End-of-Life Vehicles Recycling

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End-of-life vehicle (ELV) recycling is a process that spends energy and could be an energy source as well. This part of energy recovering depends on many different factors related to the broad and local aspects of ELV recycling. The ELV recycling process is consuming energy from different energy sources (electrical, fossil), however, this consumption is lower in relation to energy consumption during the production of new vehicle parts from the very beginning. ELVs have, in the first phase, been considered as an environmental problem, which must be solved through many decision-making approaches, directives, and standards. Accordingly, it may be concluded, that this issue is very complex since it includes a lot of relations concerning ELV recycling, as well as broad infrastructure and socio-economic environment factors. On the other hand, there is not enough relevant and reliable information related to the ELV recycling and energy recovery through ELV recycling process. This information can be obtained through user responses, financial analysis, business analysis, or some government body relevant information sources. Due to new regulations related to ELV recycling, the responsibility of manufacturers is becoming increasingly important. They are obligated to design and revise their processes and adapt them to new legislation norms.

Keywords: ELVs ; Recycling ; energy recovery ; ELV regulations

1. Introduction

End-of-life vehicles (ELVs) have, in the first phase, been considered as an environmental problem, which must be solved through many decision-making approaches, directives, and standards [1]. Consequently, ELV recycling is a thoroughly researched issue related to different aspects, such as volume [2][3], dismantling technologies and disassemblability [4][5][6][7], emission-control and decomposition [8][9], impact of hybrid and electric vehicles [10][11], recycling technologies [12][13][14][15][16], socio-economic benefits [17][18][19][20][21], development of financial policies [22], plastics recycling [23][24], impact on quality and environment [25][26][27][28], information technologies application [29][30], sustainability [31], reverse logistics [32], legislative boundaries and environmental performance [33], and infrastructure [34][35]. Other research sources present methods and business potential for components re-use [36], definition of treatment centers for ELV processing [37], presentation of evaluation economics and material destinations remanufacturing optimization model according to a ELV legislation [38], passenger vehicles aluminum parts recycling [39], development of ELV costing frameworks [30], application of Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE) method to select the best ELV management method [40], and Analytic Hierarchy Process (AHP) method for selection of equipment for detoxification of ELVs [41].

2. End-Of-Life Vehicles Recycling Procedures

Some authors suggested simulation approaches (Berzi et al. [42]) and dynamic modeling [43] to present influence of different parameters on recycling rate, energy recovery, and recycling infrastructure, and nonlinear optimization model [44] to illustrate the relationship between particle size reduction and liberation during the shredding and recycling of ELVs. Shmidt et al. [45] focused on the identification of the environmental impacts and relevance for combinations of recovery/recycling and lightweight vehicle design options through the whole life cycle. Mazzanti and Zoboli [46] introduced the possibilities for specific economic instruments influencing the producer responsibility principle in waste and recycling policy. Smith and Keoleian [47] introduced the energy usage reduction and pollution prevention in the USA through remanufacturing a medium-sized gasoline automotive engine. There are suggestions discussing that recycling technology innovation could be a significant driver for technology shift in the automotive industry [48]. Mixed-integer linear programming (MILP) model for ELV recovery network design constituted from dismantling centers and processing facilities has been introduced by Qi and Hongcheng [49]. Furthermore, mixed-integer nonlinear programming (MINP) has been suggested for optimal long-term planning in the EU and in the Republic of Serbia vehicle recycling facilities by Simic and Dimitrijevic [50][51]. Literature shows the application of regression analysis to estimate the global flow of base metals (iron, aluminium, copper, lead, and zinc) in the used automobile trade [52]; prediction to determine the impact that pre-shredder treatment could have on achieving 85% recyclability rate in 2015 [53]; and to elaborate end-of-life product-specific material flow analysis [54]. Current technologies within the Industry 4.0 concept allowed the development of smart dismantling monitoring and smart trolley system for ELV recycling centers [55]. A literature review showed that previous research dealing with the recycling process, mainly solves various problems of a local character. Consequently, it is suggested that a definitive solution, and accordingly, additional comprehensive research is needed [56].

Additionally, the materials used in the production of vehicles are constantly changing. Therefore, the individual types of ELV waste components are further considered, since the impact on the environment and energy recovery from components, such as oil, tires, plastics, and glass, are significant. Waste oils and hazardous liquids from ELVs are the components that are isolated first [57]. In the recycling process, the tank is dismantled, so that the oil is separated through the equipment for extraction and purification and further used as a consumable resource (after removing excess water and filtering the particles) in the heavy industrial plants and power plants. Stricter emission controls can limit this, so a better option is to use refined oil as a lubricant, although this is not currently widely practised. Oil filters can retain large amounts of waste oil that can be reused using special filter presses before recycling. The larger issues are related to the antifreeze and motor fuel, which after purification require subsequent chemical treatment, which was confirmed by research on the application of LCA for conditions in the Republic of Serbia. The car is not disassembled further before these processes are finished [58].

When considering the total amount of plastic waste, ELVs participate with a share of 5%. The main challenge for successful polymer recycling is their diversity and the complicated and time-consuming processes of their collection and sorting. Globally, it can be estimated that the amount of plastic waste in the world reaches approximately 250 Mt per year. This was estimated through the amount of plastic produced worth 265 Mt in Europe in 2010. With this estimated number, taking into account the longer lifespan of ELVs in the world compared to Europe, which results in less waste plastic per car, waste cars generate plastic waste in the amount of about 10 million tons per year. These amounts of plastic waste in the world can have a great negative impact on the environment and society.

Plastic treatment, including ELV plastics, can be performed in four ways: Reuse, material recovery, energy recovery, and landfilling. Material recovery involves mechanical recycling, chemical recycling, and biological or organic recycling, while energy recovery involves the use of plastic waste as a substitute for fossil fuels to produce heat, steam, or electricity. The main difference between recycling technologies is the change in material structure. Mechanical recycling does not change the structure, while chemical recycling does. In addition to mechanical recycling, chemical, and raw material recycling technologies, there are various solutions for plastic waste treatment, such as dissolution, solvolysis, pyrolysis, gasification, etc., while energy recovery from plastic waste is most often performed at power plants or waste incineration plants. The ecological sustainability of different material recovery technologies is determined by the input material. For instance, blast furnaces that can use heterogeneous waste plastic, as raw material found in ELVs scrap, may be more suitable than mechanical recycling process [59].

Two types of glass are used in cars—reinforced and laminated. Tempered glass is easy to remove from a vehicle when it breaks. Laminated glass does not break, so it needs to be removed manually, which requires a lot of time and resources. The ease of removing the glass in the disassembly phase depends on the way the glass is sealed during production. The use of rubber seals makes the process of removing glass much easier compared to the method of direct glueing. In the case of rubber seals, the complete window can be removed, but the more commonly used procedure of direct bonding with glue involves cutting the glass disk in as large a diameter as possible, leaving a significant part of the glass in one piece. In European countries, part of the waste glass of vehicles is currently recycled, although the largest percentage of glass from ELV is disposed of in landfills as crushed residue. Disassemblers usually do not remove the glass from the ELV vehicle before sending it to the crushers because its removal is time-consuming and the value of the glass waste is relatively low. The estimated value of glass from one ELV is about 0.5 euros. In order for this process to be cost-effective, it is necessary to process fifteen ELVs per hour, which is not feasible using current methods. Market reports on recycled materials across Europe (Germany, France, UK, Hungary, etc.) have estimated that mixed auto glass has a negative economic value of 25 to 35 euros per ton. Although glass recycling, due to its uneconomical nature is not currently the most preferred option for companies, it will have to be increased in accordance with the requirements of the First Annex of the Directive on the removal of glass at the dismantling stage. Until then, most of the waste glass from ELV ends up as the rest of the crushing in landfills [46].

Based on the application of LCA, it can be concluded that the strategy of obtaining energy is based predominantly on the recycling of tires, followed by the recycling of plastics, fabrics, oils, etc. [60]. At the same time, part of the used components is refined and reused as a second-hand commodity.

Waste tires and their disposal are a global concern for the environment. They are not biodegradable, and it is estimated that about 1.5 billion tires are discarded worldwide annually [61]. Waste tires in landfills can be the culprit for the release of hazardous substances into the environment and pose a danger as a potential fuel for unquenchable fires. In 2006, Directive 2006/12/EC prohibited the disposal of tires, forcing their reuse, recycling, and recovery (3R).

With this in mind, various options for disposing of tires have been introduced, such as [62]: Reuse of newer tires, in accordance with the legal standards of the tread; reuse for landfills—whole tires can be used in tire construction process; recycling by grinding—crushed rubber is used for covering sports areas and children's playgrounds, for brake linings, as landscaping mulch, greenery, carpet mats, as well as the addition of rubberized asphalt for roads. Rubber granulate is also used in the production of new tires, as an additive to the primary rubber with a share of 5%. Other recycling techniques include cryogenic fragmentation, devulcanization, microwave technologies, and other techniques that are constantly evolving. Through the cryogenic fragmentation process tires are exposed to lower temperatures, leading to brittle tires characteristic, suitable for further processing. The advantage of this type of fragmentation is lower energy consumption and easier separation of metal and textile parts from rubber, which gives a cleaner final product. During the cryogenic process, there is a small amount of environmental pollution. Rubber granulate has a very wide application in infrastructure, agriculture, construction, and industry. Energy utilization—tires have a high calorific value (20% higher than coal) which can be used to obtain energy at combustion, pyrolysis, or incineration processes in cement kilns. Pyrolysis is expanding with the new line plant. Burning tires in cement kilns produces a large amount of thermal energy, but this process also releases polluting gases, which may harm the environment and human and animal health.

However, the energy aspect, as well as an appropriate methodology, have not been investigated adequately. Similar research to the analyzed subject refers to the reduction and recycling of automobile shredder residue (ASR) through life cycle assessment (LCA) in order to improve recycling generation rate in Japan [63]. The authors of the same research stated that recycling ASR and recycling parts for reduction of ASR, which include bumpers, seats, instrument panels, weather strips, and window shield glass, may be considered as effective in recovering energy generation rate increase. Additionally, the same authors predict that international specialization in the manufacturing process will affect the scrapping process, and that it is necessary to apply LCA on ELVs for logistics and plants for both domestic and international projects. With this in mind, the results on LCA all indicate that promoting material collection and energy recovery from the residues would minimize the total environmental impact of ASR recycling [64]. Further research confirmed that in the year 2011 the recycling and energy recovery rate of ASR and its equivalent was 93.3%, which results in approximately 99% of ELVs being reused, recycled, and recovered [65]. Furthermore, Vermeulen et al. [66] concluded that ELV energy recovery treatments (incineration, pyrolysis, or gasification) may be observed as a low-cost recycling route, as no complex, energy-consuming mechanical pre-treatment is necessary. Observing dismantled ELV parts such as waste tires, it has been presumed that they are utilized for energy recovery (59%) in various facilities, including paper mills and cement plants [67]. In Italy, in order to reach the 85% recycling and 95% recovery rate in 2015, the implementation of innovative and economically sustainable material and energy recovery processes from car fluff appear unavoidable [68].

Accordingly, it may be concluded, that this issue is very complex since it includes a lot of relations concerning ELV recycling, as well as broad infrastructure and socio-economic environment factors. On the other hand, there is not enough relevant and reliable information related to the ELV recycling and energy recovery through ELV recycling process. This information can be obtained through user responses, financial analysis, business analysis, or some government body relevant information sources. Due to new regulations related to ELV recycling, the responsibility of manufacturers is becoming increasingly important. They are obligated to design and revise their processes and adapt them to new legislation norms.

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