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Post-Shred Materials Recovery Technology Development and Demonstration

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"This presentation does not contain any proprietary or confidential information"

Purpose of Work

- The objective is to develop, demonstrate and benchmark technology for the cost-effective recovery of lightweighting materials, including plastics, and other materials from post-shred residue

- The ultimate goal is to determine the performance (e.g. yield, purity, efficiency, and cost) of these emerging technologies such that an optimized and integrated process for recovering materials from shredder residue can be developed

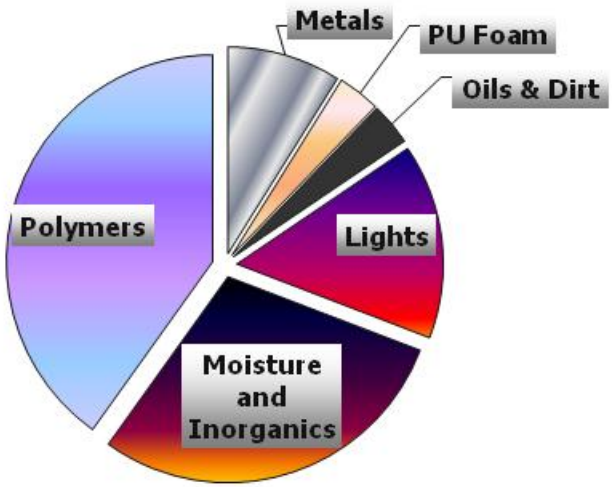
Previous Review Comments

- Recommendation: Future work should be focused on the following,
  - Benchmarking of emerging recycling technologies in Europe
    - *VW-SiCon*
    - *MBA Polymers*
  - Development and demonstration of advanced materials recovery technologies, including materials recovery, chemical conversion and thermo-chemical conversion
    - *TPI glycolysis*
    - *CWT*
    - *Argonne technology validation plant*
- Recommendation: Technical cost models of the most promising recovery processes need to be developed
    - *CWT*
    - *Argonne materials recovery process*

Approach

- Characterize shredder residue from a number of sources to determine composition variability
- Conduct bench-scale and large-scale process/technology tests to benchmark technology
- 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

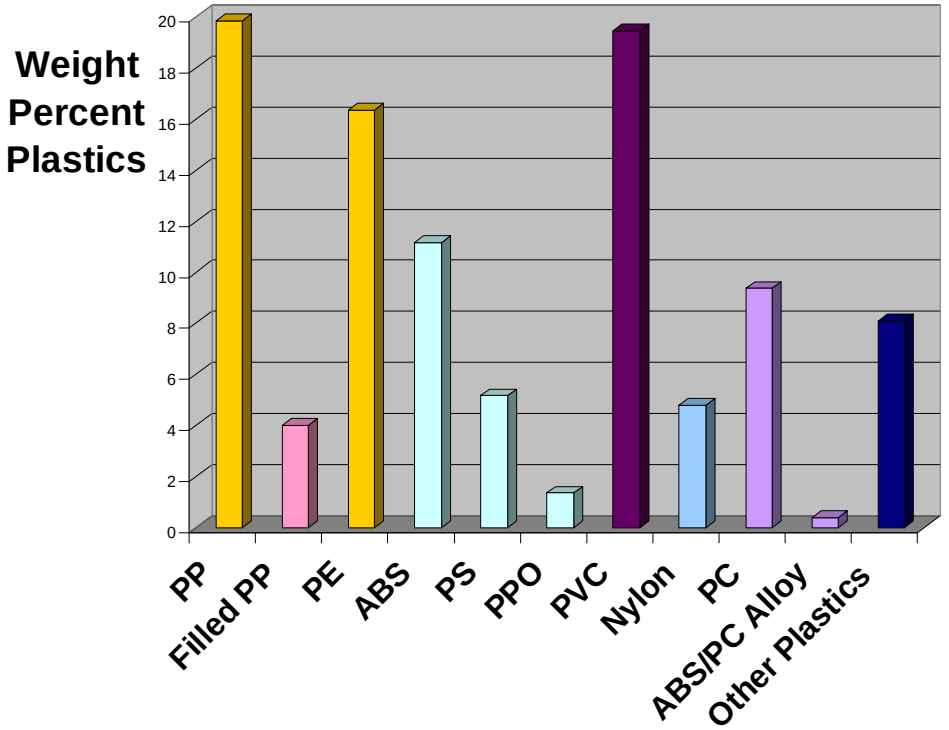
Background
--What is Shredder Residue?



- Complex mixture of waste resulting from the shredding of cars, other durables, and scrap metal to recover metals for recycling

- Over 5 million ton/yr generated in the U.S.

Starting Shredder Residue



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

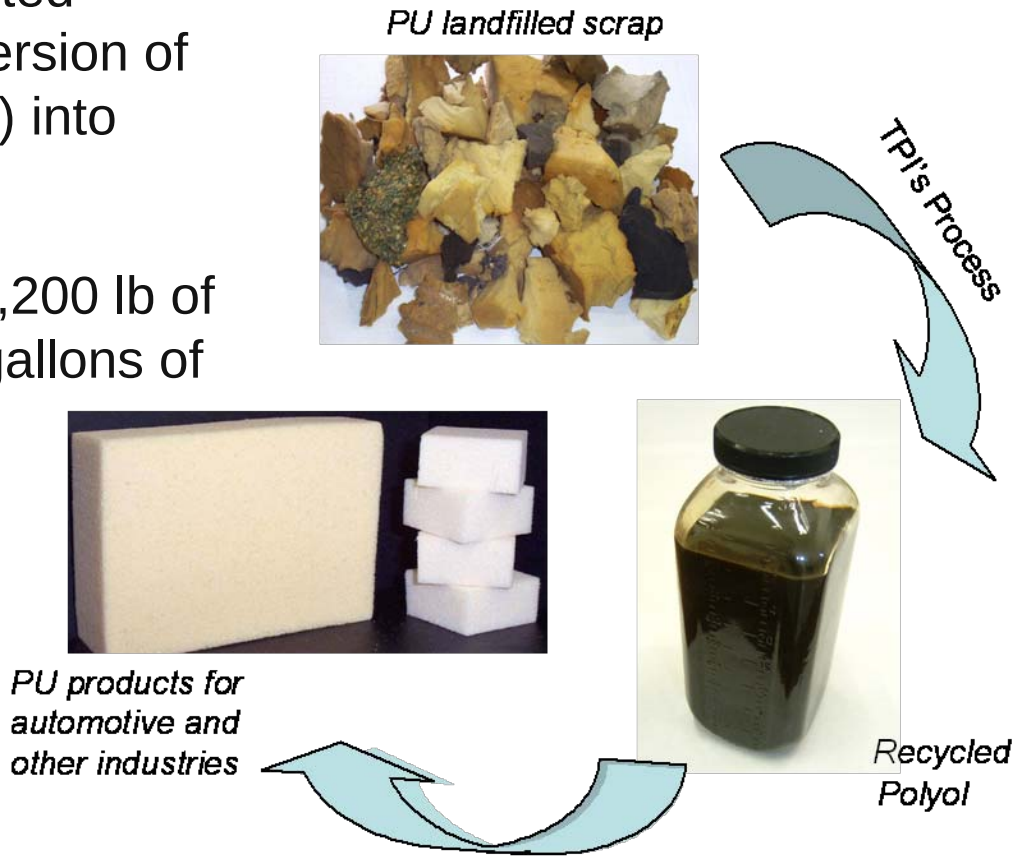
- Essentially, “shredder residue is shredder residue” - all shredder residues contain recoverable polymers and residual metals
- Process technology developed at Argonne achieved high yields and high quality of the targeted materials
- Others have recovered polyolefins but at lower yields and/or quality
- 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 substitute fuel
- Literature shows shredder residue can be used as an alternate fuel

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
- Benchmarking has been completed on numerous unit operations for concentrating plastic fractions such as:
  - Water tables
  - Mineral jigs
  - Optical sorters
  - Electrostatic separators
  - Kinetic Density Separator (KDS) (Recycling Avenue/Delft University)

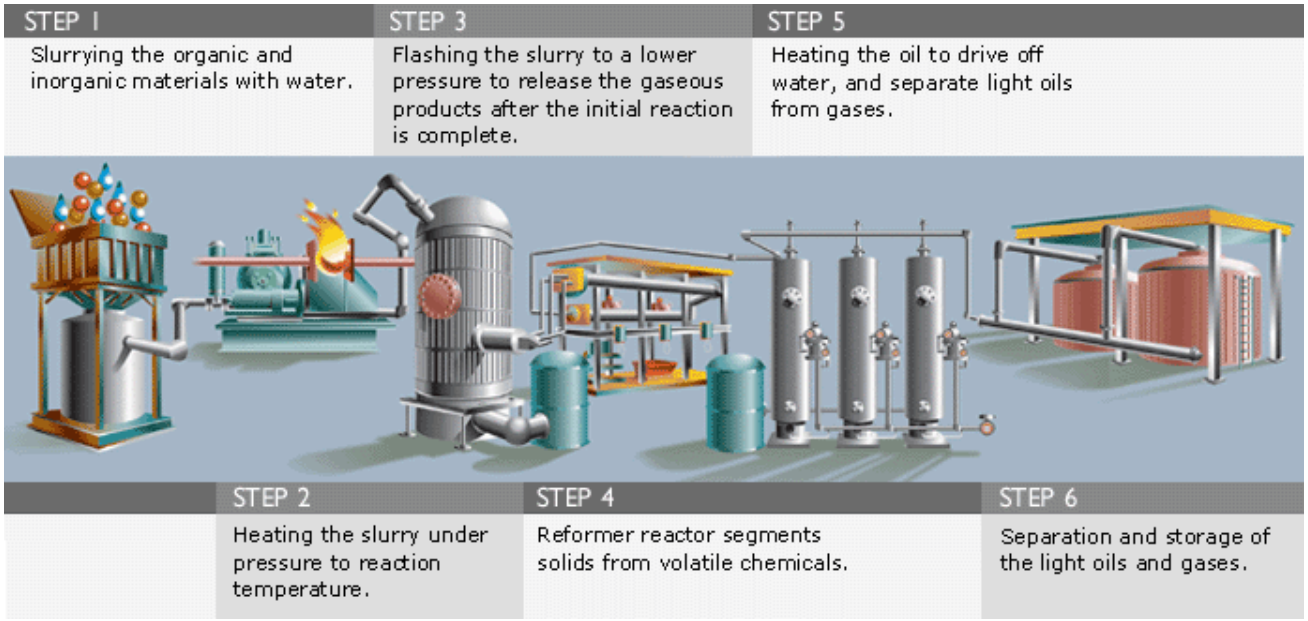
Troy Polymers, Inc. ---Glycolysis Process

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



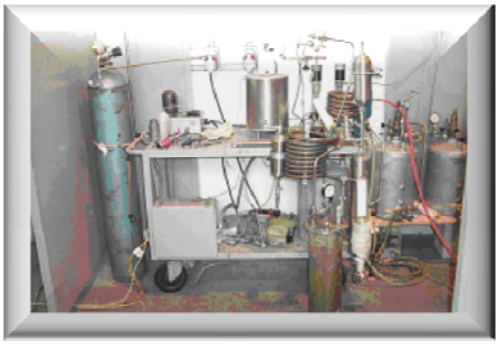
Changing World Technologies ---Thermo-chemical Conversion

- 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 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 their process
- A controlled 2,000 lb test run is scheduled to be completed during the 3rd quarter of FY 08
  - Analysis will be completed in 2008
  - Validation of the mass and energy balances
  - Confirmation of process economics



CWT's Bench Scale Unit

CWT's Pilot Plant Unit

National Recovery Technologies, Inc.

- An equipment manufacturing and engineering company, that provides sorting solutions to the recycling industry
- NRT was awarded a phase II SBIR for the “Development of High Speed Multispectral Imaging for Sorting Automotive Plastics”
- Argonne supplied NRT pre-identified individual plastics, a polymer concentrate, and concentrated fractions of the polyolefins from shredder residue

NRT Commercial IR Bottle Sorter

NRT Commercial IR Flake Sorter

Argonne Recycle Process R&D

- 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
- Recover over 95% of the residual metals
  - 5-15 weight percent of the shredder residue
- Recover 90% of the targeted polymers
  - 20-50 weight percent of the shredder residue

Argonne's Mechanical Separation Pilot Plant

Argonne Process R&D ---Continued

- Designed, built and installed 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 flotation separation module

Argonne's Wet-Density/Froth Flotation Pilot Plant

Technical Cost Model

- CWT process will be completed in FY 08
- Completed a detailed cost model for the Argonne process
- Capital cost estimates are based on quotes from vendors for commercial scale equipment
- Operating cost estimates are based on pilot plant operating experience
  - 110 tons of shredder residue
  - Multiple shredders
- Revenue estimates:
  - Residual metals based on commodity pricing
  - Polymeric materials based on verbal quotes subject to product quantities and consistency

Technical Cost Model of the Argonne Process -- Design Capacity 20 ton/hour @ 2000 hours/yr

Equipment Costs		
Mechanical Separation System Equipment (20 ton/hour)	$1,540,000	
Wet Separation System Equipment (10 ton/hour)	1,135,000	
PP/PE Upgrade Subsystem (3 ton/hour)	375,000	
SOC Removal Subsystem (budgetary estimate)	1,000,000	
Subtotal Equipment Costs		**$4,050,000**
Auxiliaries and Installation		
Mobile Equipment and Auxiliaries	$550,000	
Plant Installation	500,000	
Subtotal Auxiliaries and Installation		**$1,050,000**
Land and Buildings		**$1,000,000**
TOTAL INSTALLED PLANT COST		**$6,100,000**
ESTIMATED ANNUAL OPERATING COSTS		**$1,600,000**
Potential Revenue		
Residual Metals (1.5 ton/hour)	$1,500,000	
Polyolefins (1.1 ton/hour @ $500/ton)	1,100,000	
Styrenics (1.5 ton/hour @ $100/ton)	300,000	
Mixed Rubber (3.0 ton/hour @ $100/ton)	600,000	
Alternate Fuel (3.9 ton/hour @ $20/ton)	156,000	
Avoided Landfill Costs (11.0 ton/hr @ $20/ton)	440,000	
TOTAL REVENUE		**$4,096,000**

Technology Transfer
---Argonne Technology Validation Plant

- We are proposing to validate the Argonne shredder residue separation technology by developing and operating a full-scale, 20 ton per hour, “technology validation” plant

- We have a shredder whose willing to accept the risk of this “first-of-a-kind” facility
  - This shredder will make an investment of $5 million the first year, with a total of $7 million over three years

Plans for Next Fiscal Year

- Complete evaluation of the CWT process including process economics
- Complete benchmarking of the VW-SiCon process
- Finalize the design for the Argonne process
- Process, in the Argonne pilot plant, shredder residue generated by controlled shredding of automobiles in an uncontaminated shredder
  - Big three late models (’02-’07)
  - Pre-2000 ELVs mix

Summary

- 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 substitute fuel
- Polyolefins from shredder residue can be recovered, upgraded and recycled
- Argonne and MBA Polymers confirmed that the styrenics fraction from shedder residue can be upgraded and recycled
- Argonne developed a technology platform for materials recovery from shredder residue, which has been proven in a 1/10th scale pilot plant
  - The technology is ready to be validated on a full scale basis
- The primary issue that remains to be resolved with regard to shredder residue is the SOCs issue in particular the PCBs

Publications

- FY 07 six papers
  - *Mass Balance and Composition Analysis of Shredder Residue*, SAE Paper No. 2007-01-0527, 2007 SAE World Congress
    - *Selected for the Society of Automotive Engineers 2007 Transactions Set "best of the best technical papers of 2007"*
  - *Thermoplastic Separation and Recovery from Various Mixed Scrap by the Argonne Developed Froth Flotation Technology*, Proc. Of the 13th Annual Global Plastics Environmental Conference (GPEC) 2007
    - *Selected as the Lead Technical Paper for the conference*
- FY 03-FY 06 eleven additional papers