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END-OF-LIFE VEHICLE DISPOSAL AND IT'S INFLUENCE TO THE ENVIRONMENT

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RESEARCH ARTICLE

ABSTRACT: Motor vehicle industry is nowadays exposed to numerous serious challenges, mostly related to its influence to environment. Motor vehicles during their life cycles affect the environment in several aspects: through consumption of energy and other resources, through production of waste in design process and usage, and through disposal at the end of their life cycle. First two aspects are in consideration for many years and there is noticeable improvement in reducing the effects, but vehicle disposal at the end of life cycle is relatively new area of research. This paper presents main items of international legislative related to end-of-life vehicle recycling process, as well as responsibilities of all participants in this process, from producers to dismantlers and landfills. Also, current legislation in Serbia is presented, with suggestions and ways for future improvement. At the end, concrete data of recyclability and reusability rates for some vehicle models are given, approving the positive effects of applied legislation on vehicle influence to the environment.

KEY WORDS: end-of-life vehicle, recycling, environment, legislative

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ODLAGANJE VOZILA NA KRAJU ŽIVOTNOG VEKA I NJEGOV UTICAJ NA ŽIVOTNU SREDINU

REZIME: Industrija motornih vozila je danas izložena brojnim ozbiljnim izazovima, uglavnom vezanim za njen uticaj na životnu sredinu. Motorna vozila tokom svog životnog ciklusa utiču na životnu sredinu u nekoliko aspekata: kroz potrošnju energije i drugih resursa, kroz proizvodnju otpada u procesu dizajna i upotrebe, i odlaganjem na kraju njihovog životnog ciklusa. Prva dva aspekta se razmatranju već dugi niz godina i vidljivo je poboljšanje u smanjenju efekata, ali odlaganje vozila na kraju životnog ciklusa je relativno nova oblast istraživanja. Ovaj rad predstavlja glavne stavke međunarodnog zakonodavstva vezane za proces recikliranja vozila, kao i odgovornosti svih učesnika u ovom procesu, od proizvođača do demontaže i deponije. Takođe, predstavljeno je sadašnje zakonodavstvo u Srbiji, sa sugestijama i načinima za buduće poboljšanje. Na kraju, dati su konkretni podaci o mogućnosti reciklaže i ponovne upotrebe kod nekih modela vozila, čime je potvrđen pozitivan efekat primenjenog zakonodavstva a tiče se uticaja vozila na životnu sredinu.

KLJUČNE REČI: kraj životnog ciklusa vozila, reciklaža, životna sredina, zakonodavstvo

END-OF-LIFE VEHICLE DISPOSAL AND IT'S INFLUENCE TO THE ENVIRONMENT

Saša Mitić, Ivan Blagojević

1. INTRODUCTION

Vehicle production is continuously growing. Since the end of World War 2, when the global world development and restructuring of the world industries led to growing of the automotive industry, we have constant increase of vehicle production in the world. Following the exact data of produced vehicles in the past, the situation is that from year 1950, when the world production amounts 10 million units, we came up to 58 million units in year 2000 [1]. In next 15 years the increase was more than 50%, so we had more than 90 million vehicles produced in 2015. Report for year 2016 shows 95 million produced vehicles, which indicates further growing of world vehicle production (Figure 1).

End of year 2008 and beginning of 2009 was the only period since 1950 when the drop of vehicle production was recorded, and it was caused by global financial crisis that shaken all industrial and commercial branches. But very quickly, yet in year 2010, increase of vehicle production recovered all reductions from previous year, so again we have constant and stable tendency of vehicle production growing.

Also, all relevant forecasts indicate that this tendency should be kept on in near future.

Regarding the information about vehicles that were sold per year, it was noticeable that their number consistently follows the number of produced vehicles in each year, with slight reduction comparing to them. The only exception was year 2009, when the number of vehicles that were sold surpassed the number of produced vehicles. The reason for that situation was planned reduction of vehicle production and obvious selling of certain number of vehicles from the stocks.

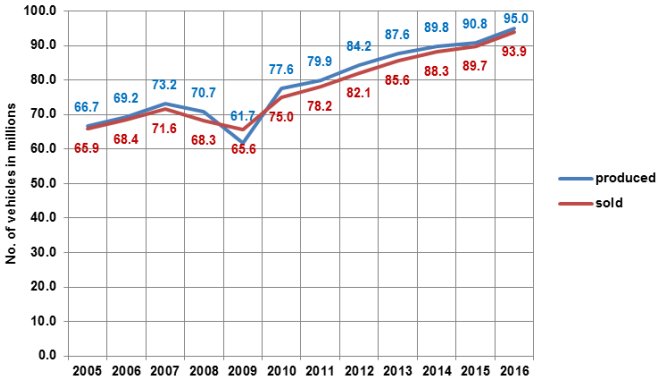


Figure 1. Worlwide vehicle production and selling, period 2005-2016

For further analysis, it is very important to analyze the information about current number of vehicles in use and its structure. This number also increase from year to year, and approximately have the same tendency as the vehicle production. The tendency remains the same for passenger and commercial vehicles (Figure 2).

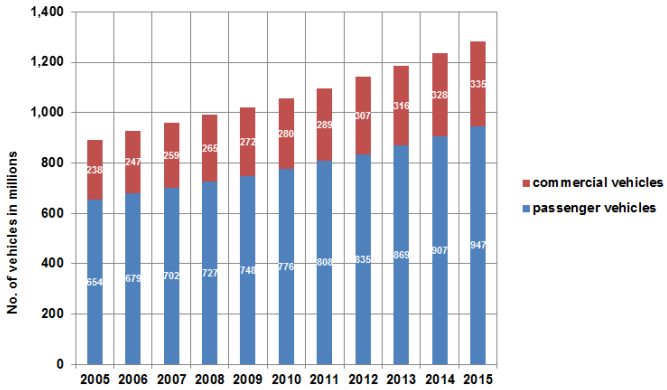


Figure 2. Worldwide vehicle production and selling, period 2005-2015

All previously mentioned indicators unambiguously indicate the importance of research in this field and creation of global strategy for managing the end-of-life vehicles (ELV). According to available data, and if we derive information for year 2015, we come up to the following figures:

- The number of vehicles sold in year 2015 was approximately 90 million units;
- Increase of number of vehicle in use comparing to year 2014 was approximately 47 million units.

The difference between these figures indicates the number of vehicle units in year 2015 that came up to the end of their life cycle, and that number is 43 million units! Negligence of these indicators and not-setting up of appropriate measures could lead us to the situation for our planet to become one big landfill. On the other hand, real situation indicates that the real number of ELVs is probably lower than officially presented. That fact is related to massive export of used vehicles from EU member countries to the rest of Europe (mainly east Europe, Russia, etc.) and some North African countries. Obviously, the profit achieved with vehicle export is much higher, so the problem of ELV treatment EU member countries solve through export. But, the problem of ELV treatment has not been solved, it just has been postponed and transferred to other countries to deal with it [13].

2. INTERNATIONAL LEGISLATIVE

Considerable national policies and voluntary agreements by major automobile manufacturers have been developed concerning the environmental impact of vehicles over their lifetimes. At the end of 1999, ten EU member countries (Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom) had specific regulations and/or industrial voluntary agreements addressing to ELV. These countries represent almost 96% of ELV estimated to be in the European Union [6].

The Directive of European Parliament and of the Council 2000/53/EC of September 18th, 2000 [3] organized former national policies and voluntary agreements. It was aimed to harmonize these existing rules and to push the EU governments and automobile industry to comply fully with the Directive and to translate its key requirements into national laws. The ultimate goal of Directive 2000/53/EC is to put only 5% of ELV residues into landfills. It states:

1. Member States shall take the necessary measures to encourage the reuse of components which are suitable for reuse, the recovery of components which cannot be reused and the giving of preference to recycling when environmentally viable, without prejudice to requirements regarding the safety of vehicles and environmental requirements such as air emissions and noise control;
2. Member States shall take the necessary measures to ensure that the following targets are attained by economic operators:

a) No later than January 1st, 2006, for all ELVs, the reuse and recovery shall be increased to a minimum of 85% by an average weight per vehicle and year. Within the same time limit the reuse and recycling shall be increased to a minimum of 80% by an average weight per vehicle and year; for vehicles produced before January 1st, 1980, Member States may lay down lower targets, but not lower than 75% for reuse and recovery and not lower than 70% for reuse and recycling. Member States making use of this subparagraph shall inform the Commission and the other Member States of the reasons therefore;

b) No later than January 1st, 2015, for all ELVs, the reuse and recovery shall be increased to a minimum of 95% by an average weight per vehicle and year. Within the same time limit, the reuse and recycling shall be increased to a minimum of 85% by an average weight per vehicle and year.

Waste prevention, reuse, recycling, and recovery of the ELV constituents so as to reduce automotive shredding residues (ASR) waste disposal are the objectives of the EC Directive 2000/53/EC. Figure 3 is a schematic representation of the participants in the ELV chain, according to the EU Directive. The main actor is the producer, a vehicle manufacturer or professional importer of a vehicle into a EU member state. The producer links the upstream (supplier) and downstream in the ELV chain (collector, dismantler, and shredder). On the other hand, collaboration between collector, dismantler, and shredder are necessary to successfully meet the directive goals.

The vehicle produced has to at least meet the following goals: low energy consumption, easy dismantling, suitable recycling, and less toxic metals (as shown in Figure 3). To fulfill these goals, the producer has to know the technical and economical facilities, recyclability rate, and efficiencies of the downstream ELV chain. On the other hand, the producer will provide the dismantling information for each new type of vehicle put on the market. The design of vehicles appropriate for dismantling, recycling, and reuse, and free of some hazardous substances (Pb, Hg, Cd, and Cr) will significantly improve the cooperation of the supplier-producer chain [5].

The Directive 2000/53/EC require that the ELV collector and dismantler should be certified (licensed), and as a result, the number of licensed dismantlers in the EU member countries has increased significantly, exceeding 1,000 licensed enterprises per country in the top five producers of vehicles in the EU. The dismantler's role is the removal for sale of reusable parts such as engines, transmissions, gearboxes, and body parts. According to the Directive 2000/53/EC, removing pollutants from the vehicle becomes an important task of the dismantler business. This involves the draining of liquids and removing of environmentally harmful constituents such as the battery. Furthermore, dismantlers are certified to destroy the waste resulting from removing the pollutants (i.e., depollution). These tasks by the dismantler will facilitate the subsequent hulk shredding and will reduce the ASR generated by the shredder operators.

Shredding steps include dismantling small parts for recycling, hulk shredding, and ferrous and non-ferrous metal separation. The separated materials will likely go to automakers for use in the production of the same components from which they are issued. Energy can be

recovered from combustible parts of ELV by using them instead of fossil fuels in industrial operations, such as cement plants. The remaining part of the vehicles, ELV waste, will go to a landfill under strict waste control. This will be material for which there is no justification for recovery [8].

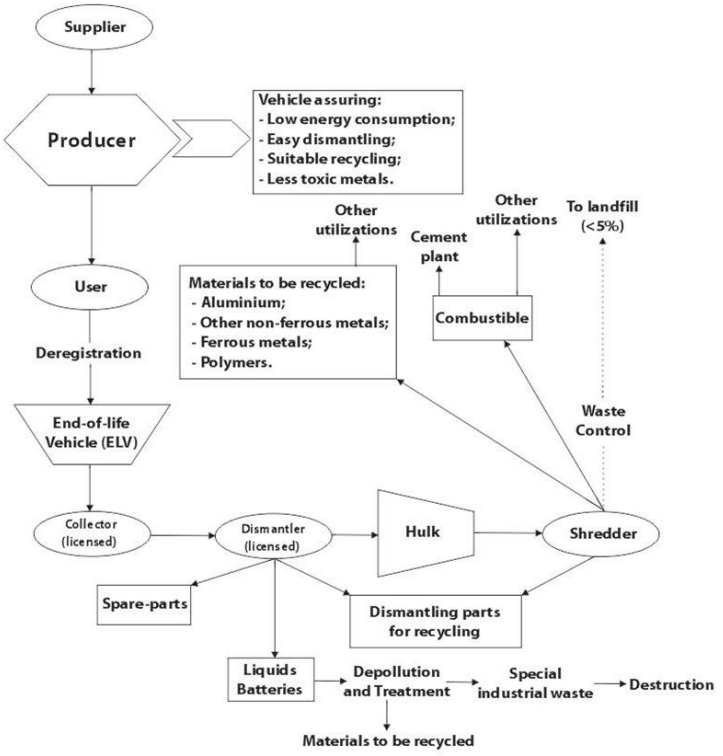


Figure 3. Main steps in ELV recycling process, according to EC Directive 2005/64/EC

EC Directive 2000/53/EC was used as a base for adoption of another Directive, 2005/64/EC [4], which is related to the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability. This Directive strictly prescribe responsibilities of vehicle manufacturers, as well as responsibilities of National Competent Authorities to ensure the fulfillment the Directive's requirements.

Some of the requests related to vehicle manufacturers:

- The manufacturer shall make available to the Type Approval Authority the detailed technical information necessary for the purposes of the calculations and checks, relating to the nature of the materials used in the construction of the vehicle and its component parts
- The manufacturer and the Type Approval Authority jointly identify the reference vehicle in accordance with the criteria prescribed by this Directive
- For the purposes of checks of the materials and masses of component parts, the manufacturer shall make available vehicles and component parts as deemed necessary by the Type Approval Authority

- The manufacturer must be in a position to demonstrate that any version within the vehicle type complies with the requirements of this Directive;
- The manufacturer shall recommend a strategy to ensure dismantling, reuse of component parts, recycling and recovery of materials. The strategy shall take into account the proven technologies available or in development at the time of the application for a Vehicle Type Approval;
- The manufacturer declares measures aiming at the reduction of the quantity and the harmfulness for the environment of end-of life vehicles, their materials and substances.

The competent body shall ensure that the manufacturer has taken the necessary measures to:

- Collect appropriate data through the full chain of supply, in particular the nature and the mass of all materials used in the construction of the vehicles, in order to perform the calculations required under this Directive;
- Keep at its disposal all the other appropriate vehicle data required by the calculation process such as the volume of the fluids, etc.;
- Check adequately the information received from suppliers
- Manage the breakdown of the materials;
- Be able to perform the calculation of the recyclability and recoverability rates in accordance with the standard ISO 22628: 2002 [7];
- Verify that component part prescribed as not to be reused in the construction of new vehicles is reused;
- Mark the component parts made of polymers and elastomers in accordance with Commission Decision 2003/138/EC of February 27th, 2003 establishing component and material coding standards for vehicles pursuant to Directive 2000/53/EC of the European Parliament and of the Council on ELV.

Also, EC Directive 2005/64/EC prescribe the component parts of vehicles belonging to category M1 and those belonging to category N1 which must not be reused in the construction of new vehicles:

- All airbags, including cushions, pyrotechnic actuators, electronic control units and sensors;
- Automatic or non-automatic seat belt assemblies, including webbing, buckles, retractors, pyrotechnic actuators;
- Seats (only in cases where safety belt anchorages and/or airbags are incorporated in the seat);
- Steering lock assemblies acting on the steering column;
- Immobilizers, including transponders and electronic control units;
- Emission after-treatment systems (e.g. catalytic converters, particulate filters);
- Exhaust silencers.

When the vehicle fulfills all requirements regarding the EC Directive 2005/64/EC, which has to be verified with appropriate Test Report, competent authority issue an Approval Certificate. Generally, it means that any new produced vehicle (vehicle of new type) could not be placed into market without valid Approval Certificate.

EC Directive 2005/64 has entered into force in November 2005, starting with application from December 2006, depending of the level of requirement fulfillment. These cases are covered with Transitional provisions.

The same thing is related to requests of UN Regulation 133 [12], which deals with the approval of motor vehicles with regard to their reusability, recyclability and recoverability,

within member parties of 1958 Agreement at the World Forum for Harmonization of Vehicle Regulations (WP 29). Since the number of member parties of 1958 Agreement is much higher than EU member countries, the process of harmonization took much more time, so UN Regulation 133 entered into force from June 2014. Comparing with EC Directive 2005/64/EC, it was noticeable that all requirements were almost the same, and it was on the line with EU legislative and UN Regulations harmonization process.

3. NATIONAL LEGISLATIVE

increasing rate. The best indicator is that in last 3 years this branch of industry engage more than 10,000 people. Nowadays there are about 2,200 companies dealing with waste collecting and recycling. Comparing with year 2009, when only 200 companies in this field existed, the improvement is enormous.

Along with engineers and environment experts, recycling industry engages waste collectors all around the country as well. Very often they came from marginalized social groups, so they are covered with social security and included in legal flows.

The way of ELV management in Serbia has not been systematically covered, although nowadays exist approximately 2.3 million registered vehicles, average of 16.5 years. With no integrated and system approach to vehicle recycling, Serbia suffers great loss of resources (materials, energy, employment), and on the other side there are a lot of negative ecological consequences. Serbian trip for joining to EU and status of candidate imposed much more serious approach to this matter than it was in the past.

Relevant national legislative related to ELV management is as follows:

1. Waste Management Law [14];
2. Waste Management Strategy for Period 2010-2019 [15]
3. Methods and Procedures of End-of-Life-Vehicles (ELV) Management Regulation [10].

All 3 main documents were enetered into force in 2010, and generally they were designed for thoroughly covering the whole field of ELV management. Some of main activities scheduled with these documents are [2]:

- Responsibilities of manufacturers, local authorities and all other participants involved into ELV chain
- Procedures to be taken for ELV, from the owner to the landfill
- Keeping the evidence about all steps in ELV management
- Issuing the appropriate documents needed for completing the ELV management procedure
- Short-term and long-term predictions of development process for ELV management
- Predictions about annual amount of waste by categories
- Managing the statistic data regarding the recycling process annually
- To form database of registered and approved vehicle recycling facilities
- Implementing of EC Directives into national legislative documents
- Keeping all financial flows through ELV management under control.

The implementation of legislative is another part of the story, unfortunatelly not very successful at the moment. One of the reasons is previously mentioned fact that this is younges industrial branches in Serbia, faced with numerous problems. The other reason is very slow and difficult process of “mind changing” and acceptance of changes in long-term praxis.

Some of the problems noticed through implementation of new legislative are [9], [11]:

- The treatment of ELV is not in accordance with requirements related to environmental protection
- ELV management system still does not exist as organized activity
- It is still noticeable the presence of dumped vehicle landfills with possibility for people to come and dismantle needed used parts for certain financial compensation
- Domestic manufacturers still do not provide complete information about materials used for vehicle production, coding of components and general information regarding recycling requirements
- There is no designed policy of population education regarding the vehicle recycling
- Penalty policy is still too "soft", and without stronger implementation of legal part of legislative and higher penalties there is no further strong implementation of ELV management efficiently.

4. RECYCLABILITY AND RECOVERABILITY RATES

The method for calculating recyclability and recoverability rates is specified by Standard ISO 22628:2002. It is based on four main stages inspired by the treatment of ELVs. Recyclability and recoverability rates depend on the design and material properties of new vehicles, and on the consideration of proven technologies – those technologies which have been successfully tested, at least on a laboratory scale, in this context.

The calculation method of this Standard cannot reflect the process that will be applied to the road vehicle at the end of its life.

This Standard specifies a method for calculating the recyclability rate and the recoverability rate of a new road vehicle, each expressed as a percentage by mass (mass fraction in percent) of the road vehicle, which can potentially be

- Recycled, reused or both (recyclability rate), or
- Recovered, reused or both (recoverability rate).

The calculation is performed by the vehicle manufacturer when a new vehicle is put on the market.

The calculation of the recyclability and recoverability rates is carried out through the following four steps on a new vehicle, for which component parts, materials or both can be taken into account at each step:

- Pretreatment
- Dismantling
- Metals separation
- Non-metallic residue treatment.

Recyclability rate, Rcyc, of the vehicle, is calculated as a percentage by mass (mass fraction in percent), using the following formula:

$$R_{cyc} = \frac{m_P + m_D + m_M + m_{Tr}}{m_V} \cdot 100 \quad (1)$$

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

$$R_{cov} = \frac{m_P + m_D + m_M + m_{Tr} + m_{Te}}{m_V} \cdot 100 \quad (2)$$

where:

m_p –mass of materials taken into account at the pre-treatment step (all fluids, batteries, oil filters, liquefied petroleum gas (LPG) tanks, compressed natural gas (CNG) tanks, tyres, catalytic converters);

m_D –mass of materials taken into account at the dismantling;

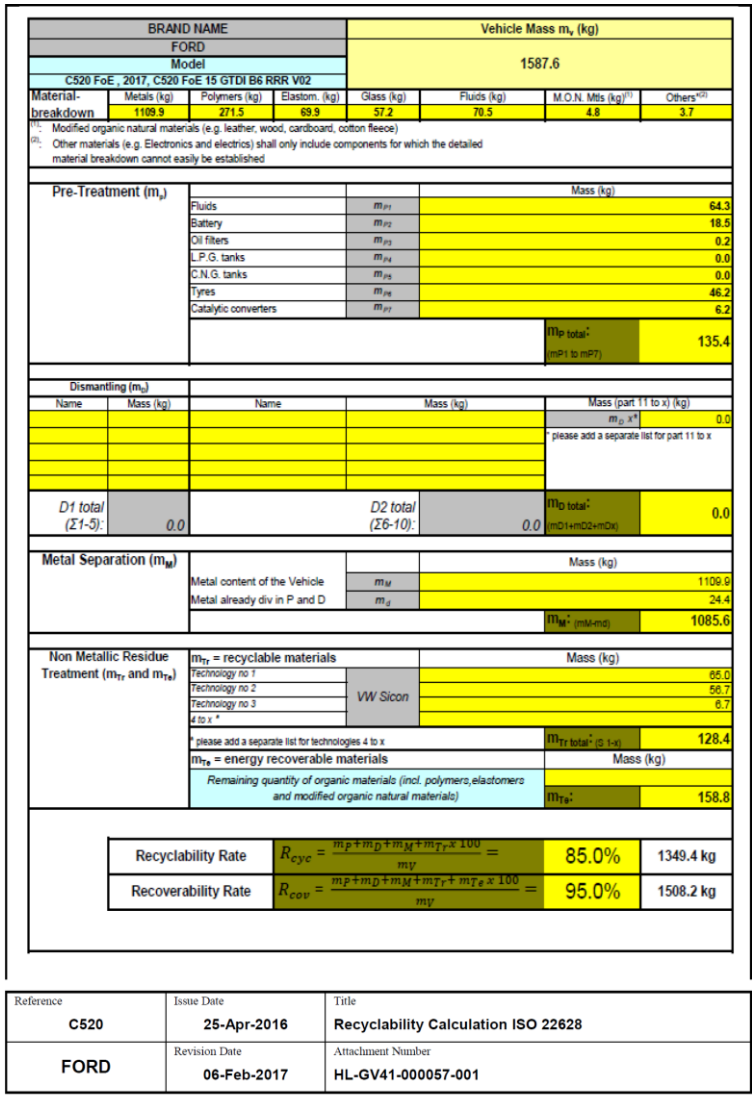
m_M –mass of metals taken into account at the metal separation step;

m_{Tr} –mass of materials taken into account at the non-metallic residue treatment step and which can be considered as recyclable;

m_{Te} –mass of materials taken into account at the non-metallic residue treatment step and which can be considered for energy recovery;

m_V –vehicle mass.

For the calculation purposes, a partial mass parameters are determined respectively, at each of these four steps. At the end, the data for the calculation shall be reported using the formalized table review, either on paper or in electronic form. This formalized review has to be presented to the National Type Approval Authority. Also, it presents a part of Information Document that follows Approval Certificate according to EC Directive 2005/64/EC and/or UN Regulation 133. Figure 4 shows completed formalized table for one of the passenger vehicle models, with clear view to all parameters related to material breakdown and mass rates in recycling process.



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		$m_{Tr\ total}$* (3 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	$R_{cyc} = \frac{m_P+m_D+m_M+m_{Tr} \times 100}{m_V} =$	85.0%	1349.4 kg
Recoverability Rate	$R_{cov} = \frac{m_P+m_D+m_M+m_{Tr}+m_{Te} \times 100}{m_V} =$	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 4. Formalized table review for passenger vehicle (Ford Kuga)

5. CONCLUSIONS

ELV Management became very important part of environmental protection. More and more vehicles are in use and consequently large number of vehicles finishes its life cycle every day, becoming subject of ELV recycling process. Therefore, strong and distinct legislative is needed in order to protect environment. Current international legislative, provide reliable and clear way for ELV managing in the future, but only if it is going to be applied strictly.

Regarding Serbian national legislative, year 2010 was turning point, because 3 main acts were entered into force. Unfortunately, application of legislative is not thorough, hence the

effects of possible positive impact are missing. On the other hand some important parts of legislative, especially in "Methods and Procedures of End-of-Life-Vehicles (ELV) Management Regulation" were not written distinctly, so we have different interpretations, and in some cases we have inability to implement them for ELVs because of bad formulations. Therefore, national legislative need to be revised, and much more adopted to international, especially to EC Directive 2005/64/EC and UN Regulation 133.

Having all previously mentioned, main conclusion is imposing by itself: without strong and strict legislative application, it is impossible to keep ELV recycle process under control. Without that control, having in mind enormous number of very old vehicles on the market, Serbia could become big landfill for ELVs, with no possibility to recover for many decades. If we want to avoid that scenario, we need to change our way of thinking, to educate young generations indicating the importance of environment protection and to act "green"

ACKNOWLEDGMENTS

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