A Sustainability Assessment of Rare Earth Elements

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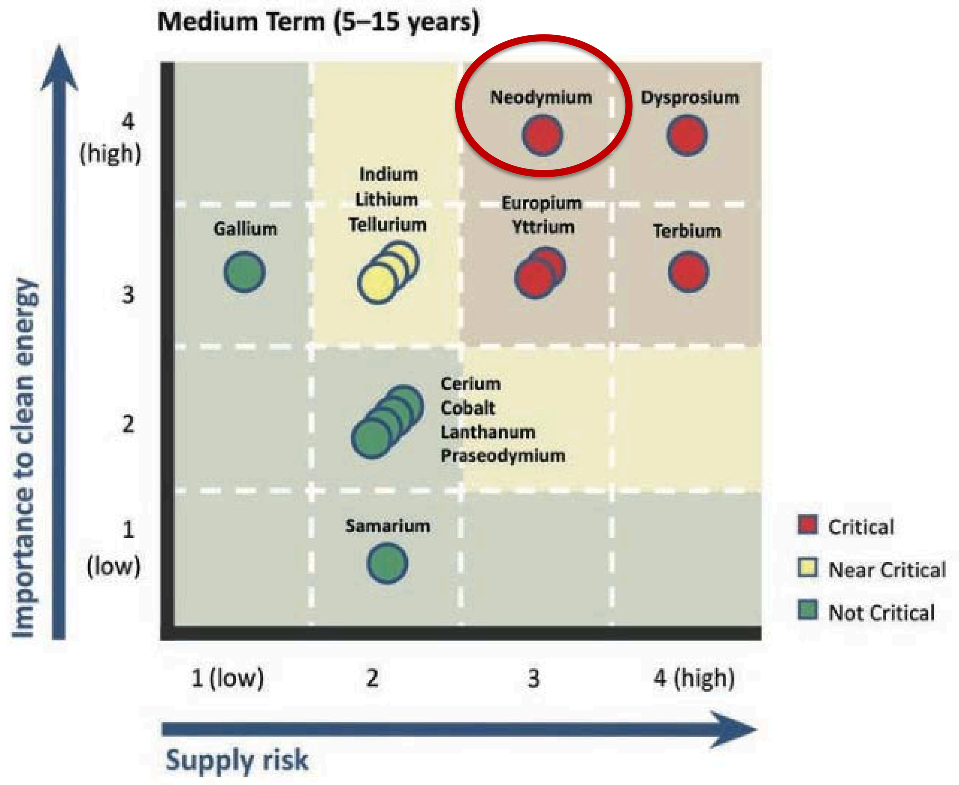
Background

My research examined eight of the seventeen rare earth elements (REEs): Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Europium, Terbium, and Dysprosium. In today's society, the major uses for these elements are in magnets and phosphors. Permanent REE magnets are smaller, lighter, and more powerful than other magnets and are used in everything from headphones to wind turbines. Whereas phosphors are used in displays for electronics and energy-efficient lighting.

Though REEs are referred to as "rare" they are actually quite abundant in the Earth's crust, however they are difficult to find in high concentrations. China has a monopoly over the REE industry, so if any other country tries to open a REE mine of their own, they will lower their prices until the company goes bankrupt and then they increase the price again. In 2011, REE prices skyrocketed because we believed that they were almost completely mined. In this panic, many REE dependent companies stockpiled REEs. However, since the market stabilized and companies have their stockpiles most people have gone back to ignoring that this is a problem, even though the threat of running out is still real. In 2010, during the crisis, the US Department of Energy published the Critical Materials Strategy, which featured supply and demand charts for REEs that are important to green technology (Bauer et al., 2010).



This chart, created by the USDOE in the Critical Materials Strategy, depicts elements that are at risk of depleting and important to green energy and examines which are in the most critical conditions (Bauer et al, 2010).

Method

The most reliable way to increase REE supply without mining is to begin recycling. With this in mind, my mentors and I decided to first create a concise set of tables displaying the amount of REEs in common products and future green technology. That information allowed us to determine which REE is the most needed and readily available to begin recycling. Following that we conducted a small financial viability assessment to determine if recycling said REE would be worth it.

Data and Tables

Common Products Containing Rare Earth Elements

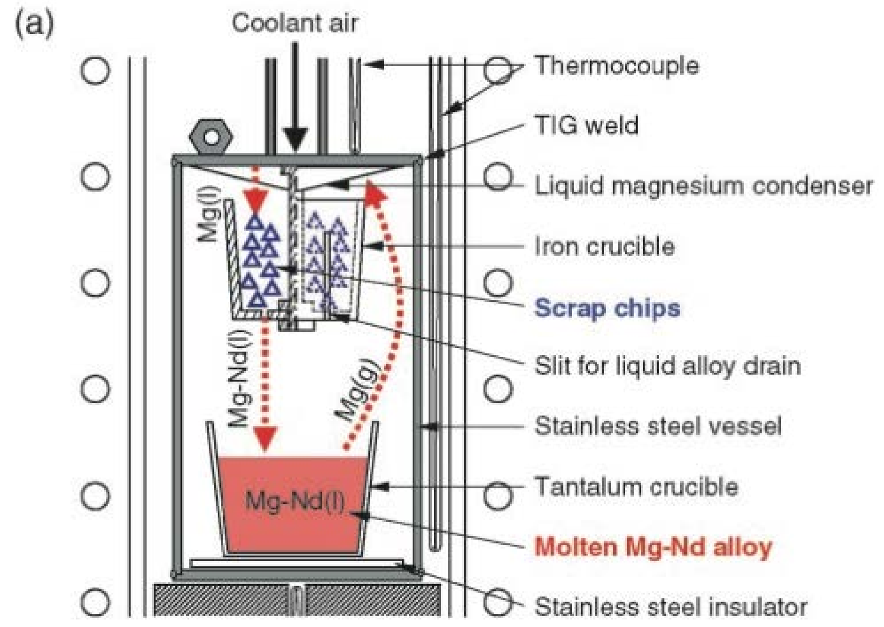
	Products						
Rare Earth Element	**Headphones**	**Speakers**	**Cell Phones**	**TV/CPU screen**	**Catalytic Converters**	**Hard Disk Drives**	**Light Bulbs**
Yttrium			Neglible	0.04 g/in^2	N/A		1.5 - 2.25g
Lanthanum					N/A		0.17 - 0.26 g
Cerium					N/A		0.16 - 0.24g
Praesodymium	0.025g	4g	0.03g			0.1g	
Neodymium	0.625g	100g	0.2g			2.5g	
Europium			Neglible	0.006 g/in^2			0.07 - 0.11g
Terbium			Neglible	N/A			0.10 - 0.14g
Dysprosium	0.1g	16g	0.013g			0.4g	

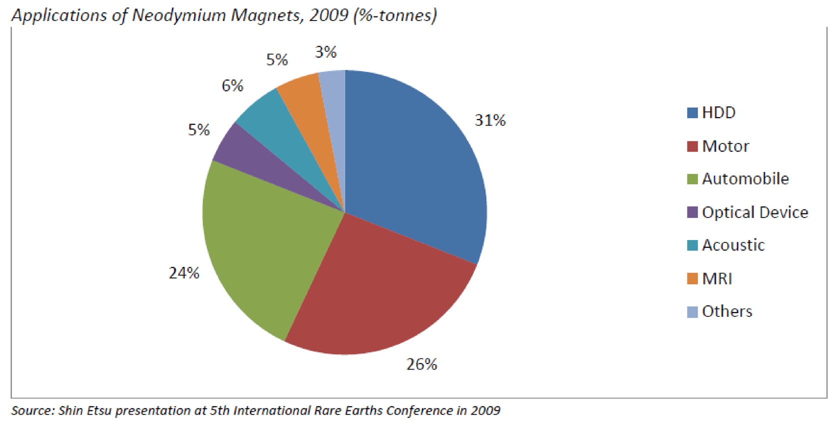
Rare Earth Dependent Green Technology

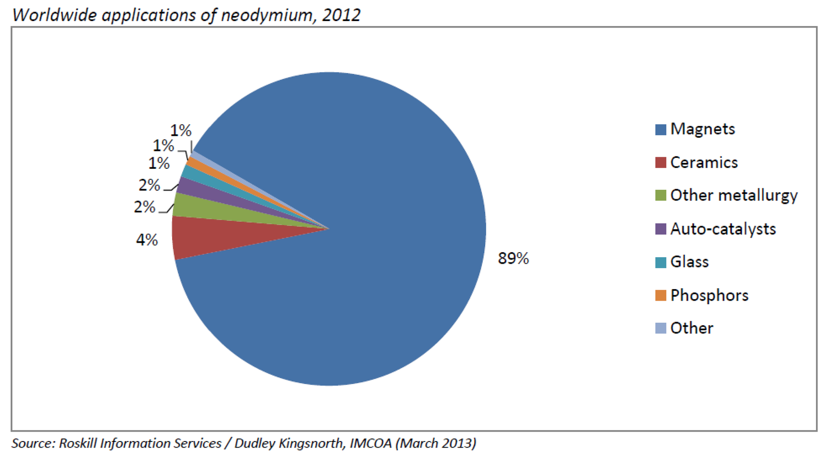
	Rare Earth Element							
Technology	**Yttrium**	**Lanthanum**	**Cerium**	**Praseodymium**	**Neodymium**	**Europium**	**Terbium**	**Dysprosium**
Wind Turbines				N/A	170 - 181 kg/MW			20.5 - 39 kg/MW
Vehicle Batteries (NiMH)		0.49 - 0.73 kg	0.69 - 1.03 kg	0.07 - 0.10 kg	0.20 - 0.31 kg			
Vehicle Magnets				N/A	310 - 620 g			22.5 - 55 g
Fluorescent Tube Bulb	2.46 g	0.29 g	0.26 g			0.12 g	0.16 g	
Fluorescent Bulb	1.5 - 2.25g	0.17 - 0.26 g	0.16 - 0.24g			0.07 - 0.11g	0.10 - 0.14g	

For data sources please refer to
https://docs.google.com/document/d/1b6PXj8NVKF9HLSfdyrwuTWApjhA9jCtjZwjaAauT8Ds/edit

Based on the data I gathered for my tables, the most abundantly used REE is Neodymium. Nd is primarily used in NdFeB magnets which are smaller, lighter and more powerful than other magnets lending themselves nicely to the advancement of electronics. However, once these magnets are taken out of the electronics the Nd can be extracted from the magnet scraps and recycled. The most cost-effective method of extraction I found through my research was developed by Toru H. Okabe and his team; this process used Magnesium as an extraction medium while the Neodymium is cycled through the apparatus seen below (Okabe, 2003).



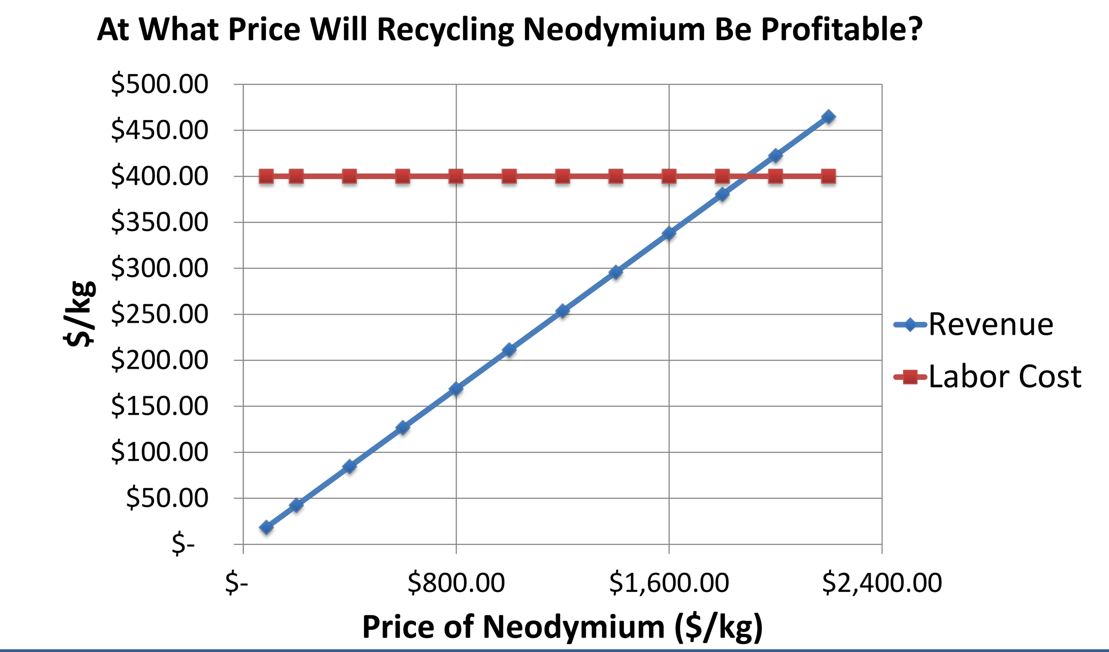




The above image is a diagram of the apparatus used by Okabe and his team to extract Neodymium from NdFeB magnet scrap (Okabe et al). The top right chart displays the uses of NdFeB magnets. The right chart displays the uses of Nd itself.

Viability Results

Using the method shown in the flow chart of the supplementary text, I determined that if a business recycling Nd magnets were to be started right now, they would be losing approximately $15,000.00 a day. Based on that information, it is obvious that its not economically feasible to recycle Nd as business right now. However, I determined what the price Nd would have to reach in order for it to be worth doing. And based on my calculations, the price would have to reach $1,893.50/kg in order to break even. This price is over twenty times the current price so we would either have to develop a better system to break down the headphones or wait for the price to skyrocket.



Future Plans

- Analyze global Nd supply and demand chart to determine when it would be worth recycling Nd
- Make scaled up model of Okabe's apparatus to see if efficiency remains the same
- Focus on other products that are high-demand and high-REE-intense

References

- Okabe, T. H., Takeda, O., Fukuda, K., & Umetsu, Y. (2003). Direct Extraction and Recovery of Neodymium Metal from Magnet Scrap. *Materials Transactions*, *44*(4), 798–801. http://doi.org/10.2320/matertrans.44.798
- Bauer, D., Diamond, D., Li, J., Sandalow, D., Telleen, P., Wanner, B., & (DOE). (2010). *Critical Materials Strategy: US Department of Energy*. *Agenda*. http://doi.org/10.1177/1532708609351151

Acknowledgments

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