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Industry Study

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Strategic Materials Industry

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STRATEGIC MATERIALS 2010

ABSTRACT: As is the case with most industrialized countries, the United States stands at a crossroads with regards to the supply of the raw materials needed for the continued relevance of its domestic manufacturing capability. World economic globalization has touched all facets of the industrial supply chain - from the production and refinement of raw materials to the manufacturing of the products consumed by economies throughout the world. For a variety of reasons, most raw materials mined and refined from locations across the world are more cost competitive than their domestic equivalents. Many U.S. mining and manufacturing companies have relocated to other countries in an effort to keep down costs of production and preserve the competitiveness of their products on world markets. The U.S. sits atop very abundant sources of minerals and metals, even if its capability to mine and refine those elemental building blocks to supply its manufacturing industries is declining.

The societal demand for a greener economy and more generally the "post-information age" technological evolution is likely to lead to a new industrial age. Needs for manufactured products in sectors like energy supply, transport, energy saving appliances, and robotics will be growing in the coming years. In this context, the continuous trend towards a "service economy" that has been observed since the 1970s may need to be revised. Mining and metal working industries that used to be considered as "dirty" industry are on the verge of becoming more strategic than ever and will require governmental attention.

Opinions on the urgency of the problem span the Globalization/Protection continuum. Globalization adherents argue that the global economy will continue to drive down costs and make raw materials available and affordable worldwide. Protectionists argue that each U.S. order for foreign materials means fewer jobs for American workers, and increasing national dependence on other countries to supply the rudiments of our national manufacturing power. The Strategic Materials Industry Study (SMIS) group suggests a balanced approach between to desire for low cost consumer products and the assurance that the U.S. can produce the metals and minerals needed to maintain the instruments of its national power.

From the strict perspective of national security, we propose in this paper a pragmatic approach to availability and affordability of materials needed for strategic purposes. Acknowledging that sourcing every material needed domestically is currently unrealistic we propose that a dedicated, interagency organization take charge of monitoring and mitigating supply risks for strategic materials by concurrently stimulating domestic production and adopting smart management of imported resources.

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PLACES VISITED

Domestic:

United States Geologic Survey, Reston VA
Electron Energy Corporation, Landisville PA
Carpenter Technologies, Reading PA
Titanium Metals Corporation, Morgantown PA
Kennametal, Latrobe PA
Henderson Molybdenum Mine, Empire CO
Colorado School of Mines, Golden CO
Molycorp, Greenwood Village CO
Army Research Lab, Aberdeen MD
ADMA Corporation, Hudson OH
TIMKEN, Canton OH
RTI, Niles OH
General Electric Aviation, Cincinnati OH
Brush Wellman, Elmore OH
Iluka Titanium Mine, Stony Creek VA

International:

CODELCO (Chile's State-run Copper Company), Santiago, Chile
COCHILCO (Chilean Copper Commission), Santiago, Chile
National Mining Association, Santiago, Chile
CONAMA (National Environmental Commission), Santiago, Chile
SONAMI (National Mining Association), Santiago, Chile
Chuquicamata Copper Mine (CODELCO), Calama, Chile
SQM Lithium Mine, Antofagasta, Chile
Escondida Copper Mine, Antofagasta, Chile
Consejo Minera (National Mining Council), Santiago, Chile
Freeport McMoran (Private Copper Mine), Santiago, Chile
El Teniente Copper Mine (CODELCO), Santiago, Chile
Molymet, San Bernardo, Nos, Chile
SERNAGEOMIN (National Geological and Mineral Service), Santiago, Chile

INTRODUCTION

The strengths of the United States include vast natural resources that are among the most diverse and plentiful in the world. Combined with intellectual capacity to discover and to innovate in combination with an entrepreneurial spirit, this physical abundance propelled the United States to international preeminence during the industrial age. Metals and minerals have been a key element of this success. Moreover, many of these materials are particularly important to sustain the instruments of U.S. national power, in particular in its economic and military dimensions. However attitudes today suggest that people take materials for granted, forgetting they comprise everything we use. Access to these strategic materials is challenged by market, regulatory and geopolitical factors. These factors do not always work to our advantage.

Demand for metals and minerals is driven by economic growth throughout the world, but the pursuit of new technologies such as "green" energy, and the desire to maintain or gain a technological advantage have also been identified as important factors. This demand spurs an increasing global competition for such materials and a high volatility in their prices.

Many of these materials are particularly important to sustain the instruments of U.S. national power, in particular in its economic and military dimensions. Access to these strategic materials is challenged by regulatory and geopolitical factors.

Many recently published industry articles warn of supply chain risk. For example, there has been a decline of mining and processing of rare earth elements (REEs). These enable the manufacture of high performance magnets and other materials that are key components in aerospace and military systems, green, and other future technologies. As our domestic mining and processing capabilities have declined, we have increased our dependence on Chinese and other foreign imports. This kind of import dependence has attracted the interest of the media and fueled congressional inquiries. China is often blamed for threatening the U.S. future national security, economy, and way of life, either by the intentional actions or merely by the mechanical effect of China's new role as a major global consumer and producer.

Recommendations for the mitigation of these adverse effects are the main output of this study. The U.S. government should monitor and understand the impact these challenges have on national security and explore the policy options we propose in order to manage and improve access to strategic materials in support of the instruments of national power. While recognizing that a strong economic base provides the foundation of all instruments of national power, this paper focuses on issues of risks associated with strategic materials and their role in national security.

To examine this issue, the 16 students of the Strategic Materials Group within the Industrial College of the Armed Forces analyzed a large bibliography and interviewed experts both in the classroom and during various domestic and international field studies. This report is the result of their research.

We recommend establishment of a Strategic Materials Management Office. This would be an interagency group, pulling together disparate components of current offices from DoD, DoE, USGS, DoC and others as appropriate. It would serve as the government's central agency for the collection, classification, and distribution of information regarding strategic materials from both domestic and foreign sources. The office would be responsible for assisting government and private industry through information management, information sharing, and recommendations on matters related to accessing strategic materials from both domestic and foreign sources. This office would also study the implications of existing policy on domestic mining and U.S. manufacturing capabilities and would be tasked to make policy recommendations to align mining policies and manufacturing capabilities with national and private industry goals and objectives.

In liaison with the U.S. Geological Survey (USGS), this office would receive and maintain information related to known locations, size and grade of domestic mineral reserves, as well as maintain information related to foreign sources that provide or are able to provide strategic materials, and trade policies effecting assured and market-based access to strategic materials. The office would work closely with government and industry in order to develop a criticality matrix and risk assessments associated with supply chain interruptions, nominate minerals determined to be strategic, recommend to the Strategic Materials Policy Board (SMPB) materials to be categorized as strategic or critical, recommend policy to ensure U.S. competitiveness and viability, and review and provide recommendations on existing and future policies and trade agreements that affect access to strategic materials. Additionally, based on national security priorities, this office will provide focus for the nation's public and private investment in research and development (R&D) and science, technology, engineering, and mathematics (STEM) activities and be prepared to make policy recommendations in support of these programs.

DEFINITIONS AND CONTEXT

A Brief Introduction to Materials and Minerals

The 118 elements of the periodic table constitute the basic bricks of the materials needed to make any object. Most of these elements come from mineral resources: the USGS identifies 124 minerals mined and processed to make non-fuel materials.

Depending on the form in which these minerals are found in the earth, the steps in converting minerals to manufactured products can be fairly simple, or quite complicated and expensive. Rocks must be crushed, ores have to be extracted and concentrated, and minerals have to be processed into metals, alloys, or useful chemical compounds. These compounds or refined elements may require further processing. Metals may need melting, forging and milling or casting before they can enter the manufacturing process. Powdered chemicals or metals can take their own path to finished items.

The abundance of these minerals in the Earth's crust should be distinguished from their industrial availability. For example, although titanium is a very abundant element, the quantity of titanium metal is limited by the processing capability. Moreover, its price is relatively high compared to metals like iron or even copper because the process to extract and purify the metal is costly. That is why titanium metal is found only in high added value manufactured products (in particular, aircraft components) where its special properties are necessary to fulfill particular requirements.

A medium-complexity system like a car contains a lot of different minerals: iron and steel, aluminum, carbon, copper, silicon, lead, zinc, manganese, chromium, nickel, magnesium, sulfur, molybdenum, vanadium, platinum, and trace amounts of 19 other elements.[1] It is estimated that each year over 25,000 pounds of new minerals are required for every person in the U.S. to make the items routinely used, contributing to provisions like food, shelter, infrastructure, transportation, communications, healthcare, and defense that comprise our current standard of living.[2]

Technological Trends Are Challenging Material Supply

Since the Stone Age was replaced by the Bronze Age, technical progress was driven by the availability and use of more and more chemical elements. The exploitation of the specific properties of the rarest ones can lead to dramatic improvements of components. For example, a magnet made from samarium-cobalt will be, for the same weight, 4 to 5 times stronger than its ferrite equivalent.[3] Recent technologies such as mobile communications, laptop computers, and robots were made possible by the use of more "exotic" chemical elements.[4]

In the short term future, there are strong societal demands for a "greener" economy that will use alternative energies, clean energy for transportation, and energy saving products. To attain the performance goals required for an economically viable exploitation of these concepts, large quantities of special materials will be needed-some of which are in limited supply or available only in a few places. Their availability should not be taken for granted and the competition for some of them will be exacerbated by the pressure of the demand from expanding economies in China and India.

Thus the "green economy" initiative is at risk of trading the U.S. dependency on foreign oil for a dependency on foreign minerals and foreign-made products. Off-shore tidal and wind generation technologies are reliant on the rigidity and corrosion resistance of titanium. While titanium is abundant, current domestic production has not always kept up with the demand. Wind power turbines need more than 700 pounds of Neodymium per megawatt.[5] Neodymium is one of the Rare Earth Elements, currently not mined in the U.S. and available only from China.

The high performance magnets used in high tech sensor technology and a recent generation of high efficiency electric motors also require Neodymium and other Rare Earth Elements. The current volume of production is growing, driven by the success of hybrid cars. Many worry that there simply may not be enough supply to meet this growing demand. Rhenium is another costly element with supply vulnerabilities. While Rhenium can make alloys that allow better turbine engines such as those designed for the most advanced military aircraft, it is extremely expensive and available only as a byproduct of a byproduct of some copper ore processing. Designers have found some alternate technologies to avoid dependence on these materials, but the properties of both Rare Earth Elements and Rhenium are attractive, "Engineering out" some materials is not always possible and, in any case, requires more R&D. Marc Tarpenning, co-founder of the famous all-electric sport car company Tesla Motors,[6] suggested using AC induction motors rather than rare earth-based engines due to the limited availability of REEs and the relative abundance of the materials required to make induction motors.[7]

Materials and National Security

At first blush, the material requirements appear similar between the military and for commercial goods. After all, US acquisition practices have largely migrated over the past two decades from military specification to "commercial off the shelf" technology. Although this is true for a number of products used in the military, a more in-depth analysis though shows that products used in national security mission also require products that are highly reliable and exhibit known characteristics across their intended operational domain. For example, the radiation encountered by spacecraft and satellites require that those vehicles be manufactured with materials that can withstand the harsh environment of space. The shock imposed on the electronics of guided projectiles requires that the electronics be fabricated with materials that can withstand huge G-loads imposed throughout its launch profile. Products developed for national security must be made using materials and techniques that meet the requirements for suitability and effectively for their intended domain and mission area.

Criticality Matrix

For each material, there is a market with specific demand and supply issues. The volumes are also very different: millions of metric tons of copper are produced worldwide every year; only a few tons of rhenium. Their importance for defense and for the economy varies considerably as well as their prices. So prioritizing the importance of materials for industry or national security requirements is essential. This would help determine potential material issues in supply chains and could provide direction for exploration and mining operations decisions.

The criticality matrix developed in a report from the National Research Council of the National Acadamies is the best method we have found to classify the supply risk of a mineral. The matrix evaluates the impact and the risk of a supply restriction. Impact (vertical axis) and risk (horizontal axis) are categorized on a four-level scale from low to high. A mineral assessed with both a high level of impact from a supply restriction and risk of a supply restriction has to be analyzed to ensure supply availability or engineered out. For example, the matrix represented in figure 1 shows the criticality of rhodium supply for the U.S. economy.

The National Research Council report used statistical approximation to assess the impact of supply restriction on the whole U.S. economy (see graph below).[8] However, criticality matrices can be built by any company for the materials it needs.

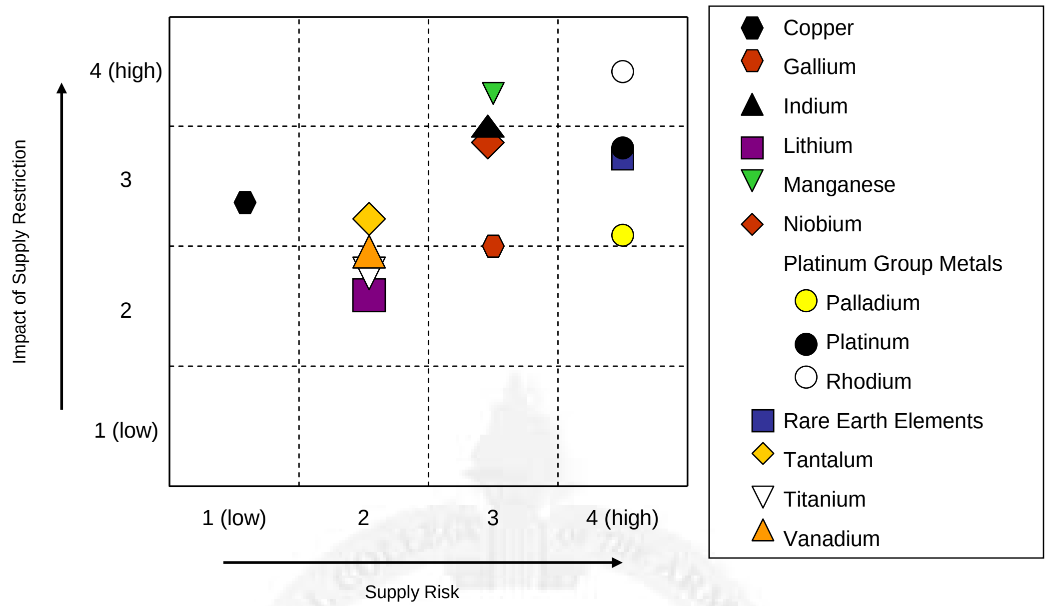


Figure 1: Minerals Criticality Matrix

DoD's Definition of Criticality and Its Consequences

The U.S. Department of Defense (DoD) does not use the criticality matrix method and has given a different meaning to the term "critical". Congress directed the Department of Defense (DoD) to establish a Strategic Materials Protection Board (SMPB) in order to "determine the need to provide a long-term domestic supply of strategic materials designated as critical to national security, and analyze the risk associated with each material and the effect on national defense that non-availability from a domestic source would have."[9] The SMPB identified two different categories of materials – strategic and critical. In a report from December 2008, the Department of Defense Strategic Materials Policy Board (SMPB) offered two definitions for differentiating materials in defense applications[10]:

A strategic material is one in which the material is "essential for important defense systems and unique in the function it performs – there are no viable material alternatives available."[11] Therefore, the strategic materials industry is defined as any industry that mines or manufactures a material that is "essential for important defense systems and unique in the function it performs."[12] This industry consists of the mining and manufacturing of metals and specialty metals. Examples of such materials include titanium, cobalt, rhenium, molybdenum, helium 3, rare earth elements, tungsten, lithium, and beryllium.

A critical material is a strategic material for which the DoD "dominates the market" implying that "[its] full and active support are necessary to sustain and shape the strategic direction of the market, and … there is significant and unacceptable risk of supply disruption due to vulnerable U.S. or qualified non-U.S. suppliers."[13] Utilizing this definition, the SMPB identified only one material – beryllium - as critical and as warranting "special actions necessary to maintain a long term domestic supply."[14] Identification of a material as critical is the key to initiating DoD action to secure a domestic supply. In fact, in the case of beryllium, the DoD helped the Brush-Wellman company to build a new beryllium production facility using DoD funding, under the Defense Production Act.[15]

Many congressmen were not satisfied with such restrictive definitions from the DoD and would have preferred that DoD take a more comprehensive industrial policy approach for all the strategic materials for defense.

While we use the terms "critical" and "strategic" in the same way as the SMPB, we do not limit the scope of our discussion to only the materials currently considered by the SMPB. Rather, we use these concepts as threshold categorizations to drive U.S. government planning to avoid or mitigate supply disruptions.

The National Defense Stockpile[16]

One method of assuring access to strategic and critical materials has been through the National Defense Stockpile (NDS). Since it was established by the Strategic Materials Act of 1939, this stockpile has been a reserve of strategic and critical materials deemed unavailable in the U.S. in adequate supply to protect the nation against a dangerous and costly dependence upon foreign sources of these materials in time of national emergency.[17] In recent years, a sharp decline in requirements resulted in a congressionally mandated disposal program that began in fiscal years 1982–1992 and continued through fiscal year 2006. More than $6 billion worth of materials were sold on the open market during this period.

Today, surging requirements from developing nations have caused sharp price hikes for many strategic and critical materials. At the same time, commercial and military manufacturing firms in the United States have reported shortages of materials needed for defense production, Lanthanum, cerium, europium, and gadolinium were identified as having already caused some kind of weapon system production delay and the report recommended further study to determine the severity of the delays. Coupled with strict mining regulations that close or hinder development of new domestic resources, U.S dependence on foreign supplies are likely to increase, thus expanding the range of materials that would require stockpiling. In such an environment, the current stockpile statutory management structure may not be sufficiently flexible to respond to critical defense needs.

To this end, Congress asked DoD to review its current stockpiling strategy. The preliminary report found a lack of information detailing which materials were forecasted to be required for future weapons systems, domestic production capacity, and alternatives for addressing shortfalls. Additionally, DoD has begun a review, on its own initiative, assessing its dependency on rare earth elements that should be completed by the end of September 2010. It also concluded that reconfiguration of the National Defense Stockpile is necessary to respond to rapidly evolving markets.

Other Legal Tools of the Department of Defense

The United States Congress has developed a number of policy tools over the years that are relevant to the Strategic Materials industry. A brief outline is provided in the following table:

Program/Law	Applies to	Description
Buy America Act	**All Federal Procurement**	**Requires 50% of content be produced in America**
Title 10 Specialty Metals	**All DoD Procurement**	**100% of the specialty metals utilized in DoD end products must be melted in US (or seek waiver)**
Committee on Foreign Investment in US (CFIUS)	**Voluntary, all of USG**	**Inter-agency committee that reviews the national security implications of foreign investments in U.S. companies or operations**
Defense Production Act (DPA) Title III	**DoD**	**Create assured, affordable, and commercially viable production capabilities and capacities for items essential for national defense**

The Specialty Metals Clause of the Berry Amendment is the only program that is specifically targeted at the strategic materials industry. This act has received significant attention over the last three years: it was moved into U.S. Code Title 10 and was modified by the 2007, 2008, and 2009 defense appropriations bills.

Visits to U.S. Industry

Mining Activities

Mining activities are shaped by geology. According to the USGS, that studies the existence and value of mineral deposits, geological resources are spread unevenly worldwide leading to competition for access

The U.S. Government's response to that challenge has existed for a long time. Historically, concerns for mineral resources for the defense industry existed as early as the 19th century. After World War II, Army officers in West Point were given courses on mineral resources. The current way of dealing with strategic materials was taken from the Cold War era and the need to modernize it is largely supported by government and industry experts.

However, geology is not the only factor to consider. The word "resources" is used to mean economically exploitable minerals whereas the word "reserves" simply means that mineral deposits have been identified. These notions are relative since they depend on the price of the commodity and on the extraction and beneficiation technologies available.

Minerals are fundamental to the U.S. economy, contributing 13% or $1.9 trillion annually to the Gross Domestic Product (GDP) and employing approximately 1.5 million workers in and servicing the mining industry.[18] Moreover, the mining activity has a 3.33 multiplier effect on downstream economic activity.[19]

We visited the Henderson Mine in Empire, Colorado, that produces molybdenum ore. The key factors of success of this activity were obvious: a very high grade ore that enables the mine to produce the best molybdenum concentrate and a highly efficient process (flotation).

We also visited titanium sands mining operators in southern Virginia. They shared the same features and also provided an example of successful reclamation of land after the extraction of the mineral resources.

Metallurgy and Metal Working Activities

During the study, we visited several metallurgy facilities producing special alloys, titanium (metal and metal powder), tungsten, steel and bearings, beryllium, and samarium-cobalt magnets in Pennsylvania and in Ohio.

All these facilities have in common state-of-the-art technologies aimed at high added-value products. These products are continuously improved as a result of significant corporate R&D investment. All these companies were part of the defense industrial base that supports the U.S. armed forces.

The review of financial data for each of them showed that, despite the loss of activity due to the global economic crisis, all these companies are profitable and are sustainable in the short term. However, most of them have concerns for their future profitability.

International Focus Chile – Largest Exporter of Copper in the World

Chile is geographically enriched with the largest copper deposits in the world. Of the top five copper mines worldwide based on size, Chile has the top four. Even after more than 80 years of mining in certain regions, there is approximately 40 more years of known copper reserves.

Because of the abundance of natural resources, the Chilean mining industry is one of the most robust economic drivers in Latin America and leads the world in the production of copper, mineral nitrates, rhenium and lithium. Exporting 61% of its copper to Asia, (China receiving the major part), 17% to the Americas, 18% to Europe, and 4% to other countries, Chile has demonstrated tremendous capacity in its mining production and natural resource reserves.[20] Chile is the third largest producer of molybdenum, fourth largest producer of silver, and the fifteenth largest producer of gold. The Chilean mining industry accounts for between 15 and 20% of the country's GDP ($154 billion).[21]

Despite the global economic crisis in 2008, a sharp decrease worldwide in commodity demand, significant labor strikes at various mines, the threat of a swine flu epidemic and a recent magnitude 8.8 earthquake, Chile's mining industry has suffered only nominal economic losses in the short term. As a result of a $4 billion dollar government stimulus package financed with the stockpiling of prior year copper revenues, Chile's economy as a whole and its mining industry in particular have shown tremendous resilience, with an anticipated GDP growth of 5% in 2010.[22]

We surveyed various areas of the mining and metal/mineral processing sectors of the country. State and privately owned copper mines were visited, as were lithium extraction from natural brine facilities, a molybdenum and rhenium roaster, and various governmental agencies and trade associations. The field study highlighted several areas of the Chilean mining and metal/mineral sectors that can be compared to or contrasted with similar areas in the US.

Globalization has improved Chile's prosperity: liberal trade policies and multi-lateral free trade agreements (FTAs) have facilitated the country's integration in the world economy. During the recent economic recession and the subsequent price drop of commodities, China continued to purchase copper, essentially regulating its price. In addition, a stable tax regime makes Chile attractive to foreign investors. An important data point is that Chile is a very important supplier, and in some cases the sole supplier, of several important metals, ores, and minerals. Likewise, globalization has assisted prosperity in the U.S., but the share of mining industry in the U.S. GDP has declined. Another major difference is that in the U.S., raw strategic materials are frequently imported, then processed, refined, and manufactured into a final product. In contrast, Chile exports 100% of their raw materials and imports consumer products.

Chinese economic presence in Chile, while not readily transparent, is of growing significance: Chile's liberal policy with respect to foreign investors; trade agreements with China in particular, allows China to be a noteworthy buyer of Chile's commodities, although it is not yet a major investor in the mining companies. However, officials of the companies visited stated that neither Chile nor the companies have restrictions on foreign investment and would welcome Chinese investment. In the long term, this situation may prove to be a concern for the United States from a regional strategy perspective.

Unlike the United States, Chile has governmental policies that are supportive of the mineral and mining industry. Chile also enjoys vast public support of an industry that the US sometimes considers unsafe and environmentally unsound. Also, unlike the U.S., the Chileans see mining as a key resource and revenue source for their country, and copper in particular is referred to as "Chile's salary." We noted however, Chile's lack of value chain activities, preferring to export the ore rather than engage in smelting or manufacturing activities.

Chile has a similar level of environmental concern as the U.S. The Chilean government has a newly created Ministry of Environment that has good, but immature, policies and infrastructure. Multinational mining companies have taken the initiative to be good stewards of the land and water and are making great strides to comply with their own standards, as well as those of the countries with which they do business. Reuse and recycling were common themes at every facility, especially in the Atacama Desert, where water and energy are critical components and scarce commodities.

One environmental issue that is important to the U.S., but not currently an issue for Chile, is reclamation of land upon closure of a mine. Part of the mining permit process in the U.S. includes detailed plans for reclamation. This is not the case in Chile. Because Chile has never closed a major mine, and does not plan to do so for the next 40-70 years, they have no plans for reclamation and companies are not required to have those plans until five years prior to a mine closure.

Chile shares a similar problem with the U.S. in that education in STEM is inadequate to meet some needs of the country's mining, metals and mineral industries. Each mine, agency or association visited echoed that concern. However, because there are no partnerships between government or industry and academia, either for education or innovation, Chile does not anticipate immediate resolution for this consideration.

Unlike the U.S., Chile's mining industry is referenced and codified in its constitution. Referred to as the Constitutional Mining Law and passed in 1981, it states that changes in the mining industry require a constitutional amendment. Such codification underscores Chile's commitment to and support of an industry that is critical to its economy.

Identifying Issues

During our study, we discovered a vibrant strategic material industry in the U.S. We have been able to measure how its production is important for the acquisition and maintenance of credible defense capabilities. However, during visits we made in the facilities we visited as well as interviews we had with leading subject matter experts including the DoD, the USGS, the Colorado School of Mines, and the Army Research Laboratory, we also identified issues and weaknesses in this industry. The next paragraphs are devoted to analyzing these issues and propose recommendation to address them in order to ensure the sustainability of this key industry.

FINDINGS AND ANALYSIS[23]

We focused our survey on two areas: the evolution of the business economic background and the framework for U.S. government policy.

Domestic Issues

The Current Business Environment

Mining costs and corporate taxes are higher in the U.S. than in many foreign competitor countries. Additionally domestic companies have to take into account policies and regulations such as environmental and safety controls as well as a lengthy and complicated mining permitting process. Such hurdles create delays that prevent the opening of mining facilities in a timely manner to enter the very volatile market of materials.

Environmental interests and laws frequently have second- and third-order unintended consequences that make it economically difficult to conduct business. The proposed *Cap and Trade Bill* under debate in Congress and its impact on electric energy were cited as a major concern by several industry people we have met. Their concern was that the bill would create such a burden for power intensive industries (for example, in the recycled titanium melting industry, energy is the most expensive input) that the cost to operate them would become prohibitive.

Issues specific to the mining activity

Vast areas of the U.S. are still unexplored for mineral reserves, in particular in the federal lands. The USGS considers that there is potential for more mining in the U.S. However, the

National Mining Association is concerned that the domestic business environment is based on outdated concepts and suffers from cumbersome processes that discourage new mining projects. Today's mining legal framework was established in the late 1800s and have not significantly been amended since that time, except to become more restrictive. Federal, state and local mine approval processes impose byzantine regulations, causing increases in the dollar cost (some as high as $15 billion) and time to permit new mines and refine mined products.[24] The process to obtain a permit for mining operations in the United States now takes an average of seven years while it is only one year in Chile. One recent permit application took 18 years to process, much longer than in any other mineral-rich country.[25] These disincentives for mineral exploitation in the U.S. are forcing mineral exploitation and downstream beneficiation, refining, and material production activities to seek better investment recovery elsewhere.

Because privately owned companies that conduct mineral exploration operations are not required to report their finding to the U.S. government, there is a large uncertainty on the quantity of domestic mineral reserves. This information, if analyzed, sorted, and cataloged would be valuable to U.S. government, allowing the monitoring of this vital area of our economic and military power.

Strengths and Weaknesses of Research and Development (R&D) in the U.S.

Although many innovation opportunities still exist in the field of information technology, it has now reached a mature level and is not likely to drive growth as it did in the 1990s and 2000s. The next high growth sectors are most probably in the "green" energy and transportation business as well as in robotics and nano/bio systems.[26] For all these applications, material technologies will be key.

The companies we visited said that they spend significant amounts of money on R&D (2 to 3% of sales) and that they were leaders in innovation and technology. DoD is also a major investor in material R&D. The technologies for materials mining, processing, recovery and recycling are still somewhat immature compared to other scientific areas. Investing additional R&D funds for improved processes will help recover the US competitive advantage in manufacturing high end materials.

However, as it was recently demonstrated for the rare-earths,[27] materials R&D is slowly moving offshore because companies are investing in laboratories located close to their increasingly delocalized production facilities. The consequence is that U.S. companies have to turn increasingly to foreign sources to conduct their development of new materials. By the end of 2007, China and India constituted a bit over one-third of global R&D staffs—and this was an increase of over 10% from just three years prior.[28]

U.S. federal R&D funding is decreasing. As a matter of fact, American companies spent three times more on litigation than on research. The United States is in 22nd place in the fraction of GDP devoted to non-defense research. These trends demonstrate that expertise is leaving the U.S. which will significantly hamper the ability of domestic companies to remain competitive or relevant in the long-term.

Companies also discussed their long term relationships with academia, with a variable level of satisfaction. Some companies are concerned by the shortage of qualified geologists, metallurgists, and engineers in the U.S. More U.S. students in science, technology, engineering, and mathematics (STEM) are needed to maintain the material industry. More should be done to promote and retain our brightest minds. This means grooming future generations by promoting a diverse robust education and training structure.

Globalization and International Issues

The supply of some minerals is unlikely to meet the demand based on current technologies. For example, A Toyota Prius (Prius III) needs 2.2 lbs of neodymium for its motor magnets. The world market for cars and light trucks is about 50,000,000 units per years. Thus 50,000 (metric) tons of neodymium per year would be necessary to switch to this technology. Since the average content of neodymium in REE is between 10 and 15%, this would mean mining at least 400,000 tons of REE per year (more than 3 times what was mined this year). Even with two new mines in the U.S., it would be difficult to match the demand.

The issue of the allocation of rare resources to the most valuable application will become more acute in the coming years. If the market was not too distorted, these rare materials would be automatically allocated to applications where they are indispensable and bring the best added value. However, the material markets are distorted and this issue has to be addressed in the context of a global economy.

<u>The U.S. Dependency on Foreign Controlled Sources</u>

Over the past 30 years, America's reliance on minerals from abroad has steadily grown. In 1978, the U.S. was more than 50% import dependent for 25 mineral commodities, and 100% import dependent for only 7. By 2009, more than 50% of U.S. apparent consumption of 38 mineral commodities came from imports, with 100% import reliance for 19.[29] However, foreign dependency may not be an issue in itself and should be carefully examined.

As globalization and world market competition for minerals continue to grow, so will the risk of disruption of foreign supplies of minerals. The reliance on non-domestic material sources for strategic materials poses a threat to the U.S. supply chains.[30] In particular, the United States is increasingly dependent on materials needed for production of weapon systems. Given current projections, the United States will become increasingly dependent on foreign sources for CERTAIN materials needed for production of weapon systems. Examples of potential reliance on foreign strategic material sources include rare earth elements from China, aerospace-grade titanium from Japan and Kazakhstan, and tungsten from China.[31]

Foreign ownership of U.S. mines is another reason for concern – if not now, then perhaps in another decade. Foreign countries, either through state-owned or commercial corporations, currently own 65% of the metal ore mining industry in the United States. It is possible these firms could decide to sell the materials they control to other customers.

<u>The Trend toward Globalization and Its Impact</u>

Globalization has brought about fundamental resource redistribution challenges for certain commodities and products (e.g., minerals, related manufacturing, and various supply-chain related operations, etc.). This leaves the United States less self-sufficient, and with greater challenges to return to the level of self-sufficiency of previous decades.[32] There are multiple consequences for the availability and quality of the materials the U.S. industry needs to build defense systems. This trend also reduces available mining and processing jobs.

Competing for Resources

The demand by developing industrial nations such as China and India for materials needed to develop infrastructures is increasing. As developing states increase their demand, there will be risks of supply disruptions (even for non rare materials) and of increase of their price. However, any increase of price may make existing mineral reserves in the U.S. economically viable, which could stimulate new or revived mining that would mitigate shortages for certain strategic materials.

The USGS compared the amount of copper in use *per capita* in industrial states (United States, Western Europe, and Japan) that in developing countries such as China, India, and Brazil. In developing countries, the copper use per capita is significantly lower than in industrial states, respectively 7 to 76 kilograms *per capita*. Thus, copper use is likely to continue increasing as countries develop. In anticipation of India's increased demand for materials, Chile and their state owned company, Codelco, are "looking at this closely and developing trade agreements with India."

The Chinese Industrial Policy

China has successfully entered the global mining industry and for some materials, such as rare earth elements, is now in a monopolistic position. Low labor costs and few environmental protections have allowed China to produce minerals at costs that led existing mines in the U.S. to close. Although there are several REE companies in China, they are all driven by the central government's policies and thus behave like a monopoly. The Chinese government can thus act as the price maker on REE markets. Moreover, China would prefer exporting products with more added value than raw materials, and has reduced the volume of its exports quotas by 10 % this year. In 2012, it is expected that the Chinese consumption of REEs will equal its production and, in the context of an administered "socialist" economy, this means that China may simply export no more REEs. This national preference is not aimed at maximizing the profit of the companies but is part of a general policy aimed at attracting manufacturing companies to China.[33]

The market will not solve the shortage of REEs in the short term because China, the major actor on the market, does not play by rules that would allow a normal market performance. Moreover, China has developed a policy to prevent supply disruptions for its own needs. It has purchased mines around the world and partnered with some governments in Africa to obtain mining rights. This exacerbates competition for global resources.

The Attraction of the Chinese Market, and Its Problems

U.S. companies cannot ignore a large potential sales market such as China's. Indeed, they have been compelled to establish various levels of operations in China to attempt to exploit its huge opportunities. However, balancing the maintenance of a domestic capacity at the expense of being out-competed in the Chinese market is a difficult challenge: from a national security perspective, some industrial capabilities should be maintained for security of supply concerns; from an economic point of view, there are short-term concerns of losing jobs and longer-term risks of erosion of technological know-how. Industry experts expressed hesitation to establish production facilities in developing countries due to Intellectual Property Rights (IPR) concerns.

Conclusions

Based on current trends, we forecast a decline in the U.S. strategic materials industry over the next twenty years with several mines and manufacturers leaving the country or disappearing completely. In order to reverse this trend, the U.S. should undertake policy initiatives including reduction of taxes, development of incentives and increased investment in education and research. This would require hard political choices and making recommendations in this field would go far beyond the scope of this paper.

In the next paragraph, we describe a policy more focused on the specificities of the strategic materials industry and its implementation.

RECOMMENDATIONS

Domestic Issues

Competitiveness

Governmental regulation is a key contributor to the cost of production. Federal, state, and local governments should carefully consider the impacts of both existing and new regulation, to strike the proper balance between the public good and the ability to develop and leverage domestic resources to fuel the instruments of national power. Today's regulation constitute a burden for the materials industry that jeopardizes its competitiveness.

The DoD market for minerals is miniscule compared to the broader U.S. economy. Thus, the best way to ensure access to minerals in U.S. critical weapons, C4I systems, and components is to preserve the broader U.S. industrial base from mining to manufacturing that involves those minerals. This supply chain linkage is especially critical and must be re-invigorated to support the national objective of creating "green industry" and "green jobs." Unfortunately the competitiveness of mining, material refining, and manufacturing businesses in the U.S. is deteriorating.

While there is a definite need to consider the environmental factors and compliance in the conduct of mining, a responsible adjustment is in order. Immediate changes to laws and public policy are required to reverse the present course of mining and manufacturing decline.

A Mineral Policy

To create diversity of supply of designated strategic materials, the Assistant Secretary for Policy and International Affairs, U.S. Department of Energy summarized the available options "We need multiple, distributed sources of strategic materials in the years ahead. This means taking steps to encourage extraction, refining, and manufacturing here in the United States, as well as encouraging our trading partners to expedite the environmentally sound creation of alternative supplies."[34] A recent example of this has been the exploration for and discovery of REE deposits in Australia, North America, and South Africa in response to China's monopolistic behavior with regard to their REE resources.

The United States should enact policies focused on growing the domestic mining and refining industry to increase its leverage on global commodity markets.

Government policy and incentive programs should be established to encourage mineral exploration. This effort should reward government agencies, companies, partnerships or corporations that discover and report on commercially viable concentrations of minerals. Because no such policy exists, information related to discovery of mineral reserves by private companies is not being shared with the government.

Research & Education Objectives

The primary goal of U.S. policy in the area of R&D should be to maintain U.S. leadership and its competitive advantage across the globe.

The U.S. must increase private and public funding for non defense R&D. This is necessary to arrest the continuing decline in R&D, in particular on industrial processes. U.S. policy should also seek to expand the scope and breadth of R&D efforts to cover all aspects of basic and applied research with respect to strategic materials, across all phases of strategic material processing (extraction, processing/refining, manufacturing/alloying, and recover/recycle/reusing). For example, titanium metal production continues to rely on a reduction process that has not significantly changed since its development in the 1940s. The result is the continued use of a time and energy-intensive production process that causes the high cost of titanium metal products.

The U.S. should also codify, in law, a responsible agency for oversight and management of public R&D. The disparate efforts of U.S. agencies, academia, and industry dilute the impact of R&D and lose the potential for synergistic results. As a result, the U.S. government should facilitate the coordination of these activities by using a portfolio management approach. This R&D portfolio would be segmented into individual materials and groups of materials which would compliment each other. For example, the R&D portfolio will include a REE segment whereby information can be freely exchanged between participating agencies. The primary risk to portfolio management is the lack of trust and support from private industry and academic institutions. In order for R&D portfolios to maximize returns on investments, information and data (often proprietary in nature) must be shared, managed, and safeguarded by the agencies. U.S. policy must foster better coordination; increase fiscal investments across government, industry and academia; expand the scope and breadth of R&D; and leverage and safeguard materials expertise, data, and information through R&D portfolios.

U.S. policy must foster an environment that produces sufficient STEM-qualified individuals to support the strategic materials and other technical industries. STEM policy should focus on two goals: early intervention/engagement and incentives. The complicating factor is the overall economic downturn that prevents any definitive assessment on the availability of trained personnel. Unemployment rates remain high across many industries that rely on STEM graduates, but perhaps more importantly, we must understand that market conditions are the ultimate determinant on the demand for STEM graduates. Until salaries for STEM graduates become competitive with other disciplines (examples: finance and business), the supply of STEM graduates will remain low among U.S. students.

Regardless, output of STEM graduates is a direct reflection of the difficulties of K-12 education in preparing students for the rigor of a STEM curriculum. Further, policy should focus on cultivating opportunities during primary and secondary education by showing the utility and applicability of pursuing STEM degrees. Finally, U.S. policy on STEM education must account for the role of the overall job market for STEM graduates.

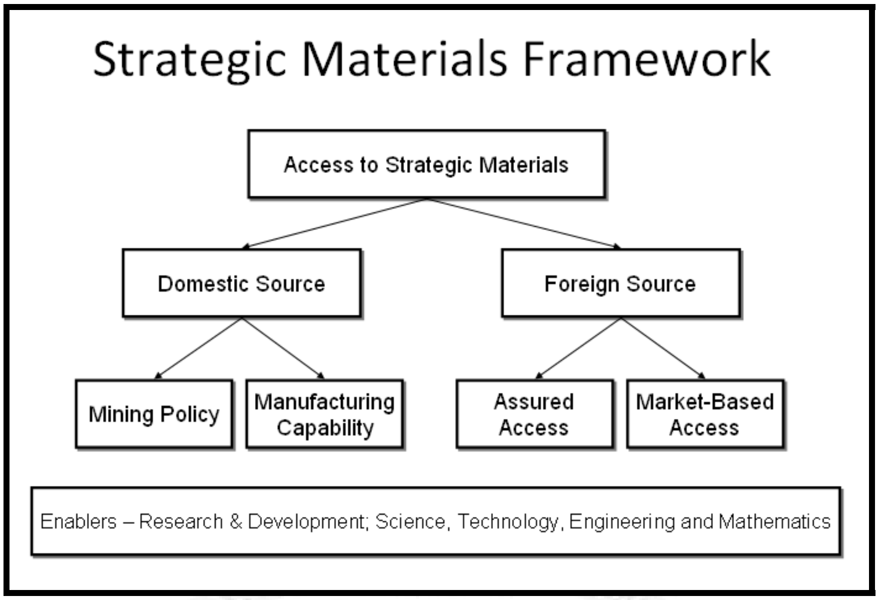
International and Globalization Issues

The U.S. can only import minerals that others countries are willing to export. In an ideal global marketplace, access to minerals and metals would be subject to undistorted market forces. However this is not the reality of today's geopolitical climate. In an effort to maintain their market share, increase their exports, and maintain employment, some metal and mineral producing countries overproduce and dump those commodities on the world market, driving the price down and making it economically infeasible for other potential firms to enter (or re-enter) the market. The U.S. should demand freer markets for materials and address the monopolies issues and more generally all anti-competitive behaviors. To ensure the diversity of sources is useful to mitigate the issues created by foreign dependencies.

The United States has a wide spectrum of tools to foster productive trade relationships with other countries and protect itself from practices that stifle fair global trade: aid initiatives to create, sustain and foster good relationships with other countries; mutually productive trade agreements to ensure adequate supply of commodities and fair pricing based on undistorted market.

RECOMMENDED ACTIONS FOR U.S. POLICY

The management of strategic materials can be based on a simple framework. The purpose of this framework is to manage supply risks for both foreign and domestic sources in a global market context. On the one hand, we are interested in supporting and developing the domestic mining and processing industries. On the other hand, some commodities can only be easily supplied from abroad.



These issues will require constant monitoring. Supply risks can have dramatic impact on a single or on multiple U.S. government agencies as well as on the U.S. economy. A dedicated organization at the interagency level would be useful to coordinate and plan actions to mitigate risks. Focusing on national security, the top-down flow in the diagram above can be used to analyze individual risks and identify appropriate action to be described in the following paragraphs.

Domestic Issues

Improve Competitiveness of the Mining, Metallurgy, and Metal Manufacturing Industries

A Competitiveness Policy

The propositions to increase the competitiveness of U.S. high tech products (including "green products)" and the profitability of their production are many fold. In the mining domain, measures facilitating permits and mining on federal lands (to be discussed with the National Mine Association) should be prioritized to foster mining activities. Scrap industry for rare materials should also be incentivized.

The United States should develop a policy framework that focuses on production costs, energy costs, and regulatory structures that will allow the U.S. companies to stay competitive in the global market. In particular, all the environmental regulations should be examined and waivers could be granted for critical materials.

This industrial policy should re-balance the comparative advantage of industrial activities versus services.

Mineral Policy

Working together, industry and government can make better strategic decisions regarding domestic mining, foreign purchases and future trading policies regarding mineral resources. The

U.S. Geological Survey should publish more detailed data and knowledge for use by engineers and businessmen.

The USG should enact policy that rewards companies, partnerships or corporations that discover and report on commercially viable concentration of minerals. USGS should maintain a closed database on the location of all these mineral reserves to be used for government reference and analysis. In the end, a clearer visibility on domestic availability of minerals would help the Strategic Materials Management Office prevent dangerous dependencies on foreign sources.

Federal lands should be reasonably re-opened for exploration, claims, and extraction of strategic materials. The five-year standard for mining lease permits on federal lands should be expanded to allow companies sufficient time to recover their permitting and other investments.

The United States needs to review and update all pertinent policies, regulations and laws that deal with mining and processing of the natural resources. Several things can be done to streamline the existing process for obtaining the permits necessary for mineral exploitation. The federal, state, and local permitting requirements should be de-conflicted to ensure that requirements from each level are not duplicated in other levels, but are complementary. Reasonable limits such as 1-2 years must be placed on the public "comment and answer" phase to the permitting process.

The R&D Policy

A large R&D program should be earmarked for "green technology" and other high growth sectors. This could be an interagency program with groups contributing to the pool as needed. A significant part of the pool should be devoted to material manufacturing processes, thereby focusing universities on the current industry issues and attracting gifted students to these topics.

The U.S. government should reinforce STEM education programs and create opportunities for STEM graduates. U.S. policy could also readily leverage existing programs, like Pell grants, to provide incentives to the students pursuing STEM degrees in college. Immigration controls for foreigners who graduate from STEM programs should be eased.

Orienting a portion of the DoD R&D on technologies that have a potential for dual use civilian applications (inexpensive fuel cells for example) would sustain American advantage on technological consumer products due to a large spill-over of the technologies. This has been the case in the past for jet aircraft, nuclear power supply, electronics, internet, and the Global Positioning System (GPS). This would provide a high level of return on taxpayer money invested in defense technologies, and provide a considerable side-benefit from the effort to resource national security that has become a heavier burden since the beginning of the recent conflicts in Iraq and Afghanistan.

International and Globalization Issues

Ensure Security of Supply for the Defense Industry

U.S. materials management policy should focus on mitigating the effects of material shortages on the defense industry. To this end, we recommend monitoring the market and, if there is a significant risk of supply disruption, using an appropriate control or set of controls from the materials management framework to prevent or diminish the disruption. In particular, stockpiling practices should be modernized. The U.S. government should also invigorate its trade negotiations with other countries and secure agreements for long term access to minerals and metals important for its national security. Finally, the U.S. government should pursue partnering options with friendly countries to ensure the stability of the supply chains of minerals like titanium, copper and beryllium.

Open markets

The Government should strengthen the Department of Commerce (DoC) to provide more comprehensive monitoring of world metals and minerals prices, as well as policies of foreign governments to identify potential barriers to unfettered trade.

The DoC should use existing tools available for other countries that engage in trade practices that are considered unfair. We have a range of protective mechanisms at our disposal to try to level the playing field. The U.S. can petition the World Trade Organization (WTO) to adjudicate trade disputes, and can use our diplomatic influence to proffer solutions. If diplomatic and WTO options do not resolve trade disputes, the US can turn to unilateral protective measures. The U.S. can levy import tariffs on products from a country that attempt to flood the US market with commodities at unfairly low prices. The US could impose export quotas on domestically made products to that country in an effort to counter their unfair practices. Obviously, diplomatic approaches are the preferred approach; they are less disruptive to markets and industries, and do not generally have the second and third order effects associated with punitive sanctions.[35]

FINAL THOUGHTS

Availability and affordability of strategic materials are crucial issues for the U.S. defense as well as for civilian supply chains. In this paper, we focused on national security issues and we proposed the establishment of a pragmatic scheme to mitigate supply risks at the interagency level. This scheme addresses both domestic and imported supplies.

On the domestic side, improving the status of the U.S. among mineral and metal producers is a must because significant capabilities to support the defense industry have to be maintained on our national soil. This would also allow U.S. companies to have a significant role in the global market avoiding dangerous monopolies.

Imports of minerals will always be necessary or desirable for economic reasons. We proposed a practical way to address the supply risks they always imply. Implementing it would have to be done case by case. The political momentum (apparently bi-partisan) that has been recently observed on strategic materials issues may offer an historic opportunity to push these ideas to modernize the way our nation deals with strategic materials.

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[9] Office of the Secretary, *Analysis of National Security Issues Associated With Specialty Metals*, Federal Register, Vol 74, No. 34, February 23, 2009, 8061.

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[13] Ibid., 8062.

[14] Ibid., 8061.

[15] Ibid., 8062.

[16] This is based on several congressional testimonies

[17] Administered by different agencies over the years, the National Defense Stockpile (NDS) has been under the administration of Department of Defense since 1988, with operational aspects delegated to the Defense Logistics Agency. The size and intent of the NDS has fluctuated based on both geopolitical and security pressures throughout the years.

[18] U.S. Geological Survey, *Mineral Commodity Summaries 2010*, 5-15. This reference document is published on an annual basis; this report is the earliest Government publication to furnish estimates covering non fuel mineral industry data. Data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for more than 90 individual minerals and materials.

[19] Ibid.

[20] National Service of Geology and Mining brief to Strategic Materials Industry Study seminar on May 13, 2010 (Santiago, Chile). Some key wavetops presented were that mining represents approximately 20% of the country's GDP and it is an attractive investment industry because the well-established and legal frameworks to protect investors' interests. In terms of exploration, in 2008, $500 million was spent on exploration. This is about 4% of total mining exploration in the world. When compared to the fact that Chile has 36% of the world's known Cu reserves, this seems a very good return on investment. However, not just exploration, but also business models are noteworthy. Indeed, any foreign country can come to Chile and mine, provided they play by the rules governing exploration, and exportation of both profit and capital. Finally, this industry has demonstrated resilience, vibrancy and economic flexibility in keeping with market-capitalist trends to cede as much as possible to the free-market. Consider that in 1990, Cu production in Chile was done by 60% of state owned enterprises (SOEs), while today, SOEs constitute less than 30% of mining. Thus, foreign mining occupies about 70% of the country's mining. In short, Chile may fairly claim it manages is resources and industry with a good deal of success.

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[27] Brian J. Fifarek, "Globalization, Offshoring, and the Location of innovation: A Case Study of Rare-Earth technology," Thesis, Carnegie Mellon University, Carnegie Institute of Technology (February 17, 2008), 115-116.

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[29] U.S. Geological Survey, *Mineral Commodity Summaries 2010*, 5-15. Some might argue that import-reliance is not an important issue if our suppliers are friendly, if there are supply-chain risk mitigations, if there are suitable substitutes, and for that matter, if those minerals do not support critical systems tied to the long-term economic viability or defense of U.S. existential challenges.

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