POLYPROPYLENE RECOVERED FROM SHREDDED END-OF-LIFE DURABLE GOODS

Brian Riise

MBA Polymers Inc.

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Polypropylene Recovered from Shredded End-of-Life Durable Goods

- Company Overview
- End-of-Life Processing of Durable Goods
- Processes to Recover Plastics from Shredder Residue
- Polypropylene Products from Shredder Residue
- Special Considerations for Polypropylene Recovered from Shredder Residue
- Product Development Case Studies

What does MBA Polymers do?

MBA Feed Material

MBA Products

Shredded plastic-rich mixture from durable goods such as electronics or automobiles

Pellets that can be used in new products

MBA Polymers history of growth and innovation

Richmond, CA
USA (1997)

Guangzhou
China (2005)

Kematen/ Ybbs
Austria (2006)

Worksop, Notts.
UK (2010)

1992 — 2000 — 2005 — 2006 — 2010 — 2016

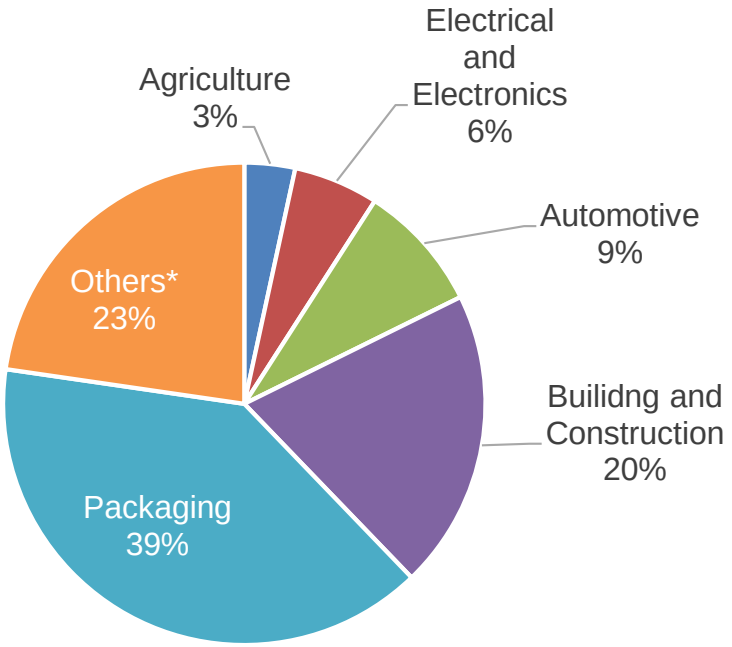
MBA begins work on plastics separation

Facilities in China and Austria recover plastics from shredded waste electrical and electronic equipment (WEEE)

Facility in UK recovers plastics from shredded end-of-life vehicles

2015
>100,000 mt/yr of feed

Plastics Demand by Market Segment (Europe 2014)



- Plastics volumes in Electrical and Electronics Equipment (E&EE) and automotive are smaller than for other segments
- Recycling rates for plastics from E&EE and automotive segments are also smaller than for other segments
- Plastics recycled from end-of-life E&EE and automotive should be most suitable (and of the right type) for new E&E and automotive applications

* *Others* includes consumer and household appliances, furniture, sporting goods, health and safety and others.

Source: *Plastics – the Facts 2015: An analysis of European plastics production, demand and waste data*, data from PlasticsEurope (the Association of Plastics Manufacturers in Europe) and EPRO (the European Association of Plastics Recycling and Recovery Organisations)
http://www.plasticseurope.org/documents/document/20151216062602-plastics_the_facts_2015_final_30pages_14122015.pdf

Recycling of End-of-Life Vehicles

- 12-15 million cars recycled per year in the US* (27 million worldwide‡)
- 150 kg of plastic per car§
- ~2 million metric tons of plastic per year in ELVs (just in the US)

* http://en/wikipedia.org/wiki/Vehicle_recycling and http://www.worldautosteel.org/life-cycle-thinking/recycling/

§ *Chemistry and Light Vehicles*, Economics & Statistics Department, American Chemistry Council, July 2013.

‡ *Plastics Market Watch: Devalued is now Revalued*, SPI, 2016, http://www.plasticmarketwatch.org/

Recycling of End-of-Life Vehicles

Re-usable parts

Bumpers, catalytic converters

Tires, batteries, fluids

Dismantling and Decontamination, followed by crushing

Shredder

Metal removal

Ferrous and non-ferrous metals

Upgrading

Recycling of Waste Electrical and Electronics Equipment

- ~40 million metric tons of Electrical and Electronics Equipment reaches the end of life each year*
- ~30% of E&E Equipment is plastic‡
- ~15 million metric tons of plastic potentially available for recycling

* https://i.unu.edu/media/unu.edu/news/52624/UNU-1stGlobal-E-Waste-Monitor-2014-small.pdf
‡ S. Haig et al., "Electrical Product Material Composition", WRAP Study, Axion Consulting, October 2012, http://www.moew.government.bg/files/file/Waste/EEO/Electrical_product_material_composition_overview.pdf

Recycling of WEEE (especially in the EU)

Re-usable parts

Materials for direct recycling

Batteries, cords

Dismantling and Decontamination

shredder

Metal removal

Ferrous and non-ferrous metals

Electronics shredder residue (ESR)

ASR and ESR are Large Sources of Plastic

Upgraded ASR

- PP, HDPE, ABS, HIPS and mineral filled PP are target plastics (~70-80% of Upgraded ASR)
- ***PP is largest volume component (~1/3 of Upgraded ASR)***
- Other plastics ➔ waste to energy
- Residual metals and wires are recovered and sold
- Very little goes to landfill

European ESR

- ABS, HIPS, PP and PC/ABS are target plastics (~60% of ESR)
- ***PP is ~6% of feed***
- Other plastics ➔ waste to energy
- Residual metals and wires are recovered and sold
- Very little goes to landfill

Challenges for recycling ASR and ESR plastics back into high value products

- Plastic-plastic separations and purification
- Removal of non-plastic contaminants (e.g. rubber and wood)
- Demanding mechanical property requirements
- Demanding requirements for processability (i.e. PCR plastic should process similar to comparable virgin plastics)
- Presence of “legacy” heavy metals and flame retardants

Technologies for recycling ESR plastics back into high value products

- Air classification
- Density (wet)
- Froth flotation
- Scan/sort systems (e.g. metal detection, X-Ray sorters, NIR, color)
- Electrostatic sorting
- Other proprietary sorting steps
- Additives to recover or enhance properties
- Vacuum degassing
- Melt filtration

MBA Polymers Process Overview

ESR feed

Upgraded ASR feed

Size Reduction and Removal of Non-Plastics

Plastic separation, purification and blending

Intermediate (flake) product

Compounding, de-volatilization and melt filtration

Product Testing

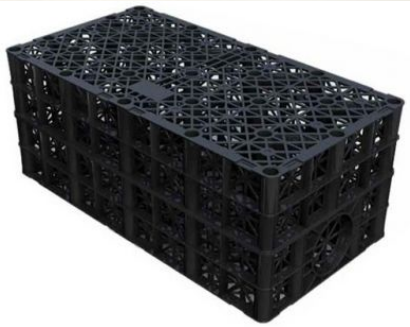
Product pellets

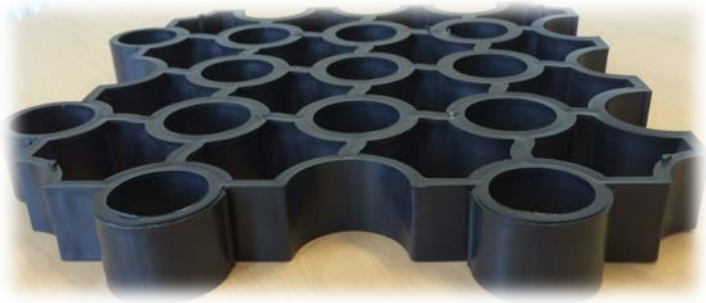
Products from Shredder Residue

	ASR	ESR
Plastics	PP, mineral filled PP, ABS, HIPS, HDPE	ABS, HIPS, PP, PC/ABS
“Natural” color	Light black	Dark gray
Available colors	Dark gray to black	Light gray to black
Volume of PP	~1/3 of feed	~6% of feed
PCR content of PP	Typically >97%	Typically >99%
RoHS and REACH-compliant	Yes	Yes
Substances of very high concern (SVHC) and GADSL	Below limits in the candidate list of SVHC published by the European Chemicals Agency (ECHA) and in the Global Automotive Declarable Substances List (GADSL)	

Example Products Manufactured from PP from ASR

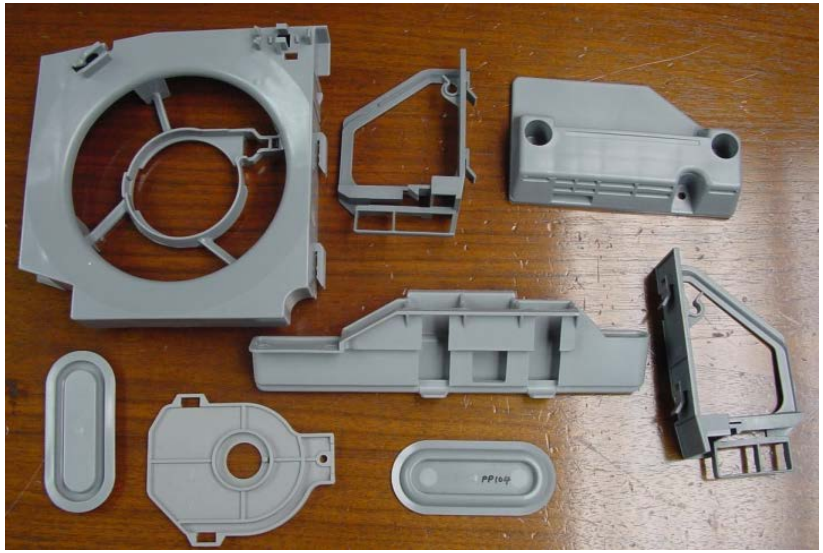
- Storage Box Lids
- Paint cans (blends with virgin or regrind PP)
- Paint trays
- Flower pots
- Dust bin lids
- Automotive parts
- Pallets/crates
- Pipe fittings
- DVD case





Example Products Manufactured from PP from ESR

- Appliances
- Furniture components
- Clothes hangers
- Automotive (cable duct)

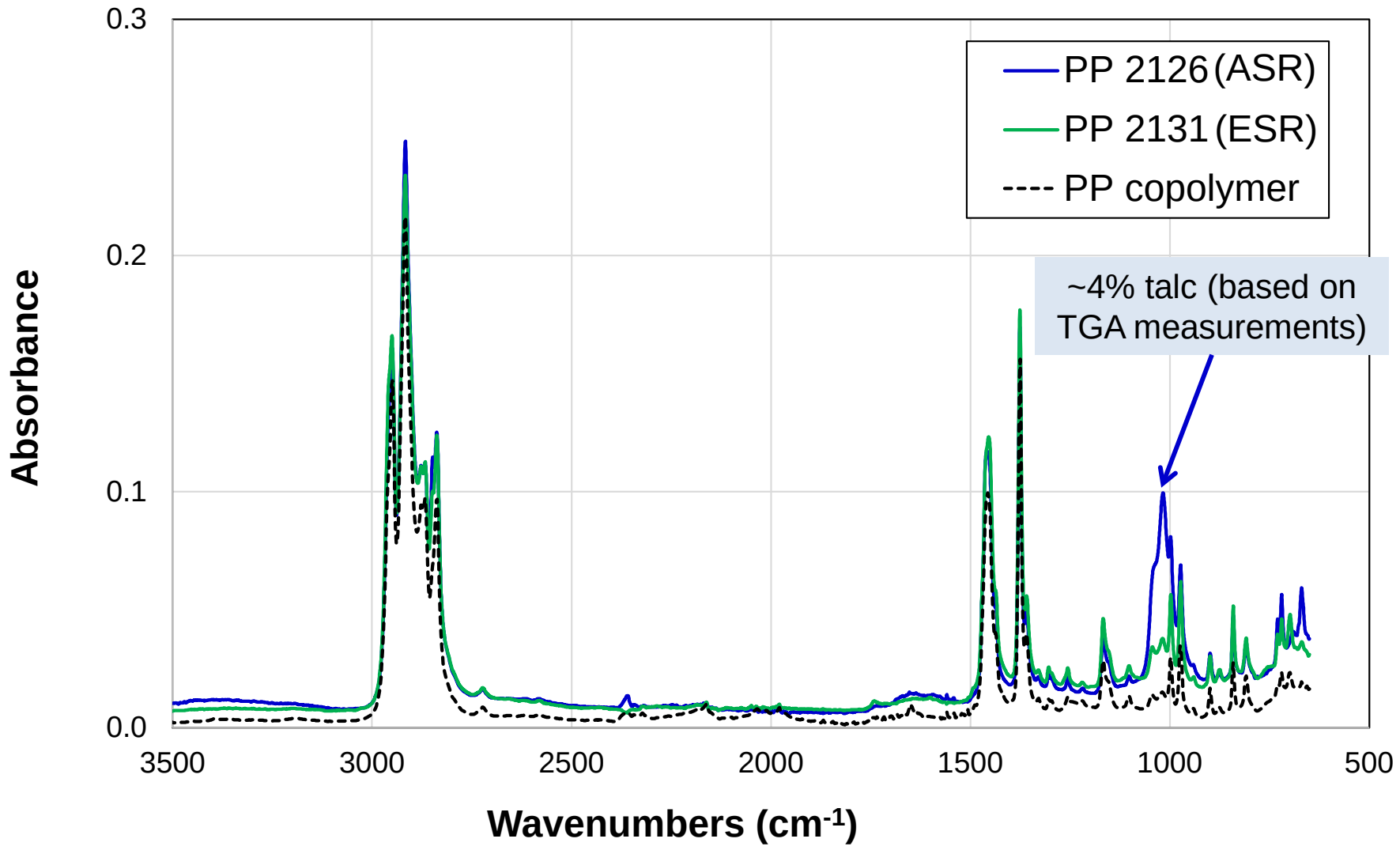


Properties of Polypropylene from Shredder Residue

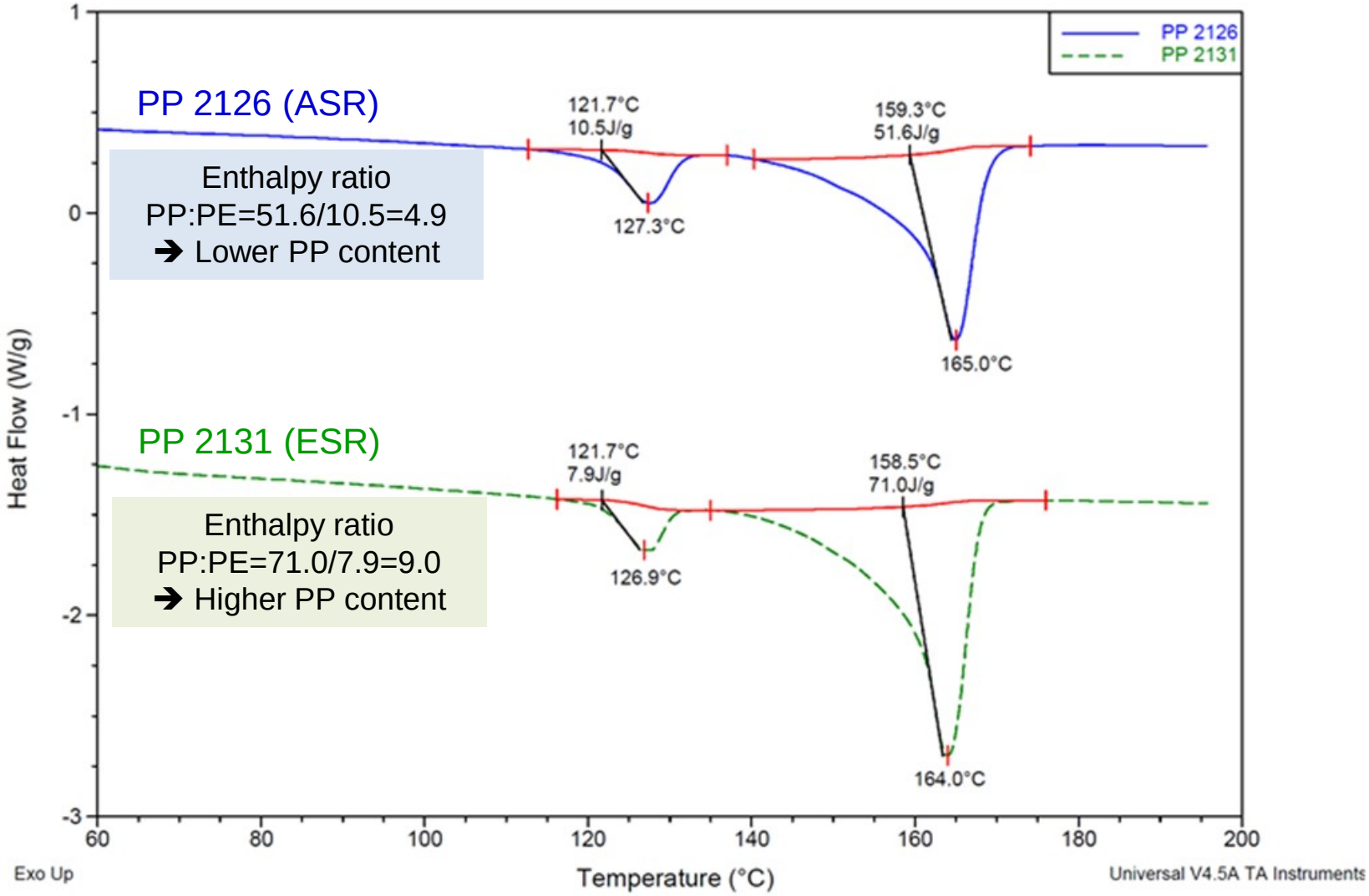
Property	Standard	Units	PP 2126 (ASR, UK)	PP 2131 (ESR, AT)
MFR (230/2.16)	ISO 1133	g/10 min	7	8
Izod impact, notched	ISO 180	kJ/m^2	20	6
Tensile stress at yield	ISO 527	MPa	19	24
Flexural Modulus	ISO 178	MPa	900	1500

- Other MBAUK Grades include:
  - Higher MFR grades from ASR PP (PP 2143, PP 2172, PP 2172N, PP 2182)
  - Higher impact grade from ASR PP (PP 2127)
  - Medium impact grade from ASR PP (PP 2123)
  - ~20% mineral (mostly talc) filled PP as recovered from the ASR feed

FTIR of Polypropylene from Shredder Residue



DSC of Polypropylene from Shredder Residue



Special Considerations for Polypropylene from Shredder Residue

- Volatiles and odors (especially from ASR, less problematic for ESR)
- Flexural Modulus limitations (for ASR PP)
- Color limitations
  - Standard colors are “light black” (from ASR) or “dark gray” (from ESR)
  - Lighter and darker colors are possible using colorants and/or color sorting, but very light gray or deep black (e.g. RAL 9005) are difficult to achieve
- Contaminants
  - Trace amounts of non-melts such as wood, paint, coatings and rubber end up in the flake product
  - Melt filtration removes non-melts larger than about 100-150 µm
  - Bigger problem for ASR than for ESR
- Substances of Concern
  - PP contains trace amounts of “legacy” substances of concern, so we DO NOT recommend our products for toys, for medical applications or for applications that involve food contact or human oral contact
  - PP is RoHS-compliant and SOCs in PP are below limits in the ECHA candidate list of SVHCs or in the Global Automotive Declarable Substance List (GADSL)

Product Development Case Studies

Case Study: PP from ASR for Paint Cans

- Requirements:
  - MFR >20 g/10 min (MFR of base material is ~7 g/10 min)
  - Dark gray color (color of base material is “light black”)
  - Impact strength
  - Creep resistance (under load simulating stacked paint cans)
  - Shrinkage similar to virgin PP
  - Use at 25% in virgin PP
- How accomplished?
  - Peroxide added to increase the MFR
  - Add TiO_2 masterbatch to achieve dark gray color
  - Additive to improve flexural modulus (helps with creep test)

Case Study: PP from ESR in Cable Duct

- PP from MBA Polymers Austria is used in a cable duct application in a luxury automobile
- Challenges such as odor/ volatiles and long-term thermal stability were overcome during the development of this product
- Product is molded by Schlemmer
  - Founded in 1954
  - Headquarters near Munich, Germany
  - 23 production sites in 19 countries worldwide (mostly EU and Asia, but some also in the Americas and Africa)
  - 2500 employees
  - 263 million € consolidated net turnover in 2015
  - Certifications include ISO/TS 16949, ISO 14001 and ISO 9001:2000
  - Active member of VDA, ZVEI and SAE

Summary

- Shredder Residue from end-of-life durable goods (e.g. WEEE and ELVs) are large potential source of plastics
- Our technology enables the recovery of PP and other plastics from shredder residue, and the products have been sold into various applications
- Despite some limitations of PP products recovered from shredder residue (compared with virgin PP grades), it can be used in a wide variety of applications including new durable goods
- Case studies demonstrate that PP from shredder residue can be successfully used in demanding applications, including paint cans and automotive interiors

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LCA of our plant in Austria: P. A. Wäger and R. Hischier, “Life cycle assessment of post-consumer plastics production from waste electrical and electronic equipment (WEEE) treatment residues in a Central European plastics recycling plant”, *Science of the Total Environment* 529 (2015) 158–167. available at http://www.sciencedirect.com/science/journal/00489697

Company contact: MBA Polymers, Inc.
info@mbapolymers.com