UNIVERSITEIT GENT

FACULTY OF ENGINEERING AND ARCHITECTURE

Uitdagingen voor de mechanische recyclage van kunststoffen

Prof. Dr. Kim Ragaert

Head of 'sustainable use and recycling of polymers' research

Center for Polymer and Material Technologies CPMT
Department of Materials Science & Engineering
Faculty of Engineering and Architecture, Ghent University, Belgium
kim.ragaert@ugent.be

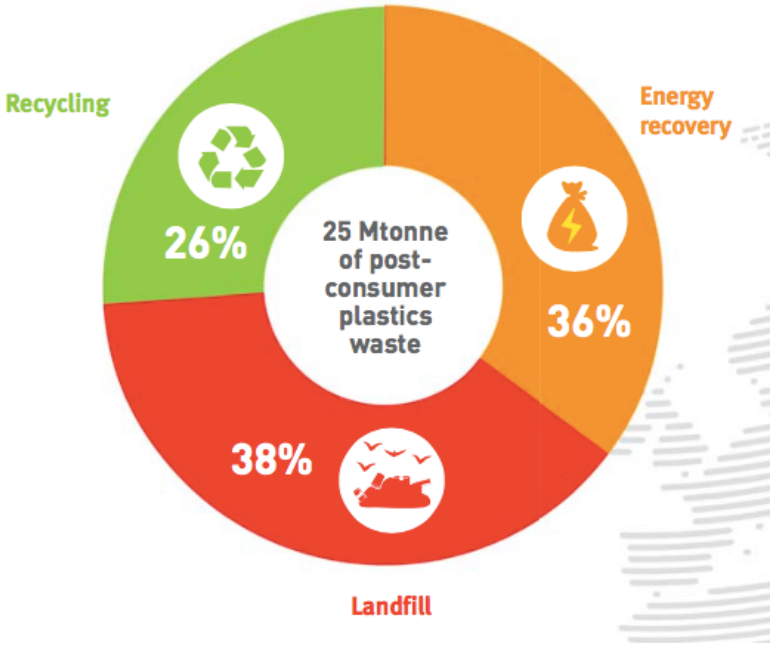
Onderzoeksgroep CPMT

- UGent – Ingenieurswetenschappen & Architectuur
- Vakgroep Toegepaste Materiaalwetenschappen

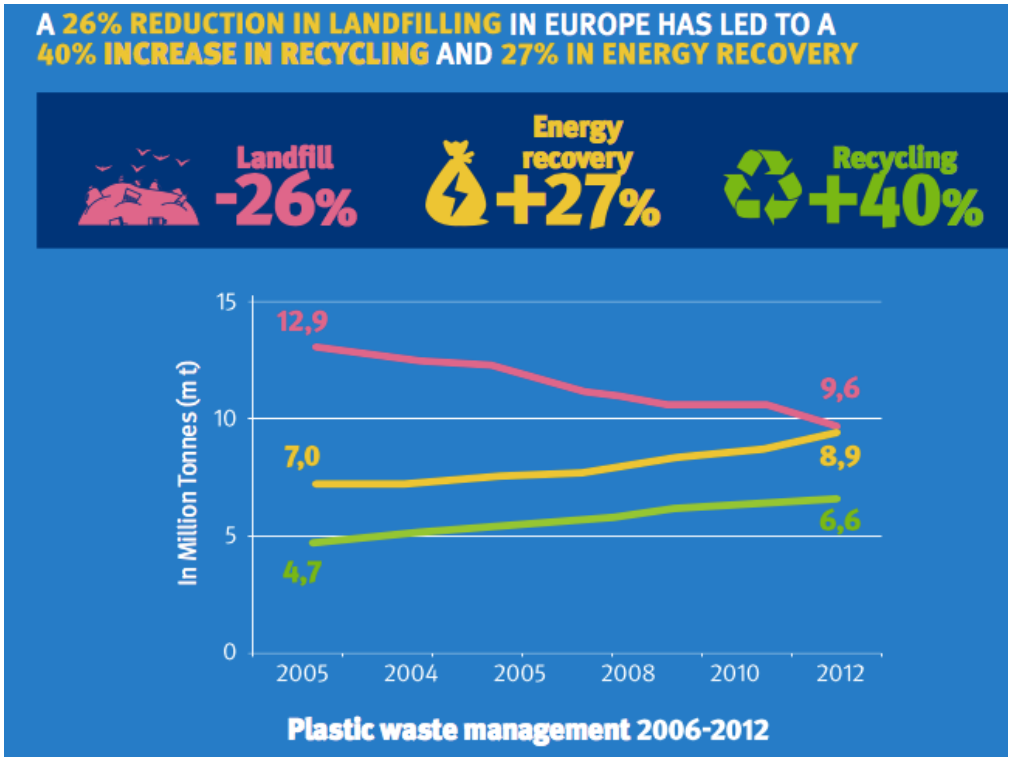
Overview

- Introduction & Framework
  - Solid Plastic Waste in the EU
  - The origins and pathways of SPW
- Mechanical recyling of mixed plastics
  - What are the challenges?
  - How do we adress them?
  - Where does the future lead?

Solid Plastic Waste: the now



Source: PlasticsEurope, Plastics the Facts 2014



Recent legislation on SPW

Green Book Plastic Waste in a Nutshell

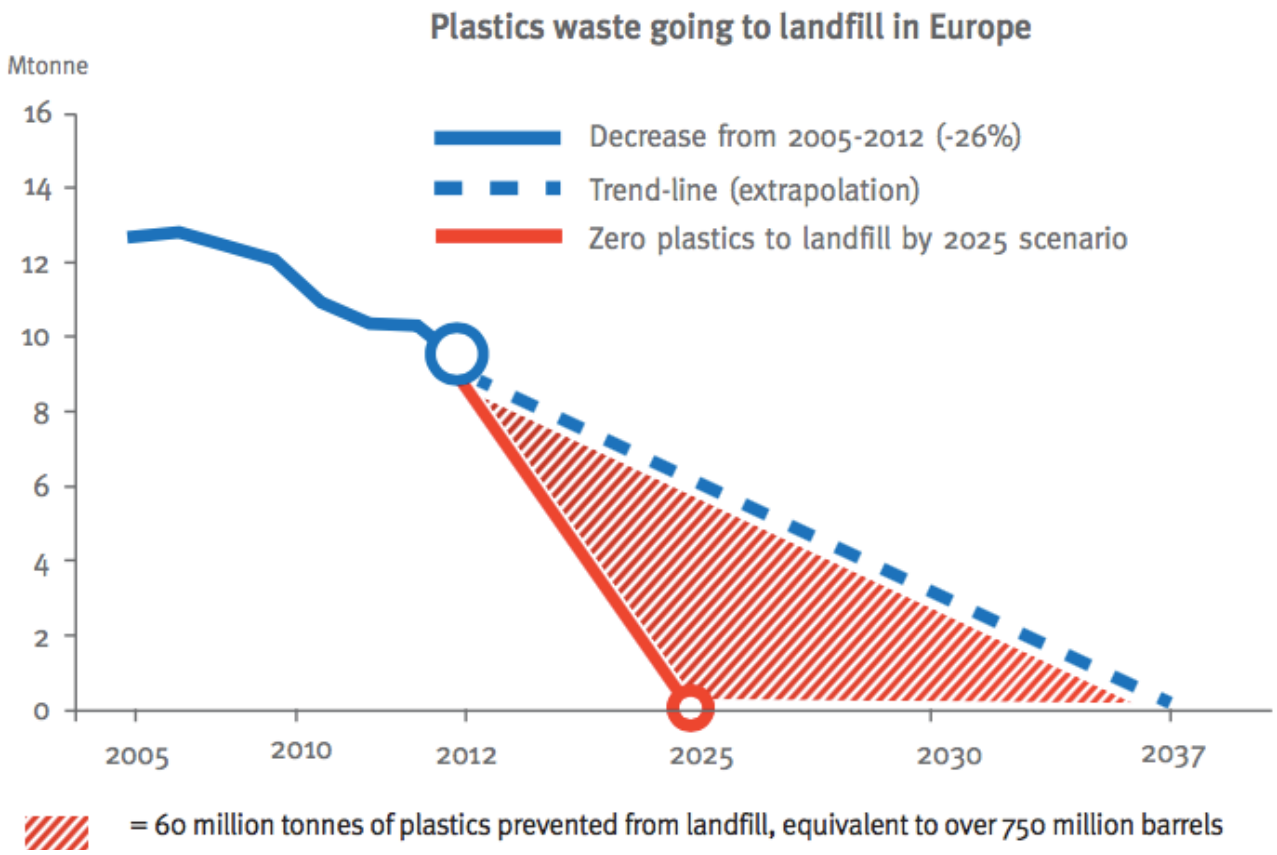
- → Transit to circular economy, Resource efficiency, new economic models
- → End landfilling Plastic waste
- → Design allowing full, simple and economic recycling, consumer information
- → Thermal treatment must remain an exception
- → Capture ALL plastic waste rigorously
- → Extended producer responsibility in the focus
- → Enhanced international co-operation (ESM)
- → Internalisation of costs (*polluter pays*)
- → Full implementation and control

We need new investments (sorting & recycling) & new applications for r-plastic

H. Maures,
EU Commission - DG ENV,
2014 (Frankfurt)

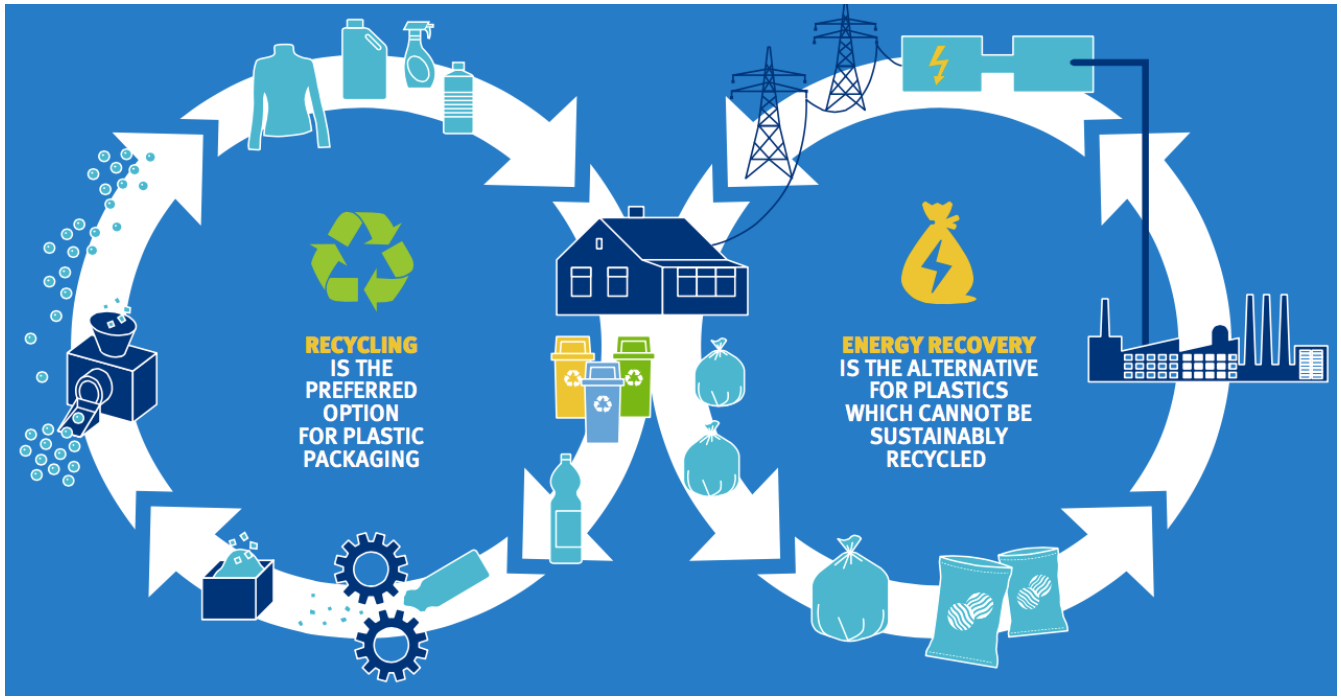
Solid Plastic Waste: the tomorrow?

Landfilling should be out of the question



Source: PlasticsEurope

Solid Plastic Waste: the tomorrow?

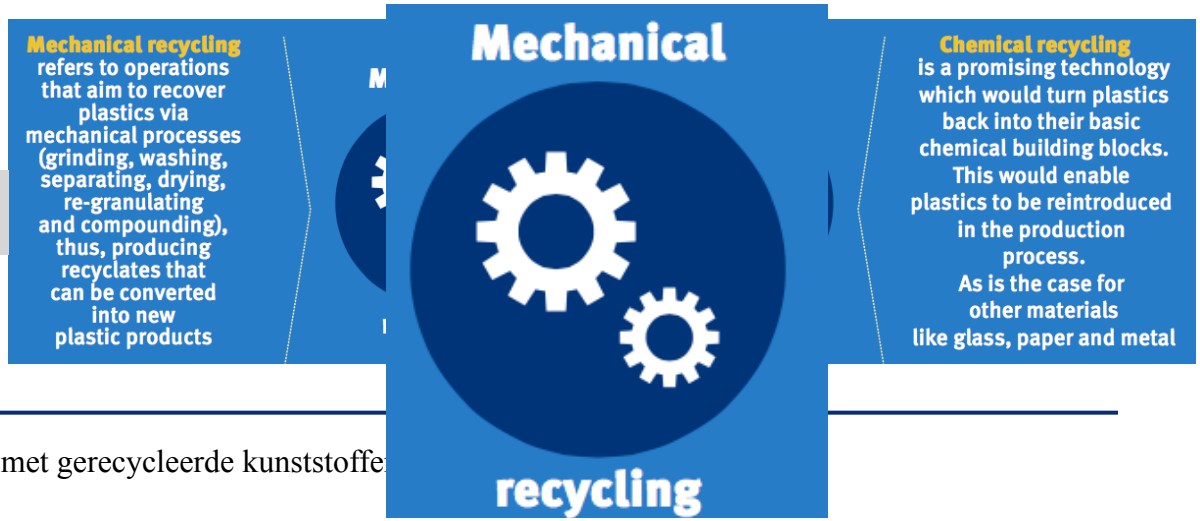


There is a limit to the cost-benefit balance for **recycling** plastics

35-50%

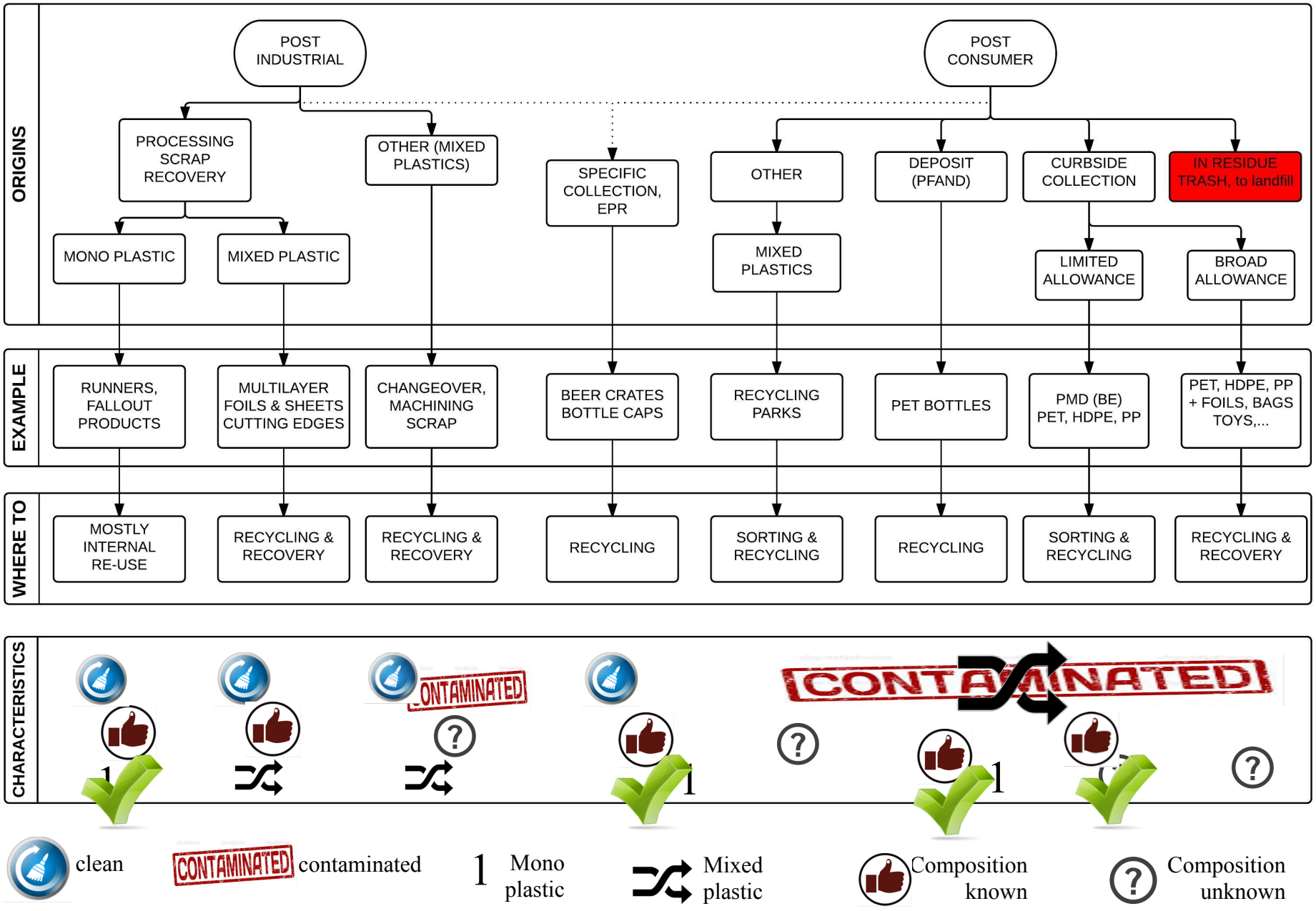
Recovery remains a more than acceptible option beyond this limit

How to **recycle**?



Source: PlasticsEurope

SPW: where does it come from?



SPW: pathways

- Many (mono) streams are already well-handled
- Some streams have very good system in place
  - e.g. PET bottles from PET-HDPE-PP
- Most remaining SPW is mixed plastics

- For (re-)processing: mono-streams are better
- So try to separate/sort as much as possible

Current separation of mixed plastics

Mono streams are always better

MECHANICAL SORTING BY SIZE, SHAPE AND WEIGHT

- ***Wind shifting***
- Ballistic

OPTICAL SORTING

- ***Near infrared*** (NIR) + MIR
- Laser
- Colour or shape

DENSITY SORTING

- ***Float-sink tank***
- Centrifuge
- Hydrocyclone

OTHER SORTING

- ***Manual*** (by product)
- Electrostatic (ES)
- X-ray

Upcoming: tracers

Current separation of mixed plastics

What are the issues?

- *Odours (post consumer) & colours*
- *Contaminations (paper, wood, metal)*
- What is possible on products, is not always possible on flakes
- Cost – benefit of separation?
  - e.g. mixed polyolefins
- Separation is not always possible
  - e.g. multi-layer foils (PET-PE)

MIXED PLASTICS

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  (processing, after sorting)
  - What are the challenges?
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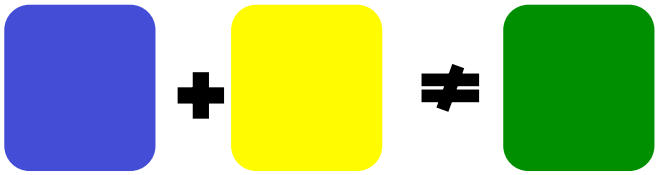
Mechanical recycling of mixed SPW

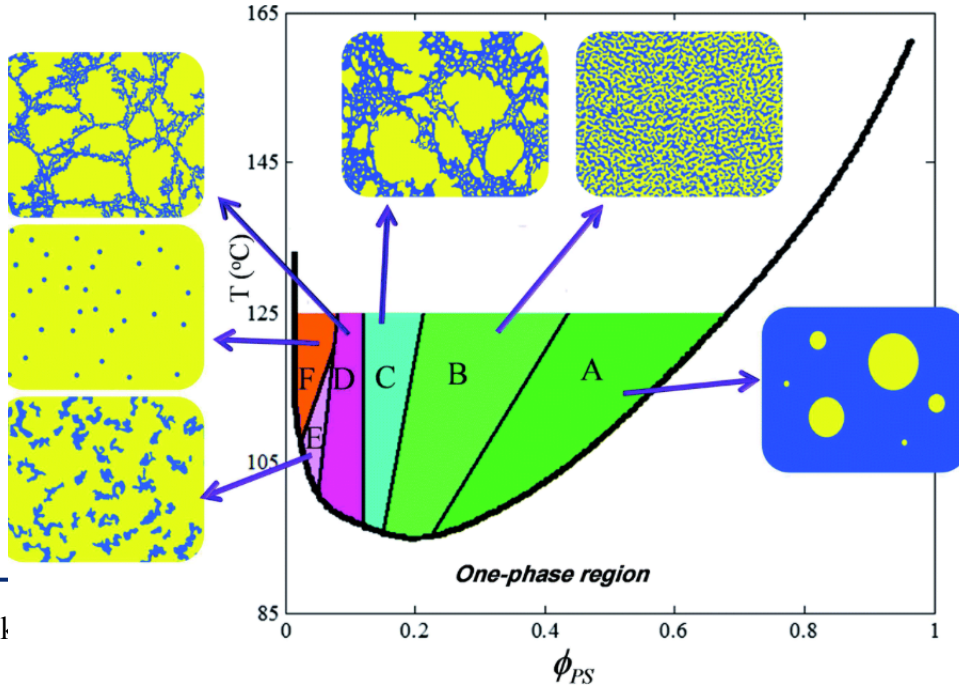
- Inflow:
  - post-industrial and post-consumer
  - separation impossible or not viable

- What exactly is the problem?
  - Non-constant composition (some cases)
  - ***Immiscibility of polymers***

‘Polymers do not mix’

- Mixed plastic waste = blend
- Plastics **will not mix** spontaneously in the screw, not even the ones that are ‘alike’ like PP-PE





Yeganeh et al, Anomalous phase separation behavior in dynamically asymmetric LCST polymer blends
RSC Adv., 2014,**4**, 2809-12825

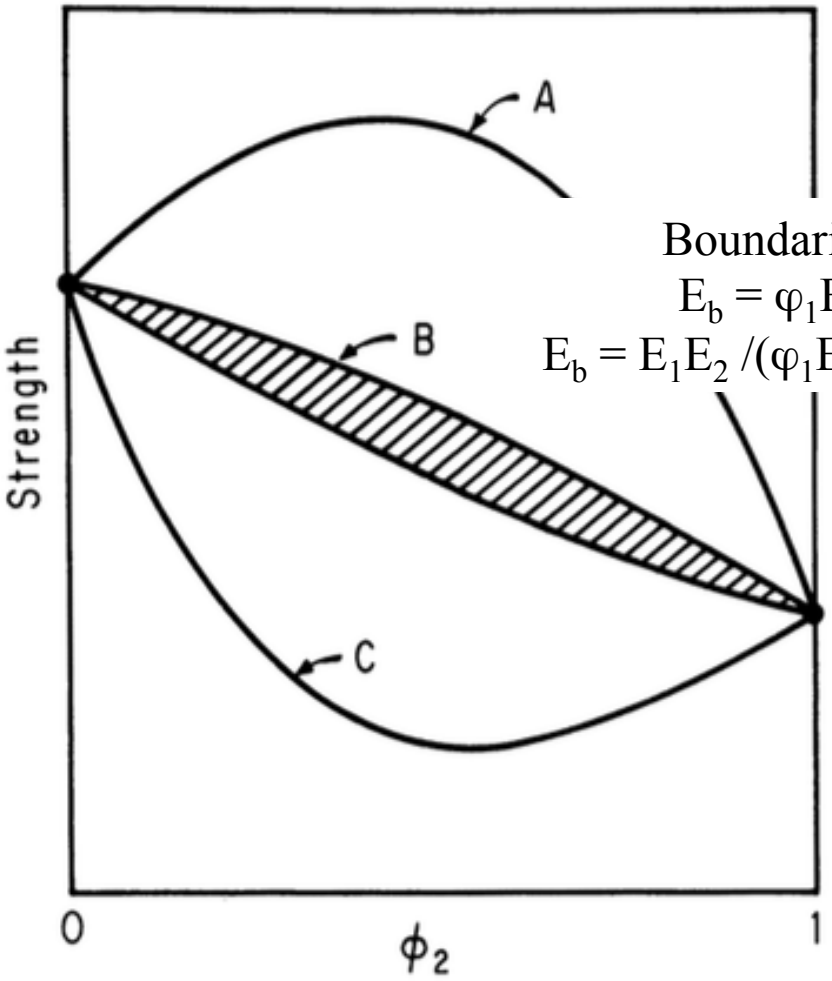
Why care about immiscibility?

Mechanical properties dependent on miscibility

A. *Synergy in miscible blends (rare!)*

B. (nearly) additive response for immiscible blends (good adhesion)

C. Grossly immiscible blend: failure due to poor interfacial adhesion



Boundaries for B:

$E_b = \varphi_1 E_1 + \varphi_2 E_2$

$E_b = E_1 E_2 / (\varphi_1 E_2 + \varphi_2 E_1)$

Source: Paul, Polymer Blends: Phase behaviour and property relationships, 1985

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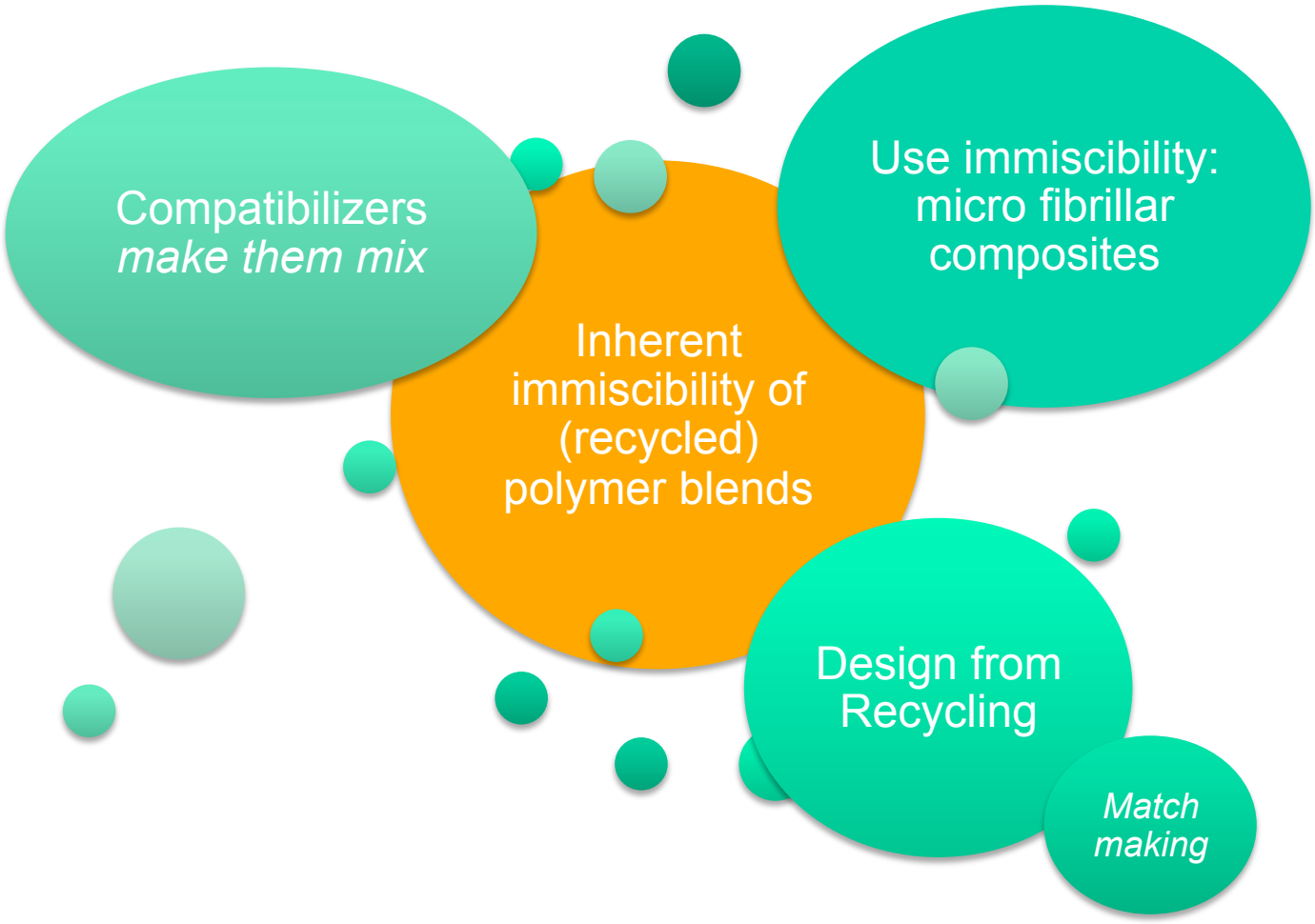
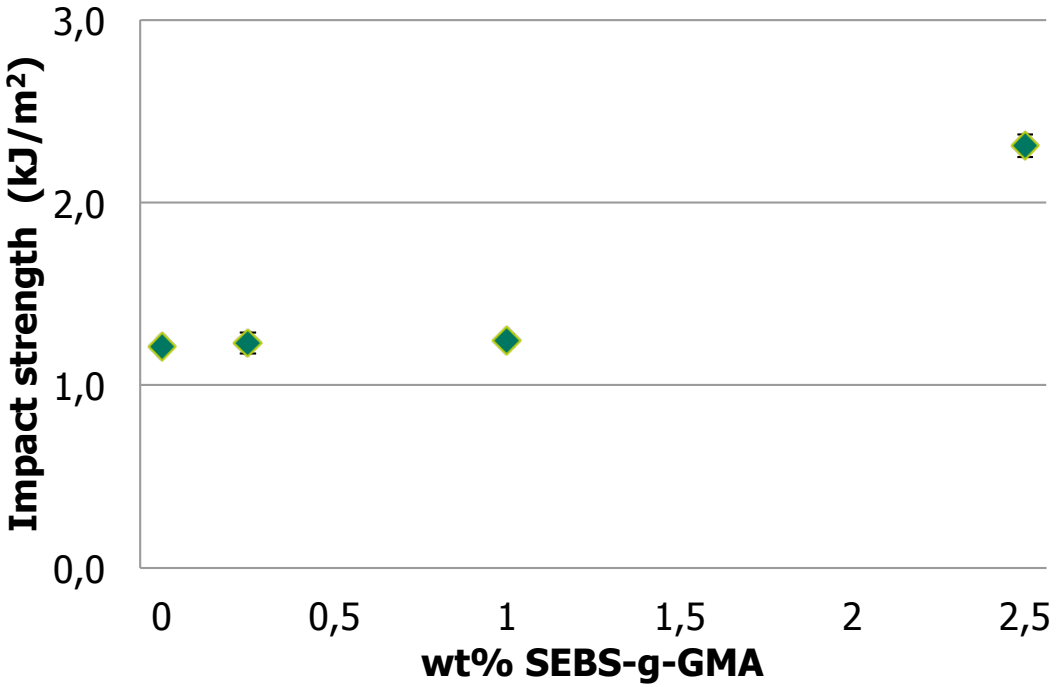
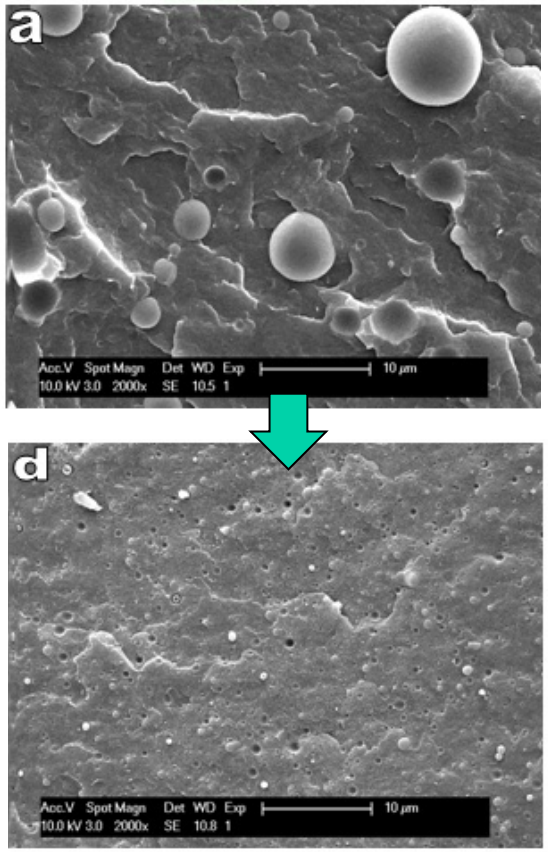
How to process mixed SPW



The use of compatibilizers

Compatibilizers reduce effects of phase separation = improve mechanical performance





Example 2: addition of 2,5 wt% SEBS-g-GMA tot 80/20 PP-PET

Upcycling: micro fibrillar composites

Polymer-polymer composites

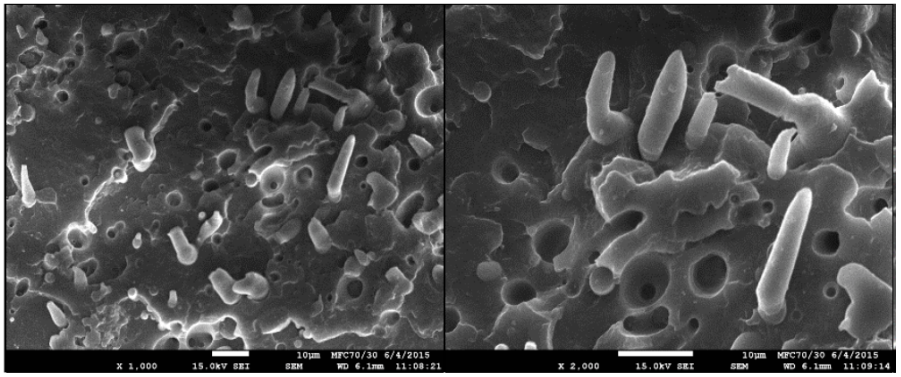
Instead of adding compatibisers (= reducing immiscibility)

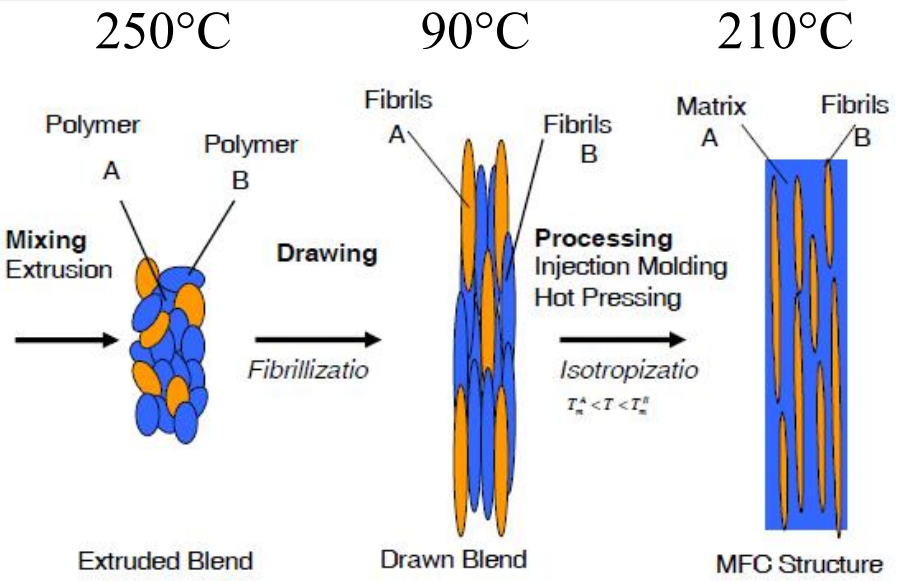
→ Taking advantage of immiscibility and strengthen matrix with second phase

= ***Micro Fibrillar Composites***

→ Upcyling mixed streams (e.g.: PP + PET)

→ Upcycling composite based recyclates





Source: Evstatiev et al., Polymer Engineering and Science 42 (2002)

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Resource efficiency

match making

Design from Recycling

≠ Design *for* Recycling

Instead:

1. Designing products specifically for to be manufactured in recycled polymers *(‘as is’ or upgraded w/ virgin)*
2. **Matchmaking** between recycled (mixed) polymers and (new) products
3. Identifying strengths of existing waste streams (upcycling)
4. Demonstrate eco- and resource efficiency

Design from Recycling - example

'problem material'

- Recycled PE, contaminated with Al
- Source unknown
- Is currently sold as 'low value'

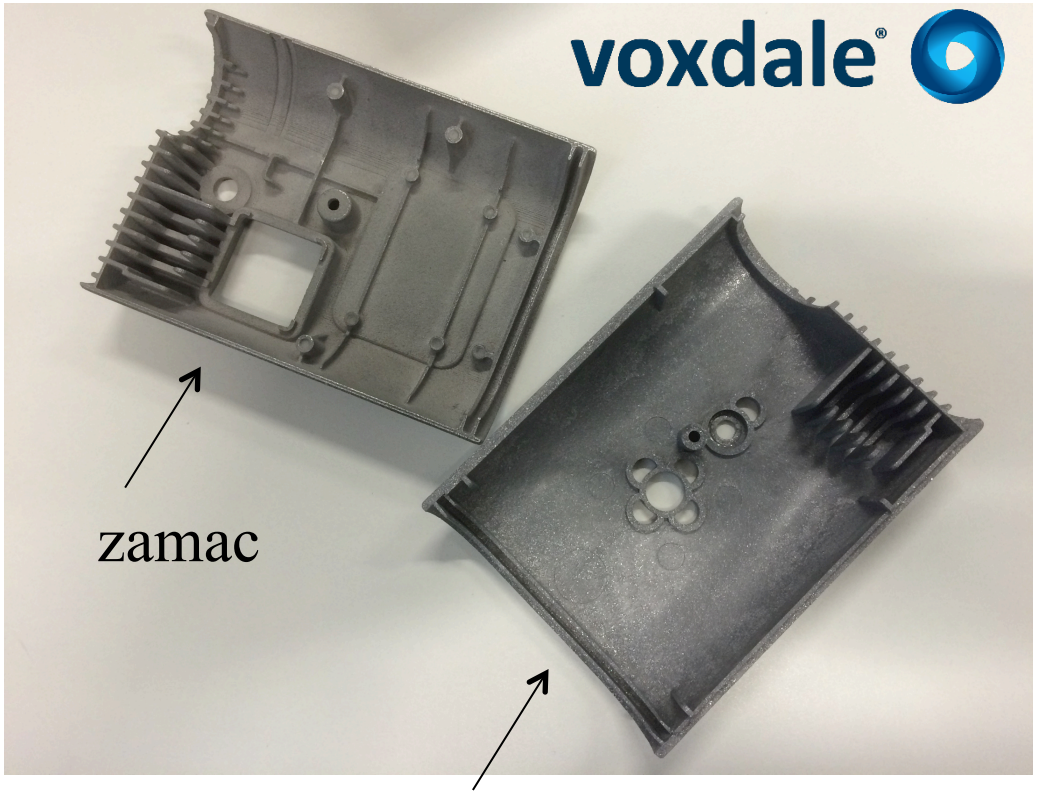
→ possible strong points

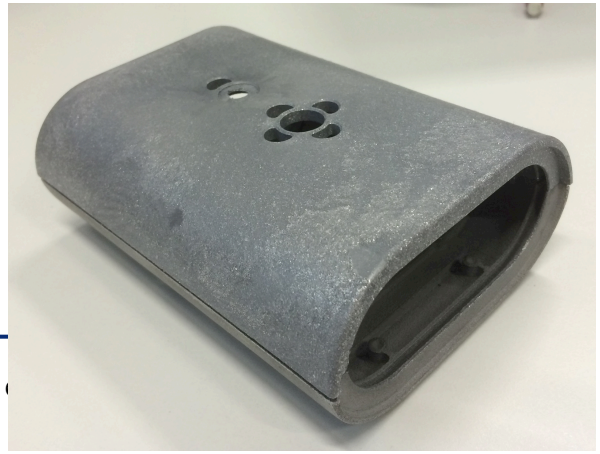
- → Design look
- → Conductivity (heat, ESD) (?)
- → Stiffness (> 1 GPa), impact properties (near 20 kJ/m^2)

Design from Recycling

Identified product: mini-beamer cover

Design from Recycling - example





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Future outlook

- Legislation will continue to increase pressure

- **Improved processing of mixed SPW**
- **Improved resource efficiency**
  - ***Design from Recycling***

- Improved sorting
- More Design 4 Recycling
- 3D printing?
  - Obstacles: shrinkage, uncertain composition

Contact information

Technologiepark 915

9052 Zwijnaarde

Part of

Member of

prof. dr. Kim Ragaert

Sustainable Use and Recycling of Polymers & Composites

kim.ragaert@ugent.be

0476/322 700

prof. dr. Ludwig Cardon

Head of CPMT

ludwig.cardon@ugent.be

0478/224 335