# TABLE OF CONTENTS

Lists of Tables, Figures & Boxes .................................................................................................................. 6
Acknowledgements ........................................................................................................................................... 8
Executive Summary ......................................................................................................................................... 9

## 1. Introduction ........................................................................................................................................... 13
   1.1 Purpose ............................................................................................................................................... 13
   1.2 Methodology & Approach .................................................................................................................. 14
   1.3 Scope of the Research ........................................................................................................................ 14
   1.4 Limitations ......................................................................................................................................... 16
   1.2 Overview of Product Stewardship ...................................................................................................... 16
   1.3 Product Stewardship in Practice ........................................................................................................ 17
   1.4 Principles of Product Stewardship as Adopted by the OEA ............................................................... 17

## 2. The OEA & U.S. EPA ............................................................................................................................. 19
   2.1 The Minnesota Office of Environmental Assistance ........................................................................ 19
   2.2 The U.S. EPA Office of Solid Waste .................................................................................................. 19

## 3. The Automotive Industry ....................................................................................................................... 21
   3.1 Overview of Industries in the U.S, European Union & Japan ............................................................. 21
      3.1.1 United States Automotive Industry Overview ........................................................................... 21
      3.1.2 European Union Automotive Industry Overview ....................................................................... 22
      3.1.3 Japanese Automotive Industry Overview ..................................................................................... 22
   3.2 Vehicle Design – Platforms & Material Selection ............................................................................ 22
      3.2.1 Automotive Platforms ................................................................................................................ 22
      3.2.2 Automotive Design – Overview of A Generic Design Process ................................................... 24
      3.2.3 Material Selection in the Automotive Design Process ................................................................ 27
   3.3 Current End-of-Life Vehicle Management in the U.S. ..................................................................... 29
      3.3.1 U.S. Recycling Infrastructure ....................................................................................................... 29
      3.3.1.1 ASR in Municipal Solid Waste ............................................................................................... 31
   3.4 Environmental Issues & Drivers for U.S. Auto Manufacturing ....................................................... 32
      3.4.1 Domestic Drivers ........................................................................................................................ 32
      3.4.2 International Drivers ................................................................................................................... 33
      3.4.3 Influence of the European Commission’s ELV Directive on the U.S. Industry ......................... 34

## 4. Company Goals Regarding Material Use ............................................................................................. 36
   4.1 Industry Activities Related to Material Use ....................................................................................... 36
   4.2 Automotive Manufacturers Goals & Activities Regarding Material Use ......................................... 38
      4.2.1 BMW Group ............................................................................................................................... 38
      4.2.2 DaimlerChrysler ...................................................................................................................... 41
      4.2.3 Ford ........................................................................................................................................... 44
      4.2.4 General Motors ........................................................................................................................ 47
      4.2.5 Honda ......................................................................................................................................... 49
      4.2.6 Nissan ......................................................................................................................................... 51
      4.2.7 Toyota ......................................................................................................................................... 53
   4.3 Automotive Supplier Goals & Activities Regarding Material Use .................................................. 55
      4.3.1 Delphi Corporation .................................................................................................................... 55
      4.3.2 Lear Corporation ....................................................................................................................... 57
      4.3.3 Magna International ................................................................................................................ 59

## 5. Trends in Automotive Design & Available Technologies ...................................................................... 60
   5.1 Automotive Design Trends ................................................................................................................ 60
      5.1.1 Number of materials & Number of components ....................................................................... 60
      5.1.2 Electronics .................................................................................................................................. 61
      5.1.3 By-Wire Technology .................................................................................................................. 62
      5.1.4 Safety Systems & Safety Standards ......................................................................................... 62
5.1.5 Weight Reduction .......................................................... 63
5.1.6 Recyclability .............................................................. 63
5.1.7 Recycled Content ......................................................... 64
5.1.8 Recycling & Recovery Techniques .............................. 65
5.1.9 Responsibility for Design ............................................ 66
5.2 Available Technology ....................................................... 66
5.2.1 Fuel Systems .............................................................. 66
5.2.3 Adhesives & Fasteners .............................................. 67
5.2.4 Painting & Coating .................................................... 67
5.2.5 Design Techniques ................................................... 67

6. Materials Used, Trends & Examples .................................. 68
6.1 The Use of Plastic .......................................................... 69
6.1.1 Trends in Use of Plastic .......................................... 70
6.2 The Use of Composite Materials .................................... 72
6.2.1 Trends in Use of Composites .................................... 72
6.3 The Use of Steel, Aluminum & Magnesium .................... 73
6.3.1 Trends in Use of Aluminum & Magnesium ............... 73
6.4 The Use of Bio-based Materials or Natural Fibers in Plastics ................. 74
6.4.1 Trends in Use of Bio-based Materials or Natural Fibers in Plastics .......... 74
6.4.2 Examples, Opportunities & Challenges .................... 74

7. Substances of Concern, Trends, Examples & Opportunities ............. 76
7.1 Mercury ........................................................................... 77
7.1.1 Trends in Use of Mercury ....................................... 77
7.1.2 Alternatives, Opportunities & Challenges ................. 78
7.2 Cadmium ........................................................................ 79
7.2.1 Trends in Use of Cadmium ...................................... 79
7.2.2 Alternatives, Opportunities & Challenges ................. 79
7.3 Lead ............................................................................... 79
7.3.1 Trends in Use of Lead ............................................. 80
7.3.2 Alternatives, Opportunities & Challenges ................. 80
7.4 Hexavalent Chromium .................................................. 82
7.4.1 Trends in Use of Hexavalent Chromium .................... 82
7.4.2 Alternatives, Opportunities & Challenges ................. 83
7.5 Brominated Flame Retardants ....................................... 83
7.5.1 Trends in Use of Brominated Flame Retardants .......... 83
7.5.2 Alternatives, Opportunities & Challenges ................. 84
7.6 The Use of Poly-Vinyl Chloride (PVC) ............................ 86
7.6.1 Trends in Use of PVC ............................................ 86
7.6.2 Alternatives, Opportunities & Challenges ................. 86
7.7 Other Substances ........................................................ 87
7.7.1 Sodium Azide ........................................................ 87
7.7.2 Polychlorinated biphenyls (PCBs) .............................. 88
7.7.3 Hybrid Batteries .................................................... 88
7.7.4 Tires ........................................................................ 89

8. Examples of Recycled-Content Materials & Opportunities ................ 90
8.1 Recycled Content – Issues & Challenges .......................... 92

9. Examples of Recyclable Materials & Opportunities ...................... 94
9.1 Recyclable Material – Issues & Challenges ......................... 96

10. Materials That Currently Make-Up Automotive Shredder Residue .... 98
10.1 Relationship Between Key Trends & ASR Volumes ............... 99
10.2 Relationship Between Increased Recycled-Content Material Use & ASR Volumes ........... 101

11. Component Re-use ........................................................... 102

12. Partnerships ................................................................. 103
13. Lessons Learned
13.1 Involving all Stakeholders
13.2 Cost Challenges
13.3 Commitment Challenges
13.4 Sorting Challenges
13.5 Consistent & Constant Supply of Feedstock
13.6 Challenges to Introducing New or Alternative Materials
13.7 Challenge of Dealing With Existing Vehicles
13.3 Commitment Challenges
13.2 Cost Challenges
13.4 Sorting Challenges
13.5 Consistent & Constant Supply of Feedstock
13.6 Challenges to Introducing New or Alternative Materials
13.7 Challenge of Dealing With Existing Vehicles

14. Sources of Information: Literature

Appendices
Appendix 1. Company Profiles
1. BMW Group
2. DaimlerChrysler Corporation
3. Delphi Corporation
4. DuPont
5. Ford Motor Company
6. General Motors Corporation
7. Lear Corporation
8. Magna Intier

Appendix 2. Organization Profiles
1. Alliance of Automobile Manufacturers (Submitted Response)
2. Automotive Recyclers Association (Interviewed)
3. Ecology Center (Interviewed)
4. Environmental Defense (Interviewed)
5. Institute of Scrap Recycling Industries (ISRI) (Interviewed)
6. International Institute for Environmental Economics at Lund University (PhD Researchers Interviewed)
7. Michigan Technological University (Written response)
8. Suppliers Partnership for the Environment (not Interviewed)
9. USCAR Vehicle Recycling Partnership (VRP)(not Interviewed)

Appendix 3. European Commission ELV Directive

Appendix 4. Japanese Auto Recycling Law

Appendix 5. Voluntary Product Stewardship Initiatives in the U.S. & Canada
1. Carpet American Recovery Effort (CARE), U.S.
2. Electronics Product Stewardship (EPS) Canada
3. National Electronics Product Stewardship Initiative (NEPSI), U.S.

Appendix 6. International Materials Data System (IMDS)

Appendix 7. VRP Preferred Practices

Appendix 8. Ford & Alcan Closed Loop Recycling

Appendix 9. Lead-free Electro-coat

Appendix 10. Canadian Automotive Product Stewardship Partnership Project

Appendix 11. Oeko-Tex Standard for Textiles

Appendix 12. GM Dismantling Manual (excerpt)

Appendix 13. Straw-man Scenario

Appendix 14. Discussion Points Based on Challenges & Research Findings

Glossary of Terms
Lists of Tables, Figures & Boxes

List of Tables

Table 1. List of companies and organizations interviewed during the research.................................................................14
Table 2. Chrysler Vehicle Engineering objectives for the 1997 Dodge Dakota instrument panel........................................27
Table 3. Diversity of materials used in components of mid-sized cars and pick-up trucks.....................................................28
Table 4. Adapted from Automotive Alliance of Manufacturers Summary of environmental activities in the U.S. Automotive Industry related to materials, recycling and substances of concern, in relation to start of European Commission’s ELV Directive.................................................................35
Table 5. BMW recycling and environmentally compatible new car design commitments......................................................38
Table 6. Characterization (select materials) of a generic vehicle in 1995..............................................................................68
Table 8. Comparison of material composition of a generic vehicle for 1995, 2001 and 2020..................................................72
Table 9. Profile of materials in 1532kg (3377 lb) generic vehicle that are found in amounts of 10 kg (22 lb) or above, or are identified OEA within the scope of this research, and estimate of where each material goes at end-of-life. ........................................................................................................................................98
Table 10. EPS Roles and Responsibilities..................................................................................................................131
Table 11. Substances that are banned or restricted from decoration materials under the Oeko-Tex Standard. 141

List of Figures

Figure 1. Stages of generic vehicle design process, from concept to building prototypes, testing the vehicle, retooling product equipment and launch of the vehicle........................................................................................................24
Figure 2. Nissan approach to incorporate recycling into its product development process..................................................25
Figure 3. Illustration of the vehicle recycling infrastructure and main stages that a vehicle may go through at end-of-life.................................................................................................................................31
Figure 4. Illustration of targets from ELV Directive in the European Union........................................................................33
Figure 5. Number of mercury switches per vehicle by model year for Ford, GM and DCX vehicles. Data from Michigan Switch Program, Alliance of Automobile Manufacturers.................................................................37
Figure 6. Comparison of renewable raw materials in BMW models..................................................................................40
Figure 7. Number of Parts Launched Containing Recycled Non-Metallic Materials.................................................................46
Figure 8. Roles in the Life Cycle Management of Vehicle Environmental Impacts..............................................................47
Figure 9. Use of recycled plastics in Vauxhall/Opel Vehicles (European subsidiaries of GM).............................................49
Figure 10. Principle recyclable parts on Nissan Vehicle, the “March”....................................................................................51
Figure 11 How Nissan incorporates environmental issues such as recycling into its product development process .................................................................52
Figure 12. Use of recycled plastics in Vauxhall/Opel Vehicles............................................................................................65
Figure 13. Use of thermoplastics by major market, 2001........................................................................................................70
Figure 14. Sales and use of select thermoplastic resins in transport and other markets between 1997 and 2001. .....................................................................................................................................................71
Figure 15. Recycling of plastics for vehicles...................................................................................................................94
Figure 16. Breakdown of Magna customers (%).................................................................................................................70
Figure 17. Vehicle teardown at end-of-life.....................................................................................................................120
Figure 18. Vehicle entering a car shredder at end-of-life.................................................................................................122
Figure 19. 2012 Goals for Carpet Recovery................................................................................................................123
Figure 20. Strawman Scenario for Diverting ELV from Landfill: Targets for Major Steps in the Recycling Process to Achieve 95% Recyclability.................................................................146
List of Boxes

Box 1. The Global Nature of Vehicle Platforms ................................................................. 22
Box 2. Handling End-of-Life Vehicles at DaimlerChrysler’s German facilities ................ 25
Box 3. Innovations implemented at Lear & new technology applied for Lear products in the last 2 years that contribute to environmental improvement .......................................................... 57
Box 4. Maine Mercury Switch Law .................................................................................... 78
Box 5. The Importance of Identification & Sorting to Economical Plastic Recycling .......... 96
Box 6. Electronics Product Stewardship (EPS) Canada Mission & Vision ......................... 130
Box 7. Electronics Product Stewardship (EPS) Canada Proposed Handling Charges ........ 131
Box 8. Agreement, NEPSI Finance System, March 2002 ................................................... 134
Acknowledgements

This research report benefited greatly from the interest and cooperation of people in the companies and organizations that participated. The Study Team would like to thank the people within each company and organization who provided examples and insights on the topic, and who took time to comment on drafts of this report. However, the findings of this report are the responsibility of Five Winds International and do not necessarily reflect the views of the OEA, EPA or any of the individuals acknowledged within.

Our thanks also to the study sponsors Garth Hickle, Bill Sierks and John Gilkeson of the Minnesota Office of Environmental Assistance. Thank you to Julie Rosenbach of the U.S. EPA Office of Solid Waste and Jason Swift of the U.S. EPA Region 5 Waste Management Branch, as EPA’s assistance grant made this work possible. Thank you all for your input and patience throughout this work.

The Study Team was comprised of James Fava, Jennifer Hall, Andrea Russell, Konrad Saur, Shannon Turnbull and Jennifer Clipsham of Five Winds International. For more information on this study please contact:

Garth Hickle
Product Stewardship Team Leader
Minnesota Office of Environmental Assistance
garth.hickle@moea.state.mn.us
651.215.0224

Julie Rosenbach
U.S. EPA Office of Solid Waste
Municipal and Industrial Solid Waste Division
rosenbach.julie@epa.gov
703.308.6241

Jason Swift
U.S. EPA Region 5
Waste Management Branch
Swift.Jason@epamail.epa.gov
312.886.0754

Jennifer Hall
Five Winds International
j.hall@fivewinds.com
519.822.6668 x228
Executive Summary

Today, approximately 95% of the cars and trucks we drive in the U.S. enter the vehicle recycling infrastructure when they reach the end of their useful life. Each individual vehicle is recycled at a rate of more than 75% by weight. This collection and recycling rate is high when compared to other products such as appliances, aluminum cans or paper products, which are collected at rates of 52%, 55% and 42% respectively. This is partly because recyclers are able to recover and resell useable automotive components and to recycle most metal materials from the vehicle. Remaining materials however, are shredded and sent to landfill as automotive shredder residue (ASR). Five million tons of ASR is disposed of in landfills in the U.S. each year. Several factors influence this process, including the types of materials in the vehicle (both valuable and less-valuable materials), the ease of recovering each material and whether there are markets for the recycled materials.

While there is much activity in the U.S. to reduce emissions generated during vehicle use, find alternative fuel systems and address environmental impacts of operations, other end-of-life issues associated with vehicles have been less researched to date. There may be potential to further reduce the environmental impact of vehicles through increased use of recyclable materials and materials with recycled-content, and reductions in materials of concern.

This report presents information on the vehicle design process, materials used in vehicles and some of the trends in materials used. It also describes factors that can influence materials used and presents challenges and opportunities to address materials of concern, recyclable materials and recycled-content in vehicles. In these areas it was found that there are opportunities to improve the environmental performance of vehicles across the life cycle, referred to as product stewardship in this report. This Executive Summary presents conclusions drawn from the report, as follows:

There may be potential to further reduce the environmental impact of vehicles through vehicle design. It is important to understand the vehicle design process in order to find effective points for making any design changes. During the vehicle design process, there are certain optimal points for making changes to a vehicle’s design (i.e., making a car door with a new recycled-content plastic, or using a lead-free solder in an electronic component), be it to an existing vehicle or a new vehicle model. Likewise, there are points during the design process that are sub-optimal (in terms of cost efficiency) for making such changes. In addition, vehicle sub systems are often shared among vehicles and combine to form what are known as vehicle platforms. From each platform a large number of different vehicles may be built and sold globally (i.e., a mid-sized sedan platform may support economy cars as well as luxury cars). Once a design is changed, that change might be reflected in all the vehicles on that platform, globally. For this reason, it is possible that a design change made in the U.S. may be reflected in cars produced and sold overseas, while vehicles designed in the European Union (e.g. to meet requirements of the ELV Directive) or in Japan may also be produced and sold in the U.S.
While automakers in the U.S. have long been undertaking environmental activities, international drivers are challenging the industry to go further on specific issues. Over the past two decades, U.S. automakers have set goals and worked to restrict uses of mercury, lead, cadmium and hexavalent chromium in specific vehicle components. Many U.S. automakers are also working to increase the use of materials with recycled-content or materials that are recyclable. Collectively, automakers are working on certain issues, such as the USCAR Vehicle Recycling Partnership’s (VRP) “preferred practices” for recycling. The European Union’s End-of-Life Vehicle Directive will challenge automakers to go further, in some areas. It specifies the elimination of substances of concern, sets recyclability targets and encourages more recycled content to be incorporated in vehicle designs. According to some manufacturers, the Directive has already influenced further reduction in lead and hexavalent chromium and has led to new supplier requirements in data collection. Today, most automakers in the U.S., the European Union and Japan require their suppliers to disclose all materials used in vehicles by entering this data into an international materials database system (IMDS).

Several trends in automotive design, while not entirely driven by environmental concerns, may impact recyclability. First, companies are looking to use fewer types of materials in an attempt to reduce costs. This may positively influence the recyclability of vehicles in future, in part because less sorting may be needed at the end of life. Second, electronics are increasingly used in vehicles in navigation and entertainment systems, among others. This trend may pose problems to vehicle recycling as electronics contain highly varied materials (from different plastics to flame retardants to heavy metals such as lead). Third, reducing vehicle weight for fuel efficiency will change the material make up and will in turn affect recyclability.

There are also trends in the materials used in vehicles that will affect recyclability. First, there is a clear increase in the use of plastic materials. Currently, these are not recovered or recycled from vehicles at a high rate. To a lesser extent, there is an increase in the use of composites (which, to date, are not highly recyclable) and an increase in the use of natural fibers or other bio-based materials. Automotive manufacturers and suppliers are researching new materials, such as soy based urethane foams. It is as yet unclear how these may impact vehicle recyclability.

Several research groups in the U.S., Europe and Japan have been developing technologies to separate and recycle plastics from ELVs. While these technologies now exist, they are not widely available or applied. This is partly because they are not yet cost effective, there are no strong markets for the recycled materials and the markets for virgin plastics are well established. Without an applied infrastructure to separate and recycle plastics, and subsequent markets for their resale, higher recyclability goals set by automakers will not reduce the amount of ASR going to landfill. Without a recycling infrastructure, there is less incentive to invest in selection and testing of recyclable materials.1

An increase in the use of recycled content in vehicles would require a consistent and large supply of feedstock. There is currently a lack of infrastructure in the U.S. for identifying, separating and recycling volumes of plastic large enough to support the automotive industry.

Automotive manufacturers are using recycled content in some applications; however there are opportunities for it to be used more. This may help to develop markets for recycled materials from vehicles, but perhaps also from carpets and plastic beverage containers as well. Important challenges include the resources needed to test and approve these new materials, as well as life cycle studies to determine whether they actually reduce the environmental impacts from vehicles. For instance, using recycled content may compromise recyclability.

Automakers and suppliers recognize mercury, cadmium, lead, hexavalent chromium and brominated flame retardants as important issues. The use of these materials is being reduced in several applications. In cases where they are still used, alternative designs and materials exist or are under development. Thus, there may be opportunity to support research on alternative design solutions and to support the changeover from existing materials, technologies or designs. The same may be true for uses of PVC, sodium azide and various potential materials in hybrid batteries.

The use of electronics in vehicles is increasing, and these contain heavy metals, flame retardants and materials that are difficult to separate and recover at end-of-life. This is true for electronics in both automotive and non-automotive applications. Currently, the electronics industry is working on product stewardship initiatives in several U.S. States, in the European Union and globally. There may be opportunity for the automotive industry to both support this work (i.e., supporting environmentally preferable or eco-labeled electronics) and to be involved in it.

Establishing consistent communication and feedback among manufacturers, suppliers and end-of-life managers will be essential to helping make the end-of-life treatment of vehicles more cost effective. To enhance communication about recyclable materials in vehicles, new materials in vehicles (such as composites or plastics containing natural-fiber) and materials of potential concern, it will be important to identify all parties who may be affected and engage them, both early and throughout a collaborative process. As examples, it may be possible to learn from BMW’s approach to certifying vehicle recyclers, or Mercedes Benz’s recycling system of service stations in Germany. Furthermore, there may be potential to increase “labeling” or otherwise marking certain types of materials in the vehicle. This could make it easier for each actor in the chain to recognize potentially valuable materials and find opportunities to dismantle, separate and recycle materials that are currently sent to landfill. In addition, it may be worth exploring how to encourage manufacturers, suppliers, material producers and recyclers to set and report publicly on goals for environmental improvement. This could help to educate customers on the environmental impacts of

---

vehicles, progress being made to address these impacts and how they may be able to support these efforts. In turn, this could stimulate demand for vehicles designed for better environmental performance.

**Using a life cycle approach to assess potential new materials is important.** Life cycle assessments are currently the best-known approach to uncover certain environmental trade-offs among various alternatives. For example, the industry is moving away from using hexavalent chromium and flame retardants (PBDE and PBB), yet there may be a need to better understand the environmental impact of any alternatives to these. Additionally, the increasing use of bio-based materials may improve certain aspects of environmental performance, but may also reduce performance in other aspects, such as recyclability. To ensure effective use of resources for environmental improvement, it may be prudent for government and industry to further work together on alternatives and understanding the life cycle impacts of these alternatives.

**As new vehicle designs continue to evolve, it will be important to identify and prevent life cycle environmental impacts.** It will be most resource-effective to further focus on prevention instead of clean up, and avoid developing technology today that becomes unacceptable tomorrow.
1. Introduction

Today, approximately 95% of the cars and trucks we drive in the U.S. enter the vehicle recycling infrastructure when they reach the end of their useful life. This collection rate is high when compared to appliances, aluminum cans or paper products, which are collected at rates of 52%, 55% and 42% respectively. There is a well established industry in the U.S. for automobile recycling and each vehicle is recycled at a rate of more than 75% by weight. Recyclers recover useable automotive components and recycle metal materials for sale. Remaining materials are shredded and sent to landfill as automotive shredder residue (ASR). Several factors influence this process, including the types of materials in the vehicle (both valuable and worthless), markets for their recycled products and how easy it is to recover these materials. While there is much activity in the U.S. to reduce emissions generated during vehicle use and find alternative fuel systems, other end-of-life and manufacturing issues associated with vehicles have not been as well researched to date. There may be potential to further improve vehicle recycling through increased use of recyclable materials and materials with recycled-content. And there may be potential to reduce the use of materials that become a concern to human health and the environment, when vehicles reach their end of use.

This research report presents information on the materials used in vehicles and some of the trends in types of materials used. It also describes factors that can influence which materials are used, as well as certain challenges and opportunities to address materials of concern, recyclable materials and recycled-content in vehicles.

1.1.1 Purpose
This report has been prepared for the Minnesota Office of Environmental Assistance (OEA) under a grant from US EPA Region V. The purpose of the report is to present information on certain materials used in the automotive industry and to highlight the potential for product stewardship initiatives that will result in the increased use of recycled materials and the reduction in use of materials of concern.

The report is intended to serve as a survey of existing activities within the automotive industry and provide an introduction to materials use and selection. The report does not make policy recommendations or comment on the benefits or drawbacks of regulatory means to achieve environmental goals.

The U.S. EPA is interested in researching if additional opportunities exist where partnerships can be developed to further minimize the environmental footprint of the automotive industry. Collaboratively, both parties have worked on Pollution Prevention Programs and Hazardous Waste Minimization Programs targeting mainly waste reduction efforts during the manufacturing process. Together they have also worked to comply with fuel economy standards and have partnered on the development of fuel cell technology. These programs demonstrate a great deal of progress, which the EPA is interested to continue.
1.1.2 Methodology & Approach
Information in this report is based on a review of published articles and interview conversations with companies and organizations in the automotive sector. Automotive manufacturers, automotive part suppliers, material suppliers, auto recyclers, scrap dealers, academics and NGOs were interviewed (Table 1). Throughout the report, the sources of various statements are cited generically (for example, “one company explained”) in attempt to provide some confidentiality and encourage open sharing of information. The information in this report is not a comprehensive inventory of all environmental activity in the automotive sector, but it is believed to be representative given the Terms of Reference for this research.

In June 2003, all contributors were invited to review a draft of this report. The OEA and EPA also invited additional experts to review the draft report. This final report reflects the additional information and editorial comments provided by these reviewers. However, the full contents and findings of this report are the responsibility of Five Winds International and do not necessarily reflect the views of any of the organizations or individual acknowledged within.

<table>
<thead>
<tr>
<th>Companies &amp; Organizations Interviewed During the Research:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Alliance of Automobile Manufacturers (written response)</td>
</tr>
<tr>
<td>• Automotive Recyclers Association</td>
</tr>
<tr>
<td>• BMW AG</td>
</tr>
<tr>
<td>• Delphi Corporation</td>
</tr>
<tr>
<td>• DuPont Flooring Systems</td>
</tr>
<tr>
<td>• Environmental Defense</td>
</tr>
<tr>
<td>• Ecology Center</td>
</tr>
<tr>
<td>• Ford Motor Co. (no direct interview, but information provided during tour of Ford’s facilities)</td>
</tr>
<tr>
<td>• Institute of Scrap Recycling Industries Inc. (ISRI)</td>
</tr>
<tr>
<td>• Lear Corporation</td>
</tr>
<tr>
<td>• Magna International, Inc.</td>
</tr>
<tr>
<td>• Northwest Auto Parts</td>
</tr>
<tr>
<td>• Lund University, International Institute for Industrial Environmental Economics</td>
</tr>
<tr>
<td>• Michigan Technological University, Department of Mechanical Engineering-Engineering Mechanics</td>
</tr>
</tbody>
</table>

The mention of any company, product, or process in this paper does not constitute or imply endorsement by EPA. Please note that EPA has verified none of the claims made by these organizations. The information contained herein represents the findings of the authors, and does not necessarily reflect opinion, findings or guidance of the Environmental Protection Agency.

1.1.3 Scope of the Research
Research focused on the use of recycled-content materials, recyclable materials, PVC, brominated flame retardants, cadmium, lead, mercury and hexavalent chromium in vehicles. The OEA and EPA outlined these materials in the Terms of Reference for this research. Given the variety of potential environmental issues associated with these materials and the fact that automotive manufacturers, suppliers, dismantlers and recyclers are working to manage the use of these materials, they are of interest as potential opportunities for product stewardship.
This report is structured to address specific topics detailed by the OEA and EPA in the Terms of Reference for this research. These topics are:

- Key materials used in vehicles, important characteristics of these materials and other factors influencing material selection (Section 6);
- Trends in vehicle design and materials used (Section 5 and 6);
- Current examples and opportunities to address heavy metals and brominated flame retardants used in vehicles, other examples and opportunities to reduce toxicity\(^3\) and materials of concern and examples and opportunities to reduce PVC used in vehicles (Section 7);
- Current examples and opportunities to address recyclability\(^4\) or recycled-content of plastics and other materials in vehicles (Section 8 and 9);
- Correlation between materials used and the composition and volume of auto shredder residue (ASR) (Section 10);
- Public goals set by automotive manufacturers and certain automotive suppliers, specific to material use (i.e., goals for vehicle recyclability, recycled-content, materials of concern) (Section 4); and
- Current effects on the U.S. market (existing or anticipated) from the European Commission’s Directive on End-of-Life Vehicles (ELV) and Japan’s automotive recycling system (Section 3).

It is important to recognize that this report does not conclude on which materials have the greatest environmental impact or benefit across the vehicle’s life cycle (i.e., whether recycled-content materials are better than recyclable materials, or whether a heavy metal used in one vehicle component is more problematic than another). Life cycle studies would be needed to understand any risks, environmental impacts and benefits associated with each material and proposed alternative materials.

The research was also defined by geographic scope. Focus is on the U.S. automotive industry and opportunities for product stewardship here in the U.S. However, the automotive industry is global, so the report often describes vehicle design activities and environmental initiatives occurring in Western European or Japanese automotive companies because they indicate what vehicle design solutions the industry may or may not be able to achieve. As U.S. companies often own companies in Western Europe and Japan (and vice versa) it is not always easy to distinguish between environmental activities that are specific to the U.S. operations and those that are only occurring overseas. This report attempts to distinguish between domestic activity and activity in Western European or Japanese companies, where possible.

---

3 The degree to which a substance or mixture of substances can harm humans or animals. A more complete description is provided by the EPA/OA/Office of Communications, Education, and Media Relations: Terms of Environment: Glossary, Abbreviations, and Acronyms (Revised December 1997).

4 Ability of component parts, materials or both that can be diverted from an end-of-life stream to be recycled, Source: ISO 22628:2002(E) Road Vehicles – Recyclability and recoverability – Calculation method
1.1.4 Limitations
Access to information was not equal across all interested stakeholders from the material supply, vehicle production and end-of-life chain. Despite efforts in the initial stages of this research, plastics manufacturers contacted did not provide information or participate in interviews. Also, certain companies and organizations from other sectors were hesitant to participate or refused to disclose information on some of the issues covered in this research.

To protect the interests of those who provided information or participated in interviews, many of the details in the report are not attributed to exact sources. This reduces the value of the information to some degree.

In some cases, the research was limited by perceptions carried over from past projects or initiatives between government and the automotive industry. For example, the issue of mercury switches in vehicles has a long history, and in some cases the details of that issue may have hindered discussions on other issues relevant to the present study.

1.2 Overview of Product Stewardship

The U.S. EPA describes product stewardship as a “product-centered approach to environmental protection … product stewardship calls on those in the product life cycle – manufacturers, retailers, users, and disposers – to share responsibility for reducing the environmental impacts of products”. In particular in Minnesota, product stewardship calls on manufacturers to participate in the financial and physical responsibility for collecting and recycling products at the end of their useful lives. When manufacturers share the costs of recycling products, they have an incentive to use recycled materials in new products and design products to be less toxic and easier to recycle, incorporating environmental concerns into the earliest phases of product design.

Product stewardship encourages manufacturers, retailers and consumers to treat products as resources rather than waste, changing how they think about the products they make, buy and use.

Companies that are accepting the challenge of product stewardship are recognizing that it also represents a substantial business opportunity. By rethinking their products, their relationships with the supply chain, and the ultimate customer, some manufacturers are dramatically increasing their productivity, reducing costs, fostering product and market innovation, and providing customers with more value at less environmental impact. Reducing use of toxic substances, designing for reuse and recyclability, and creating take-back programs are just a few of the many opportunities for companies to become better environmental stewards of their products.
1.3 Product Stewardship in Practice

The concept of product stewardship continues to inform corporate decision-making and government policy on an international level. As mentioned, European and Asian governments have adopted product stewardship regulatory frameworks for a variety of products including packaging, electronics and automobiles. In North America product stewardship has evolved in a different fashion, with a mix of voluntary agreements, industry programs, state policy and in the case of Canada, provincial regulation.

Product stewardship is an important principle for reducing the overall environmental impacts of a product and has been implemented by a wide spectrum of manufacturers producing consumer products. Product stewardship is starting to be viewed as an important competitive distinction for companies that seek to capitalize on the growing interest in environmental preferable purchasing and corporate responsibility. For instance, the Sony Corporation has contracted with Waste Management-Asset Recovery Group to accept Sony-branded products free of charge at more than a dozen Waste Management facilities in Minnesota. C&A Floorcoverings, a manufacturer of commercial carpeting, has developed a reclamation program that recovers discarded carpet tiles and utilizes them as a feedstock for new carpet.

In the U.S., Congress has not enacted federal policy or a specific program to promote stewardship for a particular product. To date, the focus has been on state-level activity and, in particular, an interest in voluntary multi-stakeholder dialogues to develop industry-wide agreements. The National Carpet Recycling Agreement signed in 2002 is the most prominent example of this approach. Similar initiatives are underway with the electronics industry and with paint manufacturers (Please refer to Appendix 5 for descriptions of product stewardship programs).

Experience with product stewardship programs in each product sector will be an important resource for any future product stewardship programs (whether in the automotive industry or any other product sector). It is therefore important to note each product sector has unique characteristics that may require different approaches to product stewardship and end of life management in particular.

1.4 Principles of Product Stewardship as Adopted by the OEA

The following principles of product stewardship were adopted by the OEA as part of the state product stewardship policy issued in 1999.

1. All parties who have a role in designing, producing, or selling a product or product components assume responsibility for achieving the following goals:

   - Reducing or eliminating the toxic and hazardous constituents of products and product components.
• Reducing the toxicity and amount of waste that results from the manufacture, use and disposal of products.
• Using materials, energy and water efficiently at every stage of a product's life cycle, including product manufacture, distribution, sale, use and recovery.

2. All purchasers and users are responsible for reducing the amount of toxicity and waste that result from their use and disposal of products, and for using products in a manner that conserves resources.

3. The greater the ability of a party to influence the life cycle impacts of the product, the greater the degree of responsibility the party has for addressing those impacts.

4. Parties responsible for addressing environmental impacts of products have flexibility in determining how to best address those impacts.

5. The costs of recovering resources and managing products at the end-of-life are internalized into the costs of producing and selling products, so that those costs are not paid for by government.

6. Government provides leadership in product stewardship in all its activities, including but not limited to, promoting product stewardship in purchasing products, making capital investments in buildings and infrastructure, procuring services, and ensuring products are recycled or properly managed at the end of their useful lives.
2. The OEA & U.S. EPA

The Minnesota Office of Environmental Assistance (OEA), under a grant from the U.S. Environmental Protection Agency (EPA) and Region 5, has undertaken this research project on the automotive industry and issues of material use, material selection, substances of concern, recyclability and recycled-content in order to understand whether there is potential for product stewardship to support environmental improvement in the sector.

2.1 The Minnesota Office of Environmental Assistance

The OEA is experienced in implementing and supporting product stewardship initiatives in several product sectors. The OEA is actively promoting several voluntary product stewardship initiatives, including those with the carpet and electronics industries in the U.S. (described in Appendix 5), to promote toxicity reduction, address substances of concern and enhance recyclability and recycled-content in products as appropriate. Also, the first state policy on product stewardship in the U.S. was adopted by the OEA in 1999. The policy sets product stewardship objectives that the OEA has been pursuing through several efforts. Relevant to this research, these efforts include:

| Support of manufacturers initiatives: | “The OEA also promotes product stewardship through support for manufacturers' initiatives...In addition to event promotion and media exposure, the OEA provides technical assistance to support ongoing collection and recycling activities.” |
| Establishment of industry-wide commitments: | “The OEA is committed to working cooperatively with businesses, non-governmental organizations, retailers and others to develop voluntary commitments to increase the collection and recycling of identified consumer products. In 2001, the OEA participated in an effort with the state governments, U.S. EPA and the carpet industry to develop the first national product stewardship agreement in the U.S. The OEA is currently participating in a similar effort with the electronics industry and will continue to identify opportunities to promote product stewardship in this manner” |
| Policy development: | “The [M]OEA is working with the Legislature, state agencies and other stakeholders to promote the development of product stewardship policies.” Adapted from Product Stewardship in Minnesota, www.moea.state.mn.us |

2.2 The U.S. EPA Office of Solid Waste

The U.S. Environmental Protection Agency (EPA) has also established a history promoting product stewardship. In 1998, the EPA published a brochure entitled “Extended Product Responsibility: A strategic framework for sustainable products.” In it, the EPA states:
“Extended Product Responsibility, an emerging environmental principle, can help businesses spark product innovation, cut costs, and enhance customer loyalty, while growing market share at home and abroad.”

The U.S. EPA is interested in product stewardship as a product-centered approach to environmental protection. Also known as extended product responsibility, product stewardship emphasizes the importance of reducing the environmental footprint of products at every stage of their life cycle. It also recognizes the need for every player in the product's life cycle, from manufacture, use to end-of-life management, to take responsibility for reducing the environmental impact of the product.

There is comparatively little in the way of national mandates for product stewardship in the United States, unlike Europe and elsewhere. Still, EPA is working with several product sectors including carpets, electronics and beverage containers to promote greater product stewardship. EPA is partnering with manufacturers, retailers and others through a variety of collaborative efforts to help make the manufacture, use and end-of-life management of these products more environmentally sustainable.

Many of these efforts involve partnerships with multiple stakeholders, although each effort has its own unique issues and challenges. EPA views the steps taken by the auto industry as an opportunity to promote a product stewardship approach that encourages reductions in the use of toxic materials, promotes the balance between recycled-content, recyclability and energy efficiency, and creates opportunities and incentives for more environmentally benign processes and products throughout the life cycle.

The EPA is working with the automotive industry in several capacities, including pollution prevention in the supply chain through the recently formed Supplier Partnership for the Environment. This program demonstrates a great deal of progress, which the EPA is interested in building upon. EPA is interested in exploring with the states and the automotive industry where there are additional opportunities to reduce the environmental footprint of automobiles through better product stewardship.
3. The Automotive Industry

This section describes vehicle production and sales in the U.S., the European Union (EU) and Japan. It explains how vehicles are designed and how domestic vehicle designs can connect to vehicle designs in the European Union or Japan. It also describes how vehicles in the U.S. are currently handled when they are no longer in use. Together, this information is essential background for understanding:

- What auto manufacturers are doing to improve recycling, recyclability and the use of substances of concern,
- How this may link to international activity, and
- Where the opportunities for product stewardship may lie.

3.1 Overview of Industries in the U.S, European Union & Japan

The research is based on the U.S. automotive industry, but also refers to the automotive industries of Japan and the European Union. As background and context, this section describes the magnitude and basic structure of the automotive industries in these three regions.

3.1.1 United States Automotive Industry Overview

In the U.S., domestic car production in 2001 was 5.11 million vehicles. Together, domestic car and truck production totaled 11.42 million vehicles in 2001, 17.47 million cars and trucks were sold, and a total of 230,428,326 cars and trucks were in operation in the U.S. in 2001. Total revenue for new car and new truck dealers was $690.4 billion U.S.D for 2001. In 2002, 16.6 million new cars were sold (not including trucks) and domestic auto manufacturers had 62% of the U.S. market share. Each year, approximately 10 - 14 million vehicles reach their end-of-life and enter the recycling infrastructure in the U.S.

Of all passenger vehicles sold in the U.S., the proportion of minivans, pickup trucks and sport utility vehicles is increasing. In 2001, sales of these vehicles surpassed the sale of passenger cars for the first time. In May 2003, GM reported a 13% increase in the number

---

of minivans, pickup trucks and sport utility vehicles from one year ago. Ford sold 1.8% more in May 2003 than it did in April 2003.11

3.1.2 European Union Automotive Industry Overview

Motor vehicle (cars and light trucks) production in Western Europe in 2001 was 16.7 million units with a total of 1.183 billion vehicles (cars and light trucks) in operation in 2001.12 The industry employs close to 1.1 million people.13 Approximately 12 million vehicles become ELVs each year and 25% (by weight) of each is landfilled, while 75% by weight is recycled.14 For more information on the European automotive industry, please visit the European Automakers Association: http://www.acea.be/ACEA/index.html

3.1.3 Japanese Automotive Industry Overview

Motor vehicle production (cars and light trucks) in Japan in 2001 was 9.78 million units and 5.9 million vehicles were sold15. Approximately 4.1 million vehicles were exported from Japan in 2001. Japanese scrap dealers recycle about 5 million vehicles a year and this is expected to increase with the anticipated passing of a new auto-recycling law that is expected to go into effect in Japan in 2004.16 For more information on the automotive industry in Japan, please visit Japan’s Automobile Manufacturer’s Association: http://www.jama.org/home.cfm

3.2 Vehicle Design – Platforms & Material Selection

This section of the report explains vehicle design and how materials are selected within the design process. The purpose is to provide context, helping the reader understand what might be involved in changing a vehicle design to incorporate recycled-content, improve recyclability or eliminate a material of concern (See Box 2 at the end of this section). This section serves as background for the discussion on ‘trends in automotive design’, ‘materials used’, ‘substances of concern’ and subsequent opportunities for product stewardship.

3.2.1 Automotive Platforms

---

It is becoming increasingly common for manufacturers to utilize a single manufacturing platform for several of its vehicles worldwide. This is because it enables the company to save money on design and testing as well as to export vehicles to different marketplaces with relatively few changes. This does not always mean the vehicle that goes to the market will look the same, but rather that the “guts” of the vehicle are almost identical. Thus while the styling may differ, the chassis and engine components, electronic systems, braking, etc, can be the same. Because of this, it is reasonable to assume that improvements made to vehicles produced in other countries may eventually become global. For example, a change to a gearbox in a vehicle designed in Europe will result in the same gearbox being used worldwide on vehicles using that platform and specifications. Thus multiple vehicles and countries benefit from the improvement. See Box 1 for more information.

**Box 1. The Global Nature of Vehicle Platforms.**

“OEMs are constantly commonizing processes, concepts and components both within and between current and future platforms to create global platforms. The goal: provide greater effective production and design flexibility to meet market needs while converging the number of overall platforms utilized globally to enhance economies of scale, increase quality, and raise capacity utilization. It is anticipated that by 2004 a third of all vehicles produced in the world will come from one-million unit global platforms - the emerging markets would be relegated to the lowest rung if not integrated into an increasingly rationalized global vehicle production environment.

Ford’s effort with the C-segment Focus underscores the industry shift. Built in several countries on four continents by 2003, C170 is Ford’s highest volume global platform. Eventually this one nameplate (in hatchback, sedan, and wagon forms with projected sales of almost one million units worldwide) will be on sale in more than 40 countries.”


Online: [www.covisint.com](http://www.covisint.com).

An example of this type of global platform is General Motors’ Epsilon platform. Epsilon is a front wheel drive mid-size sedan platform Saab and Opel developed jointly that many North American vehicles are, and will be, based on. This includes the 2004 Chevrolet Malibu, the 2004 Pontiac Grand Prix and the 2004/5 Saturn L car. The Malibu actually underwent relatively few changes for the American market, maintaining much of the exterior styling used in the Opel Vectra. Additionally, there will also be a future Cadillac and a few Holden’s (GM brand in Australia) designed on the Epsilon platform. In Europe it is used for the Opel Vectra (the first car released on the market using the platform in April 2002) and Saab 9-3. The platform architecture will likely account for 1.2 million GM cars worldwide over the next several years. This illustrates how design changes made in a given country will affect vehicles manufactured in others.

---

17 Raynal, W. Structurally Sound: The Epsilon platform could become one of General Motors’ most important, [www.autoweek.com](http://www.autoweek.com), July 12, 2002.

3.2.2 Automotive Design – Overview of A Generic Design Process

Figure 1 below outlines the generic product development cycle for an automobile. Within the cycle, there are several milestones where various requirements must be met for the design to progress through the cycle.

For example, there may be several requirements outlined in the concept stage, which must be detailed quantitatively before moving to the design stage. Then, at the end of the design stage, design teams will have to report on progress on meeting those requirements before moving into the Model/Prototype stage.

Figure 2 illustrates Nissan’s approach to incorporating environmental considerations into the vehicle design process. The generic stages of the development process are on the left side of the graphic, while the incorporation of recycling targets is shown down the center. The graphic demonstrates the companies’ use of recycling targets to drive the design process and improve the vehicles recyclability and recycled-content.

---

The highest degree of freedom to make changes in the design of an automobile is in the earliest stages. This is also where the greatest chance to avoid costly changes later on can occur. For example, if the design team or company does not foresee an issue on their radar as being important, it may not be addressed in the early design stages. However, once tooling has begun, if the issue does become a significant one, it can cost the company millions of dollars to delay the product launch and make a change to the design and resulting tooling in the manufacturing plan. An example of an issue currently challenging manufacturers is what is referred to as “Design for Disassembly”. This refers to vehicles designed from the beginning of the development stage with a set of requirements for disassembly. These requirements may include targets on recyclability, as shown in the Nissan example above, targets on time to dismantle components or sub-systems, etc. Design for Disassembly can help companies to manage the cost of end-of-life regulations such as the European Union ELV. See Box 2 below for how DaimlerChrysler is utilizing Design for Disassembly to help keep the costs of end-of-life take back of vehicles to a minimum.

Additionally, the development cycle for a single vehicle is distinct from the cycle for an entire platform. For example, while it may be possible to plan for use of an Hg-free HID headlamp as late as 24 months prior to beginning the manufacture of a specific vehicle, a materials use change of this nature would not normally be incorporated into other products until those other products were programmed for a front end redesign affecting the headlamp.

---

20 Nissan 2001 Environmental and Social Report.
Box 2. Handling End-of-Life Vehicles at DaimlerChrysler’s German facilities.

“If they really were making a film of the ELV disposal process at DaimlerChrysler … the director … and her cameramen might capture the vehicle recycling process something like this:

“Scene 1: A sad-looking Mercedes driver appears on the scene. He’s finally decided that his faithful old car has reached the end of the road. He picks up the phone, dials the hotline on 00800 1 777 7777, and asks the DaimlerChrysler Customer Assistance Center for the address of the nearest ELV collection point. A glance at the map reveals that, as promised, the collection point is within a 50 kilometer (31 mile) radius of his home. A tired smile crosses his face.

“Scene 2: Our hero drives to the collection point which turns out to be a certified Mercedes dealership, no less. The dealer checks the vehicle data, then parks the car on a special ELV parking lot. The former owner gives the hood a last loving pat and says goodbye to his old friend. A few days later, the postman will bring him a momento – the official disposal certificate called for by law.

“Scene 3: The old Mercedes is taken from the collection point to a specialized dismantling facility under contract to DaimlerChrysler. At this point, the camera could show the main dismantling hall at ATC in Stuttgart, for example. To the left, we see a row of high-bay shelves full of parts. Once they have been tested to make sure they are fully serviceable, these will be sold to other Mercedes drivers as used spares. To the right, we see a mechanic in blue overalls carefully taking the old Mercedes apart, nut by nut, bolt by bolt.

“The first step is to drain the vehicle completely by removing all the operating fluids – from the radiator, fuel tank, sump and brake system, to the windshield washer system and even the shock absorbers. “We have a special extraction system which removes all the fluids from a vehicle,” says Stefan Mareien, “it leaves hardly a trace.” The next step is dismantling. The airbag and pyrotechnic belt tensioners are removed and triggered to render them harmless. Then the battery, tires, engine and windows are all removed and the cables are released from their terminals and pulled out. Anything that could prove useful as a spare part is stored on the high-bay shelves. Other parts are sorted into special containers for separate recycling processes: glass to glass, tires to tires, plastics to plastics, wires to wires. A few hours later, all that is left is the bare bodyshell, which is then shipped to a shredding plant. After the metal has been removed for melting down, only the so-called “light shredder fraction” remains – a mixture of plastics, textiles, glass, paint and rust. To date, this has been landfilled or used for thermal energy recovery, but research is in progress to identify applications for this material, too.

“This is where the film comes to an end. Of course, the recycling process we have described not only applies to old Mercedes but to old Chrysler, Jeep®, smart and Mitsubishi models, as well. As Anita Engler says, “We have included all the Group’s brands for Germany and the EU in the recycling scheme. And we’re out to make the dismantling process as efficient as possible.” Such efficiency not only helps the environment, it helps DaimlerChrysler, too. Under the End-of-Life Vehicle Directive, by 2007 at the latest, manufacturers must take back all end-of-life vehicles of their brands, irrespective of age, at no cost to the consumer. Effectively, this shifts the burden of paying for disposal from the consumer (the motorist) to the manufacturer. So the more efficient the dismantling process, the lower the cost that the manufacturer must bear. With this in mind, it is easy to see why it makes sense for cars to be designed so that–at the end of the road – they are easy to take apart. At DaimlerChrysler, this is the job of the Design for Environment Department (DFE). Based at the Sindelfingen Plant [Germany], DFE was established in 1996 and is continually looking for ways to make Mercedes vehicles even more environmentally compatible and easier to reuse and recover. Important points here include the use of uniform plastics and renewable resources. According to Bruno Stark, who heads up the department: “We started work in this area well before the introduction of the End-of-Life Vehicle Directive, but the new law has certainly stepped up the pressure.”

3.2.3 Material Selection in the Automotive Design Process

“Vehicle manufacturers are faced with many specific, and often conflicting, requirements when designing and constructing automobiles. Every component, and the material from which they are made, must adequately perform its primary function, must be durable, must contribute to the appearance, comfort and style of the vehicle, and above all must be safe.”


Material selection is influenced by many elements in the vehicle design process. Design of automotive components must adhere to a set of quantitative performance requirements (Table 2). For instance, design of a luxury vehicle might emphasize performance requirements on styling and comfort, while design of a sports vehicle may focus on acceleration, handling and maneuverability requirements. It is important to understand that characteristics and properties of a particular material are only one part of the many factors considered when deciding which material to use for a particular component (e.g., seat covering material) in a sub-system (e.g., cars interior) in a vehicle. For instance, the weight of a material is often a key factor, but must be balanced with considerations on cost, strength, innovation, competitive positioning and performance goals, such as noise, vibration and airflow, to name a few. To measure if performance requirements are met, testing is conducted on the material, component and the component sub-system, not only the material itself. While material innovations do affect design, it is ultimately the component and the system that must meet the performance goals.

A set of vehicle engineering objectives defined by DaimlerChrysler North America is presented as an example in Table 2.

**Table 2. Chrysler Vehicle Engineering objectives for the 1997 Dodge Dakota instrument panel.**

<table>
<thead>
<tr>
<th>Vehicle / Engineering Objectives 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program objectives for the 1997 Dodge Dakota instrument panel are described below briefly for illustrative purposes:</td>
</tr>
<tr>
<td>• To achieve crashworthiness performance which limits femur loads to 80% of FMVSS 208 requirements (8,000 N). <em>This level for the structural IP is designed to be in a safe range for guaranteeing full compliance with FMVSS 208 when the entire vehicles is tested.</em></td>
</tr>
<tr>
<td>• To have defroster performance 30% better than the 1996 model, bringing driver defrost time to 15 minutes and the total defrost time to clear a fully iced up window to 20 minutes</td>
</tr>
<tr>
<td>• To double the demister flow from the 1996 level of 4.5 cfm per outlet, while providing duct performance of 50 cfm per outlet with a total of four outlets</td>
</tr>
<tr>
<td>• To improve overall fit and finish of the IP and to have zero buzz, squeaks and rattles, in an effort to minimize warranty issues and improve customer appeal</td>
</tr>
<tr>
<td>• To meet all internal cost targets</td>
</tr>
<tr>
<td>• To improve ergonomics</td>
</tr>
</tbody>
</table>

---

In the design process, automotive designers set performance standards that suppliers must meet in their proposed designs. Thus, rather than specify which material is used for what purpose, suppliers can choose from a variety of materials, as long as they meet the performance requirements laid out by the OEM. Key considerations for suppliers may include:

- Performance,
- Manufacturability,
- Quality,
- Durability,
- Safety,
- Light weight for improved fuel efficiency,
- Cost (includes costs of the material, processing and warranty),
- Recyclability,
- Styling requirements, and
- Consumer preference.

Table 3 below illustrates the diversity of materials used in comparable components in mid-sized cars and trucks. This table demonstrates how different vehicle programs and different sets of performance requirements will lead to the use of different materials.  

### Table 3. Diversity of materials used in components of mid-sized cars and pick-up trucks.

<table>
<thead>
<tr>
<th></th>
<th>Taurus</th>
<th>Intrepid</th>
<th>Accord</th>
<th>S-10 Pickup</th>
<th>Frontier Pickup</th>
<th>Tacoma Pickup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headliner</td>
<td>Urethane</td>
<td>PE fiber</td>
<td>Cardboard</td>
<td>Urethane</td>
<td>Resinated fiber</td>
<td>Resinated Fiber</td>
</tr>
<tr>
<td>Intake Manifold</td>
<td>Plastic / Aluminum</td>
<td>Plastic</td>
<td>Aluminum</td>
<td>Plastic / Aluminum</td>
<td>Aluminum</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Bumper Beam</td>
<td>Steel</td>
<td>Steel</td>
<td>Steel</td>
<td>Steel</td>
<td>Steel</td>
<td>Steel</td>
</tr>
<tr>
<td>Body Panels</td>
<td>All Steel</td>
<td>Aluminum hood</td>
<td>All Steel</td>
<td>All Steel</td>
<td>All Steel</td>
<td>All Steel</td>
</tr>
<tr>
<td>Steering Knuckles</td>
<td>Iron</td>
<td>Aluminum</td>
<td>Iron</td>
<td>Iron</td>
<td>Iron</td>
<td>Iron</td>
</tr>
<tr>
<td>Valve Covers</td>
<td>Plastic</td>
<td>Plastic / Aluminum</td>
<td>Aluminum</td>
<td>Plastic / Aluminum</td>
<td>Aluminum</td>
<td>Aluminum</td>
</tr>
</tbody>
</table>

Traditionally, performance requirements specified manufacturing, use and occupational health and safety requirements, among others, but had little specifications on how the vehicle should perform at the end of its use. However, this continues to change as requirements for designing a vehicle today ban or restrict the use of certain substances of concern (substances that pose environmental problems during vehicle use or end-of-life management).

---

Currently, the OEMs have requirements for both recyclability and materials of concern imbedded in their vehicle design processes. Statements of Work and Target Agreements, among others, are formal parts of the product development process used to communicate these requirements to suppliers. To meet vehicle requirements, engineers must balance between product attributes to address competing requirements (such attributes might include fuel economy, durability, cost, etc.) during vehicle design. The ongoing challenge of balancing these attributes might mean that an attribute such as recyclability does not take precedence. However, the research indicates that the relative importance of recyclability, toxicity and end-of-life performance is growing as design practices, consumer preferences, economic incentives, and technologies change. In addition to including requirements on these areas, manufacturers often embark on concept vehicle designs, or special projects, which may have an overriding preference for materials that are more recyclable and/or less toxic.

3.3 Current End-of-Life Vehicle Management in the U.S.

This section provides an overview of how vehicles in the U.S. are currently handled when they are no longer in use. Additionally, this section describes the current state of vehicle recycling in the U.S., along with some of the environmental issues and drivers facing the industry.

3.3.1 U.S. Recycling Infrastructure

For more than 75 years in the U.S., automotive recyclers have been developing a disassembly process to reclaim reusable components and materials from salvaged, or “end-of-life” automobiles. The North American recycling industry recycles an estimated 14 million end-of-life vehicles in the U.S. and Canada each year\(^{25}\) and approximately 95%\(^{26}\) of cars in North America enter the disassembly process when they reach end of use. Today, more than 75%\(^{27}\) of the vehicle by weight is recycled and the remaining portion of the vehicle landfilled as ASR (about 25% by weight). As landfill space is measured by volume, it is interesting to note that about 25% of the vehicle by volume is recycled.\(^{28}\)


\(^{26}\) I.e., in 2000, 95.4% of vehicles that reached their end-of-life were recycled, according to the Steel Recycling Institute’s website article entitled “Steel: Driving Automobile Recycling” Available online at [http://www.recycle-steel.org/index2.html](http://www.recycle-steel.org/index2.html).

\(^{27}\) While the ARA and the majority of literature sources indicate that today, 75% of a vehicle by weight is recycled, others in the industry cite 85% is recycled by weight. A study by Richard Paul, *How Prepared are U.S. Dismantlers to Meet the EU Directive for ELV Recycling* (SAE 2001-01-3744) is based on a rate of 84% by weight, but it does note reasons why this estimate may currently be too high and the actual percent of each vehicle recycled, by weight, may be lower.

\(^{28}\) Written communication. K. Mills, Director, Pollution Prevention Alliance, Environmental Defense. 16 June 2003.
Nearly 12,000 auto dismantlers operate in the U.S. generating a reported $8.2 billion in sales each year.\(^{29}\) However, a significant challenge in determining recycling rates and the recyclability of vehicles is that the materials being recycled today are typically from vehicles designed and manufactured over a decade ago. This is a challenge because as new materials are tested and put into the marketplace, real-time data on recycling is impossible to obtain.

In the U.S., modern auto dismantlers and recycling businesses drain hazardous and recyclable fluids from end-of-life automobiles, dismantle undamaged parts and prepare the remaining vehicle hulk for materials recycling (Figure 3). Salvaged parts are cleaned, tested, inventoried, and sold as replacement parts to the market. According to the ARA, this avoids the use of 11 million gallons of oil (because it is not necessary to manufacture new replacement parts) and conserves energy and resources by re-using and re-building “core” parts.

The industry has undertaken “joint efforts”, such as the USCAR VRP (est. 1991) to develop standards for material selection and design guidelines and to promote and realize vehicle recycling and increase the use of recycled materials in vehicle design.\(^{30}\) However, while this progress on environmental issues in the U.S. automotive industry has been increasing and efforts are starting to be reflected in mainstream vehicle platforms (e.g. via targets for recycled-content and recycling), each actor in the industry is facing challenges and constraints.

\(^{29}\) Survey of ARA, conducted in 1997 by Axiom Research Company.  
\(^{30}\) Alliance of Automobile Manufacturers. Written communication. 9 May 2003.
3.3.1.1 ASR in Municipal Solid Waste

Materials from end-of-life vehicles that are not recycled are known as ASR and include plastics, rubber, wood, paper, fabrics, glass, sand, dirt, and ferrous and non-ferrous metal pieces. In the U.S. about 5 million tons of ASR is disposed of in landfills each year, comprising a small percentage of the total municipal solid waste stream. While a small percentage of the total, ASR constitutes a single stream that is more than the amount of carpets and rugs in landfills.

The increase in minivans, pickup trucks and sport utility vehicles on the road in the U.S. may have implications for the amount of material used and eventually the volume of ASR in landfills.

---

31 Figure provided by the Alliance, in “attachment 2” of a document sent 25 June 2003.
32 At the time of completion, the actual percentage of ASR in the MSW stream could not be found.
3.4 Environmental Issues & Drivers for U.S. Auto Manufacturing

3.4.1 Domestic Drivers

Profit is an important factor driving recovery of end-of-life vehicles. As illustrated in Figure 3, components and materials recovered from old cars can be sold in the marketplace. Finding and growing markets for these materials drives their recovery and related technologies. Dismantlers and material recyclers have traditionally recovered and sold components and metals salvaged from end of life vehicles for recycling.

The desire to reduce the weight of vehicles is also influencing material use and environmental performance considerations. There is pressure to continually increase the fuel economy of vehicles, resulting from the CAFE (Corporate Average Fuel Economy) standards, consumer expectations and fluctuating crude oil costs. Weight reduction is one way to improve fuel economy. Secondly, there is growing pressure to meet targets for recyclability and recycled-content in European Union markets, as well as internal company targets (see Section 4 below). These two pressures often present manufacturers with challenges in environmental performance that are not easily reconciled, as illustrated in the example below:

“An example given ... was the use of steel vs lighter materials. Use of steel would make it easy and inexpensive to recycle, but it makes the car heavier. It 'is probably a more important priority today to make cars lighter to get the fuel consumption down than it is to make them recyclable at the highest extent.' ... DFE today can be divided into 'design for emissions, lower consumption' and 'design for recycling.' Going for design for emission and lower consumption could be a drawback for design for recycling.”

This has forced automotive suppliers to use a life cycle perspective to evaluate the impact of their products, in order to understand these trade-offs. For example, a change made to increase a car’s fuel economy could lead to increased environmental burden during production and reduce the recyclability of the vehicle at the end-of-life. By uncovering competing issues, companies are able to make better decisions and avoid compromising one performance criteria for the other unknowingly.

33 The automotive industry has worked to produce the new standard “ISO 22628:2002(E) Road Vehicles – Recyclability and recoverability – Calculation method” to help to ensure consistent calculation methods are used when determining compliance with requirements such as those laid out in the EC End-of-Life Vehicles Directive.

3.4.2 International Drivers

Overall, it is important to realize that due to the global nature of automotive design and the move to more centralized design platforms, as discussed in Section 3.2, international regulations and initiatives will impact the materials used in vehicles around the world. This is because a single vehicle platform designed in Japan, for example, may be utilized for several different vehicles worldwide. Thus a change made to the platform itself will result in a change to each of those vehicles manufactured and sold worldwide. For example, if a platform changed from a steel to magnesium cross car beam, each of the vehicles manufactured using the platform may be manufactured using the magnesium beam, regardless of where they are produced and sold. Furthermore, companies stated that vehicles are designed according to the highest worldwide government health and safety regulations. This enables companies to shift products among markets with minimal changes to each model for different markets, which would be more costly than building a single vehicle that meets the majority of standards and regulations around the world.

Internationally, a Directive on End-of-Life Vehicles (ELV Directive) in the European Union is of recent significant focus. Currently, all manufacturers selling vehicles into the European Union have to comply with the Directive. It is aimed at dealing with the 8 to 9 million tonnes of waste generated by end-of-life vehicles in the European Community each year. The overriding objective of the European Commission’s ELV Directive is to reduce and prevent waste from end-of-life automobiles. The Directive sets targets for the proportion of each vehicle that should be recovered and recycled by 2006 (85%) and 2015 (95%) (Figure 4). It also restricts certain uses of lead, mercury, cadmium and hexavalent chromium in cars put on the market after July 2003 (Appendix 3). It also stipulates that manufacturers, not consumers, must bear the costs of disposal. In turn, suppliers of automotive components will have to meet requirements set by automakers that aim to comply with the ELV Directive.

![Figure 4. Illustration of targets from ELV Directive in the European Union.](http://europa.eu.int/comm/research/leaflets/recycling/en/page2.html)

---

35 “End of Life Vehicles”, European Union, EUROPA website online at http://europa.eu.int/comm/environment/waste/elv_index.htm
Imperative steps toward meeting this objective are determining the material composition of all automobile components, as well as identifying any toxic materials that are present in the vehicle. This information helps determine which parts can be recycled or reused at the end of a vehicle’s life. It also enables proper management of any hazardous substances present in components or materials.

No one interviewed during the research spoke about the impact of Japan’s automotive recycling legislation in the U.S. (see Appendix 4. Japanese Auto Recycling Law).

### 3.4.3 Influence of the European Commission’s ELV Directive on the U.S. Industry

The ELV Directive in the European Union is, to some extent, driving activities of manufacturers, suppliers and end-of-life managers in the U.S. While it is recognized that the U.S. automotive industry was addressing recyclability, recycled-content and substances of concern prior to and independent of the European Commission’s ELV, it is also clear that development of the ELV, targets for recyclability and phase-out dates have influenced efforts in the U.S. to some degree.

Targets in the Directive are influencing some of the U.S. manufacturer’s activities on substances of concern, including timing for reduction or phase-out of hexavalent chromium and lead. GM, DaimlerChrysler and Ford have all committed to switch to lead-free electro-coat. In their written commitment, DaimlerChrysler and Ford include a background statement “The European End of life of Vehicle (ELV) Directive requires a significantly reduced level of "substances of concern" (Cd, Hg, Pb and Cr+6) in vehicles sold in Europe effective January 2003.” 38–39 VRP’s Substances of Concern Task Force held a forum in 2002 entitled “Approach to Heavy Metal EU Mandates” to discuss progress on eliminating hexavalent chromium from vehicles. 40

As another example of this influence, the Vinyl Institute explains “the ELV Directive will likely reduce the amount of lead-stabilized vinyl used in vehicle wire harnesses while increasing the amount of non-lead-stabilized vinyl used”. 41

Requirements within the ELV Directive are an important driver for the automotive industry on a global scale. In connection to the ELV Directive, a database for collecting information on all materials used in vehicles has been developed. 42,43 The database is called the

---

38 USCAR. Online: http://www.uscar.org/consortia&teams/VRP/PAP-Ford.pdf
39 USCAR. Online: http://www.uscar.org/consortia&teams/VRP/PPAP-DCX.pdf
41 Written communication. The Vinyl Institute. 25 July 2003.
42 This connection is clearly stated in the Automobile Manufacturers Position Paper, entitled Material Data Sheets on Purchased Parts in IMDS, Compliance with the Purchasing Requirements of the Automobile Manufacturers, authored by the IMDS Steering Committee, made up of member companies. 27 September 2001. Online: http://www.mdsystem.de/html/en/Position_en.pdf
International Materials Data System (IMDS). Several North American manufacturers are now using the IMDS, asking their suppliers to report material data into the system for vehicles being exported to Europe. It is expected that this level of reporting into IMDS will expand to vehicles sold in the U.S. in the coming years.

Once material data for each type of vehicle is entered (including more than 80 families of materials), manufacturers will have an inventory of materials in its vehicles – not only for substances of concern, but for all materials (starting with vehicles that are exported to the European Union). While manufacturers in the U.S. have been collecting and managing information on substances of concern and recycling prior to the IMDS and the ELV Directive (See Table 4), they are now also using the IMDS.

Table 4. Adapted from Automotive Alliance of Manufacturers Summary of environmental activities in the U.S. Automotive Industry related to materials, recycling and substances of concern, in relation to start of European Commission’s ELV Directive.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980's</td>
<td>• OEM’s adopt restricted substance management standard</td>
</tr>
<tr>
<td>1980's</td>
<td>• OEM’s investigate shredder residue recovery</td>
</tr>
<tr>
<td>1991</td>
<td>• Vehicle Recycling Partnership formed as part of USCAR (a consortium of DaimlerChrysler, Ford, and GM)</td>
</tr>
<tr>
<td>1993</td>
<td>• Low Emissions Paint Consortium formed as part of USCAR</td>
</tr>
<tr>
<td>Early 1990's</td>
<td>• OEM's issue recycling guidelines to engineers and suppliers</td>
</tr>
<tr>
<td>Mid 1990's</td>
<td>• OEM’s adopt plastic applications with recycled-content</td>
</tr>
<tr>
<td>Mid 1990's</td>
<td>• Opened dismantling workshop, Vehicle Recycling Development Center</td>
</tr>
<tr>
<td>1996</td>
<td>• By Resolution of 14 November 1996, the European Parliament called on the European Commission to legislate on waste streams, in particular end-of-life vehicles, on the basis of product liability</td>
</tr>
<tr>
<td>2000</td>
<td>• E.U. ELV adopted</td>
</tr>
<tr>
<td>2003</td>
<td>• ELV heavy metal restrictions take effect</td>
</tr>
<tr>
<td>2005</td>
<td>• ELV recyclability target of 85% takes effect</td>
</tr>
</tbody>
</table>

The VDA (The German Automobile Manufacturer’s Association) list and lists from each manufacturer define what suppliers must report into the IMDS. These lists are available to suppliers – and the public – on the IMDS website. Among other substances, these lists require suppliers to report on their use of materials of concern (mercury, lead, cadmium and hexavalent chromium). The IMDS is described further in Appendix 6.

---

43 The connection between ELV and IMDS is also outlined in an article by A. Holthouse, who states The main tool for reporting ELV Directive data is the IMDS (International Material Data System), which was created by EDS". The article, from 2002, is titled “Preparing for the new ELV Directive” available from the AIAG online at http://www.aiag.org/elv_doc/elv_actionline.pdf (AIAG is the Automotive Industry Action Group, an organization founded in 1982 by representatives from DaimlerChrysler, Ford Motor Company, and General Motors.)
4. Company Goals Regarding Material Use

This section briefly outlines some of the public environmental goals that are related to material use. This section does not analyze these public goals, but discussion on recyclability, recycled-content and materials of concern is provided in Section 7. Substances of Concern, Trends, Examples & Opportunities. Information provided here on Industry-wide activities was provided by the Alliance of Automobile Manufacturers (Alliance). Information on the goals of each company was taken from publicly available sources, interview discussions and the companies themselves. In all cases, the focus is only on environmental goals that relate to material use and address substances of concern, recycled-content or recyclability and does not reflect all of the environmental activities of each company.

Goals and activities of automotive companies in Europe and Japan are also described in this section. These activities are relevant because they illustrate what might be possible here in the U.S.

The global nature of the industry has been noted. While it is not always easy to distinguish between activities that are strictly domestic and activities that are only in place in European- or Japanese-based companies, this report attempts to do so whenever possible.

4.1 Industry Activities Related to Material Use

This section briefly outlines some of the broad environmental activities related to material use, undertaken by the automotive industry, either through various initiatives or partnerships or through the trade associations.

North American manufacturers have set requirements aiming to eliminate mercury, lead, cadmium and hexavalent chromium from certain uses in vehicles. Requirements restricting these substances were set at various times and for a variety of reasons (e.g., to address an environmental concern, to pre-empt regulation, to be consistent with specific limits and uses specified in the European Commission’s ELV Directive) (restricted substance lists from Ford, DaimlerChrysler and GM are referenced in the respective sections below). To illustrate, one company explained that these heavy metals are not used in certain interior components, such as seats and headliners and only brominated flame retardants remain a potential issue (however this does not include electronics in the interior such as instrument panels displays and navigation systems that contain mercury, hexavalent chromium on fasteners and lead in solder, among others).

As previously mentioned, U.S. manufacturers and suppliers report data on materials for select vehicles into the IMDS. Among other things, the IMDS has served to raise awareness about materials of concern in vehicles, according to findings from one interview. Automotive suppliers recognize that materials in the vehicle may be managed more effectively if the companies know what they are, how much there is and where they are used. Currently, the
Original Equipment Suppliers Association (OESA) and the Automotive Industries Action Group (AIAG) are exploring a harmonized approach to reporting into the IMDS in order to make requirements the same across the industry, protect proprietary information, and reduce the cost of managing this data.\(^44\)

More formally, the Alliance states “vehicle manufacturers restrict or prohibit the use of many substances through design standards that must be met internally and by suppliers. As such, there is a trend toward a reduction in the use of ‘materials of concern’...” Each of the three largest manufacturers have developed standards or guidance documents\(^45\) for the supplier community, which identify substances of concern and whether they are reportable or restricted from use. Suppliers and OEM’s use these standards in the design process to evaluate substances of concern.

Specific to mercury, the automotive industry phased out mercury switches by 2002 (Figure 5). For vehicles produced prior to the phase-out, the Alliance states that manufacturers support the removal of mercury switches from these vehicles at end-of-life and considers “the automotive recycling industry is best equipped to deal with this material”.\(^46\) (See Section 7.1, for discussion on this issue). The industry has provided information to the automotive recyclers to aid in their efforts. For example, as part of a pilot program in New York the Alliance distributed flyers on locating and removing mercury switches to over 400 dismantlers.\(^47\) The brochures are available in New York and other States. (See further discussion on mercury in 7. Substances of Concern, Trends, Examples & Opportunities).

\(^{44}\) Interview communication. June 2003.
\(^{45}\) Examples of these standards include General Motors GMW 3059, Ford WSS-M99P9999-A1, and DaimlerChrysler CS 9003.
The automotive industry has undertaken other environmental initiatives. Specific to material use and materials of concern, the USCAR VRP established goals that include:

- Reducing the total environmental impact of vehicle disposal,
- Increasing the efficiency of the disassembly of components and materials to enhance vehicle recyclability,
- Developing guidelines for material fastener and design selection, and
- Promoting socially responsible and economically achievable solutions to vehicle disposal.

The VRP developed “Preferred Practices” recommending material, fastener and design selections that will promote the further recycling of automotive materials. See Appendix 7 for full details on the VRP Preferred Practices.

USCAR also maintains a committee on Substances of Concern. Currently, the committee is developing a test method for Substances of Concern that is uniform and economically practical. To date they have developed a test methods decision tree for hexavalent chromium. OEMs are actively eliminating hexavalent chromium by conducting joint supplier forums, and investigating alternative coatings. Individual manufacturers have directed suppliers to eliminate the substance from finishing baths.

### 4.2 Automotive Manufacturers Goals & Activities Regarding Material Use

This section presents illustrative examples of activities, provided by the participating organizations and is not a complete inventory.

#### 4.2.1 BMW Group

**BMW Goals on Material Use**

The BMW Group outlined several environmental goals in its 2001/2002 report on “Sustainable Value” that relate to recycling and environmentally compatible car design. In particular, BMW has an internal standard requiring designers to measure and indicate how recyclable a component is, during the product development process. Each car model undergoes a recycling assessment and disassembly tests as well. Table 5 outlines company commitments for recycling and environmentally compatible car design.

<table>
<thead>
<tr>
<th>Environmentally compatible new car design</th>
<th>BMW recycling and environmentally compatible new car design commitments.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmentally compatible new car design</td>
<td>• Facilitate the development and implementation of an assessment method for evaluating the recyclability of vehicles within the framework of a model testing certification and creation of appropriate ISO standards</td>
</tr>
<tr>
<td></td>
<td>• Comparative environmental evaluation of concepts for body-in-white and electrical system supplies</td>
</tr>
<tr>
<td></td>
<td>• Gradual increase in the proportion of recyclates used in plastic components for future</td>
</tr>
</tbody>
</table>
The BMW Group set a goal to gradually increase the percentage of recyclates\textsuperscript{48} in plastic in BMW vehicles, in conjunction with market conditions and technical feasibility.\textsuperscript{49} Currently, BMW vehicles typically contain 12% plastic, and up to 15% of this plastic can be from recyclate, depending on the model.\textsuperscript{50} Increasing the amount of recyclates in the production of new parts is coordinated with the design engineers who are also responsible for granting final approval.

The company recognizes that “the use of plastics is increasing” and “recyclability of the materials becomes more important” for this reason.

The BMW Group expects further use of natural fibers and other renewable raw materials.\textsuperscript{51} In BMW vehicles, natural fibers and renewable raw materials are currently used as surface trim, sound insulation, inner door panels and as a fleece carrier material in the luggage compartment. See Figure 6 for a comparison of the amount of renewable raw materials used in different BMW models. The company states that these materials are lightweight, have a favorable environmental balance.

\textsuperscript{48} Recyclate is a term meaning recycled material input. i.e., if BMW increases the percentage of recyclates, it increases the percentage of recycled-content material in its vehicles.


\textsuperscript{50} BMW Group Sustainability Goals. 2001-2002 Sustainable Value Report.

BMW Activities to Meet Goals

BMW already complies with the targeted recycling quota of 85% specified for 2005 in the European Commission’s ELV Directive.

The BMW 3-series can be virtually 100% recycled in compliance with economic and environmental guidelines. The recycling concept is integrated into the design of many of the car’s components and assemblies. For example, the instrument panel is manufactured based on a new recycling approach designed to enter excess materials into a high-quality recycling process. Instead of focusing on the metals used in manufacturing a car, which make up 75% of its total mass and can be easily recycled, BMW specialists concentrate on the increasing proportion of plastics used in modern cars to reduce weight and increase fuel efficiency. The current BMW 3-series cars, for example, contain around 162 kg (357 lb) of plastic materials. This is 15% more than the previous model. Nearly 90 kg (198 lb) of these plastics can be economically recycled in compliance with BMW recycling standards.

BMW conducts comparative LCAs for components as continuous optimization process within the product development phase. LCAs of components include design and engineering operations, manufacturing and assembly, sales and service and final recycling of end-of-life vehicles.

BMW also attributes its compliance with the European Commission’s ELV Directive to a network of recycling firms organized in the European Union since 1991. BMW is currently
the only car manufacturer to assign recycling tasks exclusively to certified contract partners.\(^{52}\)

BMW established a telephone hotline in 1999 to advise customers and provide information on local vehicle recycling companies and was the first automobile manufacturer to do so. In Germany, the company created a network of 100 BMW-approved recycling firms and 110 vehicle drop-off points. These operations are audited by the BMW Group, inspected annually by independent experts, and licensed in compliance with end-of-life vehicle regulations.\(^{53}\)

The BMW Group “guarantees environment-friendly end-of-life vehicle recycling in all major EU countries”, as part of the “Together for Recycling” program co-sponsored by MG Rover, Fiat, and Renault. European recycling firms are also supported by the International Disassembly Information System (IDIS) established under the auspices of the BMW Group. IDIS contains data on cars made by 21 different manufacturers and provides information to 5,000 recycling firms in the European Union, to aid in efficient and economical recycling of end-of-life vehicles.\(^{54}\)

4.2.2 DaimlerChrysler

**DaimlerChrysler Goals on Material Use**

Daimler Chrysler has stated that the use of renewable raw materials in the automobile production process is one of its “cornerstone environmental achievements”.\(^{55}\)

Since 1993 DaimlerChrysler North America has had Vehicle Recycling Guidelines in place, which include: recycling definitions & terms, component design, material selection, and fastener selection. New vehicle programs are all required to develop recycling program objectives including: design for disassembly, recycled material content, material recyclability, and material identification.

DaimlerChrysler internal global standard CS-9003 limits or eliminates substances of concern and gives priority to recycled materials. Specifically, by 1997 there were no mercury convenience light switches in DaimlerChrysler vehicles, and by end of 2002 only mercury-free ABS switches were used.

---


http://www.bmwgroup.com/e/0_0_www_bmwgroup_com/5_verantwortung/5_4_publikationen/5_4_1_umweltbericht/5_4_1_3_downloads/pdf/sustainable_value_report.pdf


**DaimlerChrysler Activities to Meet Goals**

In 1994-95, DaimlerChrysler North America launched its Regulated Substance and Recyclability Certification (RSRC) reporting system for vehicle components. The reporting system enables the North American company to identify substances of concern early on, provides a baseline measure of recyclability and can be used to pinpoint areas for improvement. Under the system, three types of data are collected:

1. Recyclability / disassembly detail,
2. Material contents of detail components, and
3. Substances of concern.

Both internal and external suppliers are required to use the RSRC reporting system, and the system is a milestone in the company’s master timing schedule for product development.\(^{56}\)

Additionally, the company undertakes Life Cycle Management assessments to evaluate design changes on select components. The method incorporates both Activity Based Costing and Life Cycle Assessment to evaluate designs using traditional product metrics such as cost, quality, performance, and also integrates environment, health and safety and recycling criteria into decision-making. The company uses a five-step approach to an LCM analysis:

1. Identify the environmental strategy
2. Understand the organization
3. Define alternative designs/processes
4. Map the process, and
5. Perform LCM analysis.

An example of this type of analysis is a comparison between two instrument panel designs published in a Society of Automotive Engineering (SAE) paper in 1997.\(^{57}\)

In the European Union, DaimlerChrysler’s DfE group has an internal regulation specifying that wherever possible, metals and materials that make for easy thermal or mechanical recycling be used.

According to its 2002 Report, DaimlerChrysler has set and met the following objectives (these will be updated based on recent 2003 data):

- **Material Selection Objective**: To balance primary energy consumption with weight savings. DaimlerChrysler’s solution is an “intelligent lightweight design” which includes aluminum and steel.\(^{58}\)

---


• Secondary Raw Materials Objective: To recycle automotive parts back into its own automobiles (not into down-graded uses). DaimlerChrysler is concentrating on recycling thermoplastic materials, because thermoplastics account for an increasing proportion of every passenger car and are produced from crude oil.  

• Renewable Resources Objective: To increasingly use renewable materials such as flax or sisal fibers. Currently, the Mercedes E-Class has more than 50 components produced either in whole or in part from renewable materials. They equal approximately 30 kg (66 lb). DaimlerChrysler reports an increase in the share of renewable resources in large components from 12 % to approximately 15 %. For example, the lining system developed for the trunk is made up of several layers of sisal fibers with a recycled plastic binder to improve material properties.

• DaimlerChrysler has a new vehicle model called the “Vaneo,” for which it wrote nearly 50 specifications defining the environmental requirements for each individual module. Environmental requirements also applied to components purchased from suppliers. Materials used on the Vaneo are indicated on the modules themselves and the ease of dismantling of all modules has been tested.

Design for dismantling at DaimlerChrysler European facilities has lead to plastic trim panels that are easy to dismantle as no underseal is used to protect the floor pan. Trim panel insulation is also designed for easy removal. See Box 2 for a description of this process at German facilities.

DaimlerChrysler states that they are focusing on techniques to recover the current 25% of ELV cars that become ASR and go to landfills, via the CARE Car II demonstration program. The aim of the research was to reduce the amount of shredder residue going to landfill and to use this material in new automobiles. DaimlerChrysler has participated in the development of a proprietary flotation technique to automatically separate, extract and dry different types of plastic residue from ELVs. The recovery rate is 1,500 pounds of residue (680 kg) per hour. The system can effectively recycle three of the most widely used plastics in automobiles – ABS (acrylonitrile butadiene styrene resin), polyurethane foam and polypropylene. Plastics recovered are melted and formed into plastic pellets, which are mixed with virgin plastic to create the new vehicle parts. The machines also extract foams and residual metals. As previously mentioned, the program (working with 27 DaimlerChrysler suppliers) retrofitted two Jeep® Grand Cherokees with 54 recycled plastic parts.

---

63 DaimlerChrysler Environmental Report 2002. p. 44.
The automated technology has the potential to reduce the cost of recycled plastic to 30% below the cost of virgin plastic. DaimlerChrysler estimates the automotive industry could save approximately 320 million USD per year.\footnote{DaimlerChrysler Environmental Report 2002. p. 44.}

Specific applications from the CARE CAR II project include:

- Headlamp mounting modules made from recycled plastic gloves (worker gloves) and bottles, reducing materials costs by 15%;
- Body flaring/skirting made of recycled-content plastics;
- Fender liners made of material directly recovered from the materials separation process;
- Compression-molded materials made of polyurethane foam from shredder residue – can be molded into in various shapes and exhibit excellent thermal and noise insulation properties; and,
- Carpet underlay made from polyurethane foam.

\subsection*{4.2.3 Ford}


Ford’s website presents several goals the company has set for material use, recycling and recyclability. For “global material use”, Ford has set the following goals:

- Increase the recyclability of Ford vehicles;\footnote{According to Ford, end-of-life vehicles are nearly 100 % recyclable in theory. However, the cost in energy and labor to recover the final fractions often exceeds the value of the materials. Ford focuses on increasing the economically viable and environmentally sound recycling percentage through a number of means: selection of materials, labeling, reducing the number of different materials and providing information to dismantlers on materials and methods for disassembly.}
- Label 100 % of polymeric parts more than 50 grams (0.1 lb) in weight (to facilitate recycling);
- Continuously increase the recycled-content of polymers from the current level (targets are set for new vehicles as a percentage increase over the levels of previous models);\footnote{Ford's definitions of recycling and recyclability are conservative, focusing on the economic recyclability of parts and materials and counting as recycled-content only the weight of actually included post-consumer and post-industrial materials that would otherwise require disposal.}
- In addition to other substances, globally reduce or eliminate where possible the use of lead, mercury, cadmium and hexavalent chromium in line with the strictest global requirements; and
• Achieve materials and substance reporting by suppliers on materials use, polymeric part marking and recycled-content through the IMDS.69

**Ford Activities to Meet Goals**

In 1984, Ford established its Restricted Substance Management Standard to address certain substances of concern and identify substances to avoid, eliminate or phase out of Ford products (and plants). Current priority substances for reduction at Ford are hexavalent chromium, mercury, PVC and lead.70

The Ford Vehicle Environmental Engineering Recycling Group sets policy globally and dictates global recyclability and recycled-content targets. The Group was established in 1992 and in 1994 put forth new design standards for the company on recyclability. The Group has established an internal website to communicate targets and policies and to act as a resource for design teams. Designers can go on the website and enter the name of the vehicle program they are working on into the system and it will tell them the requirements for that program and provide suggestions on how to meet requirements. The site contains a “Value Resin List” that lists the recycled-content of different resins and how and where they can be used in vehicle.

The targets the Group sets for each vehicle platform are integrated into the Ford Product Development System (FPDS) early in the vehicle design process. Members of the Group meet with program teams at start of the FPDS at the “Strategic Intent” stage to discuss what needs to be done in the area of recycling to meet program approval. The Group then interacts with the design teams to track progress throughout the FPDS.

While Ford used to specify to suppliers exactly what they wanted, the company is now moving to a full service supplier approach. This means that rather than dictate materials to be used, the company gives suppliers performance specifications which include recycled-content targets and require use of the companies Restricted Substance Management Standard.

Ford’s Materials Science Department has established several goals regarding environmental improvement, including:

- Increased use of biomaterials by 2010,
- Achieving recycling friendly interiors by 2015,
- Finding new ways to work with Wet on Wet on Wet paint systems using a single bake oven technology,
- Finding UV curable clear coatings by 2005,
- Achieving closed loop optimization of sheet metal by 2010, and

---

69 IMDS is the industry-wide, Web-based database that collects information on materials used in the auto industry for compliance monitoring with global regulatory requirements including the EU End-of-Life Vehicle Directive.

70 Personal communication and tour of Ford facilities. 4 June 2003.
Coil coating steel to eliminate ELPO and e-coat – this has been recommended for Paint Engineering by Q4 2003.

In the area of biomaterials, the company is experimenting with soy based urethane foams, natural rubber reinforced SMC, polylactic acid, etc. in its research laboratories. The company is also researching the use of nanocomposite materials to replace heavier glass filled composites. Nanocomposites are more recyclable, have low thermal expansion, high heat deflection temperatures, better scratch resistance and lower weight. While these materials are currently too expensive to be utilized in mainstream design, they offer the potential to replace polyamide, RIM, PP and SMC in engine beauty covers, body panels, exterior and interior trim, IP’s, bumpers, etc., in the future. Additionally, due to their lightweight design, they may help the company to meet CAFÉ standards in the future.

Regarding recycled-content, Ford is using increasing amounts of recycled material to reduce landfill materials and to build markets for recovered materials. It is also increasing its use of renewable materials (because Ford life cycle studies show these materials have lower environmental impacts).71

To increase recycled and renewable material use, materials specialists work with Ford product development teams to identify possible applications and test materials to ensure that they meet specifications for quality, performance and cost. As a result, the number of parts launched with recycled or renewable content, and total recycled materials used are increasing (Figure 7). In 2002 Ford launched 950 parts containing recycled non-metallic materials.

In 2002, Ford announced a joint project with Alcan to establish a closed-loop recycling stream between their stamping facility in Chicago to Alcan's aluminum plant in Oswego, New York, where it is remelted and rolled once again into automotive sheet. This loop can be repeated virtually indefinitely because aluminum does not degrade when recycled (see Appendix 8 for more information).

---

Ford established the Ford-Supplier Environmental Forum in 2001, which meets periodically to explore materials management and design for environment (among other environmental issues such as climate change and approaches to integrated environmental reporting).

In March 2001, Ford requested suppliers (to all brands) phase in the use of IMDS to collect and report information required by Ford’s Global Restricted Substance Management Standard. Ford now periodically reviews suppliers’ compliance with the requirements. The company also worked with industry associations and suppliers to coordinate various restricted substance lists, aiming to reduce cost and confusion and help meet industry-wide goals to better manage restricted substances.

In 2001, Ford phased-out mercury-containing convenience light switches in all Ford products. In Volvo cars, all textiles and leathers used comply with the Oeko-Tex standard (Appendix 11), which limits certain materials and requires testing and verification.

Ford has studied the life cycle of vehicles and has identified the roles that producers, consumers and recyclers play at various stages of the life cycle (Figure 8).

<table>
<thead>
<tr>
<th>PRODUCER</th>
<th>CONSUMER</th>
<th>RECYCLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream in the life cycle</td>
<td>Green supply chain management</td>
<td>Purchase greener products (at higher price?)</td>
</tr>
<tr>
<td></td>
<td>Materials management targets</td>
<td>Provide feedback</td>
</tr>
<tr>
<td>Product ownership life cycle phase</td>
<td>Environmental performance of manufacturing (e.g., ISO14001)</td>
<td>Eco-driving</td>
</tr>
<tr>
<td></td>
<td>Design for environment, product improvement</td>
<td>Proper maintenance</td>
</tr>
<tr>
<td>Downstream in the product life cycle</td>
<td>Work with dealers on green approaches</td>
<td>Correct disposal</td>
</tr>
<tr>
<td></td>
<td>Inform consumers about choices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provide information on end-of-life</td>
<td></td>
</tr>
</tbody>
</table>

Figure 8. Roles in the Life Cycle Management of Vehicle Environmental Impacts

### 4.2.4 General Motors

**GM Goals on Material Use**

GM states that vehicles and products are being developed to achieve high levels of energy efficiency, very low levels of emissions and high recyclability, while meeting customer expectations in terms of comfort, style, performance, handling and safety. GM is committed to reducing waste and pollutants, conserving resources, and recycling materials at every stage of the product life cycle. The embodiment of life cycling thinking in the design, manufacture, use, and disposal of GM vehicles continues to grow and positively affect product programs.
Life cycle assessment provides the information base on which to balance the environmental, social, and economic consequences of decisions.

**GM Activities to Meet Goals**

According to GM sustainability reports, all technical specifications for future vehicles have requirements on “environment” and “recycling”, which include vehicle recyclability and recoverability, use of recycled materials, compliance with restricted and reportable materials requirements and end-of-life vehicle treatment. Requirements are tracked as the vehicle is designed to ensure they are met.\(^{72}\)

GM uses a Productive Material Review Process (PMRV)\(^{73}\) to review materials (and processes) for environmental impact. It also has a Design for the Environment (DFE) Group, which uses Life Cycle Analysis and DfE Assessments to find solutions. The group tracks the environmental improvements for each new vehicle program (improvements include any feature that reduces the effect of the product on the environment, e.g., reducing mass, eliminating scrap, designing parts for easy disassembly, avoiding hazardous material usage, longer life parts and the use of recycled or reprocessed materials).\(^{74}\) For example, GM conducted a LCA that compared magnesium and steel designs for the cross car beam. In the European Union, GM conducted a full vehicle LCA on the Astra G. In North America, the company has studied aluminum casting, painting, and fuel cell components (including GM’s participation in the USCAR vehicle LCA).\(^{75}\)

GM’s specification, “GMW3059 Restricted and Reportable Substances for Parts Specification” provides information on prohibited and declarable materials to engineers and suppliers.\(^{76}\) Additionally, GM has developed a general material specification “GMW3116 Recyclability, Recoverability Guidelines” that provides designers with information on how to design more recyclable/recoverable vehicles with high end-of-life values. GM requires its suppliers phase in the use of IMDS to collect and report information required by GMW3059.

GM has phased out mercury containing convenience light switches in all GM products.

GM requires all designers to seek materials that are non-toxic, take account of renewable resources, increase the percentage of recyclable materials (Figure 9) and give preference to recycled goods over virgin materials. The amount of recycled plastics in vehicles in GM’s European subsidiaries Vauxhall and Opel has been increasing. The 2001 model Vauxhall and

---

\(^{72}\) GM 2001-2002 SD Report, section on DfE/Design Process

\(^{73}\) “Materials selected to be used in our products are assessed through the Productive Materials Review Process (PMRV), which supports the release and material engineering community and is part of the Design for the Environment process. If a material is approved through this process, the information is then sent to the plant Hazardous Materials Control Committee (HMCC) the second process, for local review and implementation. The HMCC assesses the potential health and environmental impacts of those materials that support the manufacturing processes (indirect materials), but do not actually become part of our products.”

\(^{74}\) GM 2001-2002 SD Report, section on DfE/Product Life Cycle.

\(^{75}\) GM 2001-2002 SD Report, section on DfE/Product Life Cycle

\(^{76}\) GM 2001-2002 SD Report, section on DfE/Choosing the Right Materials
Opel vehicles had more than 30,000 tons of recycled materials—six times more than in 1991 (Figure 9).\textsuperscript{77}

![Use of Recycled Plastic in Vauxhall/Opel Vehicles](image)

Figure 9. Use of recycled plastics in Vauxhall/Opel Vehicles (European subsidiaries of GM).\textsuperscript{78}

In 1999, General Motors set a goal to eliminate PVC from interior panels by 2004 and informed suppliers that alternative materials must be used for new products. The goal primarily affected covering skins for instrument panels and door panels and had the potential to reduce GM’s PVC use by up to 30%. GM continues to encourage its suppliers to use PVC alternatives when possible and decisions are made on a cost-by-cost/performance-by-performance basis.

In the European Union, Opel and Vauxhall work with industries involved in taking back, treating, and scrapping ELVs to reduce the amount of automotive waste going to landfill to 5% of a car's weight, as compared to 25% in 2000, over the next 15 years.

GM is also working in partnership projects. In North America, GM works within the VRP to develop new technologies.

4.2.5 Honda

**Honda Goals on Material Use**

Honda has set a recyclability rate of 90% for new models of automobiles and in its 2002 Environment Report, the company reports that this has been met from the year 2000 and

\textsuperscript{77} GM 2001-2002 SD Report, section on DfE/Choosing the Right Materials

\textsuperscript{78} GM Corporate Responsibility and Sustainability Report 2001-2002.
onward. Honda also set a goal to reduce the amount of lead in all vehicle models lead. Honda’s goal is to reduce lead to one-third (or lower) the amount of lead in 1996 models by the end of 2003. Additionally, the company discontinued the use of sodium azide in mass-produced vehicles sold in Japan in 1998. This was due to the potential health risks that sodium azide posed to workers when airbags containing sodium azide were crushed. According to an article written in 1999 in *Ecology Center News*, Honda intended to create a 100% recyclable auto by 2010, without the use of PVC.\(^\text{79}\)

**Honda Activities to Meet Goals**

To achieve its target for 90% recyclability of all vehicle models from 2000 onward, Honda has:

- Integrated parts and reduced the number of fasteners and body attachment points, thereby making the vehicle easier to disassemble; and,
- Standardized resin materials by promoting the use of olefin resins in areas such as instrument panels, fenders, bumpers, etc.

In fiscal 2001, the company used recycled resins for two of its models and has publicly stated it is committed to increasing the use of these resins over time.

Honda vehicle models released in 2001 used one-third less lead (or less) than was used in 1996 vehicles. This achievement was a result of:

- Lead free steel crankshafts,
- Resin fuel tanks, and
- Removal of lead from ceramic print on glasses.

In July 2001, the company started selling “Honda Recycle Parts” in Japan. However, the company has identified that a current challenge for sales is that existing models cannot necessarily make use of recycled parts. Thus the company is focusing on expanding the number of models that can make use of recycled parts. Also, the company is selling parts removed from end-of-life vehicles for direct re-use, such as door panels, hoods and trunk lids.

The company is recovering bumpers from Honda dealers and general servicing and repair companies for recycling. In 2001, a total 1,186 tons of resin was recycled from bumpers.

Also in 2001, Honda evaluated five of its automobile models to determine how easy they were to dismantle. The company plans to continue improving ease of dismantling and is using the results of its evaluations in new product development and in provision of end-of-life services.

In 1997, Honda developed vehicle turnover devices for dismantling vehicles, which it sells to dismantlers. Recently, Honda evaluated the effectiveness of these devices and based on the results, it improved the efficiency of the original device and proposed a new dismantling line based on the use of the device. As a result of the improvement, the work efficiency of the entire dismantling process has almost doubled compared with dismantling using the old design.

4.2.6 Nissan

Nissan Goals on Material Use

Nissan has banned the use of mercury and cadmium in its vehicles and has targets to reduce the use of lead and hexavalent chromium. In it’s 1997 vehicles, Nissan had already reduced use of lead to half the amount used in 1996. By 2005, Nissan will decrease hexavalent chromium use to half or less of 1996 levels. On recyclability, all new vehicles launched since 1999 are 90% recyclable or higher. Nissan set a new target to reach 95% recyclability (by weight) for all new models by 2005. In the 2001 model year, the company achieved 90% or higher recyclability for the Caravan, Skyline and Stagea and 95% or higher with the March (Figure 10).

Figure 10. Principle recyclable parts on Nissan Vehicle, the “March”.

---

**Nissan Activities to Meet Goals**

Nissan’s Environmental Activities are managed by its Product Environmental Committee (PEC) which focuses its efforts on 6 main areas: fuel consumption, emissions (CO2), external noise, air conditioner refrigerant, environmental impact substances and recycling. The PEC develops policies and sets goals in each of these areas. In the product development process, progress on their implementation is managed using Nissan’s certified ISO 14001 Environmental Management System. The Vice President of Technology and Development oversees the policies and goals set by the PEC.

During the development of new models, key design targets related to the environment are set (but not limited to) in the following areas: recyclability, reducing the use of substances known to have environment impacts, dismantling efficiency and resin part marking. The company sets these targets in the design stage of the product development process (see Figure 11 below). Nissan evaluates and manages the degree of target achievement in their development process utilizing its ISO 14001 system.

![Figure 11 How Nissan incorporates environmental issues such as recycling into its product development process](image)

To help designers design new models for recycling, Nissan has Design Guidelines and Design for Recyclability Technical Standards. The guidelines and standards help designers implement changes to new designs based on older designs. The company also has efforts underway to help improve disassembly times at end-of-life for ELV’s and has used LCA to confirm that these new designs are in fact an improvement over the old designs.

---

In the area of materials use, the company has several initiatives underway. Nissan is actively reducing its use of thermoset plastics, replacing them with thermoplastics, which are more recyclable. Additionally, the company has reduced the number of different types of polypropylene it uses to six, to aid in recyclability at end-of-life. Four of Nissan’s new vehicle models released in 2001 use one half or less the 1996 level of lead use.

The company produces a subcompact vehicle called “March”, available in Japan, which is 95% recyclable (Figure 10). The company notes this is one of the highest rates in the industry and states that the high recyclability is due to the use of polypropylene and other easy-to-re-use materials. In addition, the car is designed to have 12 sections, compared with 32 sections in the previous “March,” which reduces the time it takes to dismantle the car by 40%.

Nissan also has a program to sell parts from ELV’s that can be re-used directly or re-built and then sold. Nissan has established part-removal standards and have 31 different components that can be re-used or re-built and then re-used. These include headlights, doors, fenders, hoods, starters, engines, etc.

Nissan has established a full-scale operation to directly use aluminum wheels from ELV’s as raw material for parts on new vehicles. At the time of their 2001 Environmental and Social Report, the company was using 30 tons per month as raw material for new parts and plans to increase that number to 200 tons per month.

The company also works with shredding operations and the materials industry to find more effective ways to use ASR.

To enhance communication with the recycling industry, Nissan has a quarterly publication (entitled “Communication”) intended to exchange information between the company and the recycling industry to promote appropriate treatment of ELVs. Nissan also has a “Manual on Appropriate Treatment of ELVs”. It provides information on dismantling and treatment that Nissan learned from its internal demonstration disassembly studies. Dealers and dismantlers in Japan have received the manuals.

4.2.7 Toyota

**Toyota Goals on Material Use**

Toyota set a goal to make its vehicles built in Japan 88% recyclable (on average) by March 2006, and 95% by March 2016. In Europe, Toyota’s goal is 85% recyclable by 2006 and 95% recyclable by 2015. The company reports that currently 75% to 83%, by weight, of each

---


end-of-life Toyota vehicle is reused or recycled.\textsuperscript{86,87} Toyota aims to reuse some 230,000 parts from old vehicles by 2010, a tenfold increase from the 23,000 parts Toyota reused in 2002.

Toyota has a stated goal to “manage substances of concern”. Regarding Substances of Concern, Toyota has established the following targets to be reached by 2005:\textsuperscript{88}

- Arsenic: Eliminate (except for semiconductors),
- Hexavalent Chrome: Reduce to less than one-half of 1998 levels,
- Cadmium: Eliminate,
- Mercury: Eliminate (except for electric discharge tubes), and
- Lead: Reduce to less than one-third of 1996 levels.

\textbf{Toyota Activities to Meet Goals}

As part of its effort to meet these goals for Japanese and European vehicles, Toyota is planning to reuse more parts from old vehicles (enabling the company to cut costs).\textsuperscript{89} The company will announce its plans for recycling vehicles from markets outside Japan and Europe later in 2003. Toyota uses materials derived from sugar cane, corn and other plants in the spare tire cover and floor mats for its Raum vehicle.\textsuperscript{90} The Raum’s design and use of recyclable materials make the vehicle quicker to dismantle and recycle (30% quicker than earlier versions of the Raum).\textsuperscript{91}

For Japanese and European vehicles, the company will also avoid mercury, lead, cadmium and hexavalent chromium by 2006.\textsuperscript{92} In North America, Toyota’s target is to gather baseline data for substances of concern to meet its material management goal (e.g., mercury, hexavalent chromium, lead, arsenic and cadmium). The company is working to analyze the substances of concern in typical North American-produced Toyota vehicles and has already reduced the amount of lead and the amount of chlorine (by reducing the use of various components or materials that contain chlorine, such as PVC) relative to the 1996 Toyota vehicle. Toyota has opted not to use mercury in electrical switch applications for convenience lighting. Toyota’s research shows the Toyota Camry still contains small quantities of arsenic and cadmium, and has mercury in displays only.\textsuperscript{93}

In June 2003, Toyota announced its new system for calculating the environmental burden of a vehicle across its life cycle – from raw material procurement to end-of-life vehicle

\textsuperscript{86} Toyota Environmental Report. 2002. p.41
\textsuperscript{88} Toyota Environmental Report. p.41
\textsuperscript{93} Toyota Environmental Report. 2002.
management. Calculations are made by a proprietary environmental impact assessment system called Eco-VAS (Vehicle Assessment System). Engineers in charge of vehicle development set targets for reducing the environmental impacts from that particular vehicle, in the early stage of new vehicle planning. The assessment includes the disposal recovery rate of materials (in assembly facilities and from end-of-life vehicles) and the reduction of substances of environmental concern such as lead and arsenic (as well as a number of other items such as various emissions). As the vehicle design progresses, progress toward environmental targets can be checked in an environmental database and necessary adjustments made.94

4.3 Automotive Supplier Goals & Activities Regarding Material Use

This section briefly outlines some of the environmental goals, related to material use, as set by Tier-one automotive suppliers that participated in interviews for this report. The companies are listed alphabetically. A profile of these organizations is provided in Appendix 2.

4.3.1 Delphi Corporation

**Goals & Activities on Material Use**

Delphi’s material use goals are tied to four related initiatives: Product Design for the Environment, Up-front Environmental Engineering, Lean Manufacturing, and ISO 14001 certification.

Overall, Delphi’s goal is to minimize the environmental impacts associated with its products and processes. Delphi’s Design for the Environment procedure requires material use and chemical use be reviewed before final approval to ensure minimizing substances of concern content and maximizing the recyclability of its products at the end of their useful life. On the manufacturing side, Up-Front Environmental Engineers work with product and manufacturing engineers to ensure that the manufacturing impact associated with both direct (product) and indirect (manufacturing) materials and chemicals are minimized. This activity includes looking for opportunities to minimize manufacturing generated waste, optimizing material recycling, as well as the substitution of hazardous materials with more environmentally benign alternatives. Lean Manufacturing, among other goals, strives to minimize material use as a major component of initiatives to reduce material costs. Finally, Delphi has certified most all of its manufacturing facilities to the ISO 14001 Environmental management standard. Often, as a part of a sites environmental improvement plan, site specific material use reduction and recycling goals are established.

These Delphi practices have led to numerous environmental successes including “green” products and systems:

- In May 2003, Delphi Corp. was awarded five Environmental Excellence in Transportation (E²T) Awards by the Society of Automotive Engineers (SAE). The awards were won for several categories, including materials development and usage and process innovation (see brief descriptions below) (other E²T categories were stationary energy and emissions, mobile energy, new methods and tools and emissions and process innovations).  

  - Materials Development and Usage – Delphi is now using 100-percent recycled Santoprene plastic instead of virgin material for several automotive components to reduce waste, environmental impact and energy usage. Previously, by-product Santoprene created in the various molding processes was either landfilled or used in applications that had less stringent material requirements. Through the establishment of an infrastructure to supply quality recycled material to Delphi and other molders, the use of the by-product material stream was significantly enhanced. By using recycled Santoprene on two parts, over 28 million lb. [12.7 million kg] of raw material and waste were reduced per year. Energy conservation is also enhanced through these process changes. Other parts are currently undergoing conversion so that they can utilize the recycled material.  

  - Process Innovations – Delphi demonstrated industry leadership by switching from a solvent-based to a water-based adhesive to bond brake material to shoes. This project, involving significant collaboration between Delphi engineers and material suppliers, saved equipment and chemical costs while significantly reducing volatile organic compounds (VOC) emissions. The new adhesive also proved to be more robust. With two new product lines for brake parts, Delphi used its chemical materials assessment process to evaluate different manufacturing processes and their impact on costs, equipment and the environment. A traditional method of using solvent-based adhesive was found to be expensive and to have an environmental impact. After material evaluations, Delphi selected a water-based adhesive that reduced VOC emissions by 98 percent. In addition, the new application was more robust and less complex, saving capital costs.  

- Additionally, Delphi has an electric power steering system, E•STEER™, which eliminates the steering pump, hoses, hydraulic fluids and other conventional mechanical components of a steering system. This reduces the amount of materials to be recycled or disposed of after the product’s life, reduces energy demand on the vehicle for improved fuel economy, and also reduces the vehicle’s mass.  

---

96 Delphi. Online: http://www.delphi.com/automotive/nextech/environment/
• Delphi recycles precious metals from its catalytic converters and remanufactures generators and fuel pumps for reuse. 97

• Delphi’s activities have also led to the following innovations (as noted in other sections of this report):

  o A technology to manufacture a 100%-recyclable thermoplastic polyolefin (TPO) skin instrument panel made of more than 50% recycled-content. The material and technology may be used back into skins or into other interior products.
  o Processes for recycling polyvinyl chloride (PVC) insulation, connector housings and flexible printed circuits from automotive wiring. The processes prevent cross-contamination during recycling, promote reuse of PVC and polymers, and allow full reclamation of the metals used in wiring harnesses.

4.3.2 Lear Corporation

Lear Goals & Activities on Material Use

While Lear does not publish goals specific to material use, recycled-content, etc., the company has a wide range of internal programs and activities with customers and suppliers. These clearly illustrate its environmental initiative (See also Box 3):

Specific activity to phase out substances of concern include Lear’s current work to eliminate hexavalent chromium from coatings. To help, the company is using data collected for IMDS reporting. This is a corporate-wide initiative and includes multiple customers. Lear has eliminated lead stabilizers from PVC compounds used in electrical applications such as tapes, wire insulation, and wire harness coverings and Lear-Europe is developing a lead-free solder for use in electronics. In addition, Lear has proactively approached its customers about eliminating certain prohibited substances from components that were identified through IMDS reporting and a plan is in development to accomplish this change as quickly as possible.

Lear is investigating removal of PVC from seat assembly processes.

Lear plans to increase its use of recycled materials (post-consumer and post-industrial). The company is working with its supplier partners to introduce recycled materials in products whenever feasible. For instance, Lear is conducting trials and tests to replace a prime grade material with Post-Industrial Recycled (PIR) material for many of the wire shields used in wire assemblies. To date, Lear’s Wiring Group uses over 8,000,000 pounds (3.6 million kg) of Post Industrial Recycled (PIR) nylon in convoluted tubings (industry wide) for wire harnesses and various clips. At Lear Corporation, carpet scrap is one of the largest

97 Delphi. Online: http://www.delphi.com/automotive/nextech/environment/
manufacturing scraps and Lear’s Interiors Group uses recycled carpet to make products called SonoTec EP and EcoPlus. EcoPlus is a family of patented thermoplastic engineering resins (derived from automotive carpet scraps) with high recycled-content (50% to 90%), low density, no PVC content. They are 100% recyclable. The company uses recycled-content materials in the products it manufactures, as well as the products it purchases.

Regarding the use of innovative recyclable materials in Lear products, the company’s Advanced Technology Division has a mission to work on projects that are 5 to 10 years ahead of actual production. Its focus in the environmental arena is:

- Identification of recycled and alternative materials that meet automotive specifications,
- Replacement of virgin materials with recycled materials having equivalent engineering properties,
- Use of renewable resources,
- Consolidation of the plastics used in the automotive interior,
- Elimination of restricted substances and toxic materials,
- Application of life cycle analysis to materials,
- Promotion of improved product design practices that consider environmental impact, more commonly known as Design for the Environment (DfE),
- Implication of design for manufacturing to reduce environmental impact for Lear’s manufacturing process, and
- Use of recycled materials in Lear’s door panels.

Working with Lear-Europe, Lear has developed guidelines and checklist for Green Design. Green Design guidelines help Lear Engineering choose compatible materials, design environmentally sound products, mark parts and eliminate substance of concern from Lear products. Lear also has a Program Management Process, which includes checks that influence green product design. The company is planning to strengthen this process with Design for Environment (DfE) and Life Cycle Analysis/Management tools. Lear uses Data Management Software to track components containing restricted substances and to develop a plan for elimination of those.

To optimize environmental performance, Lear’s Interiors Advanced Engineering Group investigates new products, materials and processes. Alternative materials are being considered for new programs. Certain products will provide lower mass, multi-functional design, simplified assembly and 100% recyclability. For example, molded-in head impact countermeasures that eliminate adhesives from the headliner are under development.
Box 3. Innovations implemented at Lear & new technology applied for Lear products in the last 2 years that contribute to environmental improvement

The Use of SonoTec AT in:
Lear Floor Systems: Using resulted in 30% weight reduction, 100% recyclable and 80% Post-Industrial Recycled (PIR)
Lear Dash Insulators resulted in 60% weight reduction, 100% recyclable and 80% PIR

The Use of SonoTec EP in:
Lear Dash Insulators resulted in 35% weight reduction, 50% recyclable and 70% PIR
Lear Rear Insulators resulted in 30% weight reduction, 50% recyclable and 40% PIR

Lear Plans to Use SonoTec EP/EF/LF in 2003/4, to achieve 35-80% weight reduction, 50-100% recyclable and 40-90% PIR

Lear Products contain no phenolic resins, have no odor issues and will not mildew

Electrical:
- Eliminate the Lead Die-Cast battery terminals.
- Lead-free PVC wire, tape, tubing
- Engineering has increased the percentage of plastic regrind material in housings to 25% (from 0%) and on polypropylene Insulator Plates to 100% (from 25%).
- Testing lead-free solder and processes for future electronic requirements
- Converted electronic conformal coat from high VOC’s to Silicone-based providing a 95% reduction in VOC’s.
- Developed a Printed Circuit Board (PCB) optimization program to eliminate PCB scrap material
- Increased amount of Post-Industrial Recycled (PIR) material in retainer clips (average annual consumption approximately 200,000lbs).

4.3.3 Magna International

Magna Goals & Activities on Material Use

Magna participated in an interview and provided valuable information for this report. The company has a number of environmental initiatives dealing with recyclability, recyclable materials and substances of concern, internally and in cooperation with its customers and suppliers. For example, removing substances of concern from interiors, and projects comparing the life cycle environmental impacts of different component designs represent some of the company’s activity. Magna (like many other automotive suppliers) does not necessarily publish its environmental goals on material use. The fact that environmental goals and activities were not found in public reports does not reflect the actual environmental efforts and accomplishments of the company.
5. Trends in Automotive Design & Available Technologies

Research identified several trends in automotive design. These trends themselves are not material-specific, but will influence materials used in automobiles. Two types of trends are presented here: 1) automotive design trends; and 2) trends in available technologies. Both are discussed, in relation to material use, below.

5.1 Automotive Design Trends

5.1.1 Number of materials & Number of components

Overall, the industry is moving to reduce the number of materials in vehicles, in part to reduce costs. However, there is also a trend to increase the number of components in vehicles overall and the recyclability of these components. The latter is related to the fact that vehicles are required to perform more functions (including navigation and entertainment systems, enhanced safety systems (e.g. rear-view cameras, airbag systems), communication systems and power outlets). While some technologies do reduce the number of components, these components may in turn become more complex and potentially more difficult to disassemble and recycle.98

Number of materials

Interviews indicated there is some activity in manufacturers and inside suppliers to decrease the number of materials used. Some companies have internal efforts to use materials from a “preferred materials list”. In a specific example, Nissan has reduced the number of different types of polypropylene it uses to six. One of the drivers, in addition to cost, for reducing the number of materials in design is the improvement of the recyclability of components or systems.

With respect to the number of different plastic materials, the Alliance states that there is a trend to reduce the number of different types of plastics used in vehicles, this can be at least partially attributed to the decreasing number of material specifications from OEMs in North America. In a separate example, a Japanese OEM is working to reduce the number of plastics it uses and is choosing plastics that are more common.99 This is partially an effort to meet recycling targets in the European Commission’s ELV Directive, but is also being done (or considered) by other automakers as an effort to reduce costs.

While there is a trend to reduce the number of materials used in vehicles by automakers the complexity of components is increasing. ISRI stated that certain vehicle sub-systems are currently difficult to disassemble and effective segregation of materials from these systems could be a barrier to recycling. For example, removing electronic systems from instrument panels and door panels is a challenge. Ford’s Corporate Citizenship website discusses an increase in “the complexity of automobiles and the number of materials used to make them” and attributes this to the addition of “new features for safety [discussed below], comfort and other purposes while seeking weight reduction to improve fuel economy”.100

**Number of components**

The Alliance notes that in certain sub systems, the number of components is being reduced. For example, door panel systems now have several molded in features (such as arm rests and storage pockets) that used to be separate components. This is also the case for certain bumper designs. On the other hand, instrument panels are one example of where, in general, the number of components is increasing (navigation, entertainment, communications, safety components and systems), though the number of materials is, in most cases, decreasing.

### 5.1.2 Electronics

Electronics are increasingly used in vehicles, for navigation, to lower emissions, improve safety, for entertainment, communication and other functions discussed previously. Specifically, electronics are being incorporated into headliners and door panels (e.g. speakers). The Alliance note that the number of flat panel display screens in vehicles has increased in recent years but appears to have stabilized in 2002-2003. According to Environmental Defense, the use of flat panel displays has not stopped growing, but is growing a lower rate and while the number of applications for these screens may have leveled off, the number of vehicles with flat panel displays is increasing.101 Data on the vehicles of various manufacturers shows that the number of vehicles with flat panel display screens (and HID headlamps) grew from 2000 to 2003.

These electronics come from a complex supply chain and have historically contained a range of heavy metals, PVC and flame retardants similar to materials and substances used in consumer electronics. However, Directives on Waste from Electronics and Electrical Equipment (WEEE) and Restrictions on Hazardous Substances in EEE (RoHS) in the European Union may push to reduce the use of these substances in consumer electronics. While these Directives do not cover automotive products at this time, there is potential that changes in the electronics industry to comply with the Directives could also influence electronics in vehicles.

---


101 Written communication. K. Mills, Director, Pollution Prevention Alliance, Environmental Defense. 16 June 2003
5.1.3 By-Wire Technology

In addition to electronics in the interior, designs are moving away from mechanical parts to electronic systems for braking, steering and other driving functions. By-wire technology is a trend in design to help advance the technological capabilities of vehicles that may have indirect environmental impacts (negative or positive).

This will eliminate certain components, pumps and fluids. Both electronic braking and electronic steering will reduce and eliminate the use of certain fluids (total vehicle fluids account for roughly 74 kg (163 lb), or 5%, of the car’s mass, according to an LCA conducted on a 1995 generic vehicle by USCAR AMP) as well as certain mechanical components such as the steering pump and hoses. However, these systems may increase energy demand on the vehicle (i.e., higher voltage batteries may be required, not necessarily demand on the engine). Additionally, they may lead to the use of new mechanical components that are smaller and potentially more sophisticated and unfamiliar. For example moving from pumps and castings to electronic modules with solder, plastic and circuit boards. These may be more difficult to dismantle, separate and recycle but they may reduce emissions because they have lower mass and do not rely on the engine for power. Overall, while by-wire technology does eliminate the need for fluids, if the latter are properly removed and handled at the end of life, the environmental issues of non by-wire technology can be minimized.

5.1.4 Safety Systems & Safety Standards

Vehicle designs are incorporating an increasing number of technologies that improve vehicle safety, including airbags. Some vehicle models have safety systems with 14 airbags, though 2 or 4 is a more typical number for the average vehicle. Airbags contain sodium azide propellants to deploy the airbag on collision. This research did not uncover any other material related trends associated with airbags or safety systems (i.e., there does not appear to be any specific trends regarding the use of plastics, fabrics or other materials in safety systems). As previously noted, Ford’s website on Corporate Citizenship discusses a connection between new features for safety (as well as comfort and others) and an increasing complexity of automobiles and the number of materials used to make them.

The industry has well-established standards for safety performance of components, systems and vehicles. For example, standards for coating fasteners or standards governing re-use of airbags. In some instances, these standards may appear as initial barriers to substituting a substance of concern, recycling or recycled-content. A challenge to the re-use of airbags is that they are designed specially for each vehicle they are used in. The installation of the wrong air bag into a vehicle could jeopardize safety performance. Under USCAR, OEMs

---

102 Data on the “generic vehicle” is data aggregated from three different vehicles (4-door sedan vehicles).
103 Delphi Automotive. Online: http://www.delphi.com/automotive/nextech/environment/
have developed a safe deployment procedure for airbags and recommend that used airbags be destroyed. While this is an extremely sensitive area and no actors are suggesting that vehicle safety should be compromised, it is worth noting here as a challenge to recycling and the re-use of components.

5.1.5 Weight Reduction

There is a trend to reduce vehicle weight. Lighter weight vehicles can have better performance in many areas, including increased acceleration and better fuel efficiency. Corporate Average Fuel Economy standards, a sales weighted averaging standard, must be balanced against other criteria in the design process. CAFE Standards are a key driver for automakers to improve fuel efficiency and can result in reduced vehicle emissions. In the European Union, Kyoto commitments under the Kyoto protocol are partially driving weight reduction targets to reduce emissions. Reducing the overall mass of the vehicle is only one way to change fuel economy (others include reducing rolling resistance, improving aerodynamics and improving powertrain performance).

The material implications of producing a lower weight vehicle can vary greatly from materials that contain recycled-content or are easily recyclable to materials that complicate or prevent recycling. Lightweight design solutions can incorporate plastic, aluminum, magnesium and more efficient uses of steel, among others, as well as “mixed designs” that incorporate metals and plastics together (e.g. components made of both steel and plastic). In its 2001-2002 Sustainable Development Report, GM discusses the use of aluminum engines and other weight saving technologies such as “intelligent glass” that is thinner, lighter and meets all requirements on safety, noise and solar control.

In some cases, lighter materials and designs can have higher initial or life cycle costs. For instance, plastic-on-steel technologies may be considered more economically attractive than aluminum or other lightweight materials in a particular application. Such material combinations can complicate material segregation and recycling, but do not necessarily prevent it if it is possible to identify and separate the materials at the end of the vehicle’s life.

5.1.6 Recyclability

OEMs have had internal global goals and standards for recyclability for a number of years. Externally, formal goals and targets for recyclability have been established in the European

---

105 See http://www.uscar.org
106 In particular, ISRI states it is in “full support of vehicle safety and does not want to compromise vehicle safety systems, but end-of-life management of un-deployed airbag units creates both worker safety concerns. Un-deployed units create potential explosion situations for the worker handling those units and have been known to create explosions when introduced in feedstock at aluminum smelter. These potentials could possible be controlled by the use of a centralized deployment system on the vehicle that would allow deployment of all airbags prior to shredding operations.” Written communication, J. Hayworth. ISRI. 19 June 2003.
107 GM 2001-2002 SD Report, section on DfE/
Commission’s Directive on end-of-life vehicles. The Directive specifies that by 2006, a minimum 80% of the vehicle must be re-used or recycled, by average weight and vehicle year and this increases to 85% for 2015. Most OEM goals and standards for recyclability of components and systems are in line with these percentages and dates.

The three plastics most widely used in automobiles – ABS (acrylonitrile butadiene styrene), polyurethane foam and polypropylene – contain recycled-content in various components. However, in the U.S., these components are currently not separated at end-of-life and are not recycled except in small quantities for research projects by organizations such as the USCAR VRP.

Examples of recyclable automotive components raised during this research include fascias and thermoplastic polyolefin (TPO) instrument panels among others. Mercedes-Benz is recycling components from ELVs back into new components (see Section 9 on examples of recyclability).

### 5.1.7 Recycled Content

Overall, North American manufacturers and suppliers are undertaking many efforts to increase the recycled-content of materials used in vehicles. DuPont’s Engineering Polymers group produces 25% post consumer recycled-content resin (Minlon®) for the auto industry. The recyclate is produced from recycled carpets and is used to produce air cleaner housings, engine covers and other vehicle components. In 2002, roughly 10% of the carpets that DuPont collected were used in automotive applications. In 1997, Visteon and Ford described activities to produce engine air cleaner housings from polyamide material recovered from carpets. According to a press release from Visteon, these components are used in nearly 3 million vehicles annually and utilize 27 million square feet of waste carpet (preventing the carpet from being sent to landfills). Delphi recycles 28 million pounds (12.7 million kg) of post-industrial nylon 6,6 carpet fiber for use in automotive components such as electrical connectors. In the European Union, manufacturers have stated they will increase recycled-content and the use of renewables (some of these goals are outlined in Section 4). For instance, Vauxhall / Opel vehicles (GM owned) are increasing the amount of recycled plastics, from 5,100 tonnes in 1991 to 31,000 tonnes in 2001 (Figure 9).

---

5.1.8 Recycling & Recovery Techniques

Techniques for recycling and recovering components and materials from end-of-life vehicles continue to develop. While up to 25% of vehicles (by mass) end up in landfills at the end of use, the composition of that percentage is different today than it was 5-10 years ago.\(^{111}\) According to ISRI, there has been a significant change in the composition of shredder residue. However, such changes in composition are not only based on new techniques and technologies, but also on the market demand for certain materials. The market will dictate which components and materials are economical to recover. For example, foam is not currently recovered, but given an (hypothetical) advance in manufacturing, or adhesive technologies, etc., a market for recycled foam might be created and foam would then be recovered from ASR.

When considering how to increase re-use and recycling to above 75%, there is discussion indicating that dismantling and separation costs (specifically the labor costs) will be much higher than costs for shredding and incineration (for energy recovery). However, incineration for energy recovery is less acceptable to the U.S. public and such practices are not widespread. In the European Union, there is an interest in incineration for energy recovery to meet the ELV target for 95% re-use and recovery in 2015 (though energy recovery is limited to 10% of the vehicle by weight). Several persons stated that materials from end-of-life automobiles are not currently incinerated partially due to the high costs (in the European Union).

---


\(^{111}\) This comment refers to apparent changes in the types of plastics and non-metallic materials that comprise the ASR. The comment is anecdotal, as no representative study of shredders has been done to quantify this change. Source: ISRI. Interview communication, April 2003.
5.1.9 Responsibility for Design

Increasingly, automakers are purchasing “fully-engineered”, integrated systems and modules, rather than individual components. Suppliers may be categorized as “Tier .5”, to indicate this, as opposed to simply Tier 1 or Tier 2 suppliers. Overall, Tier .5, 1 and 2 suppliers are taking a greater role in designing components, modules and systems as well as integration of those systems, than they have taken in the past. On its website, Ford notes the increasing reliance “on external suppliers to provide parts, components and assemblies”.\(^{112}\)

This is relevant to material use and material selection issues, as suppliers may have greater influence regarding goals and initiatives for recyclability, recycled-content and substances of concern, than they have had in the past. However, one interviewee explained that no supplier can claim to meet targets within the ELV Directive, for example. Such claims must be made on the scale of the whole vehicle.\(^{113}\)

5.2 Available Technology

5.2.1 Fuel Systems

To date, alternative fuel systems are low volume, niche market products in the U.S., according to the Alliance. The Alliance states that it is not currently possible to predict any increase in market penetration of an individual alternative fuel vehicle type.

The Alliance perceives that alternative fuel technologies will have comparatively little immediate or short-term impact on material usage, aside from batteries used in fuel cell vehicles, hybrids or battery-electric vehicles. These include nickel-metal-hydride or lithium-ion batteries with alkaline electrolytes and metallic additives. Nickel-cadmium and lead-acid batteries have also been used in certain alternative-fuel-vehicle technologies.

Specific to hydrogen fuel technologies, research indicates that components include fuel cell stacks, fuel processors, electrolyzers and the systems around them. Materials for these systems include steel (for high pressure applications) or composites, as well as catalysts that include platinum and rhodium. Understanding the life cycle environmental implications of these alternative systems will be important to ensure environmental progress. One company referred to an SAE guideline on fuel cell recyclability, “SAE Fuel Cell Recyclability Guideline – SAEJ2594”.


\(^{113}\) Interview communication. June 2003.
5.2.3 Adhesives & Fasteners

Water-based adhesives are now used in many applications in the interior of vehicles. There is also a trend toward water-based adhesives for other applications, because of their low VOC content. In addition, the Alliance noted that dry film and heat-cured adhesives are being used more because they are easy to apply and also have low VOC content.

The industry is working to eliminate hexavalent chromium from the finishes of fasteners and other components. According to the Alliance, this involves working with suppliers to develop Cr$^{6+}$-free finishes for fasteners. The Alliance notes that the finish used for fasteners affects the ability of the fastener to achieve proper torque and to maintain that torque. According to one manufacturer, there is also an ISO Standard that states fasteners are to be plated with hexavalent chromium (in order to meet performance measures) (the ISO Standard referred to during the interviews was not found, but may be contained within the ISO 25.220 series on surface treatments and coatings, or the 77.060 series on corrosion of metals).

5.2.4 Painting & Coating

Technologies for painting and coating can influence the types of materials used in automotive designs. For example, “in-mold paint technology” has been used to color certain components. This technology was used to color the fascia of the 2002 Dodge Neon and Chrysler engineers state there is potential to use it for all exterior panels.$^{114}$ Coloring the fascia in this way eliminates the need for paint to be applied to the component in manufacturing. This has been conducted on a small scale to date, but the technology has the potential to influence the types of plastics used in vehicles.

5.2.5 Design Techniques

Computer models are widely used by designers to conduct stress analyses of structural or load bearing components as well as to reduce the amount of material used without compromising performance. These have several purposes, but it is interesting to note that, among other things, the analyses can identify any areas with an excessive amount of material and where the amount of material can be reduced without compromising its performance.

---

6. Materials Used, Trends & Examples

This section describes certain types of materials used in vehicles, including plastics, composites, steel, aluminum and bio-materials, along with important characteristics of the materials and other factors influencing their use. This section also presents trends in the use of these materials. Finally, preliminary ideas and examples for reducing materials of concern for certain applications in automobiles are presented. Ideas and examples are drawn from interview discussions.

Overall, a generic\textsuperscript{115} vehicle in 1995 contained approximately 9\% plastic (143 kg or 315 lb), 73\% metal (1123 kg or 2476 lb), 5\% fluids (74 kg or 163 lb) and 13\% other materials (192 kg or 423 lb).\textsuperscript{116} Of this, the car interior comprised approximately 15\% of the car’s weight, with carpet weighing almost 13 kg (28 lb). Based on a study by USAMP,\textsuperscript{117} the main types of plastic, metal and other materials used in automobiles were recorded and some of these are shown in Table 6.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass (kg)</th>
<th>Mass (%)</th>
<th>Material</th>
<th>Mass (kg)</th>
<th>Mass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum – cast</td>
<td>71</td>
<td>4.663</td>
<td>Polypropylene (PP)</td>
<td>25</td>
<td>1.6</td>
</tr>
<tr>
<td>Aluminum – extruded</td>
<td>22</td>
<td>1.438</td>
<td>Polyurethane (PUR)</td>
<td>35</td>
<td>2.3</td>
</tr>
<tr>
<td>Copper</td>
<td>18</td>
<td>1.1</td>
<td>Polyvinyl Chloride</td>
<td>20</td>
<td>1.3</td>
</tr>
<tr>
<td>Lead</td>
<td>13</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Non-Ferrous Metals</strong></td>
<td><strong>138</strong></td>
<td><strong>9.0</strong></td>
<td><strong>Total Plastics</strong></td>
<td><strong>143</strong></td>
<td><strong>9.3</strong></td>
</tr>
<tr>
<td>Cast Iron</td>
<td>132</td>
<td>8.59</td>
<td>Ethylene Propylene Diene Monomer (EPDM)</td>
<td>10</td>
<td>0.68</td>
</tr>
<tr>
<td>Pig Iron</td>
<td>23</td>
<td>1.48</td>
<td>Carpeting</td>
<td>11</td>
<td>0.73</td>
</tr>
<tr>
<td>Steel – cold rolled</td>
<td>114</td>
<td>7.46</td>
<td>Glass</td>
<td>42</td>
<td>2.8</td>
</tr>
<tr>
<td>Steel – electric arc furnace</td>
<td>214</td>
<td>13.94</td>
<td>Tire</td>
<td>45</td>
<td>3.0</td>
</tr>
<tr>
<td>Steel – galvanized</td>
<td>357</td>
<td>23.29</td>
<td>Rubber – not including tire</td>
<td>23</td>
<td>1.5</td>
</tr>
<tr>
<td>Steel – hot rolled</td>
<td>126</td>
<td>8.23</td>
<td>Rubber – extruded</td>
<td>37</td>
<td>2.4</td>
</tr>
</tbody>
</table>

\textsuperscript{115} Data on the “generic vehicle” is data aggregated from three different vehicles (4-door sedan vehicles).
Total Weight of Generic Vehicle: 1532 kg (3377 lb)

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass (kg)</th>
<th>Mass (%)</th>
<th>Material</th>
<th>Mass (kg)</th>
<th>Mass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel - stainless</td>
<td>19</td>
<td>1.23</td>
<td>Total Ferrous Metals</td>
<td>985</td>
<td>64</td>
</tr>
<tr>
<td>Total Other Materials</td>
<td>192</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The complete list of materials is available in a report published by SAE International titled “Life cycle inventory of a generic U.S. family sedan overview of results USCAR AMP project”.

According to the 2002 edition of Ward’s Motor Vehicle Facts & Figures (Table 7) the main trend in materials use is toward materials that are lightweight and deliver performance attributes such as improved safety and fuel economy gains.


<table>
<thead>
<tr>
<th>Material</th>
<th>1978 Model Year Vehicle</th>
<th>2001 Model Year Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Metals</td>
<td>73.8%</td>
<td>69.6%</td>
</tr>
<tr>
<td>Non-ferrous Metals</td>
<td>5.5%</td>
<td>11%</td>
</tr>
<tr>
<td>Plastics</td>
<td>5.0%</td>
<td>7.6%</td>
</tr>
</tbody>
</table>

6.1 The Use of Plastic

Numerous types of plastic are used throughout the vehicle. Plastics are used in the interior for instrument panels (dash board), steering columns, headliners, door panels, carpeting and seating systems among others. Plastics are used in the exterior of vehicles as body panels, bumpers, wheel wells, etc. They are also used to make engine and chassis components such as manifolds, wire harnesses, etc.) In general terms, plastic is a material of choice in many applications because of its relatively low cost. It is also easy to machine and manufacture, and is lightweight. Plastics have a wide spectrum of physical and technical properties. Technically, plastics are recyclable, however, it can be difficult to economically separate and identify the various types of plastics and find valuable markets for the recycled material, so in practice, little plastic is recycled from vehicles.

---

6.1.1 Trends in Use of Plastic

The use of plastics in automotive applications is increasing. According to the American Plastics Council, the use of plastics in the transportation market increased from 3,411 million pounds in 1997 to 3,595 million pounds in 2001 (1,547 to 1,631 million kg)(Figure 13). Transportation is responsible for 4% of the plastics used in the U.S., ranking fifth after packaging, building/construction, consumer/institutional, “all others” and exports. Figure 14 shows the use of plastics in transportation markets relative to other markets for plastic.

The Alliance notes that the amount of plastics by weight in vehicles is increasing. For example, various plastics are replacing aluminum and cast iron in intake manifolds, steel and aluminum in valve covers, brass in radiator cans and sheet and cast iron in clutches, power steering and brake fluid reservoirs. Additionally, plastics are being used to make body panels, in place of sheet metal and to make gas tanks in place of steel. Also, the use of steel is being optimized, which means that less steel is used with respect to plastic (such as in car body panels).

DaimlerChrysler’s 2002 Environmental Report cites that thermoplastics “are coming to account for an increasing proportion of every passenger car”. Figure 14 shows that transportation markets are accounting for a greater proportion of thermoplastics sales. The Alliance states that in vehicle interior, polyolefins such as polypropylene, polyethylene and thermoplastic polyolefin (TPO) are being used with greater frequency.

---

120 Source: American Plastics Council.
In a workshop sponsored by the Argonne National Laboratory and the U.S. Department of Energy Office of Advanced Automotive Technologies, vehicle manufacturers, suppliers, recyclers, and researchers met to consider vehicle recycling. The group developed a “strawman” scenario up to 2020, which assumes 15% of a vehicle by weight will be plastic (see Appendix 13). This is an increase from the 9.3% plastic found in the study of a 1995 generic vehicle, described above. This scenario assumes that the percentage of thermosets and thermoplastics in particular will rise. However, the Alliance notes this prediction of 15% by weight is high and is not supported by trend data between 1978 and 2001 (Table 8).

It is interesting to compare the vehicle material composition (percentage by weight) of the 1995 generic car, Ward’s Motor Vehicle data on the 2001 Model Year Vehicle and the strawman scenario car (2020). An additional comparison can be made against BMW vehicles, which typically contain 12% plastic.

---

122 Source: American Plastics Council.
123 Aside of developing the strawman scenario, the group was unable to reach a consensus on specific goals and targets.

<table>
<thead>
<tr>
<th>Material Category</th>
<th>1995 Generic Automobile</th>
<th>2001 Model Year Vehicle (Ward’s)</th>
<th>2020 Scenario Automobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>73%</td>
<td>75.1%</td>
<td>75%</td>
</tr>
<tr>
<td>Plastic</td>
<td>9%</td>
<td>7.6%</td>
<td>15%</td>
</tr>
<tr>
<td>Other</td>
<td>18%</td>
<td>17.3%</td>
<td>10%</td>
</tr>
</tbody>
</table>

6.2 The Use of Composite Materials

Composite materials are used in many automotive applications. Glass fiber reinforced polypropylene composites are used in components ranging from floor pans, to headliners, to cross-car beams. Composites allow a high degree of design freedom and can offer properties such as stiffness and impact resistance. They are generally not as easy to recycle as plastics or metals, due to their use of fillers and reinforcement materials such as glass fibers. Carbon-fiber composites are also used, though they are more expensive than glass fiber and so are limited to minor applications.

There are also composite materials known as “MX Composites”, or metallic composites, such as aluminum and sand. They can reportedly offer lower weight, may be used for chassis components, however, their initial cost is higher than other traditional materials. The research uncovered no further detail on these types of composites.

6.2.1 Trends in Use of Composites

There appears to be an increasing interest in the use of composites for some applications. One company noted composites are used in specific applications to reduce the mass of the component or system. A manufacturer explained that in its European-manufactured vehicles, composites (such as carbon fiber) are increasingly used on a small scale in niche vehicles, such as sport utility vehicles, for performance reasons. In interiors, there is a notable increase in the use of carbon-reinforced and glass-fiber reinforced material, with the exception of Toyota, who is phasing out the use of glass-fiber reinforced material out of their vehicles. It was noted that for exterior applications composites are better used in structural components than in body panels because the panels have to be painted and this can be difficult when using composites. In addition, sheet molding composite does not enable high quality powder coating (used in part because of high rates of material utilization and near zero VOC emissions) to adhere effectively.

With respect to end-of-life, the ISRI noted that current recycling technologies are not yet ready to handle composites. The difficulty they present is that the fibers or other additives used to reinforce the material must be separated from the main material, most often plastic. However, manufacturers are researching composite recyclability in partnership projects, such

---

as a recent project between Denso and DuPont Canada that successfully tested a method to recycle nylon composite radiator end tanks from end-of-life vehicles.\textsuperscript{127}

Ford is researching nanocomposite polyolefins to replace other composite materials. The nanocomposite polyolefins are more recyclable and have low thermal expansion. While they are currently too expensive to use in mainstream design, they offer the potential in the future to replace polyamide, RIM, polypropylene (PP) and sheet molding composite (SMC) in engine beauty covers, body panels, exterior and interior trim, instrument panels and bumpers, among others. Additionally, many companies in Europe are now using renewable fibers such as flax and hemp in place of glass fibers in composite materials. See Section 6.4 for examples of this.

### 6.3 The Use of Steel, Aluminum & Magnesium

Steel is a traditional material commonly used in many components in automotive design. Its strength properties, abundance and low price make it a common choice. Steel is used in the car body, engine block, chassis, cross car beams and other power train and structural components. Stainless steel has also been used in interior and exterior trim applications.

Aluminum and magnesium are used in several places in the vehicle power train and structural components, though currently the amount used is lower than that for steel (i.e., 6% aluminum versus 54% steel, by weight). Properties of aluminum, which make it desirable for certain applications, include its low weight, the number of different alloys available and the fact that it can be extruded. Magnesium also has low weight and strength properties which make it desirable in many applications, such as cross car beams.

#### 6.3.1 Trends in Use of Aluminum & Magnesium

It is generally agreed that the amount of aluminum and magnesium in vehicles is increasing. Aluminum in vehicles has grown from approximately 14 kg (32 lb) per car in the 60’s to an average of 100 kg (220 lb) per car currently.

While a small number of vehicle models have aluminum bodies (e.g., Audi, Volkswagen and Jaguar), it is generally agreed that this is a specialty application and is not common across all models (e.g., neither of the companies with aluminum body cars have used the aluminum body in many main models, most likely due to higher cost and potentially also because of performance criteria). To date, most persons agree that the initial cost of aluminum is a key barrier to its further increased use.

6.4 The Use of Bio-based Materials or Natural Fibers in Plastics

Bio-based materials include plastics with natural feeds, such as seed oil or agricultural waste feeds and corn-based plastic (PLA). Plastics with natural fiber content, such as flax or sisal fibers have been used by DaimlerChrysler on a small scale in its European manufacturing.\(^{128}\)

These materials have properties comparable to traditional plastics such as polyurethane (with hydrocarbon feedstock) or glass reinforced plastics. Currently in North America, many persons state that bio-materials and plastics containing natural fiber are more expensive than the materials traditionally used. One European manufacturer is using plastics with bio-based feeds in a small number of components in vehicles to learn more about the performance of these materials in practice.

6.4.1 Trends in Use of Bio-based Materials or Natural Fibers in Plastics

Currently, there is a more activity using plastics with natural fibers in the European Union than in North America. DaimlerChrysler, Toyota and Ford are currently using plastics with natural fiber content in Europe. One company noted that there have been sporadic pushes to incorporate bio-based material into vehicles manufactured in North America, and North American OEMs have been testing certain bio-materials in their research laboratories. Another company explained several companies are looking for opportunities to use these types of materials in vehicle designs, but customers are not demanding them and use is certainly not widespread.

The Alliance explains that biomaterials, natural fibers in plastics, other renewable materials and plastics with recycled-content are increasing in use in automotive components. This is only the case when these materials meet the performance requirements for the component, system and vehicle.

6.4.2 Examples, Opportunities & Challenges

Overall, it is agreed that fibers in plastics decrease the recyclability of the plastic, but can offer other environmental benefits across the vehicle life cycle.

The Alliance noted that “it is logical to expect an increased presence of these materials in automobiles” only as more development work is conducted, as performance meets or exceeds the current standards and as costs are reduced. For example, one person noted that polymers used in vehicles, such as polyurethane, will increasingly have natural feeds (oil seed feeds, agricultural waste feeds, etc.), particularly in the European Union\(^{129}\) and one company stated that while European customers are beginning to request the use of renewable materials in small applications, this is not occurring in North America. Furthermore, one manufacturer

\(^{128}\) DaimlerChrysler. Online: www.daimlerchrysler.com/index_e.

\(^{129}\) Peck, P., International Institute of Industrial Environmental Economics at Lund University, Sweden. PhD. Candidate. Telephone Interview. 7 May 2003
observed that currently, supplies of bio-based materials or natural fiber plastics are not sufficient to support large scale manufacturing in North America (it noted the same supply constraint with recycled-content materials).

Ford is experimenting with biomaterials such as soy based urethane foams, natural fiber reinforced SMC, polylactic acid, etc. in its research laboratories. Ford’s Materials Science Department has also set a goal to increase usage of biomaterials by 2010.
7. Substances of Concern, Trends, Examples & Opportunities

This section describes the use of mercury, cadmium, hexavalent chromium, lead, brominated flame retardants and PVC in vehicles. It also describes performance characteristics of the materials and other factors influencing their use in vehicles. Trends in the use of these materials and examples of where they have been managed, reduced or replaced are also discussed. The OEA and EPA outlined these materials in the Terms of Reference for this research. They are of interest regarding potential opportunities for product stewardship given the variety of potential environmental issues. Also, automotive manufacturers, suppliers, dismantlers and recyclers are working to manage the use of these materials, other product sectors include these materials on restricted material lists or as part of product stewardship programs and they are included in the European Commission Directive on end-of-life vehicles. While there is no agreement on what a “substance of concern” is, each of these materials is identified by automotive suppliers, manufacturers, dismantlers and recyclers as issues to be addressed to some extent.

Three additional topics, sodium azide, PCBs and hybrid batteries are also described here. These are included because they were raised as issues during the research and interview process (environmental impacts of these materials are outside the research scope and are not discussed).

For all materials, it is important to recognize that any substitute or alternative design will also have environmental impacts which should be understood before any specific change is advocated (for example, there are environmental impacts associated with the use of silver in solder and the use of trivalent chromium, titanium dioxide and tetra-bromo-bisphenol-a, among others). While this report discusses various potential alternative materials that were raised during interview discussions, it does not evaluate their environmental life cycle impacts.

In addition, the research uncovered examples where alternatives went beyond material substitution (e.g. trivalent for hexavalent chromium) to new components or systems that eliminated the need for that substance. For example, certain trim panel designs can eliminate the need for undersealing, which contain PVC (see DaimlerChrysler’s activities to meet goals in Section 4 for a description of trim panel designs). This type of change can provide both environmental and cost benefits. Changes to vehicle design “that reduce use of materials occur as normal good business practices that improve cost/performance”.130

---

130 Written communication. The Vinyl Institute. 25 July 2003.
7.1 Mercury

Until 2002, mercury was used in convenience light switches, such as hood and trunk lights, and in “g-sensor” switches for anti-lock braking systems (in the order of 1000 mg, or 0.03 ounces). By 2002, mercury was no longer used in convenience lighting and ABS switches. It is still used in high intensity discharge (HID) headlamps (10 mg), in backlighting for instrument panel displays and in flat panel display screens used for navigation and entertainment systems and in certain other instrument clusters (e.g., “heads-up” windshield displays).

For decades, mercury-free headlamp systems have been in use in vehicles. Currently mercury is being used in some headlamp systems for illumination and possibly other design purposes. These headlamps contain approximately 0.5 mg of mercury.

In instrument panel displays, mercury is an illuminant. In flat panel display screens mercury is used to provide the proper intensity for viewing in ambient light or direct sunlight. Flat panel displays contain between 5 – 10 mg of mercury, varying with the size and location of the screen.

According to a study published by SAE, neither mercury in bulbs or instrument panel displays is “routinely collected by U.S. dismantlers, except for reuse.”

7.1.1 Trends in Use of Mercury

There are currently no alternatives for mercury in displays, and the use of electronic systems and flat panel displays in vehicles is increasing. Replacement technologies are being investigated and depending on their design, instrument panels can also be illuminated with non-mercury lighting sources. Flat panels are used in a variety of electronics outside automotives, and regulations (i.e. the Directives on WEEE and RoHS in the European Union) and product stewardship initiatives (in certain U.S. states) are encouraging development of designs that reduce or eliminate the need for heavy metals such as mercury.

Due to voluntary company initiatives, state legislation and international drivers, there is now a trend to reduce and eliminate remaining uses of mercury. Manufacturers have all set goals to this end. In addition to voluntary company goals, there is also legislation in California,

---

134 Written communication. Alliance of Automobile Manufacturers, June 2003.
Maine, Minnesota, New Hampshire, Rhode Island, and Vermont on mercury in vehicles (including requirements to provide information (labeling) on the location and amount of mercury in a product, requirements to remove and recover the mercury at end-of-life, or otherwise restrict its use). Some State and local governments have “mercury component disclosure requirements” in specification for purchasing vehicles.

### 7.1.2 Alternatives, Opportunities & Challenges

There are divergent viewpoints over who is responsible to pay for the removal of mercury switches from cars that have yet to enter the end-of-life stream. According to the Alliance, auto dismantlers are essentially the “end-of-life stewards” of automobiles in the U.S. and “the automotive recycling industry is best equipped to deal with” mercury from switches in end-of-life vehicles (see 4.1 Industry Activities Related to Material Use). Alternatively, the ARA does not agree that its members should be responsible for the cost to recover such materials. It maintains that responsibility should not fall to industries without influence over the use of mercury in the vehicle (see further discussion on cost challenges in Section 7).137

The Alliance noted that there are electric arc furnace operators that pay a premium for mercury-free scrap. For this reason, market mechanisms related to other substances of concern and recycling in general may be of interest for further study.

To deal with mercury switches in existing vehicles when they reach their end-of-life, the ARA noted that they have been advised by manufacturers to check vehicles made in the early to mid-eighties for mercury in switches. If dismantlers know which vehicles contain mercury switches, the switches are removed and handled accordingly. While ARA states its members have been involved in mercury pilot project in various parts of the country (as described by the Alliance in 4.1 Industry Activities Related to Material Use) it has not seen information on which vehicle models contain mercury switches, component model use or location. ARA explains that manufacturers have consistently said they cannot be definitive about which models or year of vehicles have mercury switches, because production of convenience switches was outsourced.138 This illustrates the type of issues that might be avoided, as environmental impacts are considered at the earliest stages in vehicle design.

According to the OEA, non-mercury illumination sources for flat panel displays are commercially available. However, the Alliance noted that these non-mercury technologies do not meet all industry performance criteria for vehicle use. One company specifically explained that while there are non-mercury technologies available for consumer electronics, automotive illumination is different and there is currently not non-mercury technology considered acceptable for automotive applications.139

139 Interview communication. April/May 2003.
Box 4. Maine’s Mercury Switch Law

In April 2002, the Maine legislature passed the nation's first law to mandate manufacturer responsibility for the removal of mercury from vehicles. The law requires automakers to create a Statewide system for collecting and recycling mercury-added switches from motor vehicles. Automakers must pay a minimum of $1 bounty for each switch turned in, and pay for transport and recycling of switches collected according to universal waste rules. The service of removing mercury-added switches must be offered to consumers at no charge. The law also includes the following provisions, effective January 1, 2003:

- New motor vehicles cannot be sold in Maine if they contain mercury switches.
- Replacement switches cannot be sold in Maine if they contain mercury.
- Used motor vehicles cannot be sold in Maine if all mercury switches have not first been removed.
- All mercury switches must be removed from a vehicle before it can be crushed or shredded.

The law upholds an earlier Maine statute that requires labeling of all mercury-added products sold in Maine. As of July 15, 2002, all vehicle manufacturers must affix a doorpost label listing mercury-added products that may be contained in the vehicle.

7.2 Cadmium

In the past, cadmium has been used as an additive in pigments for both coating and plastic applications. Additionally, cadmium has been used in coatings for metals. Cadmium does not corrode easily and can impart color – properties that have made it desirable in the past.

7.2.1 Trends in Use of Cadmium

Automakers, suppliers and manufacturers of other products have set goals to reduce, and in most cases eliminate, the use of cadmium. The metal is listed on “hazardous material” lists of manufacturers and others in the industry.

7.2.2 Alternatives, Opportunities & Challenges

In most cases, the use of cadmium has been eliminated. For certain coating applications, there is a move to replace cadmium coatings with zinc coatings, but the higher cost of zinc is an important challenge to this particular replacement.

7.3 Lead

Cars contain lead in batteries, wheel weights (to balance wheels) and in the solder of some electronic components. Lead may also be used in the manufacturing of coated wire and cable, as a plastic stabilizer in some PVC cabling applications and in electro-coat primer. In PVC cable and wire sheathing, small amounts of lead sulphate prevent breakdown of the plastic cable from ultraviolet light and heat. Lead has typically been used in electro-coating, a

---

140 Toxic Use Reduction Institute. Wire and Cable Supply Chain Initiatives. Online: http://www.turi.org/business/wire_and_cable.htm
process used to treat components such as wheels, truck chassis, cross beams, seat tracks and the body of vehicles. The electro-coating process provides resistance to corrosion and fluids during the life of the vehicle, enables additional coating layers (base coat, clear coat) to adhere, and improves the overall appearance of visible components of the vehicle. Lead is also used in electronic contacts, enabling contacts to mate better than other materials do.

**7.3.1 Trends in Use of Lead**

In the U.S., consumers can return used lead-acid batteries to garages, retailers or manufacturers. Additionally, auto recyclers collect and handle used car batteries. The lead is then recovered from the batteries and refined for resale. There is a long established market for lead from used batteries and its recovery is economical. The recovery rate for lead acid automotive batteries is 93%. However, the remaining (un-recovered) 7% of these batteries contribute 42,000 metric tons of lead to the environment, and thus represent significant potential for preventing this pollution, according to a recent report from the Ecology Center and Environmental Defense. The report also notes lead from vehicle batteries accounts for the major use of all lead in the U.S. (not only the major use of lead in vehicles).

There may be a trend away from using lead as a plastic stabilizer in wire harnesses. The example of this is provided by the Vinyl Institute, that explains how “the ELV Directive will likely reduce the amount of lead-stabilized vinyl used in vehicle wire harnesses while increasing the amount of non-lead-stabilized vinyl used”.

Lead-free electro-coat is now available to the automotive industry with corrosion resistance that is comparable to lead containing alternatives. This was driven in part by state laws such as Minnesota’s law on “Toxics in Specified Products”. GM, DaimlerChrysler and Ford have all committed to switch to lead-free electro-coat by 2003.

**7.3.2 Alternatives, Opportunities & Challenges**

Lead is used in tin-lead soldering alloys. Examples from one company indicate that there is potential to change welding practices to eliminate the need for solder altogether, in some

---

143 Written communication. Alliance of Automobile Manufacturers, June 2003.
145 Written communication. The Vinyl Institute. 25 July 2003.
147 USCAR. Online: http://www.uscar.org/consortia&teams/VRP/PAP-Ford.pdf
148 USCAR. Online: http://www.uscar.org/consortia&teams/VRP/PPAP-DCX.pdf
149 USCAR. Online: http://www.uscar.org/consortia&teams/VRP/PPAP-GM.pdf
applications. Eliminating the need for solder could save money and would reduce the use of lead in the vehicle. Another potential alternative is silver solder, mentioned by one company interviewed. However, drawbacks include higher costs as well as higher soldering temperatures, which in turn may require different plastic materials to withstand these temperatures. The electronics industry is making some headway in other lead-free soldering alloys for computers (driven in part by the European Commission’s Directives on WEEE and RoHS), but a vehicle has more stringent requirements for durability and stress tolerance (e.g., a vehicle lasts much longer and is exposed to a much wider range of temperature and environmental conditions than a desk-top computer), which may make some of these alternatives inappropriate for use in vehicles.

Currently, there is no “commercially produced, drop-in replacement for the lead-acid (starting-lighting-ignition) battery.” High-voltage electric and hybrid-electric vehicles do use lead-free battery systems – alternatives that offer certain performance advantages over lead-acid batteries but do not currently match the low purchase price of lead-acid batteries, given current economies of scale and existing infrastructure. There has also been some recent discussion about changing from 12-volt to 42-volt batteries in order to improve power in vehicles (e.g., to provide for the power requirements of electronic braking, steering and other technologies). During one interview, it was noted that this period of change might offer opportunity to look at alternative battery materials. As mentioned previously, it will be important in all cases to understand the environmental implications of any proposed alternative, in comparison to the existing technology/material.

Several persons stated there are alternatives to lead wheel weights and references from the Ecology Center further support this. According to the Ecology Center, alternative external balancing technologies include tin, steel, tungsten, plastic (thermoplastic polypropylene) and ZAMA (a zinc-aluminum-copper alloy). While tin appears to be the favored “drop-in” alternative to lead, a tin weight has to be approximately 50% longer than a lead weight because it is so much lighter (a company called TRAX in the U.K. produces tin weights). For several years, a Japanese company called Azuma has commercially produced

---

150 Written communication. K. Mills, Director, Pollution Prevention Alliance, Environmental Defense. 16 June 2003. For more information, see Battery Alternatives Factsheet, online at http://www.environmentaldefense.org/pdf.cfm?contentid=2894&filename=FactSheet_batteryalts.pdf

151 Written communication. K. Mills, Director, Pollution Prevention Alliance, Environmental Defense. 16 June 2003.


155 According to Jeff Gearhart of the Ecology Center (Written Communication, 24 June 2003), the company LNP Plastics INC produced highly filled Polyamide 6 weight for Mercedes. LNP Contact is Robert Russell at (610) 363-4500.

156 This is in collaboration with the International Tin Research Institute (ITRI). TRAX contact is John Halle at +44 1938 554297, ITRI contact is Kay Nimmo at +44 1895 272406.
steel adhesive and ram-on weights for aftermarket applications.\textsuperscript{157} Dionys Hofmann (one of the larger manufacturers in Europe) and other manufacturers in Italy are starting to produce ZAMA weights of between 5 to 50 milligrams (customers include Fiat).\textsuperscript{158}

There are also some internal balancing systems under study as alternatives to wheel weights (including injecting plastics, glass or metal beads into the tire). For example, glass beads are used by heavy duty vehicle fleets throughout the U.S. and Canada, working by “electrostatic cling” against the lining of the tire at the neutralizing balanced positions.

However, interviews indicated that while they are exploring alternatives, current solutions require large, cumbersome designs, unfamiliar materials and obscure alloys which may in fact have their own environmental problems. The European Union ELV Directive contains a phase out requirement for lead wheel weights and presumably alternatives are being developed in the European Union.

### 7.4 Hexavalent Chromium

Hexavalent chromium is used in vehicles for plating and as a metallic cover to plastics in certain applications (e.g. bumpers). According to the Alliance, hexavalent chromium is used as a finish for certain fasteners and, as with any finish (plating or coating), it affects the ability of that fastener to remain in place at any given torque setting. Hexavalent chromium may also be used in welding and spray painting. Hexavalent chromium can produce a hard surface and is highly resistant to corrosion, making it excellent for plating and coating steel or other materials. It can also provide color and adhesion for organics (e.g. paint) and has desirable properties such as ease of application, durability, resiliency and low cost (partly due to inexpensive equipment),\textsuperscript{159} when used for coating zinc plated automotive parts.

#### 7.4.1 Trends in Use of Hexavalent Chromium

Hexavalent chromium is designated as a hazardous substance (toxic, sensitizing and carcinogenic)\textsuperscript{160} and there is a clear trend to find alternatives that will reduce (or eliminate) it from automobiles and other products. DaimlerChrysler, Ford and GM have hexavalent chromium on their designated and restricted substance lists and require complete elimination of it from manufacture of products and vehicles by January 2007, July 2005 and 2006 (model

\textsuperscript{157} According to Jeff Gearhart of the Ecology Center (Written Communication, 24 June 2003), AZUMA manufactures both adhesive and clip-on steel weights called “Ironbond”. For more information, http://www.gol.com/azuma, or azwbw@gol.com.


\textsuperscript{160} For example, stationary sources of hexavalent chromium contribute to 51% of the total hex chrome emissions in California. The California Air Resources Board has adopted an airborne toxic control measure in 1988 to reduce emissions of hexavalent chromium from chrome plating and other sources. California Air Resources Board. \textit{Hexavalent Chromium at John Swelt}. Online at http://www.arb.ca.gov/ch/aq_result/crockett/cr_cr6.htm.
year) respectively. The USCAR’s VRP has Substances of Concern Task Force, which among other things held a forum in 2002 entitled “Approach to Heavy Metal EU Mandates” to discuss progress on eliminating hexavalent chromium from vehicles.

To date, trivalent chromium is used in place of the hexavalent form in some plating applications. However, interviews indicated that the industry may not be ready to exclude all uses of hexavalent chrome by the date set in the ELV Directive.

7.4.2 Alternatives, Opportunities & Challenges

Hexavalent chromium finishes are being replaced by steel and trivalent chrome, for certain applications. The research did not uncover any more specific alternatives or examples. Replacing hexavalent chromium with other finishes will require a new torque specification to be set for these fasteners (i.e. torque specification is related to the finish). This is not a problem when designing a new vehicle but could be more of a challenge regarding service parts. Specifically, the redesigned fastener would be added to the car during servicing but “torqued” according to the specification for the old (hexavalent chromium finished) fastener instead of according to the proper torque setting for the re-designed fastener.

7.5 Brominated Flame Retardants

Brominated and other halogenated flame-retardants are added to plastic materials and textiles in order to meet various fire-protection requirements. Thus, they are used in the interior of cars (fabrics, plastics and seating foams) and also in other components (cables, component housings and insulation materials), to prevent burning or to slow burning should fire begin in the car. They are also used in nearly all electronics (printed circuit boards) and other electrical products.

7.5.1 Trends in Use of Brominated Flame Retardants

Two flame retardants, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), are of particular focus and most automakers, suppliers and manufacturers are trying reduce their use. One company expects OEM restrictions on brominated flame retardants will become “must meet restrictions” as is currently the case with restrictions on certain uses of mercury, lead, hexavalent chromium and cadmium. One company explained that it is working to avoid flame retardants and other additives as much as possible, in part because they interfere with internal material recycling. The company is working to identify a small number of flame retardants (and small number of additives) that can be used without contaminating the recycling loop.

Chlorinated paraffin\footnote{Short chain chlorinated paraffins are listed in the U.S.’s TRI and are designated as toxic in Canada and the European Union. Written communication, S. Brauer, US EPA Region 5. 19 June 2003.} substances may also be used as flame retardants in plastics and rubber (they are also used in high-performance paints and coatings for moisture and chemical resistance and in vinyl as a secondary plasticizer).

While there are alternatives for flame retardants in some applications, there are currently no substitutes on the market for several of the flame retardants used in electronics\footnote{Danish Environmental Protection Agency. 2002. \textit{Brominated Flame Retardants in Widespread Use}. Online: \url{http://www.mst.dk/project/NyViden/2000/05130000.htm}}. According to the Danish Environmental Protection Agency, tetra-bromo-bisphenol-a (TBBA) is being used as substitute in some thermoplastics.

### 7.5.2 Alternatives, Opportunities & Challenges

Generally, companies interviewed did agree that brominated flame retardants are slowly being pushed out of use and that there is effort to replace them. For interior applications, flame test requirements are a main barrier to this effort. In some instances, testing standards may state the amount of substance to be used as opposed to performance measure to be met.

Certain materials, such as glass fiber and PVC may require less, or no, flame retardant substances, as they have flame resistant properties\footnote{Written communication. The Vinyl Institute. 25 July 2003.}. One person cited another example with toluene di-isocyanate (TDI) and methylene diphenyl di-isocyanate (MDI). TDI is used in polyurethane foam that requires flame retardant additives, while an alternative MDI based foam does not burn as easily and flame retardants are not needed. MDI may also be recyclable and less volatile than TDI, though it is not mainstream and there is currently a small market for it. There are, however, toxicity issues related to manufacturing sites producing and using MDI and TDI, which may prevent their use as substitutes.

The Danish government describes several alternatives to brominated flame retardants, though they may have disadvantages when compared to the flame retardants they replace\footnote{Danish Environmental Protection Agency. 2002. \textit{Brominated Flame Retardants in Widespread Use}. Online: \url{http://www.mst.dk/project/NyViden/2000/05130000.htm}}. There are three main types of alternatives: flame retardants containing organic phosphorous; flame retardants containing nitrogen; and inorganic flame retardants, which are used separately or in combination (and in practice, information about the compounds and their combinations is confidential, proprietary information). The Danish government found that, to date, risk assessments have not been done on most alternatives and they have been studied only to a limited extent. Certain alternatives have adverse effects on health and the environment, such as organic phosphorous emitted from flame retardants in products during their useful life.
7.6 The Use of Poly-Vinyl Chloride (PVC)

The plastic poly-vinyl chloride (PVC) is a type of plastic made from chlorine. It is used in vehicle cables and wiring and in interior components such as door panels, arm and headrests or instrument panel skins. It is also used in exterior accessories and trim, undercoating and sealers and in ducts for heating and cooling the car. PVC is recyclable. It is inexpensive and can be formulated to have a number of properties, which make it useful in a wide range of applications and products. PVC has heat and fire resistant properties, which make it preferable for certain components (such as cable insulation). In most instances, flame retardants do not need to be added to meet fire protection standards, as PVC is inherently flame retardant. Common PVC use in vehicles include:

- Arm and Head Rests
- Mud Flaps
- Exterior Accessories & Trim
- Seat Covers
- Heating and Cooling Ducts
- Seat Belt Latches
- Instrument Panel Skins
- Steering Wheel Covers
- Interior Trim
- Undercoatings & Sealers
- Mats
- Wiring

7.6.1 Trends in Use of PVC

Some companies in the U.S. have established goals to phase out uses of PVC, while others maintain that it is a safe and cost effective material. According to the Vinyl Institute, “industry statistics and independent market analyses show a clear trend toward PVC growth in the U.S.”, across all markets.

In the U.S. auto sector, there does not appear to be a certain trend in how much PVC is used. Both GM and Ford talk about PVC in their public goals on environmental performance (see Section 4.2 Automotive Manufacturers Goals & Activities Regarding Material Use). According to an article written in 1999 in Ecology Center News, Ford and DaimlerChrysler have eliminated PVC from instrument panel skins in select car models and the Ford Focus has “50% less PVC than previous models”. The article also noted that Honda intends to create a 100% recyclable auto by 2010, without the use of PVC. One company noted they perceive a growing trend toward “halogen-free” materials, especially from Asian customers, though not necessarily a trend away from PVC specifically (e.g. Toyota’s intent to reduce the use of chlorine in its vehicles). One company has replaced PVC in most major applications in European-manufactured vehicles, including the instrument panels. However it noted PVC is still present in some cable insulation.

---

166 Written communication. The Vinyl Institute. 25 July 2003.
168 Written communication. The Vinyl Institute. 25 July 2003.
There are alternatives for almost all applications of PVC in vehicles, but apparently few of these alternatives yet compete with the current low cost and performance of PVC.

### 7.6.2 Alternatives, Opportunities & Challenges

Debate over the impacts of PVC and various PVC formulations on human health and the environment continues. PVC contains 57% chlorine and uses over 30% of the chlorine produced in the world. The Alliance of Automobile Manufacturers maintain “the plastics industry has reduced additives that have caused concern such as lead and low molecular weight phthalates” from PVC. While some automakers have goals to reduce the use of PVC in interiors, progress toward these goals may be halted because alternatives prove too expensive and because of designer’s preference for this well-known and widely used material.

Instrument panel skins have historically been made of PVC. There are examples showing that thermoplastic polyolefin (TPO) is a feasible replacement from a performance standpoint. TPO does not contain, but is made with, chlorine and some polyolefin alternatives (used in cables) can contain significant quantities of flame retarding additives. The cost of TPO is currently higher than that for PVC. TPO is recyclable, as is PVC. Thus, there is potential that TPO may contain recycled-content making it more cost competitive with PVC. TPO was also proposed to replace PVC in interior trim and other interior components, cabling, undercoating, sealers, fabric seating and carpet backing. Currently, neither PVC nor TPO is post-consumer recycled from automobiles. This illustrates the importance of taking a life cycle approach to material selection.

More generally, polyethylene and polypropylene can be used in place of PVC in certain applications. Polyethylene is used in PVC-free power cables as insulation and sheathing. These alternative materials (also known as low-smoke, zero-halogen or LSOH cables) have fire-resistance properties that match PVC and also perform better during fire because they generate less smoke and do not release chlorinated compounds. Currently, all PVC-free cables are more expensive. For surface applications, flexible polyurethane, polyolefin and TPU may offer alternatives to PVC, though TPU is reportedly six or seven times more expensive than PVC. In other applications, EPM, EPDM and EVA have been used to substitute PVC. Many thermoset plastics cannot be recycled and this is likely an important consideration when replacing PVC.

Undercoatings and sealers use PVC, but there are some designs that enable manufacturers to eliminate the need for undercoatings or sealers in certain applications (for example, DaimlerChrysler has a plastic trim panel design that does not require underseal to protect the floor pan).

---

171 Written communication. The Vinyl Institute. 25 July 2003.
Delphi’s European operations currently have a process for recycling PVC (along with other materials) from automotive wiring. In the mainstream industry process for vehicle dismantling and recovery, if the wire can be segregated, it can be processed and the PVC insulation can be recycled. However, PVC insulation is currently shredded and generally ends up with automotive shredder residue (though the copper can be recovered using separation technologies such as the use of eddy currents).\(^{173}\)

It is also worth noting that some of the bio-materials discussed previously may prove to be alternatives for certain applications of PVC. No data on this was found during the research.

### 7.7 Other Substances

During the course of the research, sodium azide, PCBs and hybrid batteries were raised as potential concerns regarding end-of-life vehicle management. For this reason, each of these is discussed briefly here.

#### 7.7.1 Sodium Azide

Airbags in cars contain sodium azide (or naturimazide, $\text{NaN}_3$)\(^{174}\) as a propellant. In the airbag, the sodium azide is in tablet form and stacked in a metal canister. To provide an idea of scale, a driver’s-side air bag typically contains about 50 mg (0.001 ounces) and the passenger-side air bag contains about 200 mg. When the airbag deploys, the sodium azide burns and the reaction products are inert. Auto manufacturers recommend airbags be deployed prior to shredding. If they are not deployed the airbag canisters create a risk of exploding (if handled by dismantlers or accidentally passed through automobile shredders into secondary furnaces) or a potential health hazard (if crushed and sodium azide is released to the environment). USCAR has set a standard procedure for deploying airbags.\(^{175}\)

### Alternatives, Opportunities & Challenges

Vehicles can contain a number of airbags (one example has 14 airbags, though a more typical number is 2) and as automakers improve vehicle safety systems, the number of airbags could continue to increase. Honda discontinued the use of sodium azide in mass-produced vehicles sold in Japan in 1998 (see Section 4.2 Automotive Manufacturers Goals & Activities Regarding Material Use). The ARA has the understanding that sodium azide has been phased out of use as a propellant in airbags.\(^{176}\)

---


\(^{174}\) Sodium Azide, or naturimazide ($\text{NaN}_3$), is the principal chemical used to generate nitrogen gas in automobile safety airbags.

\(^{175}\) See http://www.uscar.org

Alternative propellants include pressurized gases such as Argon. There are also alternative propellants to sodium azide (guanidinium nitrate, C\textsubscript{6}H\textsubscript{6}N\textsubscript{4}O\textsubscript{3} was one of the examples mentioned during the research). Issues pertaining to performance, environmental impacts and hazards associated with the alternatives were not within the scope of the research.

### 7.7.2 Polychlorinated Biphenyls (PCBs)

Poly-chlorinated bi-phenyls (PCBs) were once used in vehicles as an insulating oil or heat medium (as well as in white goods and other durable products). Their use has been banned since 1979, but material recyclers still report some level of PCB contamination in waste from automobiles, electronics and/or other products that are recovered and shredded. The Alliance state that PCBs in shredder residue are not coming from automobiles, but are coming from other products. It is important to note that the origin of the PCBs remains unclear to ISRI, but waste contaminated with PCBs is considered toxic waste under TSCA in the U.S. and cannot be used or recycled into products.

**Alternatives, Opportunities & Challenges**

PCBs were banned from products by federal legislation in the U.S. in 1979 and since that time, alternatives have been found for all uses. However, ISRI members still periodically identify low PCB levels in shredder residue materials, which precludes recyclability.

### 7.7.3 Hybrid Batteries

As previously noted, there is some concern about materials that may be used in batteries of any new hybrid vehicles. The ARA stated that currently, its members are not clear on how they would handle these batteries. To properly manage vehicle components and materials, auto dismantlers and recyclers have to know what to look for and where. The ARA stated that to date, Toyota has provided information on dismantling and recycling issues surrounding hybrid batteries (the research indicated that GM has dismantling manuals, though these are only for traditional lead-acid battery vehicle models)(Appendix 12). To date, the Rechargeable Battery Recycling Corporation (RBRC)\textsuperscript{177} programs cover small nickel-hydride or lithium-ion batteries, but would not include those from automobiles. In March 2002, the European Commission proposed a ban on the use of cadmium batteries in electric vehicles. If passed, the proposed ban would come into effect from the end of 2005.\textsuperscript{178}

\textsuperscript{177} For more information, find the RBRC online at www.rbrc.org.
7.7.4 Tires

Tires were not included in the scope of work for this report, as outlined by OEA. However, the research provided some interesting information and based on this, tires could be explored further as a potential opportunity for product stewardship initiatives.\textsuperscript{179} (Potential environmental and health issues from tires arise as rubber is lost during tire wear and as polycyclic aromatic hydrocarbons, carbon black and rubber particles are released. To give an idea of scale, sources indicate some 24 to 163 mg/km/vehicle\textsuperscript{180} of abraded particles are released during regular wear of tires on a light duty vehicle. This calculates to between 95,813 and 650,733 Mtons of particles released in that year).\textsuperscript{181} A large portion of particles from tire wear is small enough to penetrate deeply into lung tissues and lead to respiratory problems.\textsuperscript{182})

\textsuperscript{179} For more information, contact Mr. Jeff Gearhart at the Ecology Center in Ann Arbor Michigan. Tel. +1.734.663.2400.
\textsuperscript{180} RAINS-PM Study: International Institute for Applied Systems Analysis. IIASA; A 2361; Laxenburg; Austria http://www.iiasa.ac.at/~rains/PM/docs/documentation.html.
\textsuperscript{182} RAINS-PM Study: International Institute for Applied Systems Analysis. IIASA; A 2361; Laxenburg; Austria http://www.iiasa.ac.at/~rains/PM/docs/documentation.html.
8. Examples of Recycled-Content Materials & Opportunities

This section describes current examples of recycled-content materials in vehicles, as well as other opportunities for using recycled-content materials.

Metals are widely recycled from end-of-life vehicles and metals used contain recycled-content. According to the Alliance, steel from vehicles was recycled at a rate of 91% to 98% between 1993 and 2000, while steel from all sources was only recycled at a rate between 64% and 69%, over the same period. Cast iron in automobiles contains more than 75% recycled-content and aluminum typically has more than 35% recycled-content. As mentioned earlier, in 2002, Ford and Alcan established a closed-loop recycling stream. Aluminum from Ford’s stamping facility in Chicago is returned to Alcan's aluminum plant in Oswego (NY), where it is remelted and rolled once again into automotive sheet. This loop can be repeated virtually indefinitely because aluminum does not degrade when recycled (see Appendix 8 for more information).

Non-metallic materials can also contain recycled-content. In North America, plastics with recycled-content are being used increasingly in mainstream vehicle production. BMW vehicles typically contain 12% plastic, and up to 15% of this plastic can be recycled-content, depending on the model.\textsuperscript{183} Because polypropylene and polyurethane are two of the most commonly used plastics in vehicles, examples of recycled-content polypropylene and polyurethane are provided below:

- Polyurethane foam from various sources is recycled into “premium grade” carpet underlay, according to data from the Alliance. DaimlerChrysler notes the foam has superior-performance to that made from virgin, or non-recycled-content materials.\textsuperscript{184}
- DaimlerChrysler’s Mercedes E-Class has a bumper made of recycled polypropylene.\textsuperscript{185}
- The Mercedes E-Class also has front wheel-arch liners made entirely\textsuperscript{186} of material recycled from the Mercedes-Benz Recycling System of service stations (in Germany). It is a combination of old Mercedes battery housings (polypropylene) and old Mercedes bumpers (polypropylene and EPDM).\textsuperscript{187}
- At a demonstration level DaimlerChrysler retrofitted two demo vehicles (Jeep® Grand Cherokees) with 54 components made from post consumer recycled-content materials. The materials are directly recovered from ELV automobiles, including recycled polyurethane foam, polypropylene and ABS.\textsuperscript{188}

\textsuperscript{183} BMW Group Sustainability Goals. 2001-2002 Sustainable Value Report.
• DaimlerChrysler’s demo vehicles also feature an air induction system made of recycled polypropylene, with heat-resistance equal to an induction system made with virgin polypropylene.

• DaimlerChrysler also reported using polyurethane foam from ASR in compression-molded materials. The materials are formed into various shapes and exhibit excellent thermal and noise insulation properties.¹⁸⁹

Thermoplastic polyolefins (TPO) can also be made with recycled-content. Delphi’s North American operations have designed an instrument panel with a thermoplastic polyolefin skin that utilizes over 50% recycled-content. The TPO instrument panel is currently used by Delphi customers in Europe and the U.S. It was developed jointly among Delphi, a European customer and a polymer supplier. In addition to the recycled-content, the panel is 100% recyclable at end-of-life.

It is also possible to recycle HDPE into recycled-content materials for vehicles. In 1997, the VRP conducted a demonstration project to recycle HDPE fuel tanks into door panels, fuel tanks and potentially other automotive components. The VRP also worked with Exxon Mobil, the American Plastics Council and Visteon in this effort. The end-of-use fuel tanks were collected, prepared and ground, digested (with wood), steam exploded and processed into automotive parts. This same process was also tested with mixtures of other plastics, but many people have stated that this technology is still too expensive to employ and others state that there is not a strong enough market for the recycled product.

Sound-deadening material can be made from end-of-life carpet material and one interview revealed that sound-deadening materials are likely the highest recycled-content application in vehicles currently. Carpet underlay systems also contain recycled-content materials, as do insulation, headliners and other non-visible components.

The Alliance describes additional examples of post consumer recycled-content materials (though not from ELVs) in its member’s vehicles:

• PET soda pop bottles are recycled into grille opening panels and trunk trim;
• Computer housings are recycled into grills and lamp housings;
• Tires are recycled into splash shields; brake pedal pads & new tires;
• Battery housings (polypropylene) are recycled into wheel opening liners, accelerator pedals;
• Bottle Caps and cotton bale wrappers are recycled into air conditioner and heater plenum housings and fan shrouds;
• Old bumpers are recycled into new bumper reinforcements;
• Polycarbonate water bottles are recycled into headlamps, grilles and air cleaner housings (DaimlerChrysler reported a 15% reduction in material costs by producing headlamp-mounting modules from recycled plastic bottles and gloves);
• Reclaimed PVC plastic is used in floor mats;¹⁰⁰

---
• Headliner core and luggage rail racks are made from plastic soda bottles;
• Head lamp bezels are made from post-consumer nylon fiber; and,
• Floor mats and molded parts are made from ground rubber.\(^{191}\)

Industrial carpeting is recycled into engine fan modules and air cleaner housings. DuPont produces a resin for the auto industry made of 25% post consumer recycled-content from carpets. The resin (Minlon®) is produced by DuPon’s Engineering Polymers division.

At a demonstration level, the Argonne National Laboratories recovered polyurethane foam from seats, sorted and washed it for re-use as seating foam and as insulation.

### 8.1 Recycled Content – Issues & Challenges

Overall, the research indicated that it is possible to use materials with post consumer recycled-content in a wide range of automotive components. In addition to the use of metals with recycled-content in vehicles (over 25%), it is possible to have some degree of recycled-content in nearly all plastic components. In particular, hidden and non-visible components without high stress requirements can incorporate recycled-content.

The use of post consumer recycled-content plastics in actual high volume vehicle applications is increasing, but it is not widespread. High cost, relative to virgin plastics, is cited as a primary barrier to their use, as is an inconsistent supply. For example virgin polypropylene is one of the most widely used plastics in vehicles,\(^{192}\) however recycled polypropylene can currently be more expensive than virgin material. According to one company, the three common plastics in vehicles (ABS, polyurethane foam and polypropylene), as virgin material cost less than other virgin materials for these applications. For this reason, the economics to identify, separate and recycle them are currently not favorable (i.e. the recycled ABS would currently cost more than virgin ABS). Perception and constraints from the time it takes to test new materials are also cited as barriers.

Inconsistent and limited supply of recycled-content plastics are also barriers to further increasing their use. Infrastructure required to provide a sufficient quantity of material and a secure supply to manufacturers does not currently exist in the U.S. The Alliance explain vehicle production requires a large and consistent stream of materials, which means a developed infrastructure is necessary to deliver materials (such as recycled-content or renewable materials) in required volumes.

In safety related applications there is hesitancy to use secondary feedstock, as any changes require extensive testing at many levels. For instance, the material itself must be tested

---


\(^{192}\) DaimlerChrysler Environmental Report 2002. p, 44.
against performance and processing requirements, the component that the material is a part of must also be tested, as well as the vehicle. Therefore, to avoid extra time and cost for new testing, alternative materials may be passed over in favor of materials that have been tested and used successfully in the past. However, with OEM requirements for recycled-content materials this is changing, and time and cost resources can be used effectively if the new material is tested within the product development process for a new vehicle or during a vehicle design change. For this reason, manufacturers explain they build recycled-content or other environmental goals into the product development process. However there are still many challenges to overcome in order to meet and increase these goals.

Restrictions on the use of re-grind plastic in many safety standards and guidelines have been one challenge. This may be related perception and the idea that recycled-content materials cannot be as high quality as virgin materials.
9. Examples of Recyclable Materials & Opportunities

This section describes current examples of recyclable materials in vehicles, beyond those components and materials conventionally recycled, as well as other opportunities for using recyclable materials. Ultimately, the recyclability of vehicles and not recycled-content, will impact ASR volume and for this reason it is important to discuss these examples.

As noted previously, metals are highly recyclable and are usually recycled due to market demands and economic returns (e.g. 91% or more of steel from vehicles is recycled, and nearly all lead from batteries is recycled). Plastics can be both mechanically recycled or taken back to chemicals (feed-stock) and recycled back into vehicles, as illustrated in Figure 15 below.

In a joint effort, the automotive industries in North America and the European Union developed an automated materials separation system to more effectively recycle three of the most widely used plastics in automobiles – ABS [acrylonitrile butadiene styrene resin], polyurethane foam and polypropylene. To date, the separation system is not in widespread use, due to the high cost of investment for the equipment, high operating costs, and the performance disadvantages of the resulting materials.

In Germany, Mercedes-Benz has a system called the Mercedes-Benz Recycling System at repair facilities. Mercedes-Benz takes old Mercedes battery housings (polypropylene) and old Mercedes bumpers (polypropylene and EPDM) and recycles that material back into new

---

195 A number of companies contributed to the effort: Polyurethane Council (PURRE), Textron, Mayco, Venture, Johnson Controls, Reiter Automotive, Collins & Aikman, Sarnamotive Blue Water, Foamex, VitaFoam, Tennex, Federal Mogul, Magna, Lear, A. Schulman, Ferro, Washington Penn, and Lavergne Group.
vehicles. Specifically, front wheel-arch liners in the Mercedes E-Class are made entirely of this recycled material.\textsuperscript{196}

In Japan, Nissan Motor Company produces and sells a subcompact vehicle called “March”, which is 95% recyclable. Nissan notes this is one of the highest rates in the industry and states that its recyclability is due to the use of polypropylene and other easy-to-re-use materials (Figure 10). In addition, the car is designed to have 12 sections, compared with 32 sections in the previous “March,” which reduces the time it takes to dismantle the car by 40%.\textsuperscript{197}

The fascia of the 2002 Dodge Neon is 100% recyclable and its manufacturing scrap can be reprocessed for use in fascia substrate or compounded for use in non-critical applications (such as wheel well liners). DaimlerChrysler engineers state there is a potential to use this recyclable material and the “color in mold” technology for all exterior panels (as previously discussed, the technology does not require painting).\textsuperscript{198}

Currently, nearly all of the materials used in a lead-acid battery are recycled. This includes the acid and the battery's case and cover, as well as the lead.

Delphi has technology to manufacture instrument panels made of thermoplastic polyolefin (TPO) skin that is 100%-recyclable (as mentioned previously, it is also made of over 50% recycled-content). The technology produces near zero process wastes and uses water-based primer and topcoat systems to reduce ozone-depleting volatile organic compound emissions.\textsuperscript{199} In 1999, Delphi began using this TPO skin technology in other automotive interior products.

Delphi’s European operations have a process to recycle PVC insulation, connector housings and flexible printed circuits from automotive wiring. The processes is able to:

- Prevent cross-contamination during the recycling process;
- Promote re-use of PVCs and polymers; and
- Allow full reclamation of metals used in wiring harnesses.

As Delphi explains, harnesses from the 9 million vehicles scrapped annually in the European Union contain approximately 90,000 metric tons of copper, 35,000 metric tons of PVC and 20,000 metric tons of polymers. The company calculated that this material represents a potential value of more than $200 million annually.\textsuperscript{200} No equivalent figures for North America were uncovered during the research.

\textsuperscript{199} Delphi Corporation. Online: http://www.delphi.com/automotive/nextech/environment/
\textsuperscript{200} Delphi Corporation. Online: http://www.delphi.com/corporate/citizenship/environment/
The amount of polypropylene in vehicles is second only to polyurethane, according to USAMP’s life cycle study of a 1995 vehicle. However, it can currently only be recycled into products other than vehicles because once recycled it loses some of its original strength properties (given current technology).

The Vinyl Institute note Visteon (an automotive supplier) recycles PVC post-industrial instrument panel scrap (post-industrial scrap refers to scrap from manufacturing, as opposed to scrap from end-of-life vehicles).²⁰¹

In addition to plastic, glass from windshields and windows is included in ASR sent to landfill. In general, automotive glass is not recycled from vehicles because of contamination and costs of technology needed to process the glass.²⁰² For example, windshield glass is tempered, covered with plastic laminate and has other special properties to impart safety and performance characteristics, which are barriers to recycling. The VRP sponsored a separate project to tackle the issues of separating and recycling the plastics and glass in windshields.²⁰³ However, glass from doors and windshields that is not broken is dismantled and re-sold in the marketplace.

### 9.1 Recyclable Material – Issues & Challenges

There can be an important difference between recyclable materials and materials with recycled-content, in terms of their environmental life cycle performance (e.g., a recycled-content plastic may not be recyclable). But it is also important to distinguish between a material that is “recyclable” and material that is actually recycled. In many cases, a plastic is technically recyclable but no recycling facilities exist and there are no strong markets for the recycled product. In vehicles, recyclable plastics are used in some components, but currently these are shredded and sent to landfill as ASR when the vehicle reaches its end-of-life.

To be recycled, end-of-life handlers must be able to identify the plastic that is to be recycled. If it is not easily identifiable, it cannot be separated or recycled. While vehicle manufacturer design specifications have required polymeric parts marking since the 1990’s, better exchange of information along the product chain from suppliers, to manufacturers, to dismantlers and recyclers could help to address this barrier. In addition to labeling or other forms of information exchange, design for dismantling could increase the recycling rate of recyclable materials. However, it should be noted that the driver behind parts marking was the assumption that plastic parts would be separated and recycled at end-of-life. Because this has not been the case in the U.S., the current focus is on developing automated sorting systems that can be easily integrated into the dismantling process.

²⁰¹ Written communication. The Vinyl Institute. 25 July 2003.
To illustrate… Only scrap that is well sorted can be recycled economically. If we consider bumpers as an example, plastic bumpers are separated from the metal frame bumpers to be recycled separately. Then, certain plastic bumper types can be sorted again, such as separating PE from ABS plastics. Looking at the PE plastics, it is clear that some may have fillers based on chalk, while others have fillers based on glass fibers. The chalk filled bumpers are then different again, with a variety in amount of chalk and color of paint. At this point, no commercial recycler will sort these into several fractions because the economic and environmental benefits do not currently justify it.

Example is adapted and altered from JCI “Johnson Controls IMDS User Guide”. 

Also, if there is a market for a plastic it will be recovered and sold, as is the case with metals from ELVs.

An article by R. Paul offers five main reasons for why “plastics, at this time, except for plastic battery casings, do not enjoy a high rate of recovery from ELV’s or material recycling”. While two of these reasons have been previously discussed (i.e., ability to identify recyclable plastics and need for strong markets for recycled product), the article presents three additional points (points 1-3):

1. Virgin material for parts product is inexpensive;
2. Technology to process this material by selective dismantling is not profitable;
3. Technology to recover high value plastic parts from ASR has not been demonstrated on a commercial scale;
4. An infrastructure for the identification, collection, transportation and handling of plastic does not exist; and
5. Markets for recycled plastics for use in the manufacture of new products has not been developed, largely due to the first four reasons.204

One company explained that it is already technically possible to recycle almost 85% of the vehicle (by weight) without much additional information or design changes. However, it observed that reaching 95% recyclability will require more work between suppliers and manufactures (and perhaps also recyclers) to re-design problem parts.

---

After all fluids and parts for re-use or re-manufacture are removed, the vehicle is put through a shredder. The output of the shredder is divided into ferrous and non-ferrous metals and the remaining non-metallic fractions are defined as ASR (although the ASR does contain trace amounts of metals, from electronics and other components). ASR is primarily made up of glass, plastics, foam and rubber. The ferrous and non-ferrous metals are typically recovered and sold on the commodity market for recycling. The ASR is used for daily cover in landfills or is disposed in municipal sanitary landfills. Table 9 below illustrates the main materials used in vehicles and indicates whether they end up in landfill or are recycled or reused at end-of-life.

Table 9. Profile of materials in 1532kg (3377 lb) generic vehicle\textsuperscript{205} that are found in amounts of 10 kg (22 lb) or above, or are identified OEA within the scope of this research, and estimate of where each material goes at end-of-life.\textsuperscript{206}

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass (kg)</th>
<th>Mass (%)</th>
<th>EoL</th>
<th>Material</th>
<th>Mass (kg)</th>
<th>Mass (%)</th>
<th>EoL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum – cast</td>
<td>71</td>
<td>4.663</td>
<td>R</td>
<td>Polypropylene (PP)</td>
<td>25</td>
<td>1.6</td>
<td>ASR</td>
</tr>
<tr>
<td>Aluminum – extruded</td>
<td>22</td>
<td>1.438</td>
<td>R</td>
<td>Polyurethane (PUR)</td>
<td>35</td>
<td>2.3</td>
<td>ASR</td>
</tr>
<tr>
<td>Aluminum – rolled</td>
<td>3.3</td>
<td>0.2</td>
<td>R</td>
<td>Polyamide (PA 66)</td>
<td>10</td>
<td>0.67</td>
<td>ASR</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
<td>R</td>
<td>Polyester Resin</td>
<td>11</td>
<td>0.75</td>
<td>ASR</td>
</tr>
<tr>
<td>Lead</td>
<td>13</td>
<td>0.85</td>
<td>R</td>
<td>Acrylonitrile Butadiene Styrene (ABS)</td>
<td>9.7</td>
<td>0.64</td>
<td>ASR</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.91</td>
<td>0.06</td>
<td></td>
<td>Polymethyl Methacrylate (PMMA)</td>
<td>20</td>
<td>1.3</td>
<td>ASR</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.32</td>
<td>0.02</td>
<td>?</td>
<td>Polyvinyl Chloride</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Non-Ferrous Metals</strong></td>
<td><strong>138</strong></td>
<td><strong>9.0</strong></td>
<td></td>
<td><strong>Total Plastics</strong></td>
<td><strong>143</strong></td>
<td><strong>9.3</strong></td>
<td></td>
</tr>
<tr>
<td>Cast Iron</td>
<td>132</td>
<td>8.59</td>
<td>R</td>
<td>Ethylene Propylene Diene Monomer (EPDM)</td>
<td>10</td>
<td>0.68</td>
<td>ASR</td>
</tr>
<tr>
<td>Pig Iron</td>
<td>23</td>
<td>1.48</td>
<td>R</td>
<td>Carpeting</td>
<td>11</td>
<td>0.73</td>
<td>ASR</td>
</tr>
<tr>
<td>Steel – cold rolled</td>
<td>114</td>
<td>7.46</td>
<td>R</td>
<td>Glass</td>
<td>42</td>
<td>2.8</td>
<td>ASR</td>
</tr>
<tr>
<td>Steel – electric arc</td>
<td>214</td>
<td>13.94</td>
<td>R</td>
<td>Tire</td>
<td>45</td>
<td>3.0</td>
<td>ASR</td>
</tr>
</tbody>
</table>

\textsuperscript{205} Data on the “generic vehicle” is data aggregated from three different vehicles (4-door sedan vehicles).

\textsuperscript{206} Data amended from table in SAE International publication “Life cycle inventory of a generic U.S. family sedan overview of results USCAR AMP project”. Nr. 982160. Total Life Cycle Conference and Exposition, Graz, Austria, 1-3 December 1998.
### 10.1 Relationship Between Key Trends & ASR Volumes

The trends in automotive design and material use indicated an increasing use of plastic, aluminum, magnesium, composites and bio-materials or natural fiber plastics. Given the current situation, increasing plastics has the potential to increase the volume of ASR because most plastics are not currently recovered or recycled from end-of-life vehicles. The same will be true for increased use of composites, bio-materials and natural fiber plastics, as there is no widely used technology for recycling these materials, nor is there a large scale market for the recycled product to date. Alternatively, aluminum and magnesium are highly recycled. It is reasonable to assume that they will continue to be recovered and recycled from end-of-life vehicles as their use increases and will therefore not cause an increase in ASR. It is important to note that there is generally a 10-year time lag between material composition of vehicles put on the road today and material composition of the ASR stream.

Trends related to the use of “materials of concern” were also presented previously. The use of mercury, cadmium, lead, hexavalent chromium and brominated flame retardants, is decreasing in vehicles. The effect should be a decreased amount of these materials in ASR, though it is unclear whether this would impact the recyclability of the ASR. There is no clear trend regarding PVC and thus no speculation is provided on the amount of PVC in future ASR streams.

Of the broader trends in automotive technology and design, several may impact ASR composition and volume. Specifically, the research indicated that automakers and suppliers aim to reduce the number of materials used. This has potential to reduce the volume of ASR from each vehicle, because there would be fewer materials to identify and separate (if a separation system is in place).
The other main trend identified is a move to use more electronics and electrical systems in vehicles. In most applications, the electronics are not recyclable (because of the mix of heavy metals and other metals, plastics and resins, flame retardants and other additives and other materials in small quantities) and interviews indicated they might also compromise recyclability of the component (headliner or door panel) in which they are embedded.

The European Commission has enacted a Directive on waste electronics and a Directive on hazardous substances in electronics. These Directives do not apply to automotives at this time. However, as they come into force and the electronics industry develops new designs and alternatives to comply with them, it is possible that recyclability and end-of-life management of the electronics in vehicles could also improve. However, it should be noted that any changes in vehicle design over the next 5 to 10 years will not have an impact on ASR volume or composition for an additional 10 to 15 years (i.e., 2018 to 2028).

There is potential for growth in the use of alternative fuel vehicles, though they are currently a niche market. Research indicated that the materials used in batteries in various alternative fuel technologies may be a concern to end-of-life vehicle management. The predominant lead-acid battery is recovered and 95% of it is recycled. Currently it is not known what will happen at end-of-life to new batteries used in electric vehicles, which are not lead-acid. In addition, alternative fuel vehicles may require some unique materials in the fuel handling systems, which may potentially impact end-of-life and ASR in future.

Though there is no current technology in use to separate all of the various polymers and other non-metallic materials in ASR, ARA did report that it is technically possible to recover and recycle a much higher proportion of the existing 25% of the vehicle that currently goes to ASR, based on technologies it has seen in facilities in the European Union and work done by CARE CAR II and the VRP. However, this does not include economic feasibility or existence of markets for the recovered materials, nor does it account for potential changes in behavior that may be required (e.g., to source or specify recyclable or recycled-content materials).

To divert ASR from landfill, Nissan Motor Company will begin processing ASR this fall at its Oppama Plant in Yokosuka, Kanagawa Prefecture. Nissan will rebuild part of its waste incinerator to do so, marking the first time any car maker has used existing incineration facilities at its own plant to process ASR. Japan’s Automotive Recycling Law becomes effective in the second half of 2004 requires OEMs to recycle ASR either on their own or through an outside recycling firm. While Nissan will continue to outsource ASR processing as it has done in the past, it will also process ASR at it’s Oppama Plant waste incinerator in order to collect data. Nissan will use the data to learn more about ASR processing, which could lead to “reduced costs and better new vehicle design”, according to an article in GreenBiz.com. The Oppama Plant also has a “Waste Zero Emission” campaign, which

---

lowered the amount of plant wastes and provided surplus furnace capacity required for processing.\textsuperscript{209}

\textbf{10.2 Relationship Between Increased Recycled-Content Material Use & ASR Volumes}

The technology developed through the VRP and CARE CAR II projects has the potential to bring a portion of ASR back into automobile production (through flotation separation and other technologies). If high costs and other barriers can be addressed and the technology can be used on a broad scale it could significantly affect ASR volumes, as well as design priorities for material use (recycled-content and recyclability, as well as the use of substances of concern).

Furthermore, using recycled-content material in vehicles may have the effect of diverting other wastes from landfill because it creates a market for material recycled from carpeting, computer housings, soda pop bottles, cotton bale wrappers, plastic gloves, PET beverage containers, etc.

11. Component Re-use

Reusing parts from old vehicles generates an estimated 7 billion U.S. dollars each year.\(^{210}\) As with recycled materials, if there is a strong secondary market for a component, that component will be recovered and sold for re-use. For instance, navigation screens have a high resale market. The ARA provided a number of additional examples of the direct re-use of components in maintenance and repair of vehicles, including transmission and other fluids, suspension components, brakes, carpet, wiring harnesses and glass. Earlier in the report, wiring harnesses and glass were identified as problematic to recover and recycle.

Catalytic converters cannot be sold for re-use. However, there is a market for the precious metals (platinum group metals) in the catalytic converters, which are recovered and recycled given their market value.

Re-use of airbags has been banned in New York State. This means that recovered seats and dashboards that contain airbags cannot be re-used and sold intact. Technically, it is possible to re-use airbags in vehicles and this re-use would provide economic incentive for auto dismantlers to pull airbags out of vehicles. However there are major barriers because airbags are part of the vehicle’s safety system and a re-used airbag is perceived to be of lower quality, or less safe. In addition, manufacturers often state, “vehicle warranties may not be honored if re-used parts are used”. There is also a risk of liability (or perceived risk of liability) for the automotive industry if they endorse the use of used parts. For example, consumers involved in vehicular accidents often sue automakers for damages and if the vehicle involved in the accident contained used parts, the automaker could be held liable due to the perception issue raised above.

In the vehicle’s interior, re-use of components is generally much less common, according to one company. The company stated that electronics evolve so quickly in the interior that used parts could be incompatible (e.g. stereo, dashboard or navigation electronics). In addition, interior designs are based on consumers’ perception and thus visibly “re-used” parts that the vehicle owner can see are not popular.

Toyota has announced its intentions to increase the use of parts from old (end-of-life) Toyota vehicles (see 4.2 Automotive Manufacturers Goals & Activities Regarding Material Use). In the European Union, the BMW Group explained that it supports component re-use in secondary markets but not in new vehicles. BMW will certify re-used engines as “certified” BMW replacement parts and will cover them with a BMW guarantee. The Alliance, however, stated that new vehicles will not contain used components, as consumers expect that a new vehicle will have only new components.

---

12. Partnerships

The automotive industry and in some case government agencies have initiated a number of partnerships to examine end-of-life vehicle issues and generate ideas to address these. As mentioned previously, the USCAR initiative and the related VRP (est. 1991) are among these. The VRP developed “Preferred Practices” for materials, fasteners and design selections to promote further recycling of automotive materials. The VRP also set goals to reduce the total environmental impact of vehicle end-of-life management, increase the efficiency of the disassembly of components and materials to enhance vehicle recyclability, develop material selection and design guidelines, and promote socially responsible and economically achievable solutions to vehicle end-of-life management.

Interviews emphasized the importance of cross-industry partnerships in order to continuously improve the end-of-life management of vehicles. For instance, vehicles currently contain many “black boxes” of unknown components and materials. To effectively and economically manage end-of-life vehicles, suppliers, manufacturers, dismantlers and recyclers need to know what materials may be contained in vehicles and where to look for them. Partnerships can enhance communication about recyclable materials in vehicles, new materials in vehicles (such as composites or plastics containing natural-fiber) and materials of potential concern. One interview indicated that materials should be labeled so that information could be shared along the entire product chain. Partnerships might enhance such activities.

Design-for-environment (DfE) or design-for-recycling (DfR) initiatives may also benefit from partnerships along the entire vehicle chain, as DfE / DfR can depend on communication among OEMs, customers, dismantlers and recyclers. One interview indicated that the ARA was not aware of GM’s dismantling guides, which partly indicates potential for furthering communication.

According to one interview, partnering at the start of a vehicle (or component) design project offers the best potential results for change.

Interviews also indicated that there might be potential for industry-government partnerships that involve designers, procurement officers, recycling operators and other decision-makers from supplier companies, recyclers and OEMs, as well as the environmental managers from these companies. It is worth considering whether this would help government decision-makers better understand automotive design, purchasing, dismantling and recycling and in turn help to support the ongoing environmental initiatives within automotive manufacturers, suppliers and recyclers.

It can be noted that working as a group, automotive manufacturers in the U.S. can only conduct collaborative research to a certain point. This is because they are only allowed (by law) to work together on pre-competitive research projects, until that research reaches a point when it can be implemented. At that point, the companies are prohibited from working together further. Despite this, manufacturers do work together in initiatives such as those
mentioned above, in an effective manner. For example, the Low Emissions Paint Consortium of USCAR worked together to research new technologies to reduce VOC emissions from paint shops. This is an example of an effective pre-competitive research project.

In Canada in 2001, the Canadian Government initiated a partnership project to help build capacity in the area of product stewardship/DfE in the Automotive Parts industry in Canada. The project was a partnership between Five Winds International, Natural Resources Canada, Industry Canada, Magna International, 3M Canada, University of Waterloo and the Auto Parts Manufacturers' Association. The project led to the development of a DfE Training Module and Case Study for integrating eco-efficiency and DfE techniques into product development and manufacturing processes in Canadian automotive parts manufacturing (see Appendix 10).
13. Lessons Learned

Companies and organizations interviewed during the research raised a number of challenges to addressing materials of concern, recyclability and recycled-content in vehicles. The purpose of this section is to state challenges identified during the interviews and not to propose solutions.

13.1 Involving all Stakeholders

There is a perception from the interviews that all actors in the value chain involved in vehicle design and manufacturing are not engaged in discussions on environmental initiatives. For example, both ARA and ISRI expressed an interest in being more involved than they have been in the past in environmental initiatives. In order for real change to occur in the industry, all of these actors need to be engaged in discussions and activities. This will not only ensure better decision-making takes place, but such an approach in fact requires a life cycle perspective.

13.2 Cost Challenges

Overall, costs were cited as a challenge to switching to new or different materials. For this reason, it is important to emphasize the importance of measuring life cycle costs. If virgin materials are compared with recycled materials based solely on the purchase price, then only short-term, limited economic factors will drive decisions. As previously noted by several interviewees, including the Alliance, a life cycle approach is the preferred method for determining the most cost effective solutions to environmental issues.

Material alternatives often appear to cost more initially. There are costs associated with testing and approving new, alternative materials, processes or designs, as well as potential costs for re-tooling equipment or other capital investment to switch materials. For example, one company proposed a new design that would decrease the component’s total weight and lower the cost, but this new design was not used in the end due to the high up-front costs of re-tooling.

Currently, ASR is made up of many materials. This can include various polymers, glass and trace metals. Separating these materials from one another currently requires a high number of sorting steps and is a costly process. For this reason, it is currently not economically feasible to sort ASR into material streams for sale to recyclers.

Furthermore, without significant demand for the recycled product, there is currently no way to recover the costs of this separation and recycling of materials in ASR. As landfill space in most states is still readily available and affordable, it is even less financially viable to separate and recycle ASR.
While some materials from vehicles are landfilled, others must be removed and specially treated. Today, vehicle dismantlers and material recyclers in the U.S. pay to remove components and materials deal with the cost of heavy metals and other materials of concern that may contaminate material streams (e.g., metal streams). There is dispute over who should bear these costs. An example already explained, is that the ARA does not agree with the Alliance’s position that “the automotive recycling industry is best equipped to deal with” mercury from switches in end-of-life vehicles (see 4.1 Industry Activities Related to Material Use) and does not believe that ARA members should be responsible for the cost to recover such materials. On the other hand, the Alliance explain that automotive recyclers make a profit of many components and materials from end-of-life vehicles and therefore must be responsible for managing the entire end-of-life vehicle. This debate over responsibility illustrates the potential type of positive impact that a product stewardship initiative could have a positive impact by helping to address end-of-life issues and move forward to improve recyclability, recycled-content and substances of concern.

With respect to materials of concern, recyclers also expect in future to be faced with costs for handling hybrid batteries, as recycling processes for hybrid and fuel cell vehicles have not yet been established. The ARA stated that members do not currently know how they will handle these new components. Yet at this time, there are a limited number of hybrid vehicles that use batteries other than lead acid and there are no fuel cell vehicles that will go to dismantlers for some years to come (i.e. 10 years is considered an average vehicle life span). Other unknown or “black-box” components can pose un-recoverable costs to recyclers if they must be handled separately and cannot be resold. If OEMs and suppliers do not know and communicate the material content of such components, recyclers cannot manage them cost effectively.

Given current infrastructure, post consumer recycled-content plastics are often more expensive than virgin materials. This is currently the case with polypropylene, one of the most commonly used plastics in vehicles. DuPont’s Engineering Polymers division identified that cost is the largest barrier to increasing the sale of post consumer recycled-content carpet material to the auto industry. This is because of the cost to de-manufacture the used carpet and isolate the material needed for the resin (as noted previously, DuPond Engineering Polymers makes and sells a 25% post consumer recycled-content resin, Minlon®, to the auto industry for air cleaner housings, engine covers and other components).

This high cost of post consumer recycled plastics is connected to the fact that there are well established markets for many existing virgin plastics and the fact that prices for virgin raw materials such as oil remain low. New recycled materials may be competitive technically, but they cannot compete financially against existing established markets.
13.3 Commitment Challenges

If manufacturers and suppliers do not specify or purchase these materials, recycling companies will not invest in the technology to recycle them. Yet, at the same time, if these materials are not recovered and recycled, they are not available to manufacturers and suppliers. Commitment and interest from the industry to increase recyclability or use recycled-content materials in vehicles could help provide the demand for recycled products.

13.4 Sorting Challenges

In addition to cost barriers are technical barriers to recycling. The sorter (manual or mechanical) must be able to distinguish among the different materials. To date, most research indicates that it is not yet economically, and in some cases technologically, feasible to separate all of the different polymers and other non-metallic materials in ASR.

However, a recent study of the technology and economics of recycling in the European Union concluded that recycling of 85% and recycling, re-use and recovery of 95% of vehicles by weight are technically feasible via shredder processing plants. While economic feasibility is influenced by the issues discussed above (i.e., recycling costs, markets for new material, roles of manufacturers and the recycling industry, etc.) the technology for increased recycling of end-of-life vehicles is available.

13.5 Consistent & Constant Supply of Feedstock

A large and consistent supply of post consumer recycled plastics will be required in order to support automotive production processes. The research found several efforts have been made to improve separation of shredder residue and recycle materials for sale, but no full-scale operations in the U.S. exist currently.

13.6 Challenges to Introducing New or Alternative Materials

In many instances, the challenge is not finding an alternative material, but demonstrating that the material meets all requirements for performance cost and safety. When pressed with timing, budget and testing requirements, many components are made with existing materials and specifications. For this reason new materials are most often introduced at the time of model changeover (typically every 4 to 10 years) when additional testing already occurs. One company noted that it is often preferable to manage the weaknesses of a material that are well known, than to trouble shoot the potential downfalls and unforeseen problems of a new material (e.g., the material may lead to problems with corrosion or joining or in production) outside of model changeover. This can restrict all actors in the product chain (designers,

---

purchasers, suppliers, recyclers) from making changes that could reduce the environmental impact of vehicles. To address this recyclability and material of concern requirements are embedded in the product development process.

The research indicated the potential to strengthen communication between material engineers and design engineers at both OEMs and suppliers, to ensure effective sharing of information on material selection and attributes (environmental and otherwise). Overall, it may be important for the government to aid in helping decision-makers in other parts of companies (e.g., purchasing, marketing and communication departments) to see the business benefits associated with environmental performance efforts.

13.7 Challenge of Dealing With Existing Vehicles

Viewpoints diverge over who should be responsible to pay for the removal of mercury switches from cars that have yet to enter the end-of-life stream. While auto manufacturers (discussed previously) state the automotive recycling industry is best equipped to deal with mercury from switches in existing vehicles, the ARA maintain that manufactures should be accountable and not transfer the cost to industries who had no responsibility for its introduction in the product stream. However, there may be potential to improve the information that manufacturers and the supply chain proved to recyclers. The more information recyclers have, the better equipped they are to look for opportunity to dismantle, recover and sell components and materials. For instance, the Alliance noted that some electric arc furnace operators will pay a premium for mercury-free scrap. While the Alliance maintain that this provides an incentive for recyclers to remove mercury switches, the ARA position is that mercury switches could be removed from vehicles while still in service, through recalls and replacement at the automotive dealership by the manufactures.
14. Sources of Information: Literature

We would like to thank the authors of the reports cited in this paper. However, the contents of this report are the responsibility of Five Winds International and do not necessarily reflect the views of any of the individuals acknowledged within.


Alliance of Automobile Manufacturers About the Alliance. The Alliance of Automobile Manufacturers Website, Online: http://www.autoalliance.org/about.htm


Automotive Recycler’s Association. What is the ARA? ARA Corporate Website, Online: http://www.autorecyc.org/docs/about/ara.htm


BMW Group. 2002. BMW Group 2001-2002 Sustainable Value Report. Online: http://www bmwgroup com/e/0_0 www bmwgroup com/5_verantwortung/5_4_publikation en/5_4_1_umweltbericht/5_4_1_3_downloads/pdf/sustainable_value_report.pdf

The BMW Group. Corporate Facts – The BMW Group in Overview. BMW Group Corporate Website, Online: http://www bmwgroup com/e/nav/index.html?http://www bmwgroup com/e/0_0 www bmw group com/2_investor_relations/2_investor_relations.shtml?3_0

CARE. About Us. Carpet America Recovery Effort Website, Online: http://www.carpetrecovery.org/about/index.asp


The Ecology Centre. About the Ecology Centre. Ecology Centre Website. 
http://www.ecocenter.org/about.shtml


Ford Motor Company. *Ford Motor Company’s 2002 Annual Report*. Ford Corporate Website, Online:
Product Stewardship Opportunities within the Automotive Industry

http://www.ford.com/NR/rdonlyres/e4mpera6vymppbxj4ks53re7qicwh4xe3jl3xm3q6fjp2uzcdus52v5pu3smd2kgs6mwyawp7cbng4ddavw6nug/2002_annual_report_02.pdf


International Institute of Industrial Environmental Economics. *Research & Education*. IIIEE Website, Online: www.iiiee.lu.se


Nissan 2001 Environmental and Social Report.


*Plastics in End-of-Life Vehicles*. Online: www.plastics-in-elv.org


The Rechargeable Battery Recycling Corporation. Online: www.rbrc.org


Supplier Partnership for the Environment. Online (as of 4 August 2003):
http://www.supplierspartnership.org/


http://www.carpetrecovery.org/about/mou.asp


Appendices

Appendix 1. Company Profiles

This section of the report describes the automotive manufacturing companies who responded via the Automotive Alliance of Manufacturers and the automotive parts and material suppliers that contributed to this research. The exceptions are GM, Ford and DaimlerChrysler which responded to the interview questions together via the Alliance of Automotive Manufacturers (Alliance).

1. BMW Group
Headquartered in Munich, Germany, BMW Group has global representation in over 130 countries. The BMW Group has automobile plants in Germany, Austria, U.S.A, South Africa, Brazil and the UK. BMW Group brands include BMW, MINI, and Rolls-Royce (since January 2003). In 2002, BMW Group produced 930,221 vehicles and 167,037 MINIs resulting in total revenues of more than EUR 42 million. The company employs approximately 101,395 individuals worldwide. For more information, please visit: http://www.bmw.com

2. DaimlerChrysler Corporation
With 365,600 employees globally, DaimlerChrysler is headquartered in Stuttgart, Germany and Auburn Hills, Michigan. DaimlerChrysler has manufacturing facilities in 37 countries sells products to more than 200 countries. The company sold 4.05 million units passenger cars and 485,400 units commercial vehicles in 2002, and earned revenues of EUR 149.6 billion ($156.8 billion USD) in 2002. DaimlerChrysler passenger car brands include Maybach, Mercedes-Benz, Chrysler, Jeep®, Dodge and smart. For more information, please visit: http://www.daimlerchrysler.com/index_e.htm

3. Delphi Corporation
Delphi is a world-wide manufacturer of mobile electronics and transportation components and systems technology. Multi-national Delphi conducts its business operations through various subsidiaries and has headquarters in Troy, Mich., USA, Paris, Tokyo and São Paulo, Brazil. Delphi's two business sectors - Dynamics, Propulsion and Thermal Sector and

---

Electrical, Electronics, Safety & Interior Sector - provide comprehensive product solutions to complex customer needs. Delphi has approximately 192,000 employees and operates 176 wholly owned manufacturing sites, 42 joint ventures, 53 customer centers and sales offices and 32 technical centers in 41 countries. Delphi can be found on the Internet at www.delphi.com.

4. DuPont
E.I. du Pont de Nemours and Company operates in more than 70 countries worldwide (in North America, South America, Asia Pacific, Europe, the Middle East and Africa) and has approximately 135 manufacturing and processing facilities worldwide. The company’s combined revenues in 2002 were $24 billion U.S.D and the company employed approximately 79,000 people. DuPont has six major businesses, one of which is DuPont Performance Materials made up of DuPont Engineering Polymers, DuPont Packaging and Industrial Polymers, DuPont Teijin Films, and DuPont Dow Elastomers. DuPont Automotive falls under the Engineering Polymers business unit.

DuPont Automotive provides OEM’s with a number of interior products, including headliners, seats, door and flooring systems, etc. In a recent environmental initiative, DuPont produced Sontara®, spunlaced polyester for scrim for a single polymer-type "green seat" that can be recycled as a single unit.

DuPont Textiles and Interior Business operates a Carpet Reclamation® program. The program began in 1992 and is the only program of its kind accepting carpet regardless of fiber type, manufacturer and backing type. To date, the program has collected and recycled almost 100 million pounds (45.3 million kg) of used carpet and saved over 200,000 cubic yards (152,900 m³) of landfill space. Post consumer carpet is removed, collected and shipped to a DuPont recycling center. The program guarantees that the carpet will not end up in a landfill. Carpets are sorted according to their recycling value and processed into reusable materials for products such as:

- Automobile Parts
- Carpet Cushion (DuPont™ Ecosoft™)
- Sod reinforcement
- Filtration Pipes
- Carpet Backing
- Flooring Tiles
- Fiber-reinforced boards
- Erosion control modules

---

214 Company at a Glance. DuPont Global Website. 

5. Ford Motor Company
Ford Motor Company is headquartered in Dearborn Michigan, and has operations in close to 130 countries. The company celebrates its 100th anniversary in June 2003. In 2002 Ford sold approximately 6.9 million light trucks and cars to global markets and revenue for the company in 2002 was approximately $163 billion USD. Ford’s vehicle brands include Lincoln, Mercury, Mazda, Volvo, Jaguar, Land Rover, Aston Martin. For more information, please visit: http://www.ford.com/en/default.htm

6. General Motors Corporation
Headquartered in Detroit Michigan, General Motors Corp. employs 349,000 people globally in its core automotive business and subsidiaries. GM has manufacturing operations in 32 countries and its vehicles are sold in more than 190 countries. In 2002, GM sold more than 8.5 million cars and trucks, nearly 15 % of the global vehicle market. GM's automotive brands are Buick, Cadillac, Chevrolet, GMC, Holden, HUMMER, Oldsmobile, Opel, Pontiac, Saab, Saturn and Vauxhall. In some countries, the GM distribution network also markets vehicles manufactured by GM Daewoo, Isuzu, Subaru and Suzuki. For more information, please visit: http://www.gm.com

7. Lear Corporation
Lear Corporation, headquartered in Southfield, Michigan, U.S.A, is the world's fifth-largest automotive supplier of interior systems. Net sales in 2002 for the company were $14.4 billion. Lear employs close to 115,000 employees in more than 300 facilities located in 33 countries. The company develops and manufactures all six interior systems: seat, instrument panel/cockpit, door and trim, overhead, flooring and acoustic and electronic and electrical distribution. Global customers include Opel, GM, Volvo, DaimlerChrysler, Toyota, Suzuki, Hyundai, Porsche, Holden, VW, Ford, Peugeot, Fiat, Jaguar, Renault, Mitsubishi, BMW, Vauxhall, Audi, Isuzu, Daewoo, Rover, Saab, Nissan, Mazda, Ferrari, Rolls-Royce, Honda, Subaru, and others. For more information, please visit: http://www.lear.com/html/lear_corporation.htm

8. Magna Intier
Intier Automotive is the interiors company of Magna International. Intier Automotive has manufacturing and R&D facilities in the U.S., Canada and Mexico, employing 13,800, 19,400 and 7,800 people in those countries respectively. Total sales reached $3.9 billion in 2002.\textsuperscript{219} Intier Automotive develops, manufactures and delivers complete vehicle interior systems, including cockpit modules, modular door systems and panels, overhead systems, complete seat systems, specialty seat mechanisms, and closure systems, including latching systems, glass moving systems, power sliding doors and liftgates, and door modules. The company’s customer base includes DaimlerChrysler, Ford, General Motors, BMW, Volkswagen, Renault-Nissan, Fiat, Mitsubishi, Toyota, Honda, and their respective operating divisions and subsidiaries, as represented in Figure 16.\textsuperscript{220} For more information, please visit: http://www.intier.com/

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure16.png}
\caption{Breakdown of Magna customers (%).}
\end{figure}

Appendix 2. Organization Profiles

This section of the report describes the organizations that were interviewed for this research or those which are referred to throughout this report.

1. Alliance of Automobile Manufacturers (Submitted Response)
The Alliance of Automobile Manufacturers, Inc. is a trade association of motor vehicle manufacturers (composed of car and light truck manufacturers), which represent more than 90% of U.S. vehicle sales. Alliance member companies have approximately 620,000 employees and more than 250 facilities in 35 states. Formed in 1999, the Alliance serves as a leading advocacy group for the automobile industry on a range of public policy issues, including current issues such as climate change and SUV safety. Members of the Alliance include the following ten companies: BMW Group, Volkswagen, Ford Motor Company, Mazda, DaimlerChrysler, Nissan, Toyota, Mitsubishi, Porsche, and General Motors. For more information, please visit: http://www.autoalliance.org/index.html

2. Automotive Recyclers Association (Interviewed)
The Automotive Recyclers Association (ARA) is an international trade association servicing approximately 1,100 member companies through direct membership. ARA is the only trade association serving the automotive recycling industry in 14 countries internationally. The organization’s primary goal is to further develop the automotive recycling industry through programs and services. An important role is to encourage member facilities to implement environmental management programs that ensure proper management techniques for fluids and solid waste materials generated from the disposal of motor vehicles. ARA continues to further vehicle recycling efforts with the major automobile manufacturers and participates in many studies and projects dealing with the disassembly and recycling process in automotive design. For more information, please visit: http://www.autorecyc.org/

---

221 About the Alliance. Alliance of Automobile Manufacturers. http://www.autoalliance.org/about.htm
222 What is the ARA. Corporate Website for the Automotive Recycler’s Association. http://www.autorecyc.org/docs/about/ara.htm
3. Ecology Center (Interviewed)
The Ecology Center (EC), founded in 1970, is a membership-based, nonprofit environmental organization based in Ann Arbor, Michigan. The Ecology Center works for a just and healthy environment through grassroots organizing, advocacy, education, and demonstration projects. Some of the group’s major campaigns include: its Environmental Health Project (uncovering connections between environmental pollutants and human health) and the Auto Project (promoting solutions to reduce and eliminate pollution from automobile manufacturing). Specific initiatives under the Auto Project include: The Clean Car Campaign, the Clean Car Pledge, the Mercury In Vehicles Campaign, the Switch the Switch Campaign and Clean Production & Toxics Reduction. For more information on the Ecology Center and its initiatives, please visit: http://www.ecocenter.org

4. Environmental Defense (Interviewed)
Environmental Defense is an environmental non-profit organization established in 1967 to address environmental issues. Environmental Defense employs approximately 250 staff, bringing together scientists, lawyers and economists to solve complex environmental problems. It works in seven main program areas: Oceans, Living Cities, Global and Regional Air/Energy, Environmental Health, Environmental Alliances, Ecosystem Restoration, and International. The NGO has over 300,000 members, and an annual budget of $42.8 million (in FY 2001). Environmental Defense’s “Clean Car Campaign” presses automakers to design cars and trucks that are far cleaner in their production, use and disposal. The Campaign emphasizes reducing greenhouse gas emissions and the use of materials that are harmful to public health. The NGO also has a climate change campaign and has produced “A Guide to Cleaner Vehicle Production, Use and Disposal”. Environmental Defense national

headquarters are in New York City and its tag line is “finding the ways that work”. For more information on the organization and its programs, please visit: http://www.environmentaldefense.org/home.cfm

5. Institute of Scrap Recycling Industries (ISRI) (Interviewed)
The Institute of Scrap Recycling Industries, Inc. is the trade association of the scrap processing and recycling industry. ISRI represents 1,200 companies in the U.S. and worldwide, including suppliers of equipment and services to the industry, that process, broker, and consume scrap commodities, including metals, paper, plastics, glass, rubber, and textiles. ISRI represents some 200 shredding facilities in North America. The American scrap recycling industry's products are worth at least $20 billion a year. ISRI’s primary objective is to bring about a greater awareness of the industry’s role in conserving the future through recycling and in increasing recycling by promoting Design for Recycling®. To do this, the association provides training and education to its members through seminars, workshops, roundtables, an annual convention and exposition, publications, and audiovisuals. It is also part of ISRI’s mission to educate the public about the benefits of recycling. For more information on ISRI, please visit: http://www.isri.org/.

6. International Institute for Environmental Economics at Lund University (PhD Researchers Interviewed)
In response to a perceived lack of preventative approaches to environmental problems (environmental management, design for environment, pollution prevention etc.) among those making decisions about policy, production and environmental protection, the Swedish Parliament established the International Institute for Industrial Environmental Economics (IIIEE) at Lund University in 1994. “The IIIEE is engaged in research activities with the overall ambition to further preventative environmental strategies in society, with a particular focus to industry and the factors that govern industrial behavior. The focus has moved progressively from production, to product, to production systems, and is today described as

---

sustainable production and consumption systems, recognising the increasingly critical issue of consumption as a barrier to achieving environmentally-sustainable economic systems.**228**

Cleaner Product Systems are one of the four main research areas of the IIIEE. The IIIEE places emphasis on industry and government efforts towards cleaner production and is an excellent source of information on tools, methodologies and approaches to cleaner production. For more information, please visit: [http://www.iiiee.lu.se/](http://www.iiiee.lu.se/)

### 7. Michigan Technological University (Written response)

The mechanical engineering - engineering mechanics department at Michigan Technological University is one of the largest in the nation and is the largest in the college of engineering at Michigan Tech. The department is structured along four areas of teaching and research: design/dynamic systems; energy-thermofluids; manufacturing industrial; and solid mechanics. Heavy emphasis is placed on graduate student participation in laboratory investigations, industrial projects, and interdisciplinary studies. The department has more than 40 full time faculty members and 150 graduate students, with 45 students in the doctoral program.

### 8. Suppliers Partnership for the Environment (not Interviewed)

General Motors, in partnership with the U.S. EPA, developed the Suppliers Partnership for the Environment program. To date, other OEMs are becoming involved in the Partnership. The objectives of the Partnership are to develop and share tools, information, knowledge, good practices and technical support to ensure that supplier's products and processes provide environmental improvement and cost savings for participants of the program.229

Participants in the program include230:

<table>
<thead>
<tr>
<th>Government Liaisons</th>
<th>Supplier Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA (Office of Pollution Prevention &amp; Toxics, DfE)</td>
<td>Ashland, Inc</td>
</tr>
<tr>
<td>National Institute of Standards &amp; Technology (Manufacturing Extension Partnership)</td>
<td>B.A.E. Industries</td>
</tr>
<tr>
<td></td>
<td>Delphi Corporation</td>
</tr>
<tr>
<td></td>
<td>Federal-Mogul Corporation</td>
</tr>
<tr>
<td>OEM Partners</td>
<td>Freudenberg-NOK</td>
</tr>
<tr>
<td>GM (DfE, Purchasing)</td>
<td>Haas Corporation</td>
</tr>
<tr>
<td></td>
<td>Johnson Controls, Inc</td>
</tr>
</tbody>
</table>

228 IIIEE. Online at [www.iiiee.lu.se](http://www.iiiee.lu.se), Research & Education.
The Supplier Partnership program provides OEMs with a forum for addressing environmental improvements in the supply chain and an opportunity to reach lower tier suppliers, while adding business value at the same time. Participating suppliers can realize cost savings, customer attention, recognition from customers and assistance in addressing environmental opportunities and process efficiencies. SP provides government with a delivery system to provide technical expertise and resources as well as opportunities to collaborate with other programs (e.g. Waste Wise, Energy Star, etc).

For more information, please visit: [www.supplierspartnership.org](http://www.supplierspartnership.org) (active May 7th, 2003)

9. USCAR Vehicle Recycling Partnership (VRP)(not Interviewed)

In 1991, the Vehicle Recycling Partnership (VRP) was created with an aim to promote and conduct research that aids in developing technology for the recovery, reuse and disposal of materials from end-of-life vehicles.

The mission of VRP is to “identify and pursue opportunities for joint research and development efforts pertaining to recycling, re-use and disposal of motor vehicles and vehicle components. The partnership also will promote the increased use of recyclable and recycled materials in motor vehicle design.” The VRP established several goals, including goals to develop material selection and design guidelines, reduce the total environmental impact of vehicle disposal, increase the efficiency of the disassembly of components and materials to enhance vehicle recyclability and promote socially responsible and economically achievable solutions to vehicle disposal. The VRP falls under the United States Council for Automotive Research (USCAR), the umbrella organization of DaimlerChrysler, Ford and General Motors formed in 1992 to “further strengthen the technology base of the domestic auto industry through cooperative, pre-competitive research. For more information visit USCAR at [www.uscar.org](http://www.uscar.org) or the VRP at [www.uscar.org/consortia&teams/consortiahomepages/con-vrp](http://www.uscar.org/consortia&teams/consortiahomepages/con-vrp).

---

Appendix 3. European Commission ELV Directive

The European Commission is one of the most well known government bodies to undertake product stewardship initiatives and has done so in the form of Extended Producer Responsibility (EPR) legislation. The European Commission has a directive on end-of-life vehicles (the ELV Directive) and all automotive manufacturers selling into the European Union will have to comply with the directive. The directives objective is to “prevent waste from end-of-life vehicles and promote the collection, re-use and recycling of their components to protect the environment.” Part of the intention of these directives is to influence the design of products manufactured in and imported into the European Union in a manner that reduces the volume of waste and the hazardous nature of that waste. The implication is that these directives will also affect manufacturing in the U.S. and other nations that export to European Union member states.

The European Commission’s End-of-Life Vehicle (ELV) Directive is valid for new cars put on the market from July 2002 and for all cars on the market from January 2007, which includes cars put on the market before July 2002. If the car has a negative market value it should be taken care of at no cost for the last owner. The car producer should meet a significant part of recovery cost. Recovery targets set out in the ELV include:

- From January 2006, for all end-of-life vehicles, the reuse and recovery shall be increased to a minimum of 85% by an average weight per vehicle and year.
- From January 2015, for all end-of-life vehicles, the reuse and recovery shall be increased to a minimum of 95% by an average weight per vehicle and year. Energy recovery is limited to 10%.
- Vehicles put on the market after 1 July 2003 should not contain lead, mercury, cadmium or hexavalent chromium other than in cases listed in an annex of the Directive.


Traditionally, 75% of end-of-life vehicles are recycled, which is primarily metal content of vehicles. The ELV Directive aims to increase the rate of re-use and recovery to 85% by 2006 (by average weight per vehicle and year), and to 95% by 2015. It also aims to increase the rate of re-use and recycling over the same period to at least 80% and 85% respectively by average weight per vehicle and year. Overall, the objective is waste prevention and the directive states that automobile manufacturers and material and equipment manufacturers are required to:

- Reduce the use of hazardous substances when designing vehicles;

• Design and produce vehicles which facilitate the dismantling, re-use, recovery and recycling of end-of-life vehicles;
• Increase the use of recycled materials in vehicle manufacture; and
• Ensure that components of vehicles placed on the market after 1 July 2003 do not contain mercury, hexavalent chromium, cadmium or lead (with various exceptions noted in the Directive’s Annex II).

Member states must also establish systems to collect end-of-life vehicles and waste used parts, ensuring that all vehicles are delivered to authorized treatment facilities.
Appendix 4. Japanese Auto Recycling Law

The recycling network in Japan is long established with nearly 5,000 scrap dealers nationwide. An "End-of-Life Vehicle (ELV) Recycling Initiative", initiated by the Ministry of Economy, Trade and Industry (METI), is expected to become law at the end of 2004.

Japan’s legislation came about from a voluntary initiative. In 1984, the country had problems with illegal dumping of ASR, which eventually led to environmental degradation of a particular Island and water way, and gained much public concern. Following this event, Japan introduced a voluntary initiative for the auto industry to reduce volumes of ASR and later the Japanese government introduced a legislation for end-of-life vehicles.

Since the ELV recycling initiative began, members of automobile-related industries have begun collecting and managing harmful chlorofluorocarbon gases, treating airbag inflators, reducing shredder residue, and developing schemes to meet the ELV requirements. Among other things, the law will require that consumers be charged an estimated 20,000 yen per vehicle (U.S. $163.50) for recycling airbags, ozone-depleting chlorofluorocarbon gases and the solid waste remaining after vehicles are stripped and processed. Some government agencies expect that the law will stimulate competition and thus enable a 95 % recycling rate by 2015. This would represent an increase in recycling of 15 % from the current recycling rate of 80 % and is comparable to rates in Germany and the Netherlands.

Around the same time, Japan established its “Basic Law for Establishing a Recycling-based Society”, which impacts vehicles and other product categories.
Appendix 5. Voluntary Product Stewardship Initiatives in the U.S. & Canada

There are a variety of examples of voluntary product stewardship initiatives in North America. These may be initiated to prevent legislation, but are also often driven by the benefits that can be achieved through proactive environmental management strategies. While product re-design is not an explicit goal, many of the initiatives provide incentives to design products that do not require the use of substances of concern and. Three voluntary product stewardship initiatives in the U.S. and Canada are described below to provide context and background for this research:

1) Carpet America Recovery Effort (CARE), U.S.
2) Electronics Product Stewardship (EPS) Canada
3) National Electronic Product Stewardship Initiative, U.S.

1. Carpet American Recovery Effort (CARE), U.S.

CARE is a voluntary initiative of the U.S. carpet industry together with the U.S. EPA to prevent carpet from ending up in municipal landfills. Approximately 96% (equal to 4.7 billion pounds, or 2.1 billion kg, in 2002) of post-consumer carpet goes to landfill each year in the United States.\(^{233}\) The CARE initiative places emphasis on developing carpet reclamation and recycling methods and resulted from the signing if a Memorandum of Understanding for Carpet Stewardship (MOU) on January 8, 2002, in Atlanta, Georgia. Members of the carpet industry, various levels of government, and representatives from non-governmental organizations negotiated for two years to reach agreement on goals and how the initiative would be administered.

CARE is funded and administered by the carpet industry, which commits itself to the following:

- Enhance the collection infrastructure for post-consumer carpet;
- Serve as a resource for technical, economic and market development opportunities for recovered carpet;
- Develop and perform qualitative measurement and reporting progress toward the national goals for carpet recovery; and
- Work collectively to seek and provide funding opportunities for activities to support the national goals for carpet recovery.\(^{234}\)

Representatives from government will work with the industry to identify alternatives and help overcome barriers to recycling and reuse of post-consumer carpet.

---

\(^{233}\) The Challenge of Waste Carpet. Carpet America Recovery Effort website. [http://www.carpetrecovery.org/about/mou.asp](http://www.carpetrecovery.org/about/mou.asp)

\(^{234}\) About Us. Carpet America Recovery Effort website. [http://www.carpetrecovery.org/about/index.asp](http://www.carpetrecovery.org/about/index.asp)
CARE has set national goals over ten years, see Figure 19 below, and is planning to achieve a 40% landfill diversion rate by 2012.

The CARE initiative is really the first national, sector-wide product stewardship initiative of its kind in the United States and could be considered a model for future product stewardship initiatives.

![Figure 19. 2012 Goals for Carpet Recovery](image)

2. Electronics Product Stewardship (EPS) Canada

The consumer electronics industry, under the leadership of Electro-Federation Canada and the IT industry, under the leadership of the Information Technology Association of Canada (ITAC) have joined forces with other stakeholders including Industry Canada, Environment Canada, Natural Resources Canada, provincial governments, the Federation of Canadian Municipalities (FCM) and others to develop a coordinated, strategic response to the end-of-life electrical and electronics equipment challenge. This partnership has created Electronic Product Stewardship (EPS) Canada, a not-for-profit organization to develop and implement a solution. EPS Canada’s Vision and Mission are shown in Box 6.235

Sixteen multinational companies in the electronics industry are members of the consortium and have provided initial funding to launch the program. These include Apple, Brother, Canon, Dell, Epson HP, Hitachi, IBM, Lexmark, LG Electronics, Panasonic, Sanyo, Sharp, Sony, Thompson Multimedia, and Toshiba. The initial program will focus on personal

---

computers, monitors, television sets, laptop computers, printers, and other peripheral devices (keyboards, mice, cables etc). Other products will likely be added as the program evolves and expands over time.

EPS Canada, the voice for the industry members, is governed by a set of guiding principles that were determined through consultation with the industry members. The principles are:

1. **Level playing field for all involved companies** – EPS wants provincial governments to put into place sufficient enforcement mechanisms that all affected companies will be required to participate.
2. **Shared responsibility** – EPS advocates for shared responsibility between local, provincial, and federal governments, consumers and industry.
3. **Consumer waste stream** – EPS wants to focus solely on consumer products through municipal waste stream, not commercial.
4. **Economic and environmental efficiency** – The goal of EPS is lowest overall costs together with the highest environmental standards.
5. **Fair treatment of historic and orphan waste** – EPS asserts that this waste must be dealt with fairly, not penalizing existing manufacturers.
6. **Environmental management** – Products must only be managed in locations that have environmental and health protection laws acceptable to Canada.\(^{236}\)

EPS Canada is proposing a solution for end-of-life electronics that would be managed by a national program office and involve environmental handling charges (see Box 7)\(^{237}\), visible to consumers, to cover recycling costs that consumers would pay when they purchase electronic equipment. Revenues generated would be passed from brand owners to a national program office, which would be used to fund waste management contracts with electronics recycling companies.

EPS Canada has also outlined a number of roles and responsibilities for different stakeholders in its business plan. Table 10 below summarizes the roles and responsibilities of stakeholders envisioned by the members of the consortium.

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Proposed Roles and Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government</td>
<td>• ID collection points in province</td>
</tr>
<tr>
<td></td>
<td>• Put appropriate regulations in place requiring all electronics manufacturers to participate in an individual corporate program or in the collective program to minimize free riders</td>
</tr>
<tr>
<td></td>
<td>• Recognize investment by industry in launch of program and return investment to</td>
</tr>
</tbody>
</table>

---


<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Proposed Roles and Responsibilities</th>
</tr>
</thead>
</table>
| Project Manager and Advisory Board | Manage implementation of program across provinces and territories  
  - Work closely with operators of transfer stations, landfill sites, depots etc.  
  - Promote system to households, brand owners and retailers to maximize participation  
  - Manage budget, create statistical analysis of material recovered etc.  |
| Industry | Invest close to $1 million to create a national program management office  
  - Delegate responsibilities and provide funding to provincial or territorial organizations to manage their regions  
  - Initiate handling charge to pass along to consumer (with explanatory flyer)  
  - Pass along revenues from handling charges to national program office  |
| Retailers | Show handling as separate item on bill of sale  
  - Provide purchasers with point of sale information on reuse and recycling options in the province as well as uses of handling fee  
  - Retailers will be supported if they choose to run special drop-off events to maximize product recovery  |

It is still unclear who will actually be recycling and managing the e-waste and whether EPS Canada is planning to depend on existing e-recycling infrastructure or look to develop other options. EPS Canada is currently in the process of consulting with different stakeholders across Canada for feedback on their proposed business plan and expects to launch its first end-of-life management program in 2004.\(^{238}\)

A similar initiative, the National Electronics Product Stewardship Initiative (NEPSI), has been launched in the United States and is also working towards developing a national strategy for managing end-of-life electronic waste.\(^{239}\)

The National Electronics Product Stewardship Initiative (NEPSI), which began in January 2001, is similar to EPS Canada in that the goal is to develop a national strategy to deal with electronic waste and that each initiative involves “a sharing of responsibility for the reuse and recycling of electronics by those who produce, sell, and use these products”.\(^{240}\) The process by which each group has gone about determining its strategy is slightly different. NEPSI is facilitated and chaired by the Center for Clean Products and Clean Technologies at the University of Tennessee through grants from the U.S. EPA. Stakeholders of the NEPSI process were contacted and coordinated through the Center for Clean Products and Clean Technologies as well.

Stakeholders for the NEPSI process include representatives from a variety of government, industry and other groups. As of March 2003, there were 49 stakeholders involved in the process, fifteen government representatives, sixteen producers from the electronics industry,

---


and eighteen representatives from other stakeholder groups (e.g. non-governmental organizations, academia, waste management companies, electronics recycling companies, etc.). For a full list of current stakeholders, please see the NEPSI homepage at http://eerc.ra.utk.edu/clean/nepsi.

3. National Electronics Product Stewardship Initiative (NEPSI), U.S.

The NEPSI group has expressed that its overall goal for undertaking this stakeholder dialogue exercise, is "the development of a system, which includes a viable financing mechanism, to maximize the collection, reuse, and recycling of used electronics, while considering appropriate incentives to design products that facilitate source reduction, reuse and recycling; reduce toxicity; and increase recycled-content." NEPSI is initially only looking at computer monitors, CPUs, and computer peripherals through the multi-stakeholder process. A “road map” for the NEPSI process was developed, outlining how the pieces of the national system for electronics collection, reuse, and recycling will be worked on separately in NEPSI Subgroups and then brought back together in the full NEPSI Stakeholder Group in the time allotted for the process to achieve a consensus.

Gary Davis, from the Center for Clean Products and Clean Technologies at the University of Tennessee, outlined ten elements of product stewardship initiatives for electronics that needed to be addressed through the NEPSI stakeholder process in a presentation he delivered at one of the initial meetings. These were:

1. Scope of the types of products covered.
2. Coverage of “historical products” and the timeframe for implementation.
3. Whether and how “orphan” products are included.
4. Responsibility for end-of-life management, including collection.
5. What that responsibility entails and internalization of costs.
6. Whether other entities in the product chain have defined responsibilities.
7. Whether the responsibility is individual or collective.
8. Recycling targets (rates and dates) for end-of-life products covered.
10. Design guidelines and other design-oriented programs.

After lengthy discussions, NEPSI stakeholders reached an important point in the dialogue and agreed at a meeting in March 2002 to work toward establishing a financing system that will include the costs of managing used electronic products in the overall purchase price of new electronic products. The agreement (Box 8) commits stakeholders to develop an action plan for establishing this financing system that includes federal legislation needed to


facilitate the implementation of the system. The action plan will also include steps that can be taken during the period before the “front-end” system is in place nationally that will improve existing systems for managing used electronics and prepare for the new financing system.\textsuperscript{243}

Participants are still working on developing specifics around the financing system (e.g. timeframe for implementation, how to make the system convenient for consumers, whether it can provide incentives for product design, etc.) as well as addressing other elements of effective product stewardship initiatives (outlined above).

\begin{table}[h]
\centering
\begin{tabular}{|p{1\textwidth}|}
\hline
\textbf{Box 8. Agreement, NEPSI Finance System, March 2002} & \\
\hline
1. We agree to work toward the development of a front-end financed system that will strive to meet the goal of the NEPSI process. This system may be managed by a third-party organization. Although other systems may be favored by some stakeholders, we will focus our efforts in the remainder of the NEPSI process to work out the issues associated with this type of system. & \\
\hline
2. We agree to work together as part of the NEPSI process to develop draft federal legislation or a consensus about the elements thereof by the end of the September NEPSI meeting that will facilitate the operation of a national front-end financed system. & \\
\hline
\end{tabular}
\caption{}
\end{table}

Appendix 6. International Materials Data System (IMDS)

The IMDS was established to track the substances used in vehicles. It is, in part, connected to producer responsibility legislation in the European Union member states. It was initiated by eight German car manufacturers and Volvo in 1996, and is operated by the IT company called EDS. Currently, Ford and GM in the U.S require all suppliers to report into the system.

Concept

The automotive OEMs require suppliers to submit information for each component they supply into the IMDS. In turn, the OEMs query the IMDS to obtain materials information on each component in their car in order to map the complete contents of the cars they produce. Data can be accessed by design engineers and others within the OEMs, and may be used to set design requirements and other targets.

All information submitted to the IMDS is based on a “basic substance list” and, with respect to materials of concern, is based on the restricted substances lists of each OEM. Suppliers may have to report different information (e.g., different substances or amount of substance used) for different OEMs. Also, the lists are updated so OEMs and suppliers can query the status of a specific substance.

At one time there was discussion on whether the information submitted by suppliers could also go to authorities in order to cut down on overall reporting requirements, however this in not occurring currently.

Operation

IMDS is a divided database. Suppliers can only view information that they input and OEMs can only see information from their own suppliers.

Status

The IMDS has been operating (accepting data) since January 2000. In March 2001, Volvo/Ford and Volkswagen sent notices to their suppliers, telling them they must submit data to the IMDS. By 2002, the North American OEMs had all notified their suppliers. Today, the database is operating as intended and population of the database will continue to be a long term effort.

Drivers

The end-of-life vehicles directive comes into force on 1 July 2003. The OEMs need to know prior to this where they have deviations from the ELV requirements so they can put phase-out plans into place. Suppliers began submitting information in 2001 and there was supposed
to be time for OEMs to get an indication of data availability, quality and potential trouble spots.

As many car models will be in use for more than 15 or 20 years – many OEMs see the need to know what they are putting out there.

As might be expected, supplier response has been varied. Some suppliers have known for a year that they would have to submit their product information and are doing so. Others do not yet think they are capable. To date, data is being requested from Tier One through Tier 5 suppliers. It is important to note that IMDS offers a one day, online training course.

For Further Reference

Introductory information is available on the public information pages of the IMDS website at http://www.mdsystem.de. The website also provides links to the OEMs and the EDS homepage.
### Appendix 7. VRP Preferred Practices

#### Vehicle Recycling Partnership  
- Preferred Practices -

**Material Selection**
- Use Recyclable Materials – Select materials for which recycling technologies are currently practiced.
- Use Recycled Materials – Select materials that have recycled-content.
- Standardize Material Selection – Standardize the material type(s) used on selected applications and across product lines.
- Limit Material Types Used Within Assemblies – Use one material type for all components within an assembly. Reducing the material types makes separation easier.
- Use Compatible materials in Coatings/Laminates/Assemblies – Select materials that do not require separation for recycling. Some materials are considered contaminants in current recycling processes.
- Minimize Substances of Concern – Control or eliminate the use of substances that are potentially hazardous in the manufacture and recycling of vehicles

**Fasteners**
- Facilitate Disassembly – Select fastener systems which facilitate disassembly by any method, including destruction, after the vehicle reaches the end of its useful life.
- Reduce Fasteners – Reduce the number and types of fasteners used. Select fasteners that do not require separation for recycling.
- Use Snap Fits – Use molded-in snap-fits where possible to reduce use of additional fasteners.
- Use Compatible Adhesives – Joining or bonding materials of the same type with compatible adhesives enhances recycling.

**Design**
- Mark Plastic Parts – Use the SAE Surface Vehicle Recommended Practice – J1344 for marking plastic parts to facilitate recycling and repair.
- Integrate Parts – Reduce the number of parts used within an assembly.
- Design for Disassembly – Design assemblies so that they may be easily removed for reuse or recycling.
- Minimize Offal – Design parts and tooling that will optimize material usage.
- Minimize packaging – Design parts/assemblies to minimize the need for packaging. Select packaging that is reusable, has recycled-content, and/or is recyclable.
Appendix 8. Ford & Alcan Closed Loop Recycling

Ford and Alcan Launch First North American "Closed-Loop" Recycling of Aluminum Autobody Sheet

October 17, 2002

Idea:
Under the joint project, Ford recovers aluminum process scrap from its Chicago Stamping Plant and returns it to Alcan for recycling directly back into autobody sheet (closed-loop recycling). Previously, the recovered aluminum was sold into the general scrap market in combination with other metals, thus diminishing both its quality and value and making it unsuitable for re-use in autobody applications.

Conditions:
Key to success is the ability to segregate the AA6111 scrap from other steel and related byproducts generated in Ford’s plant. Ford invested nearly $400,000 in modifications to the existing separation system to produce "clean" aluminum scrap.

Project:
The high-value material (clean scrap) is shipped from the Ford plant to Alcan's aluminum plant in Oswego, New York, where it is remelted and rolled once again into automotive sheet. This loop can be repeated virtually indefinitely because aluminum does not degrade when recycled.

Benefits:
"Up to 85% of the aluminum's primary value can be retained by segregating the scrap and turning it back into automotive sheet metal," said Tom Gannon, vice president, Alcan Automotive. "The recycling of aluminum requires only five% of the energy used to produce the primary metal," explained Andy Acho, Ford Motor Company's worldwide director of Environmental Outreach and Strategy. "This is an important factor in reducing the total cost of this component to Ford. Moreover, recycling eliminates 95% of the greenhouse gas emissions associated with primary production, thereby providing tremendous environmental advantages."

Source: Alcan Inc., 10/17/2002
Contact: Alcan Automotive, Charles Belbin, 248/489-5615, charles.belbin@alcan.com or AutoCom Associates, Larry Weis, 248/647-8621, lweis@usautocom.com/
Website: http://www.usautocom.com
Appendix 9. Lead-free Electro-coat

Electro coating is a method that uses electrical current to deposit coating onto a part or assembled product. Because of its ability to coat even the most complex parts and assembled products with specific performance requirements, electro-coating is used throughout industry as a means to coat products in various categories such as: agricultural equipment, appliances, automobiles, automotive parts, marine components, transformers, metal office furniture, lawn & garden equipment and furniture, fasteners, trim appliances. A properly formulated and applied electro-coat provides excellent corrosion and fluid resistance, appearance and topcoat adhesion.

Cathodic epoxy electro-coat is most often used for numerous automotive applications. Electro-coat is used on wheels, truck chassis, space frames, cross members, seat tracks, and other components. Auto bodies and parts are primed almost exclusively with cathodic epoxy electro-coat.

Typically, the electro-coat is the first coat of primer the bare metal body receives. It is applied to the body by electro-deposition as the body travels through a dip tank containing the electro-coat bath. This bath is made up of an electro-coat resin and an electro-coat paste mixed with water.

Heavy-metal-free electro-coat technology has been driven by recent pending federal and local legislation. The newest generation electro-coating was designed to meet the most recent requirements of the marketplace: heavy-metal free, high transfer efficiency, zero hazardous air pollutants, enhanced corrosion protection, minimal VOCs, lower bake temperature (time to cure to the part using heat) and possibly one-feed component. A replacement for the lead is Titanium Dioxide.

Information collected from an article by J. Hess, entitled HAPS- and Lead-Free Electrocoat for Automotive Applications. Published by Chrysler Corporation in Products Finishing Magazine. PF Online: www.pfonline.com.
Appendix 10. Canadian Automotive Product Stewardship Partnership Project

Automotive Partnership Building DfE Capacity

**Background**
Design for Environment (DfE) is an eco-efficiency tool that integrates environmental considerations directly into the product design process and helps to find synergy among environmental initiatives, quality and cost considerations.

**Helping Build Capacity**
Five Winds International in partnership with Natural Resources Canada, Industry Canada, Magna International, 3M Canada, University of Waterloo and the Auto Parts Manufacturers’ Association completed a project to build capacity for DfE in the Canadian automotive parts sector. The project led to the development of a DfE Training Module and Case Study for integrating eco-efficiency and DfE techniques into product development and manufacturing processes in Canadian automotive manufacturing.

The DfE Training Module has been developed to provide designers, engineers and environmental managers with a real understanding of how eco-efficiency and DfE concepts and tools can be integrated into existing product design processes. The Case Study, developed by Five Winds International, Magna International and 3M Canada compared two door panels by utilizing several DfE tools including Life Cycle Assessment, to identify the key environmental aspects of the designs. The documented Case Study is used as an integral component in the Training Module.

**Results**
The project concluded with the delivery of a two-day DfE training event attended by numerous Canadian automotive parts manufacturing companies. Environmental management, engineering and design functions were represented as well as government, university and automotive company observers. The legacy of this project is a DfE Training Module and Case Study specific to the needs of the automotive industry. For further details about this initiative or to book a place at an upcoming training event contact Five Winds International at the address below.

For more information please contact:
Kevin Brady, Director
Five Winds International
Tel: (613) 722.6629
k.brady@fivewinds.com
Appendix 11. Oeko-Tex Standard for Textiles

Volvo Cars (a company owned by Ford) ensures that all textiles and leathers used in Volvo vehicles comply with the Oeko-Tex standard. The Oeko-Tex standard specifies that harmful substances are not present in textiles above a significant amount and requires testing and verification. It is described below. For more information visit: www.oeko-tex.com.

In 1992, Austrian\textsuperscript{244} and German\textsuperscript{245} research Institutes joined to develop the "Öko-Tex Standard 100" (Oeko-tex Standard) and the associated internationally registered label for textiles that meet the Standard. The Oeko-tex Standard enables textile and clothing products to be tested for their human ecological properties. The Standard contains analytical tests for certain harmful substances and gives limiting values based on scientific considerations. If a product fulfills requirements in the Standard, the producer is licensed to use a registered mark "Schadstoffgeprüfte Textilien nach Öko-Tex Standard 100" on that product. The Oeko-Tex label indicates that textiles:

- Do not contain allergenic dye-stuffs and dye-stuffs, that can be split off carcinogenic alylamines of the MAK-groups III A1 and III A2.
- Have been tested for pesticides and chlorinated phenols.
- Have been tested for the elution of heavy metals under sweat conditions.
- Do not contain formaldehyde or formaldehyde far below any legal requirements.
- Have a pH - value similar to our skin
- Do not have chlor-organic Carriers
- Do not have finish for clothing

The Oeko-Tex Standard covers four product classes: Products for Babies; Products with Direct Contact to Skin; Products without Direct Contact to Skin; and Decoration Materials. This latter class, "Decoration Materials" includes products and accessories used for decoration such as tablecloths, wall coverings, furnishing fabrics and curtains, upholstery fabrics, floor coverings and mattresses.

The substances that are banned or restricted from decoration materials are listed below, along with limit values. This data is cited from the Oeko-Tex Association online at http://www.oeko-tex.com/en/main.html.

<table>
<thead>
<tr>
<th>Limit Values &amp; Fastness</th>
<th>Product Class</th>
<th>IV: Decoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH value\textsuperscript{246}</td>
<td>4.0 - 9.0</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{244} The Austrian textile research institute ÖTI (Österreichische Textil-Forschungsinstitut) in Vienna.
\textsuperscript{245} The German "Forschungsinstitut Hohenstein" Institute.
\textsuperscript{246} Those products which must be treated wet during the further processing can have a pH value within 4.0 - 10.5; those leather products, coated or laminated, in product class IV a pH value within 3.5 and 9.0 is accepted.
<table>
<thead>
<tr>
<th>Limit Values &amp; Fastness</th>
<th>Product Class IV: Decoration material</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formaldehyde [ppm]</strong></td>
<td></td>
</tr>
<tr>
<td>Law 112</td>
<td>300</td>
</tr>
<tr>
<td><strong>Extractable heavy metals [ppm]</strong></td>
<td></td>
</tr>
<tr>
<td>Sb (antimony)</td>
<td>-</td>
</tr>
<tr>
<td>As (arsenic)</td>
<td>1.0</td>
</tr>
<tr>
<td>Pb (lead)</td>
<td>1.0</td>
</tr>
<tr>
<td>Cd (cadmium)</td>
<td>0.1</td>
</tr>
<tr>
<td>Cr (chromium)</td>
<td>2.0</td>
</tr>
<tr>
<td>Cr^VI</td>
<td>under detection limit 250</td>
</tr>
<tr>
<td>Co (cobalt)</td>
<td>4.0</td>
</tr>
<tr>
<td>Cu (copper)</td>
<td>50.0</td>
</tr>
<tr>
<td>Ni (nickel)</td>
<td>252</td>
</tr>
<tr>
<td>Hg (mercury)</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Pesticides [ppm]</strong></td>
<td></td>
</tr>
<tr>
<td>Sum (incl. PCP/TeCP)</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Chlorinated phenols [ppm]</strong></td>
<td></td>
</tr>
<tr>
<td>Pentachlorphenol (PCP)</td>
<td>0.5</td>
</tr>
<tr>
<td>2,3,5,6-Tetrachlorphenol (TeCP)</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>PVC plasticizers (phthalates) [%]</strong></td>
<td></td>
</tr>
<tr>
<td>DINP, DNOP, DEHP, DIDP, BBP, DBP: Sum</td>
<td>256</td>
</tr>
<tr>
<td><strong>Organic tin compounds [ppm]</strong></td>
<td></td>
</tr>
<tr>
<td>TBT</td>
<td>1.0</td>
</tr>
<tr>
<td>DBT</td>
<td>-</td>
</tr>
<tr>
<td><strong>Other chemical residues [ppm]</strong></td>
<td></td>
</tr>
<tr>
<td>Orthophenylphenol (OPP)</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Dyes</strong></td>
<td></td>
</tr>
<tr>
<td>Cleavable arylamines</td>
<td>not used 258</td>
</tr>
<tr>
<td>Carcinogens</td>
<td>not used</td>
</tr>
<tr>
<td>Allergens</td>
<td>not used 261</td>
</tr>
</tbody>
</table>

247 Only for natural materials (inclusive wood) and metallic accessories.
248 No requirement accessories made from anorganic materials.
249 No requirement accessories made from anorganic materials.
250 Quantification limits: for Cr^VI 0.5 ppm, for arylamines 20 ppm, for allergenous dyestuffs 0.006 %.
251 No requirement accessories made from anorganic materials.
252 Including the requirement by EC-Directive 94/27/EC.
253 Only for natural fibres.
254 Only for natural fibres.
255 The individual substances are listed in Appendix 6.
256 The individual substances are listed in Appendix 6.
257 Quantification limits: for Cr^VI 0.5 ppm, for arylamines 20 ppm, for allergenous dyestuffs 0.006 %.
258 The individual substances are listed in Appendix 6.
Limit Values & Fastness

<table>
<thead>
<tr>
<th>Limit Values &amp; Fastness</th>
<th>Product Class IV: Decoration material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorinated benzenes and toluenes [ppm]</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Biological active products

- Flame retardant products
  - General
    - PBB, TRIS, TEPA: not used

Color fastness (staining)

| To water | 3 |
| To acidic perspiration | 3 - 4 |
| To alkaline perspiration | 3 - 4 |
| To rubbing, dry | 4 |
| To saliva and perspiration | - |

Emission of volatiles [mg/m$^3$]

| Emission of volatiles [mg/m$^3$] | 0.1 |
| Formaldehyde | 0.1 |
| Toluol | 0.005 |
| Styrol | 0.002 |
| Vinylcyclohexen | 0.002 |
| 4-Phenylcyclohexen | 0.03 |
| Butadiene | 0.002 |
| Vinylchloride | 0.002 |
| Aromatic hydrocarbons | 0.3 |
| Organic volatiles | 0.5 |

Determination of odors

| Determination of odors | 4 |
| General | no abnormal odor |
| SNV 195 651 (modified) | |

Compilation of the individual substances

Forbidden flame retardant substances
1) Polybrominated biphenyles (PBB), CAS Nr. 59536-65-1
2) Tri-(2,3-dibromopropyl)-phosphate (TRIS), CAS Nr. 126-72-7
3) Tris-(aziridinyl)-phosphinoxide (TEPA), CAS Nr. 5455-55-1

Phthalates

---

261 Quantification limits: for Cr(VI) 0.5 ppm, for arylamines 20 ppm, for allergenous dyestuffs 0.006 %.
262 The individual substances are listed in Appendix 6.
263 The individual substances are listed in Appendix 6.
264 No requirements for 'wash-out' – articles.
265 For pigment, vat or sulphurous colorants a minimum grade of colour fastness to rubbing of 3 (dry) is acceptable.
266 For textile carpets, mattresses as well as foams and large coated articles not being used for clothing.
267 No odour from mould, high boiling fraction of petrol, fish, aromatic hydrocarbons or perfume.
268 For textile carpets, mattresses as well as foams and large coated articles not being used for clothing.
1) Di-iso-nonylphthalate (DINP), CAS Nr. 28553-12-0
2) Di-n-octylphthalate (DNOP), CAS Nr. 117-84-0
3) Di(2-ethylhexyl)-phthalate (DEHP), CAS Nr. 117-81-7
4) Diisodecylphthalate (DIDP), CAS Nr. 26761-40-0
5) Butylbenzylphthalate (BBP), CAS Nr. 85-68-7
6) Dibutylphthalate (DBP), CAS Nr. 84-74-2
Appendix 12. GM Dismantling Manual (excerpt)

Excerpts from General Motors Dismantling Manual for the Chevrolet Corvette 2001 are presented below. The company has similar manuals for some ten different GM vehicles.

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Quantity</th>
<th>Total Weight or Vol.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel tank</td>
<td>PE</td>
<td>2</td>
<td>10.86 kg</td>
</tr>
<tr>
<td>Fuel tank isolator</td>
<td>PUR</td>
<td>1</td>
<td>0.34 kg</td>
</tr>
<tr>
<td>Fuel filler neck insert</td>
<td>PA-66</td>
<td>1</td>
<td>0.24 kg</td>
</tr>
<tr>
<td>Fuel tank tube</td>
<td>PA-6</td>
<td>1</td>
<td>0.20 kg</td>
</tr>
<tr>
<td>Battery</td>
<td>Multiple, including lead</td>
<td>1</td>
<td>16.52 kg</td>
</tr>
<tr>
<td>Wheel weights</td>
<td>Lead</td>
<td>8</td>
<td>0.14 kg</td>
</tr>
<tr>
<td>Rear tire</td>
<td>EPDM</td>
<td>2</td>
<td>30.57 kg</td>
</tr>
<tr>
<td>Front tire</td>
<td>EPDM</td>
<td>2</td>
<td>27.12 kg</td>
</tr>
<tr>
<td>Instrument cluster light tube</td>
<td>Mercury</td>
<td>1</td>
<td>20-40 mg</td>
</tr>
<tr>
<td>Hood weatherstrip</td>
<td>EPDM</td>
<td>1</td>
<td>0.34 kg</td>
</tr>
<tr>
<td>Master cylinder reservoir</td>
<td>PP</td>
<td>1</td>
<td>0.15 kg</td>
</tr>
<tr>
<td>Valve cover shield</td>
<td>PA-66</td>
<td>2</td>
<td>0.64 kg</td>
</tr>
<tr>
<td>Intake manifold</td>
<td>PA-66</td>
<td>1</td>
<td>3.64 kg</td>
</tr>
<tr>
<td>Battery tray</td>
<td>PP</td>
<td>1</td>
<td>0.43 kg</td>
</tr>
<tr>
<td>Coolant reservoir</td>
<td>PP</td>
<td>1</td>
<td>1.31 kg</td>
</tr>
<tr>
<td>Air cleaner tube</td>
<td>PP</td>
<td>1</td>
<td>0.36 kg</td>
</tr>
<tr>
<td>Power steering pump reservoir</td>
<td>PA-66</td>
<td>1</td>
<td>0.24 kg</td>
</tr>
<tr>
<td>Washer fluid reservoir</td>
<td>PE</td>
<td>1</td>
<td>0.63 kg</td>
</tr>
<tr>
<td>Radiator bracket</td>
<td>PA-66</td>
<td>1</td>
<td>0.82 kg</td>
</tr>
<tr>
<td>Radiator cooling fan</td>
<td>PA-66</td>
<td>2</td>
<td>0.86 kg</td>
</tr>
<tr>
<td>Radiator tank</td>
<td>PA-66</td>
<td>2</td>
<td>0.62 kg</td>
</tr>
<tr>
<td>Radiator cooling fan frame</td>
<td>PA-66</td>
<td>1</td>
<td>1.54 kg</td>
</tr>
<tr>
<td>Air cleaner cover</td>
<td>PP</td>
<td>1</td>
<td>0.86 kg</td>
</tr>
<tr>
<td>Air cleaner frame</td>
<td>PP</td>
<td>1</td>
<td>0.29 kg</td>
</tr>
<tr>
<td>Air cleaner housing, lower</td>
<td>PP</td>
<td>1</td>
<td>0.50 kg</td>
</tr>
</tbody>
</table>
Appendix 13. Straw-man Scenario

In a workshop sponsored by the Argonne National Laboratory and the U.S. Department of Energy Office of Advanced Automotive Technologies, vehicle manufacturers, suppliers, recyclers, and researchers met to discuss vehicle recycling in 2020. The group developed a strawman scenario for 2020, which assumes 15% plastic in vehicles (Figure 20). This is an increase from the 9.3% plastic found in the study on a 1995 generic vehicle. The scenario assumes that the percentage of plastics (primarily thermosets and thermoplastics) will rise 3%.

The main assumptions pertaining to this scenario are:

 Aside of developing the strawman scenario, the group was unable to reach a consensus on specific goals and targets.

• The end-of-life material content of vehicles in 2020 will be similar to today’s vehicles (as a percentage of total weight); hybrid and fuel cell vehicles will not make up a significant percentage of EOL vehicles; changes in the relative proportion of steel and aluminum used will not affect overall recyclability; the percentage of plastics (primarily thermosets and thermoplastics) is expected to rise 3%
• Dismantling will recover about 10% of the mass of the vehicle; this material will be mostly metal and small amounts of other materials such as fluids
• About 90% of the vehicle will be enter shredding and sorting operations; conversion to chemicals and fuels and energy recovery will ensure that almost no plastics go into the landfill
• The 5% entering the landfill will be other materials which have no economic value
Appendix 14. Discussion Points Based on Challenges & Research Findings

Based on the challenges raised during the research, several points were developed for discussion among participants in the review session. EPA Region 5 hosted the session in June 2003, to give participants an opportunity to review and comment on the draft report. The discussion points have been amended and are listed below:

- What are the options for fostering markets and outlets for material recovered and recycled from vehicles?

- Is there potential for industry sectors to come together for discussion on an infrastructure for consistent recycled-content feed-stocks?

- Vehicles are increasingly using plastics and electronics / electrical systems. How should these be designed to facilitate end-of-life handling or treatment? Or should they be?

- There is interest in bio-based materials, natural fiber based plastics and other materials from renewable sources. In cases where they are more environmentally preferable, what needs to happen to move them more into the mainstream?

- What are the remaining challenges to making toxicity, or recyclability attributes (as appropriate) more important in vehicle design? Is there a role for government to help support the industry in overcoming these challenges?

- Consider the difference between performance goals for overall environmental improvement, versus specific goals on material or technologies. Is the life cycle approach the right approach?

- Is it important to address substances of concern and toxicity even in applications that do not constitute the largest use of that substance (e.g. PVC, mercury)?

- Will a focus on recycled-content build reliance on waste streams and stifle incentives for changing materials or reducing material use?

- Companies are currently using “preferred materials” lists and reducing the number of materials used for economic reasons. How well is this connected to improving environmental performance? Can this connection be used to help build the business case for environmental performance improvement?

- Is there a need and foreseeable benefit of educating future designers and engineers, via University curricula, on issues of material toxicity or recycling/recycled-content (i.e., to overcome perception issues as well as technical issues)?
• Can government and industry work to explore some of the existing standards (e.g., fire protection or coating) and regulations (e.g. TSCA regulations on ASR) that may be hindering re-use of parts, recycling and re-design to eliminate substances of concern (without compromising other requirements such as safety)?

• The U.S. auto sector is not only comprised of large manufacturers, but also many smaller companies in the supply chain. As automotive suppliers have an increasing role and responsibility in the design of vehicles, how might the onus for design specifications that affect environment performance change?
Glossary of Terms

Alliance: Refers to the Alliance of Automobile Manufacturers. See Appendix 2.

ASR: Auto Shredder Residue is the materials from end-of-life vehicles that are not recycled and are sent to landfill (plastics, rubber, wood, paper, fabrics, glass, sand, dirt, and ferrous and non-ferrous metal pieces).

CARE CAR II Project: A demonstration project undertaken by the automotive industry, suppliers and material suppliers looking at techniques to recover the current percentage of end-of-life vehicles that become ASR and go to landfills. The aim of the project was to reduce the amount of shredder residue and to put it back into automobiles.

Design for Environment (DfE): The integration of environmental aspects into the design process.

Fascia: Term referring to front panel, exterior section of a vehicle. May also refer to vehicle dashboard (and may be spelled facia).

HDPE: High density polyethylene polymer.

ELV: An acronym for end of life vehicles. These are vehicles that are no longer in use and are set for dismantling, re-use of components and recycling of materials and final disposal.


Manufacturer: In this context, manufacturer refers to manufacturers of automobiles (also referred to as Original Equipment Manufacturers, or OEMs).

MDI: Methylene diphenyl di-isocyanate

OEM: Original Equipment Manufacturers. See also manufacturer.

OESA: Original Equipment Supplier Association.

PET: Poly ethylene terephthalate polymer.

Platform: See vehicle platform.

SAE: Society of Automotive Engineers
Supplier: In this context, supplier refers to suppliers of automotive components (e.g., seats, dashboards, etc.). It also refers to suppliers of materials used to make these components, though these are more often referred to as material suppliers.

TDI: Toluene di-isocyanate

TPO: Thermoplastic polyolefin

TRI: Toxics Release Inventory

USAMP: United States Automotive Materials Partnership.

Vehicle Platform: Basic vehicle structure upon which various different vehicle models are built.