Market Driven Technology Development for Sustainable End-of-Life Vehicle Recycling: A Perspective from the United States

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Today's Presentation

- *Background of U.S. Government/Industry Collaboration*
- *Current CRADA Objectives and Accomplishments to Date*
- *Summary of Argonne Mechanical Separation/Froth Flotation Technology*
- *Conclusions*

Recycling End-of-Life Vehicles (ELV) of the Future Cooperative Research and Development Agreement (CRADA)---U.S. Public/Private R&D Partnership

- *CRADA*
  - *Cooperative research and development agreement (contract) to do cost-shared R&D*

- *ELV CRADA Partners (US ELV CRADA Team)*
  - *Argonne National Laboratory/ U.S. Dept. of Energy*
  - *American Plastics Council*
  - *USCAR's Vehicle Recycling Partnership (DaimlerChrysler, Ford, GM)*

- *Organizing Theme*
  - *To achieve greater fuel-efficiency and safety, today's cars incorporate an increasing share of innovative lightweighting materials. While these materials greatly enhance efficiency during vehicle use, they can present special challenges to recycling.*

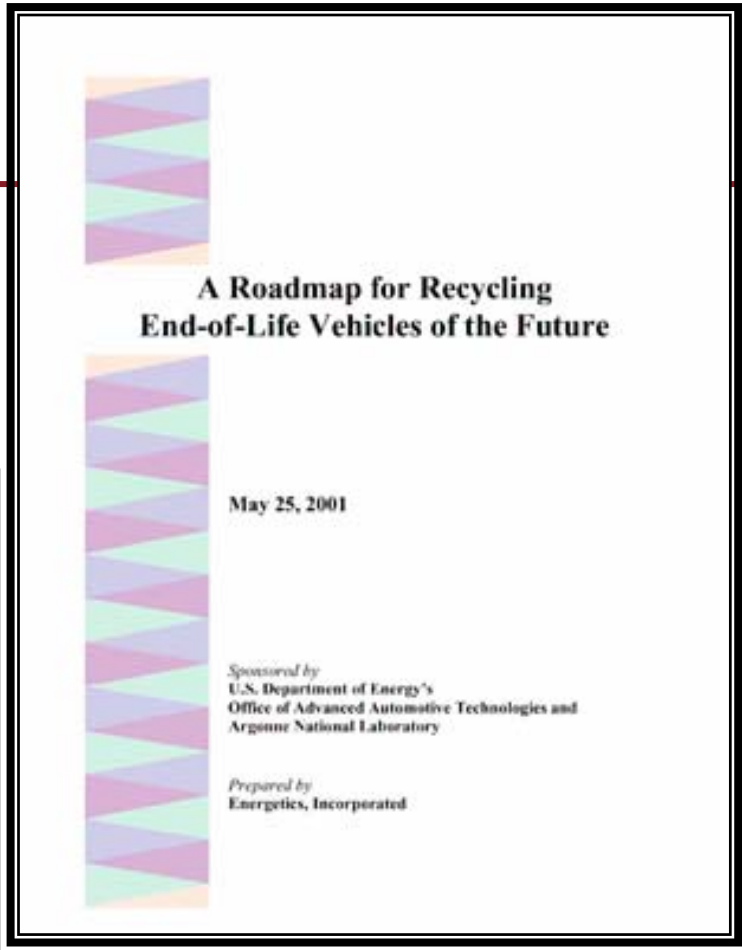
A Brief History of Collaboration

- *1991 Vehicle Recycling Partnership formed*
- *1994 **First** CRADA (among VRP, Argonne and APC)*
  - *Dismantling*
  - *Seat foam recycling*
- *1997 **Second** CRADA among VRP, Argonne and APC Demonstration of Argonne froth flotation technology (post-consumer appliance plastics)*
- *1999 DOE PNGV (now FreedomCAR) funds*
  - *Argonne --- polymer matrix composite recycle*
  - *Aluminum Alliance --- LIBS alloy sorting*
- *2001 ELV Recycle Roadmap released*
- *2003 **Third** CRADA among VRP, Argonne and APC*
  - *Sustainable recycling*

Current R&D Portfolio Evolved from Roadmap

- *Roadmap Issued May 25, 2001*
  - *Information*
  - *Technology*
  - *Markets*

Albany Research Center
The Aluminum Association
American Plastics Council
Argonne National Laboratory
Automotive Parts Rebuilders Assoc.
DaimlerChrysler Corp.
Department of Natural Resources, Canada
Ford Motor Co.
General Motors Corp.
Institute of Scrap Recycling Industries
Massachusetts Institute of Technology
Oak Ridge National Laboratory
Rochester Institute of Technology
Steel Recycling Institute
Sandia National Laboratory
US DOE



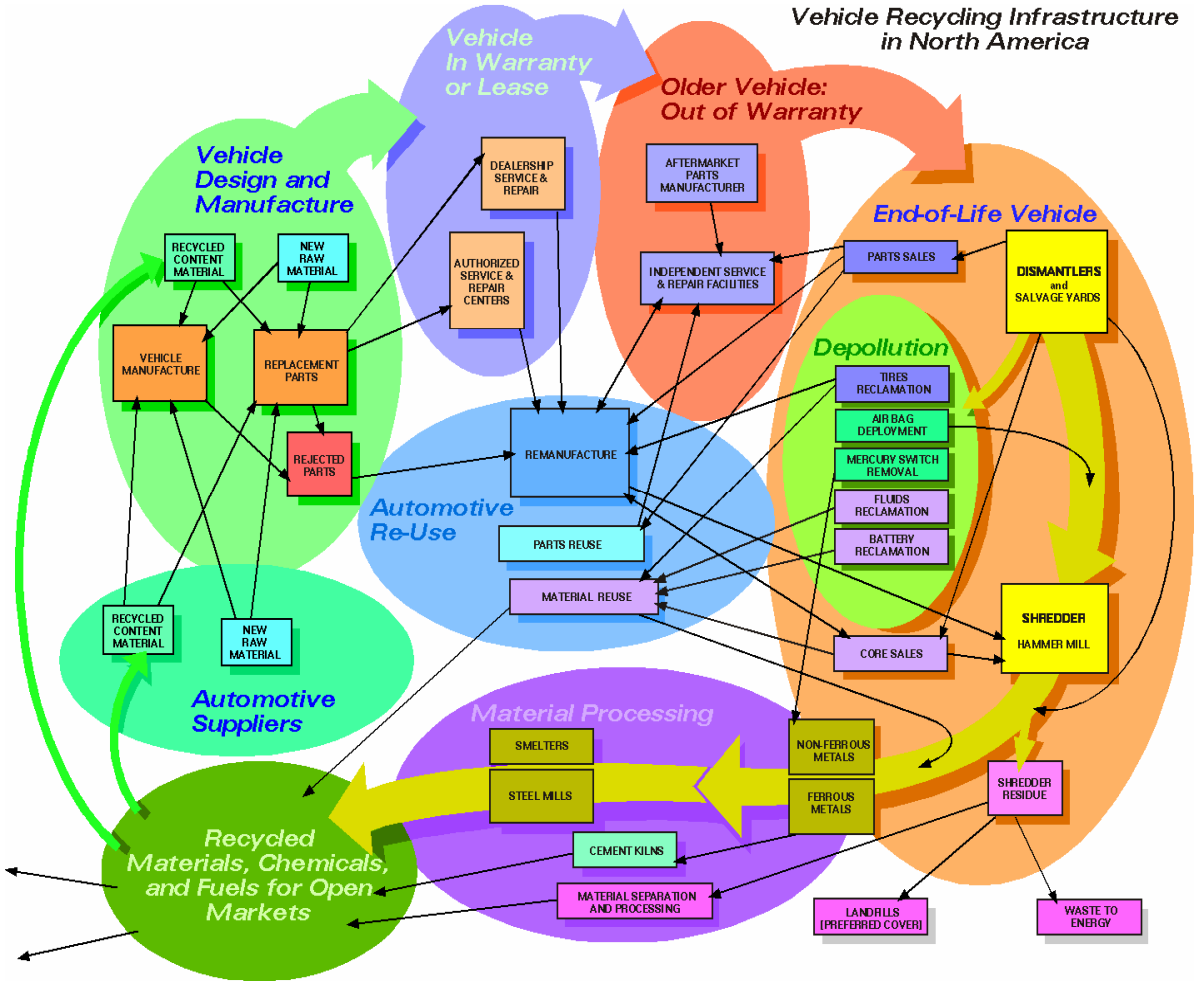
ELV Recycling is a Market Driven Success Today

75% of automotive materials are recycled

More than 12000 dismantlers

About 20000 remanufacturers

About 200 shredders



The Roadmap recommended---

- *The recyclability of ELVs is presently limited and several technical and economic barriers need to be overcome to increase recovery and recycling*
  - *Lack of commercially proven technical capabilities to cost-effectively separate, identify and sort materials*
  - *Lack of profitable post-use markets*
- *Development of technology to recycle today's materials will provide the basis for recycling of future materials*
- *Focus should be on post-shred technology demonstration*
- *Industry-wide collaboration is needed*
- *Worldwide technology needs to be tracked and information disseminated to users*

US ELV CRADA Team Objectives and R&D Agenda

- *Objectives*
  - *Enable optimum recycling of all current and future automotive materials*
  - *Remove recycling barriers to use of advanced, lightweight materials*
  - *Continue to enable market driven vehicle recycling*

- *R&D Agenda*
  - *Develop and demonstrate sustainable ELV recycle technology*
  - *Demonstrate the feasibility of resource recovery from shredder residue (materials, thermo-chemical conversion, and energy recovery)*
  - *Develop strategies and technologies for control, minimization, or elimination of substance of concern*
  - *Benchmark recycle technologies*
  - *Stimulate markets for reprocessed materials*
  - *Transfer technology to practice*

Accomplishments to Date

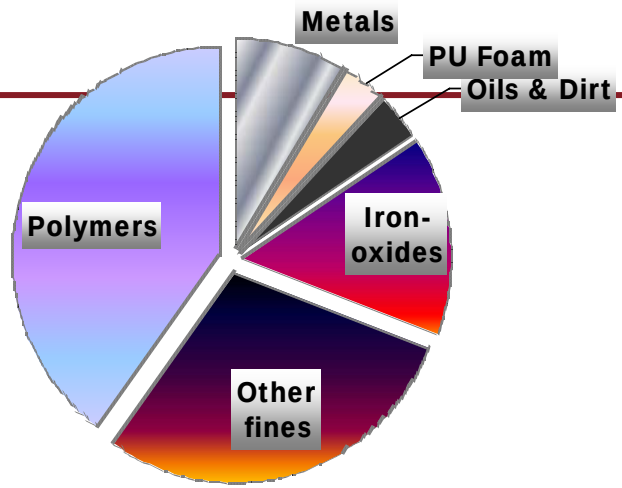
- *Developed a modular LCA for evaluation of alternative "post-shred" recycle technologies*
- *Designed, built and installed 1/10 scale mechanical separation and froth flotation pilot-plant at Argonne*
- *Confirmed the technical feasibility of recovering and reusing polyolefins from shredder residue (trials are ongoing to recovery additional plastics)*
- *Changing World Technologies confirmed the technical feasibility of converting shredder residue to liquid hydrocarbon fuels*
- *Troy Polymers confirmed the technical feasibility of converting polyurethane foam from shredder residue to polyol initiators*
- *Process economics appear favorable, but need confirmation*

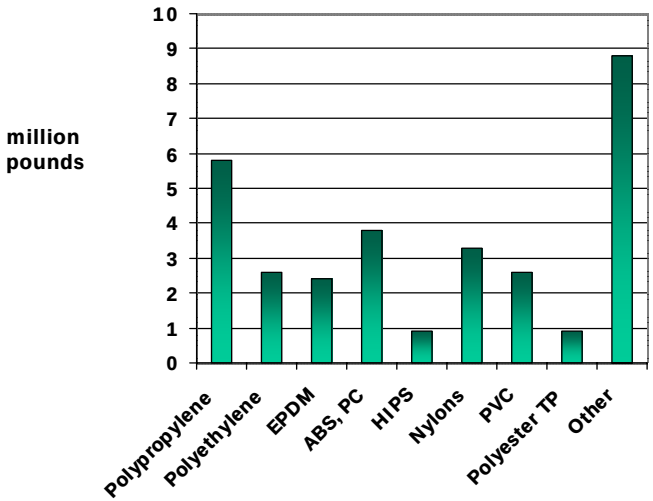
Some Key Differences in the U.S.

- *Shredder residue is NOT designated as hazardous*
- *Most shredder residue does not TEST as hazardous*
- *There are NO directives or mandates for recycling of ELV or shredder residue*
- *Landfill costs are on the order of $25 per ton*
- *Products recycled from shredder residue must have less than 2 ppm PCB's to be reintroduced into commerce*
- *Technology developed to recycle (divert from landfill) shredder residue depends on a product value proposition (as opposed to an avoided cost proposition)*

What is Shredder Residue?

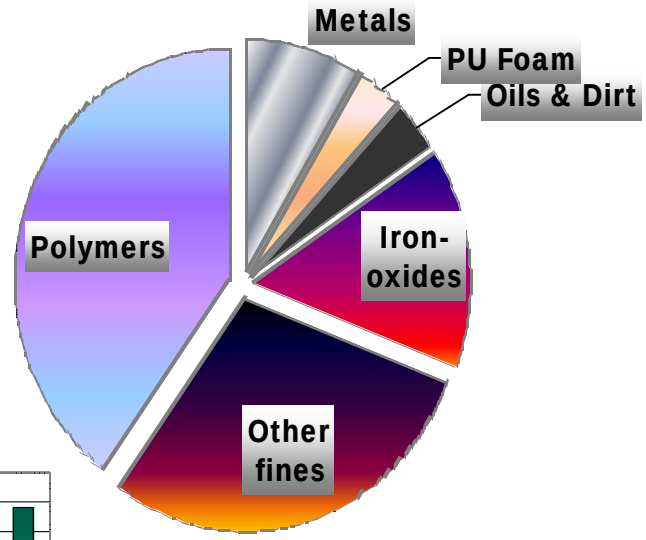
- *Complex mixture of waste resulting from shredding of cars, other durables and scrap metal to recover metals for recycling*
- *About 6 million ton/yr in U.S.*

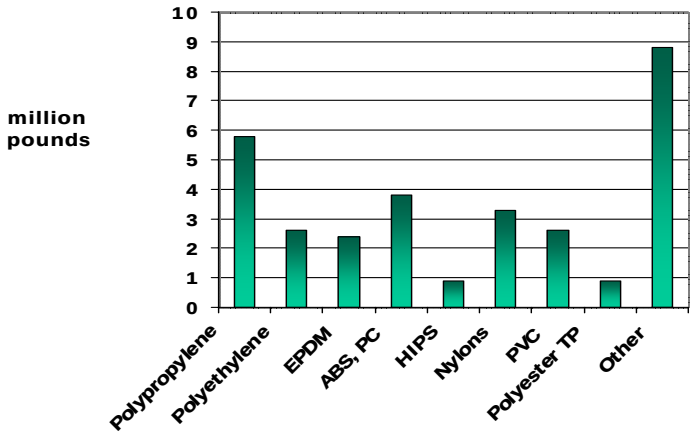




Options for Recycling the Balance of Automotive Materials

- *Separate and recover materials*
- *Convert to fuels and chemicals*
  - *Gasification*
  - *Pyrolysis*
  - *Glycolysis*
- *Energy Recovery*





Mechanical Recycling from Shredder Residue
First---Find the Polymers
Second---Recover Polymers

- *Physical separation produces material concentrates from bulk shredder residue*
  - *Foam*
  - *Ferrous and Non-ferrous*
  - *Polymer Concentrate*
  - *Fines*

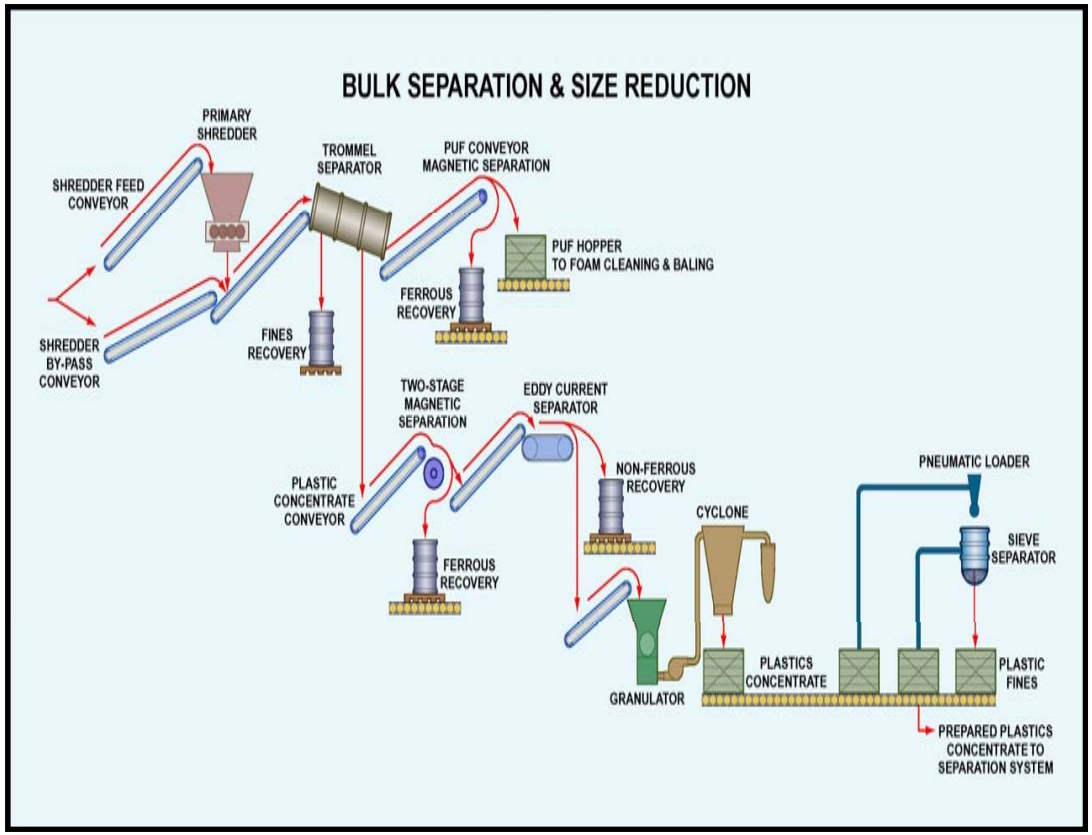
- *Polymer recovery process is a 6-stage wet (froth flotation) system for recovery of polymer fractions from the polymer concentrate*
  - *Polyolefins*
  - *ABS*
  - *Nylons*
  - *Other*

Physical Separation Pilot-Plant

Plastics Recovery Facility

Bulk Separation and Size Reduction Yields Residual Metals and a Prepared Polymer Concentrate

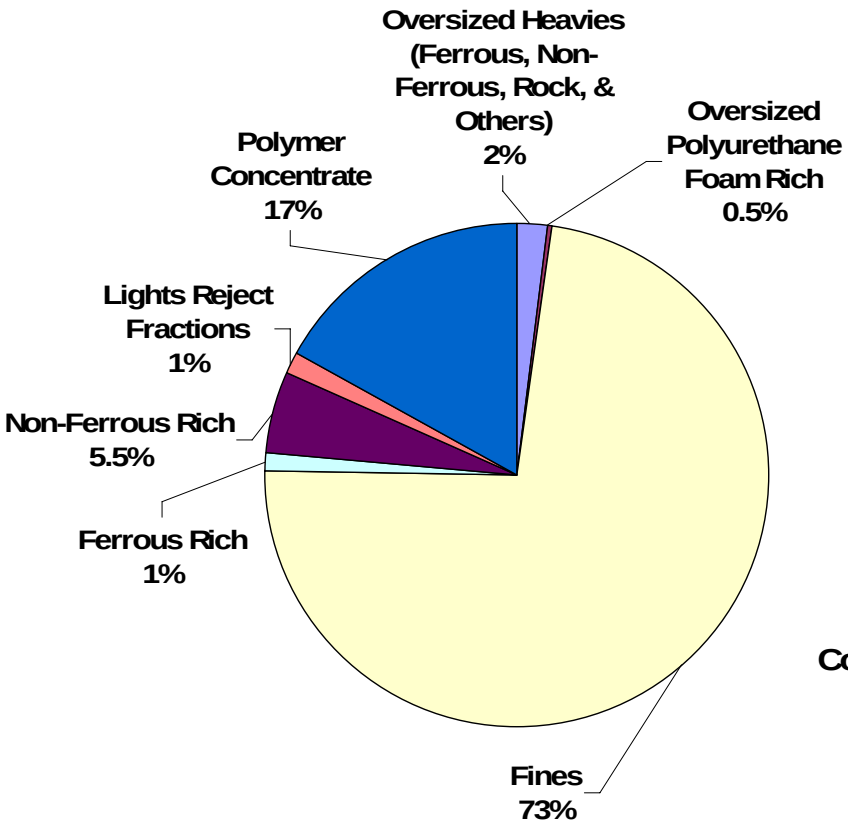
- *High yields essential for cost-effectiveness---*
- *Mass balances on multiple shredder residues indicate 95% recovery of polymers >6mm*



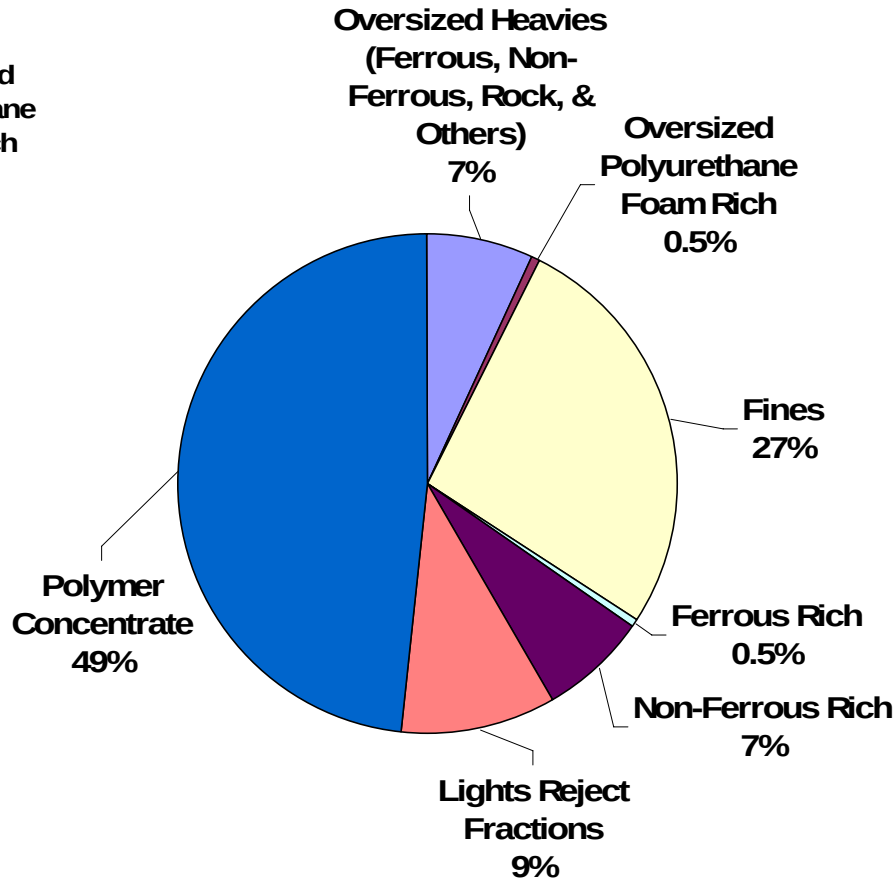
Argonne's Mechanical Separation Pilot-plant Employs Conventional Scrap Processing Technology

Fractions Recovered from Shredder Residue

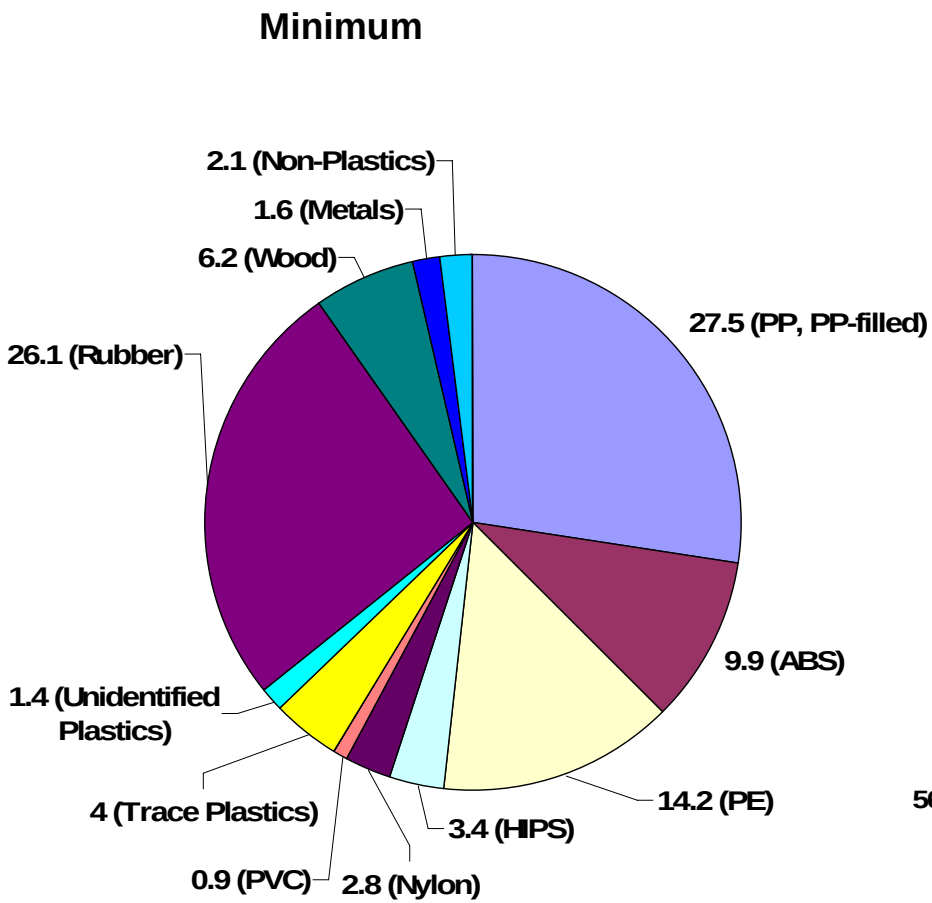
Minimum Polymer Concentrate

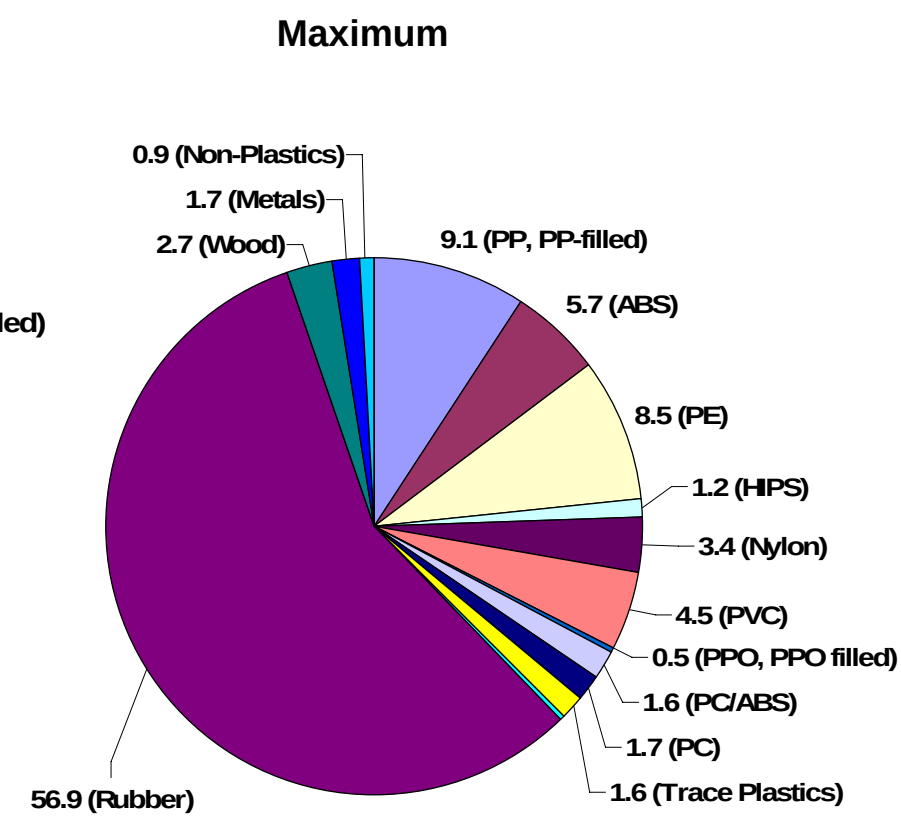


Maximum Polymer Concentrate

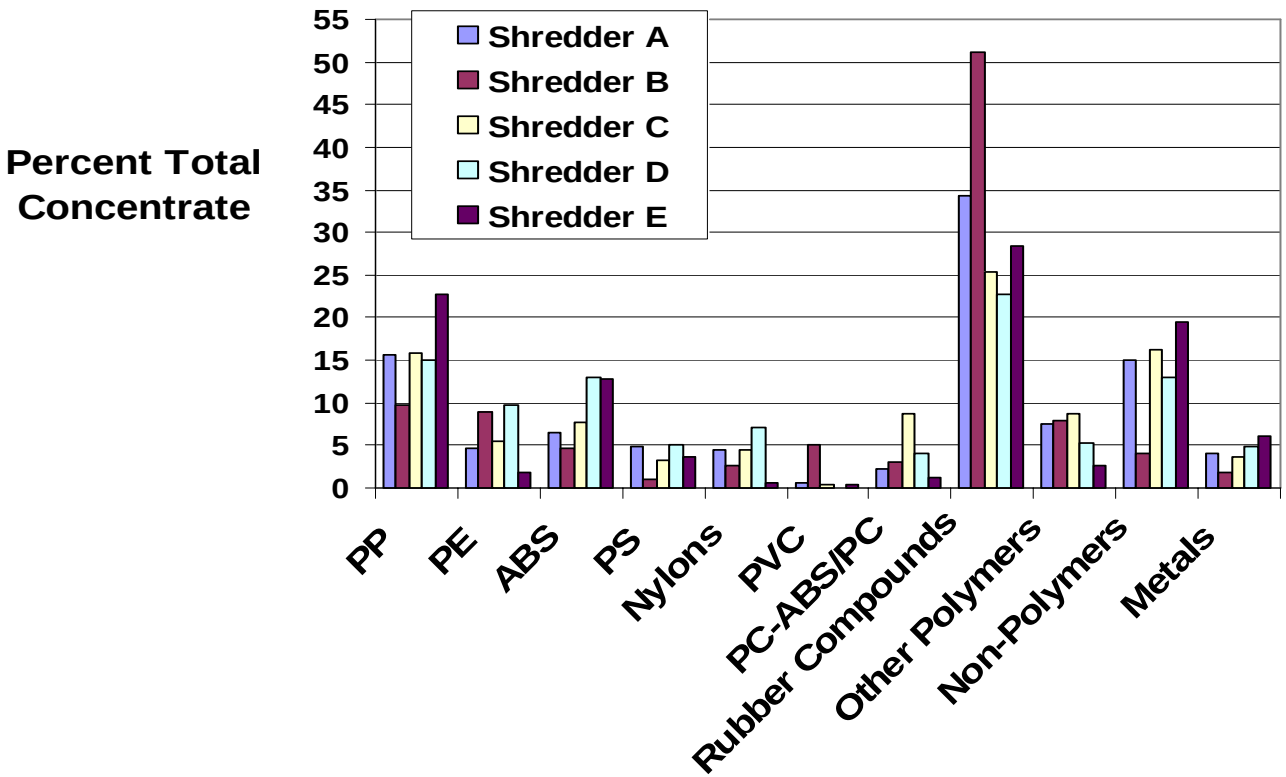


U.S. Recovered Polymer Concentrate Composition





Typical U.S. Residue Contains 25% Polymers--- Yield of Polymer Concentrate Exceeds 90%--- Concentrate Composition is Reasonably Consistent

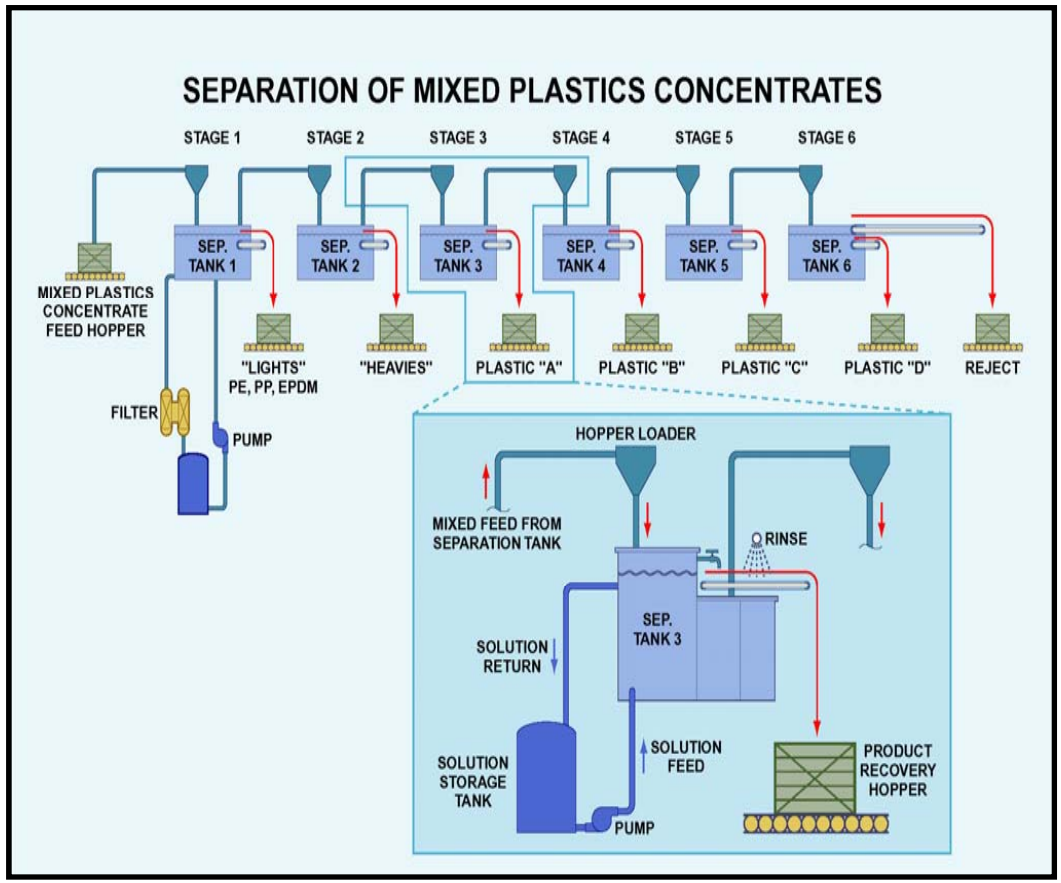


Comments on Bulk Separation of Shredder Residue

- *The Argonne bulk separation process achieved*
  - *Polymer recovery of ~95%*
- *Key variabilties are attributed to fines and rubber content---reasonably consistent polymer concentrate content*
- *EU concentrate appears richer in polyolefins, ABS, and HIPS and leaner in rubber relative to US*

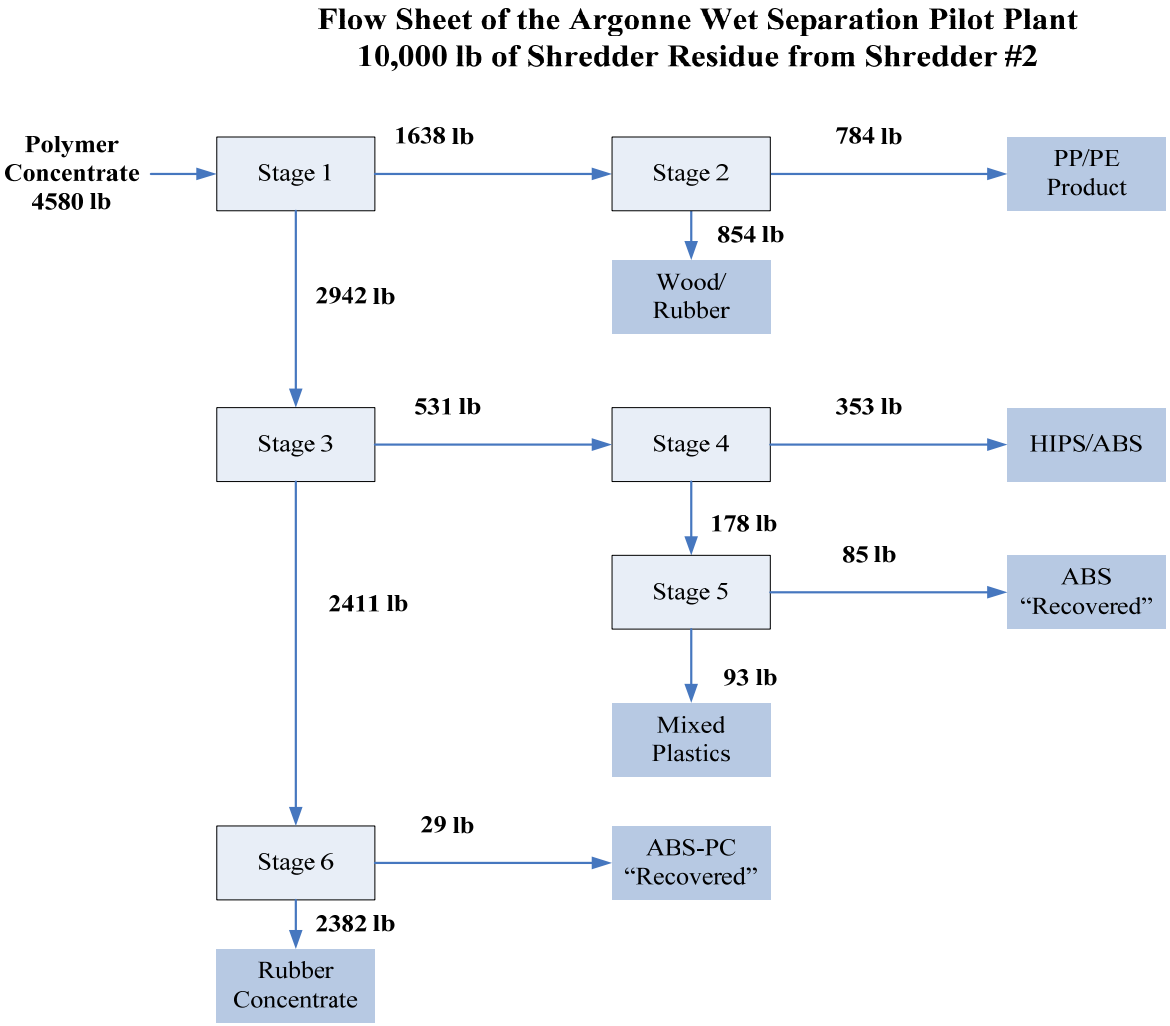
Selected Polymer Fractions are Recovered in a Multi-stage Wet Density/Froth Flotation Process

- *High throughputs essential for cost-effectiveness*
- *Density and/or settling velocities alone cannot provide an effective separation---surface modification is necessary*
- *Feed concentrate contains more than 20 polymers including wood and rubber*



Argonne Pilot-plant is Compact and Continuous

Argonne's Wet Separation: Example Trial Run



Polymer Disposition: Example Trial Run (Basis: 10,000 lbs of shredder residue)

Fraction	Shredder Residue	Polymer Concentrate	PP/PE Product	Wood Rubber	HIPS/ ABS	ABS "Recovered"	Mixed Plastics	ABS-PC "Recovered"	Rubber Concentrate
PP	558	472	373	55	0	0	0	0	0
PP (filled)	65	60	0	27	18	10	0	1	18
ABS	299	286	0	11	150	62	24	1	22
PE	476	422	355	38	5	0	0	0	0
HIPS	123	109	0	11	76	0	0	0	15
Nylon	141	125	0	6	2	6	5	0	99
PVC	255	255	0	0	0	0	0	1	239
PPO	31	29	0	0	25	1	1	0	0
PC/ABS	13	13	0	0	0	1	0	9	2
PC	238	232	0	0	0	0	0	14	205
Trace Plastics	73	71	0	0	5	1	3	1	58
Unidentified Plastics	98	92	0	0	0	0	2	0	84
Rubber and PU	2,557	2,415	50	595	43	4	58	1	1,530
Wood		100	0	60	27	0	1	0	6
Circuit Boards/Metals		110	0	0	0	0	0	0	104
Non-Plastics	5,073	59	5	50	0	0	0	0	0
Total	10,000	4,580	784	853	353	85	93	29	2,382

Mold Trials Confirm the Technical Feasibility of Re-use of Recovered Polymers for Automotive Parts

- *Steering column cover*
- *Battery tray*
- *Knee bolster*

Comments on Argonne Mechanical Process

- *Argonne has developed and demonstrated a process for recovery of polymers and other materials from complex waste streams*
- *The physical separation system is optimized for yield*
- *The froth flotation system is optimized for throughput, conditioned on recovered product quality*
- *Mold trials have confirmed the technical feasibility of the process*
- *Process economics appear positive, engineering design underway*

Conclusion: The changing automotive material mix over the past fifteen years and evolutionary technology trends relative to automobile architecture for improved safety and environmental performance may increase the recycling technical challenge

- *A joint U.S. government-industry CRADA was established in 2003 to lead the development of improved recovery and recycling methods for current and future ELVs*
- *The vision leading to this effort is one of sustainability and reduced environmental impact over the lifecycle of the automobile*
- *Ultimately, any new technology developed in response to these changes must have minimal risk--*
  - *Proven cost-effective at full-scale*
  - *Proven markets for products*
  - *Regulatory barriers removed/transactions costs minimized*

This research is funded by the American Plastics Council, USCAR's Vehicle Recycling Partnership and the U.S. Department of Energy Office of FreedomCAR and Vehicle Technologies.

Visit the U.S. ELV CRADA Team Website

(www.es.anl.gov/Energy_systems/CRADA_Team_Link/Index.html.)