PennState
College of Earth
and Mineral Sciences

Comparative Rare Earth and Critical Mineral Demands for Renewable Energy Technologies

AL-NABIL AL RAISI

UNDER SUPERVISION OF: DR. RANDY L. VANDER WAL

Project Goal

The project I was assigned focused on Solar technologies and wind turbines. The project's main goal was to initially find the Rare Earth Element (REE) and Critical Mineral (CM) components of each of these technologies and find their material intensities. The next step would be finding an estimate of the number of solar cells and wind turbines. This would then be used to determine the required Rare Earth and Critical Mineral quantities for renewable technology implementation. The last step would be comparing the projected demand to the available supply of REEs and CMs.

Solar technologies

- Solar PV panels are currently based on different sub-technologies, the most common of which are:
- • wafer-based crystalline silicon (c-Si), either single-crystalline or multi-crystalline silicon (no distinction between the two was made in this study) (5);
- • cadmium telluride (CdTe);
- • copper indium gallium diselenide (CIGS);
- • amorphous silicon (a-Si).
- Many studies assume that the majority of future solar PV installations will be of the crystalline silicon variety

Wind Turbines

- There are three general categories of mechanical designs for the generation and transmission stages of modern wind turbines: high-speed induction generators with multistage gearboxes, lower-speed direct-drive permanent magnet generators without a gearbox, and medium-speed hybrid drives that employ both gearboxes and permanent magnets. Among these types, direct drive permanent magnet generators offer least maintenance and highest efficiency.
- About 20% of all installed wind turbines use permanent magnet generators with rare earths. This limited share is likely linked to supply constraints. China currently manufactures about 90% of all rare earth magnets while consuming about 75% of the global supply. It is believed that increases in the use of rare-earth magnet generators could occur if new rare earth mines and processing facilities are established.

Material intensities

CIGS			
Rare Earth Elements	Indium	Gallium	Selenium
Material intensity (ton/GW)	28	9	161

c-Si		
Rare Earth Elements	SoG-Si	Silver
Material intensity (ton/GW)	6629	35.6

CdTe		
Rare Earth Elements	Cadmium	Tellurium
Material intensity (ton/GW)	138	156

α-SiGe	
Rare Earth Elements	Germanium
Material intensity (ton/GW)	41

Wind turbines				
Rare Earth Elements	Nd	Pr	Dy	Tb
Material Intensity (kg/MW)	127	13	13	7

Future Demand

- Future metal demand in the wind industry will depend on both the total amount of capacity installed and the choices between these two competing technologies. Elshkaki and Graedal (2013) assume that offshore wind turbines, which are nearly all direct-drive will grow to be 50 percent of total installed generation capacity by 2050. But the split between onshore and offshore installations, and even between geared and direct-drive installations between these two locations, is evolving and not yet certain.
- Future metal demand in the solar industry will depend on both the total amount of solar PV installed and choices between competing solar technologies. For example, the demand for indium depends not only on the penetration of solar PV, but also on what percentage of those installations are CIGS technology.

Reasons why I was unable to finish the project

- Poor Time management
- Unexpected travel back home
- Contracting Covid-19 during the crucial last two weeks of the program

References

- Nassar, N. T., Wilburn, D. R., & Goonan, T. G. (2016). Byproduct metal requirements for US wind and solar photovoltaic electricity generation up to the year 2040 under various Clean Power Plan scenarios. Applied Energy, 183, 1209-1226.
- World Bank Group. (2017). The growing role of minerals and metals for a low carbon future. World Bank.
- Davidsson, S., & Höök, M. (2017). Material requirements and availability for multi-terawatt deployment of photovoltaics. Energy Policy, 108, 574-582.
- Carrara, S., Alves Dias, P., Plazzotta, B., & Pavel, C. (2020). Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system. doi, 10, 160859.
- Dominish, E., Florin, N., & Teske, S. (2019). Responsible minerals sourcing for renewable energy. Report prepared for Earthworks by the Institute for Sustainable Futures, University of Technology Sydney.

Acknowledgement: Support through the EME Summer Internship Program is gratefully recognized.