Mineral Wealth & Electrification: A Producer-Country Perspective

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Technical Appendix

I. Data Sources & Uses

a. *USGS Mineral Commodity Summaries*[1]*:* The USGS provides annual commodity summaries on mineral commodity production and reserves. We used the summaries for: lithium, cobalt, copper, manganese, graphite, aluminum (bauxite), nickel, and iron. The units vary depending on the commodity; we standardized all values to metric tons.
   i. Natural graphite deposits vary in quality; only high quality "flake" and "crystalline vein graphite" are used in lithium-ion batteries (along with synthetic graphite production). USGS does not distinguish the type of graphite in production and reserves in the mineral commodity summaries; lacking more granule data at this stage, we include all graphite production and reserves but recognize this limitation.

b. *Bloomberg Terminal*[2]*:* We used market prices as of October 7th, 2024, as well as median census bank price forecasts through 2028 for each studied commodity.

c. *Bloomberg New Energy Finance*[3]**:** BNEF provides a *Transition Metals Data Hub* to subscribers, which includes forecast energy transition supply (based on mine-level analysis) and demand for different BNEF transition scenarios. We use the *supply* forecasts in our analysis, which are more conservative than the demand forecasts.
   i. For demand projections, BNEF models transition scenarios based on assumptions of global decarbonization pathways, technology adoption rates, and policy targets, taking macro factors such as economic growth, population growth, and urbanization trends exogenously. BNEF then solves for mineral demand growth based on the material intensity of the modeled transition technologies in each scenario. In practice, however, a

[1] National Minerals Information Center. *Mineral Commodity Summaries 2024*. U.S. Geological Survey, 2024. https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries.
[2] *Bloomberg Terminal*. Accessed September 30, 2024.
[3] BloombergNEF. *Metals: Transition Metal Supply & Demand Tool*. Accessed September 30, 2024. https://www.bloomberg.com/nef.

range of factors—including complex market dynamics, the long timelines needed to discover and develop profitable mines, and the uncertainties surrounding effective policy implementation and the adoption of higher-cost green technologies—will influence mineral market growth. In contrast, the mineral supply growth analysis is more granular and mine-level specific, focusing on the operational status, production capacity, and expansion plans of individual mining projects.

d. *PricewaterhouseCoopers Mining Taxes Summary Tool*[4]*:* We obtain most of the mining royalty rates from the *PwC Mining Taxes Summary Tool*, which is updated regularly and gives a comprehensive overview of taxes applied to copper, nickel, gold, lithium, iron ore, cobalt, coal, and generally (if no metal-specific rate is defined) for most mineral-producing countries.

II. **Data Limitations**

a. *Bloomberg Terminal* only provides commodity price forecasts through 2028, but we extrapolate metal supply forecasts through to 2030 and seek to compare the current view and the expected view in 2030. To handle the gap, we assumed 2% annual inflation and escalated the 2028 prices out two years to 2030 for closer comparison. This approach is obviously imperfect, but we deemed it appropriate for our stylized analysis. Additionally, there are no consensus forecasts available for graphite, so we escalate the 2024 value out six years for the 2030 figure. Finally, Bloomberg recently discontinued the relevant lithium index price (LI2CO3 EXW China 99.5%), so we access the current price from the Shanghai Metals Market website instead[5].

b. Certain countries/metals are not included in the *PwC Mining Taxes Summary Tool*. In several cases, we filled in missing data by using external sources from information on government websites, white papers, and media announcements. Information on royalty rates and accompanying sources is available on request.

c. Royalty design, in practice, is complex. Ad valorem rates may be applied to net revenue (allowing certain deductions) or blended with a profit-based royalty. While our stylized analysis of royalty rates is useful for high-level comparison, it presents a simplistic view of the complexities that inform the entire value capture picture, including royalty design. Beginning in 2025, our *Country Profiles* reports will dig deeper into country-specific royalty design including other primary value capture mechanisms within specific national contexts, as well as the current production and refining landscape down to the asset level. The reports will also delve into relevant policy and regulation, trade relationships, and socioenvironmental controversies.

[4] PwC Global. *Mining Taxes Summary Tool.* Accessed September 30, 2024. https://www.pwc.com/gx/en/industries/energy-utilities-resources/mining-metals/mining-taxes-summary-tool.html.
[5] Shanghai Metals Market. “Lithium Carbonate (99.5% Battery Grade) Price.” Accessed October 9, 2024. https://www.metal.com/Lithium/201102250059.

d. In some cases, the units reported by USGS and the market exchanges are inconsistent. We converted lithium content to lithium carbonate using standard industrial conversion factors of 5.323[6] and bauxite to aluminum using a conversion factor of 0.25[7].
    i. This makes a connected assumption that, for lithium and aluminum production, the producer country is refining onshore and selling the *refined* commodity at market prices for the refined product. While this is not strictly accurate, it is aligned with our producer country perspective on moving downstream and a stylized view on the value capture potential of transition-critical minerals.
    ii. Additionally, we are thus required to apply the royalty rate for the raw product to the refined product – in the case of aluminum, this difference may be significant in practice. This is applied consistently across producer countries for these minerals.
e. Most countries utilize ad valorem royalty rates. However, there are differences in how these rates are applied, and this information was not always available in our high-level overview.
    i. For example, Chile's royalty rate is applied to gross operating income, not gross revenue. For consistency, we apply all royalty rates to gross revenue as we only have access to total production and market prices. We emphasize that the analysis is a stylized comparison, not a forecast or prediction.
f. In this vein, some countries maintain unit-based royalties for bauxite. We "convert" these to an ad valorem royalty rate using the average unit value of imports in 2023 ($30 per metric ton) according to USGS. For example, Saudi Arabia has a unit-based royalty of $0.80 per metric ton of bauxite sold; the converted royalty rate is (0.8/30) x 100 = 2.67%.

III. Data Processing & Preparation

a. The following table details the formula, units, and a brief description of each data item prepared for the data table. The interactive map features a selected group of data items from the data table. Exceptions to specific data items are noted in the description column.

Data Item	Unit	Formula	Description
Share of World 2023 Production	Share/Percent	(Country-Level Production) / (Global Production)	A country's share of global production for a specific mineral in 2023. Only calculated for the metal-country pairs where production data is available.

[6] Pan Asia Metals. "Conversion Tables." Accessed September 30, 2024. https://panasiametals.com/investors/conversion-tables/.
[7] The IHA. "Aluminium Production: From Bauxite to Alumina." *histolu.org*. Accessed September 30, 2024. https://www.histalu.org/en/aluminium/the-main-stages-of-production/aluminium-production-from-bauxite-to-alumina.

Share of World Reserves	Share/Percent	(Country-Level Reserves) / (Global Reserves)	A country's share of global reserves for a specific mineral in 2023. Only calculated for the metal-country pairs where reserve data is available.
Annual Reserve Utilization 2023	Share/Percent	(Country-Level Production) / (Country-Level Reserves)	Calculated for each country-metal pair. The "Total" for each given country for this category is obtained as an average across metals to handle missing production/reserve data.
Current Value of 2023 Production	USD$	(Country-Level Production) * (Conversion Factor) * (Market Price)	Static estimate combining current market values of commodities and production quantities.
Current Value of Reserves	USD$	(Country-Level Reserves) * (Conversion Factor) * (Market Price)	Static estimate combining current market values of commodities and reserve quantities.
Estimated 2030 Production	Metric Tons	(Country-Level Production) * (BNEF 2030 Supply Growth Factor)	An estimate of 2030 production scaling current production by BNEF's supply growth factor. This makes the strong assumption that country-level production for a resource grows at the same rate everywhere but is useful for global comparisons.
Estimated 2030 Production Value	USD$	(2030 Production Value) * (Conversion Factor) * (2030 Price)	An estimate of 2030 production value scaling current production by BNEF's supply growth factor and multiplying by the forecasted 2030 market price. This makes the strong assumption that country-level production for a resource grows at the same rate everywhere but is useful for global comparisons.
Royalty Rate Midpoint	Percent	[(Low-end rate) + (High-end rate)] / 2	Countries sometimes have a range of royalty rates for specific commodities (based on factors like production amount, operators, etc). When a range exists, we apply the midpoint for value capture equations for simplicity and comparability. If there is no range, the “midpoint” is simply the reported royalty rate.
Estimated 2023 Royalty Value Capture	USD$	(Current Value of 2023 Production) * (Royalty Rate Midpoint)	A simplified estimate of direct value capture from royalties, utilizing the royalty rate (midpoint if applicable), current market prices, and USGS reported production. We currently exclude corporate income taxes from the value capture estimate given complexities.

Estimated 2030 Royalty Value Capture	USD$	(Current Value of 2030 Production) * (Royalty Rate Midpoint)	A simplified projection of direct value capture from royalties, utilizing the royalty rate (midpoint if applicable), current market prices, and the BNEF supply growth factor uniformly applied to USGS reported production. We currently exclude corporate income taxes from the value capture estimate given complexities.

IV. Data Presentation

a. The interactive map was created using **RShiny**, an interactive web application framework for R. The following R packages were utilized for data manipulation, visualization, and geographic mapping:

R Package(s)	**Use**
Tidyverse	Wrangling and visualization
Readxl; openxlsx	Reading and writing Excel files
sf	Handling spatial data
rnaturalearth; rnaturalearthdata	Obtaining map data
shiny	Building the interactive web application
leaflet	Generating interactive maps
dplyr	Data manipulation
DT	Rendering data tables