MODUL_2022

End of Life Vehicle Disposal

Saša MITIĆ

International legislation

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1. INTRODUCTION

The vehicle is a very complex product that contains about 15,000 parts made from different materials using various technologies. During the production process, and with waste during exploitation as well as waste at the end of the vehicle's lifetime, the environment is being degraded. These facts require that a suitable system must be established for vehicles at the end of their life, which could be managed with quality and comprehensiveness.

1.1. HISTORICAL BACKGROUND AND FOUNDATION

Waste management and waste legislation has started at the EU level in 1975, with the Directive 75/442/EEC on waste and Directive 75/439/EEC on waste oil.

Discussions about end-of-life vehicle waste date back to the 1970s. Illegal disposal of hazardous waste and an increasing share of plastic in light cutting residue have caused concern. Light cutting residue are not easy to press, therefore they have taken up a considerable space at landfills. In addition, light cutting residue are not easy to burn because they need to be prepared and processed before burning. Treatment of exhaust gases in waste incinerators was less developed in those times, and this risk has caused public concern. Contamination of metal waste with heavy metals was another question with caused concern in those times.

In 1996, within the Study for the European Commission (*Tuddenham et al.),* it was estimated that, on average, between 1990 and 1994, approximately 8.9 million vehicles ended their life within the 15 Member States of the European Union. Numbers are based on surveys on National deregistration of vehicles entering the recycling process. During those times, the number of vehicles at the end of their life treated in the country could be estimated for a few Member States, but not for all and the issue of unknown exports to countries that are not members of the European Union was mentioned. In the *JRC-IPTS* report (*Joint Research Centre - Institute for Prospective Technological Studies*) from 2000 (*Zoboli et al.*) it was estimated that between 7.6 and 10.3 million vehicles at the end of their life were available for national recycling programmes of vehicles within 15 Member States of the European Union.

In the same report (*JRC-IPTS*), the state of legislation in the European Union before the entry into force of the End-of-Life Vehicle Directive was described. This report is a document, which most closely defined the existing regulation before the End-of-Life Vehicle Directive. However, it does not cover all the questions and requests from the End-of-Life Vehicle Directive. At the time of the drafting of the End-of-Life Vehicle Directive, there was no requirement to carry out formal impact assessment, including the baseline and counter-arguments and data on lack of intervention. The report contains the following resume:

"At the end of 1999, 10 Member States of the European Union (Austria, Belgium, France, Denmark, Italy, the Netherlands, Portugal, Spain, Sweden, and the Great Britain) had special regulations and/or industry voluntary agreements for end-of-life vehicles. It is the assumption

that in these countries there are almost 96% of vehicles at the end of their life affecting the environment. Three other countries had talks on industry voluntary agreements (Finland and the Republic of Ireland) or on the introduction of laws (Denmark). Six countries (Austria, Belgium, Denmark, Italy, the Netherlands, and Sweden) combine the voluntary agreements with legislation, which directly deals with end-of-life vehicles. Austria, France, Italy, and the Netherlands had introduced voluntary agreements or initiatives across the country before the drafting of the EU directive proposal. Voluntary agreements and legislation in other countries (Belgium, Denmark, Portugal, Spain, and Sweden) were developed in 1997-1999 during the debate on the EU directive proposal. Integration process between the industry agreements and legislation happened in Denmark and Sweden after the second confrontation between industry and creators of the ecology policy. In other big countries (France, Italy, and the Great Britain), end-of-life vehicle policy is largely based only on voluntary agreements promoted by the automotive industry and includes a range of other industries. One of the main characteristics of these voluntary agreements is the absence of specific economic instruments of "free take back" and the prominence of free market relations. The agreements applied in the Netherlands represents a specific approach both for its organizational framework and for economic incentives. The recycling fee is added to the price of new cars and is redistributed to dismantlers and recycler to pay for the additional costs of recycling. Specific goals for mechanical recycling have been established. Most of national voluntary agreements and/or laws set a target recovery rate of 85% of a cars weight by 2002 and an overall target recovery rate of 95% by 2015. Most countries set goals only in terms of recovery rates (not the recycling rate, as is stated in the European Union Directive) thus enabling unlimited energy recovery of vehicle cutting residues."

In 2000, the End-of-Life Directive dealt with the management of end-of-life vehicles at the European level for the first time.

The Directive of the European Parliament and the Council 2000/53/EC from September 18th 2000, which concerns the treatment of vehicles of category M_1 and N_1 at the end of their life, consolidated previous national strategies and voluntary agreements. The goal was to harmonize the existing rules as well as to persuade the governments of the European Union countries and the automotive industry to comply with this Directive in full, also to transfer its key requirements into national regulations. The Essential part of the Directive is given in the Article 7. Main Goal of the Directive is that only 5% of residue of the end-of-life vehicle end at the landfill. The Directive states the following:

1. Member States shall take all necessary measures to support the reuse of components which are suitable for this, the recovery of components which cannot be used again, as well as to give priority to recycling when justified from an environmental point of view, without prejudice to the requirements concerning vehicle safety and environmental requirements such as exhaust gases emission and noise control.
2. Member States shall undertake all necessary measures to secure the achievement of the following goals:

a. For all end-of-life vehicles, no later than January 1st 2006, reuse, and recovery (recoverability rate) should be increased to a minimum of 85% of the average vehicle weight. At the same time, the boundary of reuse and recycling (recyclability rate) should be increased to a minimum of 80% of the average vehicle weight; for vehicles made before January 1st 1980, Member States may set lower goals but no less than 75% for reuse and recovery and no less than 70% for reuse and recycling. Member States applying this section should inform the European Commission and other Member States of the reasons for applying it.

b. For all end-of-life vehicles, no later than January 1st 2015, reuse, and recovery (recoverability rate) should be increased to a minimum of 95% of the average vehicle weight. At the same time, the boundary of reuse and recycling (recyclability rate) should be increased to a minimum of 85% of the average vehicle weight.

Implementation of the End-of-Life Vehicle Directive into the national legislation of the European Union Member States should be conducted until April 21st 2002. The specific implementation of the Directive is:

- From July 1st 2002 for vehicles put into market from this date;
- From January 1st 2007 for vehicles put into market before July 1st 2002.

1.2. GOALS OF THE END-OF-LIFE VEHICLE DIRECTIVE

Directive 2000/53/EC, which refers to end-of-life vehicles, as stated previously, was derived from the Waste Directive (75/442/EEC) from 1975 as well as, Hazardous Waste Directive (91/689/EEC) from 1991. The main goal of this Directive is, primarily, the adoption of measures for the prevention of the reproduction of waste originating from vehicles. It is imperative to improve the environmental impact of all factors involved in the vehicle life cycle, especially those involved in the end-of-life vehicle issues.

Indirect goals are:

- Determination of measures to prevent and limit waste from the end-of-life vehicles and their components by ensuring their reuse, recycling, and recovery;
- Avoiding hazardous substances in automobile production;
- Return of materials, as much as possible, into the automobile production process, through recycling;
- Improving the environmental performance of all economic participants involved in the life cycle of vehicles.

According the Article 1 of the End-of-Life vehicle Directive, “measures aimed, as a first priority, at the prevention of vehicle waste, in addition, reuse, recycling, and other forms of recovery at the end of vehicles life cycle and their components in order to reduce waste disposal, as well as to improve the environmental performances of all economic operators involved in the vehicles life cycle, especially of operators which are directly involved in the treatment at the end” are prescribed.

The Legal basis for the End-of-Life Vehicle Directive is the article 175(1) of the Treaty on the Establishment of the European Community (now article 192 of the Treaty on the Functioning of the European Union). The Directive Determines the minimal requirement, and Member States may establish stricter national requirements, in accordance with the Article 193 of the Treaty on the Functioning of the European Union.

Introductory statement (1) states: "Different national measures regarding the vehicle waste should be harmonized in order to, firstly, reduce the impact of vehicle waste on the environment, thereby contributing to the protection, preservation and improvement of the environmental quality and energy conservation, and, secondly, to ensure smooth operation of the internal market and avoid distortion of competition in the Community."

By harmonizing environmental requirement, the Directive also aims to ensure smooth functioning of the internal market and avoid distortion of competition in the Community by a Community-wide framework to ensure the coherency between the national approaches taking into account the principle of subsidiarity and the "polluter pays" principle (introductory statement(2)).[1]

End-of-Life Vehicle Directive establishes minimum requirements for managing end-of-life vehicle waste and goals for reuse/recycle and recovery. Article 4 of End-of-Life Vehicle Directive on "prevention" explicitly calls for design for reuse and recycle and establishes the interdiction of hazardous substances, namely lead, mercury, cadmium, or hexavalent chromium, except in cases and under the conditions specified in the Annex II. Criteria for the adoption of delegated acts amending Annex II, in order to exempt certain materials or components from these prohibitions, are set out in the same Article.

1.3. KEY POINTS OF END-OF-LIFE VEHICLE DIRECTIVE

- Vehicle and equipment manufacturers have to consider the dismantling, reuse and recovery of vehicles during design and manufacturing process of their products. They must ensure the new vehicles will be:
  - For multiple use and/or recycling to a minimum of 85% of the weight per vehicle;
  - For multiple use and/or recovery of a minimum 95% of the weight per vehicle;
- They cannot use hazardous substances such as lead, mercury, cadmium, and hexavalent chromium;

[1] End-of-live Vehicle Directive does not expressly refer to the term „extended producer responsibility", as defined by the Waste Framework Directive (2008/98/EC). Instead, End-of-Life Vehicle Directive states in the Article 5(4) that „Member States shall take necessary measure to ensure the delivery of vehicles to authorized facility for treatment be in accordance with paragraph 3 takes place at no costs to the end-owner and/or owner, as a result of the vehicle having no or negative market value. Member States shall take necessary measure to ensure that manufacturers cover all or substantial part of the costs of implementing this measure and/or take over the end-of-life vehicles under same conditions as it is stated in the first sub-paragraph."

- Manufacturers, importers, and distributors must provide the systems for collecting end-of-life vehicles and, where technically possible, spare parts from passenger vehicles service facilities;
- Owners of end-of-life vehicles delivered to recycling treatment must receive a confirmation of destruction; This is necessary to deregister the vehicle;
- Manufacturers must cover all or substantial part of costs included in delivery of end-of-life vehicles to the waste treatment facilities. Owners of vehicles should not pay any costs during the delivery of end-of-life vehicle to authorized institutions for waste treatment, except in rare occasions when the engine is missing or the end-of-life vehicle contains too much waste which has to be disposed of in a landfill;
- Waste treatment facilities must submit a request for approval or register themselves at Competent Authority of the EU Member State in which they are located;
- End-of-life vehicles are firstly dismantled before further treatment. Hazardous substances and components are removed and separated. Attention is paid to the potential reuse, recovery or recycling of waste;
- There are clear quantified goals for annual reporting to the European Commission for reuse, recycling and recovery of end-of-life vehicles and their parts. These goals have become more demanding as time goes by;
- This Directive is applied to passenger vehicles (category M_1) and light commercial vehicles (category N_1), but not on buses (categories M_2 and M_3), heavy commercial vehicles (categories N_2 and N_3), vehicles of historical importance (old-timers), special purpose vehicles and two-wheeled, three-wheeled vehicles and quadricycles (category L).

1.4. CHANGES IN END-OF-LIFE VEHICLE DIRECTIVE

Like all other acts of the European Commission, End-of-Life Vehicle Directive is alive and active document; therefore, constant changes are an integral part of harmonizing the Directive with actual requirements, which are presented before the vehicle design process and implementation of the recycling procedure.

Although in the beginning the changes were less frequent (approximately every three years), in the last ten years, certain changes have been recorded almost annually, all with the aim of harmonizing with other acts of the European Union and the aforementioned actualization of requirements that are set before the vehicle treatment process at the end of life.

Changes regarding the Directive 2000/53/EC on End-of-Life Vehicles are as follows:

- Commission Decision 2005/63/EC from January 24th 2005;
- Commission Decision 2005/438/EC from June 10th 2005;
- Commission Decision 2002/525/EC from June 27th 2002;

- Council Decision 2005/673/EC from September 20th 2005;
- Directive 2008/33/EC of the European Parliament and the Council from March 11th 2008;
- Commission Decision 2008/689/EC from August 1st 2008;
- Directive 2008/112/EC of the European Parliament and the Council from December 16th 2008, text of importance for European Economic Area (EEA);
- Commission Decision 2010/115/EU from February 23rd 2010;
- Commission Directive 2011/37/EU from March 30th 2011, text with EEA (European Economic Area) relevance;
- Commission Directive 2013/28/EU from May 17th 2013, text with EEA (European Economic Area) relevance;
- Commission Directive (EU) 2016/774 from May 18th 2016, text with EEA (European Economic Area) relevance;
- Commission Directive (EU) 2017/2096 from November 15th 2017, text with EEA (European Economic Area) relevance;
- Directive (EU) 2018/849 of the European Parliament and the Council from May 30th 2018, text with EEA (European Economic Area) relevance;
- Commission Directive (EU) 2020/362 from December 17th 2019, text with EEA (European Economic Area) relevance;
- Commission Directive (EU) 2020/363 from December 17th 2019, text with EEA (European Economic Area) relevance.

Greatest changes of the Directive happened through Directive (EU) 2018/849 of the European Parliament and the Council from May 30th 2018, which gave the European Commission the authority for adoption of the following changes and amendments:

- Adoption of documents needed to be implemented, and which refer to the detailed rules necessary to control the compliance of the countries of the European Union with the objectives of the Directive on end-of-life vehicles, as well as export and import of such vehicles;
- Document delegation for the change of the Directive with following amendments:
    - Exclusion of specific hazardous substance and components containing lead, mercury, cadmium, or hexavalent chromium (except in case stated in Annex II), if their use is unavoidable and determining the maximum allowed concentration levels, as well as removal of materials and components from the vehicles from Annex II, if their use could be avoided,
    - Introducing the coding standard to make identification of components necessary for their use and recovery easier,
    - Determining the minimum requirements for issuing a certificate of destruction,

- Determining the minimum requirements for treatment of end-of-life vehicles (Annex I).

In order for the changes to the End-of-Life Vehicle Directive to have a real effect in implementation, a roadmap was presented at the end of 2020 to assess the impact of the Directive. With this Roadmap, precise steps, and deadlines for improving the Directive are specified:

- Consultations with interested parties on reconsideration of the existing three exemptions in the End-of-Life Vehicle Directive (from September 15th to December 8th 2020);
- Publication the Roadmap for the assessment of impact of the End-of-Life Vehicle Directive (from October 22nd to November 19th 2020);
- Publication of the evaluation of the End-of-Life Vehicle Directive (March 16th 2021);
- Public argument on revising the rules of the European Union for the end-of-life vehicles (from July 20th to October 26th 2021);
- Suggestion of the Commission for revising the End-of-Life Vehicle Directive (2023);

Public argument on revising the rules of the European Union of the end-of-life vehicles was open for citizens, economic subjects, non-government organizations and public administrations with knowledge and/or interest regarding the end-of-life vehicles. Public argument follows the published evaluation of the End-of-Life Vehicle Directive from 2021, since it highlights some of the shortcomings of the Directive, such as:

- Deficiencies in the national systems for vehicle registration, insufficient connectivity and communication between Member States regarding the vehicle registration and deregistration;
- Need for more detailed regulations of the End-of-Life Directive, in order to support the design of new vehicles as to make the processes of dismantling and recycling and use of recycled material easier;
- Absence of special consideration of reuse;
- The scope of the End-of-Life Vehicle Directive does not consider the number of around 45 million vehicles, for example motorcycles and trucks (lorries);
- End-of-Life Vehicle Directive is not appropriate to ensure the high level of reuse and recycle of more used valuable materials such as gold, silver, palladium, tantalum, and other rare earth metals, which are present in electrical and electronic installations;
- There is no completely expanded system of manufacturers responsibilities implemented by the End-of-Life Vehicle Directive;
- End-of-Life Vehicle Directive must ensure better compliance with European green agreement and Action plan for circular Economy, especially in environmental design of vehicles in order to make reuse, reproduction and recycling, promotion of more ambitious and specific goals for reuse and recycling, use of recycled materials in vehicle production easier;

After the evaluation and public consultation, the impact assessment was carried out to support a possible revision of the End-of-Life Vehicle Directive. It is expected that the revision of the End-of-Life Vehicle Directive will result with a legislative proposal in 2022, which should make the dismantling and treatment of end-of-life vehicles more environmentally acceptable. End-of-life vehicle management is both a challenge in terms of environmental protection and an opportunity to foster the principles of circular economy for various valuable materials.

1.5. RELATED DOCUMENTS

Apart from the End-of-Life Vehicle Directive, which is considered as the main document regarding the treatment of waste vehicles, there is also a whole series of related documents necessary for the comprehensive and controlled application of procedures for dealing with such vehicles. Some of the more important related documents are:

- Directive 2005/64/EC of the European Parliament and the Council from October 26th 2005 of the Approval of motor vehicle type regarding their reuse, recycling and recovery and on changes and amendments to the Council Directive 70/156/EEC;
- Commission Decision 2005/293/EC from April 1st 2005 on determining the detail rules on following the goals on recoverability rate and recyclability rate determined in the Directive 2000/53/EC of the European Parliament and the Council on end-of-life vehicles;
- Commission Decision 2003/138/EC from February 27th 2003 on establishing the component and material coding standard for vehicles in accordance with the Directive 2000/53/EC of the European Parliament and the Council on end-of-life vehicles;
- Commission Decision 2002/151/EC from February 19th 2002 on minimum requirements regarding the Certificate of destruction issued in accordance with Article 5(3) of the Directive 2000/53/EC of the European Parliament and the Council of the end-of-life vehicles;
- Commission Decision 2001/753/EC from October 17th 2001 regarding the questioner for reports, which Member States use to report on application of the Directive 2000/53/EC of the European Parliament and the Council of the end-of-life vehicles.

1.6. MAIN PROVISIONS OF THE END-OF-LIFE VEHICLE DIRECTIVE

Basic scope of the End-of-Life Vehicle Directive is shown in the Figure 1, which provides and overview of its basic provisions.

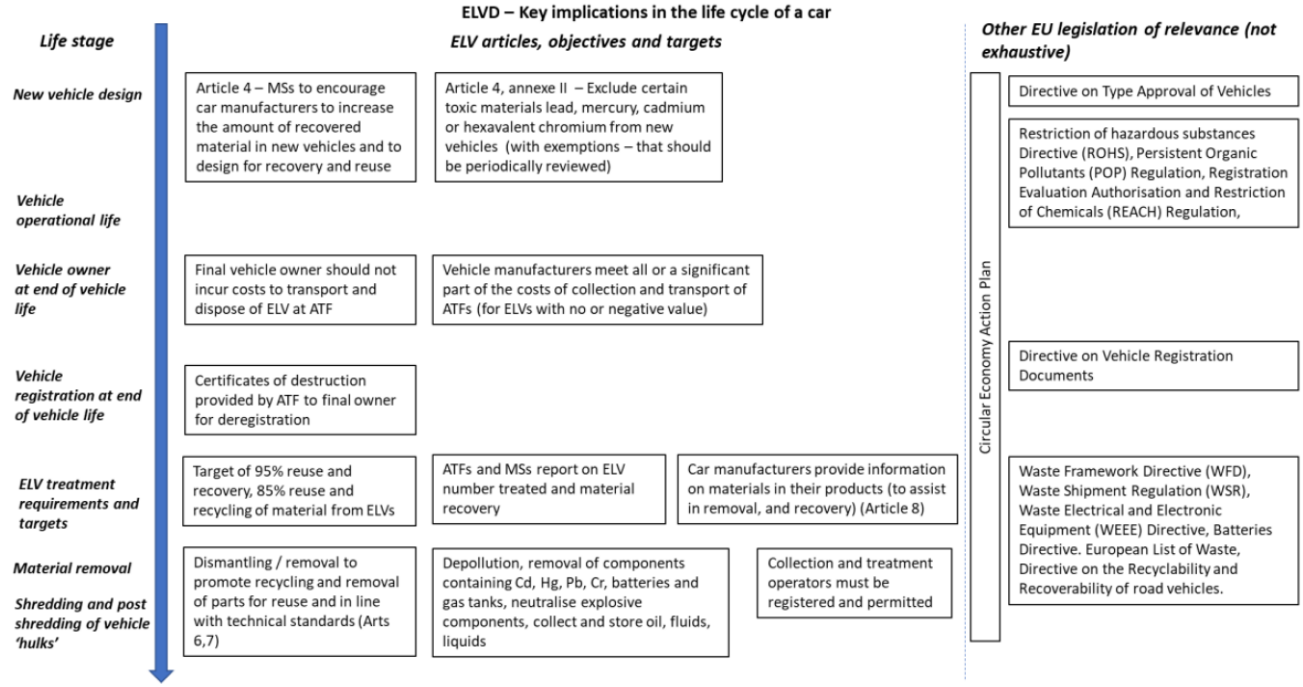

Figure 1 - Resume of the End-of-Life Vehicle Directive

As it is shown in Figure 1, the End-of-Life Vehicle Directive has an impact in several phases of a vehicle life cycle. Figure 1 also shows that the End-of-Life Vehicle Directive has some overlaps with several other laws of the European Union.

End-of-Life Vehicle Directive affects the design of new vehicles by requiring the Member States to encourage vehicle manufacturers to increases the amount of used material and to design in such a way to promote recovery and reuse.

End-of-Life Vehicle Directive contains provisions with which specific hazardous materials are excluded from new vehicles. Key legislative transitions here are with the Whole vehicle type approval of new vehicles (WVTA), with legislation relating to limitation and control of chemicals in general and aspects of designing the Action plan of circular Economy.

The next phase of vehicle life cycle when the End-of-Life Vehicle Directive has a significant effect is when vehicles come to an end of their life cycle. At this moment, the end-owner should not pay the costs of disposing the vehicle in the authorized treatment facilities. Costs of collecting and transport to the authorized treatment facilities should be covered/subsidized by the vehicle manufacturers.

After the vehicle at the end of its life cycle is treated and cleaned by the authorized treatment facilities, the end-owner should receive a Certificate of destruction. This, if often linked to

legislation relating to vehicle registration, as certain vehicle taxes (in certain Member States) can be stopped for the owner of the vehicle only when a certificate of destruction has been provided for him.

Huge part of the End-of-Life Vehicle Directive regards the treatment and disposal of contaminants of vehicles at the end of their life cycle. There are goals for reuse and recovery of materials (by mass). End-of-Life Vehicle Directive also demands from Member States to report the number of treated end-of-life vehicles. Vehicle manufacturers are obliged to provide information on materials in their products to make their disposal and recovery easier. There are specific requirements for the disposal of specific vehicle components and liquids, which represent a high risk of pollution and/or contain materials of high value. Authorized treatment facilities must be registered in accordance with minimum technical requirements and approved by the Competent Authorities of the Member States. The Aspect of the End-of-Life Vehicle Directive overlaps with general legislation on waste (i.e., Framework Directive on waste and Regulation on the waste disposal), and with specific legislation on waste flow, i.e., Battery Directive.

1.7. KEY NUMBERS WHICH DESCRIBE THE CURRENT SITUATION

- In 2016, there were 258 million registered passenger vehicles in the EU Member States and all fall into the scope of the End-of-Life Vehicle Directive. Around 90% of 34 million registered trucks is lighter than 3.5 tonnes and fall into the scope of the End-of-Life Vehicle Directive too. Trucks weighing over 3.5 tonnes do not fall into the End-of-Life Vehicle Directive. The remaining 45 million vehicles, including motorcycles, trailers, semi-trailers, tractor trucks, special vehicles, buses and trolleybuses, also do not fall into the scope of the End-of-Life Vehicle Directive;

- In 2017, 11.21 million light commercial vehicles weighing under 3.5 tonnes (category N_1) and passenger vehicles (category M_1) left the records of registered vehicles. Of those, 6.57 million were reported as end-of-life vehicles, 0.87 million were reported as used vehicles exports into countries, which are not EU Member States. Therefore, it is currently unknown where 3.77 million vehicles that left the records of registered vehicles are. Vehicles whose whereabouts are unknown are usually exported (as used or end-of-life vehicles), with this export not being declared, or dismantled but not being declared as end-of-life vehicles within the European Union (Figure 2);

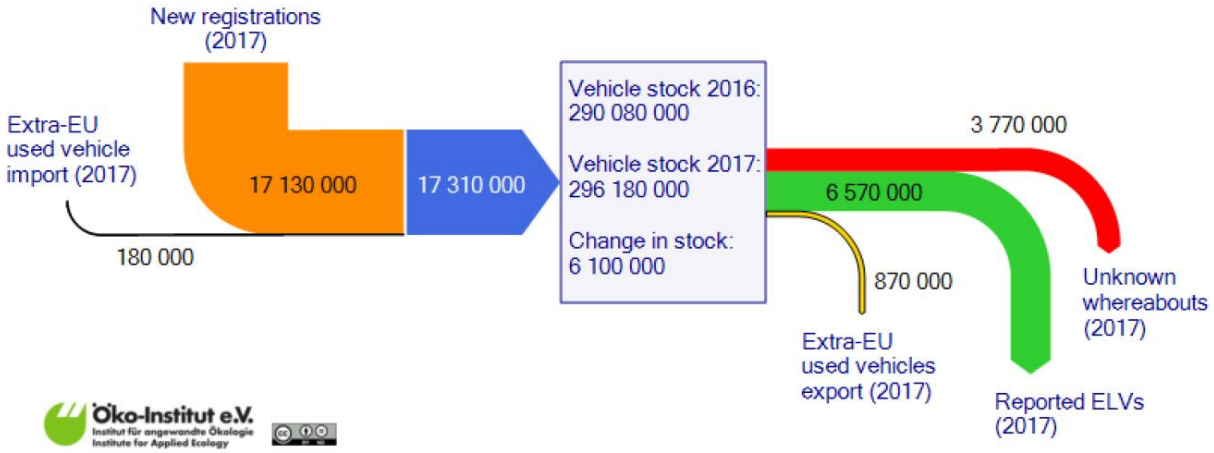

Figure 2 – Vehicles (categories M_1+N_1) whose whereabouts are unknown for 2017 in 28 EU countries (excluding Bulgaria)

- Average end-of-life vehicle weight in 2017 was 1088 kilogrammes[2]. That means that 11.21 million vehicles leaving the evidence of registered vehicles in 2017 represent 12.2 million tonnes of waste;

- Table 1 gives an average percentage composition of materials in end-of-life vehicles. Application of average composition to 12.2 million tonnes indicates the flow of material is 70% (8.5 million tonnes) ferrous metals, 4% (490,000 tonnes) non-ferrous metals (without cables), 3% (365,000 tonnes) glass, and 14.8% (1.48 million tonnes) of mixed plastic. These numbers exclude tyres, battery housings and plastic cable insulation;

- The amount of plastic used in vehicles has increased with time. For example, as shown in Figure 3, the content of plastic in the vehicle Volkswagen Golf has increased from 10% in Golf II (1989-1992), to 15.3% in Golf V (2003-2008), and to 19.5% in Golf VII (2012-2019). Average age of end-of-life vehicles is between 15 and 22 years, which means that the impact of the increasing amount of plastic in new vehicles on the end-of-life treatment of vehicles will increase in the coming years;

[2] Source: *Eurostat* – unpublished data for 2018 for 16 of 31 European Union countries and European Economic Area

Table 1 - Average percentage composition of End-of-life vehicles in 2015 in France

Polypropylene (PP) - other parts	4.4%
ABS, PVC, PC, PMMA, PS, etc.	2.2%
Polyurethane foam	2.0%
Textiles, other	1.7%
Other rubber compounds	1.1%
Polypropylene (PP) - bumpers	1.1%
Polyamides (PA)	1.0%
Polyethylene (PE) - fuel tanks	0.8%
Polyethylene (PE) - other parts	0.5%
Total	**14.8%**
Tyres	3.4%
Lead starter battery	1.4%
Wiring harnesses	1.0%
Paint	0.8%
Total	**6.6%**

Ferrous metals	70.0%
Non-ferrous metals (excluding wiring harnesses)	4.0%
Glass	3.0%
Spent oil and filters	0.7%
Catalytic converters	0.5%
Cooling or brake fluids	0.4%
Air-conditioning fluids	0.1%
Total	**78.7%**

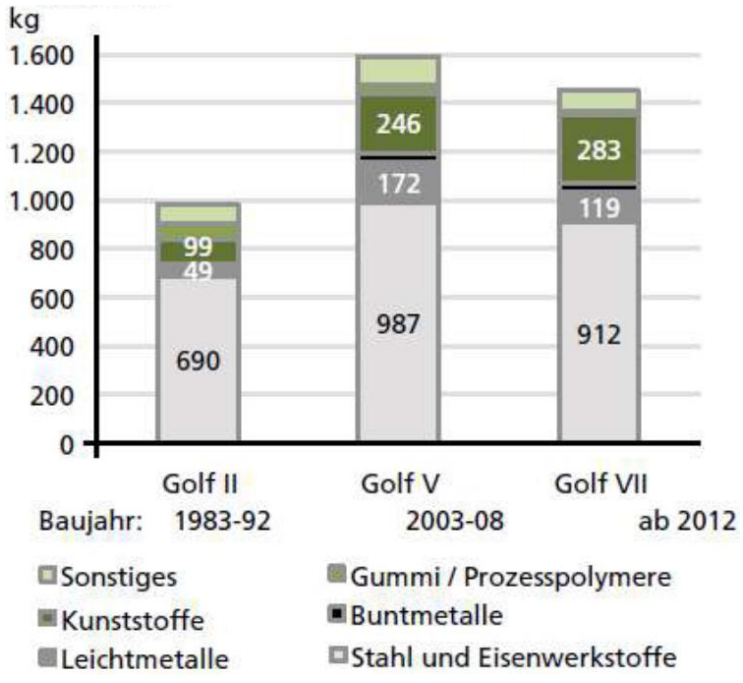

Figure 3 - VW Golf vehicle curb weight, including work fluids and material composition

- As shown in Figure 4, in 2017 most of the Member States reached the goal of 85% for the recyclability rate of vehicles at the end of their life cycle;

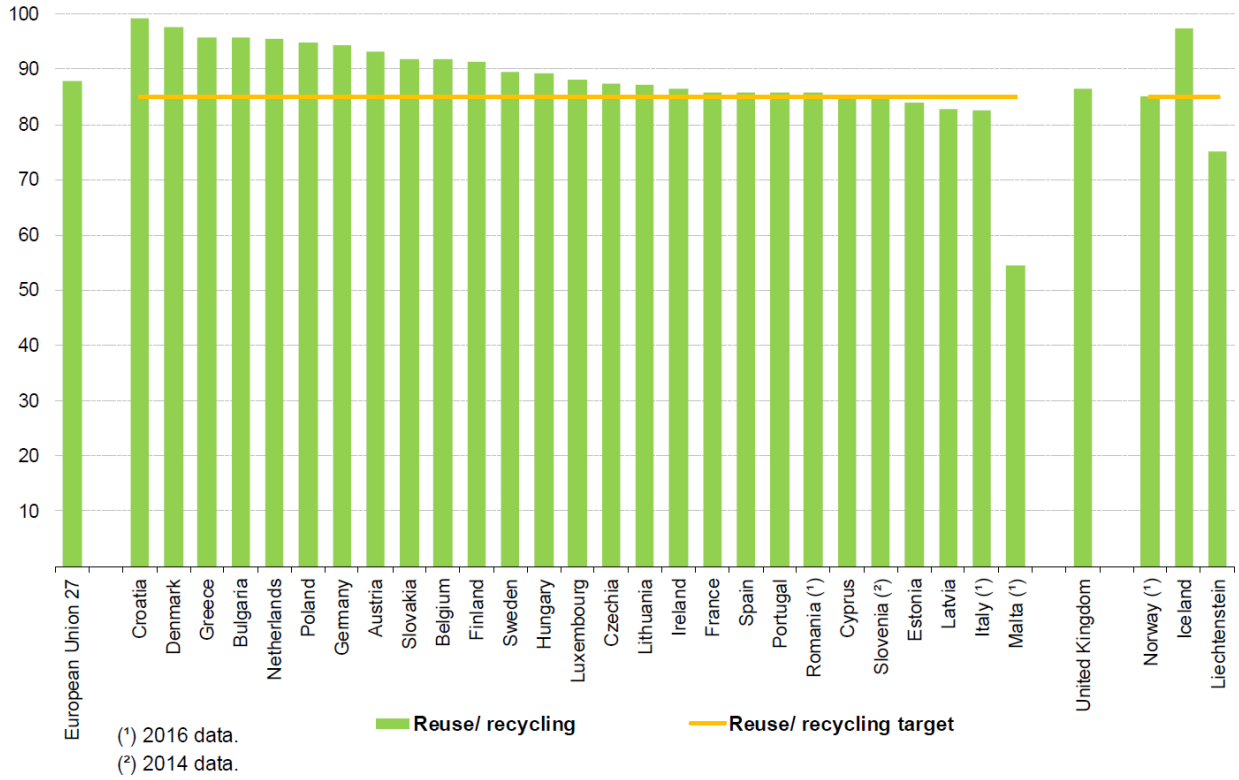

Figure 4 - Recyclability rate of vehicles at the end of their life cycle in 2017

- The share of reuse of parts and components from vehicles end-of-life cycle varies across the European Union, from zero to 33% (Figure 5). Variations may be caused by various reporting methodologies, as well as different conditions in the Member States;

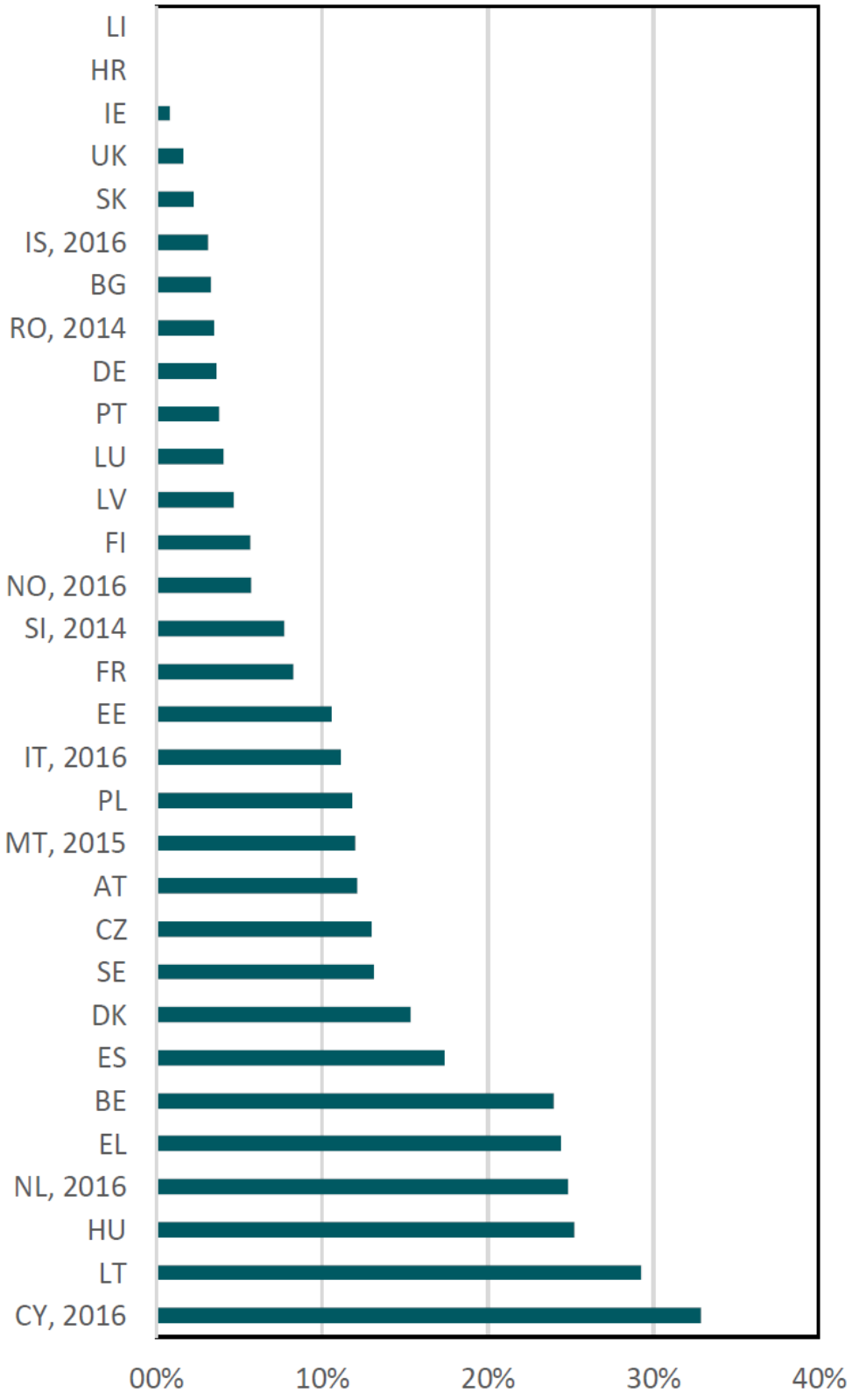

Figure 5 - The share of reuse in comparison to total share of reuse, recovery and waste disposal in 2017

- As shown in the Figure 6, some metals and metal components (such as catalytic converters and batteries) are almost 100% reused and/or recycled, but a significant part of some other materials (i.e., glass, tyres and most of the plastic) is directed to energy renewal or disposal in landfills;

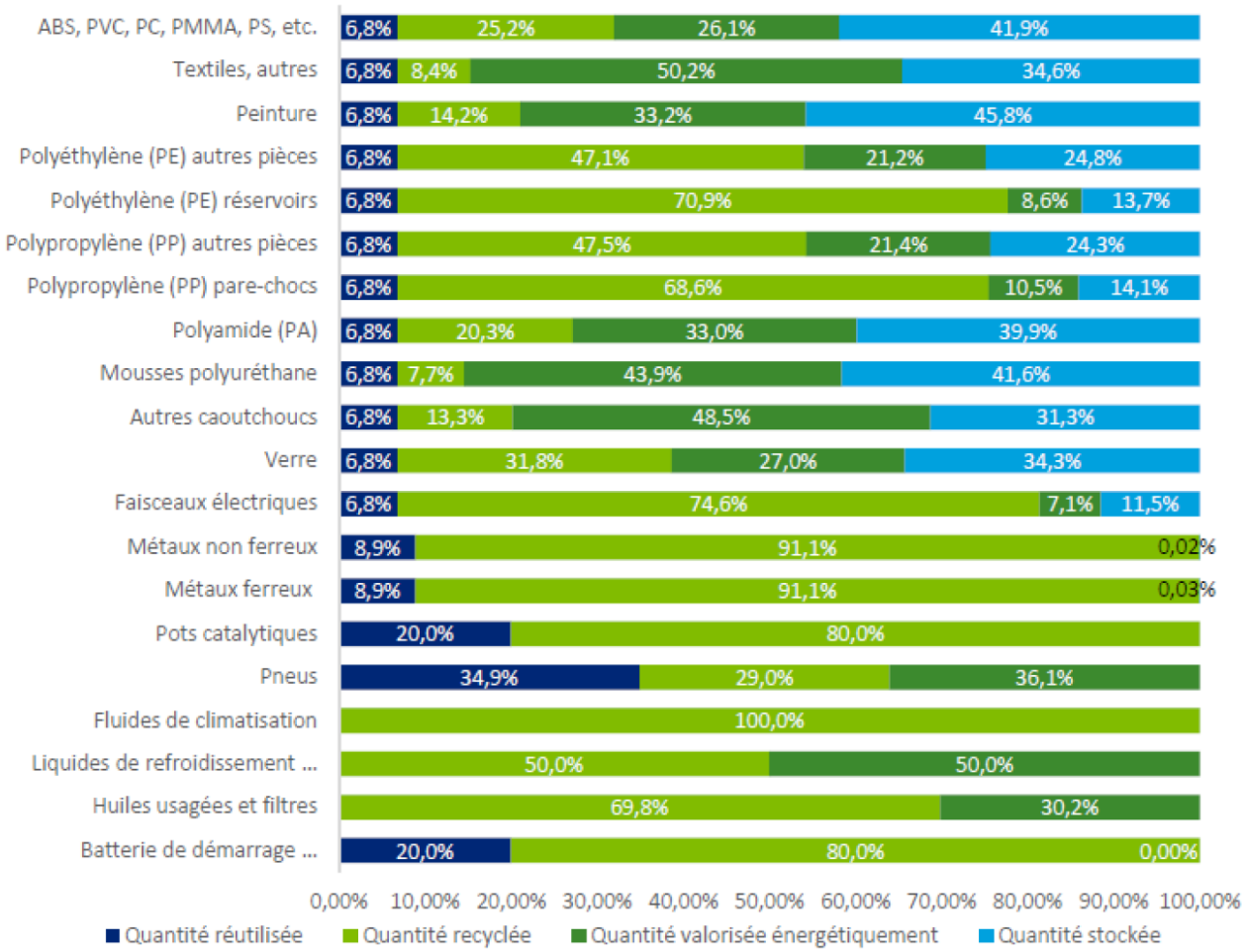

Figure 6 - Division according to type of treatment of each material in the vehicle at he end of its life cycle

- End-of-Life Vehicle Directive has established minimum technical requirements for treatments, which are used in authorized treatment facilities and cutting. Europe has around 14,000 authorized treatment facilities and 350 facilities for cutting vehicles. The number of standard and non-standard facilities before the implementation of the End-of-Life Vehicle Directive is unknown.

1.8. END-OF-LIFE VEHICLE TREATMENT: TECHNICAL BASIS

The following text provides an insight in the processes included in waste vehicle disposal, dismantling of components and shredding (+ additional shredding, which is not explicitly stated in the End-of-Life Vehicle Directive).

Typical treatment of the vehicle at the end of their life cycle is divided into different steps. First step is a treatment in the authorized treatment facility as is requested by the End-of-Life Vehicle Directive in Figure 7. Minimum requirements for installations for storage and treatment of vehicles at the end of their life cycle in such authorized treatment facilities are described in Annex I of the End-of-Life vehicle Directive. Additional national requirement may be established.

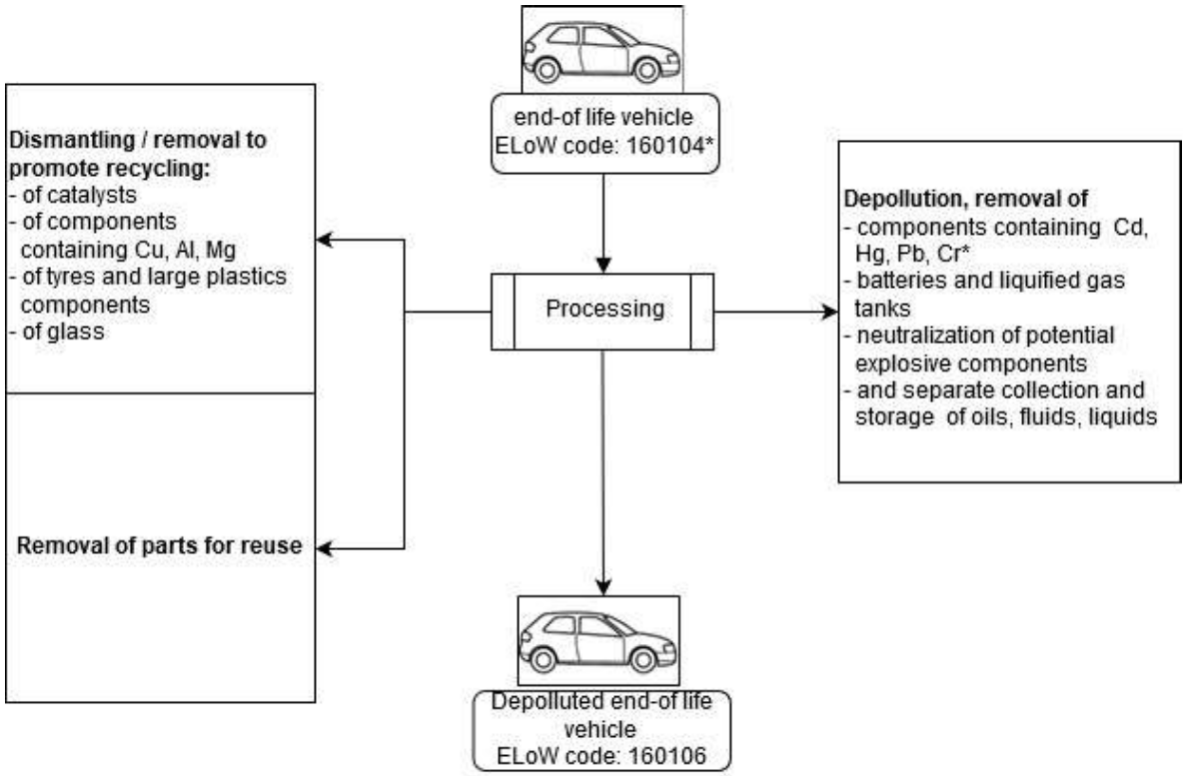

Figure 7 - Operations within the authorized treatment facility

Second step is shredding the end-of-life vehicle waste, as shown in the Figure 8. Facilities for cutting the vehicles at the end of their life cycle are regulated with referent documents with the best available techniques for waste treatment.

Facilities for cutting (some, not all of them) have integrated cutting processes (*Post Shredder Technologies*), or separate processes after cutting on the spot; other facilities for cutting send the remains of shredding process to off-site after-cutting facilities, for example, landfills if that is allowed.

Main results of the shredding process (which is considered by the sorting process and not with recycling process) are ferrous metals, aluminium and other metal fractions. *Shredder*

Light Fraction and some parts of *Shredder Heavy Fraction* are disposed of or treated in facilities with technologies and processes after cutting, as shown in the Figure 8. Technology of additional shredding is further processing of the cutting remains.

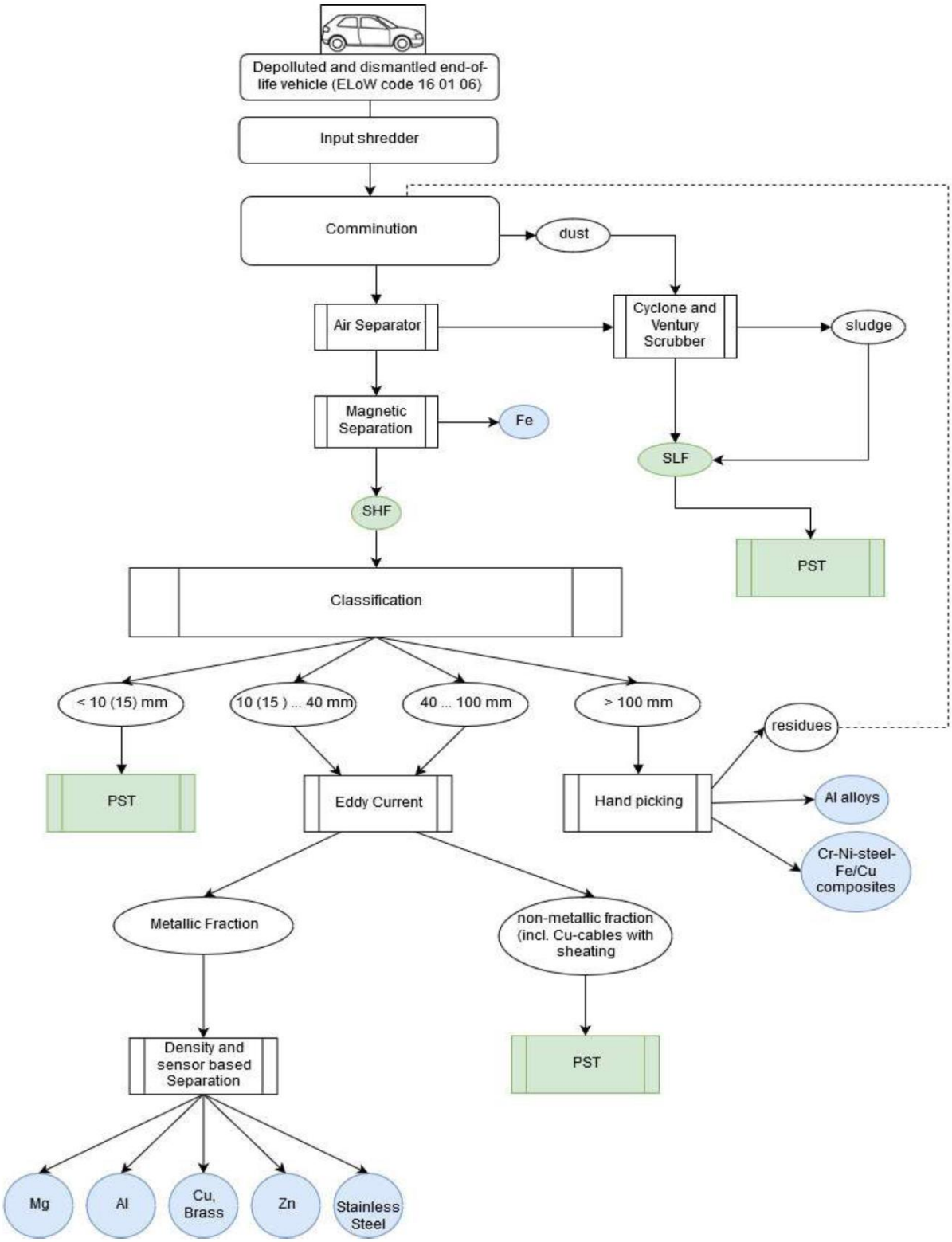

Figure 8 - Typical shredding process for end-of-life vehicles

Typical operations in the frame of after-cutting process are shown in the Figure 9. After-cutting processes are considered as necessary operations for fulfilling the recycling goals set by the End-of-Life Vehicle Directive.

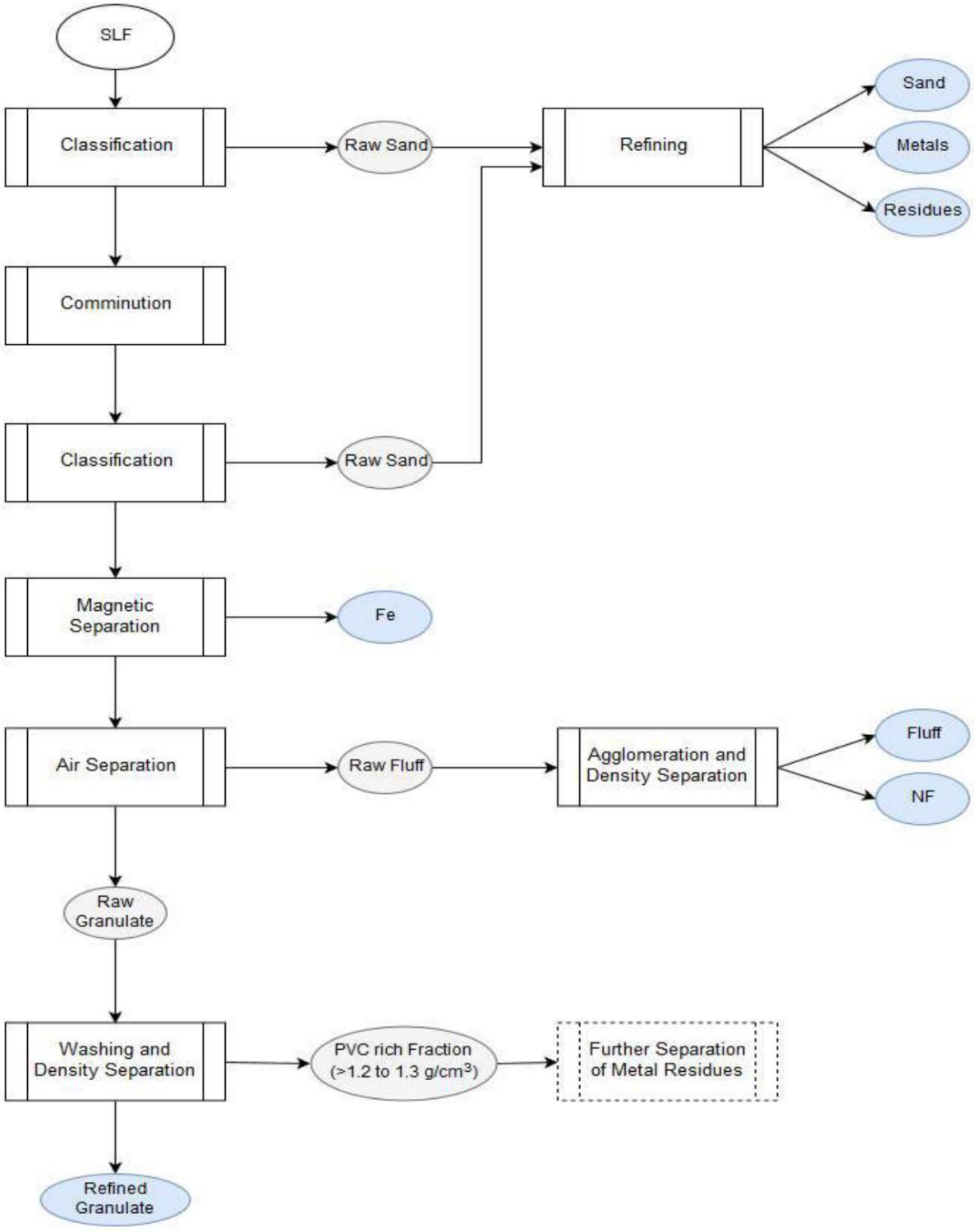

Figure 9 - Typical operations within the frame of after-cutting process

2. END-OF-LIFE VEHICLE RECYCLING APPROACH

Protection from waste accumulation, reuse, recycling and recovery of components that make up the end-of-life vehicle with the goal of reducing the waste disposal which occurred by cutting the metal waste, are the main tasks of the End-of-Life Vehicle Directive. Figure 10 is a schematic overview of participants in the end-of-life vehicle chain, in accordance with the Directive. Main participant is the manufacturer or a professional representative (importer) of vehicles in the Member State of the European Union. The Manufacturer is linked (according to suppliers) and linked down in the end-of-life vehicle chain (companies for collecting, dismantling, cutting). On the other side, cooperation between companies, which do collecting, dismantling and cutting is necessary, in order to fulfil the set goals of the Directive.

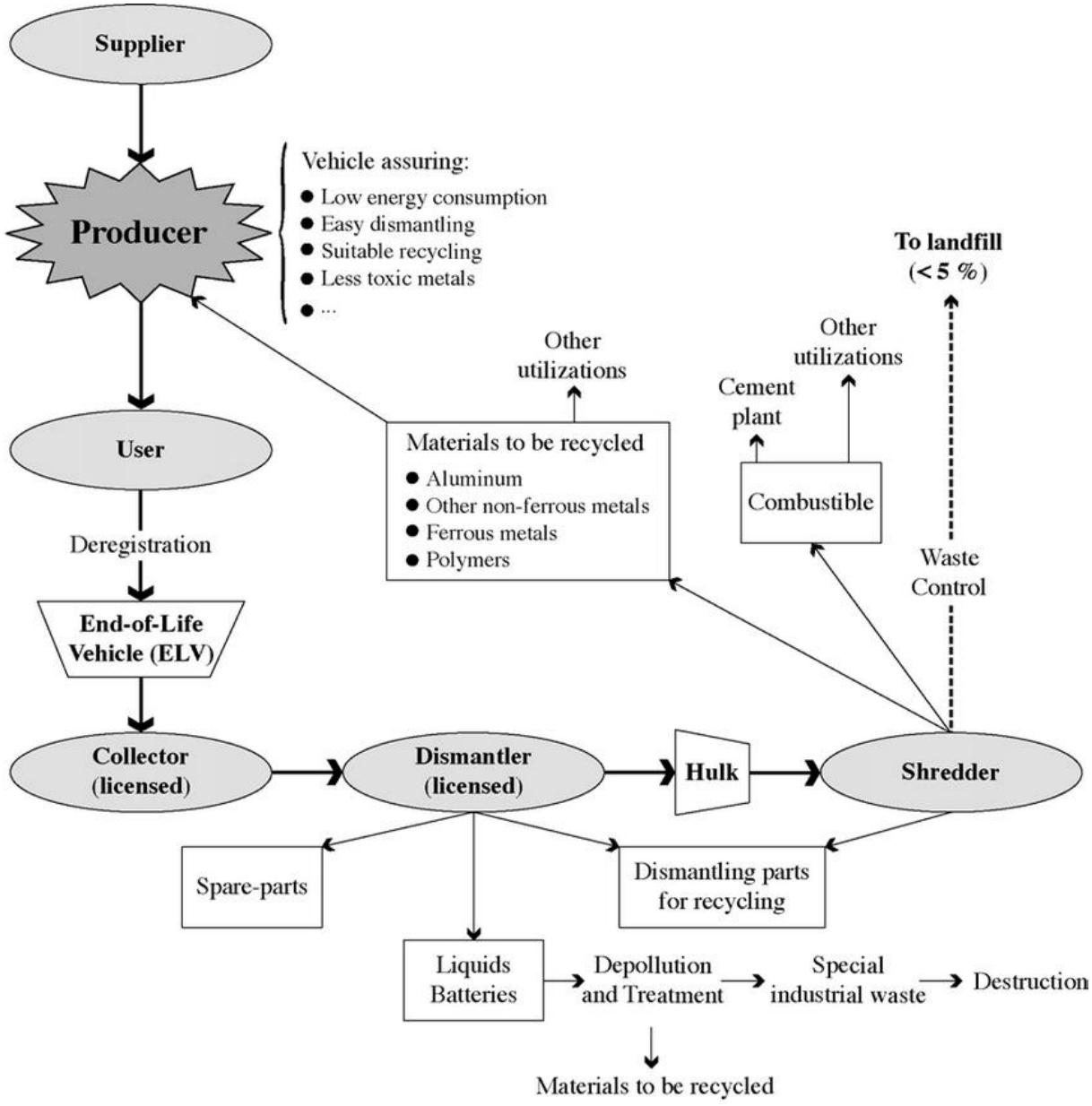

Figure 10 - Main steps through the recycling process according to End-of-Life Vehicle Directive

Manufactured vehicles should meet at least the following objectives: low fuel consumption, easy to dismantle, suitable for recycling, less toxic metals (as shown in the Figure 10). In order to meet these goals, the manufacturer must be aware of the technical and economic aspects, the recyclability rate, as well as the efficiency of the lower part of the end-of-life vehicle chain. On the other hand, the manufacturer should enable dismantling information for each new type of vehicle put on the market. The concept of vehicle adapted for dismantling, recycling and reuse, as well as being made without toxic substance (lead, mercury, cadmium or chromium), will considerably improve the cooperation within the supplier-manufacturer chain.

The End-of-Life Vehicle Directive demands that the companies for collecting and dismantling in the end-of-life vehicle chain are certified (licenced), and the result of this is that the number of licenced companies for dismantling in the European Union has rapidly increased, surpassing the figure of 1000 licenced companies per Member State in the first top five countries for vehicle production in the European Union. The role of the company for dismantling is removal of components and assemblies for further sale, if they could be used, such as an engine, transmission elements and body of a vehicle. According to the End-of-Life Vehicle Directive, the removal of potential pollutants from vehicles is becoming an important task in the framework of the company for dismantling. This includes, draining of fluids and removal of substances, which could harm the environment, as is the case with car batteries. Moreover, the companies for dismantling are certified to destroy the waste caused by removing the pollutants (Figure 10). These tasks of the dismantling companies should make further cutting of scrapped vehicle easier, as well as to reduce to cutting process residues, which occur as the result of work of the companies in business.

Steps in the cutting process include dismantling of small parts for recycling, further cutting, as well as separation of ferrous and non-ferrous metals. Separated materials then go to vehicle manufacturers for use in the manufacturing process of the same components they were originally used to make. Energy of flammable substances can be recovered at the end of the life cycle of vehicles by using them instead of fossil fuels in industrial process, such as cement factories. Remaining vehicle parts, cutting residue, go to landfills, which must have a strict waste control. That should be waste, which cannot be returned to recovery process for reuse.

Directive 2000/53/EC has served as a basis for introducing another Directive, 2005/64/EC, referring to the approval of vehicle type in relation to the reuse of components, recyclability and recoverability. This Directive very strictly prescribes the obligations of vehicle manufacturers as well as obligations of the Competent State Authority in the country of homologation regarding the control of compliance with the requirements of the Directive.

Some of the obligations of the vehicle manufacturers are:

- To deliver a complete required documentation related to material composition, display of data used in the calculation, list of components that can be dismantled;

- To define, together with the Competent State Authority, the reference vehicle that is submitted for testing in accordance with criteria defined by the Directive;
- To ensure vehicles and components for which the Competent State Authority consider are necessary;
- To ensure that all variants and versions within the defined type meet the requirements of the Directive;
- To define the so-called approved technologies of treating non-ferrous materials and recycling;
- For the purposes of information on the materials and substances used in the vehicle manufacturing process, the manufacturer declares that the processes related to restrictions on the application of materials and substances are applied to the defined type of vehicle.

Competent State Authority for homologation within its own jurisdiction should ensure that the vehicle manufacturer has taken necessary measures to:

- Collect necessary data through the whole chain of supply, especially regarding the origin and mass of all materials used in the vehicle production, in order to conduct calculation required by the Directive;
- Have available all other relevant vehicle data required by the calculation method, such as liquid volume, etc.;
- Properly check information received from the supplier;
- Form material composition;
- Prove the capability for conducting the calculation of the recyclability rate and recoverability in accordance with the ISO 22628:2002 standard;
- Verify that no one of the components from the list of those not considered adequate for reuse have been reused in the production of the vehicle;
- Mark the components made from polymers and elastomer in accordance with the requirements of the Directive.

In addition, the Directive 2005/64/EC defines the components that are not considered adequate for reuse, that is, they must not be reused in the vehicle production. There are the following components.

- All air-bags, including curtains, pyrotechnic actuators, electronic control units and sensors;
- Automatic or manual assemblies of safety belts, including strips, buckles, tensioners and pyrotechnic actuators;
- Seats (only when the safety belt connectors and/or air-bags are installed in the seat);
- Steering wheel locking assembly acting on the steering shaft;

- Immobilizers, including transponders and electronic control units;
- Systems for additional treatment of exhaust gases (i.e., catalytic converters, particle filters);
- Mufflers in the exhaust system.

When vehicle meets all requirements of the Directive 2005/64/EC, which is verified by the Report on testing of the Authorized Technical Service, the Competent State Authority for homologation issues a Approval Certificate, which is a proof of the fulfilment of the requirements. In practice, this means that no new vehicle (new type of vehicle), unless it possesses an Approval Certificate according to the Directive, cannot be put on the market, that is, cannot be found on the market.

The Directive 2005/64/EC has come into power as obligatory in November 2005, with application starting in December 2006 and onwards, depending on the level of requirements, which is included in the so-called transitional provisions.

In the process of global world economy growth, the goals of the Directives of the European Union become a sensitive question for the complete world manufacture in automotive industry. Thus, regulations and approaches to regulations of different countries can be compared with each other. If, for example, compare the regulations of Japan, as a major world vehicle manufacturer, with the regulations of the European Union, it is clear that most of the selected items from the regulations (i.e. terms of application, manufacturer's obligations, costs,…) are similar. In both cases, the vehicle manufacturers have the most important role in the infrastructure systems related to waste production, as well as collecting the treatment of end-of-life vehicles.

The situation is the same with the requirements of UN Regulation No. 133, which within the framework of the Contracting Parties of the Agreement from 1958 under Working Party WP.29, are applied to the issue of vehicles in the sense of their reuse, recycling and recoverability. Given that the number of countries that signed the Agreement from 1958 is much greater than the number of states of the European Union (by the way, all EU countries have also signed the aforementioned Agreement), the harmonization process of those countries lasted much longer, so UN Regulation No. 133 was published and applied only since June 2014. Almost all requirements of UN Regulation No. 133 are identical to the requirements of the Directive 2005/64/EC, which is in spirit of Harmonization of the European Union regulations with UN Regulations.

3. RECYCLABILITY AND RECOVERABILITY RATES

3.1. GENERAL

Aforementioned international legislation defines the calculation method for determining the recyclability rate and recoverability in accordance with the ISO 22628:2002 standard. The entire calculation is performed through four steps shown on the new vehicle, where components and materials can be considered at each step of the calculation:

- Preliminary preparation;
- Dismantling;
- Separation of substances;
- Non-metal residue treatment.

At the same time, for the purposes of calculation, the mass parameters are defined, which must be determined through the above four steps. Table 2 describes the mass designations used to calculate the recyclability rate and recoverability rate.

Table 2 - Masses – used designations and definitions

Designation	Description
m_p	Mass of materials considering the phase of preliminary preparation
m_D	Mass of materials considering the dismantling phase
m_M	Mass of metals considering the metal separation phase
m_{Tr}	Mass of materials considering the phase of non-metal residue treatment which could be considered recyclable
m_{Te}	Mass of materials considering the phase of non-metal residue treatment and which could be considered as renewable energy
m_V	Vehicle mass
NOTE: all masses are depicted in kilogrammes	

Masses m_p, m_D or m_m are determined in the first three steps, while the masses m_{Tr} or m_{Te} are determined in the final step.

3.2. MATERIAL COMPOSITION

Material composition of vehicles is formed by classification of materials used in the vehicle composition within the framework of the following seven categories:

a) Metals;

b) Polymers, excluding elastomers;

c) Elastomers;

d) Glass;

e) Liquids (fluids);

f) Modified organic natural materials (*MONM*), leather, wood, cardboard or cotton materials;

g) Other materials (components and materials for which the precise material composition cannot be formed, such as, mixtures, electronic and electrical components).

Forming the material composition is very important step and it represents the obligatory part in the vehicle testing procedure in order to obtain the Approval Certificate. As mentioned before, vehicle manufacturers are obliged, along with other necessary documentation, to submit material composition used in the vehicle production.

3.3. MASS DETERMINATION M_P, M_D, M_M, M_{TP} AND M_{TE}

3.3.1. PRELIMINARY PREPARATION – MASS DETERMINATION M_P

In this phase, the following components and materials are considered:

- All liquids (fluids);
- Batteries (car batteries);
- Oil filters;
- Tanks for liquid petroleum gas (LPG);
- Tanks for compressed natural gas (CNG);
- Tyres;
- Catalytic converters.

Fluids include fuel, engine oil, transmission oil (together with main, differential and auxiliary transmission oil and transmission distributor), power steering oil, engine coolant, brake oil, muffler oil, air conditioner coolant, windshield washer fluid, oil from engine mounts and vehicle hydraulic suspension systems.

For the needs of calculation, components, and materials in this phase of calculation are considered recoverable or recyclable.

Mass m_p is determined as the sum of all components and materials.

3.3.2. DISMANTLING – MASS DETERMINATION M_D

Some other components that can be considered reusable or recyclable may be considered at this phase, based on the following considerations:

As a general requirement, a component can be considered reusable, recyclable, or both depending on the level of decomposability, which is estimated, based on:

- Accessibility;
- Assembly technology;
- Approved dismantling technologies.

As a special requirement, the component is considered recyclable based on:

- Its material composition;
- Approved recycling technologies.

In order for the components to be recyclable, it must be indicated with which approved recycling technology they should be treated.

An additional requirement is that the reusability of the component should be a subject to consideration of safety and environmental hazards.

Mass m_D is determined as the sum of all parts, which are considered reusable or recyclable.

3.3.3. METAL SEPARATION – MASS DETERMINATION M_M

In this phase, all metals (ferrous and non-ferrous metals) that are not taken into account in the previous phase are considered. Consequently, both ferrous and non-ferrous metals are considered recyclable.

Mass m_M is determined as mass of all metals that remained on the vehicle after previous phase.

3.3.4. NON-METALLIC RESIDUE TREATMENT – MASS DETERMINATION M_{TP} AND M_{TE}

Residue of remaining materials (i.e., materials that have not been taken into account during previous preparation, dismantling and metal separation), make, the so-called, non-metallic residues.

In this phase, recyclable or recoverable residue or both can be considered.

Mass m_{Tp} is determined as a sum of non-metallic residue mass that are considered recyclable based on the approved recycling technologies (See Table 1).

Mass m_{Te} is determined as a sum of remaining masses that could potentially be used for energy renewal, after determining m_p, m_D, m_M and m_{Tp}.

Technology for energy renewal from polymers and elastomers is industrialized on the global scale. Therefore, polymers, elastomers, and other modified organic natural materials could potentially be recovered through these technologies.

3.4. CALCULATION OF THE RECYCLABILITY AND RECOVERABILITY RATE

3.4.1. RECYCLABILITY RATE

The Recyclability rate R_{cyc}, of the vehicle, as a percentage by mass (mass fraction in percent), is calculated according to the formula:

$$R_{cyc} = \frac{m_p + m_D + m_M + m_{Tr}}{m_V} \times 100$$

3.4.2. RECOVERABILITY RATE

The Recoverability rate R_{cov}, of the vehicle, as a percentage by mass (mass fraction in percent), is calculated according to the formula:

$$R_{cov} = \frac{m_p + m_D + m_M + m_{Tr} + m_{Te}}{m_V} \times 100$$

The recyclability rate and the recoverability rates are expressed in percentages (%). Considering that the required threshold values are quite high (the recyclability rate ≥ 85%, and the recoverability rate ≥ 95%), as well as that vehicle manufacturers try to keep the values “at the threshold” which is satisfactory, it is necessary to show the given values with one decimal place, with rounding as follows:

- If the number behind the decimal spot is between 0 and 4, it is rounded to the first lower integer value;
- If the number behind the decimal spot is between 5 and 9, it is rounded to the higher integer value.

Table 3 shows formalized overview of data received by the calculation method. This type of overview is also defined in accordance with ISO 22628:2002 standard and it represents an integral part of the manufacturer’s documentation, which is submitted to the Competent State Authority for homologation.

Table 3 - Formalized overview of the received data by using calculation method

Brand:					**Vehicle mass (m_V):**		kg
Model (type/variant):							
Material composition	**Metals**	**Polymers**	**Elastomers**	**Glass**	**Fluids**	**MONM**	**Other**
	Mass (kg)						

Preliminary preparation (m_p)			**Mass (kg)**	
	Fluids	m_{p1}		
	Battery	m_{p2}		
	Oil filter	m_{p3}		
	LPG Tanks	m_{p4}		
	CNG Tanks	m_{p5}		
	Tyres	m_{p6}		
	Catalytic converters	m_{p7}		
			Total m_p (sum from m_{p1} to m_{p7}) =	

Dismantling (m_D)

Component number	Name	Mass (kg)	Component number	Name	Mass (kg)	Mass (components 11 to x) kg	
1			6			m_{Dx} [a]	
2			7				
3			8				
4			9				
5			10				
Total m_{D1} (sum from m_{D1} to m_{D5}) =			Total m_{D2} (sum from m_{D6} to m_{D10}) =			Total m_D (m_{D1}+m_{D2}+m_{Dx}) =	

Metal separation (m_M)	Remaining content of metals on the vehicle:	**Mass (kg)**	
		m_M =	

Non-metallic residue treatment (m_{Tr} and m_{Te})	**Recyclable materials (m_{Tr})**			**Mass (kg)**	
	Technology no.	Name			
	1		m_{Tr1}		
	2		m_{Tr2}		
	3		m_{Tr3}		
	4 to x [a]		m_{Tr4-x}		
				Total m_{Tr} (sum m_{Tr1} to m_{Trx}) =	
	Energy renewable materials (m_{Te})			**Mass (kg)**	
	Remaining amount of organic materials (polymers, elastomers, MONM, ...):			m_{Te} =	

	Recyclability rate	$R_{cyc} = \frac{m_p + m_D + m_M + m_{Tr}}{m_V} \times 100$	%	
	Recoverability rate	$R_{cov} = \frac{m_p + m_D + m_M + m_{Tr} + m_{Te}}{m_V} \times 100$	%	

[a] Add separated lists of added components or technologies

In addition to the formalized overview of data obtained using the calculation method, Figure 11 shows the way of presenting data for the specific vehicle. By the way, this type of overview of data is an integral part of the Approval Certificate, according to the Directive 2005/64/EC or according to the UN Regulation No. 133.

BRAND NAME	Vehicle Mass m_v (kg)
FORD	1587.6
Model	
C520 FoE , 2017, C520 FoE 15 GTDI B6 RRR V02	

Material-breakdown	Metals (kg)	Polymers (kg)	Elastom. (kg)	Glass (kg)	Fluids (kg)	M.O.N. Mtls (kg)(1)	Others*(2)
	1109.9	271.5	69.9	57.2	70.5	4.8	3.7

(1): Modified organic natural materials (e.g. leather, wood, cardboard, cotton fleece)
(2): Other materials (e.g. Electronics and electrics) shall only include components for which the detailed material breakdown cannot easily be established

Pre-Treatment (m_p)

		Mass (kg)
Fluids	m_{P1}	64.3
Battery	m_{P2}	18.5
Oil filters	m_{P3}	0.2
L.P.G. tanks	m_{P4}	0.0
C.N.G. tanks	m_{P5}	0.0
Tyres	m_{P6}	46.2
Catalytic converters	m_{P7}	6.2
	m_P total: (mP1 to mP7)	135.4

Dismantling (m_D)

Name	Mass (kg)	Name	Mass (kg)	Mass (part 11 to x) (kg)	
				m_D x*	0.0
				* please add a separate list for part 11 to x	
D1 total (Σ1-5):	0.0	D2 total (Σ6-10):	0.0	m_D total: (mD1+mD2+mDx)	0.0

Metal Separation (m_M)

		Mass (kg)
Metal content of the Vehicle	m_M	1109.9
Metal already div in P and D	m_d	24.4
	m_M: (mM-md)	1085.6

Non Metallic Residue Treatment (m_{Tr} and m_{Te})

m_{Tr} = recyclable materials		Mass (kg)
Technology no 1	VW Sicon	65.0
Technology no 2		56.7
Technology no 3		6.7
4 to x *		
* please add a separate list for technologies 4 to x	m_{Tr} total: (S 1-x)	128.4
m_{Te} = energy recoverable materials		Mass (kg)
Remaining quantity of organic materials (incl. polymers,elastomers and modified organic natural materials)	m_{Te}:	158.8

Recyclability Rate	$R_{cyc} = \frac{m_P+m_D+m_M+m_{Tr} x\ 100}{m_V} =$	85.0%	1349.4 kg
Recoverability Rate	$R_{cov} = \frac{m_P+m_D+m_M+m_{Tr}+m_{Te} x\ 100}{m_V} =$	95.0%	1508.2 kg

Reference	Issue Date	Title
C520	25-Apr-2016	Recyclability Calculation ISO 22628
FORD	Revision Date: 06-Feb-2017	Attachment Number: HL-GV41-000057-001

Figure 11 - Formalized overview of data for the specific vehicle (Ford Kuga)

4. END-OF-LIFE VEHICLE STATISTICS

Constant annual growth of vehicles in use represents a great challenge to industry for vehicle recycling. In great number of cases, norms prescribed by Directives are not fulfilled, which causes additional accumulation of waste of vehicle industry. Considering the remarkable growth of electric vehicles in the last few years and plans that in the near future cars using fossil fuels to be put out of use, problems and negative impact of vehicle industry waste on the environment will become much greater with unpredictable speed.

End-of-life vehicles, 2008–2018
(number)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU-27 (¹)	*5 079 000*	*7 700 000*	*6 213 000*	*5 555 000*	*5 123 000*	*5 085 000*	*5 043 000*	*4 969 000*	*4 823 000*	*5 296 000*	*6 083 000*
Belgium	141 521	140 993	170 562	165 016	160 615	134 506	126 835	107 425	106 458	120 896	142 852
Bulgaria	38 600	55 330	69 287	62 937	57 532	61 673	80 862	85 946	92 706	102 442	99 835
Czechia	147 259	155 425	145 447	132 452	125 587	121 838	131 987	139 440	145 928	154 306	169 715
Denmark	101 042	96 830	100 480	93 487	106 504	125 650	104 413	98 929	89 039	117 124	117 519
Germany	417 534	1 778 593	500 193	466 160	476 601	500 322	512 163	473 386	412 801	506 531	560 455
Estonia	13 843	7 528	7 268	11 413	12 835	14 712	14 720	12 884	11 184	16 236	18 147
Ireland	127 612	152 455	158 237	134 960	102 073	92 467	86 950	74 910	98 213	140 788	162 521
Greece	55 201	115 670	95 162	112 454	84 456	86 205	82 863	87 050	46 573	39 761	47 141
Spain	748 071	952 367	839 637	671 927	687 824	734 776	724 820	689 760	611 446	620 055	748 306
France	1 109 876	1 570 593	1 583 283	1 515 432	1 209 477	1 115 280	1 084 766	1 016 326	1 046 083	1 138 742	1 571 776
Croatia (²)	:	:	:	:	35 213	*32 135*	19 388	16 900	20 386	21 074	27 404
Italy	1 203 184	1 610 137	1 246 546	952 461	902 611	876 052	853 584	958 245	978 960	990 876	1 030 318
Cyprus	14 273	17 303	13 219	17 145	17 547	13 212	11 160	8 293	5 151	5 453	7 523
Latvia	10 968	10 590	10 640	9 387	10 228	9 003	9 268	8 924	8 049	11 439	11 435
Lithuania	19 534	19 656	23 351	26 619	22 885	26 482	29 982	26 546	21 306	21 066	20 629
Luxembourg	2 865	6 908	6 303	2 341	2 834	2 290	2 225	1 617	1 854	1 972	3 103
Hungary	37 196	26 020	15 907	13 043	15 357	14 897	15 283	16 788	15 141	15 573	19 280
Malta	:	:	330	2 526	2 530	1 198	2 646	4 509	5 632	:	:
Netherlands	152 175	191 980	232 448	195 052	187 143	183 451	188 487	167 777	197 488	199 506	214 013
Austria	63 975	87 364	82 144	80 004	64 809	73 993	59 904	47 926	48 077	58 462	60 272
Poland	189 871	210 218	259 576	295 152	344 809	402 416	454 737	478 202	380 529	495 805	514 210
Portugal	107 746	107 946	107 419	77 929	92 008	92 112	86 713	84 158	88 559	99 910	107 140
Romania	51 577	55 875	190 790	128 839	57 950	37 989	42 138	41 886	46 572	:	:
Slovenia	6 780	7 043	6 807	6 598	5 447	:	6 260	:	:	:	:
Slovakia	39 769	67 795	35 174	39 171	33 469	36 858	29 175	26 176	36 931	35 328	39 343
Finland	103 000	96 270	119 000	136 000	119 000	99 300	94 540	99 630	114 460	128 280	120 040
Sweden	150 197	133 589	170 658	184 105	185 616	189 748	186 967	188 810	186 875	192 395	204 458
United Kingdom	1 210 294	1 327 517	1 157 438	1 220 873	1 163 123	1 149 459	1 106 846	995 527	1 103 050	1 390 185	1 406 975
Iceland	9 386	5 109	4 195	4 075	5 824	4 463	5 245	6 063	6 527	9 483	:
Liechtenstein	91	72	107	94	114	326	188	230	260	326	213
Norway	130 018	95 000	112 537	124 563	119 905	141 452	139 920	145 098	142 280	143 664	143 767

(:) not available
(¹) Eurostat estimates.
(²) 2013 data: estimated.
Source: Eurostat (online data code: env_waselvt)

eurostat

Figure 12 - Number of end-of-life vehicles in EU countries

In Figure 12, the number of end-of-life vehicles in EU countries in the period between 2008 and 2018 is shown. Manufacturers and analysts think that they do not produce as nearly as much vehicles as the users require. That can be confirmed by the data that on the territory of Europe in 2018, 15.46 million passenger vehicles have been sold, and only 6 million were excluded from traffic.

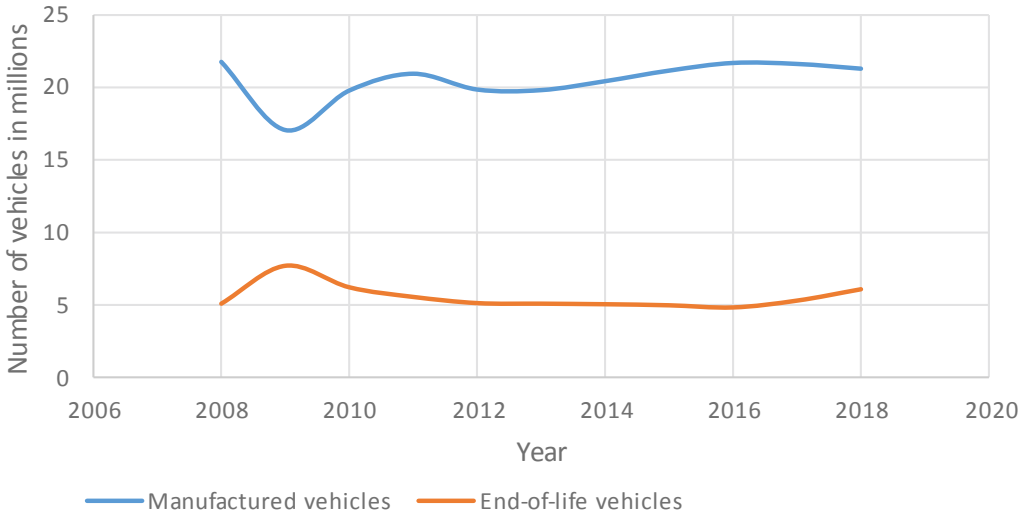

Figure 13 - Difference between the number of manufactured vehicles and end-of-life vehicles

The diagram on Figure 13 shows great difference between the number of manufactured vehicles and end-of-life vehicles on the territory of EU Member States in the period between 2008 and 2018. There are 14.96 million new vehicles annually.

VEHICLES IN USE, BY AGE

Passenger cars

	2019	2018	2017	2016	2015 (≤5 years)	2014	2013	2012	2011	2010 (≤10 years)	>10 years	Total	Average age (in years)
Austria	285,606	308,882	332,294	315,133	297,271	288,496	295,397	307,447	314,571	276,887	2,017,564	5,039,548	8.3
Belgium	501,259	503,310	491,963	464,002	383,339	343,458	324,597	306,945	345,576	304,529	1,844,793	5,813,771	9.1
Croatia	–	–	–	–	(326,638)	–	–	–	–	(577,463)	1,151,448	1,728,911	14.6
Czech Republic	249,915	261,437	271,595	259,693	230,857	192,314	164,736	174,009	173,282	169,236	3,842,464	5,989,538	14.9
Denmark	204,400	194,911	199,529	194,935	190,272	176,067	171,142	159,901	147,326	127,000	884,742	2,650,225	8.8
Estonia	24,406	23,851	23,920	23,579	23,709	24,809	23,994	25,379	24,702	18,827	557,750	794,926	16.7
Finland	109,595	120,061	121,033	125,674	118,500	115,618	112,924	119,808	136,638	119,861	1,520,595	2,720,307	12.2
France	2,341,000	2,317,000	2,257,000	2,155,000	1,929,000	1,783,000	1,798,000	1,877,000	2,127,000	2,135,000	17,496,000	38,215,000	10.2
Germany	3,285,437	3,210,512	3,261,026	2,966,117	2,762,454	2,585,468	2,469,862	2,525,996	2,516,171	2,206,106	19,926,828	47,715,977	9.6
Greece	113,338	101,807	86,389	77,335	74,201	68,905	56,793	56,411	92,891	133,836	4,385,389	5,247,295	16.0
Hungary	128,092	114,861	104,364	92,300	87,636	86,204	82,734	90,066	93,399	87,281	2,842,733	3,809,670	13.5
Ireland	109,291	130,068	143,340	174,698	166,377	144,939	121,765	126,383	134,011	132,120	789,106	2,172,098	8.4
Italy	2,029,591	2,007,930	2,037,790	1,880,704	1,595,948	1,346,404	1,262,557	1,318,654	1,627,793	1,808,837	22,629,024	39,545,232	11.4
Latvia	15,916	14,857	15,193	14,228	14,299	15,446	15,184	17,859	20,191	17,669	496,033	656,875	14.0
Lithuania	23,563	22,515	22,158	21,683	24,679	24,055	25,864	29,057	35,124	34,566	1,000,820	1,264,084	16.8
Luxembourg	51,833	49,209	46,109	39,681	30,220	28,188	23,073	22,088	19,720	17,641	98,562	426,324	6.5
Netherlands	459,707	489,807	467,214	440,747	500,072	430,337	450,401	522,362	569,585	497,072	4,111,268	8,938,572	11.0
Poland	531,468	505,680	482,966	450,386	431,814	415,563	418,421	466,058	547,161	580,255	19,530,394	24,360,166	14.1
Portugal	208,695	230,258	232,313	228,281	217,139	190,093	155,304	138,620	186,895	244,511	3,172,891	5,205,000	12.8
Romania	120,525	94,337	74,658	105,869	112,239	130,196	158,909	107,748	122,792	193,481	5,680,482	6,901,236	16.5
Slovakia	98,388	93,195	92,993	92,334	88,967	87,078	81,922	88,351	95,463	93,247	1,479,417	2,391,355	14.0
Slovenia	46,658	53,885	59,701	62,352	65,768	61,557	58,579	61,276	67,699	62,195	645,342	1,245,012	11.7
Spain	1,205,207	1,221,166	1,131,544	1,054,954	958,807	794,514	659,317	624,794	725,718	905,502	15,726,693	25,008,216	12.7
Sweden	248,495	302,351	331,331	330,630	303,864	272,967	239,857	236,915	269,202	251,892	2,100,400	4,887,904	10.0
EUROPEAN UNION													11.5
Norway	142,556	153,187	165,836	157,307	163,533	156,395	157,758	156,044	157,641	143,879	1,214,854	2,768,990	10.7
Switzerland	302,951	299,997	310,698	311,850	318,902	295,320	294,662	308,759	292,554	250,133	1,586,362	4,572,188	8.6
United Kingdom	2,296,506	2,333,720	2,485,552	2,610,586	2,525,071	2,352,984	2,132,636	1,894,148	1,765,108	1,819,666	12,952,282	35,168,259	8.0

Figure 14 - Number of vehicles in use per production year

Figure 14 shows us drastic differences between in EU countries, when approximate annual production of vehicles in use for 2019.

Total recovery and reuse rate of end-of-life vehicles, 2008–2018
(% of weight of vehicles)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU-27	85.8	85.3	87.6	89.2	89.9	90.6	91.4	92.8	92.7	93.7	92.9
Belgium	90.2	90.6	91.2	90.6	93.0	93.0	94.2	96.7	96.4	97.3	97.3
Bulgaria	86.7	89.2	89.2	92.0	91.3	94.1	95.0	95.1	95.6	98.8	95.8
Czechia	86.0	86.3	86.3	86.3	86.3	86.3	86.3	95.7	95.4	95.6	99.3
Denmark (*)	82.9	82.3	90.7	92.9	92.6	86.7	86.1	97.6	97.1	99.6	98.2
Germany	92.9	86.7	106.2	108.2	106.3	103.8	101.4	95.8	98.0	98.4	95.7
Estonia	92.7	87.4	78.4	79.0	85.1	86.4	88.4	87.0	89.8	89.9	91.2
Ireland	81.8	82.3	77.4	82.7	87.8	91.6	90.7	91.8	92.8	94.6	95.2
Greece	85.7	87.4	86.5	87.7	90.3	91.5	85.5	68.9	108.0	99.5	108.3
Spain	85.7	86.0	85.7	87.4	88.2	91.5	93.5	95.0	93.4	94.0	92.6
France	81.4	82.1	81.9	84.8	87.0	89.3	91.3	94.3	94.8	94.6	94.2
Croatia	:	:	:	:	99.9	100.0	96.2	99.5	99.5	99.7	97.7
Italy	87.1	84.6	85.4	85.3	82.3	82.8	85.1	84.7	82.6	83.2	82.6
Cyprus	79.8	92.9	86.9	86.6	86.9	86.6	90.2	90.7	93.2	91.9	96.8
Latvia	89.0	86.0	86.1	86.0	97.9	92.6	92.4	87.0	94.5	84.1	96.0
Lithuania	85.0	86.0	88.5	87.4	90.1	92.4	94.4	95.0	95.4	95.1	95.4
Luxembourg	85.0	85.0	88.0	90.9	95.0	95.0	95.0	97.0	96.0	96.2	95.9
Hungary	84.4	86.2	86.8	86.2	86.2	91.7	95.6	95.2	95.8	96.9	95.8
Malta	:	:	64.2	87.1	96.0	91.9	45.0	77.7	54.4	:	:
Netherlands	85.6	85.2	95.3	96.2	96.1	95.9	96.0	97.0	98.7	98.7	98.4
Austria	96.1	96.1	96.5	97.6	94.2	96.7	96.1	96.9	96.9	97.9	97.8
Poland	80.1	88.0	89.8	91.5	92.8	90.3	88.0	97.0	96.3	98.6	95.3
Portugal	87.2	86.9	86.8	87.9	87.6	90.5	92.7	92.7	92.1	93.8	94.9
Romania	86.5	85.3	85.5	86.8	86.0	87.4	88.5	90.8	92.1	:	:
Slovenia	89.7	87.3	90.6	90.3	103.0	:	91.3	:	:	:	:
Slovakia	88.8	89.6	90.2	94.6	91.2	93.7	96.0	89.4	97.4	97.5	96.8
Finland	81.0	81.0	95.0	95.0	95.0	95.0	97.3	97.3	97.3	97.3	97.3
Sweden	91.0	90.0	91.1	90.8	90.6	91.3	91.3	96.8	94.6	97.2	95.3
United Kingdom	84.0	83.5	85.6	85.6	88.1	88.9	90.7	96.9	92.2	94.1	92.8
Iceland	98.3	83.0	95.2	82.0	100.0	99.6	97.7	98.5	96.8	97.6	:
Liechtenstein	100.0	92.3	92.3	92.4	92.7	89.0	90.6	90.8	85.6	84.7	85.7
Norway	82.7	86.0	94.7	93.3	93.8	94.7	97.5	96.7	97.7	97.2	97.4

(:) not available
(*) 2013 data: estimated.
Source: Eurostat (online data code: env_waselvt)

eurostat

Figure 15 - Mass recoverability rate of end-of-life vehicles in EU countries

As mentioned previously, Directive 2000/53/EC, defines the mass recoverability rate of vehicles, which was increased from 85% to 95% of total mass in 2015. Figure 15 shows us that in the period from 2015 to 2018, not once has the satisfactory recoverability rate on the territory of EU countries has been achieved, even though many countries were successful in that.

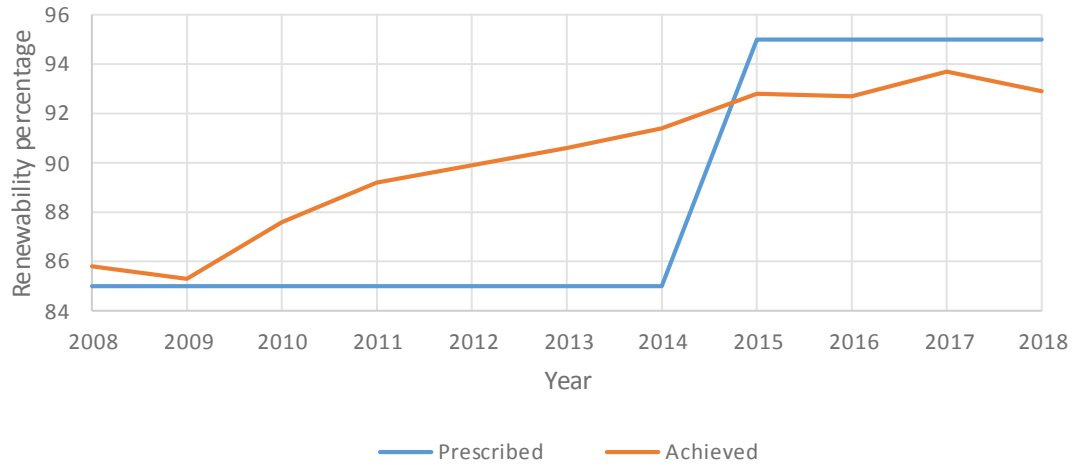

Figure 16 - Ratio of prescribed and achieved recoverability rate in EU countries

Total recycling and reuse rate of end-of-life vehicles, 2008–2018
(% of weight of vehicles)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU-27	82.9	82.0	83.5	84.4	84.6	85.3	85.4	87.0	87.1	87.9	87.3
Belgium	88.0	88.4	89.0	88.2	88.7	88.2	89.2	91.3	92.1	93.2	93.5
Bulgaria	81.0	82.7	88.9	90.0	89.5	93.2	94.1	94.4	94.6	97.6	94.8
Czechia	80.0	80.3	80.3	80.3	80.3	80.3	80.3	90.2	90.3	91.9	95.5
Denmark (¹)	82.7	82.0	90.5	92.8	92.4	*86.6*	86.0	91.2	88.8	91.5	89.9
Germany	89.2	82.9	95.5	93.4	92.3	89.8	89.5	87.7	89.3	89.5	87.1
Estonia	92.4	87.2	77.3	76.1	80.9	77.7	87.0	86.0	85.8	85.9	87.1
Ireland	75.9	78.9	77.0	80.5	81.8	80.4	82.1	83.3	86.0	85.9	86.4
Greece (²)	85.7	86.5	84.5	85.2	82.8	88.8	80.4	64.5	*100.0*	91.9	98.7
Spain	82.5	82.6	82.8	82.9	83.0	83.6	84.3	85.0	85.4	85.8	85.9
France	79.9	78.6	79.0	80.8	82.4	85.3	85.9	87.5	86.9	87.4	86.9
Croatia	:	:	:	:	97.2	100.0	89.5	92.8	93.9	99.3	97.4
Italy	84.3	81.8	83.2	84.8	80.8	82.2	83.4	84.6	82.5	83.2	82.6
Cyprus	78.3	87.1	81.1	84.0	84.7	84.3	87.7	89.1	90.3	89.2	89.8
Latvia	87.0	85.0	85.7	85.4	97.6	92.4	92.2	86.6	94.3	84.0	96.0
Lithuania	85.0	86.0	88.1	87.2	89.2	92.1	93.5	94.6	94.9	94.8	92.4
Luxembourg	84.0	81.0	85.0	82.9	85.0	84.0	87.0	87.0	86.0	94.3	94.1
Hungary	83.0	84.4	82.1	84.4	84.4	90.7	90.3	94.6	95.4	95.5	95.1
Malta	:	:	64.2	87.0	95.8	91.9	45.0	77.7	54.4	:	:
Netherlands	84.4	84.1	83.3	83.1	83.7	86.0	86.1	87.7	88.9	87.1	87.1
Austria	83.7	82.9	84.2	82.8	83.4	85.0	85.8	86.9	87.2	86.6	86.2
Poland	79.5	87.1	88.8	89.5	90.4	88.6	85.5	94.7	94.3	95.7	93.4
Portugal	80.8	84.3	82.8	82.9	82.7	82.9	83.8	84.0	83.5	85.2	86.1
Romania	83.7	80.1	80.9	82.9	84.0	83.8	84.1	85.1	85.1	:	:
Slovenia	87.6	84.1	88.6	86.1	100.0	:	85.9	:	:	:	:
Slovakia	88.4	88.8	88.4	93.1	89.9	92.5	94.8	88.4	96.1	95.7	95.1
Finland	81.0	81.0	82.5	82.5	82.5	82.5	82.8	82.8	82.8	82.8	82.8
Sweden	83.0	86.0	84.4	84.4	85.0	84.6	84.4	84.6	86.7	88.2	86.8
United Kingdom	82.5	82.1	83.0	83.4	84.1	85.5	86.9	87.3	86.4	86.5	85.2
Iceland	98.2	83.0	95.2	82.0	100.0	99.6	97.7	98.5	96.8	97.5	:
Liechtenstein	96.0	76.0	76.0	80.0	77.2	78.2	78.7	80.5	75.6	75.1	74.5
Norway	82.2	83.0	83.9	73.6	75.5	75.4	82.9	85.2	85.2	86.2	87.7

(:) not available
(¹) 2013 data: estimated.
(²) 2016 data: estimated.
Source: Eurostat (online data code: env_waselvt)

eurostat

Figure 17 - Mass recyclability rate of end-of-life vehicles in EU countries

In contrast to recoverability rate, recyclability rate, which is also prescribed by the Directive 2000/53/EC (85% from 2015) was achieved every time until 2018 at the level of EU. However, many countries lag far behind.

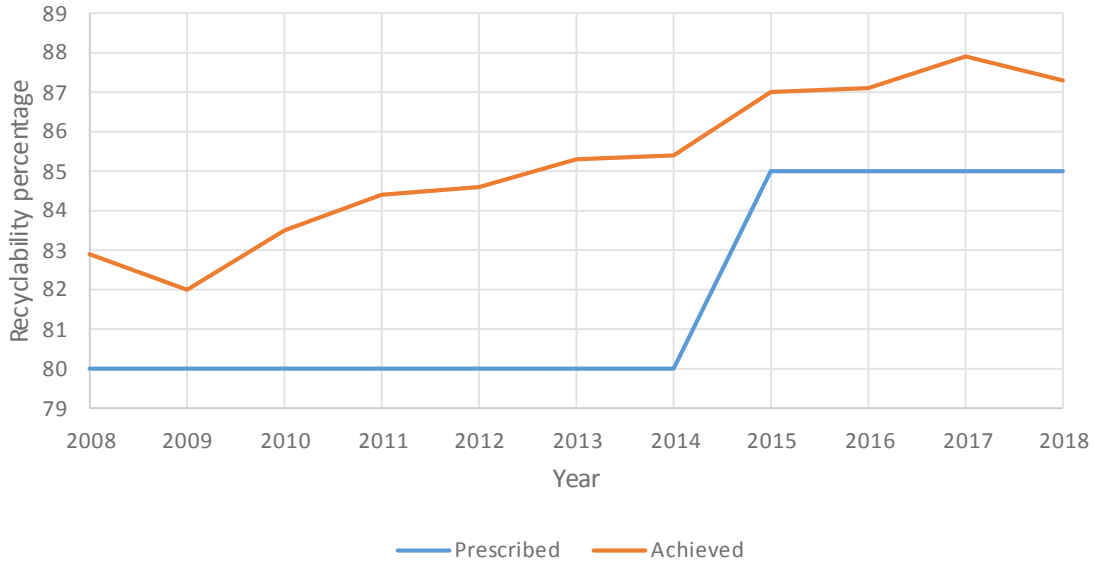

Figure 18 - Ratio of prescribed and achieved recyclability rate in EU countries

Total vehicle weight according to registration papers, 2008–2018
(tonnes)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU-27 (1)	*4 789 000*	*7 108 000*	*6 096 000*	*5 540 000*	*5 109 000*	*5 332 000*	*5 279 000*	*5 217 000*	*5 128 000*	*5 699 000*	*6 732 000*
Belgium	144 121	144 726	176 446	171 747	171 466	145 652	138 703	119 054	119 188	148 459	177 439
Bulgaria	38 600	63 027	74 422	65 428	59 191	62 723	82 258	88 066	92 111	104 457	103 032
Czechia	132 533	147 217	135 479	118 147	114 800	114 833	122 450	131 392	139 881	160 587	171 412
Denmark (2)	101 173	99 515	104 866	100 816	114 392	*128 869*	118 597	109 762	100 957	134 331	136 717
Germany	387 693	1 596 831	516 128	468 459	475 719	490 771	502 656	474 379	420 113	530 311	595 761
Estonia	13 716	7 712	7 679	12 123	14 056	16 391	16 617	14 857	14 113	19 539	22 015
Ireland	136 624	163 070	169 155	139 279	105 339	98 015	92 208	79 405	104 105	149 235	172 273
Greece	51 828	115 849	92 158	104 590	78 433	81 619	79 668	84 046	45 570	38 654	45 971
Spain	712 440	913 787	805 623	644 707	659 960	772 110	761 648	724 807	642 514	651 560	858 686
France	1 046 624	1 464 843	1 548 451	1 501 850	1 229 096	1 210 605	1 115 190	1 057 580	1 103 927	1 221 498	1 718 098
Croatia	:	:	:	:	33 221	29 017	22 584	19 617	18 912	24 662	30 616
Italy	1 106 929	1 379 027	1 240 204	986 391	874 887	959 542	953 690	1 036 562	1 086 425	1 096 145	1 201 500
Cyprus	12 703	15 400	11 764	15 259	15 617	11 759	10 468	8 152	5 094	5 159	7 267
Latvia	10 578	8 946	9 650	10 115	10 435	9 037	8 983	8 989	8 253	11 681	11 061
Lithuania	19 426	19 014	22 885	27 823	26 187	31 037	33 265	31 037	27 752	27 140	27 579
Luxembourg	2 537	6 517	6 115	2 154	2 750	2 501	2 258	1 746	2 063	2 048	3 413
Hungary (3)	28 287	27 419	15 589	14 959	14 388	14 865	*13 887*	13 380	12 527	14 249	15 925
Malta	:	:	288	2 225	2 177	1 050	2 835	4 803	6 322	:	:
Netherlands	146 316	187 296	232 239	198 173	191 260	189 138	196 215	174 152	204 400	206 489	223 216
Austria	52 202	74 211	67 997	67 384	56 180	65 475	53 310	43 934	45 338	57 065	61 149
Poland	170 100	192 281	217 636	284 307	340 212	401 639	462 202	493 468	395 216	522 299	551 221
Portugal	95 691	95 703	96 242	71 664	87 020	85 960	81 193	80 494	84 473	96 794	104 274
Romania	44 031	48 424	162 276	110 035	50 732	34 566	38 137	38 851	44 637	:	:
Slovenia	4 790	5 428	5 305	5 703	4 528	:	5 960	:	:	:	:
Slovakia	29 885	54 051	27 396	30 341	26 373	29 678	24 710	23 199	34 822	33 183	38 036
Finland	96 130	89 849	118 976	135 973	118 976	99 280	101 822	107 302	123 273	138 158	129 283
Sweden	178 524	162 391	207 554	226 504	231 218	240 626	237 605	242 411	240 697	249 361	266 668
United Kingdom	1 175 195	1 289 019	1 123 872	1 185 468	1 129 392	1 116 125	1 074 747	966 657	1 246 447	1 570 909	1 589 882
Iceland	9 177	4 560	4 380	4 207	5 786	5 779	6 834	7 721	8 536	12 656	:
Liechtenstein	101	80	121	105	123	354	202	261	291	373	251
Norway	134 179	98 040	116 138	130 066	141 115	163 518	158 389	177 542	176 216	180 884	188 109

(:) not available
(1) Eurostat estimates.
(2) 2013 data: estimate.
(3) 2014 data: estimate.
Source: Eurostat (online data code: env_waselvt)

eurostat

Figure 19 - Total end-of-life vehicle mass in EU countries

On Figure 19, we can consider the total mass of end-of-life vehicles across EU Member States in the period from 2008 until 2018. If we look at the percentage of unusable vehicle material, we can conclude that approximately 560,000 tonnes of waste after vehicle recycle on the territory of Europe is accumulated.

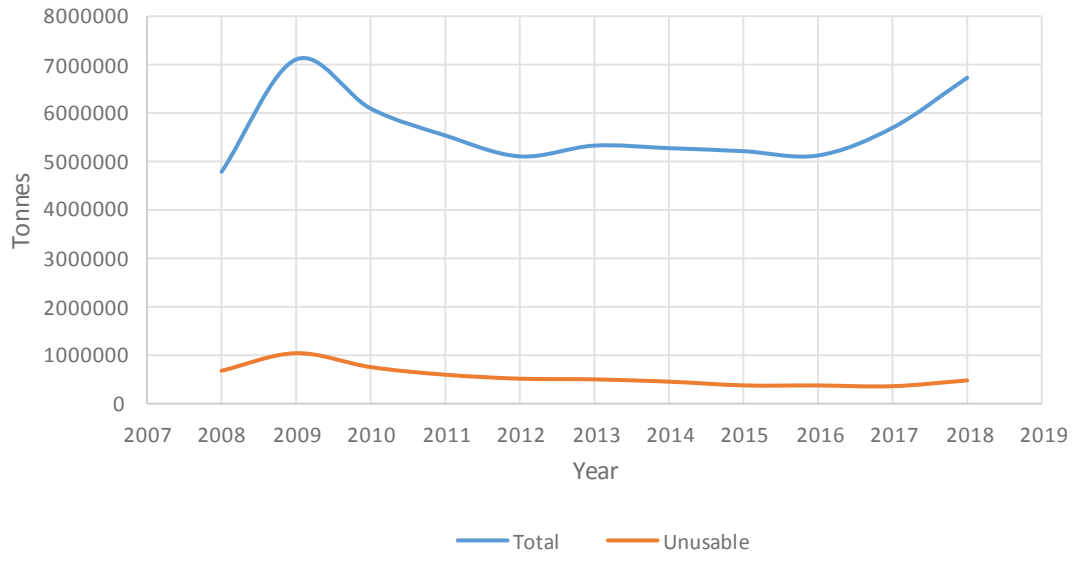

Figure 20 - Ratio of total and unusable end-of-life vehicle mass, example from France in 2016

We will consider the process and results of end-of-life vehicle recycling using the example of France in 2016.

There are 1,046,083 processed vehicles with approximate mass of 1,065.78 kilogrammes. Total amount of vehicle mass entering the recycling process in 2016 in France 1,114,988.5 tonnes. As much as 92.4% of the total number of those processed were passenger vehicles being 18.2 years old on average.

The graphic representation in Figure 21 shows the relationship of origin of vehicles entering the recycling process. We can see that almost half of the passenger vehicles are attached individual.

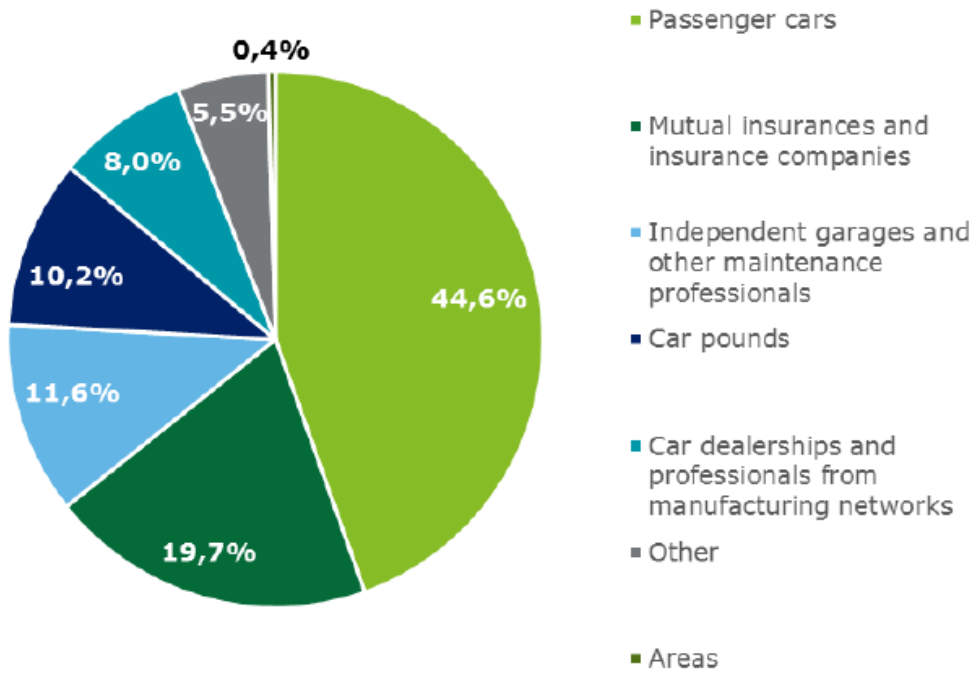

Figure 21 - The percentage of end-of-life vehicles, example from France in 2016

Material	Proportion of each material in %	Weight of each material in kg/ELV	Rectified weight of each material in kg/ELV	2015-2016 Evolution
Ferrous metals	70.0%	746.05	746.05	1.38%
Polypropylene (PP), other parts	4.4%	46.89	44.53	1.53%
Non-ferrous metals (excluding wiring harnesses)	4.0%	42.63	42.63	1.38%
Tires	3.4%	36.24	36.24	1.40%
Glass	3.0%	31.97	30.36	1.54%
ABS, PVC, PC, PMMA, PS, etc.	2.2%	23.45	22.27	1.55%
Polyurethane foams	2.0%	21.32	20.24	1.50%
Textiles, other	1.7%	17.59	16.7	1.52%
Lead-acid starter battery	1.4%	14.92	14.92	1.36%
Other rubbers	1.1%	11.72	11.13	1.55%
Polypropylene (PP), bumpers	1.1%	11.72	11.13	1.55%
Wiring harnesses	1.0%	10.66	10.12	1.50%
Polyamide (PA)	1.0%	10.66	10.12	1.50%
Paint	0.8%	8.53	8.1	1.63%
Polyethylene (PE), fuel tanks	0.8%	8.53	8.1	1.63%
Used oil and filters	0.7%	7.03	7.03	1.30%
Catalytic converters	0.5%	5.33	5.33	1.33%
Polyethylene (PE), other parts	0.5%	5.33	5.06	1.61%
Coolant or brake fluid	0.4%	4.69	4.69	1.30%
Conditioning fluids	0.1%	0.53	0.53	0.00%
Total	100.0%	1065.78	1055.3	1.41%

Figure 22 - End-of-life vehicle composition

In the table in Figure 22, we can see various materials and parts and their approximate mass fraction on the vehicle, after the dismantling process. As expected, the largest part, as much as 70%, consists of ferrous metals.

By the decontamination process, 28,340 tonnes of vehicle waste was accumulated, from which 71% was recycled.

Tyres approximately make 3.4%, which is 37,907 tonnes in 2016. Only 25% of tyres was recycled, and 37% is reusable.

96,189 tonnes of parts was dismantled from vehicles, which could be reused (approximately 92 kilogrammes per vehicle). Total mass amounts to 8.5 million parts.

After the dismantling process, 80,426 tonnes were prepared for recycling or recovery.

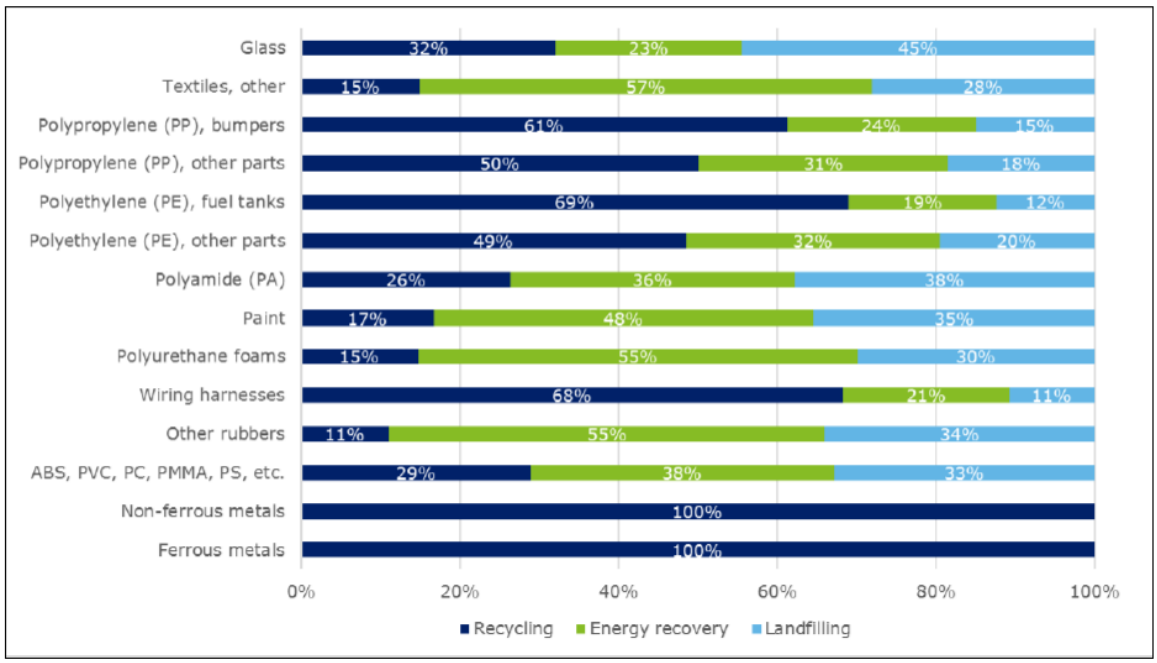

Figure 23 - Crusher performance percentage for each material (dark blue – recycling, green – renewable energy, light blue - landfills)

As presented in Figure 23 we can see that the percentage share of recycled and recovered material. An average of 71% of non-metallic material was recovered in shredders.

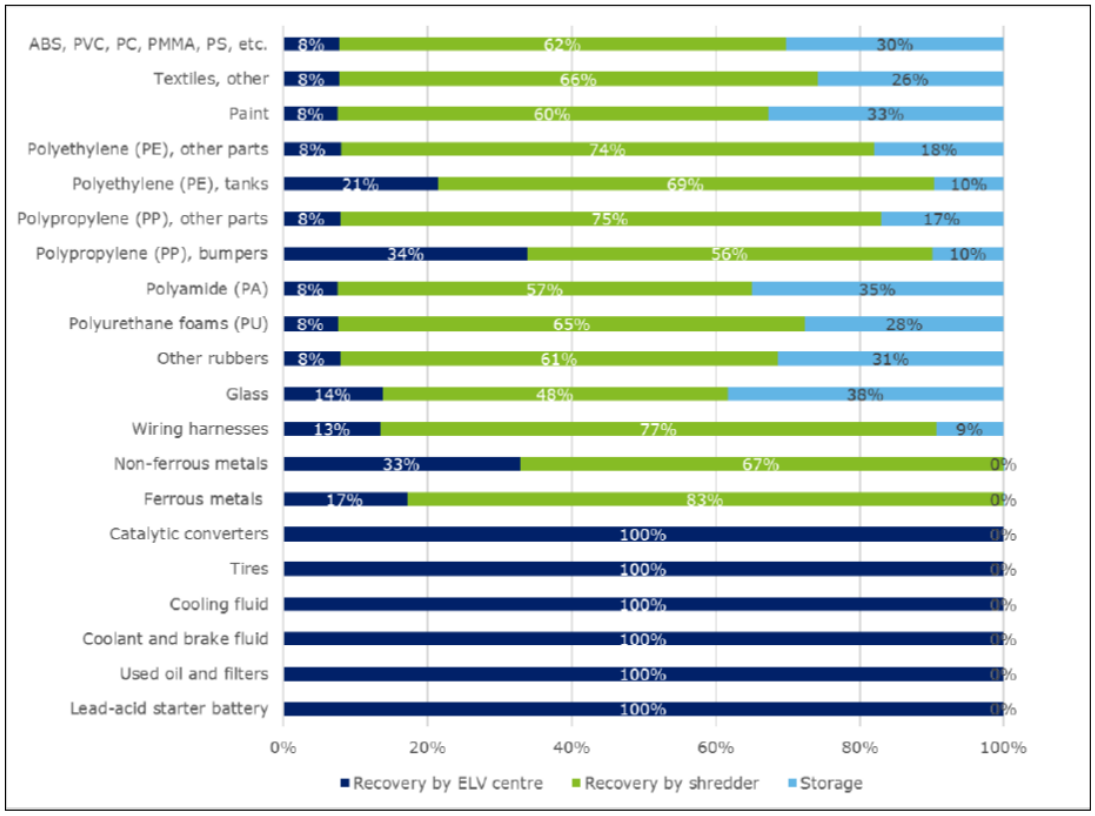

Figure 24 - Recycling process total performance for each material (dark blue – end-of-life vehicles, green – shredder, light blue - landfills)

From the display in Figure 24, we can conclude that the biggest problem for recycling are polymers and glass. In 2016, France achieved the following results:

- 86.9% recyclability rate (87.5%in 2015), which fulfilled the norm prescribed by the Directive;
- 94.8% recoverability rate (94.3%in 2015), although below the norm prescribed by the Directive, progress was made in comparison to the previous year.

5. NATIONAL LEGISLATION OF THE REPUBLIC OF SERBIA

Based on the definition given by the Law, waste are materials that are created in the production process, service or any other activity, objects excluded from use as well as materials that are created in consumption, and can be used directly or with appropriate finishing and processing as raw materials in production or as semi-products, it is concluded that used passenger vehicles can be treated as specific type of waste. In this regard, the most important laws and by-laws relevant to the recycling of used cars are:

Law on Environmental Protection ("Official Gazette of the Republic of Serbia", no. 66/19; 83/92; 53/93; 67/93; 48/94 и 53/95), which obliges the relevant economic entities to take care of the waste generated after the end of the technological process;

Law on Waste Management ("Official Gazette of the Republic of Serbia", no. 25/96 and correction 26/96) which establishes the system for waste management which can be used as secondary materials (burning, storage, recycling), and regulates the management of waste substances. In addition, with this Law, institutional framework by founding the Recycling Agency was established;

Rulebook on waste management, which have characteristics of hazardous substances ("Official Gazette of the Republic of Serbia" no. 12/95), which defines and classifies waste in accordance with the Basel Convention, the way of temporary storage on the manufacturer's location, criteria for choosing a storage location, necessary technical requirements, keeping records on hazardous waste and other;

Rulebook on criteria for choosing a location and arrangement of landfill of waste substances ("Official Gazette of the Republic of Serbia", no. 54/92), which prescribes the criteria for choosing location and arrangement of landfills of waste substances in order to protect the environment;

Rulebook on conditions and way of separation, packaging and storage of secondary raw materials ("Official Gazette of the Republic of Serbia", no. 55/2001), which contains lists and a catalogue of waste harmonized with European documents, with prescribed content of the Document on waste classification and the Document on waste collection.

Recycling is one of the youngest industrial branches in Republic of Serbia, and at the same time the only one, that has an increase. The best indicator is that in the last 3 years, this branch industry employs more than 10,000 people. There are 2,200 companies that do waste collection and recycling today. In comparison, in 2009, there were only 200 companies in this area so the process is huge.

Together with engineers and experts for the environment, recycling industry employs waste collectors all across the country. Very often, they came from marginalized social groups, so they are socially insured and involved in legal activities.

The way of managing end-of-life vehicles in the Republic of Serbia is not systematically processed, even though there are 2.3 million registered vehicles, with average age of 16.5 years. Without integrated and system approach to vehicle recycling, the Republic of Serbia has a huge loss of resources (material, energy, and employment), and on the other hand many negative ecological consequences. The road of the Republic of Serbia for joining the European Union and candidate status have set a more serious approach to this than it was the case in the past.

Relevant national legislation concerning managing the end-of-life vehicles are as follows:

1. The Law on Waste Management;
2. Strategy for Waste Management for the period 2010-2019;
3. Methods and procedures on managing waste vehicles (end-of-life vehicles).

All three main documents came into power in 2010, and are generally designed to thoroughly cover the entire area of end-of-life vehicle management. Some of the main activities foreseen in these documents are:

- Responsibilities of manufacturers, local authorities and all other participants involved in the chain of managements of end-of-life vehicles;
- Procedures to be undertaken for end-of-life vehicles, from owner to landfill;
- Keeping record on all steps of managing end-of-life vehicles;
- Issuing all relevant documents necessary for the completion of the procedure of managing end-of-life vehicles;
- Short-term and long-term predictions of development process of end-of-life vehicle management;
- Forecasts of the annual amount of waste by category;
- Keeping annual statistical data of the recycling process;
- Forming the database of registered and approved vehicle recycling facilities;
- Implementation of European Union Directives into national legislative documents;
- Keeping all financial flows under control through end-of-life vehicle management.

Application of the legislation is another part of the story which, sadly, is not that successful in this moment. One of the reasons is previously mentioned fact that these are young industrial branches in the Republic of Serbia, facing numerous problems. The other reason is a very slow and hard process of “changing the mind-set” and accepting the changes long-term.

By looking at the legal regulations, and above all by looking at the current general situation in the field of end-of-life vehicles recycling in the Republic of Serbia, the following can be stated:

- Treatment of end-of-life vehicles is not in accordance with the requirements related to environmental protection;

- The provisions of the Rulebook on conditions and methods of sorting, packaging and storage of secondary raw materials are not fully applied ("Official Gazette of the Republic of Serbia", no. 55/01);
- The system of managing end-of-life vehicles is still not established as organized activity, i.e. there is no globally organized management of this type of waste;
- The presence of landfills with vehicles at the end of their life cycle, with the possibility of people coming and dismantling the necessary used parts for a certain financial compensation, is still noticeable. When only the body remains, it is usually set on fire to burn off the paint and other anti-corrosion and anti-vibration materials, which is not legally allowed;
- Domestic vehicle manufacturers still do not provide complete information on materials used for the vehicle production, component coding and general information on recycling requirements;
- Preparation of materials, mainly metals for recycling, is done in small number of companies;
- Reparation of certain components and parts, mostly steering linkage, oscillating control arms, brake pedals, stabilizers – therefore all parts necessary for safety, is done without any quality control check and mostly with inadequate materials and technologies;
- Tradition exists mostly at recycling of steel and primarily waste generated in the production process of parts;
- Higher degree of processing is represented in the recycling of non-ferrous metals, due to higher profitability;
- Design standards for recycling, as well as standardized labelling, are not carried out or are not followed;
- Institutional and technological infrastructure for this branch of industry is not developed;
- There is no though-out education policy of population in the field of vehicle recycling;
- The penalty policy is still too "soft", and without stricter implementation of the legal part of the legislation and higher penalties, there is no further strong application of efficient end-of-life vehicle management.

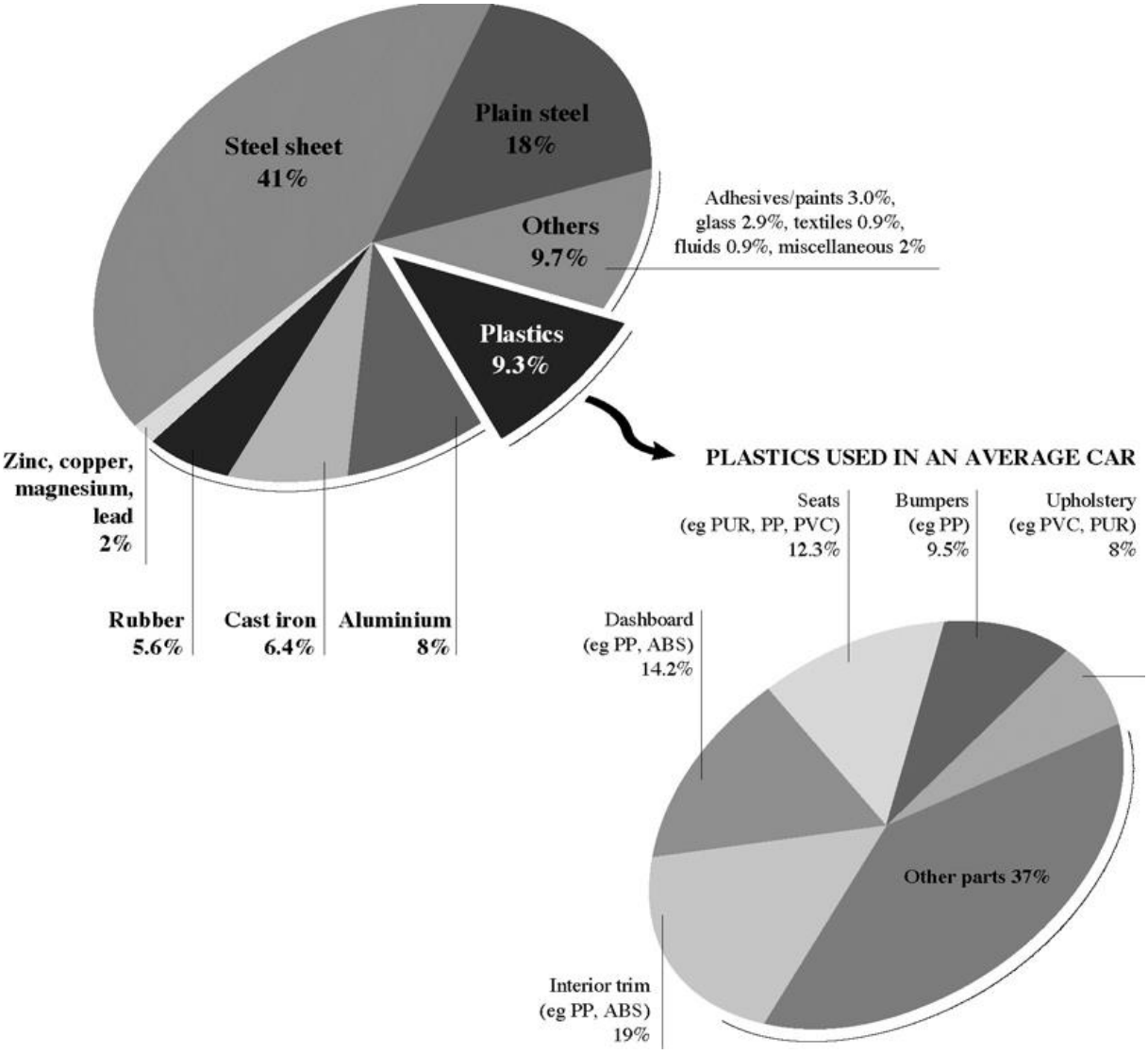

Figure 25 - Average automobile material composition

Considering all aforementioned observations and shortcomings of the current legislation in the Republic of Serbia, as well as results of the Conducted Strategy for Waste Management for the period from 2010 to 2019, the drafting of additional documents that should deal with waste management as a while, and therefore with vehicles at the end of their life cycle, as one of the most significant potential environmental pollutants, was started. Consequently, the Waste Management Program in the Republic of Serbia for the period 2022-2031 was created, with the aim of harmonizing it with the new action plan of the European Union and the transition to a circular economy.

5.1. NATIONAL WASTE MANAGEMENT PROGRAM (PERIOD 2022-2032)

New action plan of the European Union on circular economy – For cleaner and more competitive Europe (*COM/2020/98*) from 2020 sets ambitious measures to stimulate the transition to circular economy, i.e. to develop an efficient and competitive economy, which would ensure that by 2050 there would be no greenhouse gas emissions at the community level. Special attention is paid to textile sector, construction, electronics, vehicle batteries, packaging, food and plastic waste. The focus of measures in waste management is directed towards the complete avoidance of waste generating, i.e. its transformation into high-quality secondary raw materials and the good functioning of the secondary raw materials market. Action plan also suggests a series of actions for reducing the export of waste from European Union and a fight against illegal shipments. In general, proposed activities should contribute to closing the life cycle of the product through an increased degree of recycling and reuse, achieving benefits for the economy and protecting the environment.

From 2019, rules and criteria for calculating the accomplished goals based on the **Implementation Decision of the EU Commission 2019/665** are applied.

Directive 2000/53/EC on waste vehicles has set the following as main goals: prevention the generation of waste from vehicles, separation of hazardous substances from waste vehicles, reuse, recycling and reusage of waste vehicles, reducing the waste disposal of this type of waste, as well as improvement of environmental protection standards by manufacturers, importers, distributors, sellers and end-users during the vehicle life cycle, and especially during the treatment of waste vehicles.

Directive 2006/66/EC on batteries, vehicle batteries, waste batteries, and waste vehicle batteries sets maximum amounts for certain chemicals and metals in certain batteries: obligates Member States to encourage the improvement of the environmental performance of batteries; requires proper management of these batteries, including recycling, collection, “take back” programs and disposal.

Directive 2012/19/EU on waste electrical and electronic equipment as a first priority sets the prevention of generating of this type of waste. In addition, reuse, recycling and other forms of reusage encourage efficient use of resources and valuable secondary raw materials. As defined by the directive, manufacturers of electrical and electronic equipment should be registered and to finance the costs of collection, treatment and recycling of the collected waste.

Directive (EU) 2018/849 of the European Parliament and the Council on changes to the Directive 2000/53/EC on waste vehicles, Directive 2006/66/EC on batteries, vehicle batteries, waste batteries and waste vehicle batteries, and Directive 2012/19/EU on electrical and electronic equipment waste prescribed specific changes:

- Waste vehicles – measures to make sure that all end-of-life vehicles are stored (even temporarily) and treated in accordance with waste hierarchy. Also, the Member States

are required to submit the report to the Commission on reuse and goals for treatment for each calendar year;

- Batteries, vehicle batteries, waste batteries and waste vehicle batteries – requests from Member States to submit reports electronically to the Commission on achieved recycling levels in each calendar year. It also gives to Member States Authorities to use economic instruments and other measures to provide incentives for the implementation of the waste hierarchy;
- Waste electrical and electronic equipment - requests from Member States to submit reports electronically to the Commission on amounts and categories of electrical and electronic equipment they put on the market. It also gives to Member States Authorities to use economic instruments and other measures to provide incentives for the implementation of the waste hierarchy.

5.2. WASTE SUBSTANCES FOR END-OF-LIFE VEHICLES

5.2.1. WASTE VEHICLES

Waste vehicles are of heterogeneous composition, they are made of approximately 55-70% iron/steel, 3-8% non-ferrous metals, 8-18% plastic and textile, 2-4% rubber, 2-5% work fluids and 5-10% other materials. As it was said in the Introduction, the vehicle consists of more than 15,000 individual parts and approximately 40 different materials. Waste vehicles contain hazardous substances such as fuel, engine oil, oil filters, braking fluid, coolant, batteries, explosives (air bags), dangerous electronic parts and similar. For old automobiles there is an inherited problem of asbestos (i.e. brake pads) and polychlorinated biphenyls (i.e. in capacitors). A recycler ensures safe dismantling (that is, removal of dangerous components, reuse of spare parts etc.).

In recent years, an average of 160,000 tonnes of vehicles were placed on the market in Serbia (in 2020 – 157,955.3 tonnes). It is estimated that around 40,000 tonnes of waste vehicles was generated. According to the Environmental Protection Agency, the reported amount of waste vehicles generated in 2020 was 22,000 tonnes, including the waste from dismantling and maintenance of vehicles, while the treated amount is only 2,391 tonnes of treated waste vehicles (indexed numbers 16 01 04 and 16 01 06). Currently there are no reliable data in Serbia about the preparation for reuse and treatment of waste vehicles. The permit for managing waste vehicles as non-hazardous waste have 302 companies, while the permit for managing waste vehicles as hazardous material have 43 companies.

Collecting and managing the vehicles declared as waste vehicles usually includes transport of vehicles to a specific treatment facility where the processes of decontamination, dismantling and recycling are being done.

According to the Environmental Protection Agency, there are 63 legal entities/entrepreneurs, which by October 2021 were issued with permits for collecting waste vehicles categorized as hazardous waste (indexed number 16 01 04). In addition, 132 legal entities/entrepreneurs

have permits for collecting waste vehicles categorized as non-hazardous waste (indexed number 16 01 06). Adding to this, 27 legal entities/entrepreneurs have permits for transport, 16 operators have permits for storing waste vehicles categorized as hazardous waste, and 229 operators have permits for storing waste vehicles categorized as non-hazardous waste (indexed number 16 01 06).

There is a capacity for recycling **waste vehicles.** Preparation procedure for reuse starts in the dismantling or treatment facilities, where the polluting components are removed first, then the vehicles are dismantled (sometimes these two steps are connected as one – dismantling or disassembly). Removing the polluting components includes removal of dangerous parts and hazardous substances like starter motor, fuel, other fluids, airbags and all pars that contain mercury. The activity of waste treatment code 16 01 04 during 2020 was reported by 6 operators and waste code 16 01 06 was reported by 4 operators. Apart from these authorized operators, the activity of informal sector in various stages of dismantling can be assumed, considering the deviations between the estimated and registered number of scrap vehicles on an annual basis.

5.2.2. WASTE TYRES

Waste tyres are defined as non-hazardous waste (waste code 16 01 03). Tyres for passenger and cargo vehicles represent about 85% of total number of produced tyres. The Republic of Serbia has a considerable production of vehicle tyres, from which the considerable amount is being exported. In 2020, 39,882.3 tonnes of tyres (i.e., tractor tyres, trucks, busses and forklifts) were put on the market. 49,512 tonnes of waste tyres were reused and 72 tonnes were disposed of. Around 27,000 tonnes of waste tyres were recycled. 6,186 tonnes of waste tyres were imported. Waste tyres are used as fuel in the cement industry in Serbia. The amount of used for combustion in cement factories is around 6,123 tonnes (Products that after use become special waste streams in the Republic of Serbia in 2020, 2021.). Treatment options of waste tyres include the recycle of waste tyres and their use for energy purposes. At least 80% of the total amount of waste tyres collected in the previous year should be recycled, and no more than 20% used for energy purposes. There is no special scheme for collecting waste tyres.

5.2.3. USED BATTERIES AND CAR BATTERIES

Vehicle battery is a source of electricity produced by chemical reaction, which can be made from one or more primary battery cells (which cannot be recharged) or one or more secondary battery cells (rechargeable). The Republic of Serbia has a production of lead vehicle batteries, nickel-cadmium vehicle batteries and silver-zinc batteries. According to the Environmental Protection Agency, during 2020 in the Republic of Serbia, 17,950.7 tonnes of vehicle batteries were put into market. 13,599.8 tonnes are starters (vehicle batteries), 461 tonnes are portable batteries, and 3889.9 tonnes are industrial batteries. During 2020, 15,839 tonnes of batteries and vehicle batteries were processed for reuse, of which 4,782 tonnes were imported from abroad. 4,280 tonnes of batteries and c vehicle ar batteries was exported from the Republic

of Serbia in 2020 (Products, which after use become special waste streams in the Republic of Serbia in 2020, 2021.).

However, so far there is no integrated collection system for either portable batteries, industrial batteries or vehicle batteries.

5.2.4. WASTE OILS

In 2020, 36,792.9 tonnes of oil was put on the market in the Republic of Serbia, and only 2,178 tonnes were treated and 730 tonnes of was oil was exported, according to the Environmental Protection Agency. All types of waste mineral oils are classified as hazardous waste. The permit for treatment of specific type of waste oil had 25 companies in 2020. Improving the separate collection of different types of waste mineral oil and improving the treatment are priorities to achieve a high rate of waste oil recycling.

There are limited capacities for the recycle of **waste oil** and the use of oil as an energy source. At least 10 legal entities had a valid permit for the treatment of hazardous waste at the end of 2020 that can be classified as facilities for physical-chemical treatment (including the treatment of waste oils).

5.2.5. ELECTRICAL AND ELECTRONIC EQUIPMENT WASTE

Waste from electrical and electronic equipment include equipment and devices as well as assemblies and connecting parts, which are made in the industry. Waste from electrical and electronic equipment according to the Waste Catalogue is separated in-group with indexed code of waste 16 02 and 20 01. Waste from electrical and electronic products are household devices (TVs, radios, fridges, refrigerators, etc.), computers, phones, tape recorders etc. Most of this waste is classified as hazardous waste due to components it contains.

There is insufficient data on the amount of generated and collected electrical and electronic equipment waste. In addition, there is no data on handling of hazardous electronic waste and there is small number of operators involved in the recycling of this type of waste. Estimates of the amount of electrical and electronic equipment placed on the market show those in recent years, about 60,000 tonnes of electrical and electronic equipment have been placed in the Republic of Serbia. According to the data from the Environmental Protection Agency, during 2020, operators reported that they have treated 47,716 tonnes of waste electrical and electronic equipment through reusing process. In the same period, 5 tonnes of waste electrical and electronic equipment was exported. 3,831 tonnes of components removed from disposed equipment that is, which was generated after the dismantling of waste electrical and electronic equipment for which the operators reported to have finished the treatment of reuse have also been exported. Based on the reported data on treated amounts, it is estimated that the collected amount is 6.3 kilogrammes per citizen per year. Collecting electrical and electronic equipment waste from households is still unsatisfactory. The establishment of a system for the collection of electrical and electronic equipment waste from households has been initiated.

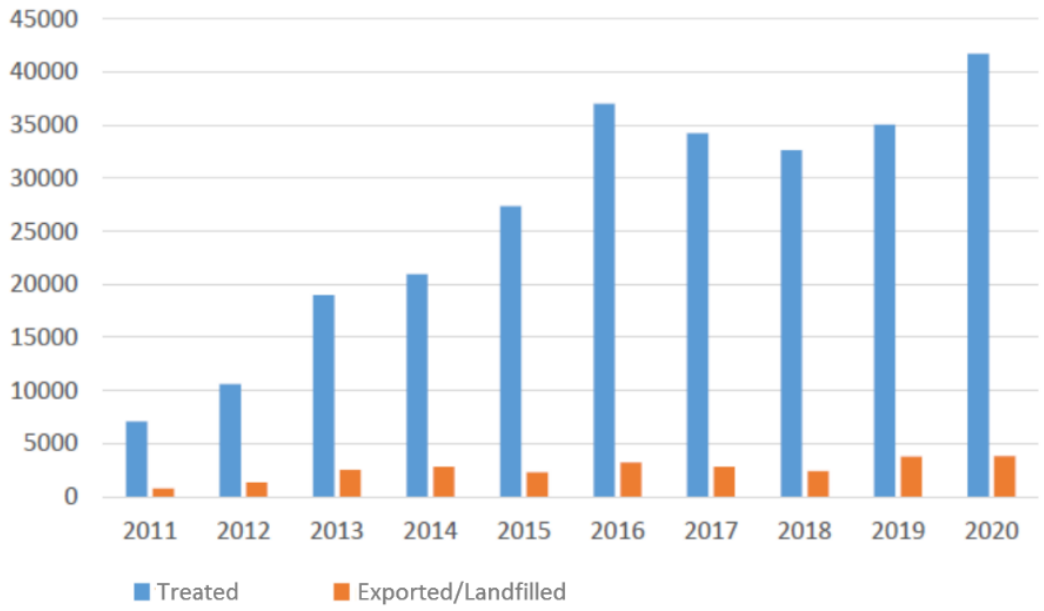

Figure 26 - The amount of electrical and electronic equipment waste treated in the Republic of Serbia, period 2011-2020 (in tonnes)

5.3. SPECIAL FLOW OF WASTE

Based on the estimates of current amounts of **waste vehicles and waste tyres** and the anticipated development, it is estimated that in 2030, 102,000 tonnes of waste vehicles and 90,000 tonnes of waste tyres will be generated.

Based on the collected and treated amounts, as well as based on the projections of the amounts put on the market, it is assumed that in the following years, 15,000 to 18,000 tonnes of **spent car batteries** will be generated. It is estimated that the collection of **used portable batteries** will increase in the following way: 0.04 kilogrammes per citizen in 2025, 0.05 kilogrammes per citizen in 2027 and 0.06 kilogrammes per citizen in 2031.

Based on the estimate of the current amount being put on the market and the information of collection of **waste oils**, it is estimated that between 22,000 and 30,000 tonnes of waste oil will be generated annually.

5.3.1. INFRASTRUCTURE AND MANAGING THE SPECIAL FLOW OF WASTE

In addition to the reduction of amount of biodegradable waste being in the landfills, specific targets for **recycling and reuse of specific waste flow** must also be met. This refers to:

- Recycling goals and reuse of packaging waste;
- Goals for collecting, recycling and reuse of electric and electronic equipment waste;
- Goals for collecting and recycling of batteries and car batteries;
- Goals for recycling and reuse of waste vehicles;
- Goals for recycling of construction waste (without excavated dirt).

For the needs of establishing a network for the collection of **waste vehicles**, it is necessary to build waste vehicle collection stations established in major cities (Uzice, Kraljevo, Novi Sad, Valjevo, and Nis), five collection stations in Belgrade and two in each of the other waste management regions.

For the needs of managing **waste oils,** the existing capacities for treatment (thermal treatment and recycling) already greatly exceed the amount currently being collected. According to the available data, potential treatment capacity can be estimated in the range of 25,000 tonnes for recycling/reuse and 16,000 tonnes for energy production. It is necessary to ensure better separate collection of waste oil and to ensure that waste oil is dealt with in accordance with the law.

It is necessary to develop a system of separate collection of **waste tyres** and the treatment of all separately collected waste tyres. In addition, it is necessary to ensure the recycling of at least 80% of the mass of the separately collected waste tyres annually.

Resume of the infrastructure needed for conducting the Waste Management Program

Table 4 - Capacities of new facilities for collecting, reuse treatment and separation of waset vehicles

Overview of needs for new infrastructure	Level of enforcement	First phase (capacity)	Second phase (capacity)	Relevant waste flow
Establishment of a suitable network for the collection of waste vehicles	National level	By 2025, three authorized facilities for the collection of waste vehicles will be established in major cities (Uzice, Kraljevo, Novi Sad, Valjevo and Nis), five authorized facilities for the collection of waste vehicles will be established in Belgrade, and two facilities will be established in each of remaining regions.		

Special goal: Strengthened capacities of institutions in the field of waste management and harmonized regulation with the regulation of the European Union

Measure 4.1. Continuation of harmonizing the legal framework with legal flows of the European Union

This measure has a goal of harmonization between the legislation of waste in the Republic of Serbia and acquis of the European Union. The corresponding differences between the legislation on waste in the Republic of Serbia and the acquis of the European Union are listed in chapters 2.1 and 2.2 of this Program. In addition, the constant development of the legal framework for the support to circular economy in the European Union requires an additional adjustment of legislation of the Republic of Serbia in terms of waste and the process of joining European Union.

Key regulative that need to be amended or adopted in order to implement the Program:

- Law on Waste Management;
- Law on Packaging and Packaging waste;
- Law on Fees for the use of public goods;
- Law on integrated prevention and control of the environmental pollution;
- Regulation on disposal of waste in landfills;
- Regulation on the plan to reduce packaging waste for 2025-2030;
- Regulation on managing the waste from construction and demolition;
- Regulation on minimum requirements for extended producer responsibility programs for certain special waste flows;
- Regulation on waste of mercury and its compounds;
- Regulation on criteria for the selection of waste management infrastructure locations;
- Regulation on the amount and conditions for awarding incentives;
- Rulebook on categories, testing and classification of waste;
- Rulebook on treatment of devices and waste, which contain polychlorinated biphenyls (PCB);
- Rulebook on the list of electrical and electronic products, prohibition measures and limitations of using electrical and electronic equipment that contain hazardous substances, methods and procedures for disposal of waste from electrical and electronic equipment;
- Rulebook on the way and procedures of managing the used batteries and car batteries;
- Rulebook on the way and procedure of managing the waste vehicles;
- Rulebook on the content of requests for registration in the Register of by-products and the Register of waste that has ceased to be waste;

- Rulebook on technical requirements and other special criteria for specific types of waste that cease to be waste;
- Rulebook on the way and procedure of managing waste tyres;
- Rulebook on the way and procedure of managing waste oils;
- Rulebook on technical and other requirements for plastic bags with additives for oxidative degradation and biodegradation, on conformity assessment and conditions that must be met by the designated body;
- Rulebook on technical and other requirements for plastic bags for carrying and on conformity assessment;
- Other regulations arising from the obligation to comply with EU regulations.

According to possible amendments to EU regulative, if necessary, further harmonization of the regulations of the Republic of Serbia will be carried out through action plans.

Competent Institution: Ministry of Environmental Protection, Autonomous Region

Implementation partners: Other ministries, Chamber of Commerce, operators, civil society organizations

6. CONCLUSION

Great works and magnificent products have always attracted and fascinated men and made them to create more and better. However, with this enchantment, men forgot about the things they left behind, the things they pile up, leave behind, and throw away. Recycling process does not just solve these problems, but is also prolonging life to all living creatures. Under the influence of recycling, numerous natural resources continued their natural course of life together with the living world on them. Through the recovery of materials, the planet resources and global capabilities are much less impaired, so the automotive industry, along with many others, continue to thrive. Unfortunately, the number of people aware of the importance of recycling, and not only vehicle recycling, is in the minority. The fact is that a large number of people, not knowing the importance of recycling have no interest in doing so. The fact is that a large number of people, who do not know the importance of recycling, have no interest in doing so. Unless the people's consciousness changes to majority, ignorance of this type can be costly.

End-of-life vehicle management has become an important part of the environmental protection. More and more vehicles are in use and with that, a huge number of vehicles end their life cycle every day, becoming the subject of the end-of-life vehicle recycling process. Strong and clear legislation is therefore necessary to protect the environment. Current international legislation ensures a reliable and clear way for end-of-life vehicle management in the future, but only if it is strictly applied.

As far as the national legislation of the Republic of Serbia is concerned, 2010 was a turning point, as three main acts came into power. Sadly, however, the application of legislation is not thorough; therefore, the effects of a possible positive influence are absent. On the other hand, some important parts of legislation, especially methods and procedures of end-of-life vehicle management are not clearly written, so we have various interpretations, and in some cases even the impossibility of implementation for end-of-life vehicles because of bad wording. Therefore, national legislation needs to be revised, and much more adopted internationally, especially Directive of the European Commission 2005/64/EC and UN Regulation No. 133.

Considering all previously mentioned, the main conclusion is imposed by itself: without strong and strict legal application, it is impossible to keep the process of recycling of end-of-life vehicles under control. Without that control, considering a huge number of very old vehicles on the market, Serbia could become an enormous landfill of end-of-life vehicles, without the possibility to recover within a few decades. If we wish to avoid this scenario, it is necessary for us to change the way we think, to educate younger generations pointing out the importance of environmental protection and to "ACT GREEN".

In addition, it can be concluded that the recycling process has an impact not only on the survival of the automotive industry, but also on the survival of the planet Earth and humanity.

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International legislation

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