Critical Materials: A Compelling Case, Part 3

SMT Perspectives and Prospects

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Tumultuous forces involving geopolitical pull, along with technological and market push, have emerged since I published the first two parts of this topic in February and May 2022, respectively. Here, I will consider the impact of these new forces.

Critical materials and minerals that are the foundation for essential goods have long been sourced from areas with wars, near-wars, and some unfriendly nations; this causes high-risk concerns. When Russia invaded Ukraine on Feb. 24, 2022, for example, it elevated the uncertainty of materials and minerals. Then Hamas' attack on Oct. 7, 2023, added further peril to the availability, reliability, and security of the global supply chain. The potential hazards from these high-risk uncertainties have drawn intense attention across the national landscape.

Energy use (specifically electricity) continues to increase. This demand comes from the phenomenal growth of power-hungry data centers—some new data centers need grid connections as large as 500 megawatts—and increased deployment of potent AI tools, the need for high-performance computing, and a push for electrification. These market forces create a heightened criticality for some materials and minerals, including lithium, nickel, and some rare earth minerals.

On the national level, efforts have been made to preserve these minerals, yet a robust and integrated national strategy is needed that includes plans that are deliberate, comprehen-

sive, and speedy. They must call for a further holistic and amalgamated approach to ensure economic prosperity and national security, as well as global competitiveness.

Critical Materials and Minerals Going Forward

The criticality of materials and minerals goes to the most crucial ingredients for indispensable products and those that the U.S. has little control over due to the lack of our domestic natural resources and sources, or those that originate from high-risk areas. Mission-critical end uses also need to be considered.

The Energy Act of 2020, defines[1]:

- A "critical material" as any non-fuel mineral, element, substance, or material that the Secretary of Energy determines: (i) has a high risk of supply chain disruption; and (ii) serves an essential function in one or more energy technologies, including technologies that produce, transmit, store, and conserve energy; or
- A "critical mineral" as any mineral, element, substance, or material designated as critical by the Secretary of the Interior, acting through the Director of the U.S. Geological Survey.

The 2023 Final Critical Materials List determined by DOE includes the following:

- Critical materials for energy: aluminum, cobalt, copper, dysprosium, electrical steel, fluorine, gallium, iridium, lithium, magnesium, natural graphite, neodymium, nickel, platinum, praseodymium, silicon, silicon carbide and terbium.
- Critical minerals that include the following 50 minerals (per the Secretary of the Interior, acting through the director of the U.S. Geological Survey, published a 2022 final list of critical minerals): Aluminum, antimony, arsenic, barite, beryllium, bismuth, cerium, cesium, chromium, cobalt, dysprosium, erbium, europium, fluorspar, gadolinium, gallium, germanium, graphite, hafnium, holmium, indium, iridium, lanthanum, lithium, lutetium, magnesium, manganese, neodymium, nickel, niobium, palladium, platinum, praseodymium, rhodium, rubidium, ruthenium, samarium, scandium, tantalum, tellurium, terbium, thulium, tin, titanium, tungsten, vanadium, ytterbium, yttrium, zinc, and zirconium.

Examples of Critical End-Uses

Nickel, lithium, and some rare earth elements are the most critical materials for energy yet bear the biggest supply risk.

The price of nickel (Ni), for example, has been uncharacteristically volatile during the past couple of years. It soared into an uncontrolled spike on March 8, 2022, reaching a record $100,000 a metric ton on the London Metals Exchange (LME). However, the price later pulled back, and because of this dramatic pricing volatility, the LME paused trading on

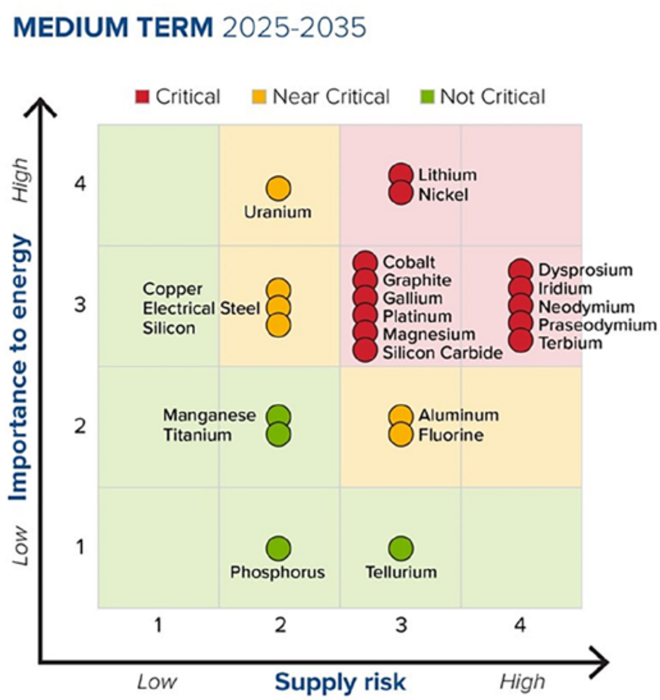

Figure 1: Levels of supply risk to the importance of energy in time horizon, 2025–35[1].

March 8, 2022, and did not resume until eight days later. It caused a review by regulators and LME, and resulted in litigation[2]. It now stands as a warning signal that pricing volatility can indicate inadequate reliability and/or is associated with undue market manipulation.

Nickel is not a fancy metal but a key ingredient for stainless steel and lithium-ion batteries that power electric vehicles (EVs). Russia and China are major suppliers of nickel, as is Indonesia. Russia also supplies oil, gas, and other essential minerals, including palladium (Pd), an essential element for catalytic converters, and semiconductor and electronics manufacturing. It is reported that about one-third of the world's palladium comes from Russia. About two-thirds of the world's lithium and cobalt, essential for electric vehicles, is processed in China.

As a key ingredient in making batteries for EVs, cellphones and laptops, lithium demand reportedly would quadruple by 2030.

According to estimates from the USGS, the U.S. has consumed an average of 8,300 metric tons of rare-earth oxides annually in recent years. The U.S. is racing to catch up with China and other countries on rare-earth supplies, as these minerals are in ever-greater demand. Some uses include EVs, offshore wind turbines, and permanent magnets.

Titanium, which is crucial for manufacturing jet airplanes and military aircraft, has been heavily sourced from Russia. A unique metal known for its high strength, light weight, and corrosion resistance, it cannot be readily substituted. Even though some materials may not risk direct exposure, indirect impact is expected to trickle down throughout the global supply chain.

According to the Critical Raw Materials Alliance, China produces 60% of the world's germanium and 80% of gallium. Both elements are essential in manufacturing electronics and semiconductors. For example, germanium is used in fiber optic products, solar products for space, and night-vision goggles, while gallium is a critical material for semiconductors to make essential gallium compounds (e.g., gallium arsenide, gallium nitride).

Role of Business and Government

In business, long-term investment requires deliberations under the spotlight of reliable and secure critical materials. Corporate boards should be addressing this through an enterprise risk management program. For instance, Exxon Mobil announced its plans to drill for lithium in Arkansas and start producing battery-grade lithium by 2027[3]. Exxon's goal by 2030 is to become a major U.S. supplier of lithium to makers of EV batteries.

Research and funding should be prioritized in government and academia, with action and implementation taken accordingly.

Furthermore, the integrated cross-agency program relevant to critical materials and minerals is duly warranted to tackle the technologies, processes, and manufacturability effectively and speedily. It is easier said than done; yet it is the time to do so.

The Role of Artificial Intelligence and Supply Chain Challenges

Critical materials and minerals will have an overarching impact on the global supply chain across all industries and sectors. Once the chain is broken, the whole system fails.

Recently, the supply chain experienced unprecedented disruptions and hurdles due to a slew of factors and root causes. Simply put, these fundamental supply chain issues can be attributed to decades of globalization, offshore manufacturing, and technological changes, in conjunction with many diverse suppliers being embedded in each product. Consequently, managing today's global supply chain is a daunting task, and securing reliable sources of materials and minerals requires an ongoing effort.

The bulk of battery manufacturing, for example, occurs in Southeast Asia, and establishing supply chains for key materials, such as lithium-hydroxide, can take anywhere from three to seven years. As demand rises, the multiple steps—ranging from developing alternate supply sources and establishing strategic partnerships to innovating new materials and battery technologies—should be the path forward to securing a stable supply chain.

Is sodium-ion battery technology a viable alternative? Sodium is more abundant than lithium, less vulnerable to geopolitical challenges, and brings a substantially lower cost—the price of sodium carbonate is $286/ton vs. battery-grade lithium carbonate at $20,494/ton.

Developing and deploying AI tools that manage the supply chain in a timely way will alleviate some of the bottlenecks. One viable task is a model that combines data with artificial intelligence to predict unconventional deposits of rare earth and critical minerals.

Semiconductor "chips" are another example. High computing chips (GPU, CPU, TPU) are not only figuratively hot in terms of market demands, but literally hot in terms of temperature. AI tools to facilitate chip design and subsequent packaging and PCB assembly to facilitate thermal management are expected to boost productivity and innovative products required by the continued advances in AI technology and AI tools. AI can "reciprocally" help as an effective tool for chip design and chip manufacturing as well.

Conclusion

Securing reliable sources of materials and minerals may be challenging, but it's a must. It's a necessity to diversify sourcing routes for key materials and develop alternatives for industries that have become highly dependent on unsecured sources. New AI tools can facilitate the required outcome. **SMT007**

References

1. U.S. Department of Energy.
2. "London Metal Exchange Wins Fight on Nickel," *The Wall Street Journal,* Nov. 30, 2023.
3. "Exxon Starts Drilling for Lithium," *The Wall Street Journal,* Nov. 14, 2023.

Appearances

Dr. Jennie Hwang will deliver a Professional Development Course, "Artificial Intelligence—Opportunities, Challenges & Possibilities," and "High Reliability Electronics for Harsh Environments," April 7 and 8, respectively, at IPC APEX EXPO 2024.

Dr. Jennie S. Hwang, an international businesswoman, international speaker, and a business and technology advisor, is a pioneer and long-standing leader in SMT manufacturing since its inception, and in developing and implementing lead-free electronics technology and manufacturing.

She has served as chair of Artificial Intelligence-Justified Confidence for DoD Command and Control study, chair of AI Committee of the National Academies, and Review Panels of NSF National AI Institutes. An International Hall of Famer (Women in Technology), she has been inducted into the National Academy of Engineering, named an R&D-Stars-to-Watch, and received the YWCA Achievement Award. She has held senior executive positions with Lockheed Martin Corp., and was CEO of International Electronic Materials Corp. She is currently CEO of H-Technologies Group, providing business, technology, and manufacturing solutions.

She has served as chair of the Laboratory Assessment Board, the DoD Army Research Laboratory Assessment Board, and the Assessment Board of Army Engineering Centers. She is on the board of Fortune-500 NYSE companies and civic and university boards, Commerce Department's Export Council, National Materials and Manufacturing Board, NIST Assessment Board, various national panels/committees, and international leadership positions.

She is the author of 10 books (four as co-author) and 700+ technical/editorial publications. She is a speaker and author on trade, business, and education issues. Her formal education includes four academic degrees (Ph.D., M.S., M.A., B.S.), as well as Harvard Business School Executive Program and Columbia University Corporate Governance Program. To read previous columns, click here.