
**Recycling of rare earth elements —
Requirements for providing
information on industrial waste and
end-of-life products**

*Recyclage des terres rares — Exigences pour la mise à disposition de
données relatives aux déchets industriels et aux produits en fin de vie*





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Foreword

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This document was prepared by Technical Committee ISO/TC 298, *Rare earth*.

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Introduction

Rare earth elements (REEs) comprise the lanthanoid series elements plus scandium and yttrium, which have similar chemical and physical properties and are often found in the same ores and deposits. The importance of REEs has increased greatly due to their important role in high performance and functional applications in permanent magnets, electric vehicles, motors, wind generators, light-emitting diodes (LED), nickel-metal hydride (NiMH) batteries, etc. Magnets can be also classified into manufacturing methods. The type of magnet is useful information for recycling procedures.

Magnets account for the highest market share of REEs by value. REE-containing multi-component alloys can have a complex compositional make-up. The variants include compositions such as $\text{Sm}_{62}\text{Co}_{38}$, $\text{Sm}(\text{Co}_{0.69}\text{Fe}_{0.2}\text{Cu}_{0.1}\text{Zr}_{0.01})_{7.2}$, $\text{Sm}(\text{Co}_{0.67}\text{Fe}_{0.22}\text{Cu}_{0.1}\text{Zr}_{0.07}\text{Ti}_{0.01})_{7.1}$, $\text{Sm}_2\text{Fe}_{17}\text{N}_x$, $\text{Nd}(\text{Fe},\text{Mo})_{12}\text{N}_x$, $\text{Sm}_3(\text{Fe},\text{M})_{29}\text{N}_x$, sintered $\text{Nd}_2\text{Fe}_{14}\text{B}/\alpha\text{-Fe}$, $\text{Sm}_2\text{Fe}_{17}\text{N}_x/\alpha\text{-Fe}$, PrFeCuB , $\text{Tb}_x\text{Dy}_{1-x}\text{Fe}_2$ ($x \sim 0,3$) and others are used in permanent magnets. Due to the complexity involved in processing of these magnets, several different manufacturing routes are used. During the production stages, industrial waste containing REEs is produced and often recycled. Magnets found in end-of-life (EOL) or broken electronics, hard disk drives, motors, generators, etc. also contribute to waste.

Phosphors and luminescence applications of REEs constitute about a one-third share of the total demand for REEs. REEs contained in $(\text{La}_{0.6}\text{Ce}_{0.27}\text{Tb}_{0.13})\text{PO}_4$, $(\text{Y}_{1.94}\text{Eu}_{0.06})\text{O}_3$, $(\text{Ba}_{0.9}\text{Eu}_{0.1})\text{MgAl}_{10}\text{O}_{17}$, $\text{Ca}_{0.98}\text{Eu}_{0.02}\text{AlSiN}_3$, $(\text{Y}_{0.98}\text{Ce}_{0.02})_3\text{Al}_5\text{O}_{12}$, etc. are important materials used in phosphor and LED semiconductor technology. The LED manufacturing process is complex and is undergoing much change with the growth of the industry and the changes in demand patterns of associated commodities. During the production stages of LEDs, a lot of waste is created, which is recycled. EOL LEDs found in broken smartphones, TVs, display panels, cameras, etc. also contribute to waste.

Batteries make up a relatively lower amount of the total demand for REEs. REEs contained in multi-component alloys such as LaNi_5 , $\text{La}_{0.8}\text{Nd}_{0.2}\text{Ni}_{2.5}\text{Co}_{2.4}\text{Si}_{0.1}$, $\text{La}_{0.8}\text{Nd}_{0.2}\text{Ni}_{2.5}\text{Co}_{2.4}\text{Al}_{0.1}$ and $\text{MmNi}_{3.5}\text{Co}_{0.7}\text{Al}_{0.8}$ are used in rechargeable NiMH batteries due to their superior hydrogen storage properties. The production of these NiMH batteries produces waste, which is generally recycled. EOL batteries also contribute to waste.

Numerous categories are schematically illustrated in [Figure 1](#) in which waste can be generated during manufacturing to the EOL stage for magnets, LEDs and batteries.

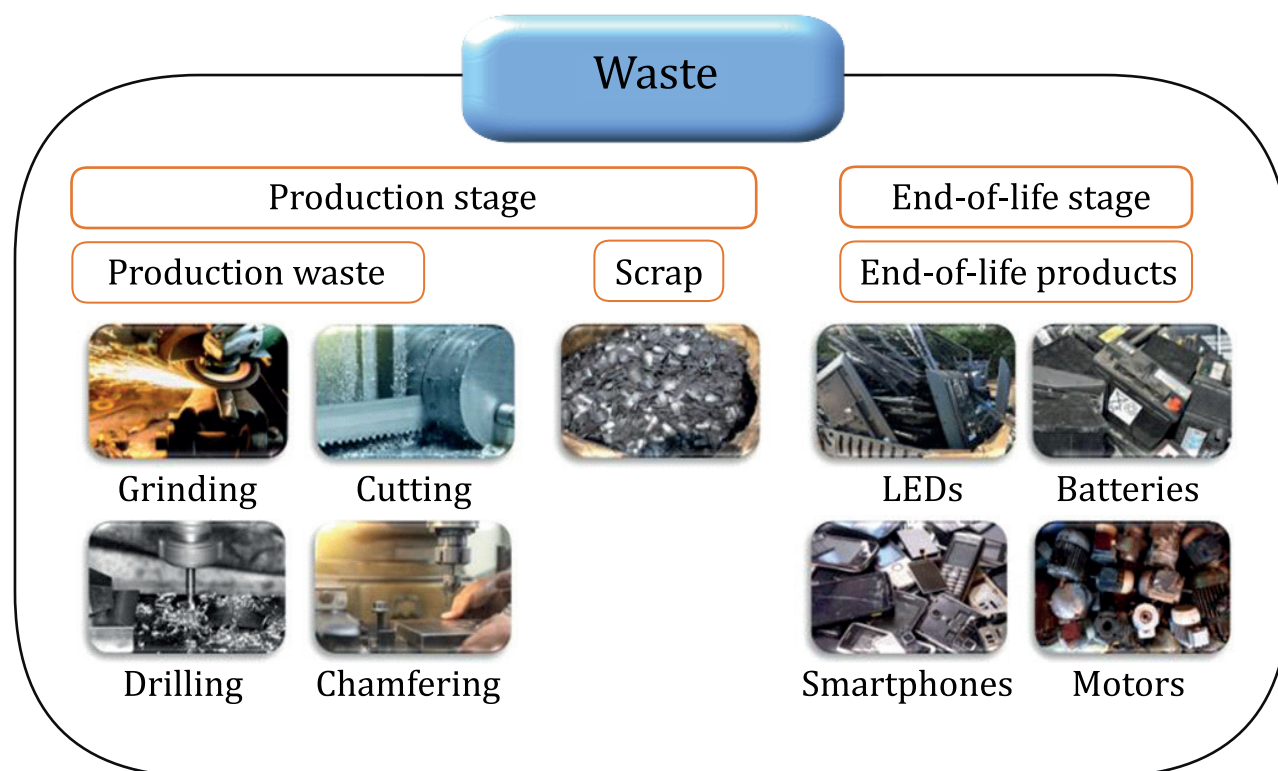


Figure 1 — Waste generation during various processes

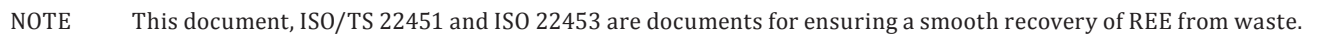
Resource scarcity of these valuable commodities is inevitable. Furthermore, the accumulation of waste materials creates environmental and economic problems. A viable option to ensure a smooth balance of supply and demand is to recycle these elements.

[Table 1](#) summarizes the expected REE waste stock that will be accumulated until 2020^[3]. It also gives the indication of recycled REE stock until 2020 by keeping in view the maturity of recycling techniques and industry.

Table 1 — Expected REE waste stock in the year 2020^[3]

REE application	Expected REE stock in 2020 (tons)	Recycling process efficiency	Recycled REE in 2020 (tons)
Magnets	300 000	55 %	2 333
Lamp phosphors	23 000	80 %	6 600
NiMH batteries	50 000	50 %	1 750
NOTE This table presents the current distribution, however, markets and waste distribution can change over time.			

There is a big difference in amount of waste generated by REEs and what is recycled due to a lack of maturity of recycling technologies and communication formats between manufacturers/producers and recyclers. In the REE recycling process, an important initial step is the identification of products containing REEs. A typical recycling process is shown in [Figure 2](#).



This document defines REE-related substances that are recycled at the product stage as waste or EOL products and suggests ways to facilitate their recycling through an identification of the waste composition. ISO/TS 22451 specifies measurement methods of REEs in industrial waste and EOL products. ISO 22453 focuses on the management of a database obtained from communication with the producer, recycler and a management agency for effective recycling. The simultaneous application of these three documents is necessary to ensure the complete and efficient recycling of valuable REEs.