Comparing Environmental Impacts of Natural Resource Extraction and Recycling Processes for Rare-earth Magnet Production

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Abstract

The environmental impact of producing rare-earth magnets is evaluated using the Life Cycle Impact Assessment (LCIA) model LIME2. First, characterization factors and weighted values are developed for neodymium (Nd) and dysprosium (Dy), which are not provided in the existing LIME2 model. To develop the characterization factors, we estimated the reserve volumes of Nd and Dy from the volumes and compositions of rare-earth oxide ores. We then surveyed the inventory data for two different processes for obtaining Nd and Dy to produce rare-earth magnets, namely, extraction from ore and recycling from post-consumer products. Finally, the environmental impact associated with rare-earth magnet production was evaluated by integrating the impacts of the different categories. A comparison of the LCIA results among different production processes suggests where the greatest opportunities for reducing the environmental impact may be.

Keywords: *Life Cycle Impact Assessment, Resource Consumption, Neodymium, Dysprosium, Recycling.*

Introduction

Rare-earth magnets (REM) have a strong magnetic force, and hence, they are used in motors for various high-performance products, such as hybrid vehicles, air conditioners, washing machines and wind turbines. REMs are typically produced from an alloy of neodymium (Nd), iron (Fe) and boron (B). Dysprosium (Dy) is sometimes added to make REMs heat-resistant. Because of the strong magnetic force provided by REMs, products that use REMs can save energy and reduce Green House Gas (GHG) emissions. However, various categories of environmental impact accompany the consumption of rare-earth metals through their production processes. For example, energy consumed in smelting and refining processes contributes to climate change, and mining leads to transformation of land use. Furthermore, the consumption of the metal resource itself is considered to be a significant impact due to the fear of depletion of the resource reserves. Therefore, together with the benefits of REMs, these negative impacts must be evaluated when considering how REMs might contribute to a sustainable future.

Life cycle impact assessment (LCIA) can evaluate different categories of environmental impacts associated with primary metal consumption (Swart and Dewulf , 2013; Yellishetty *et al*., 2009). LCIA models include many sub-models and provide impact coefficients for many substances. Therefore, users can calculate the impact arising from a particular process by collecting inventory data. The environmental impacts from the production processes of major metals such as iron, aluminum and copper have been evaluated and included in the existing LCIA models. However, the environmental impacts of most rare-earth metals are not yet included.

In this work we used the Japanese LCIA method "Life-cycle Impact assessment Method based on Endpoint modeling version 2 (LIME2)" to develop impact coefficients, called characterization factors, for consuming the rare-earth metals Nd and Dy extracted from ores. Then, we used the developed characterization factors and inventory data to evaluate the environmental impact associated with producing REM by aggregating the impacts of different categories. We evaluated two processes: producing REM from rare-earth metals extracted from ore and recycling of REMs after they have been recovered post consumption. A comparison of the aggregated results suggests the opportunities for reducing the environmental impact.