The REMIX project

The technological challenge for mixed plastics recycling

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Content

- The REMIX objectives
- Main technical challenges of mixed plastics recycling
- The packaging, ELV and WEEE challenges in detail
- The WEEE study case and its pilot line
- Conclusion
* A Preparatory Action for the Recycling of Mixed Plastics Waste (Response to the call for tenders N° 154/PP/ENT/PPA/12/6476)

1. A state-of-play of the current situation in mixed plastics recycling
2. Benchmark of existing and emerging technologies
3. The identification of existing and emerging markets for recycled mixed plastics waste
4. Demonstration at pilot line of sorting and recycling process using mixed plastics WEEE
Mixed plastics wastes are polymer compositions resulting from waste streams containing at least two polymers or blends of polymers.

- 24.5 Mt of post-consumer plastics waste are generated each year.
- Mostly in packaging, but not only!
Plastics waste generation per sector and plastic treatment (EU27, 2011)

Where/how do they end up?

- Landfill: 25%
- Energy recovery: 42%
- Mechanical Recycling: 33%
- Feedstock recycling: 0%
- Incineration: 0%

24.50 Mt

EU27 percentages of post-consumer plastics wastes going to landfill (2011)

Source: Consult GmbH
A multitude of plastics ... for a multitude of applications

Bio-based plastics, rPET ...

Fibre-Reinforced Composites ...

Moulded Interconnect Devices ...

www.recyclingbins.co.uk
The different levels of complexity of plastics recycling

Post production monomaterial parts converting industry

Post production multimaterial parts

Post consumer multimaterial parts

Post consumer monomaterial parts

« 2/3 of recycled PP in automotive come from monomaterial post production wastes » (Renault)
Mixed plastics general issues

☑ **Most plastics are chemically not compatible**

« 5% of non compatible plastics => Up to 50% of properties loss »

→ A minimum of sorting is mandatory

☑ **Plastics are in a narrow range of density**

With densities overlappings depending on formulation and additives

☑ **Colour sorting is not suitable**

Any plastic can have any colour

☑ **Variability of the sources**

Plastics composition of post consumer streams are changing depending on seasons, areas, pretreatments ...
Today’s commercial applications of recycled mixed plastics?

**Diluted in virgin materials:**
- No need to develop specific tools/equipments
- No risks regarding availability and stability
- Slight decrease of the overall production costs

**Direct use:**
- Mainly low added value plastic parts
- Often thick and bulky parts
- Specific tools/equipments required

*Park bench out of mixed plastics, source: Recycledplastics.co.uk*

There are only few high added value products made of 100% of post consumer plastics
Key technical challenges

Collection
- Large scale collection
- Increasing the stability of the streams

Sorting
- Increasing throughputs
- Lowering costs
- Removing contaminants and hazardous substances
- Sorting black plastics

Compounding
- Dealing with the variability of the stream → stability, disponibility
- Improving materials properties

Conversion
- Adapting tools and equipments
- Learning how to process the materials
- Learning to design plastic parts made of recycled plastics

Characterizing faster and more efficiently from streams to end-products
Packaging is the most advanced plastics waste stream.

**Waste packaging Composition**

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE</td>
<td>32%</td>
</tr>
<tr>
<td>PP</td>
<td>19%</td>
</tr>
<tr>
<td>HDPE</td>
<td>19%</td>
</tr>
<tr>
<td>PET</td>
<td>15%</td>
</tr>
<tr>
<td>PS</td>
<td>9%</td>
</tr>
<tr>
<td>PVC</td>
<td>3%</td>
</tr>
<tr>
<td>Others</td>
<td>3%</td>
</tr>
</tbody>
</table>
### Packaging Challenges

#### Technical success stories

- PET
- HDPE - LDPE

#### Technical bottlenecks

- Contaminants, which decrease recovery yields
- Not chemically compatible labels (PVC)
- Multilayers packaging (food conservation improvement)
- New materials (PLA bottles, oxoplastics)
- Increase of black parts (Trays, wine bottles...)
- Mix of Rigid and flexible plastics

#### Economical limits

- Large scale Collection
- Competition with landfill and energy recovery
- Low price of virgin materials
- Investments needed to sort more plastics (PS...)

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**Diagram:**

1. Product Manufacture
2. Product Use
3. Collection & Reprocessing
4. Raw Material

**Images:**

- PET bottles and materials
- HDPE - LDPE materials

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**Technical Loop:**

- Closed loop recycling
- Recycling process
- Sustainable packaging solutions
ELV recycling is not about plastics

Plastics consist of a by-product of the ELV recycling process
ELV plastics waste treatment in the EU27 (2011)

- Mechanical recycling: 13%
- Energy recovery: 21%
- Feedstock recycling: 1%
- Landfill: 65%

New Clio Renault plastic content
170kg – 17%

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight</th>
<th>Material</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>36 %</td>
<td>PE</td>
<td>4 %</td>
</tr>
<tr>
<td>PU</td>
<td>24 %</td>
<td>PC</td>
<td>4 %</td>
</tr>
<tr>
<td>PA</td>
<td>11 %</td>
<td>PVC</td>
<td>3 %</td>
</tr>
<tr>
<td>PET</td>
<td>6 %</td>
<td>PMMA</td>
<td>3 %</td>
</tr>
<tr>
<td>ABS</td>
<td>5 %</td>
<td>Others</td>
<td>5 %</td>
</tr>
</tbody>
</table>
## ELV plastics challenges

<table>
<thead>
<tr>
<th>Technical bottlenecks</th>
<th>Economical limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity of plastics incl. PVC, plastics with fillers and legacy additives...</td>
<td>Prohibitive dismantling costs =&gt; shredding</td>
</tr>
<tr>
<td>Mainly black =&gt; automatic sorting difficult</td>
<td>The level of investments needed to sort plastics</td>
</tr>
<tr>
<td>Contaminants : rubbers, PU foam, wood, residual metals, oil, fuel ...</td>
<td>Low Price of virgin materials</td>
</tr>
<tr>
<td>Increasing use of composites to decrease the average car weight</td>
<td>Competition with landfill</td>
</tr>
<tr>
<td>Increasing use of plastic parts with electronic functions</td>
<td>Large scale collection</td>
</tr>
</tbody>
</table>

Trends => ELV in 10 to 15 years
WEEE plastics fraction
(20 to 25 wt% of the WEEE)

Shredded to recover metals ... and precious metals from Electronic cards
=> again, the plastic fraction is a by-product

Including exports!

Main polymers used in E&E sector (Western Europe, 2000)

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>33 %</td>
</tr>
<tr>
<td>PS</td>
<td>19 %</td>
</tr>
<tr>
<td>PP</td>
<td>18 %</td>
</tr>
<tr>
<td>PU</td>
<td>8 %</td>
</tr>
<tr>
<td>PVC</td>
<td>4 %</td>
</tr>
<tr>
<td>PC</td>
<td>4 %</td>
</tr>
<tr>
<td>PE</td>
<td>1 %</td>
</tr>
<tr>
<td>Others</td>
<td>7 %</td>
</tr>
</tbody>
</table>

WEEE plastics treatment in the EU (2011)
Behind WEEE: 3 different streams

Collection group 1: Large domestic appliances
Collection group 2: Cooling & freezing appliances
Collection group 3: ICT & CE incl. TV
Collection group 4: Lamps
Collection group 5: Small domestic appliances

- Relatively simple mixtures of plastics
- Comingled collection of small consumer WEEE
  Except screen collected separately

Generate mixtures after metal recovery
# Small Consumer WEEE (except screens) challenges

<table>
<thead>
<tr>
<th>Technical bottlenecks</th>
<th>Economical limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity of plastics incl. PVC, plastics with fillers (talc, glass, CaCO₃...)</td>
<td>Prohibitive dismantling costs =&gt; shredding</td>
</tr>
<tr>
<td>Brominated Flame retardants BrFR (15 to 30%)</td>
<td>Competition with landfill</td>
</tr>
<tr>
<td>Legacy additives / RoHs (Cd...)</td>
<td>Low price of virgin materials</td>
</tr>
<tr>
<td>At least 50% of black plastics =&gt; automatic optical sorting is difficult</td>
<td>The level of investments needed to sort plastics</td>
</tr>
<tr>
<td>Contaminants : rubbers, wood, residual metals...</td>
<td>Large scale collection</td>
</tr>
<tr>
<td>Increasing use of filled-PP</td>
<td></td>
</tr>
<tr>
<td>Increasing use of plastic parts with electronic functions</td>
<td></td>
</tr>
</tbody>
</table>
Why choosing Small Consumer WEEE as a case study?

- Collected quantities are expected to grow from 400kT/year up to 1MT/Year

- Challenging key technical bottlenecks:
  - to sort black plastics, also relevant to other streams (ELV, packaging …)
  - to sort end-of-life plastics containing legacy additives

- Stopping the exports of hazardous WEEE to Asia

- Similar collection and recycling schemes all over Europe
Vision of “Optimal” Treatment
To recover ABS and PS free of BrFR

Preparation
Screening – Dedusting – Grinding – metal removal – drying -

Sink and Float separation
Simplify the mixture (PP-ABS-PS)
Remove plastics with BrFR

Mechanical Recycling
Filtration
Compatibilization

Dry separation
Electrostatic and tribo-électrostatic sorting
To recover good purity ABS and PS and PP

Characterisation – Parts production
- Mechanical properties
- REACH and RoHS compliance

Use Case
Sink and Float sorting

- 2 Stages: density = 1.08 and density = 1

**Fraction <1 – PP (PE and others)**
- 5 to 10%

**Fraction 1.08<d<1 – ABS and HIPS**
- Needs post treatment
- 45 to 55%

**Fraction >1.08**
- Mixture of plastics incl. BrFR
- Energy recovery
- 40 to 45%
ELECTROSTATIC sorting

KWS (Hamos) To remove conductive materials (metals, some remaining wood and also some conductive rubbers)

Use Case

0.2 %

99.8 %
TRIBOELECTROSTATIC separation

Use Case

Electrode

ABS

Mix recirculated

PS

45 %

45 %
Extrusion

**Pellets production**

ABS – 230°C – filtration 300 µm

PS – 220 °C - filtration

Elastomers and non melted plastics removed with filtration during extrusion phase
# Recovered ABS and PS properties approximately 50% of initial stream

<table>
<thead>
<tr>
<th></th>
<th>ABS</th>
<th>PS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purity</strong></td>
<td>&gt; 95% ABS</td>
<td>&gt; 90% PS</td>
</tr>
<tr>
<td><strong>Tensile modulus (MPa)</strong></td>
<td>2430 ± 20</td>
<td>2180 ± 20</td>
</tr>
<tr>
<td><strong>Tensile elongation (%)</strong></td>
<td>4.2 ± 0.7</td>
<td>8.7 ± 4</td>
</tr>
<tr>
<td><strong>Tensile strength (MPa)</strong></td>
<td>40 ± 1</td>
<td>24 ± 1</td>
</tr>
<tr>
<td><strong>Charpy notched impact 23°C (kJ/m²)</strong></td>
<td>10 ± 0.8</td>
<td>4.18 ± 0.32</td>
</tr>
<tr>
<td><strong>MFI (g/10min)</strong></td>
<td>28</td>
<td>8.5</td>
</tr>
<tr>
<td><strong>Legacy additives</strong></td>
<td>RoHs compliant Br : 320 ppm</td>
<td>RoHs Compliant Br : 733 ppm</td>
</tr>
<tr>
<td><strong>Prospector Pro database virgin materials with « similar » properties</strong></td>
<td>≈ 30 ref.</td>
<td>≈ 15 ref.</td>
</tr>
</tbody>
</table>

*Except elongation at break*
No doubt on the quality of recovered plastics

=> adequation between market price and treatment cost?
Viability of pilot plant model at industrial stage?

Industrial inputs
Not linked to « waste market »

Feedstock price 0€/T or 100€/T ?

Investments, labour, utilities ...

Waste treatment 60€/T ?

Waste treatment linked to « waste market »
Exportation, incineration costs, Landfill costs, legislation ...

ABS flakes 650€/T 750€/T

PS Flakes 550€/T 650€/T

Linked to virgin material market

?
Thank you for your attention