Economic and Environmental Benefits of Electric, Hybrid and Conventional Vehicle Treatment in Lithuania

Rasa Tverskytė, Kamilė Petrauskienė,
Jolanta Dvarionienė,
Kaunas University of Technology
Institute of Environmental Engineering
Kaunas, Lithuania
e-mail: rasa.tverskyte@ktu.edu
e-mail: kamile.petrauskiene@ktu.edu
e-mail: jolanta.dvarioniene@ktu.lt

***Abstract*—End-of-Life Vehicles' (ELV) recovery and recycling is encouraged not only due to the targets set in the Directive on ELV, but also due to economic and environmental benefits. Automotive remanufacturing serves as a specific circular marketing system of recovered parts' reuse that can bring economic benefit both for dismantling companies and consumers. Moreover, in terms of greenhouse gas emissions, reuse of the recovered parts or the secondary resources from ELV may save CO_2 emissions in manufacturing new cars or their parts. For this reason, four passenger cars with different engine types were analysed in order to reveal the economic and environmental benefits that ELV dismantling and reuse of the recovered vehicle parts may bring to dismantlers and passenger car owners. The results showed that the greatest economic benefit is that 41% of ELV-hybrid car mass can be sold in parts that would save up to 3,835 Eur as an economic benefit for the dismantlers and 17,153 Eur for the consumers. In addition, 35% of ELV-electric car mass can be sold in parts for reuse and it can bring 8,812 Eur for the dismantling company. Meanwhile, consumers would save up to 6,614 Eur when buying used parts for their car repair. Besides, an ELV-petrol car and an ELV-diesel car can be sold in parts 27% and 25%, respectively, and make economic benefits accordingly. In terms of global warming, treatment of ELV parts can save CO_2 emissions caused by metal extraction. As a result, a secondary resource recovery can save 23–44% CO_2-eq needed for the primary metal extraction.**

Keywords-electric and conventional car; economic benefit; environmental impact; end-of-life vehicles.

I. INTRODUCTION

According to the Circular economy principles, through the reuse, remanufacturing and refurbishing, the global economy is increasing [1]. Automotive recycling is playing a significant role in environmental and economic sectors as more and more End-of-Life Vehicles (ELVs) are generated worldwide. In 2019, there were 1,520,159 registered passenger cars in the Lithuanian market [2]. It means that more than every second Lithuanian resident owns a car. Due to the economic growth and faster living pace, the number of registered passenger cars is increasing every year, as well as that of ELVs. The use of secondary resources, promotion of ELV recycling technologies and the increasing use of recovered and recycled materials provide a promising outlook in order to gain economic and environmental advantages.

There were 210,114 ELVs generated in Lithuania in 2018 [2]. The Directive 2000/53/EC on ELV states: "No later than 1 January 2015, for all ELV, 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" [3]. According to the data of Environmental Protection Agency of Lithuania, in 2018 the ELV reuse and recovery rate reached 95.4%, and the reuse and recycling rate – 92.4%.

Automotive dismantling plays a big role in a vehicle's life cycle. While consumers are choosing either to buy a used part or a new one, the prices are making a significant impact on their decision making. In this study, practical research was performed in order to reveal how much it costs to buy all the necessary parts from dismantling companies. Furthermore, the prices of the used parts from dismantlers were compared with the prices of the new parts placed on the market. The difference showed an economical benefit that consumers may have.

The goal of this study is to evaluate and compare the economic and environmental benefits of the treatment and bringing materials back to the market (upcycling) of a Battery Electric Vehicle (BEV), a Hybrid Electric Vehicle (HEV) and Internal Combustion Engine Vehicles (ICEVs). This research is novel firstly because it provides a comprehensive, comparative analysis of the end-of-life passenger cars with four different engine types. Secondly, it applies directly to the Lithuanian conditions; and thirdly, the analysis adds a comparison of Life Cycle Assessment (LCA) results focusing on the end-of-life phase of BEV, HEV and ICEVs powered with diesel and petrol.

This paper is organized as follows: Section I provides the relevance and issues of the study, ELVs recycling and recovery goals, as well as, the situation in Lithuania. Section II introduces the methodology of economic and environmental assessment, inventory analysis, the scope and methods of the research. Section III presents the results of the economic and environmental analysis of selected passengers cars' treatment. Section IV concludes and summarises the paper.

II. METHODOLOGY

In the study, the four passenger cars with different engine types were analysed in accordance with the most popular models registered in the Lithuanian road vehicle fleet. It was also taken into account that the average age of the car is 16 years. Besides, this number is very close to the global average – 15.8 years [4]. The analysed models were 2005–2008 Volkswagen Golf plus with 1.4 petrol engine, 2005–2008 Volkswagen Golf A5 plus with 1.9 diesel engine, 2011–2013 Nissan Leaf with 24 kWh battery and 2003–2009 Toyota Prius 5 door hatchback with hybrid 1,5 petrol engine and 16 kW battery. For the detailed information about each passenger car parts, their weight and composition, International Dismantling Information System was used [5].

 ISBN: 978-1-61208-826-6

Five local dismantling companies were interviewed about each part demand on the market. The prices were checked and compared in e-shops. The economic benefit for dismantlers was evaluated by calculating the prices of the used parts, waste management costs and the value of secondary materials. Labour force and equipment prices were not evaluated and included in the analysis.

For the environmental analysis of selected passenger cars, a methodology of Life Cycle Assessment (LCA) was used. According to Hauschild et al. [6], LCA is an effective tool that can be used in the field of (electric) mobility in order to answer the questions regarding comparisons between different types of vehicles, as well as, to analyse the disposal scenarios, mainly regarding the treatment of the main components, especially batteries, electric motors and car body.

The LCA study of BEV, HEV and ICEVs powered with diesel and petrol was carried out following the procedure and recommendations indicated in the European standards series – ISO 14040 and ISO 14044 [7][8]. The goal of this LCA study is to evaluate the environmental impacts throughout the electric, hybrid and conventional vehicles' production and end-of-life stages. The end-of-life stage involves dismantling, recovery and recycling activities. The ReCiPe method at the midpoint level was used and the indicator of global warming as one of the most significant impact categories was selected, expressed in kg CO_2-eq [9]. For the life cycle impact assessment and interpretation, database Ecoinvent 3.5 and software SimaPro 9.1 were used.

III. Results and discussion

The result revealed that most vehicle parts can be reused for the same purpose in HEV – Toyota Prius (42%), while the least number of reusable parts was determined in VW Golf powered with diesel (25%). The economic benefit for dismantlers for each vehicle differs from 2,412 Eur (VW Golf powered with petrol) up to 8,812 Eur, the most valuable parts are in Nissan Leaf, the least valuable parts are in VW Golf with petrol engine. The biggest savings belong to Toyota Prius users (17,154 Eur) and the least difference between the new and used parts belongs to Nissan Leaf users (6,615 Eur). Toyota Prius owners feel much more motivated to look for alternatives instead of buying a new part than Nissan Leaf owners.

According to the surveyed dismantling companies, not many electric cars – Nissan Leaf – are becoming ELVs, because this model is newer than 16 years, still convenient to use, except when an accident occurs. This explains why the price difference between the new and used parts of Nissan Leaf is not considerable. The summarised results of economic benefits for vehicle dismantlers and consumers are presented in Table I.

TABLE I. ECONOMIC BENEFIT FOR VEHICLE DISMANTLERS AND CONSUMERS

Passenger car	The share of passenger cars mass that can be sold as parts for reuse after dismantling, %	Economic benefit for dismantlers, Eur	Price of new parts, Eur	Economic benefit for consumers, Eur
Volkswagen Golf (ICEV-petrol)	27	2,412	12,540	10,128
Volkswagen Golf (ICEV-diesel)	25	2,644	16,560	13,916
Nissan Leaf (BEV)	35	8,812	15,427	6,615
Toyota Prius (HEV)	42	3,835	20,989	17,154

For the environmental impact evaluation, the main vehicle parts, such as the glider, the internal combustion engine/powertrain, Li-ion (from BEV) and Ni-metal (from HEV) batteries were analysed. According to Eurostat statistics, automotive batteries are recycled up to 80% [10]. The glider and engine / powertrain are made mostly from metal, which can be melted and used for the same purpose an infinite amount of times. In this study, it was assumed that the glider and internal combustion engine / powertrain are recycled 100% and batteries – 80%, which means that the recovered amounts of materials can be used in production and save CO_2 emissions.

The results of LCA (Table II) showed that the end-of-life stage (treatment) of the glider, the internal combustion engine/powertrain, Li-ion (from BEV) and Ni-metal (from HEV) batteries account for only 10% of the environmental impact of the production of all these car parts. For example, treatment of the glider (secondary resource recovery) can save about 37% of CO_2-eq from the glider production needed for primary resource extraction of reinforcing steel, chromium steel and copper. Furthermore, the internal combustion engine treatment can save about 44% of CO_2-eq from the internal combustion engine production needed for primary resource extraction of aluminium, steel, reinforcing steel, platinum, lead and copper. Besides, treatment of powertrain can save about 23% of CO_2-eq from powertrain production needed for primary resource extraction of aluminium, steel, chromium steel and copper. Finally, Ni-metal battery treatment can save about 24% of CO_2-eq from Ni-metal battery production needed for primary resource extraction of nickel, cobalt and zinc.

 ISBN: 978-1-61208-826-6

TABLE II. RESULTS OF GLOBAL WARMING ASSESSMENT DURING VEHICLE PRODUCTION AND TREATMENT STAGES

Vehicle parts	**ICEV-petrol**		**ICEV-diesel**		**HEV**		**BEV**	
	Production, kg CO_2-eq	*Treatment, kg CO_2-eq*	*Production, kg CO_2-eq*	*Treatment, kg CO_2-eq*	*Production, kg CO_2-eq*	*Treatment, kg CO_2-eq*	*Production, kg CO_2-eq*	*Treatment, kg CO_2-eq*
Glider	5,507	519	5,507	519	5,507	519	5,507	519
Internal combustion engine / powertrain	1,018	105	1,697	174	1,358	139	1,610	47
Batteries	n/a	5	n/a	5	719	20	1,851	284
Total	**6,525**	**629**	**7,204**	**698**	**7,584**	**678**	**8,968**	**850**

IV. CONCLUSION

The results showed the economic benefits for dismantling companies and passenger car owners/consumers. Around 42% of ELV-hybrid car mass can be sold in parts that would save up to 3,835 Eur as an economic benefit for the dismantlers and 17,153 Eur for the consumers. Besides, 35% of ELV-electric car mass can be sold in parts for reuse and it can bring 8,812 Eur for the dismantling company, while the consumers would save up to 6,614 Eur when buying used parts for their car repair. Next, an ELV-petrol car and ELV-diesel car can be sold in parts 27% and 25%, respectively. An ELV-petrol car can bring 2,412 Eur economic benefit for the dismantlers and 10,127 Eur for the consumers, while an ELV-diesel car can bring 2,644 Eur economic benefit for the dismantlers and 13,915 Eur for the consumers.

When performing the LCA analysis, there were too few separate car parts in the database to select. Only three options of the automotive parts (glider, internal combustion engine/powertrain and batteries) could be chosen. The LCA results in terms of global warming showed that treatment of ELV parts can save CO_2 emissions caused by metal extraction needed for the production of the analysed vehicle parts. As a result, secondary resource recovery can save 23–44% CO_2-eq needed for the primary metal extraction.

REFERENCES

[1] J. Korhonen, A. Honkasalo and J. Seppälä, 2018. Circular Economy: The Concept and its Limitations, Ecological Economics. Volume 143, Pages 37-46, ISSN 0921-8009. https://doi.org/10.1016/j.ecolecon.2017.06.041

[2] State Enterprise “Regitra”. Open fleet data of registered road vehicles, 2020. [Online]. Available from: https://www.regitra.lt/lt/paslaugos/duomenu-teikimas/atviri-duomenys-1/transporto-priemones-3/ 2020.10.16

[3] Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements. Official Journal L 269, 21/10/2000 P. 0034–0043.

[4] Y. Nakamoto, D. Nishijima and S. Kagawa, 2019. The role of vehicle lifetime extensions of countries on global CO_2 emissions. Journal of Cleaner Production. Volume 207, Pages 1040-1046, ISSN 0959-6526. https://doi.org/10.1016/j.jclepro.2018.10.054

[5] The website of International Dismantling Information System. [Online]. Available from: https://www.idis2.com/ 2020.10.17

[6] M. Z. Hauschild, R. K. Rosenbaum and Stig Irving Olsen, 2018. Life Cycle Assessment: Theory and Practice. https://doi.org/10.1007/978-3-319-56475-3

[7] ISO 14040, 2006. Environmental management – Life cycle assessment – Principles and framework.

[8] ISO 14044, 2006. Environmental Management – Life Cycle Assessment – Requirements and Guidelines.

[9] National Institute for Public Health and the Environment, 2017. ReCiPe 2016 v1.1. A harmonized life cycle impact assessment method at midpoint and endpoint level Report I: Characterization.

[10] EUROSTAT. Statistics Explained. Waste statistics – recycling of batteries and accumulators, 2020. [Online]. Available from: https://ec.europa.eu/eurostat/statistics-explained/pdfscache/66807.pdf 2020.10.20