SASAKAWA USA
Sasakawa Peace Foundation USA

Securing Critical Resources in a New Green and Industrial Era

Market Perspectives from Japan and the United States

Report on a Conference
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Sasakawa USA and Shorenstein Asia-Pacific Research Center, Stanford University

Contents

Executive Summary

The conference on Securing Critical Resources in a New Green and Industrial Era was the first to bring together companies from the entire rare metal supply chain, including experts and officials from both Japan and the United States, countries that rely on the entire spectrum of these resources for the manufacture of high-tech products. The conference laid out the challenges, opportunities, and limitations of creating resilient supplies of critical materials. It had a specific focus on:

- Examining the business, geologic, geopolitical, production, reputational, and environmental risks companies face in sourcing critical rare metals;
- Presenting data-driven projections on the future requirements of rare metals and on future sources to meet those requirements;
- Assisting companies and countries in identifying resource insecurities and developing strategies to improve the resiliency of supply lines of critical rare metals; and
- Identifying potential areas for U.S.-Japan collaboration to reduce resource insecurities of Japanese and U.S. companies and governments based on the two countries' shared reliance on critical rare metals.

Background

Products manufactured today differ greatly from those produced just twenty years ago. Innovative technology is driving new and improved products from components, such as batteries, to entire systems, such as airplanes. These technologies rely on an entirely new set of critical materials, namely rare metals, whose properties are indispensable for products ranging from the smallest telephone to the largest wind turbine. As new devices proliferate, advanced countries like the United States and Japan are linking their economic futures to rare metals, with current production often dominated by a single country or mine.

While the world is not running out of rare metals, it can take a decade or more to bring new supply lines online. Advanced economies are approaching a point where the speed of development and the growing number of new devices will outpace their ability to secure the rare metal materials this new industrial age requires.

Rare metals have a vastly different market dynamic than traditional commodities. Rare metal supply lines face numerous single points of failure that can lead to catastrophic results. Ensuring the right resource can be produced at the right time, at acceptable environmental and economic prices, will become increasingly challenging. The American Physical Society warns that game-changing technologies, including technologies to help deal with the threat of climate change, may be harder to develop in the future.

Topics by Panel

Panel I: Identifying resource insecurity: The unique supply line challenges of rare metals

The panel highlighted unique rare metal sourcing and production challenges. Speakers discussed the geographic origin of rare metals, ways they are processed and sold, and how they reach consumers. Panelists covered these supply lines in depth and discussed ways in which the hidden trail of rare metal supply lines can introduce uncertainty to end-use customers, who may assume minimal risk to their supplies.

Panel II: Industrial developments and the rush for new metals

The panel focused on demand for critical rare metal resources. Discussants examined the process by which new developments in green technology and the global proliferation of gadgets have increased the demand for rare metals. They covered changing patterns in the use of rare metals over the past several decades and the evolution of rare metal supply chains, as well as new sources of demand for these metals.

Panel III: Enhancing resiliency of rare metal supplies

The panel discussed strategies for companies and countries to secure a sustainable supply of rare metals. They recommended companies work with traders, processors, and mining companies and examined the rare metals most at risk for resource shortages and reasons for those risks. The discussion touched on strategies for companies and countries to address near-term geopolitical and supply risk and on necessary sources of data for companies to understand resource challenges.

Panel IV: New strategies: substitution, recycling and a circular economy

The panel discussed larger strategic questions. What are the future challenges to securing rare metal supplies? What challenges will arise in the next five or ten years that we have yet to identify? What are the resource trends we need to be aware of and the business models that can capture them? Panelists discussed the roles companies can take to secure the resources they need and the best business models for ensuring stable supplies of rare metals. The panelists also addressed the role of government in ensuring supplies for both economic and military objectives.

Conclusions

The workshop participants concluded that neither governments nor the private sector fully understand the unique supply chains of rare metals, or even the amounts produced and consumed. Long and opaque rare metal supply chains continue to run the risk of acute market shortages, price spikes, and delays in production for the specified demands of end-users, all of which the market has experienced repeatedly over the past several decades. To better understand the market and address potential supply-side, environmental, and geopolitical concerns, the participants made the following recommendations:

- To continue international research in the market through various efforts including individual geological surveys by the U.S. Department of the Interior and Japan's Ministry of Economy, Trade, and Industry (METI). Joint efforts led by Japan and the United States could catalyze broader global research efforts.
- To develop a more comprehensive risk-assessment tool for governments and other end-users that can better assess the range of risks to the supply of rare metals. The U.S. Department of Energy and METI could spearhead this initiative. These agencies should share technical information about rare metal markets, including information on use and production.
- To develop an International Materials Agency, modeled after the International Energy Agency, that would study and provide a forum to discuss mineral resources. This agency would inform private sector and government leaders about market developments by enlisting officials from various countries and collecting and disseminating statistics and research both on its own and with existing government agencies. The governments of the United States and Japan should be the driving forces behind the creation of this agency.
- To provide greater education on the importance of rare metals for green technologies, with a focus on addressing mining and processing concerns of the general population.

- To establish a central U.S. government office responsible for developing an understanding of the current rare metals system and recommending improvements. Currently, knowledge and responsibility are spread across many departments and agencies with only informal consultation and coordination taking place between them.
- To hold discussions between the United States and Japan, including at the government official, private sector business leader, and materials expert levels, to better understand and develop a strategy to mitigate the growing geopolitical risk from countries that dominate the production of rare metals (currently China in many cases).
- To hold consultations between the staffs of the Defense Logistics Agency (DLA), which, under U.S. Department of Defense (DoD) maintains the U.S. stockpile of rare metals, and METI, which maintains the Japanese stockpile, to identify at-risk materials and improve the accuracy of the assumptions and forecasts on which stockpile volumes are based. These consultations should look broadly at the grades of materials stockpiled and, if needed, the entities, either government agencies or private sector organizations, which most cost effectively maintain those stockpiles. The consultations should also address the total volume of specific rare metals maintained by both countries and plan for potential sharing in the event of shortages.
- To establish government incentives in both the United States and Japan to encourage students to study rare metal mining and processing.

Keynote Speeches

David S. Abraham, Senior Fellow, New America Foundation and Director, Technology, Rare and Electronics Materials Center

Abraham highlighted key aspects of the rare metals market, contrasting it with more widely-traded and well-known markets. Abraham defines "rare metals" as follows:

- Comprising forty to forty-five elements traded in limited quantities, often in the hundreds or thousands of tons annually (in contrast to, for example, millions of tons annually for materials like copper).
- Used in limited amounts, often a few grams or less per product, although this is changing with the rise of large-scale green technologies.
- Heavily processed and tailored to specific end-uses, unlike traditional commodities.
- Having specific properties that make them challenging to replace with substitute materials.
- Without official prices on a listed exchange; instead, they are traded in backroom deals.
- Including but not synonymous with "rare earth elements," which are a subset of rare metals. Other terms for rare metals include: "critical materials," "minor metals," "strategic materials," and "electronic materials."

Rare metals play indispensable and specific roles in high-tech, defense, and green products, and have unique supply and demand dynamics. Rare-metal demand is projected to soar because products in all three fields demand the properties that these metals afford; namely, they make products lighter, stronger, and more powerful. We use more high-tech products than ever before, both individually and collectively, especially as developing countries have become wealthier and the lifecycle of these products has decreased, meaning they must be replaced more quickly. We are also beginning to use rare metals in larger amounts in green and other products. Wind turbines, for example, use hundreds of kilograms of the rare metal neodymium in their motors (for context, energy efficient air-conditioners use only grams).

Though demand for rare metals is rising, mining companies will find it increasingly difficult to bring inexpensive and resilient supply chains online. Ore grades are dropping, forcing companies to dig more for the same quantity of rare metal. Further, since many easily mined resources have been found, mining companies must invest in expensive infrastructure to reach more remote locations to produce materials.

Processing rare metals is often more environmentally challenging, and therefore more expensive, than the production of base metals. Further, even post-consumer recycling cannot significantly increase supplies due to poor handling of end-of-life products and the difficulty and expense of the recycling process. Currently, for example, less than ten percent of the rare metals in used smartphones are recovered.

Supply lines of rare metals can also take ten to fifteen years to establish due to difficulties in fundraising, the issuance of permits, and the challenge of developing an economically-viable supply line for processing. The result is a limited number of supply lines with high risk of single-point failures. Ensuring that the right material gets to the right place at acceptable economic and environmental costs is a challenge.

The production of rare metals also runs geopolitical risk. Many of them are mined or produced in China, which is also the largest consumer of rare metals. In 2010, rare metals gained notoriety when China cut off exports of rare earths to Japan for political reasons. The price of those metals spiked ten to twenty times, though prices fell back to prior levels within a year-and-a-half.

Perhaps the greatest challenge of the next industrial era is that new gadgets proliferate globally far faster than ever before. Within just four years of the smartphone's introduction, six percent of the world owned one. With supply lines taking more than a decade to establish, the exploding demand for rare metals creates a high risk that demand can increase far faster than supply.

In this new green era, as both consumers and businesses demand energy-efficient products that rely less on fossil fuels, the use of rare metals will increase. Japan and the United States are now trading one resource dependency for another. Understanding the economic, environmental, and geopolitical impact of this transition and taking measures to ensure adequate supplies is a matter of national security.

Hon. Lisa Murkowski, Chairman, U.S. Senate Committee on Energy and Natural Resources

Senator Murkowski highlighted American dependency on imports of rare metals. The United States is reliant on these materials for an increasing number of products, from the smallest computer chips to the tallest skyscrapers. The United States now imports at least 50 percent of 47 different rare metal commodities and 100 percent of rare earth metals used. This reliance on foreign sources raises strategic and economic vulnerabilities. It is imperative that the United States develop domestic resources to ensure that the country has the resources it needs in times of stress. Senator Murkowski has introduced a bill to address rare metals vulnerability by developing new sources through mining, international cooperation, recycling, and workforce development. This bill is a necessary first step to ensure resource security.

Dennis Blair, Chairman, Sasakawa USA; and Takeo Hoshi, Director, Shorenstein Asia Pacific Research Center

In 2010, China cut off exports of rare earth metals to Japan for political reasons. China's action brought two uncomfortable truths to the attention of Japanese and American leaders and their publics. First, these metals are mined and processed in relatively small quantities and are crucial to many consumer and military products. Second, China, both as a consumer and a producer of rare metals, plays an extremely important, if not dominant, role in the market for them.

Since the 2010 cut-off, both Japan and the United States have taken steps to protect themselves from a second cut-off, but both countries remain vulnerable. Japan has found new sources of rare metals outside of China. Tokyo has invested in research and development to reduce the use of rare metals, worked to find substitutes, increased recycling, and created a rare metal stockpile. In the United States, companies have examined and altered supply chains, and the Department of Defense and other government agencies have made stockpile acquisitions and researched ways to decrease the use of rare metals in critical components.

Despite these moves, China remains the dominant market player, and it has been taking actions as well. China keeps domestic rare metal prices low to incentivize international companies to build factories in China to make use of these rare metals domestically. These factories encourage greater transfers of technology to China. To further its control over the market, Beijing has consolidated companies into state-backed entities, which has also resulted in reduced rampant smuggling, a long-term problem in the market.

With China's dominant position in the market and its previous willingness to use these resources as a political tool, more must be done to strengthen the security of the rare metal supply. The United States and Japan should take the following four steps:

1. Work together to produce better data and estimates, as no one knows the full scope of these opaque markets. The information provided by a potential joint rare metal organization could be useful to governments as well as to the companies that contribute data and expertise.
2. Invest in human resources and technological development in mining and material science to ensure they have capable scientists and engineers to produce and benefit from rare metal extraction and production.
3. Stockpile rare metals and implement other measures to mitigate supply shortages both for defense and other economic objectives. This will require including the private sector in research to understand its needs. It also entails engaging other countries with rare metals resources to help develop new supplies.
4. Work with China on rare metals. A good start would be establishing a transparent and regulated rare metals exchange governed by market forces and high-quality regulation. Prices for rare metals could be set, positions hedged, technological developments anticipated and accommodated, and smuggling discouraged. Manufacturing companies in China, the world's largest consumer of rare metals, would likely see the advantages of a commodity market for more efficient operations, and remunerative jobs would remain for those who know the rare metals market best.

Panel Discussions

The conference panels provided an overview of the challenges presented by rare metals, highlighting four main areas: supply, potential sources of demand, identifying risks and solutions to create resilient supplies, and developing strategies, such as recycling and a circular economy, for a new industrial era.

Identifying resource insecurity: The unique supply line challenges of rare metals

The risk of market failure in the rare metals sector is high. In Japan, companies and the government long ago realized that if a single rare metal could not be recovered, processed, and shipped to end-users, there was a real risk that the entire supply chain would stop. Lacking transparent markets and supply chains, many global end-users, especially outside of Japan, do not understand the supply risks they face.

As rare metals are produced in just a few concentrated locations and in limited amounts, producers often have monopolies over them. Many fear that a surge in resource nationalism in producer countries would lead to market manipulation. China, for example, took advantage of its monopoly on rare metals production in 2009-2015 to attract companies to set up operations in China. By offering lower domestic prices on the metals, it encouraged companies to set up factories in and bring intellectual property to China.

The challenge in ensuring a stable supply of rare metals is that most rare metals are mined as companion metals or byproducts of other larger-scale mining, not for the rare metals alone. Few areas of the world have a high enough concentration of these materials in large enough quantities for them to be recovered economically.

To reduce supply risk, countries have encouraged new production, but this is not a quick or easy fix. Processing techniques are often challenging, such that deposits that appear productive at first glance may not be recovered as easily as initially thought.

Limited human resources and the difficulty of finding substitute materials pose further challenges to building robust supply lines. Many countries, including the United States, have lost much of their expertise as mining has become less central to the economy. Many of those in mining and metallurgy have left the sector, and few students are entering the field. Many rare metals have such highly specific end uses that no other chemical element can provide a complete substitute; eight currently have no substitute for any of their end uses.

The question, therefore, is how to manage risk. Thomas Graedel of Yale University has proposed a three-axis approach that would examine the vulnerability of supply restrictions, supply risk, and environmental implications, as shown in Figure 1. According to Graedel, understanding the true risks of supply requires understanding environmental impacts; the geologic, economic and technological disruptions that can occur in supply lines; the importance of an individual metal to the market; and the ability of one metal to be substituted for another.

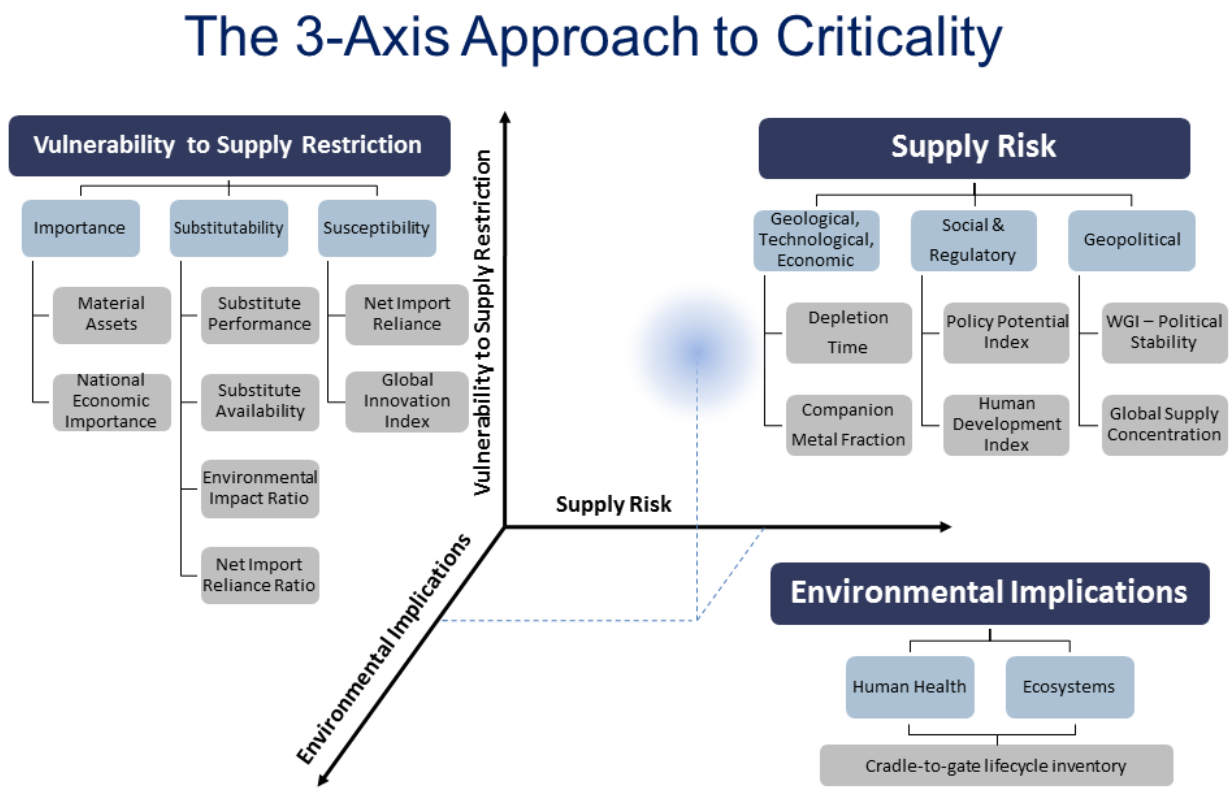

Figure 1. Thomas Graedel's approach to material criticality.

The rare metals age: Industrial developments and the rush for new metals

Very few companies seek to understand the complex and opaque supply chains that provide the materials needed for the products they make. An exception, Siemens, spent years examining the individual metals that go into its products, with the objective of identifying resources and chokepoints in its supply chains. It revamped its corporate coding system to find the rare metals in the component parts of its products. The process entailed active corporate participation in understanding the lifecycle of its products and the source of its materials. Without this kind of investigation, companies like Siemens have no understanding of the rare metals supply chains they rely on.

Siemens made understanding and building the resiliency of its rare metal supply chain a corporate rather than divisional responsibility. In addition to tracking rare metals, the company also recalibrated its investment strategy in these markets, understanding that as a major consumer it could influence price, and so took steps to secure supplies by investing in upstream suppliers.

The panel agreed that companies need to maintain stockpiles as just-in-time manufacturing can leave them vulnerable to supply chain shocks, which are common with rare metals. Over the past eight years, price spikes have occurred twice in both the lithium and vanadium markets, and once in the potash, graphite, and cobalt markets. Lithium spiked nearly 400 percent in 2009 when demand jumped, without a commensurate increase in supply. As many rare

metals are end-user specific, it is difficult to find replacements; sometimes even a different grade of the same metal is not adequate due to the demanding specifications of high tech goods. Batteries, for example, need a specific, spherically-coated form of graphite.

The panel emphasized that manufacturers should work jointly with suppliers to understand future needs and demands. European and Japanese companies, because they are often import-dependent, may be more aware of this need, which has also led them to focus more on recycling than American counterparts.

Though recycling may seem like a good opportunity to bolster security, this depends on the cost of recycling and recycling rates. Recycling only becomes feasible if the cost of extracting small amounts of metal from discarded products is comparable to the price of extracting and processing material from the ground. In many cases, the former is more expensive. Many panelists projected that the price of rare metals will increase over time, making recycling more feasible (it should be noted that predictions are subject to uncertainty).

A second challenge is that recycling rates for most metals is below one percent, though they may rise in coming years as many advanced products that use larger amounts of rare metals, such as wind turbines, reach the end of their twenty-year lifecycles. Siemens and other companies are devising motors and other components and products to be recycled more easily and at lower cost.

In forecasting the future of rare metal demand, a key factor is hyper-growth industries, such as energy storage and electric vehicles. These two technologies will largely determine the scale of future demand for rare metals.

Identifying material concerns and solutions to enhance resiliency in supply lines

Europe is very much dependent on imports of rare metals. There is little technical knowledge of rare metal mining left in Europe. European business leaders understand that finance is essential for creating robust rare metal supply lines; yet few downstream companies, especially in Germany, are willing to invest when prices are down, as has been the case in recent years.

Luka Erceg believes the world is not running out of any specific metal. Rather, it is running out of low-cost production options for many rare metals. Mr. Erceg is also concerned that the timing of production cannot always meet jumps in demand. For example, lithium produced from brines can take up to 36 months to produce, whereas supplies from hard rock can be produced immediately. As a result, supplies often come to the market in waves rather than in direct response to demand signals.

Mr. Erceg recommends against governments taking a direct market role in such areas as supply procurement. However, governments, especially the U.S. government, should foster research and acquire data about rare metal supply chains. Private Japanese trading firms collect information on rare metals effectively; the United States., by contrast, does not have comparable private sources of information.

Mr. Erceg believes the United States should draft legislation for the development of resources. As the U.S. lost much of its manufacturing, mining, and materials industries, universities reduced educational opportunities in these areas, student interest declined, and, ultimately, supply lines were affected. The United States cannot quickly reverse this trend, but legislation targeting the development of an industry, specifically increasing human capacity, can help.

According to Mr. Erceg, companies can also develop a culture of innovation to become more responsive to the markets. Tech executives must focus more on opportunities and challenges that exist in the rare metals market.

Companies need to map out supply lines, understand current market limitations, and invest in profitable ventures to overcome them.

Nick Kotaki emphasized the continued risk of China cutting off the supply of rare metals, and what happened before can happen again. Mr. Kotaki sees attitudinal barriers and structural barriers, including the limits of stockpiling because of challenging metal specifications demanded by each end-user, that limit Japan's ability to secure supplies. Another structural barrier, that processing these materials is as critical as production, shows that ensuring geographically dispersed activity is as essential for processing as it is for mining.

The attitude many companies have that rare metal markets are too small to warrant attention undermines the market. Big companies, especially in Japan, stay away from trading in rare metals, concentrating on commodities with much higher volumes and profits. At the same time, top management in companies that rely on rare metals underestimate the pressure and the importance of rare metal supply chain dynamics: they may miss the fragility of the supply lines.

Mr. Kotaki noticed that Japanese companies, because they want to maintain their relative competitiveness, do not care about the price of rare metals as long as all competitors pay roughly the same. Each Japanese company assesses risk differently: some maintain two years of buffer stocks, others just a month or two.

Geoff Bedford emphasized that rare metals are strategic, foundational materials. According to Mr. Bedford, companies need to take a broad perspective on the capabilities of rare metals and understand that they need stable, geographically-dispersed supply lines. Recycling is critical for this.

Concentrated supply in one country puts the world's manufacturing at risk. Governments can quickly change policies. China, for example, changed positions from initially encouraging companies to export rare earths to placing export quotas on them within ten years. China continues to use low rare earth prices and abundant domestic supplies to attract Western companies. Currently, Western companies are some of the biggest consumers of rare earths in China because they moved operations into the country.

Though business leaders know that the concentration of rare metal production in a single country has undermined security of the supply, they have short-term memories with regard to rare metals supply chain risks. Investors and companies that rely on rare metals seem to disregard the substantial risks of supply volatility. This is not to say they take no action to reduce reliance on rare metals. Companies have found innovative ways to use lower amounts of rare metals, but as long as there are a small number of supply sources, demand reduction does not by itself provide supply resiliency.

The panel felt that supply lines are becoming less secure. For example, while new sources of rare metals supplies come from Southeast Asia, processing is still done almost exclusively in China, and, since the U.S. company Molycorp has failed, the control China has on rare earth metal output has grown stronger.

Despite a sense of possible increasing trade frictions with China, the panel sensed that the global rare metal market is interdependent. Chinese objectives in the rare metals sector are mixed, and China does not have a single "master plan." Chinese businessmen and government officials recognize that their businesses are part of an interconnected global market, but they want to maintain a competitive edge for their companies and know their central position in the market provides an economic weapon, even if using it would have a negative impact on their own companies. The geopolitical risk that China presents is increasing, and Japan and the United States need to develop a government and industry approach to managing it.

Strategies for a new industrial age: Substitution, recycling and a circular economy

New strategies for rare metals security aim to ensure a circular economy, one where a resource once used in the economy continues to be repurposed. At the heart of this concept is reuse and recycling. These strategies help reduce volatile pricing of rare metals by adding a new sustainable source of supply. Since rare metals are often byproducts of primary metals, reused and recycled rare metals can add stability to resource supplies.

Another theoretical strategy of the circular economy is to repurpose material, though the narrow specifications for rare metals used in different applications has so far made repurposing on a large scale impractical. Companies like Siemens and General Electric have reduced and replaced rare metals in some of their products. They have also become more efficient in their use of rare metals.

Panelists emphasized that prices of rare metals are extremely volatile: they can quadruple in price overnight due to limited supply lines, and demand can jump with the development of a new technology that relies on them. Conversely, rare metal prices can drop rapidly, making planned investments in mining and processing unprofitable, leading to the termination of new projects.

Currently, except for gold and a few other precious metals, recycling is not cost-effective. Many company recycling campaigns are showcase projects more for public relations than for profit. In addition, current recycling processes can be as toxic and environmentally impactful as processing ore from the ground.

The panel mentioned that, in some cases, pollution from extracting rare metal from natural ore can be avoided by recycling, but the price of recycled ore is often much higher than that of mined ore. Despite these obstacles making recycling rare metals expensive today, the panel felt that processes and technology for recycling should be pursued both to avoid pollution and stabilize supplies.

Some panelists felt that products will be easier to recycle in the future if companies design products with reuse and recycling in mind. Recycling is inefficient because current products are not designed to be recycled. Ensuring that components get to the appropriate recyclers is challenging, and current technology does not recover all of the rare metal materials in recycled products. If companies build products with recycling in mind, there may be a drastic increase in recycled goods.

There may be ways to set standards in the production and recycling of rare metals that may reduce the environmental impact of production including the use stickers designating sustainably sourced products. Cultural approaches and societal pressure can also play a role. Japan's idea of もったいない (*mottai nai*, "no wasting") is ingrained in Japanese society, and drives recycling there. Other countries also promote recycling, and rare metals can be included in recycling systems.

Roundtables

The roundtable discussions allowed a smaller subset of the attendees to discuss various aspects of the rare metal supply and demand dynamics, especially the risks, including geopolitical risk. These sessions were conducted under Chatham House Rules.

Environmental and reputational concerns

Environmental, reputational, and social issues are the most common cause of failed and delayed mining projects. Because many rare metals must undergo numerous processes involving chemicals and chemical reagents in addition to mining, they have a potentially high environmental impact. Therefore, they increasingly face challenges at the start of production. Many developed counties, including Australia, have been grappling with how to more accurately respond to and address risk perception.

Companies, especially when working in developed countries, face the "Avatar Effect" of media vilification of the mining and military industries. One of the biggest challenges in this area is dealing with radiation, particularly radioactive materials mined along with rare metals at sites in the United States. Even when radiation is within safe limits, residents and environmental groups raise objections that can slow or stop projects. As a result, though companies are seeking ways to manage low-level risks, they sometimes pass over promising projects due to challenges in dealing with radiation.

Overcoming these environmental fears takes careful planning and communication with concerned groups. Public outreach campaigns are critical to address concerns about production. Within any plan for mining, there needs to be an understanding of three groups: intractably anti-development, pro-development, and undecided. Hard-core anti-mining groups cannot be swayed, but many in the industry can learn to speak more effectively to the undecided group.

Addressing environmental issues necessitates the development of a public outreach battle plan, a "hearts and minds" approach with a near military level of strategy and planning. The plan needs to focus on the overall benefits of mining and, in some cases, even the possibility of monetary support for local communities and affected stakeholders.

The public outreach plan should not always be an "everyone at the table" approach involving all affected groups. It must focus on developing majority support and addressing perceived risks of mining. Although companies need to understand the risks and the science behind them, it is important for the public to understand existing systems that address environmental concerns. Education is not simple and straightforward; it must be tailored to different individual groups.

Technologies of the future and resource implications

Western companies discuss the importance of the security of rare metal supply, but when the price drops, so do their incentives and interest to do so. When current prices are low and supplies are stable, companies do not want to invest in new supplies that could insulate them from the effects of price spikes. Part of the challenge is the lack of high-level attention within companies to these "no-name," unlisted resources. One participant commented, "if you can't google the price, then people don't want to deal with it." Price spikes raise interest in rare metals. Indeed, they are the only way to bring attention to these markets.

This lack of attention means that the ability of companies to finance mines in the United States remains limited. If resources are cheap in China, companies do not fund expensive mining projects in the United States. Smaller mining companies that develop deposits try creative ways of raising funds, like pushing for off-take agreements with end users. These contracts are difficult to arrange; a single company rarely needs enough of a resource to offer the support necessary to get the project moving. One participant commented that he did not see how fundraising to start new mines and processing sites for many rare metals was possible.

The only sustained support that many group participants thought was realistic was government financing. The Department of Defense in the United States seemed the most likely source. Some participants were supportive of government finance, but the projects that have thus far been funded by the U.S. government have been highly specific. Some participants recommended that government spread out its funding for more projects. Also, faster and clearer permitting standards by government regulators would help investors make decisions more easily.

U.S. industry has concerns about buying rare metals from China. Some companies placing orders for materials have met obstacles and difficulties. This has encouraged them to move their operations to China to access materials directly rather than import them. One participant commented that industry can support higher rare metal prices, but the cost would need to be shared equitably. If a company pays higher prices for resources to develop sustainable supplies, that company will be disadvantaged by competitors that do not.

What demand will the future bring? One researcher commented that resource demand for base metals may jump 200-400 percent in thirty years. But predicting rare metals demand is not possible. Scientists do not know how to predict, even just ten years in the future, technologies that will rely on them.

Some workshop participants believed that with the growing demand for green technologies, there could be a seven- to eight-fold growth in demand for many rare metals over the next decade. At the same time, scientists and engineers are becoming more efficient with rare metal materials. Manufacturers of wind turbines, for example, are finding better places to put the magnets, lowering the need for dysprosium. At the same time, the number of new products that require dysprosium will likely rise.

Identifying and reducing risk in technology supply lines

This session used the change in the rare metals market over time to examine the risks in modern technology supply lines. Before the 1970s, the United States produced nearly all of the world's rare metals. In 1971, China began producing rare metals to earn hard currency. Fortunate geologic location, a lack of environmental regulations, export incentives, and cheap labor led to an explosion in production. By the 1990s, China had become the dominant supplier of rare metals to the world.

In the 2000s, China introduced export quotas to increase the domestic use of rare metals. Japan, the main importer of rare metals, identified these quotas as a major concern and began to plan for alternative supplies, but little progress was made. In 2010, China cut export quotas, and the world's attention began to focus on China's control of rare metals. Later in the same year, during a dispute with Japan, China cut the flow of rare metals to Japan and prices spiked. Following the incident, companies started to reduce their reliance on rare metals from China.

Geopolitical risk remains high in today's rare metals supply lines. A single country's control over the production of a material can introduce insecurity to entire supply lines, making businesses dependent on the decisions of that country.

The roundtable identified various other risks beyond political risk. Participants identified concerns stemming from a lack of alternatives in production sources, the inability to find financing to open new mines, environmental challenges to producing new materials, and geographical concentration risk to both processing and mining.

To address these risks, Japan uses a four-part risk mitigation strategy, with varying degrees of success: finding new sources, recycling, substitution, and stockpiling. Rare metals are challenging to stockpile; moreover, stockpiles have been largely ineffective in times of need. Workshop participants considered Japan as no more resource secure now than it was in 2010, despite the measures taken. Supply insecurity holds true not just for rare metals but also for tungsten from China, niobium from Brazil, and palladium from Russia. An accident, natural disaster, or government decision can reduce supplies for these materials very quickly.

The participants thought that the biggest risks to the future supply of rare metals comes from low investment in developing human resources in the sector, research and development, and project development. Participants feared continued resource nationalism, environmental risks that thwart the development of projects, and a lack of high grade deposits. They felt that a lack of diversity in supply lines will continue to challenge companies that rely on rare metals from China. The consensus in the group was that China remains a challenging supplier, and that there will likely be another supply crisis before too long.

National defense and economic security concerns

The Unites States has been unsuccessful in setting up an effective resource policy, especially for rare metals. The U.S. government has no government office or coordinating agency to assess and coordinate rare metals policy. Instead, rare metals are dealt with in a fragmented way. For example, the U.S. Department of the Interior researches the production and use of rare metals; the Department of Energy examines the role and use of rare metals in green technologies and maintains numerous research institutions that examine rare metals, including the Critical Materials Hub; and the Department of Defense examines defense applications and stockpiles of rare metals. Even NASA, as a consumer and user of many of these materials, plays a role.

Research has indicated that the U.S. government lacks a comprehensive understanding of the role rare metals play in the economy and national defense. The research notes some increasing collaboration between government agencies, but coordination on policy and programs is still very limited. Congress could help identify a structure for administration coordination on these resources, and there have been several congressional bills introduced. There seems to be deeper discussion in the U.S. Senate than the House due to Senator Murkowski's interest in the issue.

An additional challenge to coordinating rare metals policy is the absence of U.S. industrial policies like those found in countries in Asia. Japan, for example, has a rare metals strategy implemented by the Ministry of Economy, Trade, and Industry. There was a sense among the panel that the lack of coordination in the United States may change in the Trump administration, as there seems to be greater emphasis on encouraging domestic U.S. production of high-tech goods, from phones and cars to defense equipment. This would put additional pressure on industries to develop domestic supply chains for these materials.

A new administration has a number of tools, including defense authorities, to increase the production of domestic materials. Panel participants were unsure if these national security authorities would be used, but felt that a Republican-held Congress would be more willing to open up additional lands to natural resource extraction, creating greater opportunities for rare metals production and processing in the United States.

One area in which the United States has been active is stockpiling. Participants acknowledged the practice as the prerogative of government, but expressed concern that stockpiling is inefficient. Due to the specialized nature of rare metals, it would be difficult to identify which form of rare metals to stockpile.

The panel finished with a discussion of a possible International Materials Agency. The sense was that there is more appetite for this type of international coordinating body in Japan and Europe than in the United States.

China's changing industrial policy and its effect on rare metals

According to a long-time expert on China, China's development policies were predictable for the thirty years after it opened its economy, but have been less so in recent years. After the financial crisis of 2007-2008, Chinese leaders judged that the United States had gone into terminal decline. They saw that development as an opportunity for China to surpass the United States in economic power and influence, but were also concerned that a United States in decline might lash out at China. The recent presidential election reinforced the view that the United States would take that course and become more dangerous. Chinese leaders believe that they need to move quickly to take advantage of U.S. decline. They know that raising their country's continued economic growth may prove difficult because of the need to innovate and challenge state-owned enterprises. Indeed, in the past thirty years, the only large economy to go from middle to high-income status has been South Korea.

China's current industrial policy emulates that of Japan and South Korea in creating large conglomerates. There is a sense in China that the country does not need to open up to foreign companies. Moreover, China is not afraid to pick winners and losers. These views are playing out in the rare metals space as large state-run companies consolidate the sector.

China focuses on rare metals in an attempt to incorporate them into a larger strategy. China seeks to move beyond the assembly and manufacture of products toward higher valued-added aspects of production, and it will use domestic resources toward that end. "Made in China 2025" is an evolving blueprint to specify areas of growth. This kind of strategy will not be aimed at denying access to resources, though that may be an unintended consequence. Instead, rare metals will be used to further a strategy of building China's economic growth. These materials are at the core of green technology and high tech applications, much like the railroad system that is being built throughout the country. Many of these industries rely on the production and stable supply of rare metals.

Processing, recycling, and a circular economy

There is great promise in a circular economy that reuses and recycles rare metals. The main goal is for companies to design for and become more efficient in recovering rare metals from products. Doing so would have a clear benefit: it would reduce the mining, thereby minimizing environmental impacts such as the extraction of radioactive materials accompanying certain mining operations. Recycling still requires the use of environmentally-taxing material recovery processes and emissions from the transportation of recycled goods. Therefore, more resources that can be used for longer periods would produce environmental benefits. While the economic and environmental gains are apparent, there are many impediments to the reuse and recycling of rare metals, particularly a lack of resources and infrastructure.

An initial challenge to recycling is obtaining sufficient quantities of rare metals to make the process economic. Currently, many tech gadgets, phones, and green technologies that use rare metals heavily are not at the end of their lifecycles. One participant commented, paradoxically, that even in Japan, where costs of waste disposal

are high, people do not throw away technologies that use rare metals because they fear that recyclers may access data in their computers and phones. Any system designed to recycle tech gadgets in Japan must allay these fears.

The participants commented that the main challenge to recycling is economics. Some products do not make economical, or even environmental, sense to recycle. Increasingly, complex alloys challenge recyclers, and it can be more challenging and costly to extract rare metals from products and return them to a usable state than to get the right grade of metal by processing new ore. Thus, while recycling many rare metals is technically possible, it is prohibitively expensive.

Currently, gold, silver, and copper are the only recyclable materials that are economical to recover from phones. One participant commented that even after the price spike of rare metals, some companies abandoned recycling programs aimed at rare metals recovery because it was too expensive. To encourage recycling and reuse, another participant commented that the United States must pass legislation to encourage companies to take back products and the public to recycle.

Companies like Tesla, BMW, and Apple are starting to accept products for recycling. Apple even has a recycling processing line, called "Liam," which recovers the components from phones on a limited basis, allowing greater recovery of rare metals. Similarly, some companies insist on using recycled materials. Germany has established a waste tax to encourage efforts, and Japan, with societal values of frugality and thrift, is a great recycler.

If companies are willing to change their business models, there will be increasing opportunities for them to be more efficient in using rare metals. For example, products can be leased and companies, rather than consumers, can own them. In such cases, companies responsible for the rare metals in their products would have an incentive to recover resources and use them more efficiently.

Conclusion

The future of our green and high tech world relies on a stable supply of resources that power it. A hundred years ago, the world jumped into a reliance on fossil fuels without fully understanding the economic, environmental, and economic implications. At the dawn of a new industrial era, where the fate of the planet requires the rapid adoption of game-changing technologies, we must understand the resources these technologies depend on — rare metals.

Rare metals are little-known now, but as demand for them increases, they will become more familiar. Now is the time for countries that rely on the production and use of these materials to understand the economic, environmental, and geopolitical ramifications of greater use of rare metals. Japan and the United States can work collaboratively to understand the rare metals market and develop more transparent, open, and sustainable production, development, and trading of these resources.

Appendix: Agenda

Wednesday, November 30

8:30 Welcome

Dennis Blair, Chairman and CEO, Sasakawa USA
Takeo Hoshi, Director of Japan Program, Shorenstein Asia-Pacific Center, Stanford University

8:40 Scene Setter: Key Issues in Critical Resources

David Abraham, Director, Technology, Rare, and Electronic Materials Center

9:30 Identifying Resource Insecurity: The Unique Supply Line Challenges of Rare Metals

Moderator: **Richard Dasher**, Director of US-Asia Technology Management Center, Stanford University
Yuko Yasunaga, Former (2009-2013) Director of Mineral and Natural Resources Division, Ministry of Economy, Trade, and Industry of Japan
Thomas Graedel, Clifton R. Musser Professor Emeritus of Industrial Ecology, Yale University
John Thompson, Wold Family Professor in Environmental Balance for Human Sustainability, Cornell University

10:45 The Rare Metal Age: Industrial Developments and the Rush for New Metals

Moderator: **Saleem Ali,** Blue and Gold Distinguished Professor of Energy and the Environment, University of Delaware; Director of the Center for Social Responsibility in Mining, University of Queensland
Yutaka Tai, Director, Materials Technology and Nanotechnology Department, New Energy and Industrial Technology Development Organization
Simon Moores, Managing Director, Benchmark Mineral Intelligence
Reinhold Schindler, Director of Purchasing Council for Magnets and Rare Earth, Siemens

11:45 Video message: Setting the Government Agenda for Ensuring Critical Resources

Senator Lisa Murkowski, Chairman, Senate Energy and Natural Resources Committee

12:30 Keynote Address: Rare Metals in Defense and National Security

Moderator: **Takeo Hoshi**, Director of Japan Program, Shorenstein Asia-Pacific Center, Stanford University
Dennis Blair, Chairman and CEO, Sasakawa USA

13:15 Identifying Material Concerns and Solutions to Enhance Resiliency in Supply Lines

Moderator: **Daniel Sneider**, Associate Director for Research, Shorenstein Asia-Pacific Center, Stanford University
Elbert Loois, Managing Partner, HTM Advisory
Luka Erceg, Executive Chairman, DryLet
Nick Kotaki, Managing Director, Material Trading Company Ltd.
Geoff Bedford, President and CEO, Neo Performance Materials

14:30 Strategies for a New Industrial Age: Substitution, Recycling and a Circular Economy
Moderator: **Martin Stuermer,** Research Economist, Federal Reserve Bank of Dallas
David Abraham, Director, Technology, Rare, and Electronic Materials Center
Steve Conlin, President, ICD Alloys and Metals
Toru Okabe, Professor and Director, Institute of Industrial Science, The University of Tokyo
Ian Monroe, Visiting Scholar, School of Earth Science, Stanford University

15:30 Summary and Way Forward
Dennis Blair, Sasakawa USA
David Abraham, Director, Technology, Rare, and Electronic Materials Center

16:00 Roundtable 1: Technologies of the Future
Lead: **Simon Moores**, CEO, Benchmark Intelligence

Roundtable 2: Environmental and Reputational Concerns
Lead: **Saleem Ali**, Blue and Gold Distinguished Professor of Energy and the Environment, University of Delaware; Director of the Center for Social Responsibility in Mining, University of Queensland

Thursday, December 1st

8:45 Roundtable 3: Identifying and Reducing Risk in Technology Supply Lines
Lead: **Clint Cox**, President, The Anchor House

Roundtable 4: National Defense and Economic Security Concerns
Lead: **Sharon Burke**, Senior Advisor, New America

10:30 Roundtable 5: China's Resource and Industrial Policies
Lead: **Tom Fingar**, Distinguished Fellow, Shorenstein APARC

Roundtable 6: Processing, Recycling, and a Circular Economy
Lead: **Elbert Loois**, Managing Partner, HTM Advisory

12:00 Open Discussion
Lead: **David Abraham**, Director, Technology, Rare, and Electronic Materials Center

13:30 Adjourn