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"The Mineral and Metal Foundations of the Energy Transition"

Congressional Testimony of
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Before the
Committee on Energy and Natural Resources
United States Senate
116th Congress

Chairman Murkowski, Ranking Member Manchin, and Members of the Committee, thank you kindly for inviting me to testify on the minerals needed for clean energy technologies. I appreciate the bipartisan spirit that this Committee brings to the energy issues of the United States. It is an honor to appear before this Committee on the critical topic of the mineral foundations of the energy transition.

My name is Morgan Bazilian, and I am a Professor and Director of the Payne Institute for Public Policy at the Colorado School of Mines. The Colorado School of Mines is a public research university, where students and faculty together address the great challenges society faces—particularly those related to the Earth, energy, and the environment. The Payne Institute was established to bring the cutting-edge science, mathematics, and engineering at Mines to bear in helping to inform policy.

Minerals and metals are central to the energy transition, but the economic, security, and geostrategic implications are all in play, depending how the U.S. policy responds.

The principal impetus for the 2017 Executive Order (13817) provides a useful framing for this hearing: "The United States is heavily reliant on imports of certain mineral commodities that are vital to the Nation's security and economic prosperity. This dependency of the United States on foreign sources creates a strategic vulnerability…"

We can be confident that the tremendous growth and innovation in technologies such as batteries for electric vehicles and grid-electricity storage, fuel cells, wind turbines, and solar photovoltaics (PV) will continue. Each of these clean energy technologies relies on significant quantities of a diverse group of critical minerals and metals.

The future energy system will be far more mineral and metal-intensive than it is today. [1] Many of these advanced technologies require minerals and metals with particular properties that have few to no current substitutes.

The opportunity for the mining industry is tremendous. An industry that has experienced enormous public pressure and critique, accompanied by offshoring production overseas, can now evolve into one fundamental to supporting a shift to a low-carbon and sustainable energy system based on domestic natural resources.

The issues related to the mineral foundations of the energy transition go well-beyond the energy and extractives sectors. There will be implications for geopolitical dynamics, defense, consumer technology, water security, industrial growth, innovation in high-tech sectors, responsible consumption and production, decent work, and equality.

My testimony will begin with some historical context and then move to future scenarios. The following sections will consider issues of security and criticality, and conclude with some thoughts on domestic energy and natural resources policy.

I applaud the Committee for robustly and persistently considering these issues. This Committee most recently held a hearing on similar matters on May 14 of this year, making this the 8th in the genre.

The continued focus on supply chains, as well as a building robust domestic industry with the "highest environmental and labor standards in the world," is appropriate and important. Your deliberations and actions can lay the foundation for a productive engagement by the U.S. on issues of global importance.

[1] See e.g., André Månberger, Björn Stenqvist, Global metal flows in the renewable energy transition: Exploring the effects of substitutes, technological mix and development, Energy Policy, Volume 119, 2018, Pages 226-241; Anna Stamp, Patrick A. Wäger, Stefanie Hellweg, Linking energy scenarios with metal demand modeling–The case of indium in CIGS solar cells, Resources, Conservation and Recycling, Volume 93, 2014, Pages 156-167; Jan de Koning, René Kleijn, Gjalt Huppes, Benjamin Sprecher, Guus van Engelen, Arnold Tukker, Metal supply constraints for a low-carbon economy, Resources, Conservation and Recycling, Volume 129, 2018, Pages 202-208.

PAST AND FUTURE

We are seeing rapidly increasing mineral intensity in the energy sector. Figure 1 helps us better understand the historical development of the energy system in terms of both energy sources and end uses. Society moved from agrarian communities using biomass, to the industrial revolution and coal, to a modern area of services and a portfolio of energy sources including petroleum, natural gas, nuclear, and renewables.

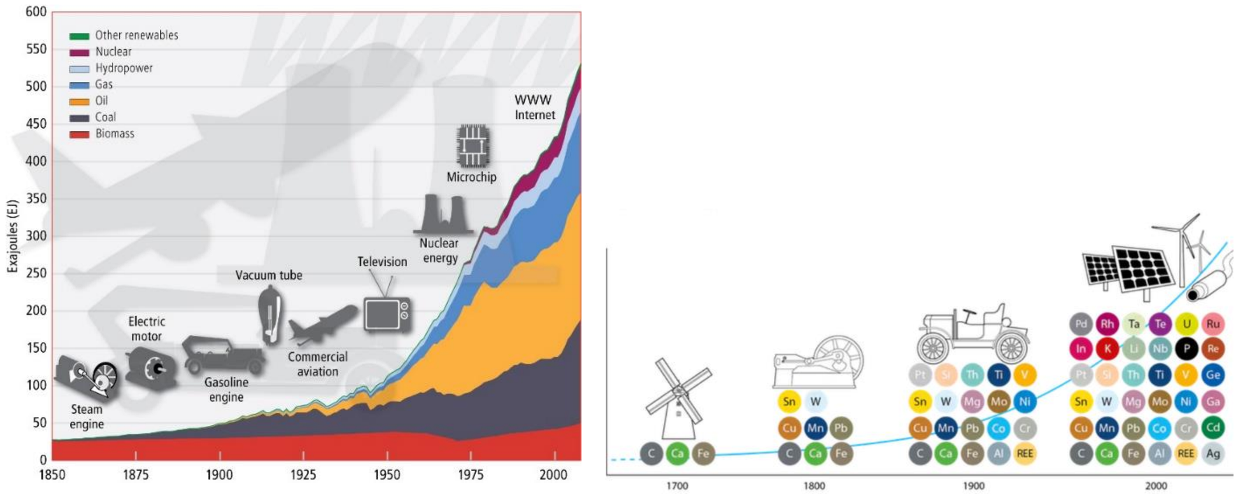

Figure 1: Left, Nakicenovic, IIASA; Right, Zepf, 2014

The current set of minerals required for clean energy technologies such as PVs, wind turbines, LEDs, and vehicle batteries is diverse (Figure 2). Each of the individual minerals have their own set of supply chain conditions, and will thus require individual examination and policy prescriptions.

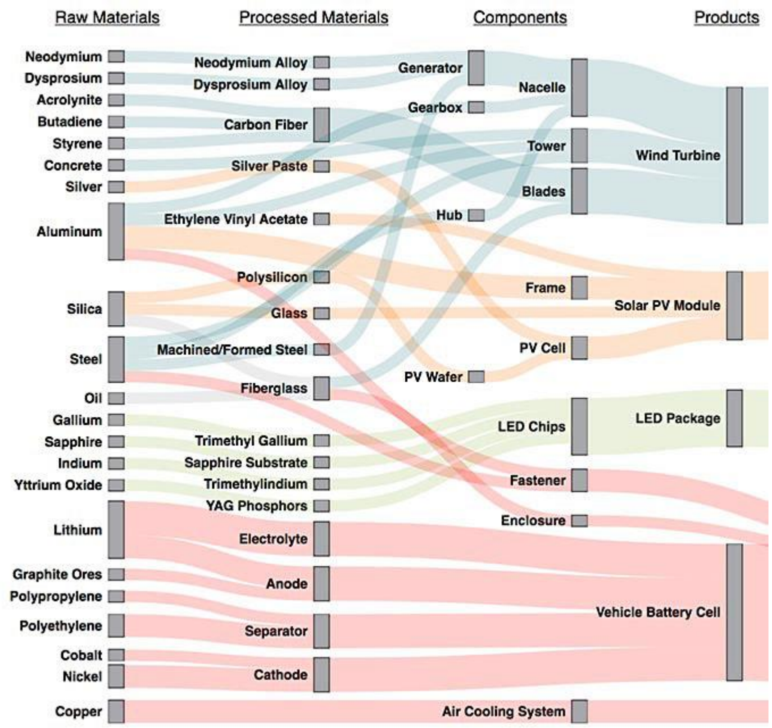

Figure 2: Mineral flows to technologies, CEMAC, NREL, 2018

My former employer, The World Bank, undertook important work in analyzing the mineral-intensity of future energy portfolios with a focus on clean energy technologies. The work shows enormous demand growth estimates for certain minerals such as lithium, cobalt, graphite, vanadium, nickel, and silver (Figure 3).

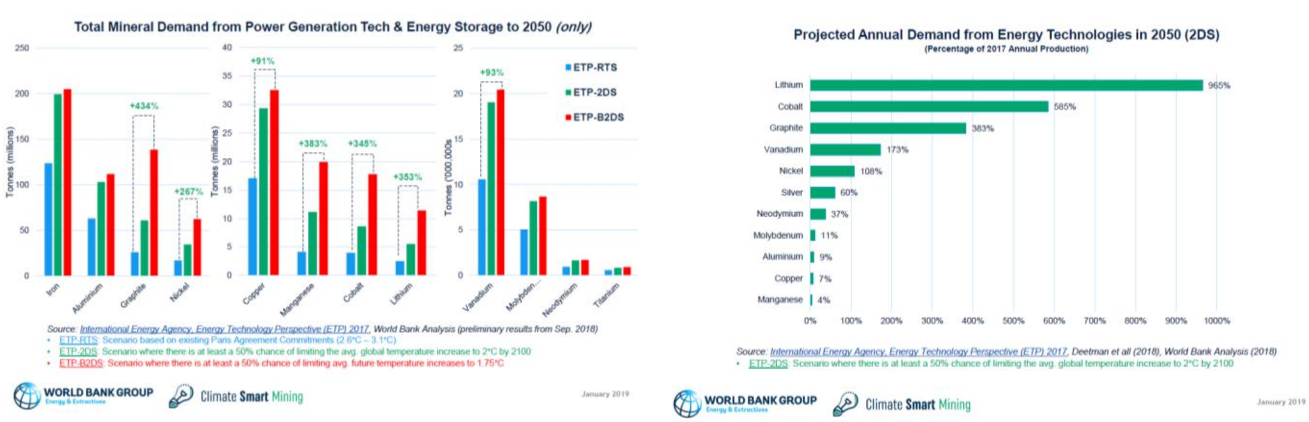

Figure 3: Scenarios of mineral demand, World Bank, 2018

This type of scenario exercise helps us better consider the effects of different policy responses. One important example comes from lithium for electric vehicle (EV) batteries. While the growth in EVs is projected to be spectacular, the price signals, and uncertainty in which minerals and metals will comprise battery chemistries going forward, are not providing clear investment signals (Figure 4).

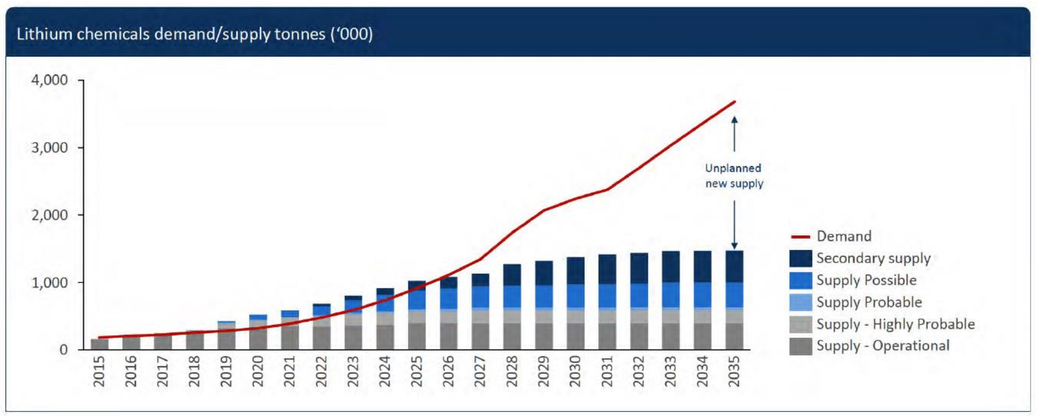

Figure 4: Supply and demand projections for lithium, Benchmark Minerals, 2019.

And while lithium may have the most pronounced risk in terms of possible supply-demand imbalances, gaps could also occur for nickel, cobalt, manganese, and even copper and bauxite. It should be emphasized that cobalt, by far, is the largest concern today, and the most uncertain.

While there may be some bottlenecks to supply, along with price implications for markets, the resource base on a geological basis for most of these minerals is large and unlikely to be a significant constraint.

MINERAL SECURITY AND CRITICALITY

In May, 2018, the Department of the Interior produced a draft list of 35 critical minerals.[2] Many of the minerals are essential for the defense or aerospace sectors, and of course, many for energy. Additional analysis is required to evaluate the criticality of specific minerals to U.S. interests, and the resilience of each supply chain to price shocks.

The U.S. is not the only country, or region, to consider mineral criticality. Japan, the EU, and Australia have all produced critical minerals lists. (Interestingly, Australia's list is not focused so much on their domestic needs, but how to provide strong export markets. The European Commission's list started in 2011, and has been updated three times since.

[2] https://www.usgs.gov/news/interior-releases-2018-s-final-list-35-minerals-deemed-critical-us-national-security-and

As is well known to this Committee, China has become the dominant world player in many critical mineral supply chains (Figure 5).

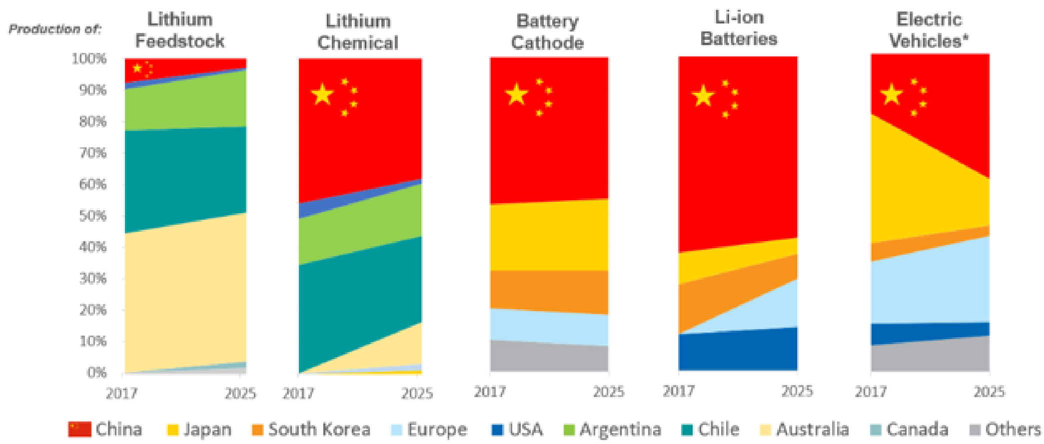

Figure 5: Who controls the Li-ion battery supply chain, IHS Markit

In response to these trends, on May 2, 2019, Chairman Murkowski introduced the bipartisan American Mineral Security Act (S. 1317).

Earlier this year, Senator Manchin proposed the bipartisan Rare Earth Element Advanced Coal Technologies Act (S. 1052). The legislation frames the issue as one with national security and geopolitical implications, particularly given Chinese dominance of the sector.

Related, the RE-Coop 21st Century Manufacturing Act (S. 2093) acknowledges the need to consider an integrated rare earth value chain to serve U.S. security interests.

In the spring of this year, China state media issued some pieces indicating a ramp-up of confrontational language around using rare earths supply as a strategic counter to the Trump administration's latest tariffs. The "tools" China has (according to their articles) include, "cutting the number of rare-earth mining licenses, raising market access standards for miners, reducing exports of primary rare earth products, and restricting outbound and inbound investment in related industries."

These issues of supply threats, international relations, security, and the related analysis is well-covered in energy policy—especially in relation to oil. The big recent change in energy security has been due to the shale revolution. The U.S. has become the largest producer of crude oil in the world, and one of the largest exporters of natural gas, through a combination of Federally-supported and private technology development as well as supportive regulations and policy. That precedent has not gone unnoticed in the mining sector.

What has become clear over decades of energy security analysis is that a reliance solely on import dependence does not account for the economic impacts of energy supply, nor many other factors, and thus is only one of many elements that need be considered for robust decisionmaking in issues of security and resilience.

The future will likely bring more globally interdependent markets and systems. As a result, it is useful to further encourage new quantitative and qualitative approaches to the issues of security and criticality—in both minerals and energy.

Additionally, some of the tools developed during the early oil shocks, such as the development of the Strategic Petroleum Reserve, are now being considered to protect access to critical materials.

DOMESTIC ACTION

The Department of Commerce released the Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals in June, 2019.[3] The six "Calls to Action" range from an improved workforce, to speeding up permitting, to acknowledging the importance of supply chains and trade, and better understanding the domestic resource base.

The Strategy provides a useful multi-pronged framework for domestic action. As each of these minerals has a very different supply chain and market structure, they will need to be individually considered for where the U.S. might best strategically focus.

The other categories of required interventions range from: resource mapping and minerals-specific scenario analytics; to technological constraints and advances in technology design and engineering; to market development and other economic approaches; to governance improvements along the value chain; to social protection and environmental management.

While it is immediately attractive to focus on mining, it is only one place to stimulate activity. From exploration, through to mining, refining, manufacturing, and recycling, each part of the supply chain offers opportunities and challenges for U.S. entry (Figure 6—battery example).

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[3] https://www.commerce.gov/news/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals

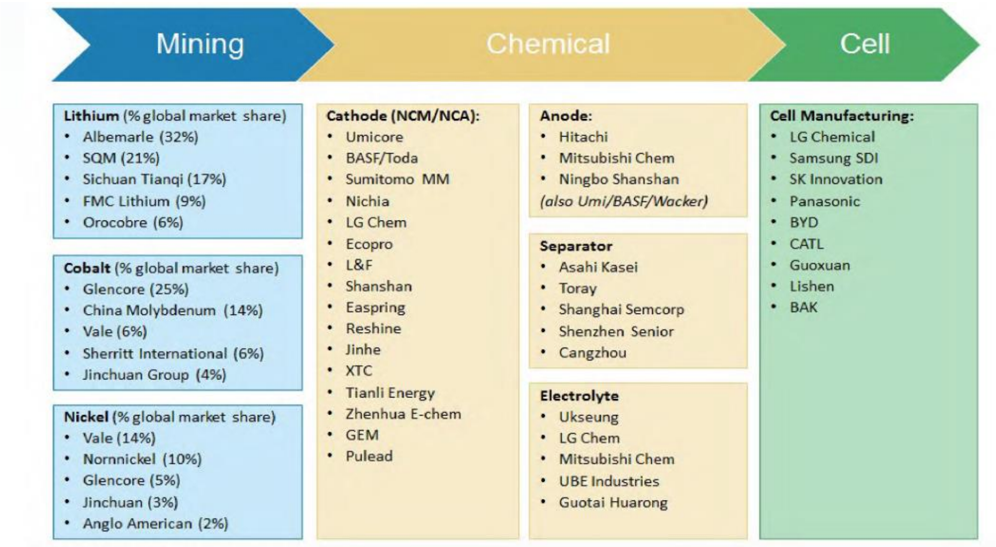

Figure 6: Battery supply chain companies, Morgan Stanley and DCDB, 2019.

At the same time, the global nature of these issues must be acknowledged, as it has been in the Commerce Strategy. Withdrawing from the Extractive Industries Transparency Initiative, as an example, does not send the right signals, and was a strategic mistake.

On a positive note, the State Department's new Energy Resource Governance Initiative has been launched with the aim to, "engage countries to advance governance principles, share best practices, and encourage a level playing field. It will also promote resilient and secure energy resource mineral supply chains."

The trade policies, including tariff-setting mechanisms and dispute mechanisms in place through the World Trade Organization will need to be dramatically improved to tackle the new patterns and scale in trade for certain of the minerals. Related, in 2016, the EU reached a deal on legislation related to the sustainable provision of minerals and metals into the bloc.

As a Professor at one of the finest technical universities in the world on these topics, I can confirm that educational training and workforce development should be foundational elements of a domestic plan.

Efforts by the Department of Energy in creating the Critical Materials Institute (originally created after the 2010 price spikes for rare earths) remain essential in maintaining the U.S. technological advantage.

Chairman Murkowski has said that, "energy and mineral security are the building blocks of a robust economy." It is clear from the literature and current indicators that this is correct.

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