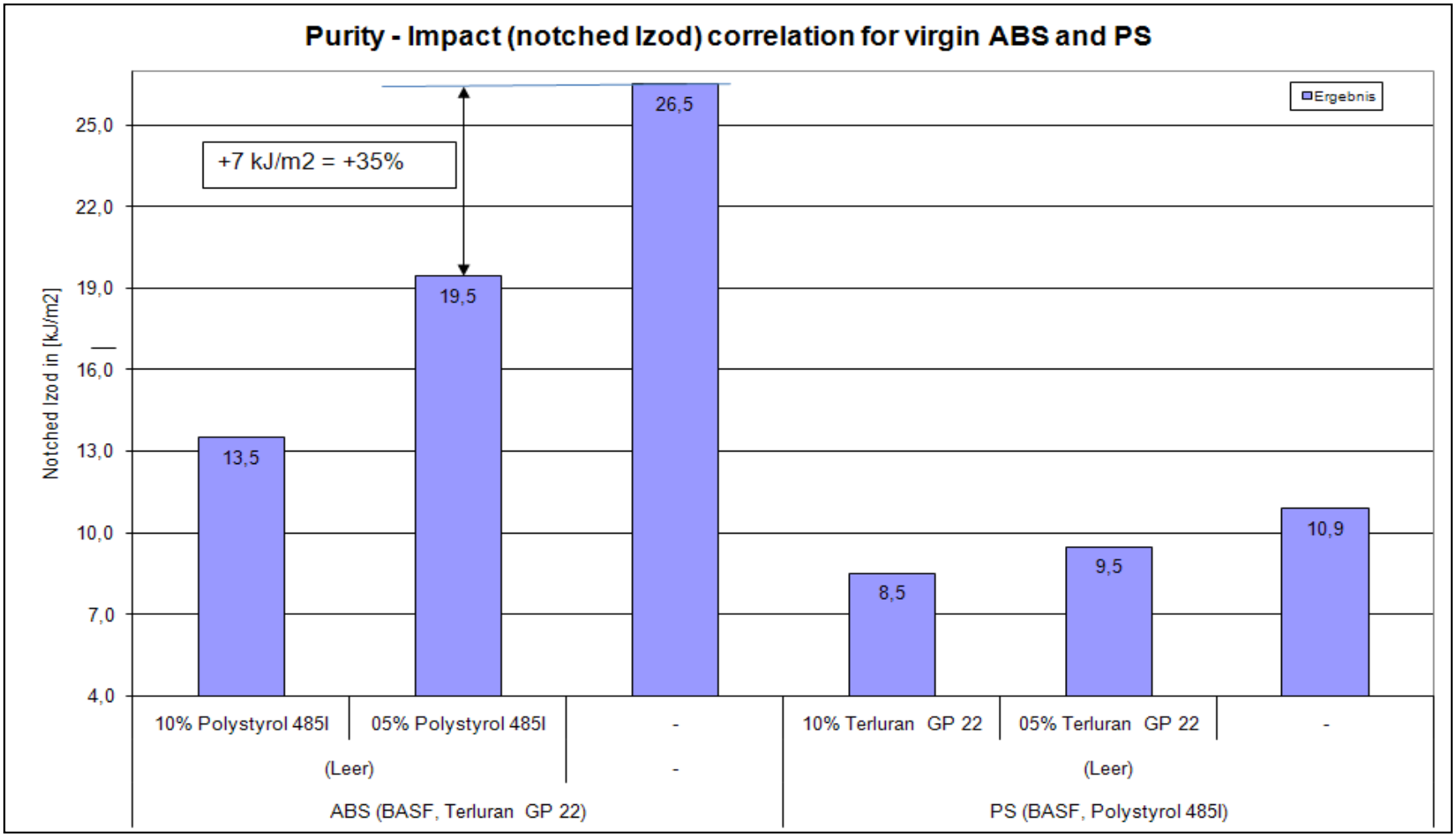



# *Effect of cleaning on mechanical properties*



| | Kennwerte vor und nach Reinigung der Mahlgüter | | | | | |
|---|---|---|---|---|---|---|
| | Reinigung | Mw E-Modul MPa | Mw $\sigma_M$ MPa | Mw $\varepsilon_B$ % | Mw Charpy U kJ / m$^2$ | Mw Charpy A kJ / m$^2$ |
| Polycarbonat Mahlgut | Nein | 2646 | 62,5 | 7,7 | 112 | 5,5 |
| | Ja | 2610 | 59,9 | 9,8 | 114 | 6,8 |
| Polyamid Mahlgut | Nein | 1937 | 50,9 | 8,1 | 90,9 | 5,3 |
| | Ja | 1890 | 47,4 | 10,1 | 91,2 | 6,4 |

# *Effect of polymer cross contamination*

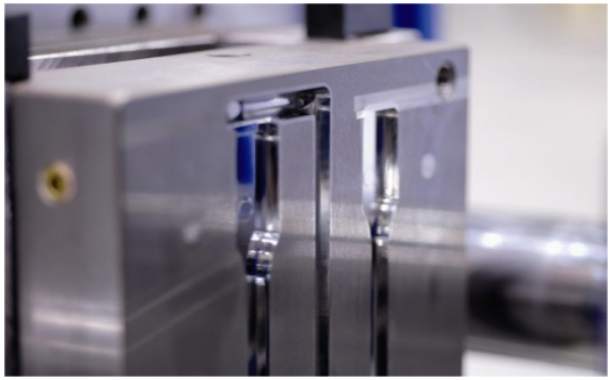


# *Effect of additives (impact modifier) on mechanical properties*

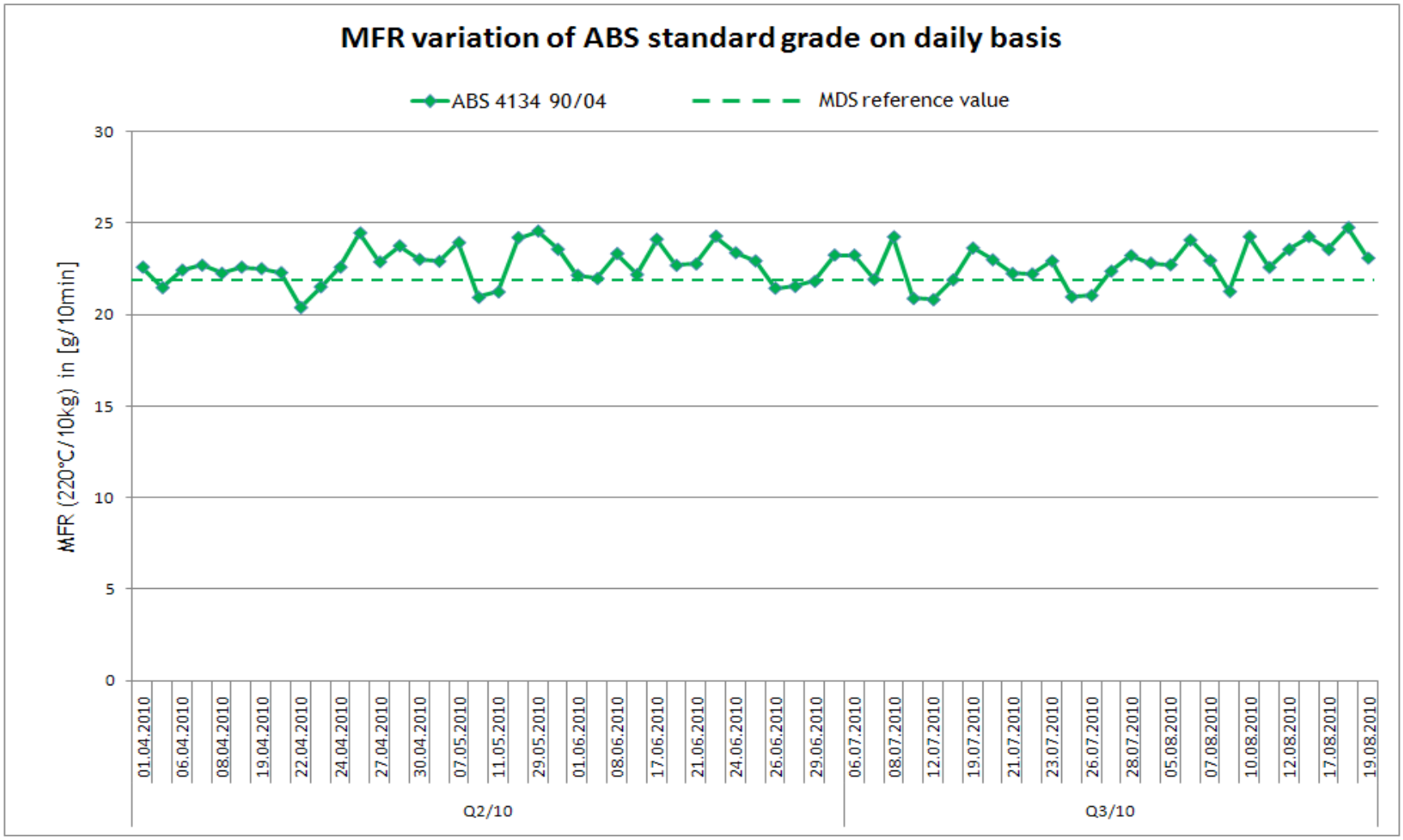
| | Mechanische Kennwerte der PC Compounds | | | | |
|---|---|---|---|---|---|
| | Mw E-Modul MPa | Mw $\sigma_M$ MPa | Mw $\varepsilon_B$ % | Mw Charpy U kJ / m$^2$ | Mw Charpy A kJ / m$^2$ |
| 100% Polycarbonat Erstextrusion | 2646 | 62,5 | 7,7 | 112 | 5,5 |
| 100% Polycarbonat Zweitextrusion (Referenzprobe) | 2630 | 60,8 | 5,9 | 115 | 7,1 |
| 98% Polycarbonat 2% Paraloid | 2544 | 57,8 | 6,3 | 117 | 10,2 |
| 95% Polycarbonat 5% Paraloid | 2417 | 54,4 | 6,6 | 122 | 13,2 |

# *Quality control in polymer recycling*

- Product Knowledge is essential for long term success on the market
- In-house quality control procedures guarantee earliest „bad trends“ detection
- Costs for Invest and staff are compensated with reduced overall operational costs and claim risks

# *Quality control in polymer recycling*



# Topics

- General Introduction
- Polymer Overview
  - Global role of polymers
  - End of life (waste) situation
- Creating high grade recycled polymers
  - Crushing /Cleaning
  - (Separation and sorting)
  - Granulation  (Modification)
- Processing of recycled polymers

styro®

## SAUBERE ROHSTOFFE

- Völliger Verzicht auf Substanzen wie Zink, Cadmium und Blei
- Völliger Verzicht auf PVC für die Herstellung unserer Stempel
- Permanentes Lieferanten-Screening nach Umwelt- und Qualitätszertifizierungen

## SPARSAMER ENERGIEEINSATZ

- Wärmerückgewinnung aus der Produktion zur Gebäudeheizung
- Kühlung der Spritzgussmaschinen mit Außenluft
- 62% des Strombedarfs stammen aus erneuerbaren Energien

## VERANTWORTUNGSVOLLE PRODUKTION

- Ca. 80% aller Produktionsabfälle werden wiederverwertet
- 100% Recycling bei mechanisch nicht beanspruchten Teilen
- Ausschuss in der Produktion ist kleiner als 0,3%
- Die gesamte Produktion ist völlig frei von Abwässern

## WENIGER $CO_2$

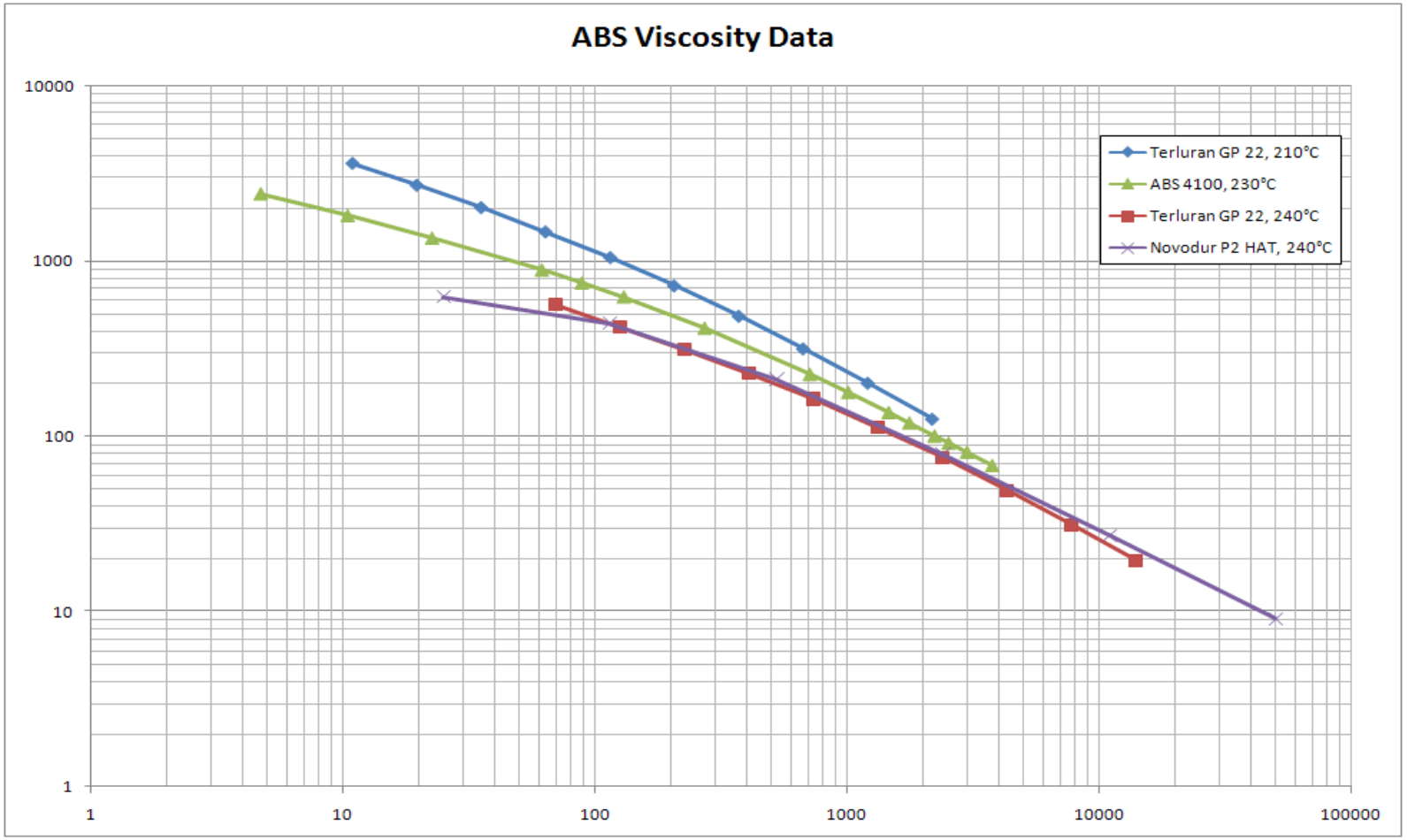
- 1000 Tonnen Einsparung an $CO_2$ Emissionen rein durch Reduktion von fossilien Brennstoffen, Erdgas und Strom seit Mitte 2001
- 250 Tonnen zusätzliche Einsparung an $CO_2$ durch Umstieg von Heizöl auf Erdgas.


**Wer Trodat Stempel verkauft, setzt also automatisch auf verantwortungsvoll hergestellte Artikel.**



GREEN
TM
Electrolux
Electrolux
ultraone

# *Recommendation I – Lowering Temperature profiles*




=> Temperature settings minus ~ 5%

# *Recommendation II – Lowering rpm (dosing)*

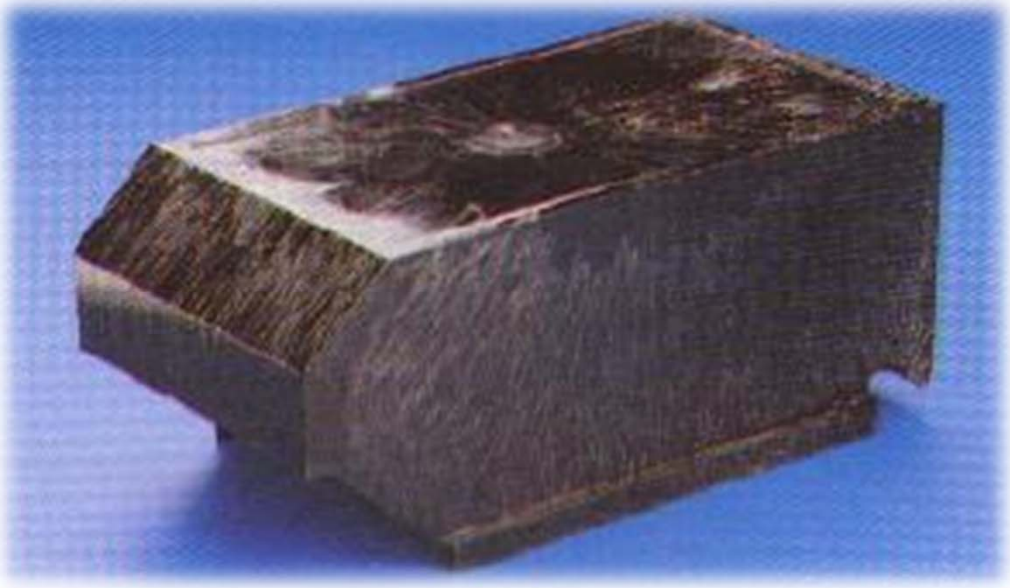
$$n\left[\frac{U}{min}\right] = \frac{Vu\left[\frac{m}{s}\right]}{D[mm] * Pi} * 60000$$

n….. Revolutions per minute
Vu… max. peripherical speed
D…. Screw diameter
Pi…..3,1415

| Polymer | Vu max [m/s] | n max [U/min] (srew diameter 40mm) |
|---|---|---|
| PP | 0,9 | ~400 |
| ABS | 0,4 | ~200 |
| PC | 0,2 | ~100 |
| PA | 0,3 | ~150 |

=> Minimized thermal stress to the melt

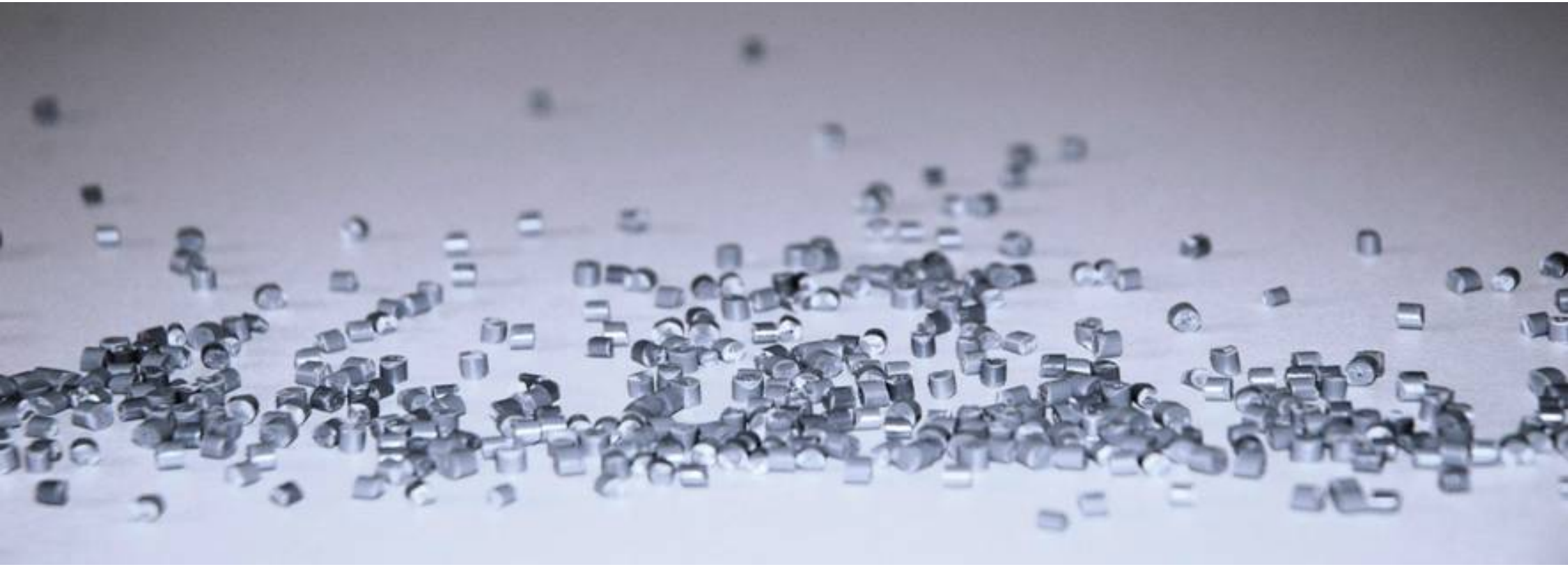
# *Recommendation III– Increasing backpressure (dosing)*



| Polymer | Backpressure [bar] |
|---|---|
| PP | 150-200 |
| ABS | 100-150 |
| PC | 100-150 |
| PA | 100-150 |

=> Homogeneous melt temperature
=> Reduction of splays

- Mechanical Recycling of polymer waste is in strong competition with energetic recycling (Incineration)
- Mechanical Recycling of post industrial or post consumer plastic waste makes sense in both, ecologically and economically.
- Effective and efficient logistics in collection of post industrial or post consumer plastics waste is the basis for sucess.
- Quality controlled effective logistics in combination with proper separation (if necessary) and granulation/modification technologies give high grade secondary raw materials suitable for high quality products



# QUESTIONS?

HEC Höggerl Engineering & Consulting

mailto: hec-office@gmx.at

mobile: 0043 664 8113644

skype: hoegue1