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# End-of-life vehicles in the light of environmental benefits identified in the products' life cycle

Key words

End-of-life vehicle, recycling, utilisation, LCA.

Słowa kluczowe

Samochód wycofany z eksploatacji, recykling, utylizacja, LCA.

Summary

The study shown in the paper concerns the last stage of the products' life cycle, withdrawing from exploitation. The research is concentrated on passenger vehicles. Different aspects of car recycling in Poland were contemplated. The general description of this initial study on car recycling scenarios and their environmental consequences is presented. Scenarios are characterised in detail to define changes in the number of vehicles recycled in Poland in the future. The LCA (Life Cycle Assessment) method and Ecoindicator 99 procedure are used to evaluate environmental aspects of the recycling processes. The main environmental impacts are classified in three general categories: human health, ecosystem quality, and resources. Obtained results illustrate the scale of environmental impacts coming from car recycling.

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## 1. Introduction

Transportation is one of the spheres of human activity that is identified with the special degradation of environment, and the car is an example of a mass product, which became an inseparable component of contemporary human live. The car, as a technical object compound of various materials, many parts and transmissions, causes a lot of unfavourable effects in its entire life cycle, from extracted raw materials to disposal of wastes.

## 2. Goal and scope of research

In relation to the influence of vehicles to the environment, until recently, most of attention was concentrate on the development of combustion engines with the aim of limiting toxic compounds emission, noise emission and the fuel consumption (including reduction of $CO_2$ emission). Taking into account present tendencies introduced to the analysis of technical objects from their life cycle perspective, it is worth taking into account both the emissions into the environment generated during exploitation of vehicles and the impact of their production and recycling stages.

In developed countries, a lot of attention was paid to waste management. In Poland, a growing number of the out-of-use vehicles force us to look closer for environment friendly ways of waste management and to accelerate activities to implement them. The aim of analysis is the evaluation of environmental consequences identified in the final stage vehicles' life cycle. Economical, environmental, technical and legal conditions of the vehicle recycling system in Poland were reviewed as a source of the data about actual situation and probable changes.

## 3. The age structure of passenger vehicles used in Poland

The actual condition of recycling in connection with the age structure of vehicles registered in Poland (Fig. 1) and constantly rising number of used vehicles by import (Fig. 2), made problems of recycling extremely important.

In 2003, more than eleven million passenger vehicles were registered in Poland and it is important that fifty-six percent of these vehicles were older than 10 years [1].

In recent years, more or less 300 thousand new vehicles are sold yearly in Poland, while more than 800 thousand used vehicles are imported [2]. Taking into account age structure and the number of vehicles that entered Poland in the same time, it is obvious that the oldest vehicles are even more than it was five years ago, in 2003. Within the last years, more than three million used vehicles were imported (Fig. 2).

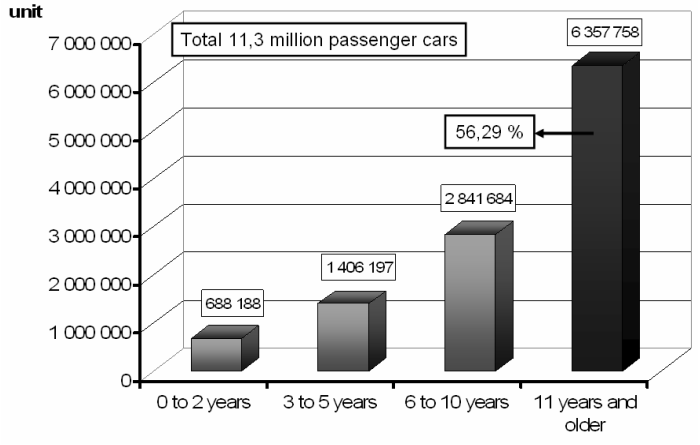


Fig. 1. The age structure of car registered in Poland in 2003 [1]
Rys. 1. Struktura wiekowa samochodów zarejestrowanych w Polsce w 2003 roku [1]

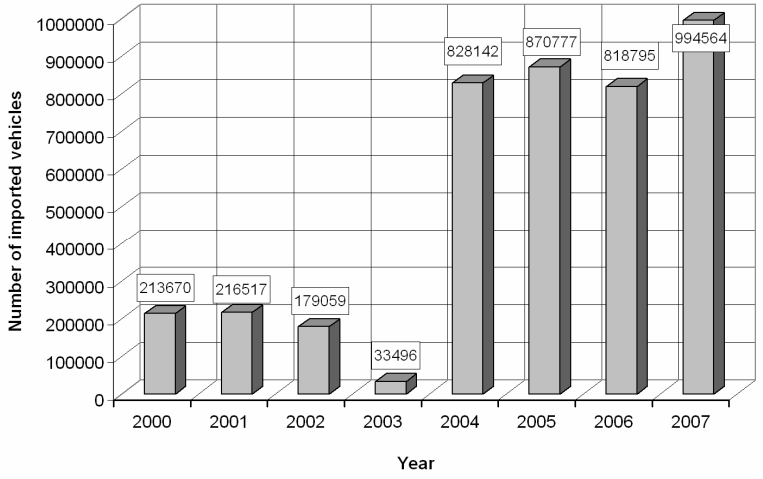


Fig. 2. The number of car imported to Poland in the period 2000–2007 [2]
Rys. 2. Liczba samochodów sprowadzonych do Polski w okresie 2000–2007 [2]

It is necessary to emphasise the fact that 61.57% of these vehicles were older than 10 years (Fig. 3).

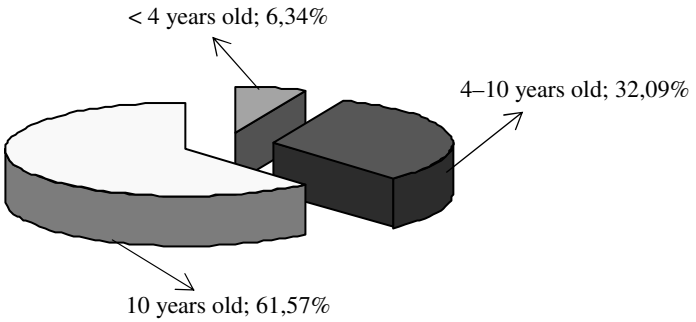


Fig. 3. The age structure of vehicles that entered Poland in 2004–2007 [2]
Rys. 3. Struktura wiekowa samochodów sprowadzonych do Polski w 2004–2007 [2]

## 4. Recycling system in Poland

The vehicle recycling system in Poland is composed of 632 legal disassembly stations and 113 legal points of collecting end-of-life vehicles [3]. Wastes recovered from out-of-use vehicles are converted in the enterprises whose locations are shown in the Figure 4.

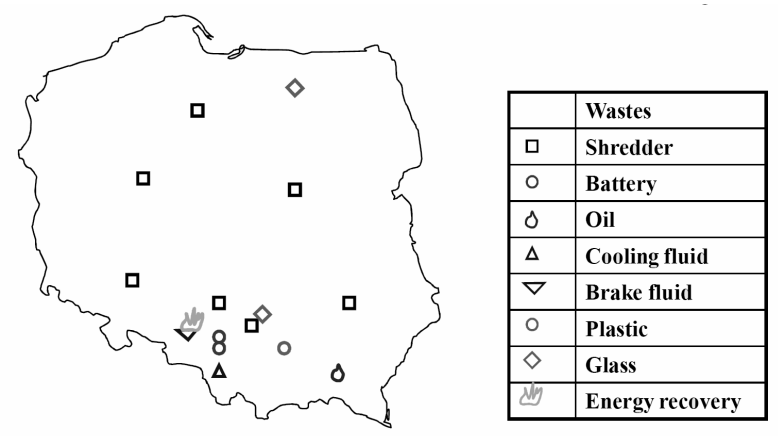


Fig. 4. Location of treatment facilities of wastes from dismantling station [4]
Rys. 4. Lokalizacja przedsiębiorstw przetwarzających odpady odbierane ze stacji demontażu samochodów wycofanych z eksploatacji [4]

One of the most important problems is a lot of illegal "recycling" enterprises intercept most of vehicles withdrawn from exploitation. For this reason, the number of all recycling stations is unknown because a lot of them may be registered as service garages, regenerated stations, scrap yards, etc. In

consequence, the exact number of all out-of-use vehicles is unknown too, but in accordance to an estimation, more or less 250 thousand end-of-life (EoL) vehicles were withdrawn from exploitation in 1997–2000 yearly [5], and the forecast for the nearest future is presented on the Fig. 5.

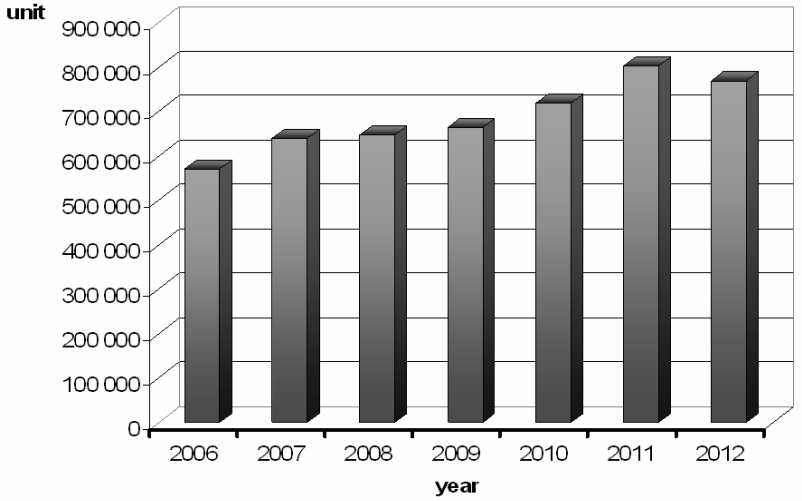


Fig. 5. Estimated number of out-of-use vehicles for years 2006–2012 [6]
Rys. 5. Prognozowana liczba samochodów wycofywanych z eksploatacji na lata 2006–2012 [6]

The estimation presented on Fig. 5 was prepared on the basis of the age structure of registered vehicles and number of new vehicles that were sold in Poland yearly. Now it is important to take into account the fact of the mass import used vehicles that enter Poland (Fig. 2) and the age structure of these vehicles (Fig. 3). For this reason, in the nearest years, we should expect many more out-of-use vehicles than it is presented on Fig. 5. In the nearest future, the number of vehicles withdrawn from exploitation in Poland should exceed six hundred thousand units yearly. Some sources indicate that even 1,400,000 end-of-life vehicles may be withdrawn from exploitation in 2017–2018 yearly [7, 8]. These numbers emphasise the scale of problems connected with waste management [9, 10].

Recycling of vehicles is a dynamically developing branch of the economy in Poland; so, there is no problem to utilise wastes from all imported vehicles, which in some European countries would be recognised as end-of-life ones. The thing is that not all out-of-use vehicles will be intended for recycling. It is undeniable that some vehicles will be disassembled by owners or left by owners in the forests, etc. Moreover, the problem is a "twilight zone" of this branch, which is developing just as quickly as legal recycling network. As a result, many more out-of-use vehicles are dismantled by enterprises, which are not entitled to run a business connected with waste transformation. For this reason, it is

assumed that only one-in-four end-of-life vehicles is delivered to the authorised recycling network [11] and remaining three vehicles find their way somewhere into the environment. Some sources indicate the fact that, in reality, more or less one million vehicles are withdrawn from exploitation yearly and even 9/10 from these vehicles are not delivered to legal disassembly stations [12].

## 5. Possibilities of recycling business changing

It is common knowledge through entrepreneurs that waste management demands taking into consideration economic, legal, technical, and environmental aspects. It is also known that even the most valuable factors cannot cover ecological effects. Thus, the problems of car recycling become more and more perceived in Poland. However, in spite of the fact that regulations of directive 2000/53/EC are implemented into Polish law system, the lack of a unified system for vehicle recycling, loopholes, the lack of outside financing system, the small number of well-equipped recycling stations and the "twilight zone" effectively restrict the development of the recycling system and limit the possibilities of significant improvements of this situation.

At present, there are some ideas for significant improvements of the recycling situation in Poland, which make up a basis to build possible event scenarios. For the requirements of these analyses, it was assumed that more than 600 thousand end-of-life vehicles should be withdrawn from use, but nobody should believe that all of them would be delivered to the legal recycling network. Different scenarios are characterised in detail to define changes in the number of vehicles recycled in Poland in the future.

The first scenario of policy concerning recycling issues in Poland is a reflection of the actual situation that only twenty-five percent of the total number out-of-use vehicles will be recycled. This scenario assumes the following:

- The lack of an unified approach to problems of vehicles recycling;
- The lack of an outside source for financing the recycling network;
- No change with reference to the authorised recycling network – an insufficient number of vehicles destined to recycling; poor condition of authorised stations, and the lack of possibilities of development;
- The lack of last owner motivation – out-of-use vehicles might be left out or delivered to illegal "twilight zone"; and,
- The quick development and increase of number of illegal "recycling stations."

The second scenario assumes implementation of directive 2000/53/EC into the Polish law system; however, in case of imprecise national regulations, the number of recycled vehicles should increase, but probably not too much. So, the

second scenario assumes some changes of law but a lack of executive regulations, and in consequence of the following:

- The lack of sanctions for organisations omitted from environmental regulations, which might lead to the development of the "twilight zone";
- The lack of outside financing of the recycling network by necessity due to large investments in connection with the adaptation of disassembly stations to directive requirements, and, at the same time, limited possibilities of development for official recycling stations because of the constant need to increase investments; and,
- In extreme cases, the decreasing number of authorised disassembly stations and the increasing average distance between stations.

In the second scenario, an insignificant increase in the number of vehicles recycled by legal network (33% from all out-of-use vehicles) is assumed.

The third scenario assumes implementation of directive 2000/53/EC into Polish legal system as well as an introduction of returnable deposit payment in order to motivate last owner to pass his end-of-life vehicle to a recycling station. The last owner would get back the deposit payment only after the destruction certificate is shown. This source of financing, which gives some possibilities and financial standing of the recycling network, should be improved. So, the third scenario assumes an increased number of recycled vehicles up to 50% percent of the total amount out-of-use vehicles, thanks to motivation of last owner to recover money, and in consequence, the limitation of "twilight zone" activity.

The largest number of recycled vehicles, seventy-five percent of the total amount, is assumed in the fourth scenario. Introduction of product payment and recycling payment should involve producers and importers to organise the recycling network. They could be support for recycling stations and the cooperation between all entities could bring the best effects. This scenario assumes the following:

- Non-returnable product-payment concerns producer of vehicles, who do not achieve required recycling index,
- Non-returnable recycling-payment concerns importers of vehicles,
- Far more possibilities of financing of legal recycling stations and quick development of authorised recycling network, and
- The largest number of possibilities to limit the range of "twilight zone" activity.

It is assumed that the significant increase in the number of recycled vehicles will occur in the authorised network – 75% from all out-of-use vehicles in the fourth scenario.

## 6. The base of research

All these individual scenarios were characterised in detail to a precise quantity of vehicles recycled in the future, according to the estimate supposing that 607 thousands vehicles will be withdrawn from use (Fig. 6).

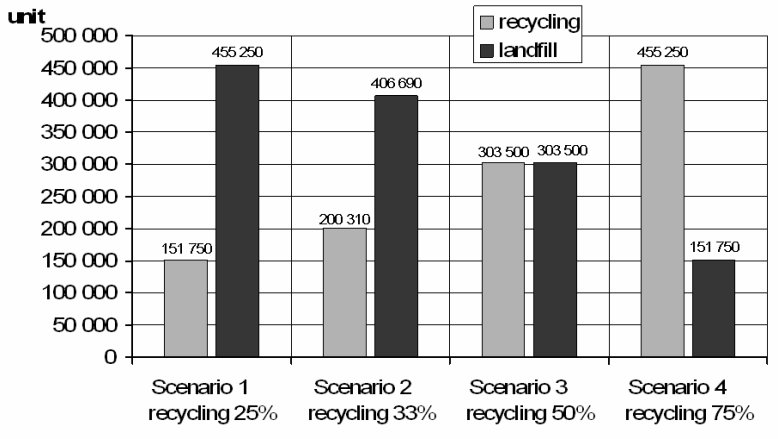


Fig. 6. Estimated number of recycled vehicles for different scenarios
Rys. 6. Szacowana liczba samochodów poddanych procesom recyklingu dla wybranych scenariuszy

The base of analysis is the number of vehicles withdrawn from exploitation and the average amount of materials, which is possible to gain from one end-of-life vehicle in Polish conditions (Fig. 7).

| | |
|---|---|
| Metals | 559,83 kg |
| Plastics, glass, rubber | 26,59 kg |
| Exploitation materials | 23,48 kg |
| Wastes | 51,72 kg |
| Total | 661,62 kg |

Fig. 7. Average mass of materials possible to gain from 1 EoL vehicle in Polish conditions
Rys. 7. Średnia masa odpadów możliwych do pozyskania z jednego samochodu wycofanego z eksploatacji

For the needs of analysis, it is assumed that the possible waste to gain from the vehicles, which will not be delivered to official recycling network, will be treated as wastes stored in a landfill site. In order to define the size of the environmental consequences of the scenarios and realised policy, the number of vehicles recycled in Poland and the quantities of different materials obtained from out-of-use vehicles were based on calculation. Ecological analysis of recycling processes was made on the basis of the Life Cycle Assessment method (Fig. 8).

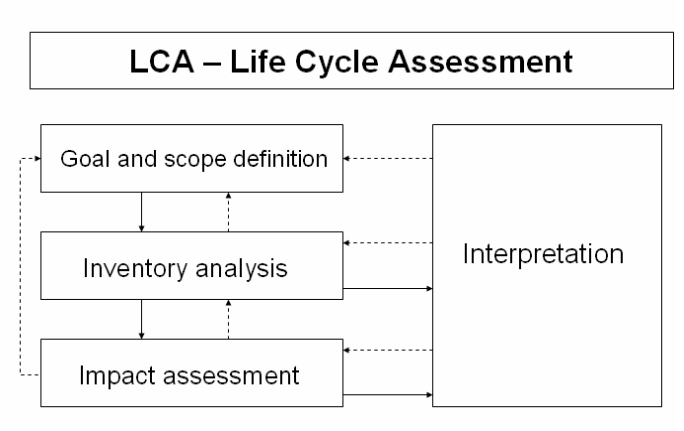


Fig. 8. Stages of the LCA method [13]
Rys. 8. Etapy metody LCA [13]

The environmental consequences were studied using Ecoindicator 99. This procedure made it possible to classified main environmental impacts into three general categories: human health, ecosystem quality, and resources.

For the calculation of environmental consequences, the SimaPro 5.1 programme was used.

## 7. Environmental consequences

The results of detailed calculation expressed as environmental consequences are presented on the next figures. Fig. 9 shows the comparison of total environmental indicators.

As one can see in Fig. 9 from analysed scenarios, only the realisation of the first scenario causes negative impact. Realisations of other analysed scenarios are characterised by positive effects in the environment. It is worth pointing out that environmental benefits from the realisation of the fourth scenario are nearly thirty times more than in case of the second scenario. Results expressed in the three main impact categories are presented in Fig. 10, and each impact category will be considered separately on Fig. 11 to Fig. 13.

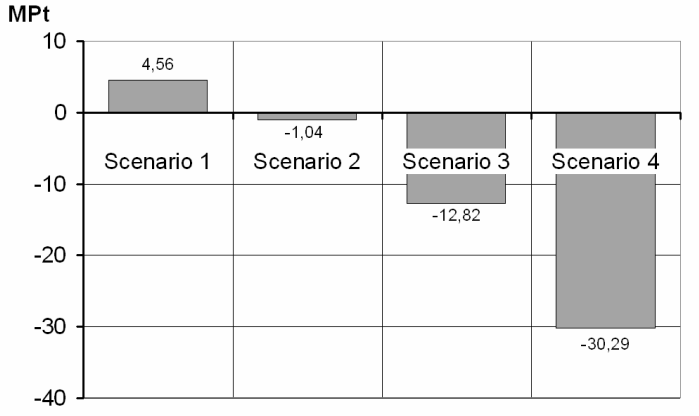


Fig. 9. Environmental indicators compared as the results of realised processes of recycling
Rys. 9. Porównanie środowiskowych wskaźników ukazujących konsekwencje realizacji procesów w analizowanych scenariuszach

Results expressed in the three main impact categories, presented on Fig. 10, show that the impacts connected with categories of human health and ecosystem quality cause the negative influence on environment, while impacts related to the category of resources are characterised by positive effects in every scenario.

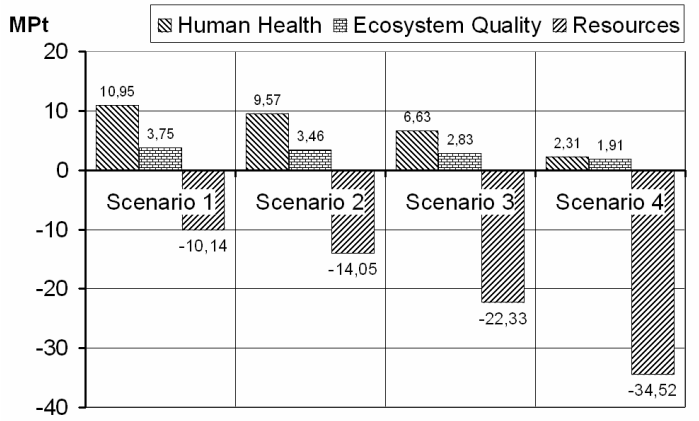


Fig. 10. Environmental impacts of analysed recycling scenarios
Rys. 10. Wpływ analizowanych scenariuszy na środowisko

The greatest influence on human health is caused by carcinogens (Fig. 11). Irrespective of the scenario, carcinogen impacts are characterised by negative factors. In case of categories, respiratory organics and climate change, there are impacts identified as environmental benefits in all analysed scenarios.

Unfortunately, the size of these impacts is significantly less and impossible to balance negative influence carcinogens on human health.

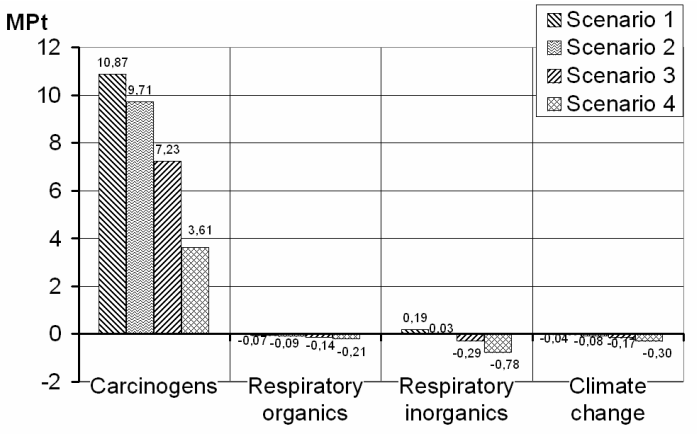


Fig. 11. Comparison of impacts considered within the category of human health
Rys. 11. Porównanie środowiskowych oddziaływań w ujęciu kategorii: zdrowie ludzkie

The results presented on the Fig. 12 show that the categories of impacts connected with ecotoxicity and land use are dominating categories in terms of influence on ecosystem quality. But the size of ecotoxicity impacts is decreasing along with a growing number of recycled vehicles, while in case of land use, negative influence is rising. So, twelve times more negative influence of ecotoxicity than land use in the first scenario was reduced to only twice more in case of the fourth scenario.

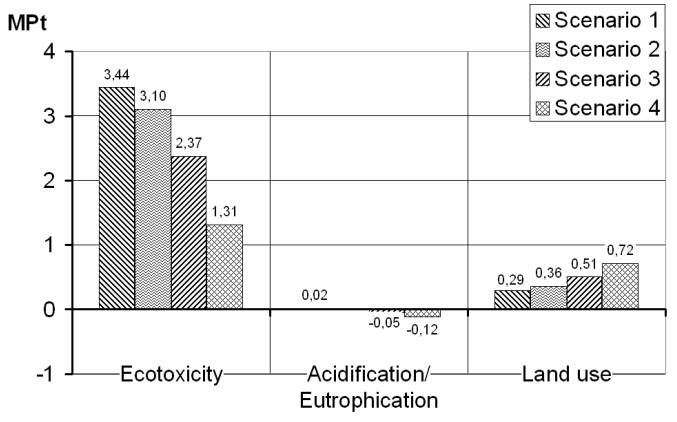


Fig. 12. Comparison of impacts considered within the category of ecosystem quality
Rys. 12. Porównanie środowiskowych oddziaływań w ujęciu kategorii: stan ekosystemu

The results presented on Fig. 13 show that impacts connected with the category of minerals have a small share in the total influence on the environment, and the main benefits of recycling are connected with the impact category of fossil fuels.

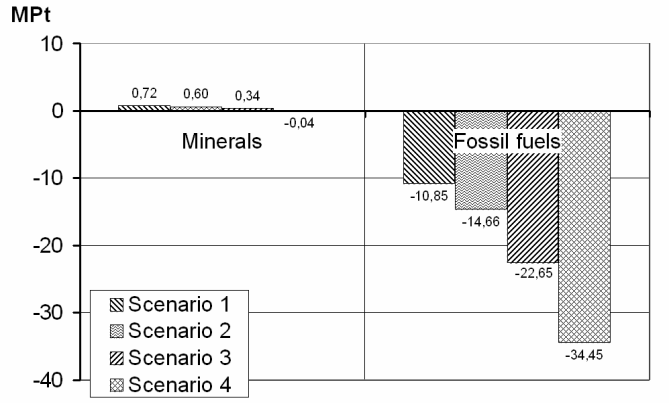


Fig. 13. Comparison of impacts considered within the category of resources
Rys. 13. Porównanie środowiskowych oddziaływań w ujęciu kategorii: wyczerpywanie zasobów

## 8. Conclusions

On the basis of presented results, we can say that not only negative impacts are connected with life cycle of passenger vehicles. Environmental benefits from recycling can be significant, and recycling of vehicles may be effective way to restrict destructive human activity in the transportation sphere. Thanks to the use of the LCA method to evaluate consequences of vehicle recycling in Poland, it was possible to show the scale of environmental problems of improper proceeding with end-of-life vehicles.

Taking into account economic, technical, legal, and logistic aspects of recycling in Poland, we can come to the following conclusions:

- There is lack of a unified recycling network.
- Most of recycling stations in Poland have larger re-manufacturing capacities than it is possible to gain waste materials.
- Implementation of directive 2000/53/EC could be helpful in achieving ecological aims because the problems of vehicle recycling are treated in a comprehensive way.
- The creation of local and national systems of the recycling network should be an imperative aim of ecological policy in Poland.

The analysis of above gathered materials made it possible to notice potential improvements of the recycling network in Polish conditions. So, organising an efficient system of waste collection and recycling network should contribute to reduce the scale of negative environmental impacts.

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**Samochody wycofane z eksploatacji w świetle środowiskowych korzyści identyfikowanych w cyklu życia produktów**

S t r e s z c z e n i e

Badania przedstawione w artykule dotyczą ostatniego z etapów cyklu istnienia produktów, etapu wycofania z eksploatacji. Jako obiekt badań obrano samochody osobowe. W artykule rozważono wybrane aspekty recyklingu samochodów w Polsce. Ponadto zaprezentowano opis rozpoczętych badań nad możliwymi wariantami zagospodarowania samochodów wycofanych z eksploatacji oraz ich środowiskowymi konsekwencjami. Na potrzeby określenia zmian w ilości samochodów możliwych poddaniu procesom recyklingu w przyszłości, szczegółowo scharakteryzowano poddane analizie warianty zagospodarowania. W badaniach wykorzystano metodę LCA (Life Cycle Assessment), która umożliwiła oszacowanie poziomu oddziaływań środowiskowych identyfikowanych podczas realizacji procesów występujących w analizowanych wariantach. W obliczeniach wykorzystano procedurę Ecoindicator 99, której zastosowanie umożliwiło prezentację wyników badań w ramach trzech głównych kategorii oddziaływań, wpływu na: zdrowie ludzkie, stan ekosystemu oraz wyczerpywanie zasobów. Uzyskane wyniki obrazują skalę środowiskowych oddziaływań identyfikowanych w procesach zagospodarowania samochodów wycofanych z eksploatacji.