# EFFICIENT USE OF CRITICAL METALS IN THE AUTOMOTIVE INDUSTRY - IDENTIFICATION, REUSE AND RECOVERY

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## ABSTRACT

The presented case study analyses the resource potential of End-of-Life vehicle recycling in Germany and the PR of China, especially of strategic and critical metals. In the recycling hierarchy the reuse of used parts always achieves the most favorable eco-balance and thus, gains the highest priority. Apart from batteries critical metals can be found in catalysts and neodymium magnets. Besides cobalt and gallium, neodymium, dysprosium, praseodymium and terbium are identified as relevant in the automotive sector and they are all classified as strategic metals.

## INTRODUCTION

The EU Disposal of End-Of-Life Vehicle (ELV) Act specifies quotas of material recycling (EU, 2000). The ELV Directive 2000/53/EC established goals to minimize the effect of ELV’s by setting recycling, reuse, and recovery targets for the materials used in all manufactured vehicles. The directive requires that 95% of ELV waste must be reused or recycled by 2015, with only 10% of this recovered through energy. In addition to pure recycling of materials, the reuse of components and subassemblies makes sense not only in line with the Lifecycle Management and Waste Act (KrW-/AbfG, 1994) from Germany but also from the economic perspective. This is also in accordance with the „Raw Material Initiative“ that was released in 2008 by the European Commission (EC, 2008). There is high pressure on saving and recovering raw materials in Europe.

The German car market has a volume of around 43 million cars (counting on January 2013) and additional 9 million cars in 2012 for recycling or export (KBA, 2013). The market is nearly stable in terms of the total car volume. At the moment we experience a change in technology since there are strong developments in electric and hybrid cars as alternative engines. Representing only 1 % of the total drive systems in 2011, forecasts are predicting a rise to 25% in total by 2030 (Shell, 2012). This change is related to a significant increase in relevance of strategic and critical metals in the automotive sector, not taken into account that the specific supply might be related to serious risks.

By the end of 2010, China’s vehicle population reached 90.86 million, up 19.3% year-on-year, deregistered 3.642 million, recycled 1.479 million ELVs. In China, there are 520 enterprises for dismantling ELVs, with 2,175 take-back stations and more than 30,000 employees. Manual dismantling operation mode guarantees a higher recycling rate. It is expected that by 2020, annual end-of-life vehicle processing capacity will be 13.65 million sets (table 1).

Table 1 Forecast of China's End-of-life Vehicle (2015-2020)

| | **Vehicle population** ($\times 10^4$) | **New vehicle** ($\times 10^4$) | **Scrapped vehicle** ($\times 10^4$) | **Rate of scrapped** (%) |
|---|---|---|---|---|
| 2015 | 11902 | 2120 | 831 | 7.0 |
| 2017 | 14460 | 2386 | 1028 | 7.1 |
| 2020 | 18841 | 3055 | 1365 | 7.2 |

China has high ambitions to reach the European recycling quota just 5 years behind the European market in 2020. Their potential of scrap cars in 2020 might equal more than one quarter of the total car market volume in Germany, considering the stable car market development in Germany.

## CRITICAL METALS IN AUTOMOTIVES

In the context of lightweight, intelligent and electric automobile, various new materials find wide applications in the industry. Meanwhile, advanced and complicated parts such as power cell, fuel cell, hydrogen storage unit and electronic control unit are constantly emerging, needing new recycling strategy to face the challenge. Counting solely the amount of secondary resources that are going to be available through ELV recycling in China, e.g. scrap steel is estimated to 15 to 22 million tons in 2020. In this context automotive parts will derive great value as resources. Besides, base metals like steel, copper or aluminum automotive parts contain more and more critical metals in future due to the technology change. The waste bulk metal oriented pattern in end-of-life vehicle recycling industry will be hard to ensure realization of 95% actual rate of recycling. Economic value in reutilization of used automotive materials and parts determines future of automobile recycling industry.

Besides cobalt and gallium, neodymium, dysprosium, praseodymium and terbium (rare earths elements) are identified as relevant in the automotive sector and they are all classified as strategic metals. Due to the high criticality of these resources and because of their limited availability, it is important to discover their destiny at the end of their service life, aiming to recover them for further use.

Taking into account the actual situation of the high percentage of combustion engines in cars most critical metals are found in:

- Catalysts
- Neodymium magnets
- Batteries

The percentage of rare earth elements will strongly increase if the electro mobility will show a tendency to hybrid cars. In this case a 50 kg drive battery contents up to 12 kg rare earth metals. This number can change by the coming years since the technology is still in its infancy and more research is needed in this field. There a numerous publications on car batteries and this paper focuses on catalysts and neodymium magnets.

### *Metals in catalysts*

A good example for resource recovery from car parts is given by the potential of motor catalysts: The ELV directive has set clear rules for the handling of automotive catalysts in the EU: In 2007 28t platinum and 31t palladium were recovered from automotive catalysts in a global scale (almost 15% of the global mining production). But despite this development it has to be underlined that even in the EU (especially in the new member states) the collection systems are not yet perfect at all.

Additional elements besides platinum and palladium in catalysts represent also rhodium, cerium and lanthanum. The content of platinum group metals (PGM) was investigated by Hagelüken, Buchert and Ryan (2006) and they could give ranges of PGM between 1 and 5 g per piece catalysts. In commercial vehicles this number could raise until 15 gram per piece.

Since the first use of automotive catalysts in the 1980s the PGM content was decreasing by the half due to more efficient technologies. With the change of the car market to more electric vehicles the number of catalysts will decrease accordingly.

The classical 3 way catalyst is loaded with a 5:1 ratio of platinum to rhodium content.

Numbers for cerium are not available at this moment. Cerium dioxide raises the gas purifying efficiency by storing the oxygen for a very short time and releasing it when needed. Lanthanum assures the temperature stability of the catalysis process and according to cerium there are hardly any reliable numbers to be found in literature.

### *Metals in neodymium magnets*

Considering the high material and energy efficiency in automotives we also observe high quality and safety standards in all cars. This results in more electronic devices, as sensors for distance or light measures for example. Additional the comfort is also increasing and many small motors operate inside our car (seat adjusting, air conditioning, the locking device, window opener, etc.).

On average neodymium magnets contain about 30 mass % of rare earth elements as neodymium, praseodymium and dysprosium. For a higher temperature resistance terbium may be added as well. A study of Mercedes-Benz (2012) states a number of 1 kg rare earth metals for the new A-class. Besides this study hardly any average number can be identified. Maybe this is due to special configurations by each customer. For example 18 motor devices can be necessary for the seat adjustment in specific car brands.

We locate 2080t of rare earth elements by taking into account the use of 10,400 t of rare earth metals for permanent magnets in 2008 (Oakdene Hollins, 2011) and its use by 20% for the automotive industry. Considering the worldwide production of cars (70,520,493) in the same year 2008 provided by the “Organisation Internationale des Constructeurs d’Automobiles” (OICA), a number of 29.5 g of rare earth metals per one single car can be assessed. Due to more electrical components in the cars, this number will increase in future.

## CONCLUSIONS

Critical metals are gaining more and more importance in the automotive sector due to the higher content of electrical devices and the increasing usage of batteries. There is still a big lack of data in the amount of critical metals in automotives. Also recycling technologies have to catch up with the rapid change in a car’s metal content. More than ever the Chinese car market has great potential for recovering critical metals. A decision tool for assessing the resources in specific car parts available for authorities, governments or industries can support the efficient use of natural resources in automotive industry significantly. The tool should assess the complete material use in automobiles and its life cycle. However, recovering valuable resources from vehicles is crucial for saving primary resources. Additionally, the assessment of cascade use for specific parts must be applied to evaluate the least ecologic and economic burden of further material use. Nevertheless, the general material flow analysis can help to identify and remedy irretrievable losses of critical resources.

## REFERENCES

European Commission (2008), The raw material initiative – meeting our critical needs for growth and jobs in Europe, *COM (2008) 699*, Brussels

EU, (2000) Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements

Hagelüken, C., Buchert, M., Ryan, P. (2006), Materials Flow of PGM in Germany, Life Cycle Engineering, *13thCIRP Int. Conf., J. Duflou, W. Dewulf (eds.)*, pp 477-482

KBA, (2013), Kraftfahrt Bundesamt Germany, Statistics, accessed May 2013, http://www.kba.de/cln_033/nn_125402/DE/Statistik/Fahrzeuge/fahrzeuge__node.html?__nnn=true

KrW-AbfG, (1994) Kreislaufwirtschafts- und Abfallgesetz, Germany, 27. September

Mercedes (2012), Study Modell A-Class, *Mercedes Studies*, accessed December 2012, http://www.mercedes-benz.de/content/germany/mpc/mpc_germany_website/de/home_mpc/passengercars/home/world/design/study.flash.html#concept_a

Oakdene Hollins (2011), Investing in Critical Metals, *Research paper June 2011*, accessed May 2013, http://www.oakdenehollins.co.uk/media/999/MetInvest_Report_Final.pdf

Shell, (2012), Mobility Scenario, *Shell Report*, accessed April 17th, 2012: http://www-static.shell.com/static/deu/downloads/aboutshell/our_strategy/mobility_scenarios/shell_mobility_scenarios.pdf