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Post-Shred Materials Recovery Technology Development and Demonstration

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Overview: *Recycling Technology R&D*

- **Timeline**
  - Start: FY 2003
  - Finish: FY 2008*
  - Percent Complete: 100%

- **Budget**
  - Total project funding
    - DOE, ~ $1000K/yr
    - Cost-share, ~ $500K/yr
  - Funding received in FY ‘08 and ‘09
    - FY ‘08, $365K
    - FY ’09, $0K

* *Project completion occurred in 2009 with carryover from 2008*

- **Barriers Addressed**
  - Lack of cost-effective technology to recover lightweighting materials from end-of-life vehicles
  - The goal is: Develop technology to recover lightweighting materials from end-of-life vehicles

- **Partners**

  Interactions/Collaborations
    - USCAR, Vehicle Recycling Partnership
    - American Chemistry Council—Plastics Division
    - Institute of Scrap Recycling Industries
    - National Recovery Technologies
    - Changing World Technologies (CWT)
    - Individual Shredder Operators
    - MBA Polymers
    - Troy Polymers
    - Salyp
    - VW SiCon
    - Delft University / Recycling Avenue
  - Project Lead
    - Argonne National Laboratory

Objectives: *Develop, demonstrate and benchmark technology for the cost-effective recovery of lightweighting materials, including plastics, and other materials from post-shred residue*

- Goals
  - Benchmark automotive materials recycling state-of-the-art and disseminate information to stakeholders
  - Determine the performance of emerging technologies with regard to yield, purity, efficiency and cost
  - Develop an integrated process for optimum recovery of materials from shredder residue
  - Demonstrate technical and economic feasibility of processes for materials recovery from ELV and shredder residue
  - Facilitate transfer of technology to industrial practice

FY 2008 Milestones

Major Milestones	Planned Completion Date	Status
Complete engineering designs and economic analysis of the Argonne process based on pilot-plant data	3rd Qtr	Done
Complete design of Argonne's upgrade system for separation of wood and rubber from the recovered polyolefins for the Argonne validation plant	3rd Qtr	Done

Approach: *Process development and demonstration*

- Characterize shredder residue from a number of sources to determine composition variability
- Conduct bench-scale and large-scale process/technology tests to benchmark technologies
- Build and operate a pilot-plant for the separation of shredder residue to produce recovered materials for market evaluation and to provide "control" samples of materials for testing of alternative technologies, as appropriate
- Conduct cost and performance analysis of alternative technologies to establish the business case for the technologies and to identify technology gaps
- Design and build a validation plant to confirm results at a large scale

Background: *What is shredder residue?*

- Complex mixture of waste resulting from the shredding of vehicles, other durables, and scrap metal to recover metals for recycling
- Over 5 million ton/yr generated in the U.S. and over 15 million ton/yr worldwide

Starting Shredder Residue

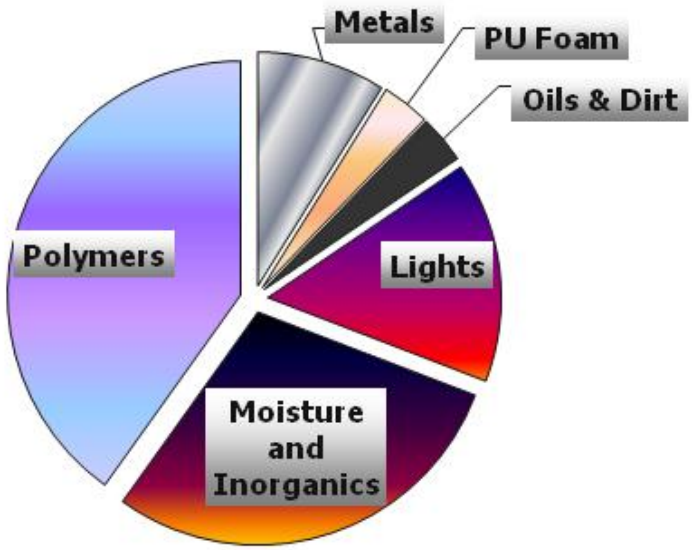
Starting Shredder Residue

Accomplishments: *What We Have Learned with Regard to Post-Shred Technology Development*

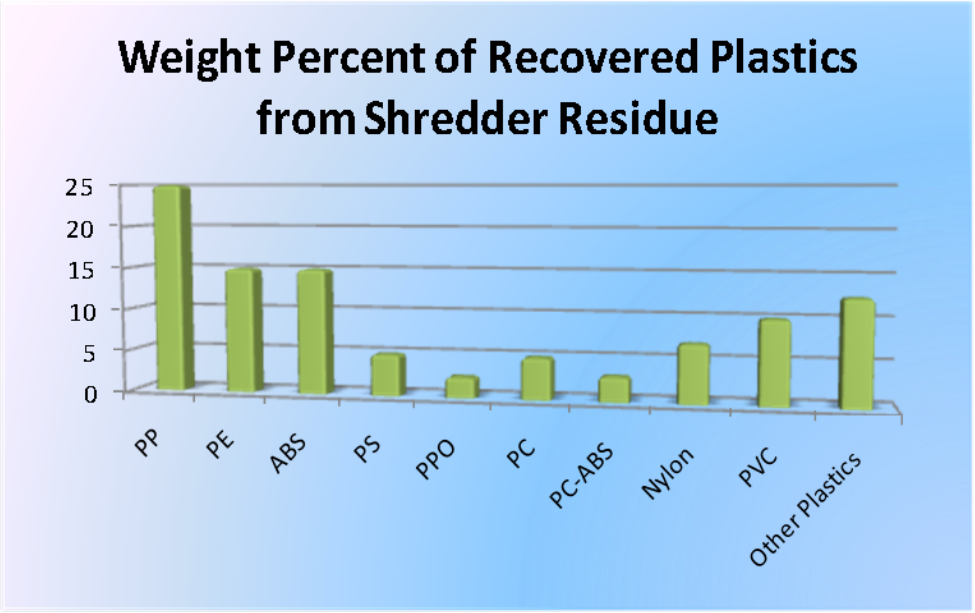
- Essentially, “shredder residue is shredder residue” all shredder residues contain recoverable polymers and residual metals
- Process technology developed at Argonne achieved high yields and high quality of the targeted materials, others have recovered polyolefins but at lower yields and/or quality
- Argonne and MBA Polymers confirmed that the styrenics fraction from shedder residue can be upgraded and recycled
- Troy Polymers successfully converted polyurethane foam from shredder residue to polyol initiators
- CWT confirmed that the organic fraction of shredder residue can be used as a feedstock to produce alternative hydrocarbon gases, liquids and solids

Characterized Shredder Residue

- Processed 150 tons of shredder residue
- Compared U.S. to EU shredder residue
- Performed a detailed material balances on shredder residue constituents



	Shredder Residue	Oversized Heavies	Oversized Foam rich	Fines (<1/4 in.)	Ferrous Rich	N-Ferrous Rich	Lights	Polymer Conc.
Weight (lbs)	40,000	2,148	756	17,640	656	1,468	1,968	10,044
PP	1,075	0	0	0	17	33	129	897
PP (filled)	403	0	0	0	0	0	9	393
ABS	763	0	0	0	5	9	13	737
PE	941	0	0	0	9	18	85	830
HIPS	261	0	0	0	4	8	15	234
Nylon	379	0	0	0	4	9	19	347
PVC	512	0	0	0	0	0	0	511
PPO	139	0	0	0	0	0	4	135
PC-ABS	151	0	0	0	0	0	1	150
PC	212	0	0	0	0	0	12	200
Other Plastics	597	0	0	0	1	0	17	579
Rubber	4,505	20	0	0	6	172	61	4,246
PU Foam	273	3	0	0	1	23	9	237
Wood	239	0	0	0	0	0	0	239
Metals	2,911	1,117	0	0	590	954	0	249
Foam, Fiber and others	21,320	1,008	756	17,640	19	241	1,597	59
Moisture	5,320	0	0	0	0	0	0	0
Total	40,000	2,148	756	17,640	656	1,468	1,968	10,044

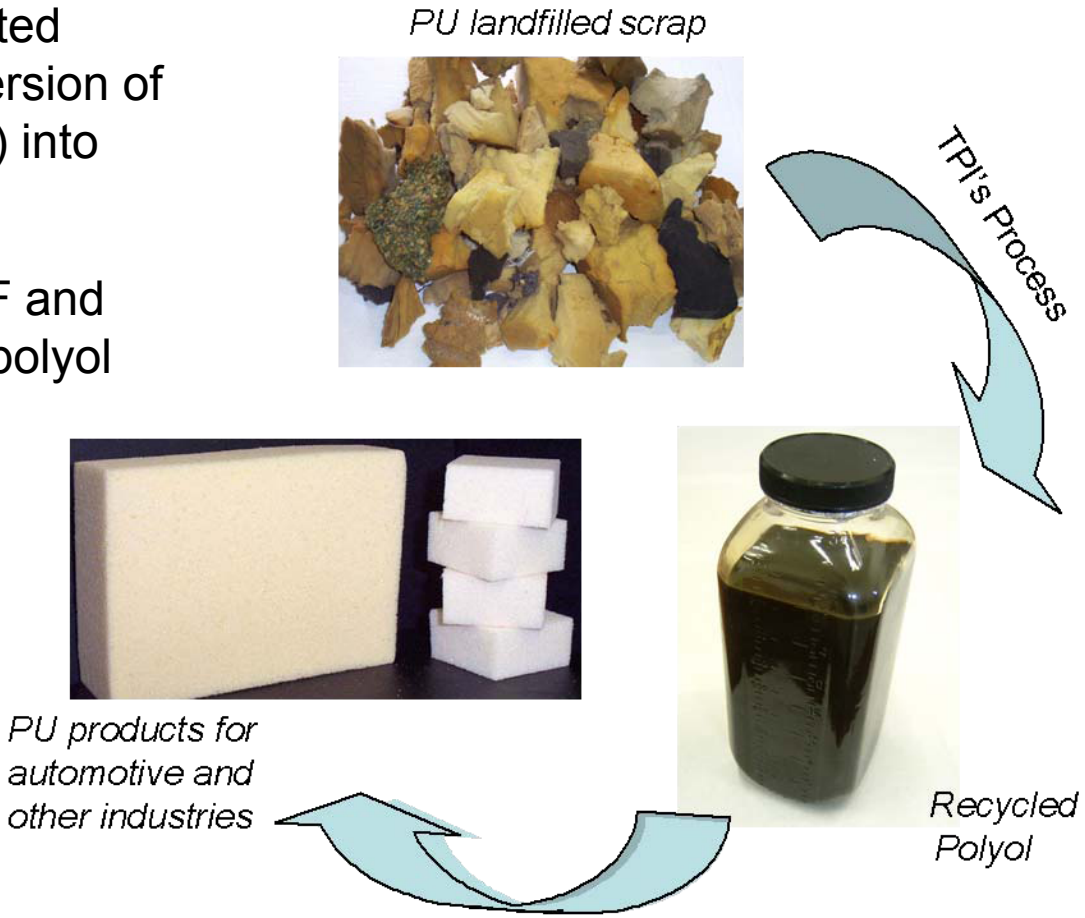


Benchmarking and R&D

- Benchmarking
  - Salyp NV, VW-SiCon and MBA Polymers
- Process R&D
  - Troy Polymers glycolysis of polyurethane foam
  - CWT thermal-depolymerization process
  - National Recovery Technology (SBIR)
  - Argonne materials recovery process development
- Benchmarking has been completed on numerous unit operations for concentrating materials targeted for recovery, such as:
  - Water tables
  - Mineral jigs
  - Kinetic Density Separator (KDS) (Recycling Avenue/Delft University)
  - Optical sorters
  - Electrostatic separators
  - Commercial scale crushers, grinders and granulators

Troy Polymers, Inc. --Glycolysis Process

- Troy Polymers, Inc. (TPI) patented glycolysis process for the conversion of mixed polyurethane foam (PUF) into polyol initiators
- TPI processed ~1,200 lb of PUF and produced about 100 gallons of polyol initiators
- The polyol initiators have been evaluated by four polyurethane suppliers
- TPI is pursuing commercial development



Changing World Technologies --Thermo-chemical Conversion

- The Changing World Technologies (CWT) thermo-depolymerization process converts industrial waste to oils, gases, and solids
- CWT's first commercial facility based on this technology was commissioned in April 2003 and converts 200 ton/day of turkey offal

Changing World Technologies ---Thermo-chemical Conversion, Continued

- CWT's thermo-depolymerization process is potentially applicable to the organic fraction of shredder residue
- A proof-of-concept bench scale test confirmed the technical feasibility of the process
- A controlled 2,000 lb test run has been completed
  - Confirmed the bench scale results
- Economic viability of thermo-chemical conversion of shredder residue organics to fuels is not established.

National Recovery Technologies, Inc.

- NRT was awarded a phase II SBIR for the "Development of High Speed Multispectral Imaging for Sorting Automotive Plastics"
  - Progress has been made in integrating light gathering optics
  - Analysis of dark colored plastics at high throughputs has not been achieved
- Argonne supplied NRT pre-identified individual plastics, a polymer concentrate, and concentrated fractions of the polyolefins from shredder residue
- Work continues on a phase III flexible high speed computing instrument, leveraged off the phase II technology
- Is not applicable to dark colored plastics from shredder residue at this time

NRT Commercial IR Bottle Sorter

NRT Commercial IR Flake Sorter

Argonne Recycle Process R&D -- Mechanical Separation Process Details

- Our approach is to separate the polymers at a high yield as a concentrate from the shredder residue, and then to separate the individual plastics from the concentrate

- Designed, built and installed 1/10th scale bulk separation pilot-plant

- Processed about 150 tons of shredder residue
  - Recovered over 95% of the residual metals
    - *5-15 weight percent of the residue*
  - Recover 90% of the targeted polymers
    - *20-50 weight percent of the residue*

- Work on the separation of the complex shredder residue serves as a spring board for developing technology for the separation and recycling of lightweighting materials of the future

Argonne's Mechanical Separation Pilot-Plant

Argonne Recycle Process R&D -- Wet Separation Process Details

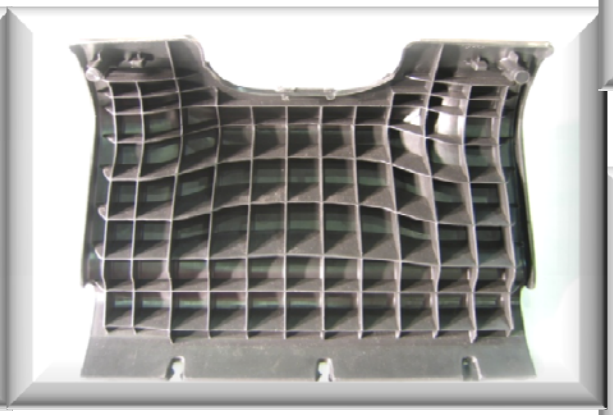
- Designed, built and installed a 1,000 lb/hr wet-density/froth flotation pilot-plant
- Developed process operating conditions for selective separation of materials from the polymer concentrate
- Designed and built a 5,000 lb/hr wet-density/froth flotation separation module
- Produced about 3 tons of 95% polyolefin concentrate

Argonne's Wet-Density/Froth Flotation Pilot-Plant

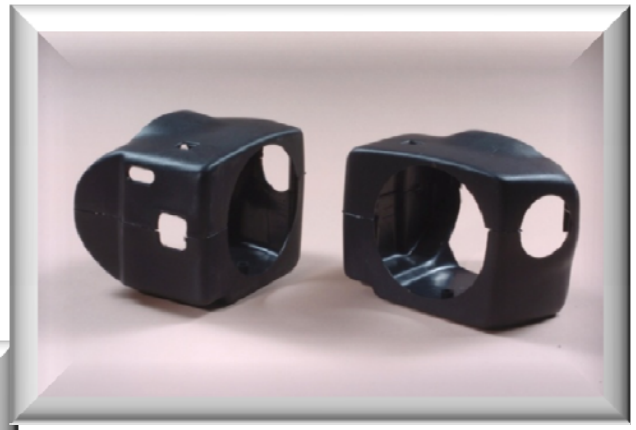
Argonne Recycle Process R&D-- Confirm the Technical Feasibility of Reusing Argonne's Recovered Polyolefins

- Mold trials were successful for producing automotive parts from the polyolefins fraction at blend rates with regrind of 0%, 25%, 50%, and 75%

Spare Tire Base Plate



Knee Bolster



Steering Column Cover

Battery Tray

Objectives for FY 2008 and FY 2009

- Design a full-scale validation plant for the recovery of automotive polymers from shredder residue based on R&D done in FY ’03 - FY ‘08
- Update economic analysis as per quotes for major equipment
- Conduct “All Auto” trials and process the resulting shredder residue
- Conduct the study to assess the potential release of nano particles from auto parts containing nano materials when recycled (USCAR-VRP interested in this study)

Summary

- Process development R&D for shredder residue recycling will be completed in FY ‘09
- The success of the research resulted in a 20 ton/hr validation plant which is under construction
- Eighteen published journal papers, conference papers and patents
- Project recognized with a number of awards
  - SAE 2007 Transaction Set “best of the best technical papers of 2007”
  - Global Plastics Environmental Conference (GPEC) Lead Technical Conference Paper for 2007
  - TMS Extraction and Processing Division Technology Award for 2008
  - GPEC Award for 2007, Enabling Technologies in Processes & Procedures, Environmental Division, Society of Plastics Engineers