

7. RECYCLING

A. Recycling Assessments and Planning

Principal Investigator: Edward J. Daniels

Argonne National Laboratory (ANL)

9700 S. Cass Ave., Argonne, IL 60439

(630) 252-5279; fax: (630) 252-1342; e-mail: edaniels@anl.gov

Technology Area Development Manager: Joseph A. Carpenter

(202) 586-1022; fax: (202) 586-1600; e-mail: joseph.carpenter@ee.doe.gov

Expert Technical Monitor: Philip S. Sklad

(865) 574-5069; fax: (865) 576-4963; e-mail: skladps@ornl.gov

Participants:

This project is conducted as part of a Cooperative Research and Development Agreement (CRADA) among Argonne, USCAR's Vehicle Recycling Partnershipⁱ, and the Plastics Division (formerly the American Plastics Council) of the American Chemistry Council.

CRADA Partner Principal Investigators:

Michael Fisher, American Chemistry Council, (703) 741-5599, e-mail: Mike_Fisher@americanchemistry.com

Gerald Winslow, VRP, DaimlerChrysler Corp., (248) 512-4802; e-mail: grwx@DCX.com

Claudia Duranceau, VRP, Ford Motor Co., (313) 390-0504; e-mail: cdurance@ford.com

Candace Wheeler, VRP, General Motors Corp., (586) 986-1674; e-mail: candace.s.wheeler@gm.com

Contractor: Argonne National Laboratory

Contract No.: W-31-109-Eng-38

Objectives

- Eliminate any real or perceived recycling barriers that might preclude the use of advanced automotive materials.
- Enable the optimum recycling of all automotive materials, current and future, thereby obviating the need for legislative recycling mandates.
- Assess the critical needs for cost-effective recycling of automotive materials and components.
- Establish research priorities to enable cost-effective recycling of advanced automotive materials and components.
- Communicate a collaborative industry/government approach to issues related to the recycling of automotive materials.
- Coordinate research with other agencies and stakeholders in the United States, Europe, and Asia.

Approach

- Consult with automotive manufacturers and recycling industries, USCAR and its affiliates, national laboratories, universities, and other relevant organizations to assess critical recycling needs/barriers.
- Develop a recycling research plan that will serve as a "working document" to guide the U.S. Department of Energy (DOE) in establishing priority goals, with an initial emphasis on lightweighting body and chassis materials.

- Establish an outreach/communication function to enable cooperation amongst, and leveraging of, resources with all stakeholders and the international community.
- Assist DOE in establishing advanced recycling research and development (R&D) initiatives and provide technical oversight to ensure that priority objectives/goals are accomplished.

Accomplishments During this Reporting Period (FY 2006)

- Conducted quarterly progress reviews with CRADA team.
- Conducted annual project review and gap analysis with CRADA team.
- Developed CRADA team presentation brochure (was prepared by Energetics) and one-pager.
- Conducted one-day peer review progress review. It was attended by experts in the field, in addition to the CRADA partners.
- Conducted one-day Roadmap workshop to update the 2001 Roadmap for Recycling End-of-Life Vehicles of the Future. The updated Roadmap will be issued in the first quarter of FY 2007.
- Launched US ELV CRADA Team website: http://www.es.anl.gov/Energy_Systems/CRADA_Team_Link/Index.html. It includes an overview of the CRADA team activities, downloadable CRADA team brochures, a bibliography of recycle literature and presentations and annual reports of the team.
- Presented papers outlining the industry/government collaboration at international conferences.
- The CRADA team held a media event for America Recycles Day. Press releases and related news stories are accessible through the CRADA team website.
- Continued liaison with the Institute of Scrap Recycling Industries (ISRI) and the Automotive Recycling Association (ARA) and held several meetings with the CRADA partners and representatives of ISRI and ARA.

Prior Accomplishments

FY 2005

- Conducted quarterly progress reviews with CRADA team.
- Conducted annual project review and gap analysis with CRADA team.
- Continued liaison with the Institute of Scrap Recycling Industries (ISRI) and held several meetings with the CRADA partners and representatives of ISRI.

FY 2004

- Conducted quarterly progress reviews with CRADA team.
- Conducted annual project review and gap analysis with CRADA team.
- Held a CRADA announcement event at Argonne on December 2, 2004 — the event was attended by representatives of the press, industry, and government.
- Established liaison with the Institute of Scrap Recycling Industries (ISRI) and held several meetings with the CRADA partners and representatives of ISRI.

FY 2003

- Developed 5-year project plan.
- Negotiated a CRADA with the VRP, the American Plastics Council (APC ... now the Plastics Division of the American Chemistry Council) and ANL, as partners; effort under the CRADA was initiated in August 2003.

Future Direction

- Conduct gap analysis and continue development and management of the R&D plan with the CRADA partners consistent with the recommendations of the updated Roadmap. As appropriate, new recycle R&D needs that are identified will be incorporated into the plan and projects for conducting the requisite R&D will be developed.

- Conduct scheduled progress reviews.
- Maintain and update the US ELV CRADA team website.
- Continue ongoing efforts toward the milestones and objectives of the CRADA statement-of-work.
- Continue outreach efforts to broaden the basis for cooperation among stakeholders.
- Continue ongoing project efforts to assist DOE in preparation of planning documents, priority recycling R&D needs, proposal reviews, and related tasks.
- Update the ELV Roadmap as necessary.
- The team will prepare papers for presentation at the SAE Congress in FY 2007.

Summary

The objective of this project is to establish priorities and develop cost-effective recycling technologies and strategies in support of the U.S. Department of Energy (DOE's) FreedomCAR and Vehicle Technologies (FCVT) Program's long-term objectives and goals. The major goals of this research are to (1) enable the optimum recycling of all automotive materials, (2) ensure that advanced automotive materials that improve the life-cycle energy use of vehicles are not precluded from use as a result of a perception that those materials are not recyclable, and (3) continue to enable market-driven vehicle recycling.

Today, cars that reach the end of their useful service life in the United States are profitably processed for materials and parts recovery by an existing recycling infrastructure. That infrastructure includes automotive dismantlers, which recover useable parts for repair and reuse; automotive remanufacturers, which remanufacture a full range of components, including starters, alternators, and engines to replace defective parts; and, ultimately, the scrap processor, which recovers raw materials such as iron, steel, aluminum, and copper from the remaining auto "hulk" after components have been recovered for recycling. Today, more than 75% of the materials from obsolete cars are profitably recoverable for recycling.

The recyclability of the remaining 25% of the end-of-life vehicles (ELVs) is limited at present by the lack of (1) commercially-proven technologies to identify and cost-effectively separate materials and components and (2) profitable post-use markets. During the next 20 years, both the number and complexity of ELVs are expected to increase, posing

significant challenges to the existing recycling infrastructure. The automobile of the future will use significantly greater amounts of lightweight materials (e.g., ultra-light steels, aluminum, plastics, and composites) and more sophisticated/complex components.

Roadmap Recommendations

A workshop to update the original roadmap, which was published in 2001, was held on September 14, 2005, at Argonne. Representatives from DOE, key stakeholders, universities and other experts attended the meeting (Exhibit 1). A draft of the new roadmap has been prepared and is being reviewed by the CRADA partners. The updated roadmap will be published during the first quarter of FY 2007. The workshop evaluated the original Roadmap and its recommendations.

The following were identified as some of the factors that can affect the recyclability of future shredder residue:

- Vehicles containing new materials of construction for lightweighting (composites, lightweight steel, aluminum alloys, and magnesium);
- Catalysts for better environmental control; and
- Vehicles powered by fuel cells, electric batteries, hydrogen, and hybrids.

The key recommendations from the original roadmap, which was developed with input from key stakeholders to guide DOE's recycle research, were:

- Come together as a unified recycling community to cost-share in the development of required new technology.

Exhibit 1. List of Roadmap Workshop Attendees.

Organization	Represented By
American Plastics Council	Trip Allen
Consultant	Richard Paul
American Plastics Council	Mike Fisher
Argonne	Ed Daniels
Argonne	Bassam Jody
Argonne	Pomykala Joe
Argonne	Jeff Spangenberg
Bayer Material Sciences	Don Schomer
DaimlerChrysler	James Frusti
DaimlerChrysler	James Ryan
DaimlerChrysler	Nakia Simon
DaimlerChrysler	Gerry Winslow
Energetics	Melissa Eichner
Energetics	Catherine Jereza
Ford	Claudia Duranceau
Georgia Tech	Bert Bras
Gesing Consultants	Adam Gesing
GM	Steve Cadle
GM	Candace Wheeler
ISRI	Dave Waggoner
PURRC	Stephen Niemiec
Rochester Institute of Technology	Nabil Nasr
Steel Recycling Institute	Bill Heenan
Troy Polymers	Ibrahim Sendjarevic
Troy Polymers	Vahid Sendjarevic
Univ. of Windsor	Edwin Tam
USCAR	Susan Bairsley
USCAR	Stacey Keast
USCAR	Mike Martin
USCAR	Virginia Smith
USDOE	Joseph Carpenter

- Incorporate reuse, remanufacturing, and recycling into the design phase for cars whenever possible.
- Recycle as early in the recycling stream as possible, while relying on the market to optimize the value and amount recycled at each step.
- Maintain a flexible recycling process that can adapt to diverse model lines fabricated with different techniques and materials from various suppliers.
- Develop automated ways to recover bulk materials.

- Emphasize R&D on post-shred material identification, sorting, and product recovery.
- Focus R&D efforts on materials not recycled today by sorters (e.g., post-shred glass, rubber, fluids, textiles, plastics).
- Develop uses for recovered materials (whether in the same or different applications) and testing specifications.
- Encourage investment in the infrastructure needed to achieve the recyclability goal. Build on the existing infrastructure.
- Develop a means to prevent the entry of polychlorinated biphenyls and other hazardous materials into the recycling stream and promote acceptable limits in shredder residues.
- Consider the recycling requirements of new technologies entering fleets as early as possible.

The Five-Year R&D Plan

On the basis of the roadmap and continuing discussions with key stakeholders, a five-year research plan was prepared. The plan includes three focus areas, as discussed below.

Area 1. Baseline Technology Assessment and Infrastructure Analysis

The focus of the work under this activity is to develop the tools and document the information necessary to make effective decisions relative to technology needs to facilitate sustainable future vehicle recycling and to make effective decisions regarding the allocation of R&D resources.

Area 2. Materials Recovery Technology Development and Demonstration

Research to be conducted in this area will initially focus on addressing technology needs for post-shred materials recovery, including mechanical recycling and conversion to fuels and chemicals. Projects that enhance pre-shred recovery — including disassembly for materials recovery and direct reuse and remanufacturing of components — will also be considered. In the long term, such components as fuel cells, advanced batteries, and onboard hydrogen reformers are more likely to enter the recycle stream through pre-shred recovery for remanufacturing, repair, and materials recovery. Research will be undertaken to determine the technology needs to

ensure the recyclability of these very advanced automotive components.

Area 3. Recovered Materials Performance and Market Evaluation

Understanding and enhancing recovered materials performance is an essential ingredient to a successful recycling program. This is especially true in automotive systems when the materials and components that are recovered have been in use for an average of from 10–15 years. Area 3 includes projects to quantify the relative performance of recovered materials vis-à-vis new or virgin materials; research on compatibilization of recovered polymers to improve performance properties; development of technologies to upgrade the recovered materials, such as separation of fibers from polymeric substrates; and development of applications for other recovered materials, such as rubber and glass.

CRADA Projects

A cooperative research and development agreement (CRADA) among Argonne, the VRP and the American Plastics Council (APC – now the Plastics Division of the American Chemistry Council) has been structured to provide a core team of expertise and the resources to enable the optimum recycling of all automotive materials.

The CRADA team's R&D agenda focuses on the following key objectives:

- Develop and demonstrate sustainable technologies and processes for ELV recycling.
- Demonstrate the feasibility of resource recovery from shredder residue, including materials recovery for reuse in automotive and other applications, chemical conversion of residue to fuels and chemicals, and energy recovery.
- Develop viable strategies for the control and minimization or the elimination of substances of concern.
- Benchmark recycling technology and provide data to stakeholders.
- Stimulate markets for reprocessed materials to support economic collection, processing, and transportation.
- Transfer technology to commercial practice.

This project (Recycling Assessments and Planning) provides for the overall management of the CRADA team activities and for communication and advocacy with other organizations. The other major projects that have been initiated under the CRADA include the following:

- Baseline Assessment of Recycling Systems and Technology (see 7.B).
- Post-Shred Materials Recovery Technology Development and Demonstration (see 7.E).
- Development of Technology for Removal of PCBs and Other Substances of Concern from Shredder Residue (see 7.C).
- Compatibilization/Compounding Evaluation of Recovered Polymers (see 7.D).

The objectives and progress on these projects are discussed in their respective sections of this report. Effort under the CRADA was initiated in the fourth quarter of FY 2003.

Outreach Efforts

While the CRADA team provides a core of expertise, cooperation with other organizations is the key to achieving the overall program objectives. In the United States, a market-driven recycling infrastructure is in place. The CRADA team is actively pursuing cooperation with the organizations and companies that are a part of that infrastructure. Cooperation with other stakeholders is also essential.

A website was launched in March of 2006 to provide for better communication and networking with stakeholders and other research teams: http://www.es.anl.gov/Energy_Systems/CRADA_Team_Link/Index.html. The website provides an update of the CRADA progress and provides access to relevant information and publications including a bibliography of mechanical, thermo-chemical conversion, and energy recovery technologies for recycling automotive materials.

The CRADA team held a media event at Argonne for *America Recycles Day*. It was attended by a number of media organizations. Articles featuring the work done by the CRADA team were written by the media members who attended. CRADA team

members were interviewed by several radio stations after the media event.

Several presentations and publications were made to further communicate with interested parties including a paper "Market Driven Technology Development for Sustainable End-of-Life Vehicle Recycling: A Perspective from the United States," presented by Edward Daniels at the 6th International Automobile Recycling Congress, Amsterdam, Netherlands, March 15-17, 2006. A joint DOE, USCAR, and APC paper on "Market Driven Recycling in North America" was presented as the keynote paper at the 2004 International Car Recycle Congress in Washington, D.C.

Several meetings with representatives of the Institute of Scrap Recycling Industries (ISRI) and the Automobile Recycling Association (ARA) were held to brief them on the CRADA objectives and projects and to elicit their participation.

To further communicate the U.S. approach to ELV recycling, a one-page CRADA summary and a CRADA brochure have been prepared and it is available at the CRADA website.

As previously mentioned, a review of the projects and ongoing efforts of the CRADA team was held September 13, 2005 and a workshop was also held on September 14, 2005, to review and update the ELV Roadmap. The updated roadmap will be issued during the first quarter of FY 2007.

Publications

1. *The R&D of the FreedomCAR Materials Program*, Carpenter, J.A., Jr., E.J. Daniels, P.S. Sklad, C.D. Warren and M.T. Smith, Proc. Of the International Auto Body Congress, Novi, MI, September 19, 2006.
2. *Market Driven Technology Development for Sustainable End-of-Life Vehicle Recycling: A Perspective from the United States*, Daniels, E.J., Jody, B. J., Pomykala, J. A. Jr., and Spangenberg, J. S., presented at the 6th International Automobile Recycling Congress, Amsterdam, Netherlands, March 15-17, 2006.
3. *Industry and Government Collaboration to Facilitate Sustainable End-of-Life Vehicle Recycling*, Daniels, E. J., 2005 ASME International Mechanical Engineering Congress & Exposition, BRTD-4: Sustainability Applications in Product Design and Manufacture, Orlando, Florida, November 5-11, 2005
4. *Market Driven Automotive Recycling in North America*, Duranceau, C., presented at the Institute of Scrap Recycling Industries Shredder Meeting, Dallas, TX (Oct. 30, 2004).
5. *Sustainable End-of-Life Vehicle Recycling: R&D Collaboration between Industry and the U.S. DOE*, Daniels, E.J., Carpenter, J.A. Jr., Duranceau, C., Fisher, M., Wheeler, C., and Winslow, G., JOM, The Mineral, Metals & Materials Society, vol. 56, no 8, pp 28-32 (Aug. 2004).
6. *Market Driven Automotive Recycling in North America*, Duranceau, C., USCAR, Carpenter, J., U.S. DOE, Fisher, M., American Plastics Council, keynote at the 2004 International Car Recycling Workshop, May 19, 2004, Washington D.C.
7. *Automotive Materials Recycling: A Status Report of U.S. DOE and Industry Collaboration*, Daniels, E. J., Ecomaterials and Ecoprocesses, Proc. of the International Symposium on Ecomaterials and Ecoprocesses, August 24-27, 2003, Vancouver, BC, Canada, pp 389-402.
8. *Effects of Transportation on the Ecosystem*, Carpenter, J.A., Jr., Ecomaterials and Ecoprocesses, Proc. of the International Symposium on Ecomaterials and Ecoprocesses, August 24-27, 2003, Vancouver, BC, Canada, pp 13-22.
9. *Automotive Technology: Looking Forward*, Sullivan, R., D. Hamilton and J.A. Carpenter, Jr., Ecomaterials and Ecoprocesses, Proc. of the International Symposium on Ecomaterials and Ecoprocesses, August 24-27, 2003, Vancouver, BC, Canada, pp 49-67.

10. *A Roadmap for Recycling End-of-Life Vehicles of the Future*, prepared by Energetics for the U.S. Department of Energy, Office of Advanced Automotive Technologies (May 2001).

ⁱ One of the formal consortia of the United States Council for Automotive Research (USCAR) set up by the “Big Three” traditionally U.S.-based automakers to conduct joint pre-competitive research and development.