11SDP-0045/2011-01-0853

Recycling of the Changing Automobile and Its Impact on Sustainability

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Prepared for the SAE 2011 World Congress, April 12-14, 2011, Cobo Center, Detroit, Michigan

ABSTRACT

Over 250 million vehicles are operating on United States roads and highways and over 12 million of them reach the end of their useful lives annually. These end-of-life vehicles (ELVs) contain over 24 million tons (21.8 million metric tonnes) of materials including ferrous and non-ferrous metals, polymers, glass, and automotive fluids. They also contain many parts and components that are still useable and some that could be economically rebuilt or remanufactured. Dismantlers acquire the ELVs and recover from them parts for resale "as-is" or after remanufacturing. The dismantler then sells what remains of the vehicle, the "hulk", to a shredder who shreds it to recover and sell the metals. Presently, the remaining non-metallic materials, commonly known as shredder residue, are mostly landfilled. The vehicle manufacturers, now more than ever, are working hard to build more energy efficient and safer, more affordable vehicles. In the process, new valuable materials and parts are constantly introduced in new models. These materials present the recyclers with new business opportunities and with new challenges when the vehicles enter the recycling stream. New tools and technologies are needed to realize these opportunities and to maximize the recycling of the ELVs. This paper discusses opportunities and challenges facing the automobile recycling industries in the future.

INTRODUCTION

The objectives of this paper are: (1) draw attention to the importance of recycling ELVs to the sustainability of the automotive industry, and (2) illustrate the need for developing the necessary tools to maintain and increase the high rate of recycling automotive materials as the make-up of vehicles changes in the future in order to meet evolving regulations. New materials, especially light weighting materials, are being used in increasing amounts in building vehicles. Technology to recycle some of these materials, such as automotive polymers from shredder residue, is not commercially available and markets for such recycled materials are not always available.

Automobiles today are among the most recycled consumer products in the world. The metals, which constitute about 75% of the weight of a vehicle are presently recycled by a market driven infrastructure consisting of dismantlers, remanufacturers and shredders. The non-metals which are made of plastics, rubber, fibers, glass and other materials are presently landfilled. A good portion of the heavy conventional steel in older vehicles has been replaced with lighter materials such as high strength steels, aluminum (Al), polymers and polymer composites (Table 1). Despite the increased use of lightweighting materials in the manufacturing of vehicles the average weight of vehicles has been increasing (Figure 1) [1]. The average weight of a vehicle today is over 4000 pounds (1818 Kg) [2]. The number of materials and types of alloys used in vehicles has also been increasing. For example, today's cars contain more than 25 different types of polymers and composites, including bio-based polymers, and about a dozen different aluminum alloys. Magnesium (Mg) use in automobiles is also increasing. A study published in 2007 [3] stated that "*Magnesium use in the automotive industry has grown by 10-15 percent per annum over the past 15 years to an average of 10-12 lbs.(4.5-5.5 kg) (range 1-35 lbs.; 0.45-15.9 kg) for an average U.S. automakers' – (3,360 lbs.; 1527 kg) vehicle. This is compared to 260 lbs. (118.2 kg) of plastics, 280 lbs. (127.3 kg) of aluminum, Al, and 2,150 lbs. (977.3 kg) of steel/cast iron.*"

Table 1 Density of common automotive materials

Material	lb/cu ft	g/cc
Iron	491	7.87
Aluminum	169	2.7
Magnesium	109	1.74
Plastics	59-94	0.95-1.5
CF*-PMC (Kevlar)	90	1.44
Standard CF	110	1.75

**CF stands for carbon fibers and PMC stands for polymer matrix composites*

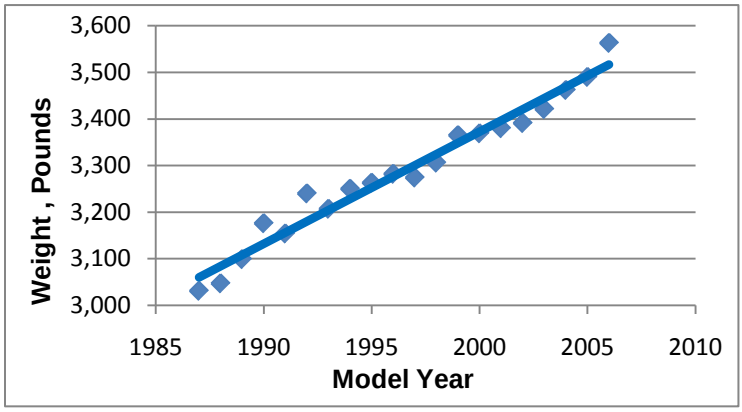

Figure 1. Weight of an average vehicle has been steadily increasing [1]. (1 lb=0.454 kg)

New types of power plants are being introduced in the form of hybrid and plug-in vehicles. Fuel cell powered vehicles and hydrogen fueled vehicles are also being developed. New pollution control additives and catalysts are likely to be introduced. These new materials and systems offer new challenges, but also new opportunities for recyclers. Recovery of these materials will generally result in increased supplies and lower costs of raw materials, thereby, benefitting all of the users of the materials. For example, Oak Ridge National Laboratory (ORNL) reported that *" … the automobile industry is not interested in using them (carbon fibers) until the price of carbon fiber drops from $8 to $5 ($17.6-$11/kg) (and preferably $3) a pound ($6.6/kg)"* [4]. Recycled carbon fibers can meet this price.

RECYCLING INFRASTRUCTURE

Today, ELVs in the United States are profitably processed for materials and parts recycling by a market driven existing infrastructure which include dismantlers, remanufacturers and shredders. The more than 15,000 dismantlers in North America receive and process over 95% of the ELVs. They recover useable parts for reuse and/or remanufacturing and some fluids including refrigerants. Remanufacturers process a full range of components and parts to replace defective ones. The shredders recover ferrous and non-ferrous metals from the remaining auto "hulk". Recycling the non-metals, primarily the polymers, in the ELVs is limited by the lack of (1) commercially-proven technologies to cost-effectively recover them as marketable products, and (2) profitable post-use markets. Therefore, the non-metallic materials are presently landfilled. Some non-metallic parts are recovered and recycled before shredding. These include tires and batteries.

The number and complexity of materials and components in ELVs are expected to increase, posing new challenges to the existing recycling infrastructure. The vehicles of the future will use greater amounts of lightweighting materials (e.g., plastics, composites, high strength steels, aluminum (Al), magnesium (Mg) and titanium (Ti)), and more complex parts such as hybrid electric batteries, alternate fuel tanks, electronic controls, "smart materials" such as shape memory alloys and maybe fuel cells. Dismantling of some of these materials in the future may be necessary in order to avoid further contamination of the shredder residue (the non-metallic material that remains after the shredder shreds the vehicles and other materials and recovers the metals) with hazardous or incompatible materials. It may also be profitable because such materials and components are likely to have relatively high market value. Therefore, it is important to incorporate reuse, remanufacturing, and recycling into the design phase for vehicles and to consider the recycling requirements of new materials entering fleets as early as possible. At the same time it is important to develop uses for recovered materials and to avoid using substances of concern which will make it more difficult and more expensive to recycle.

NEW MATERIALS OF CONSTRUCTION

Many new materials are being considered for use in future vehicles and many others will be used on a larger scale than what is practiced today. These include:

- Lightweighting metals (Aluminum (Al) and magnesium (Mg))
- Carbon fiber reinforced composites
- Glass fiber reinforced composites
- New polymers including bio-based polymers
- "Smart materials" such as shape memory alloys
- Chemicals and catalysts
- New automotive fluids
- New vehicle power trains (hybrid vehicles, fuel cells, hydrogen storage systems)
- More electronics, sensors and controls.

Each of these materials will have new requirements for maximizing their recyclability. For example improved technology will be needed to recycle the lightweighting metals. Better technology will be needed to [5, 6]:

- Separate the different Al alloys
- Separate iron (Fe) impurities from the non-ferrous metals and from re-melted Al
- Separate Mg from non-ferrous metal scrap (alternatives to chlorine fluxing for the removal of Mg from re-melted Al; improved shredding, sorting to generate a Mg stream)
- Remove copper (Cu), Nickel (Ni) and Fe to <0.04% from molten Mg
- Minimize or eliminate salt flux use in Mg processing
- Separate adhesively bonded materials

RECYCLING PROMOTES SUSTAINABILITY

Sustainability may mean different things to different people. However, for an activity to be sustainable it has to be economically attractive, environmentally friendly and socially acceptable, and provide a beneficial service to society in a responsible manner. Having a sustainable operation is a target that today's industries are striving to attain as the world faces material and energy shortages, increased costs and more stringent environmental regulations. The automotive industry and its products are major users of natural resources and a source of greenhouse emissions. In order to reduce its energy consumption and greenhouse emissions the industry is using more and more lightweighting materials in manufacturing its products. The increased interest in hybrid vehicles will increase the need for new materials such as lithium, cobalt and nickel. At the same time, regulations are calling for recycling more materials from the obsolete vehicles. Replacing the conventional steel, which is recyclable, with lighter materials will result in a reduction in the recycling rate (percent of the vehicle weight recycled) of vehicles even if the lighter materials are recycled at the same rate. Unless the lightweighting materials are recycled the drop in the recycling rate of automotive materials will be significant. Lightweighting and hybrid vehicle battery materials are expensive and unless recycled could become too costly to use and/or in short supply. Improper disposal of these materials can have adverse environmental impacts. Therefore, recycling of these materials is essential to the sustainability of the automotive industry and its suppliers.

The automotive industry is a material intensive industry. In 2007 over 16 million cars and light trucks were sold in the United States alone. At 4000 pounds (1818 kg) per vehicle this amounts to over 64 billion pounds (29 billion kg) of materials, about 75% of which is metals. Table 2 shows the energy required to produce these metals most commonly used in vehicles.

Table 2. Energy use (million Btu/ton) and greenhouse gas (GHG) emissions (lb/ ton) in production of metals [7]; (1 million Btu/ton=1.16 million kJ/tonne)

	Primary Steel	Wrought Aluminum	Primary Cast Aluminum	Primary Copper
Total energy	38.771	157.507	132.856	95.706
Fossil fuels	37.856	119.724	96.572	90.137
Coal	24.233	61.487	54.477	26.203
Natural gas	11.936	41.381	26.21	37.62
Petroleum	1.688	16.855	15.885	26.314
GHG emissions		12.141	10.099	8.468

Recycling these metals conserves over 60%, 90% and 80% of the energy used for production of steel, aluminum and copper from ores, respectively. Similarly, recycling the synthetic polymers conserves over 75% of the energy required to produce them from petroleum. Therefore, recycling of these materials contributes significantly to the automotive industry. In addition, recycling keeps these materials from becoming waste which further supports sustainability.

NEW OPPORTUNITIES

Many of the new materials will have appreciable salvage value when the vehicles reach the end of their useful life. For example, hybrid car batteries and undamaged carbon fiber reinforced composite panels can be worth hundreds of dollars. Other valuable materials include aluminum and magnesium assemblies and precious metal catalysts used for pollution control purposes and in the electronics. Therefore, future recyclers may look for such items before the car hulk is shredded. The shredders could also find additional value in the shredded hulks such as more aluminum and magnesium. The heating value of the shredder residue will increase because of the increase in polymers in the residue so that the residue can be used as a fuel source or as reducing agents.

A main driver for market driven recycling industry is economics. Can materials be separated and recovered economically and safely? To cultivate the new opportunities safely and economically the recyclers, many of whom run low-tech facilities, need to: (1) be trained to realize and capture the value of these materials and parts, (2) possess the right tools and processes so that the materials and components can be recovered economically and without degrading the quality. Even with the improved metals recovery technologies used today shredder residue containing about 10% metals is being landfilled, and (3) be able to upgrade the material or the part when necessary to meet specifications

CHALLENGES FACING DISMANTLING INDUSTRY

Dismantlers are key players in the recycling infrastructure. In addition to dismantling parts and materials for resale, dismantlers de-pollute the vehicles as required by the governing laws and regulations and as dictated by the shredders to whom the hulk is sold. Dismantlers can drain the automotive fluids including fuel, engine oil, transmission oil, coolant fluid, windshield fluid and steering gear oil. Other items such as batteries, tires and mercury switches can also be removed. Several attempts by dismantlers, here and abroad, to manually recover seat foam and plastics from ELVs were not successful primarily because of the cost involved. Dismantling of certain types of bumpers (TPO (Thermoplastic olefin) bumpers and others) had been successful especially where the bumpers were recovered by repair shops that had to replace the damaged bumpers anyway because the dismantling cost is absorbed in the repair cost.

Dismantling of certain parts will also require new tools and techniques. For example-

- Using a torch next to a magnesium part may set the part on fire.
- A high percentage of windshields on ELVs break while being removed from the ELVs.
- The efficiency and the completeness of fluid collection from ELVs depend on the fluid type and the fluid reservoir design. Fluid reservoirs sometimes are molded into complex shapes to better fit between other under-hood parts. This can make it difficult to remove all of the fluids.

- Parts made of multi layers of incompatible materials and bonded with adhesives or fasteners require complex techniques to delaminate and to remove the adhesives.

Therefore, the dismantlers need new tools and training of their employees to handle the changing vehicles. Their contribution to the recycling of ELVs is necessary for the sustainability of the automotive and recycling industry and to meeting future directives and regulations.

CHALLENGES FACING THE SHREDDING INDUSTRY

Shredders process the "hulk" after the dismantler is done with the vehicle. The role of the shredder as a market driven recycler is necessary for the sustainability of the automotive industry. Presently, the shredder's objective is to recover the ferrous and non-ferrous metals. The objective in the future is likely to change to include the recovery of the non-metals as well. The challenges facing shredders in the future are many among which are: (1) the shredder feed material is not limited to ELVs but also includes discarded home appliances, demolition scrap, discarded industrial equipment and other metal containing parts and equipment. Materials of construction of such items are varying just as the materials of construction of the vehicles. Therefore, the feed to the shredder in the future is expected to contain a large number of alloys of the different metals and a large number of polymers and composites. Therefore, the shredded mixture will require new tools to efficiently separate and recover these materials, (2) future vehicles are likely to contain less metals and more polymers and composites. Therefore, unless the non-metals are recycled the disposal cost will increase and revenues shrink. Therefore, more advanced and economical separation techniques and marketing for these materials will be required in order to maintain the profitability of this industry, (3) the non-ferrous metals constitute the major share of the shredder's revenue. These will be present in different alloys. Efficient separation and recovery of the different alloys at high recovery yields will be necessary to maximize their recyclability and value, (4) certain materials that may be used in vehicles such as hybrid batteries, unless removed could render the shredder residue hazardous. Therefore, developing automated tools for careful inspection and analysis of the feed material is necessary and (5) certain materials present in shredder residue, even at the parts per million levels may contaminate the recoverable polymers and composites and adversely impact their marketability. Examples include polychlorinated biphenyls (PCBs), mercury and heavy metals.

REGULATORY ISSUES

Regulations differ from country to country and sometimes from locality to locality within the same country. This section presents a brief review of the regulations, present and emerging, governing automobile recycling in Europe, Japan, the United States, Canada and China.

AMERICAN REGULATIONS

The shredders in the United States generate about 5 million tons (4.5 metric tonnes) of shredder residues that are mostly landfilled. Compare to the more than 250 million tons of municipal solid waste generated annually, shredder residue is a relatively small quantity. In the United States, no stringent regulations such as those in Europe exist at the federal level. In 1991, U.S. Congressman Robert Torricelli and Senator Frank Lautenberg sponsored the "Automobile Recycling Study Act," which called for an analysis of the potential for greater recycling of automotive components. This act was incorporated into a set of amendments to the Resource Conservation and Recovery Act (RCRA) of 1976 but it failed to gain approval. Since then, regulatory activities in the United States have been limited to the state level, and they addressed primarily [8]: (1) labeling of liquid containers, including washer fluid and coolant fluid bottles, (2) limits on dismantler storm water runoff, (3) landfill restrictions on mercury-containing components, and (4) classification of shredder residue as hazardous waste in California.

In 2005 Ohio's House of Representatives passed a bill exempting auto shredder residue from the waste generation fee [9]. The State of California is presently re-examining the regulations governing the disposal of shredder residue [10]. In California the regulation (Bill Number: SB 524, before it was amended in 2009) authorized auto shredder waste "that is treated as required by regulation to be used as alternative daily cover if specified requirements are met." In April of this year EPA issued an Advance Notice of Proposed Rulemaking (ANPR) on the Agency's potential reassessment of its current authorizations for PCB use and distribution in commerce. This may have an impact on recycling materials from shredder residue which is known to contain some PCBs.

EUROPEAN REGULATIONS

In September 2000, European Union (EU) legislators issued a (draft) stringent ELVs directive (Directive 2000/53/EC [September 18, 2000]) that included several provisions about the disposal of ELVs. According to the Official Journal of the European Communities (21 October 2000), the directive must be integrated into national law no later than April 21, 2002. The directive and its related

provisions assigned product accountability to the manufacturers of the vehicles [11-14]. It also required that reuse and recovery rates shall be increased to a minimum of 85% by January 1, 2006 and to a minimum of 95% by January 1, 2015. To achieve 85% and 95% recyclability rates, shredder residue must be recycled at 40% and 80%, respectively (see Figure 2). This requires development of technology to facilitate the economical separation and recovery of recyclable materials from ELVs including from shredder residue. It also requires resources to track and document the accomplishments.

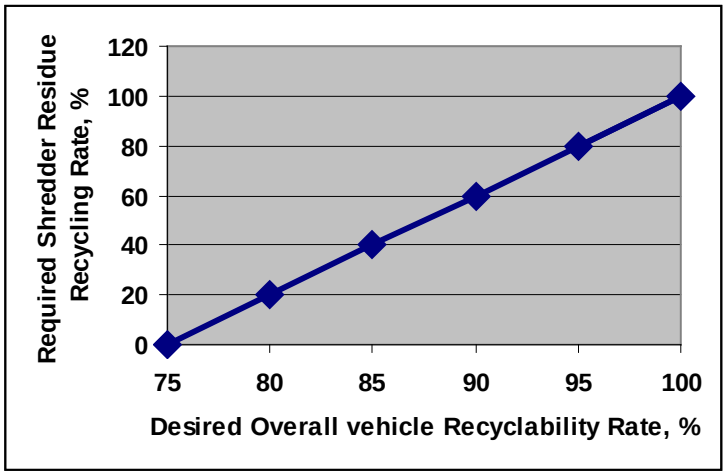

Figure 2. Shredder residue recycling rates required to achieve high overall vehicle recycling rates

The directive also specified recycling quotas for non-metals, limited the allowable energy recovery, and ordered that the vehicle manufacturer be responsible for the recovery cost [11, 12]. The directive also called for [12, 15] the following: (1) developing an infrastructure for the manufacturers to take back and recycle ELVs, (2) restricting the use of certain materials, (3) developing technical requirements for recycling plants, (4) marking components to facilitate recycling, (5) ensuring that ELVs processing does not result in the contamination of the shredder residue with hazardous species or impair the recovery of components for reuse, (6) promoting reuse and recycling as the preferred disposal routes, (7) requiring that the ELVs reuse/recover and reuse/recycle rates be 85% and 80%, respectively, by January 1, 2006 and that ELVs reuse/recover and reuse/recycle rates be 95% and 85%, respectively, by January 1, 2015, (8) addressing the dismantling, reuse, and recycling needs in the design of new vehicles, (9) limiting the amounts of lead (Pb), mercury (Hg), cadmium (Cd), and hexavalent chromium (Cr(VI)) in vehicles built after January 1, 2003, (10) requiring the removal of catalysts and components containing copper (Cu), Al, or Mg before shredding, and (11) noting that regulations concerning polyvinyl chloride (PVC) in ELVs are still pending.

Directive 1999/31/EC (April 26, 2000), which dealt with the regulation of waste disposed of in landfills, stated that whole or shredded tires cannot be disposed of in landfills and only treated waste can be disposed of in landfills. These directives can complicate the legal and economic future of shredder residue recycling technologies. For example, under the Directive 1999/31/EC (April 26, 2000), waste shredder residue disposed of in landfills can be considered the product of ELVs treatment so it could fall under "waste that has been subject to treatment." Another example is that because of the PVC in shredder residue, Directive 2000/76/EC (December 4, 2000) on the incineration of waste may require incineration under special conditions, followed by stringent gas cleanup.

There are two other European directives that can affect the disposal of shredder residue: (1) Directive 2000/76/EC (December 4, 2000) on the incineration of waste and (2) Directive 1999/31/EC (April 26, 2000) on the disposal of waste in landfills. Directive 2000/76/EC (December 4, 2000) on the incineration of waste includes the following requirements: (1) different emission regulations for dust, NOx, SOx, CO, hydrogen fluoride (HF), Total Organic Content (TOC), polychlorinated dibenzo-P-dioxins (PCDD), heavy metals, and Hg apply to municipal, medical, and hazardous wastes, (2) hazardous waste that contains over 1% halogenated organic materials must comply with PCDD/Fs (fluorinated) destruction regulations; and (3)hazardous waste that has a heating value of 12,900 Btu/lb (30 MJ/kg) or more is excluded from hazardous waste regulations.

Individual European countries have also set their own regulations. For example, in Switzerland, the Swiss automobile importers set up The Foundation for the Environment-Friendly Disposal of Motor Vehicles in 1992, and Switzerland became the first country in the world to dispose of all shredder residues by thermal processing [16]. Over 275,000 tons (250,000 metric tonnes) of shredder residue have been incinerated in municipal waste-incineration facilities. The Environment National Protection Agency (ENPA) of Italy also developed its own series of activities, including monitoring, data gathering and analysis, and reporting. In Germany, the regulation governing the PCBs in shredder residue dictates that shredder residue is incinerated as a hazardous waste and that incineration should be the primary disposal route for shredder residue. Yet, most of this waste is still disposed of in landfills [17].

In 2005 a committee reviewed the status of the implementation of the 2000 directive [18]. It was concluded that the reuse and recycling targets set in the EU Directive of 2000 are high and member States are unlikely to achieve the targets by 2015, and consideration should be given to freezing the 2006 target of 80%. In addition the committee recommended that the 2015 ambitious target of 95% for reuse and recovery should be maintained at 95%, and that dismantling of non-metallic parts (e.g., glass, plastics) should be optional instead of mandatory.

Others [19, 20] reported that up to 2005 the implementation of the Directives was inadequate. The European Parliament's Committee on the Environment, Public Health and Food Safety division requested another study [21] to assess the status of the implementation of the Directives. The study reported that although the first set of reuse, recycling and recovery targets was to take effect on 1 January 2006 some countries have not fully implemented the directives and the documentation in some member countries is still not up to par. The study reported that Sweden and the Netherlands reached the 85% target in 2005 and Belgium met the 80% reuse and recycling target in 2005, but it is still unclear whether it reached the 85% reuse and recovery target or not. Other countries may have met the 80% reuse and recycling target or are close to doing so.

The study [21] also outlined some of the reasons for the delay in implementing the Directives. These reasons include-

- Different disposal regulations in different member countries.
- Lack of adequate resources to implement the Directives including who will pay for the vehicles already in service.
- The Directive required high recycling rates which require recycling polymers and other none metallic materials. This increased the cost of disposal of ELVs.

The lack of economic technology to recover and recycle the polymers from shredder residue and the lack of profitable markets for these polymers are other major reasons that are hampering the effort to implement the directives.

JAPANESE REGULATIONS

In Japan over 5 million vehicles reach the end of their useful life every year. In 2002 Japan introduced a law (Automobile Recycling Act) governing recycling ELVs. This law requires manufacturers to recover refrigerants and airbags [22]. A law governing the recycling of ELVs (End-of-Life Vehicle Recycling Law) went in effect in Japan on January 1, 2005 [23, 24]. The law dictates that –

- Automakers (domestic and foreign) charge car buyers recycling fees.
- Vehicle owners are responsible for taking their ELVs to an authorized recycling facility.
- Manufacturers and importers are responsible for the recycling of ELVs and have to accept their own vehicles.
- The manufacturers have to properly collect and dispose of refrigerants, air bags, and shredder residue from scrap dealers.
- The costs for the treatment of ELVs, however, will be borne by vehicle owners.

CANADIAN REGULATIONS

In Canada there are federal, provincial and municipal regulations governing recycling of ELVs and the handling of resulting waste streams [25-29]. For example a dismantler in Ontario must have an Ozone Depletion Prevention permit to remove and handle refrigerants [29]. In addition the recycling industry developed their own codes of practice including, for example, the Canadian National Mercury Switch Recovery program [30] known as “Switch out”. This program is designed for removing and collecting and managing mercury lighting switches and mercury sensors in end-of-life vehicles before the vehicles are shredded. The Ontario Automotive Recyclers Association developed their own “Code of Practice” for its members. Similarly, Environment Québec developed a “Best Practice” guide for the ELVs industry.

CHINESE REGULATIONS

The number of vehicles on Chinese roads is increasing rapidly. Chen [31] reported that in February 2006 China published: the “*Motor Vehicle Product Recovery Technology Policy”. The policy established a target by 2010 “reuse and recovery “for all end-of-life automobile products, shall be increased to a minimum of 85% by average weight per vehicle, and the use of lead, mercury, cadmium, and hexavalent chromium is prohibited.” The policy requires that “starting in 2010, Chinese automobile manufacturers and importers will be responsible for collecting and recycling vehicles or will designate other authorized ELVs dismantlers to handle the business.*” It was also reported [32] that China launched a pilot program to recover and reuse parts from ELVs and that the Chinese auto makers and auto part manufacturers signed letters of commitment to the recycling program. The recycling effort will focus initially on engines, transmissions, electrical generators and few other major items. In 2008 China was considering new regulations in view of the inadequate recycling of the two million vehicles scrapped in 2008 [33].

Many, however, do not consider regulations to be an effective means of encouraging the recyclability of shredder residue and do not believe that there should be mandated ELVs recycling systems [34]. Gesing [34] pointed out that a scrap recycling system that collects scrap from various markets, processes the scrap to recover the metals, and sells the metals to consuming markets already exists. He indicated that imposing a monitoring system on this recycling system is not likely to result in an increase in recycling but only an increase in cost. He instead recommended (1) an approach to monitor and set metal, rubber, and plastic maximum content limits on any residue streams from the recycling system and (2) that air and water monitoring systems of the recycling facilities be implemented. Air should be monitored for both toxics (dioxins, furans, and polycyclic aromatic hydrocarbons) and greenhouse gas emissions. Water should be checked for contamination from liquid residue streams and by leachate from solid residue [34].

Existing and emerging regulations in different countries are likely to have an impact on what materials are used in manufacturing vehicles and on how end of life vehicles are handled.

CHALLENGES FACING THE AUTOMOBILE MANUFACTURERS

The challenges faces the international automotive companies are many including at the top of the list issues related to energy and the environment. In 2010 the Corporate Average Fuel Economy (CAFÉ) has been set at 35 miles per gallon by 2016. Presently the target for cars and light trucks is 27.5 miles per gallon. This jump will most likely accelerate the need to use lighter materials in manufacturing the vehicles. These materials are going to be more expensive and some will be produced from limited resources. In addition, the list of substances of concern that are being regulated is constantly growing. This requires continuous evaluation of the materials used in manufacturing the vehicles. Examples include fire retardants used in automotive polymers and air bag chemicals. Regulations, such as the ones on the books in the European Union will also impact the business of manufacturing and marketing cars. For example, the manufacturers may be required to-

- Address dismantling, reuse, and recycling needs of ELVs in the design of vehicles;
- Develop an infrastructure to take back and recycle ELVs
- Restrict the use of certain materials and limit the use of others such as Pb, Hg, Cd, Cr(VI) and PVC in vehicles
- Mark components to facilitate recycling.

CONCLUSIONS

The automobile industry is a material and energy intensive industry. In order to meet fuel efficiency regulations the industry is using more and more lightweighting materials such as aluminum, polymers and composites. This trend is likely to accelerate in the near future. Recycling automotive materials including the lightweighting materials is essential because it could reduce the overall cost of manufacturing vehicles, reduce the amount of energy consumed in manufacturing automotive materials and reduce the amount of waste going to the landfill. Therefore, efficient recycling of ELVs is a major contributor to the sustainability of the Industry.

Replacing conventional steel with lightweighting materials, including high strength steel, will reduce the recyclability of the vehicle unless these new materials are also recycled along with other materials that are presently not recycled. This will make it difficult to comply with governing directives and regulations. Recycling of these materials promotes the sustainability of the industry.

Recycling the new materials presents technical and economic challenges to the existing automotive recycling infrastructure. Therefore, there is a need to address these issues when designing vehicles and by developing the appropriate tools and efficient and economical technologies to facilitate the recycling of automotive materials.

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ACKNOWLEDGEMENTS

Funding for this work is provided by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program.