An Examination of the U.S. Supply Chain for Rare Earth Elements and Critical Minerals

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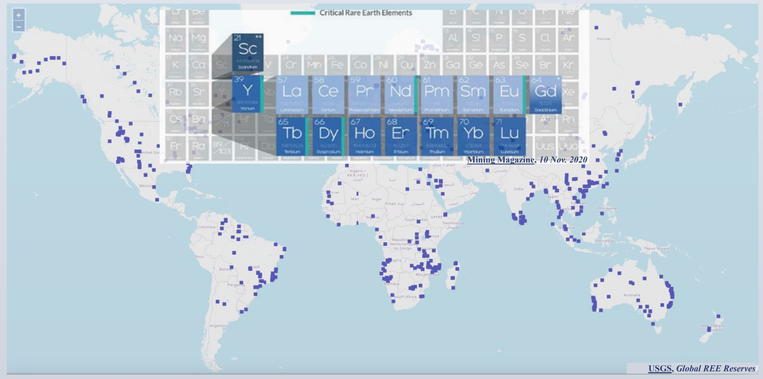
EME Summer Research Internship Program 2021

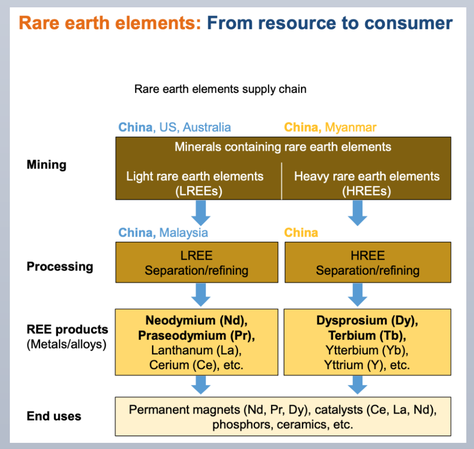
Introduction

Rare Earth Elements (REEs) and Critical Minerals (CMs) are integral to many products we use in our day-to-day lives, and are increasingly important to sustainable energy technologies. Some examples where REEs and CMs are crucially important are **Lithium**-ion batteries in electric vehicles, **Neodymium**-Iron-Boron magnets in wind turbine generators, and **Yttrium**-Aluminum-Garnet lasers used in multiple military and medicinal applications. REEs and CMs are vital to many innovations in science and technology. Currently, China holds a near monopoly on mining, processing, and refining. National security concerns have arisen due to increasing demand for REEs and CMs and China's dominant control of the market. Therefore, the United States needs to rapidly establish independence and curate domestic production of REEs and CMs to stay competitive in the global clean energy boom.



Objectives

- Define the supply chain of REEs and CMs in the U.S. and globally.
- Support the domestic production of REEs and CMs in high purity concentrations from coal and coal byproducts.
- Trace embodied REEs and CMs through imported products and identify potential for domestic replacement and end-value recovery.

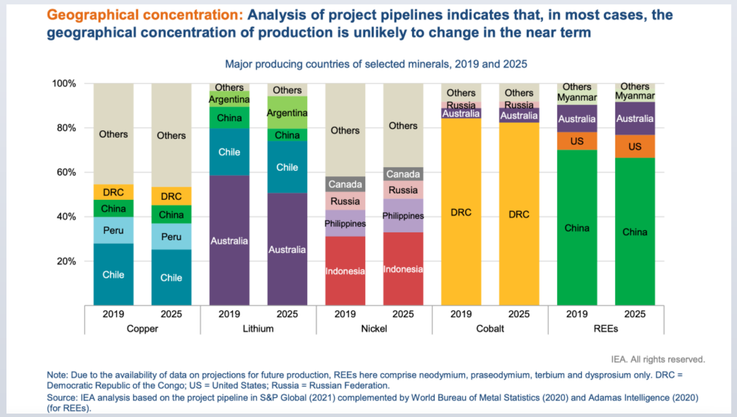


Challenges

- Domestic mines are faced with higher production costs as well as stricter environmental standards than our main competitor, China.
- China has a dominant market share position and invests in large numbers of overseas REE mines.
- New extraction techniques are not yet scalable.

Discussion

- Data from the International Energy Agency shows the control that China has on the REE markets.



- REE demand is projected to increase for renewable energy technologies, in particular wind and EVs.

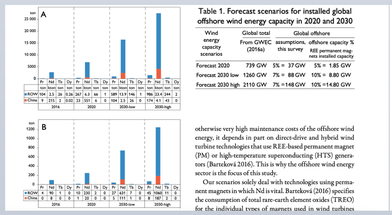
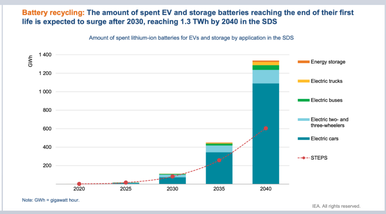


Table 1. Forecast scenarios for installed global offshore wind energy capacity in 2020 and 2030

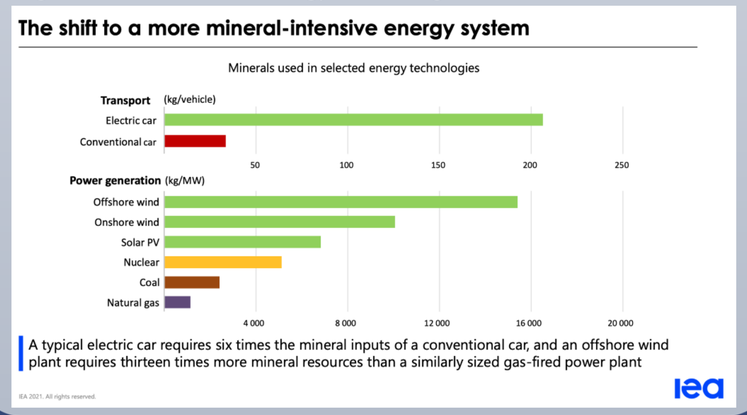
Wind energy capacity scenarios	Global total From GWEC (2016a)	Global offshore assumptions, this survey	offshore capacity % REE permanent magnets installed capacity
Forecast 2020	739 GW	5% = 37 GW	5% = 1.85 GW
Forecast 2030 low	1260 GW	7% = 88 GW	10% = 8.80 GW
Forecast 2030 high	2110 GW	7% =148 GW	10% =14.80 GW

otherwise very high maintenance costs of the offshore wind energy, it depends in part on direct-drive and hybrid wind turbine technologies that use REE-based permanent magnet (PM) or high-temperature superconducting (HTS) generators (Bartekova 2016). This is why the offshore wind energy sector is the focus of this study.

Our scenarios solely deal with technologies using permanent magnets in which Nd is vital. Bartekova (2016) specifies the consumption of total rare-earth element oxides (TREO) for the individual types of markets used in wind turbines

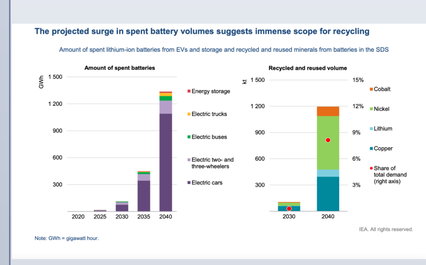


- REE and CM usage in clean energy technologies is significantly higher than traditional energy technologies.



Conclusions

- REE independence is of critical national security importance.
- It will take significant domestic investment and robust government support for the United States to become a significant producer and refiner of REEs.
- Recycling and recovery of REEs is another untapped area that the United States can pursue to increase domestic REE supply.
- Extracting REEs and CMs from coal and coal byproducts shows strong potential to increase domestic production.



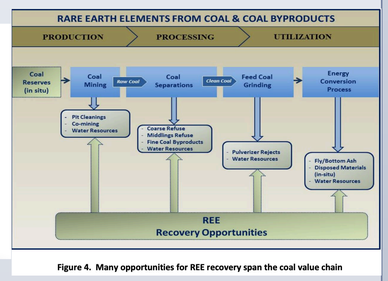


Figure 4. Many opportunities for REE recovery span the coal value chain

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Acknowledgements

- Dr. Randy Vander Wal, Advisor
- Dr. Justin Richter, Advisor
- Grace Choi, Financial Assistance
- John and Willie Leone Family Department of Energy and Mineral Engineering for Internship Sponsorship
- The support of the United States Department of Energy, National Technology Laboratory through the NETL-Penn State University Coalition for Fossil Energy Research (UCFER 0005-PSU-DOE-6825, DE-FE0026825) is gratefully acknowledged for this study.