

# End-of-Life Vehicle Recycling in the European Union

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*Vehicles, essential to society, are continually increasing in use. However, throughout their life cycle vehicles impact the environment in several ways: energy and resource consumption, waste generation during manufacturing and use, and disposal at the end of their useful lives. About 75 percent of end-of-life vehicles, mainly metals, are recyclable in the European Union. The rest (~25%) of the vehicle is considered waste and generally goes to landfills. Environmental legislation of the European Union requires the reduction of this waste to a maximum of 5 percent by 2015.*

## INTRODUCTION

Automobile manufacturing has increased in the last 20 years, reaching about 58 million units (excluding commercial vehicles) in 2000 (see [Figure 1](#)). According to estimates by the [Organization for Economic Cooperation and Development](#) (OECD), the total number of vehicles in [OECD](#) countries was expected to grow by 32% from 1997 to 2020. Automobile production is more or less equally distributed between North and South America, Europe, and Asia.<sup>1</sup>

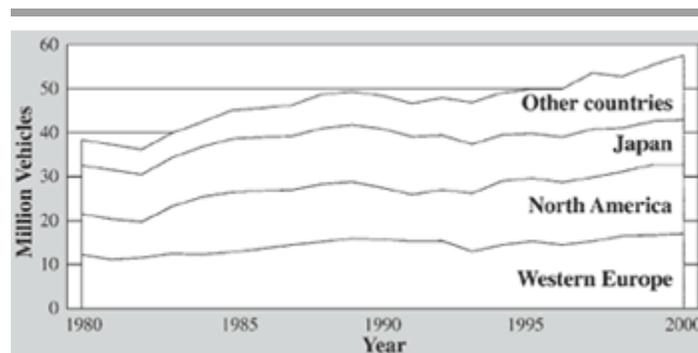
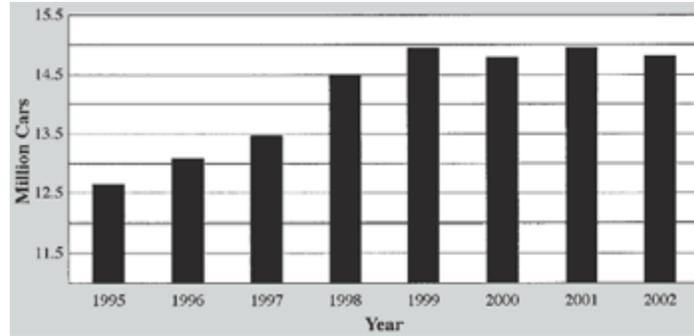


Figure 1. World automotive production from 1980 to 2000.<sup>1</sup>



**Figure 2. Passenger car production in the European Union.<sup>2</sup>**

The evolution of passenger car production in the European Union (E.U.) from 1995 to 2002 is shown in [Figure 2](#). More than 14.5 million cars per year have been manufactured since 1998,<sup>2</sup> with total automobile production (passenger cars, light commercial vehicles, trucks, and buses) in 2002 close to 17 million units. Most of the car production is concentrated in Germany, France, Spain, Italy, and Great Britain.

According to the available data,<sup>1</sup> about 160 million cars were in use in the European Union in 1995, and in 2001, that number exceeded 180 million units. More than 80% of these cars were concentrated in the five countries previously mentioned as major producers. The increasing car production and use data indicate the importance of the automobile industry in society.

However, that industry is facing a number of serious challenges related essentially to its impact on the environment. Vehicles affect the environment through their entire life cycle. Consumption of energy and resources, waste generation, greenhouse gases, hazardous substance emissions, and disposal at the end of their lives are burdens created by automobile production and use.

This paper deals with the recycling of end-of-life vehicles (ELV) in the European Union.

## **CURRENT ELV RECYCLING IN THE E.U.**

Recycling of ELV incorporates the recycling itself, recovery, and reuse. The driving force, criteria, and concept for ELV recycling result from different factors that have changed with time. For example, development of the electric arc furnace in the 1960s–1970s dramatically increased the use of vehicle shells as input scrap. Later, production of high-quality steel required the use of vehicle scrap free of nonferrous metals, prompting the magnetic separation of ferrous from non-ferrous metals. Further, the separation and recovery of aluminum from ELV was more energy efficient than production of aluminum from its ores.

Today, recycling of ELV is driven not only by economic and technological factors but also by social and environmental concerns. In other words, the automobile industry is shifting toward sustainable waste management.

Recycling options for ELV are related to the material used for vehicle manufacturing as well as the assembly of its components. Vehicle composition has been shifting toward light materials such as aluminum and polymeric constituents. As mentioned by Zoboli et al.,<sup>3</sup> in 1965 the total weight of a European car included about 82% ferrous and non-ferrous metals (2% aluminum) and 2% plastics. In the mid-1980s, the content of ferrous and non-ferrous metals averaged 74–75% (with 4.5% aluminum) and plastics were estimated at 8–10% of a European car's weight. The use of lighter materials (aluminum and plastics) improved fuel economy and reduced emissions. It is believed that a 100 kg weight reduction of a vehicle results in a fuel savings of about 0.7 L/100 km. However, introducing lighter materials to vehicles also compensates for weight increases resulting from new comfort and safety features.

The average composition of the E.U. car<sup>4</sup> in 1998 is illustrated in [Figure 3](#), which clearly shows the increase of aluminum content (~8%) in the total car weight. Ferrous and non-ferrous metals (Zn, Cu, Mg, and Pb) constitute about 67.5% of the vehicle. This figure also depicts the plastics used in average cars (~9.3%), their applications in the car body, and the major type of plastic used (polyvinyl chloride, polypropylene, polyurethane rubber, etc.).

Taking into account that the average lifespan of a car in use is between 12 and 15 years, the composition of the car represented in [Figure 3](#) will be recycled in the next decade in E.U. countries. Similarly, ELV in the recycling chain today were manufactured in the 1980s–1990s.

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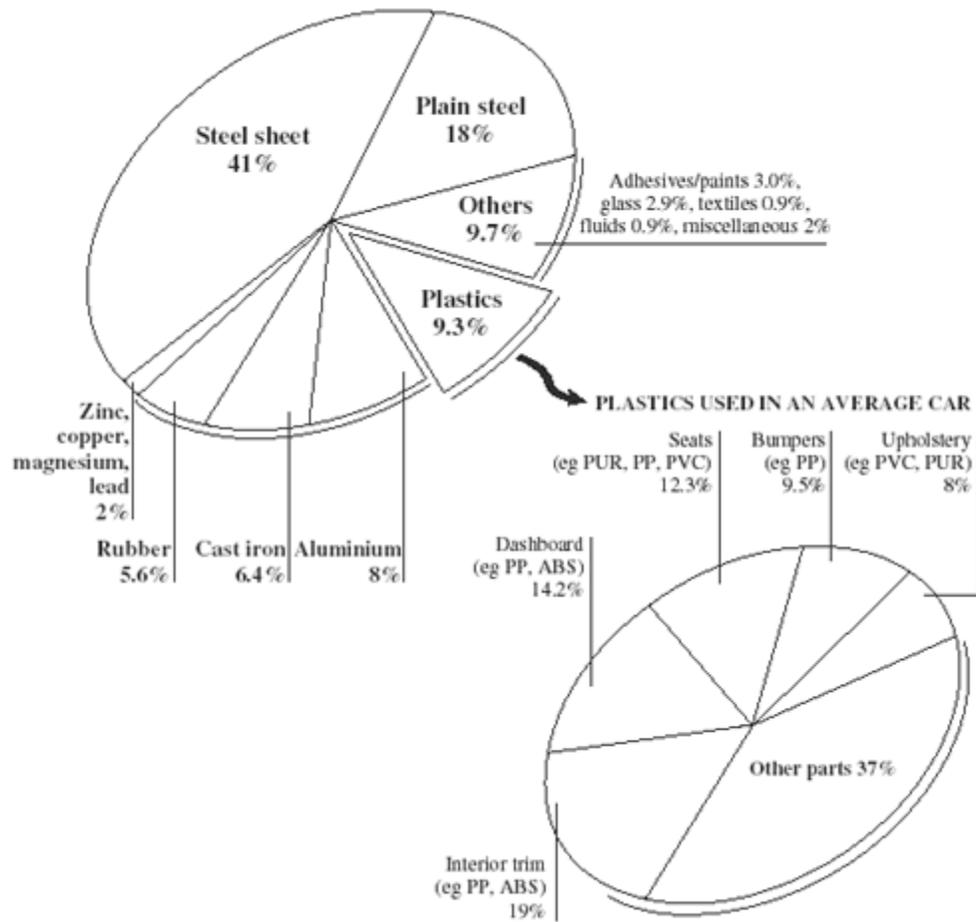


Figure 3. Material used in European Union car production (1998).<sup>4</sup>

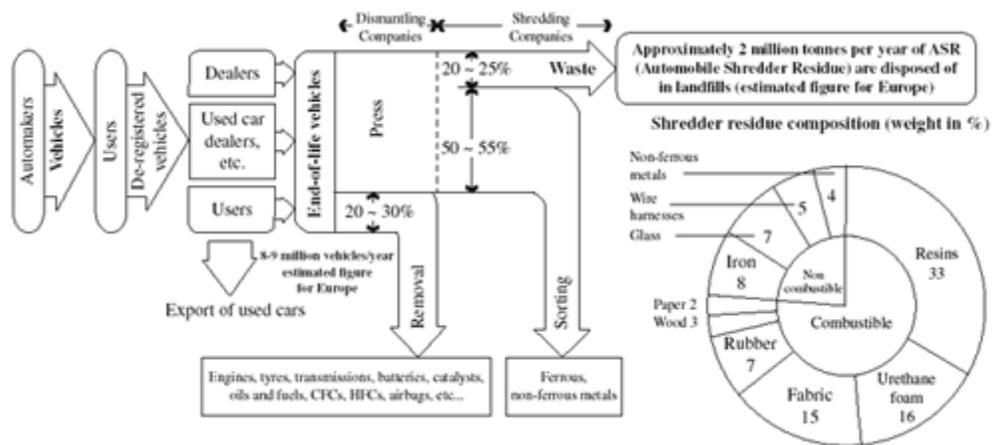


Figure 4. The disposal route for end-of-life vehicles.<sup>5</sup>

An overall schema<sup>5</sup> of the vehicles' paths starting from automakers to disposal of the shredder residue is shown in [Figure 4](#). The last car owners (i.e., users) are the starting point for the ELV chain. After de-registering the vehicles, the users can deliver their old cars to the dealers and/or to used-car dealers. The dealers, in turn, deliver the used cars to collectors/dismantlers. The deregistration of used cars can be done by users, dealers, collectors, and/or dismantlers, depending on the county rules.

About 8 million to 9 million ELV per year are estimated to be recycled in the E.U. countries. But, as noted by Zoboli et al.,<sup>3</sup> the actual number could be less than the official figure. This is due to significant export flows of ELV as second-hand cars from E.U. countries to non-E.U. countries in regions such as Eastern Europe, the former Soviet Union, and North Africa. Higher profits from selling these used cars intact rather than as spare parts and materials in the European Union can explain this phenomenon.

Collecting and dismantling companies focus on removing valuable spare parts and other components such as engines, batteries, oils and fuels, and airbags. Although these companies are essential to the reduction of ELV waste, they are small companies that are mostly interested in ELV parts that are suitable for reuse, recycling, or sale. The ELV dismantling is often done improperly, increasing the amount and toxicity of ELV waste. After dismantling, the remainders of the ELV, so-called "hulks," are processed by shredding companies.

After the hulks are shredded, the obtained materials undergo a series of mechanical and physical separations in order to recover the ferrous and non-ferrous metals. The residual of the shredding process, automobile shredder residue (ASR), represents about 20–25% of the ELV weight. Its average composition is given in [Figure 4](#).

The ELV recyclable rate of 75–80% is higher than that of simpler products such as glass containers, newspapers, and/or aluminum beverage cans.<sup>6</sup> One may emphasize that a passenger car contains about 15,000 parts.

The ASR is the weak point of ELV recycling not only in the European Union but also in the worldwide automobile industry. About 2 millions tonnes of ASR are generated per year in E.U. countries. In fact, it represents less than 1% of the total waste generated in the European Union. The ASR, while toxic enough to be classified as hazardous waste in many countries, could be considered an energy source as it contains more than 7% combustible matter (see [Figure 4](#)).

**Table I. ASR Landfill Costs in Different Countries**

Country	Cost (\$/t)
E.U. countries	
Austria	140
Belgium	55
Denmark	70–110
France	40–60

Two options will be considered for the ASR: recycling/recovery and waste disposal. Recycling belongs, above all, to industrial activities, where it is based on a proven technology and sound economics. Although many alternatives have been researched (physical separation, incineration, pyrolysis, and composite materials), it seems that the landfilling of ASR was the most appropriate option.

As shown by [Table I](#),<sup>3</sup> the cost to dispose of ASR in a landfill is different in the selected countries. The disposal cost in Germany is at least two times higher than in the United Kingdom. The high cost of disposal to landfill was one of the driving forces in the diversion of ASR from waste disposal toward more eco-efficient treatments. Shredder companies in Germany are ultimately responsible for reducing ASR and also for the environmental damage resulting from landfilling of that waste product. Environmental policies of the German automobile industry are considered a model for future automobile stakeholders to minimize vehicle life cycle environmental impacts. Tight regulations in Germany for the ELV waste may be explained, among other factors, by the important role of the automobile industry in the country economy.

Germany	60–170
Italy	75–80
Netherlands	70–90
Spain	20–60
Sweden	90–100
United Kingdom	30–35
Eastern European countries	
Poland	25–30
Czech Republic	30
Non-E.U. countries	
Australia	20
Japan	135–160
Norway	50
United States	50–60
South Africa	25–40
Switzerland	120

## FUTURE APPROACH FOR ELV RECYCLING

Considerable national policies and voluntary agreements by major automobile manufacturers have been developed concerning the environmental impact of vehicles over their lifetimes. At the end of 1999, ten E.U. member countries (Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom) had specific regulations and/or industrial voluntary agreements addressing ELV. These countries represent almost 96% of ELV estimated to be in the European Union.<sup>3</sup>

The directive of European Parliament and of the Council of 18 September 2000<sup>2</sup> organized former national policies and voluntary agreements. It was aimed to harmonize these existing rules and to push the E.U. governments and automobile industry to comply fully with the directive and to translate its key requirements into national law. The essential part of this ELV directive is given in the following (Article 7).<sup>2</sup> The ultimate goal of this directive is to put only 5% of ELV residues (ASR) into landfills. It states:

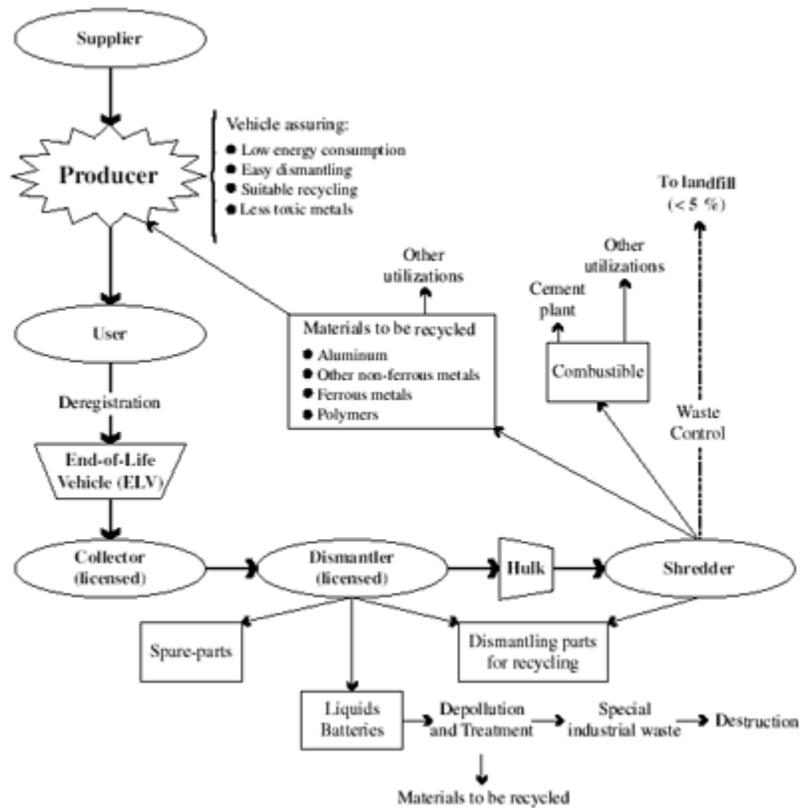
1. Member States shall take the necessary measures to encourage the reuse of components which are suitable for reuse, the recovery of components which cannot be reused and the giving of preference to recycling when environmentally viable, without prejudice to requirements regarding the safety of vehicles and environmental requirements such as air emissions and noise control.

2. Member States shall take the necessary measures to ensure that the following targets are attained by economic operators:
  - a. No later than 1 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. Within the same time limit the reuse and recycling shall be increased to a minimum of 80% by an average weight per vehicle and year; for vehicles produced before 1 January 1980, Member States may lay down lower targets, but not lower than 75% for reuse and recovery and not lower than 70% for reuse and recycling. Member States making use of this subparagraph shall inform the Commission and the other Member States of the reasons therefore;
  - b. No later than 1 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. Within the same time limit, the re-use and recycling shall be increased to a minimum of 85% by an average weight per vehicle and year.

Waste prevention, re-use, recycling, and recovery of the ELV constituents so as to reduce ASR waste disposal are the objectives of the E.U. directive. [Figure 5](#) is a schematic representation of the participants in the ELV chain, according to the E.U. directive. The main actor is the producer, a vehicle manufacturer or professional importer of a vehicle into a member state of the European Union. The producer links the upstream (supplier) and downstream in the ELV chain (collector, dismantler, and shredder). On the other hand, collaboration between collector, dismantler, and shredder are necessary to successfully meet the directive goals.

The vehicle produced has to at least meet the following goals: low energy consumption, easy dismantling, suitable recycling, and less toxic metals (as shown in [Figure 5](#)). To fulfill these goals, the producer has to know the technical and economical facilities, recyclability rate, and efficiencies of the downstream ELV chain. On the other hand, the producer will provide the dismantling information for each new type of vehicle put on the market. The design of vehicles appropriate for dismantling, recycling, and re-use, and free of some hazardous substances [Pb, Hg, Cd, and Cr(VI)] will significantly improve the cooperation of the supplier-producer chain.

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**Figure 5. Major steps for ELV recycling according to the E.U. directive.**

The directive required that the ELV collector and dismantler be certified (licensed), and as a result, the number of licensed dismantlers in the European Union has increased significantly, exceeding 1,000 licensed enterprises per country in the top five producers of vehicles in the European Union. The dismantler's role is the removal for sale of re-usable parts such as engines, transmissions, gearboxes, and body parts. According to the ELV directive, removing pollutants from the vehicle becomes an important task of the dismantler business. This involves the draining of liquids and removing of environmentally harmful constituents such as the battery. Furthermore, dismantlers are certified to destroy the waste resulting from removing the pollutants (i.e., depollution) (Figure 5). These tasks by the dismantler will facilitate the subsequent hulk shredding and will reduce the ASR generated by the shredder operators.

Shredding steps include dismantling small parts for recycling, hulk shredding, and ferrous and non-ferrous metal separation. The separated materials will likely go to automakers for use in the production of the same components from which they are issued. Energy can be recovered from combustible parts of ELV by using them instead of fossil fuels in industrial operations, such as cement plants. The remaining part of the vehicles, ELV waste, will go to a landfill under strict waste control. This will be material for which there is not justification for recovery.

In an increasingly global economy, the goals of the E.U. directives are becoming a sensitive issue for worldwide vehicle production. The regulatory approach to automobile recycling in Japan is compared with the E.U. directive in [Table II](#).<sup>8</sup> It is clear that most of the selected items (i.e., schedule, car manufacturer's obligations, costs) are similar. In both cases, the car manufacturer has an essential role in the infrastructure system of waste prevention, collection, and treatment of ELV.

**Table II. Automobile Recycling Law in Japan and ELV Directive in E.U.**

	<b>Japan (Automobile Recycling Law)</b>	<b>E.U. (ELV Directive)</b>
Schedule	Promulgated July 2002, to enter effect by January 2005	Effective from October 2000 legislation enacted in E.U. member states in 2002
Vehicle covered	Four-wheeled passenger cars and commercial vehicles (including everything from mini-cars to large trucks and buses)	Passenger cars with seating capacity of nine or less and commercial vehicles with gross vehicle weight of 3.5 t or less
Car manufacturer's obligations	Collection and disposal of fluorocarbons and airbags Collection and recycling of shredder residue Setting and publication of user charges  Design and manufacture of car models with consideration for environment and recycling	Establishment of ELV collection and recycling network From July 1, 2002: Newly registered vehicles. From January 1, 2007: All ELVs Prohibition of use of hazardous substances (lead, mercury, cadmium, hexavalent chromium). Covering all vehicles sold from July 1, 2003 Recyclability rate 95% or more
Costs	Deposited by users (managed by fund management corporation) New vehicles: deposited at time of sale Old vehicles: deposited at time of automobile inspection (depending on country)	All or most of cost borne by car manufacturers

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