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Policy Brief

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Processing options and future possibilities for sustainable recycling of Hybrid Electric Vehicles and Internal Combustion Engine vehicles at vehicle recycling sites

Highlights

- Approximately 8-9 million tonnes of End-of-life (ELV) vehicles are generated in the EU every year. The End-Of-Life Vehicle Directive (Directive 2000/53/EC) has been a success with 23 member states meeting reuse/recycling targets by 2011 and a significant number exceeding targets.
- The new generation of End-of-Life Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV), poses new recycling challenges with respect to conventional Internal Combustion Engine vehicles (ICEV).
- The key areas of difference for vehicle recyclers are the larger quantity of high power/low weight motors on an (H)EV compared to the equivalent petrol/diesel technology. Typically, an EV (with a NiMH battery type) contains 4-5 kg of rare-earth elements (REEs) compared to less than a kilo in a new petrol/diesel car.
- Apart from REEs, (H)EVs contain other critical metals such as cobalt (Co), gallium (Ga), indium (In), niobium (Nb), platinum group metals (PGMs), antimony (Sb), tantalum (Ta), and tungsten (W).
- Cobalt in particular is now being singled out due to the rapidly rising demand for Co-containing Li-ion batteries for not only (H)EVs but also laptops and smartphones.
- The current ELV recycling practice, which includes shredding, causes random dispersion of the critical metals, especially for metals, which are concentrated within specific process streams but are used in small amounts in the whole vehicle (e.g. neodymium, samarium).
- Separation of neodymium- and dysprosium-containing rare-earth magnets has not yet been adopted by industry but is possible by dismantling relevant components before shredding of End-of-Life vehicles.
- The biggest technical challenge facing the motor disassembly process is the wide variation of rotor design and magnet size.
- The technical (disassembly) challenges should be met by legislators and vehicle manufacturers /recyclers either by depollution/removal of the high REE content motors prior to shredding and downstream processing or by further downstream processing of the shredded residues to separate the valuable REE-rich fractions physically.
- The disassembly of the magnet-bearing rotor is already profitable today, mainly because of the stators' high copper wire content, even if the REEs are not recycled.

Introduction

Approximately 8-9 million tonnes of End-of-life (ELV) vehicles are generated in the EU every year. The EU response to this issue was the End-Of-Life Vehicle Directive (Directive 2000/53/EC).

This was spun out in two phases:

(1) Only vehicles built after 2002 fall under extended producer responsibility (EPR);

(2) As of January 2007 all vehicles ever produced by manufacturer have EPR.

The objectives of the Directive were to:

(1) Limit waste arising from ELVs and their toxicity;

(2) Increase rates of reuse and recycling to specified targets;

(3) Any waste remaining will be appropriately remediated.

It is generally regarded that the Directive has been a success with 23 member states meeting reuse/recycling targets by 2011 and a significant number exceeding targets.

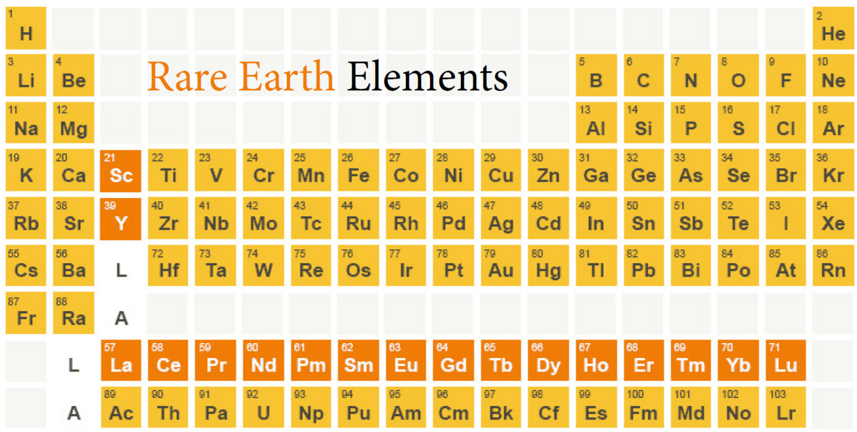
>> The European Rare Earth (Magnet) Recycling Network (EREAN) trains 15 young researchers in the science and technology of rare earths, with emphasis on the recycling of these elements from neodymium-iron-boron permanent magnets. <<

(H)EVs: a new challenge for car recyclers

Download through:
http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/erecon/index_en.htm

A new challenge is now the generation of a new type of ELVs, which will have to be handled by vehicle recyclers in the near future. Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) represent different recycling challenges with respect to conventional Internal Combustion Engine vehicles (ICEV).

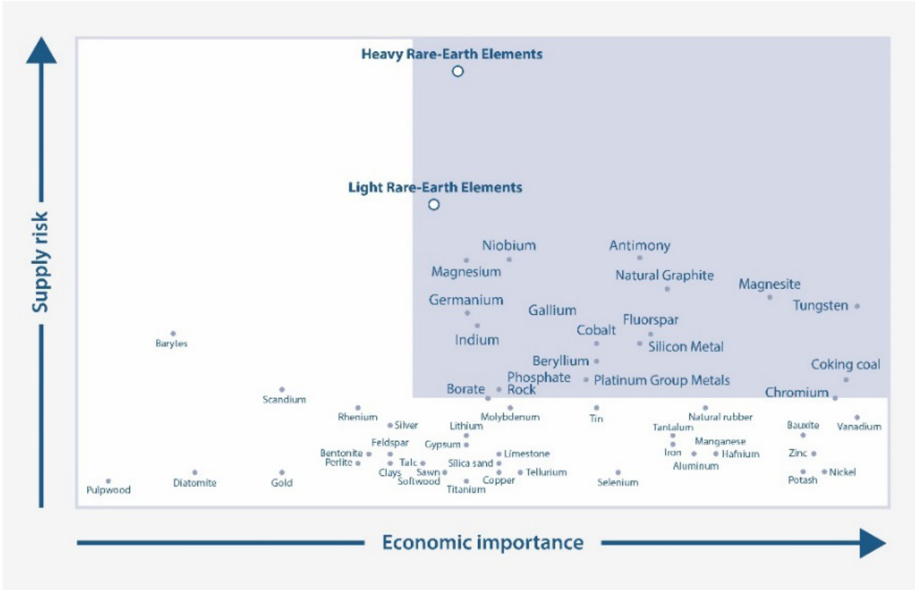
One of the key areas of difference for vehicle recyclers is the larger quantity of high power/low weight motors on an (H)EV compared to the equivalent petrol/diesel technology. This has the potential to open up new income streams for direct motor removal and recycling or the recovery of the valuable neodymium–iron–boron magnets from the motors via physical or chemical processing. The strategic nature of rare earth neodymium deposits also make it a political driver for recycling. The amount of REEs present in fully electric vehicles varies with the type/model of vehicle. Typically, an ELV EV (with a NiMH battery type) contains 4-5 kg of REEs compared to less than a kilo in a new petrol/diesel car [1]. In the case the battery is of the Li-ion type, the total amount of REEs is lower. What matters from a criticality point of view, is the presence of neodymium and dysprosium in the REE magnet motor, which is in the order of magnitude of 1 kg in total for both NiMH and Li-ion (H)EVs.



Rare-earth elements (highly relevant REEs in the permanent magnet motor of HEVs are Nd and Dy)

Other critical raw materials in (H)EVs

(H)EVs contain a complex mixture of metals and alloys and many (recyclable) materials. Apart from lithium (in Li-ion (H)EVs) and REEs, they also contain cobalt (Co), gallium (Ga), indium (In), niobium (Nb), platinum group metals (PGM), rare earth elements (REE), antimony (Sb), tantalum (Ta), and tungsten (W) are listed by EU as critical raw material in terms of high supply risks and high impact from a potential supply disruption [2]. Cobalt in particular is now being singled out due to the rapidly rising demand for Co-containing Li-ion batteries for not only (H)EVs, but also laptops and smartphones.



Critical raw materials for the EU (adapted from Ref. [2])

Current shredding process leads to dispersion

The current ELV recycling practice begins with depollution of key components (radiator, auto-cat, petrol tank, tyres) followed by shredding and disposal. Depollution starts with draining of all fluids, removal of the battery, removal of hazardous parts containing mercury or explosive components (e.g., seat belt tensioners or airbags) and dismantling of certain components for reuse and recycling (e.g., catalytic converter, tyres, and glass). This can result in underestimation of the mass of metals in a vehicle. The shredding process causes random dispersion of the critical metals, especially for metals, which are concentrated within specific process streams but are used in small amounts in the whole vehicle e.g. neodymium, samarium [3]. Neodymium magnets also stick to the shredder assembly and cause efficiency reduction. At the same time, the shredding process also causes a reduction of the critical metal concentrations when the components containing the metals are mixed with a large amount of iron or aluminium into shredder output fractions [4].

Stockpile of cars waiting for processing *

Towards high-grade recycling of ELVs

By analysing the currently practised treatment methods and recycling of End-of-Life vehicles, several potential areas for development have been identified, the development of which can lead to a (higher-value) secondary use of various recyclables contained in End-of-Life vehicles. For this purpose, the quality level ("high-grade recycling") of the current recovery paths of the treatment fractions needs to be assessed and possible material loss or contamination in the recovery chain need to be tracked. Recovery efficiency can be optimised through the design and use of improved recycling paths. Limiting the metal content of those fractions which are sent to backfilling, energy recovery or landfill sites post-shredding and extracting high-quality components before shredding open up higher quality (in the sense of a greater use of specific material properties), lower-loss and low contamination.

Energy recovery, incineration, backfilling, the use as landfill construction materials, or landfilling are typical current disposal routes for the shredder light fraction. In the case of these disposal routes, functional recycling of the recyclable materials is mostly not carried out.

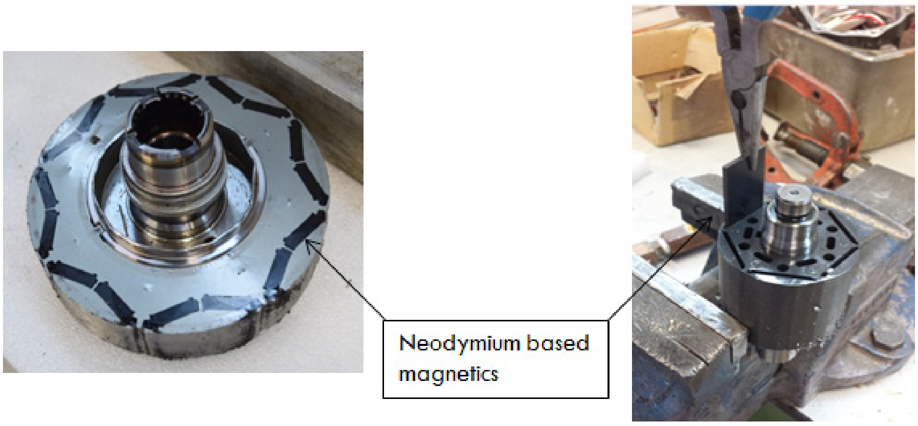
The implementation of a possible maximum metal content for shredder residues in legislation, which are destined for energy recovery/incineration or final disposal/landfill

Auto shredder residue being processed over a magnetic head pulley *

Axion recycling shredding plant *

sites, should be ambitious in order to recover as many metals as possible as secondary raw materials. Technical improvements as regards physical separation (eddy-current separation, electrostatic separation, optical/near IR sorting) mean that now post-shredder recovery of strategic and critical-metals-rich streams is feasible but not industrially practised at the moment [5].

>> DEMETER, is the European Training Network for the Design and Recycling of Rare-Earth Permanent Magnet Motors and Generators in Hybrid and Full Electric Vehicles. DEMETER concurrently develops (1) innovative, environmentally-friendly direct and indirect recycling strategies for the permanent magnets in the motors and generators of (H)EVs that are currently already on the market and (2) Design-for-Reuse solutions for motors and generators in the (H)EVs of the future. <<



Neodymium magnets in electric and hybrid cars *

REE motor recovery

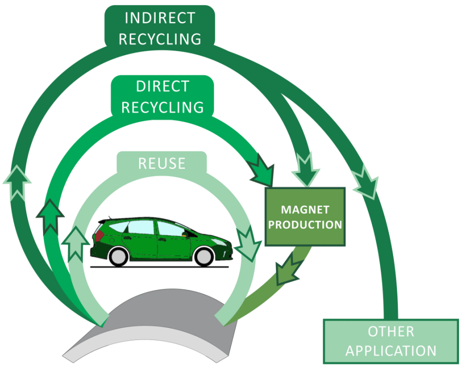
Through separation (before shredding) of catalytic converters, platinum group metals (PGM) have already a very high degree of recovery. Separation of neodymium- and dysprosium-containing rare-earth magnets has not been established but is possible by dismantling relevant components before shredding of End-of-Life vehicles.

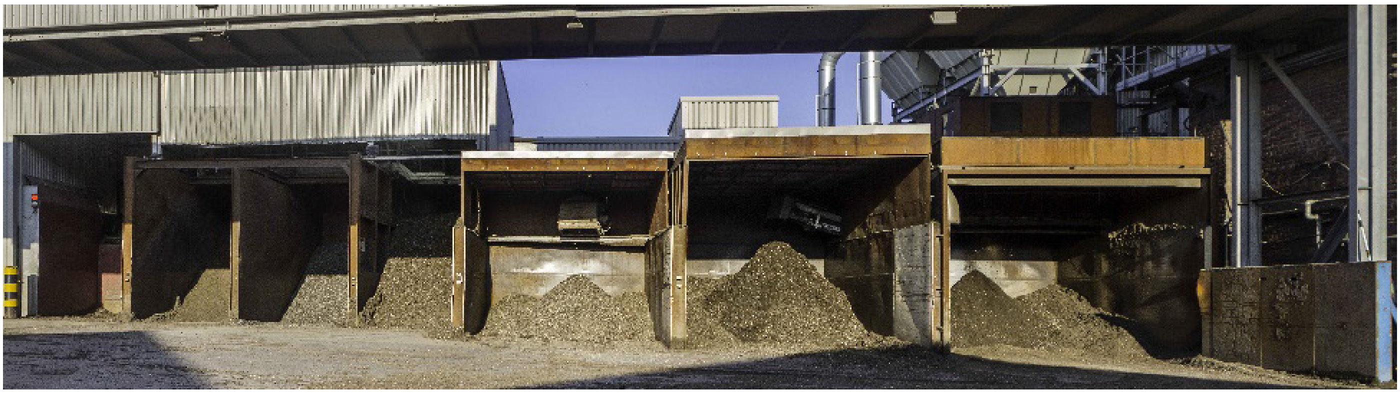
In a few recycling plants, some motors (e.g. the windscreen wiper motor) are removed for specific recycling (for copper) via specialised processors. However, at present this is not widespread. The potential to extend this process for the RE magnets in car motors is high. The complication is the sheer number of different car types being processed, the location of the suitable motors and high degree of variability in motor design assembly and valuable magnet content. Also, new electronic technologies adopted in the cars might lead to higher disassembly difficulties. However, if the motor is shredded, the REE content will be diluted and more difficult to recover.

During disassembly, the magnet carrying components such as the rotors are the most critical for removal. Disassembly of surface mounted magnets from these rotors has been tried and it has been shown that rotor disassembly could be potentially viable, even without the REEs not being recycled. This is mainly due to the high copper wire content [6]. The biggest technical challenge facing this process is the wide variation of rotor design and magnet size. Dismantling of electric motors for separation of rare-earth magnets has not yet been established industry-wide but definitely has potential.

The latter is corroborated by work in the German MORE project ("Recycling of components and strategic metals from electric drive motors—MORE"). Elwert and colleagues modelled a number of scenarios for the disassembly of permanent magnet motors from ELVs down to the rotor/stator level. The authors considered German labour costs, decentral/central processing and different permanent magnet motor types and concluded that the disassembly to the magnet-bearing rotor is already profitable today, mainly because of the stators' high copper wire content, even if in the case the REEs are not recycled [7].

Likewise, precious metal-containing fractions (from the circuit boards) can be collected with the conducting fractions via eddy-current separation (or electrostatic separation) in the copper rich fraction.





Final product stockpiles *

Conclusion

Based on the ratio of component revenues to disassembly effort, Groke et al. indicated that for eight of the 40 components of the vehicle electronics, separation and material recycling is already economically feasible under today's conditions. These are:

(1) Motors: heating fan and alternator;

(2) Electronic control units: engine control, gearbox control and drive control inverter (hybrid vehicle) and start/stop control;

(3) Sensors: oxygen sensor (lambda sensor)

These technical challenges should be met by legislators and vehicle manufacturers/recyclers either by depollution/removal of the high REE content motors prior to shredding and downstream processing (in a similar fashion as auto-catalysts are currently removed for platinum group metals) or by further downstream processing of the shredded residues to separate the valuable REE-rich fractions physically. Establishing a REE recycling process for the car recycling industry is a big challenge. However, the potential benefits of security of supply of REE going forward is a vital objective for the manufacturing industry of Europe [8].

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