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The world is on the precipice of amazing advancements - from the ability to produce and store vast amounts of energy to building trains that can funnel people around the country in mere hours. As these advancements propel us into a new industrial era, we will look back at components from our current high tech society, like today's smartphone battery, and see it as useful, but extremely limited.

As the size, power and capacity of energy storage technologies advance from powering phones to running cities; as our weapons systems continue their evolution from power to smart and stealth; and as technology inhabits very village on the planet, we must understand that there are resource implications to these transitions. This transition from reliance on our current resource base to a whole new set of resources may well be one of the most critical and hidden stories of our time.

This resource switch is profound. Take the battery. As we increase our reliance on batteries, especially for vehicles, this evolution will free average Americans from the gas pump, uncoupling them from the resource dependencies of the last generations. But this transformation will not free us from our reliance on resources. Instead, we are trading one resource dependency for another, with entirely new economic, geo-political, environmental and security implications that must be understood.

Our war fighting capabilities, our smartphones, and new technologies like the Hyperloop all rely on critical materials that were considered contaminants in the production of metals like zinc and copper just a couple decades ago.

What are critical materials? "Critical" highlights specificity and vital importance. "Materials" refers to anything produced from mined minerals. I use the word "material" rather than minerals since materials are inputs to products while minerals are the mined product. The materials are of greater value.

To develop legislation, it is vital we have a definition of that these materials are and are not. A critical material has most of the following characteristics:

1) Produced in small quantities, often hundreds or thousands of tons annually
2) Traded away from exchanges often by contract or in very narrow markets
3) Used in very specific applications and often used in limited quantities
4) Produced in limited locations and in some cases, one mine or one country dominates the production
5) Undergo a high degree of processing, where mining is often the easiest step in the production process
6) Flow through an opaque supply line facing a high degree of chokepoints well above more common commodities like oil or steel.
7) In some cases, very difficult to substitute for without losing functionality

To paraphrase an old slogan of BASF, the chemical corporation, critical materials do not make the products we use; they make them more powerful, lighter and smaller.

While every resource is critical to somebody--even wood is critical to pulp and paper manufacturers--an expanded definition beyond the above, only serves to confuse policymakers. Everything in the global marketplace is mined or grown. And a policy that labels anything one touches as "critical" undermines the importance of these materials and does not allow for the development of government policy.

Some are concerned we are running out of these resources. After all, many of them were just scientific curiosities a generation ago. The U.S. Department of Energy and the European Union both fear that the resources needed to produce many of the next generations' products may face shortages. The American Chemical Society reported earlier this decade that half the elements are at risk of resource shortage over the coming century.

I do not believe that we currently face a geologic resource shortage for critical materials. However, I am concerned that we will face resource shortfalls over the next decade, that will otherwise limit the adoption of green, high-tech and defense technologies, due to non-geologic factors: spikes in demand, the slow development of supply chains of battery-grade materials and the resource policies of other countries. Therefore, US governmental policies should be established that ensure robust supply lines. This does not mean we need to produce every material the U.S. needs here domestically. But we must ensure access to supplies globally and produce minerals at home if economic.

Understanding the Resource Dynamic

To meet our economic and national security needs, it is critical to examine the flow of these resources, understand where they are produced and how they get to the companies that need them. Indeed, some of the companies who rely on these materials often have little idea about the long-term risks facing their supply lines. <u>The challenge for them and our economy is to ensure that our supply lines will produce enough of the right material, in the right grade that gets to the right supplier at the right time and costs (both environmental and economic).</u>

Today's electronic technologies are spreading around the world far faster than any other manufactured product in history. Within four years of the smartphone's launch, nearly six percent of the world's population had one. No product, not the air-conditioner, telephone or radio, spread more quickly. A few years later the tablet computer accomplished the same feat with even greater speed. Our newer products will face these demand dynamics in an increasingly wealthy world. We must ensure that the rapid development in new technology demand does not outpace our ability to produce the material needed for them.

Potential shortfalls -- and fears of them -- will lead some companies to choose inefficient technologies. This is not some abstract theory. Just over five years ago, wind power companies like General Electric shied away from designs that used rare earth elements. At that time, the price of rare earths spiked after Beijing cut off exports to Japan and instituted increased export restrictions. In a globalized world, U.S. companies must have access to the resources they need.

Today, large multinationals are beginning to act to ensure those resources. Volkswagen announced late last year a contract for purchasing cobalt. While it does not use cobalt directly in its products, the company needs roughly 8-12 kg of cobalt material in each of the batteries it installs; it hopes to produce millions of electric vehicles yearly. But more must be done secure resources. There is a role for government, but we must understand the production challenges these resources face.

The Challenges of Production

Often mining and material processing companies cannot just turn on the spigot to increase the quantity of battery materials to meet a spike in demand, in the way it is done for oil. Like fine scotch whiskey, production of new supplies takes time, in many cases, years.

Ensuring a timely, stable, and sufficient flow of critical materials faces many hurdles:

1) Developing a new mine requires a huge capital investment in markets that are historically slow moving and allocating capital quickly. Mines can take several years to fund and up to 10 to 15 years to open.
2) Many of the critical materials are byproducts; they are not mined directly and are dependent on the production of a base material whose demand is not often linked to its byproduct.
3) Producing critical materials from minerals is a balancing act of acids and heat that can take many years to develop. There is often no "cookbook" to produce some of these materials.
4) Most of these materials are traded off exchanges in backroom deals, making it difficult to determine the size of the market, complicating investment decisions.
5) Meeting regulations for establishing a mine often takes years, meaning promising developments cannot be brought on quickly.
6) Often one country or one mine dominates the production of critical battery materials thus leading to concentration risk.

Geopolitical Risk

We also must be cognizant of where these resources are mined and produced. The countries, in parenthesis, are where most of the material is mined or produced: lithium (Australia, Chile, China), cobalt (DRC, China), manganese (South Africa, China, Australia), vanadium (China) and rare earths (China).

Cobalt is of particular concern. More than half is produced in the Democratic Republic of the Congo, which is historically unstable and corrupt. What's more, approximately one-fifth comes from artisanal mining, raising environmental and human rights concerns as well. After the mining, much of the world's cobalt is processed in China where the geopolitical risk continues.

Indeed, most critical materials, are almost exclusively mined in China. Rare earths are processed there as is cobalt. Therefore, the chokepoint for future resources could well be in Asia.

As China embarks on its new industrial policy, Made in China 2025, the country is well on its way to dominating the mining, production and deployment of the entire global battery supply line. Beijing is using critical minerals as the heart of plan to dominate the production of critical technologies for the new industrial era from lightweight planes to batteries. The country increasingly will see less reason to export battery materials freely so as to ensure supplies for its domestic industries. This is a major potential concern to resource security globally.

The Role of Government and Legislation

To ensure we will have sufficient resources, the U.S. must develop a new generation of mineralogists and material scientists who can focus on creating technologies that can mine and process critical materials. Too many potential students have been guided to other careers, leaving few to replace the large numbers leaving the fields. Funding to support our research universities is vital.

The permit process for mining and processing of minerals should be re-examined. Development policies must maintain clear, stringent environmental standards, but allow for more rapid development of resource areas where mining can occur. Slow review procedures reduce the time materials can be developed and pushed mining overseas.

We must remember that if materials are not mined in the U.S., then they are mined in countries with far less oversight, often leading to far greater environmental degradation. We cannot pretend that our lifestyles do not have global environmental impacts by restricting mining in the U.S. And we should not outsource them to places that are unable to manage them effectively. Legislation must protect areas worthy of environmental protection, and allow for the efficient development of mining in other areas.

The government must encourage the development of standards that will lead to more efficient use of resources through incentives and regulations. The goal should be to encourage greater recycling and reuse of materials with a focus on supporting a circular economy. The market does not always lead to efficient post-use material disposal; for example, recycling batteries is not often profitable. Government should consider how to offer incentives for companies to develop products that are more easily reused and repurposed. Some of our most cherish electronic gadgets are made so that parts cannot be replaced. This is waste of resources and needs to change.

We must consider restoring offices and funding within the US government that examine mineral resources globally. The United States Geological Survey needs to bolster its mineral resource market analysis and reinvigorate a resource department that has been hurt through attrition and funding cuts over the decades. The Department of State would do well to open an office that examines mineral resources, broadly focusing on market dynamics in both the ferrous and non-ferrous mineral markets.

Stockpiling is often an ineffective strategy on a national level. Critical minerals are frequently so specialized and tailored for end-uses, deciding on what form of the mineral to stockpile means that a stockpile is unlikely to meet the needs of many end-users. Additionally, with supply lines up to ten layers deep, the chokepoint to produce a technology like laser guided missiles is unlikely to be the mining of a mineral, but further down in the processing and manufacturing of the product. Without capabilities to turn that stockpiled material into a useful product stockpiling is a feel-good solution to the potential of resource shortages. Requiring companies to store critical materials that they rely upon is a more effective strategy as they know the amount and grade of material needed.

The International Materials Agency

Internationally, U.S. trade policy has worked to encourage the free flow of resources. Such work is vital but insufficient for critical materials. It is essential to develop a separate international forum to discuss mined resources. The forum would produce informed market data and reduce the specter of conflict over resources that will surely increase over the next generation as the world relies on more mined resources. Currently, resource conflicts are addressed ineffectively at the World Trade Organization.

I propose the International Materials Agency, in the mold of the International Energy Agency (which researches oil and energy markets and promotes diversity, efficiency and flexibility in the energy sector). The International Materials Agency would focus on mined materials including rare metal supply chains. It would introduce transparency to markets, collect statistics, draft market analyses, and create a forum for dialogue.

Conclusion

HR 520 provides a useful starting point to engage in discussion of critical materials. I believe the bill highlights the importance of efficient permitting to ensure these materials are produced. I believe the bill would benefit from a greater holistic approach by examining the entire supply line and ensuring that our economic and national security needs are met while simultaneously protecting the environment.

A century ago we adopted the use of oil and gas as the mainstay of our economy without considering or appreciating the impact of our decision. We are now well placed to understand the new resource dynamic and make sure we have the resources needed to support it.