Policy Brief

EU MSCA-ETN

DEMETER

September 2018

Why the electric-vehicle industry must work with the producers of rare earths to ensure a sustainable supply of these critical raw materials for Europe

- A collaboration and synergy between the electric-vehicle (EV) industry and the rare-earth permanent-magnet (REE PM) motor industry is the key to a sustainable supply of REE materials. This must be underpinned by materials passports.
- The majority of the current EV industry does not take into account REE end-of-life treatment or disposal, which hinders optimal recovery.
- Some EV companies, such as Tesla, have shown signs of hesitating to engage with the REE supply chain and have purposely designed their motors without REE permanent magnets…but this is changing!
- Exporting environmental pollution is both inherently unsustainable and unethical.

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This project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No 674973

Abstract

Information regarding sustainability is key for decision makers. This also holds true for the field of rare-earth permanent-magnet (PM) motors, for which the sustainability (economic, environment and social) is unfortunately not well understood and could become a show-stopper for future developments. The goal of this policy brief is to communicate the specific needs identified by the sustainability assessment for PM motors to better inform and support decision-making. While literature reviews are useful and informative, being informed is not enough and actions need to be taken. Therefore, we are strongly reccomending a greater, synergistic collaboration among industry suppliers and buyers of the two industries: the rare-earth element producers and the hybrid/electric-vehicle (H) EV makers.

Introduction

A recent publication, "Sustainability of Rare Earth Permanent Magnet Motors in the (H)EV industry" (Bailey et al., 2017) suggests that the (H)EV industry might not be as sustainable as perceived. A significant amount of REEs are found in the motors of EVs and HEVs. For HEVs, this is between 0.5 and 1 kg, and for EVs the range is from 1 to 2 kg (Widmer et al., 2015). However, the 'greenness' of these materials has been called into question (Stenquist, 2012, Don Anair, 2012, Hickman, 2012). Thus, a sustainability assessment was conducted and it was concluded that a deeper knowledge exchange is needed between the two industries in order for the PM motor to be seen as a sustainable product. The research needs identified by the PM motor sustainability assessment are for intersectorial collaboration, end-of-life strategies for these motors, an enhanced understanding of technological components, and a global societal perspective.

Collaboration in the REE value chain

Information about material sourcing is useful to policy makers. The source of materials and energy matter in the environmental footprint of EVs. With regard to materials in the EV motor production phase, there are no published data on the exact locations of resources and their compositions due to the involved companies' focus on confidentiality. But what we do know is that 75% of the materials are still largely coming from primary, virgin sources (Ford, 2014). Producing rare earths also necessitates the production of radioactive waste, thus the "Pollutant Discharge Standards for the Rare Earth Industry" was introduced to replace the general emission standards and set stricter maximum amounts for pollutants in water and air for the total discharge of waste water, waste air, thorium, and uranium However, according to estimates, 80% of enterprises will fail to meet these standards, and implementation could raise production costs by 70% (Zhongguo Gaoin Jishu Qiye, 2011). In order to clean up clean tech and to know more about where our (H)EV materials are coming from we should enhance the cooperation among European (H)EV industry and suppliers. We could even improve supply security and protect critical-metals investment cases through close collaboration. It is important to bring in one of the largest industries associated with REE permanent magnets, the (H)EV industry, to make a major impact on the rare-earth industry and to ensure the sustainability of REE PM motors.

GLoREIA

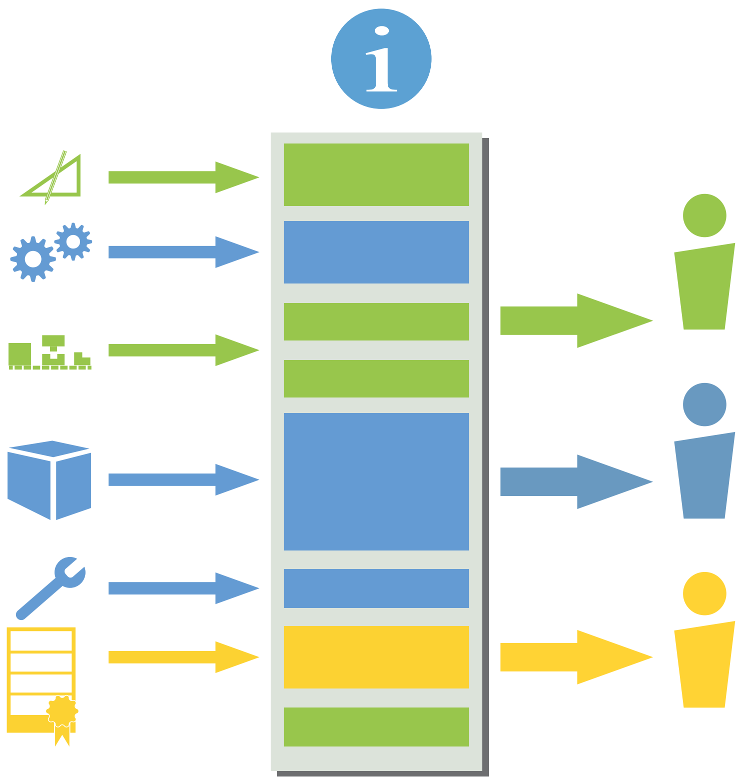
The European Commission has made large investments in FP7 and Horizon 2020 projects to secure the supply of rare earths and other critical raw materials in Europe. Many new projects have been funded withw the aim being to enhance the collaboration between industries that use critical materials. For example, EIT Raw Materials approved the GloREIA project, which stands for "Towards a Global Rare Earth Industry Association." As highlighted by the European Rare Earths Competency Network (ERECON), boosting supply security through enhanced cooperation among European end-users and other stakeholders should receive top priority ((ERECON), 2014). However, enhancing collaboration between the REE supply chain is a major challenge because unlike many other types of metals and elements, there is no REE industry association that gathers all the relevant stakeholders. The GloREIA project addresses this lack of collaboration within the REE supply chain.

Material passports

A material passport is like a certificate that contains essential information about the product. Traditionally, the critical raw materials industry is less transparent or knowledgeable about the actual substances used in their products. Developing a better understanding of what is inside a (H)EV is an important step in innovation before appropriate optimization and sustainabilty can occur. The information included in a material passport for REE PMs, for example, could include: Redesign and recycling, Material and Additives formulation, Component production, Product assembly, Service, Repariability and Dissassembling. There are ways to protect intellectual property and only to reveal pieces of relevant information where and when it is needed. This is practiced frequently in the medical and food sectors. Thus, a materials passport is more than a list of ingredients. One must also include a sustainabilty assesment on the products inside these systems. Composition is important, but context also matters. By employing material passports in this industry, a more circular supplier community would naturally fall into place.

End-of-life strategies/Recycling routes

Thus far, the most successful (H)EVs have REE motors, including the majority of newly introduced models, like the Nissan Leaf, except for Tesla, which does not use any REEs in its motor. However, it was announced on the US Environmental Protection Agency website recently that the Tesla Model 3 will contain a rare-earth permanent magnet motor instead of the AC induction motors used in all Tesla products to date



A materials passport can increase the opportunity to create circular loops within the rare-earth industry..

(EPA). Other companies are already intending to recycle REEs from end-of-life vehicles. Several years ago, Toyota, Honda, and Mitsubishi announced their campaign to start recycling rare earths; however, the status of their recycling activities is not advertised (Harman, 2012, Els, 2013) The main reasons preventing the recycling of REE PM motors—such as magnets not designed for easy removal and unknown feedstock amounts—are the result of a gap in collaboration between the (H)EV industry and the REE magnet industry.

Recycling technologies for PMs simply are not advanced enough to be considered economically viable or even sustainable. Current recycling of PMs is very minimal and practices exist only with the return of minor amounts of scrap material to the alloy manufacturing plant (Binnemans et al., 2013). Efforts to recycle the end-of-life products containing Nd-Fe-B yield a small return, and their physical extraction is difficult as these magnets are very brittle, and are deeply embedded and sometimes glued onto other products. Despite these challenges, the development of new magnet technologies and new cost-effective and innovative recycling technologies are being pursued (Dent, 2012) (IWKS, 2015, 2004). Predominantly, in the current situation, recycling efforts for these PM motors are viewed as not worth the cost. However, if there were more intersectorial collaboration or materials passports implemented, then it is likely that sufficient data would be available to improve the end-of-life strategy, such as by design for recycling, in the (H)EV industry.

A good example of a valiant first attempt at setting up a viable end-of life procedure is the H2020 project DEMETER. This project also collaborates with some automotive-industry partners, thus hopefully success will be hastened by this streamlined communication between the two industries. DEMETER aims to fill this gap by innovating and evaluating the recycling technologies for (H)EV motors. Within the context of this project, a framework will also be defined to ensure that these recycling solutions are economically and environmentally sustainable. More specific recycling routes for the large volume recycling of REEs from PM motors in industrialized facilities could increase transparency and help speed up the regulatory process of sanctioning end-of-life measures for (H)EVs.

Technological components in design for recycling/reuse

A sustainability assessment was performed in order to determine how the technology of the PM motor itself contributes to sustainability. Thus, to examine the difference between induction motors (IM) and PM motors, we refer to the aforementioned literature review that focuses on some of the technical aspects of permanent rare-earth magnets in (H)EV motors versus other types of motors used in EVs (Bailey et al., 2017). The main conclusion from this analysis is that an IM that is the same size as a PM motor will always have a lower efficiency compared with the PM motor. On the other hand, the

Contrary to popular belief, induction motors (such as those employed by Tesla) do not contain any rare-earth magnets. Instead, they work based on the current induced by the copper coils.

IM has a simpler design and could be easier to dismantle and thereby recycle. Moreover, the technological components of designing for recycling/reuse, although it increases the complexity of the sustainability question, is a component that may be dealt with at an enterprise level and not just a policy level.

Dismantling these motors from (H) EVs in an automatic or systemized manner is currently not possible. Moreover, the placement of the motor and the position of the rare-earth magnets inside are not convenient for removal. In addition, the nature of the EV and REE industries results in different types of REE PM motors used by EV companies. This is a problem for mainstream recycling because the placement of these magnets is different in almost every vehicle model, no matter if they share the same brand, make, and model. If these industries collaborated to standardize the placement of their magnetic materials then recycling could be facilitated. Despite this, the automotive industries do seem to be actively working on researching and developing dismantling and recycling techniques and incorporating them into vehicle designs. Toyota established the Automobile Recycle Technical Center within Toyota Metal Co., Ltd. in 2001 in order to look at "dismantling technologies for the magnets used in devices such as hybrid vehicle drive motors which use neodymium and dysprosium" (Corporation, 2014). Toyota is taking a two-pronged approach that many car companies are following: (1) use less rare earths when possible and (2) procure rare earths from recycled motors or urban mines. Unfortunately, to date, it has been proven that there is no constructive method for recycling the rare earths in these powerful magnets.

Ethical aspects

Importantly, (H)EV companies should communicate more strategically with the REE industry to not just continue to source neodymium and other rare-earth elements cheaply from China to avoid sometimes burdensome environmental regulation, but rather encourage the development of new products or materials to improve environmental and human health and well-being in all regions. Continuing to source REE magnets from China could be a missed opportunity to use EU regulation power to mitigate climate-changing impacts, but also hinders potential revenue to the EU economy. In other words, the sourcing of magnet-based motors from China with a high environmental impact is not only stunting the economic growth of the European automotive industry, but also serves to tarnish the (H)EV image, not polish it. This is an inherently unsustainable practice which is, paradoxically, promulgating a sustainable piece of technology. As such, we recommend that (H)EV companies work with PM motor suppliers and their REE suppli-

An example of a permanent-magnet motor typically found in (H)EVs. The magnet is contained inside the rotor, which cannot be viewed from this photo. This highlights the difficulty of their accessibility for recycling.

ers to determine any potential procurement risks when sourcing in China.

Risk of dirty image for (H)EV companies

Another ethical aspect of PM sustainability is related to the illegal mining of heavy rare earths (HREEs) in southern China, which used to be largely done by artisanal miners in the region. Most of the global supply of HREEs (e.g., dysprosium) originates from the "ion adsorption clay" ores of southern China. Since the HREEs are considered more strategically valuable, significant efforts have been made by Beijing to crack down on unbridled illegal mining in the region. Media reports have often attributed China's low rare-earth cost to poor environmental standards. Fearing irreversible pollution and the waste of resources caused by the rampant mining by the small rural mines, the central government in 1991 declared that ionic absorption clays in southern China would be kept under the protection of the state, and their mining, refining, and processing would be controlled by the central government. This policy, however, has never been effective. It was estimated that in 2012, illegal production of rare earths amounted to more than 40,000 tons. Particularly in the case of middle and HREEs mined in southern provinces, it was estimated that 70% of the resources are illegally mined.

Discussion & Conclusion

This policy brief serves to create a basis for informed decision-making on REEs ethical aspects, collaboration aspects, technological aspects, and end-of-life strategies through a knowledge of the (H)EV industry. Our recommendation to policymakers is to use material passports to determine the collection and recycling procedure for products, and to make policies which encourage close collaboration between automotive companies and REE magnet motor suppliers to ensure an economical and environmentally friendly REE PM motor. Technological change is necessary in order to render the PM motor more sustainable. Our recommendation is to make policies which encourage the close collaboration of REE magnet and EV companies to ensure that the motors are designed for recycling and reuse. We recommend that instead of sourcing only REE magnets for our motors from China, that European industry and policymakers support the development of a supply chain in several countries with stricter regulations (including Europe) otherwise the (H)EV industry risks damaging its green image.

Lastly, we promote the idea of collaboration between the two industries, since one of the policy recommendations for REE is: "to boost supply security and de-risk strategic REE investment cases through enhanced cooperation among European end-users and other stakeholders"((ERECON), 2014). We recommend to policymakers that more projects like GloREIA be funded with its prospects of bringing the two industries together, which will alleviate some of the immediate problems in regard to material sourcing and criticality.

A broad and international discussion on the need for sustainability within these

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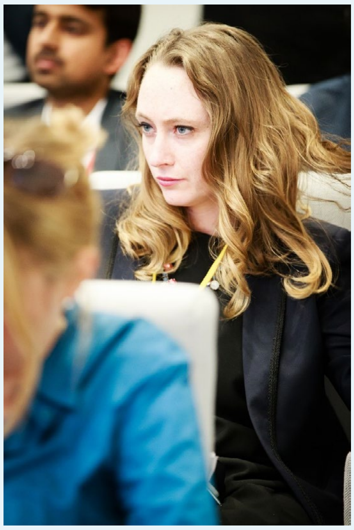
Gwendolyn is also involved in the coordination and life-cycle research management of a EIT Raw Materials funded project called GloREIA, or Towards a Global Rare Earth Industry Association. She has 2 publications in peer-reviewed journals, these revolve around the topic of sustainability assessments.



Bayan Obo is the world's largest rare earth mine. Ironically, this is where our most important materials for our sustainble technologies are made.

REIA will launch next year and hopes to become the first rare-earth association to create an LCA that will be used as a sustainability benchmark for the rare-earth industry.

two industries should be ongoing. Several elements may affect the realization of the end-of-life strategies for REE PM motors including: design for recycling, design for reuse, direct recycling of magnets coming from rotors, etc. (Eldosouky & Škulj 2018; Upadhayay et al., 2017; Sobekova Foltova et al., 2019) Hence, further guidance on incorporating recycling into motor design are of upmost importance, especially when the technology of PM motors moves so fast. In this respect, methodologies for capitalizing existing knowledge on where magnets are and where they come from are extremely important, e.g., further development of the materials passports, as well as the integration of a REE industry association as proposed by GloREIA to serve as a repository and knowledge transfer center for the PM industry. If these recommendations are hereby heeded, then the controversy surrounding the exportation of our environmental pollution might dissipate. On the other hand, if these recommendations are dismissed, then (H)EV companies in Europe might struggle to maintain a sustainable image if they continue to source ‘dirty’ materials which are not recycled.

Karel Van Acker

Prof. Karel Van Acker is a professor in sustainable materials management, coordinator of the Circular Economy @KU Leuven platform and coordinator of the KU Leuven Materials Research Centre. He also leads the policy research centre “Circular economy” for the Flemish government and is the former president and founder of the Flemish Transition Network on Sustainable Materials Management. His research is on developing strategies to realize the circular economy and on sustainability assessments of material life cycles, including amongst others biobased and composite materials, recycling of rare earths and other critical materials, landfill mining and the valorization of residues. The connection between materials and a sustainable society is the leitmotiv in Karel’s activities.

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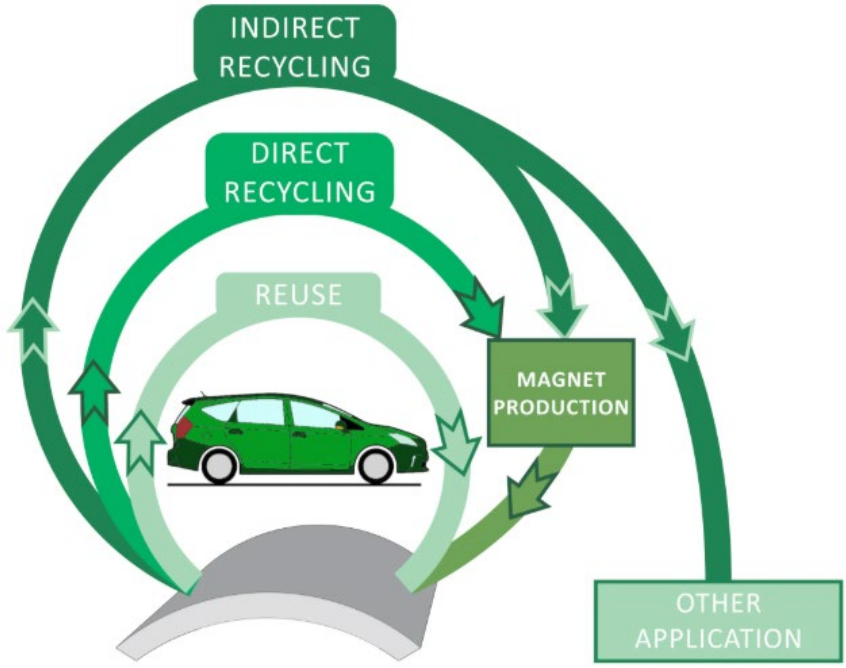
Key project information:
Project type: H2020 MSCA-ETN (01/09/2015 to 31/08/2019)
Website: http://etn-demeter.eu/project/
EU contribution: €3.8 m
Coordination: KU Leuven

The DEMETER project focuses on the recovery of large (i.e. > 30 g) REE permanent magnets in the drive motor, the power-steering motor, the stop-start motor, and the regenerative braking and range extender generators in (H)EVs and in highly Advanced ICEVs. There are three options with respect to the recovery of these devices. The first option is direct re-use: magnets could be removed from EoL motors/generators and used again in new motors/generators. This is, however, not a realistic option at present, as the magnets in the current (H)EVs were never designed to be removed and are often difficult to extract. In DEMETER the first aim is to develop strategies based on Design-for-Reuse with new generations of motors/generators that incorporate standard sizes of magnets that can be easily removed for re-use in new (H)EVs (and Advanced ICEVs). The second option is direct recycling, in which case the magnets are treated as a raw material for the production of new magnets, but using novel techniques such as hydrogen decrepitation processing, plasma/strip casting, and spark plasma sintering, to give new, ready-to-use, magnetic materials or a new master alloy that can be processed using existing magnet production facilities. The last option is indirect recycling. In contrast with the alloy route in direct recycling, indirect recycling implies that the magnet scrap material is transformed to its elemental components. The REEs are recovered from the magnets and separated from each other for use in subsequent permanent-magnet production or, possibly, in other existing or new applications, such as magnetocaloric materials or lamp phosphors. In DEMETER, not only NdFeB magnets, but also SmCo magnets are considered, as many magnet experts believe that SmCo is the better choice in certain motor applications.



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