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Industry Study

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Strategic Materials

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STRATEGIC MATERIAL 2015

ABSTRACT: The domestic economy, the defense industrial base, and U.S. national security are currently at risk because the nation is dependent on other nations for the building blocks of consumer and defense goods. The blame falls to policy decisions that tightened the domestic regulatory regime, ceded U.S. position to international competitors and the force of globalization, and diverted the nation's focus from the raw materials needed to fuel the economy. The report's recommendations strive to mitigate U.S. risk by aligning government interests of this industry, incentivizing investment, developing the workforce, implementing hedging strategies, and overcoming existing regulatory roadblocks.

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Embassy of Chile, Washington D.C.
Organization of American States, Washington D.C.
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The Honorable Henry C. "Hank" Johnson (U.S. Representative of the 4th District of GA)
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Molycorp Mountain Pass Mine, CA
Colorado Department of Natural Resources, Division of Reclamation, Mining and Safety, Denver, CO
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National Mining Society - SONAMI (Sociedad Nacional de Minería), Santiago, Chile
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INTRODUCTION

"Every year more than 25,000 pounds of new nonfuel minerals must be provided for each person in the United States to make the items we use every day."

- National Resource Council[1]

The U.S. economy and national defense depend on the availability of basic materials. Yet the average American probably has no idea where the materials they use come from, nor cares for that matter. Over the past 20 years the business of materials has mirrored the growing globalization of products and supply chains. In a hypothetical example, rare earth elements may be mined in the United States, processed or smelted in China, then shipped to Japan where they are made into magnets that are put in smartphones back in China, and then shipped to customers around the world. This example begins to frame the strategic issues surrounding materials.

Purpose

This report analyzes the U.S. Strategic Materials industry to assess its health and ability to support the national economy and national defense. In 2011, materials added more than $2.2 trillion to the U.S. economy.[2] Today's advanced electronics, aircraft, hybrid vehicles, medical instruments, and energy systems are all tailor-made from minerals to achieve their most eye-watering capabilities. Minerals are also vital to military weapon systems. For example, titanium, tungsten, and rare earth metals (a collection of 17 minerals) are all staples in the military's advanced machinery.

Increasingly the U.S. finds itself more and more dependent on foreign suppliers for these key materials. The U.S. Geological Survey (USGS) reported in its most recent survey of mineral commodities that the nation is now 50 percent dependent on imports for 40 key minerals. Even more concerning, the U.S. is 100 percent dependent on imports for 19 of these minerals. By comparison, in 1978 USGS reported on the same 40 minerals, and at that time the nation was 50 percent dependent on only 25 of the minerals and 100 percent dependent on imports for only seven.[3] This dependence eerily parallels the nation's dependence on foreign oil: it has economic, political, and national security implications.

Argument and Research Methodology

This report combines findings from research, discussion with subject matter experts, and several domestic and international site visits. The findings reveal the U.S. economy and its national security are at risk because the domestic Strategic Materials industry is shrinking. It's shrinking due to global economic trends, the domestic regulatory market, and a lack of government and private industry focus. The report offers U.S. leaders targeted policy guidance that can mitigate the risk associated with a declining domestic industry and meet a new generation of manufacturing needs.

The report is broken into six sections. The next section scopes the research and subsequent policy recommendations with a definition of the industry. Section three examines the current conditions of a representative sampling of the broader industry. A projected outlook of the industry follows section three and is based on broader global economic and regulatory trends. Section five outlines the domestic regulatory regime and the role the U.S. government plays in the industry. Finally, the last section of the paper outlines policy recommendations to mitigate U.S. economic and security risk associated with material supply chains.

DEFINING THE STRATEGIC MATERIALS INDUSTRY

Defining the strategic materials industry was a surprisingly difficult task. The general mining and metal manufacturing industry contains many steps, which required bounding for this study. Scoping that to the particular materials considered *critical* or *strategic* uncovered a set of vague, elusive, and occasionally contradictory definitions.

Description of Industry Sectors

Minerals of interest to the U.S. are found in deposits around the world, and thus the mining process begins with **exploration** for these deposits. This geologic work is done by various entities—the U.S. Geologic Survey within the government, large companies, small contractors, and individual prospectors—to find locations with sufficient grades of ore to warrant the time and expense of establishing a mine. It is generally large companies that then make the significant capital investment to build the infrastructure and facilities required to open and operate a mine. Once the material is **extracted** from the ground, all minerals have to go through some form of **beneficiation**, where the desired material ore is separated from the surrounding useless rock (known as "gangue"). This occurs in a combination of physical and chemical processes, depending on the material. These processes tend to happen near the extraction site by the same company, though not always. Next, the ore is **smelted** (likely at a different company or location), producing the higher grade slabs or plates of the metal for use by downstream customers. Some products have another step where the slabs or plates are further refined and/or **alloyed** with other metals before they pass to the manufacturing industry to turn into products. The mineral materials industry sectors are aligned with these major processes that encompass exploration through alloying, ultimately producing products for the manufacturing industry.

Difficulty Defining "Strategic"

To determine which of the mined metals were "strategic," we consulted over a dozen experts in the field from across government and industry,[4] both in interviews and in published reports. We found no universal standard for "strategic." The best published definitions are the U.S. government definitions which follow:

The first definition comes from the Strategic Materials Protection Board (SMPB), a Department of Defense (DoD)-wide group which Congress established "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."[5]

The definition they submitted in 2008 states a strategic material is, "a material

(1) which is essential for important defense systems,
(2) which is unique in the function it performs, and
(3) for which there are no viable alternatives."[6]

The SMPB further elaborated that a subset of strategic materials are "critical materials." A critical material meets the strategic material definition plus these additional criteria:

(1) the Department of Defense dominates the market for the material,
(2) the Department's full and active involvement and support are necessary to sustain and shape the strategic direction of the market, and

(3) there is significant and unacceptable risk of supply disruption due to vulnerable U.S. or qualified non-U.S. suppliers.[7]

The SMPB definition seemed too narrow, especially given the idea of "uniqueness" and DoD market domination. Creative engineers have found viable alternatives to a surprising set of materials.

Another option is spelled out in U.S. Law, Title 50, regarding the "acquisition and retention of stocks of certain strategic and critical materials," known as the National Defense Stockpile, which will be discussed later in the report.[8] Under the discretion given in this law, the President in 2012 issued the following definitions:

(1) The term "strategic and critical materials" means materials that

(A) would be needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency, and

(B) are not found or produced in the U.S. in sufficient quantity to meet such need.

(2) The term "national emergency" means a general declaration of emergency with respect to the national defense made by the President or by the Congress.[9]

This definition helpfully includes civilian needs, but in that, it becomes excessively broad. The focus on a declared national emergency is also very limiting.

A definition in between these two can be found in Title 10, which established the SMPB.

(1) The term "materials critical to national security" means materials—

(A) upon which the production or sustainment of military equipment is dependent; and

(B) the supply of which could be restricted by actions or events outside the control of the Government of the United States.

(2) The term "military equipment" means equipment used directly by the armed forces to carry out military operations.

(3) The term "secure supply", with respect to a material, means the availability of a source or sources for the material, including the full supply chain for the material and components containing the material.[10]

This definition notably includes the entire supply chain, not just extraction. A raw material may be available in the U.S., but if the only smelting facilities are in an unreliable foreign country, the supply of the material is at risk. The definition references actions outside the control of the U.S.; however, a significant reason many materials are not currently mined in large quantities in the U.S. is due to the *domestic* regulatory environment.

Industry Perspective on "Strategic"

The mining industry itself does not define which materials are strategic. Industry advocacy groups such as the National Mining Association make no distinction. Neither do the various professional societies like the Society for Mining Metallurgy and Exploration. Market research firms, the sources of much of the financial data in this report, use subdivisions defined by the Department of Commerce (DOC). DOC assigns groups of materials being extracted or processed to a North American Industry Classification System (NAICS) code, like Metal Ore Mining (2122) or Primary Metal Manufacturing (331).[11] Additional digits are added to each of these codes to indicate major sub-groupings, some including only one metal (iron), others four (copper, nickel, lead, and zinc), and then the catch-all "All-other." Virtually all the lowest level codes contain a mix of metals.

NAICS codes offer no help defining the industry because there is no unique code associated with "critical" or "strategic" materials. The limitation also complicates the search for financial data to analyze this industry. Various minerals broadly seen as strategic (like rhenium) were bundled in NAICS with materials that were clearly not (like nickel).

Working Definition

In the end, this report uses a hybrid definition. A *strategic* material is a substance the U.S. industrial base needs in substantial quantities at a reasonable cost which does not have an affordable, ready substitute. *Strategic* materials are also *critical* based on two criteria:

(1) the degree to which the material is needed for military purposes and

(2) the susceptibility of supply disruption of those materials.

Many factors can disrupt supply, but this report focuses on two primary causes: the changing regulatory environment in the U.S. and abroad; and the dependence on unreliable overseas sources.

This paper limits the focus to *minerals* (i.e., solid, natural, inorganic substances, thus excluding fossil fuels).[12] Also, s*upply* begins with the extraction of the mineral from the earth through any necessary processing to prepare the material for industrial use. Based on the report's definition, the strategic materials industry then starts with a list of minerals essential for military applications. This list is long and overlaps considerably with commercial industry, but some stressing cases include:[13]

- High-stress, high-temperature turbine blades (e.g., rhenium)
- High-strength, lightweight materials for rockets and aircraft (e.g., titanium)
- Semi-conductors for radiation-hardened electronic components (e.g., gallium)
- Magnets for missile guidance systems (e.g., rare earth minerals)

A detailed assessment of supply disruptions would be necessary to define which materials are critical (something, again, the consulted experts are reluctant to do). The U.S. does sufficiently control the extraction and processing of some strategic minerals, like copper, to meet domestic needs, and hence these are not critical. However, the *critical* materials "industry" ends up including copper and other large portions of the mineral mining and processing industry since some minerals (e.g. rhenium) are acquired as byproducts of the processing of more common elements (e.g. copper)—without copper, no rhenium. Thus, the sellers are too intertwined to cleanly untangle, as are the regulations, water needs, power required, equipment and workforce issues. Likewise, the civilian versus military buyers of these materials (e.g. in the aircraft or electronics industries) are very hard to distinguish. Thus, the health of the industry for critical and strategic materials (hereafter abbreviated as "Strategic Materials"), to the degree one exists, is inextricably tied to metals mining industry more broadly.

CURRENT CONDITIONS OF SELECT STRATEGIC MINERAL AND RELATED MARKETS

The previous section begins to highlight the challenges analyzing the Strategic Materials industry. The biggest challenge in a report like this is trying to summarize the health of the industry when each mineral or metal is really a market of its own. Given space limitations, the financial analysis of the industry is based on seven mineral markets that are representative of trends, risks, and health of the broader industry. The several minerals are copper, molybdenum, tantalum and tungsten, titanium, beryllium, and rare earth elements.

Subsequent analysis of each of these seven minerals is based on Michael Porter's Five Forces model (hereinafter referred to as Five Forces). As the name implies, the model is built on the five forces that impact the health of any industry. The forces are rivalry among competitors, power of suppliers, power of buyers, threat of new entrants, and threat of substitutes. A full description of the model and its use analyzing the industry is included in Appendix C.

Some market forces are common across all seven minerals and the broader industry. For example, mines, beneficiation, smelting, and alloying require considerable capital investment which present a barrier to entry to all but the most well-funded, established companies. Only these large companies can afford the roughly 10-year cycle to acquire permits (in the U.S.) and the associated long delay for a return on the investment.[14] Similarly, the entire industry is challenged finding a qualified workforce, both in skilled labor and engineering disciplines (power of suppliers). Finally, mineral extraction, beneficiation, and smelting operations increasingly face challenges in government environmental regulation, water consumption, and electricity.[15] The paper now examines the unique aspects of each mineral market.

Copper

	Copper (Cu) Summary			
Properties	Corrosion resistant, electrically/thermally conductive			
Market Uses	Wiring, electronics, plumbing			
Five Forces Summary[16]	Market Structure	Monopolistic competition		
	Power of Suppliers	Med	Power of Buyers	Med
	Threat of Substitutes	Low	Threat of New Entrants	Low

Table 1: Copper Summary[17]

The copper extraction market has many competitors, led by the three largest, CODELCO (owned by the Chilean government), Freeport McMoRan (U.S.), and BHP Billiton (Australia). The combined market share of the top four is 32.9%, the top eight is 46.3%, and the Herfindahl-Hirschman Index (HHI), a standard Labor Department measure of market concentration, is approximately 600, thus not concentrated.[18]

The market has very little differentiation in the final product; thus, power is biased to the buyers. The number of competitors has been slowly shrinking, and the biggest issue all companies face is diminishing ore grades, leading to a need for new or expanded mines. The threat of substitutes is primarily in recycling, given copper's virtual 100% recyclability. Plastic can substitute for pipes and aluminum and gold for wires, but all substitutes have lower performance and durability standards. Worldwide environmental and water regulations creep which make new or expanded mines very expensive are the largest threat to the industry.[19]

Molybdenum

	Molybdenum (Mo) Summary			
Properties	Strong, corrosion resistant, high-temperature tolerance			
Market Uses	Super alloys, electronics, and aerospace uses			
Five Forces Summary	Market Structure	Monopolistic competition		
	Power of Suppliers	Med	Power of Buyers	Med
	Threat of Substitutes	Low	Threat of New Entrants	Low

Table 2: Molybdenum Summary

The molybdenum extraction market has many competitors, led by the three largest, Freeport McMoRan (U.S.), CODELCO (Chile state-owned enterprise), and Southern Copper (Mexico-based private firm). Production is split between mines with direct molybdenum extraction and those where "moly" is a by-product of copper beneficiation. The top four competitors have a combined market share of 43%, the top eight have a combined 60%, indicating that the market is of low concentration.[20] The market for molybdenum is in electronics and when alloyed with steel it's used in projectiles, armor-plating, and high-speed tools[21] due to its high-stress, high-temperature, and low-corrosion characteristics.

The market has very little differentiation in the final product, thus power is biased to the buyers. The threat of substitutes is also very low[22] as it is already a substitute for tungsten and available for the foreseeable future at prices much lower than its 2007 peak. What sets molybdenum apart from other strategic materials is that the U.S. produces enough to meet its own needs, while exporting more than it imports. Thus, while essential to many military systems, molybdenum does not qualify as critical.

Tungsten and Tantalum (combined due to similarity)

	Tungsten (W) and Tantalum (Ta) Summary			
Properties - W	Highest temperature tolerance of any metal			
Market Uses - W	X-ray filaments, electron microscopes, projectiles, armor[23]			
Properties – Ta	High electrical capacitance, corrosion resistant, durable			
Market Uses –Ta	Electronics, computers, and medical devices[24]			
Five Forces Summary	Market Structure	Monopolistic competition		
	Power of Suppliers	High	Power of Buyers	Low
	Threat of Substitutes	Low	Threat of New Entrants	Med

Table 3: Tungsten and Tantalum Summary

Tungsten is primarily mined and refined in China.[25] The Cantung mine in Canada is the largest producer outside China, but the mine is estimated to only have three years of supply left.[26] The lack of global supply of tungsten, and high prices, has driven Tungsten mining underground…figuratively, to warlords in Africa and even the Revolutionary Armed Forces of Columbia.[27] Considering all this, the tungsten market seems dangerously out of balance in favor of the suppliers. As a result, the U.S. government has stockpiled over 35 million pounds of the metal (currently valued at over $262 million) in its Strategic Stockpile.[28] There are some substitutes (Molybdenum), but none are perfect because tungsten has the highest melting point of any element on the periodic table.

While tungsten supply is currently very limited, market forces appear to be correcting the supply-demand imbalance. Numerous tungsten mines have come on line or will soon, including mines in the United Kingdom, South Korea, Canada, Vietnam, Spain, Australia and even the United States.[29] Additionally, tungsten is recyclable, and approximately 59% of the U.S. 2013 demand was met through recycling.[30] Finally, China's export restrictions once created a stranglehold on the market and prices, but the restrictions are now almost irrelevant as China has become a net importer, and new mines have come on line.[31]

Tantalum shares many of the same market characteristics as tungsten, but it has no suitable substitutes in most applications.[32] Additionally, tantalum cannot be recycled in large scale.[33] DoD notes that stockpiling and export reduction are the only means to ensure enough supply of tantalum in a crisis.[34] It estimated the military needed to stockpile 310 tons of material at a cost of over $42 million.[35]

In regards to tantalum's market characteristics, something peculiar becomes readily apparent: from 2005 until 2011, the cost for tantalum was flat. This market reality is what likely led to the closing of nearly all large scale tantalum mining operations in 2009, and kept values abnormally low. Since 2011, and strict enforcement of the Dodd-Frank Act requiring tracing of "conflict" minerals in Africa, tantalum seems to have begun to operate in a more traditional commodity market structure, but this also led to prices approximately five times higher per kilogram than tungsten. According to the USGS, in 2013 nearly two thirds of the world's supply of tantalum came from Africa, with Rwanda being the largest producer while two of the largest mines for tantalum in Australia and Canada remained closed.[36] Hence, the tantalum market seems to be imbalanced in favor of the suppliers for now, though only because the low cost of mining in Africa.

Titanium

	Titanium (Ti) Summary			
Properties	Light, high-strength, corrosion resistant, high temp tolerance			
Market Uses	Super alloys, many aerospace uses			
Five Forces Summary	Market Structure	Monopolistic competition		
	Power of Suppliers	Med	Power of Buyers	Med
	Threat of Substitutes	Low	Threat of New Entrants	Med

Table 4: Titanium Summary

China, Japan, and Russia currently make up about 80% of the world supply of mined titanium.[37] The U.S. is not totally dependent on foreign raw material as the U.S. mines a significant amount of titanium in both Virginia and Florida. The domestic capacity fails to keep up with demand, though, hence the U.S. imports a significant amount from other counties such as Japan, Russia, Kazakhstan, and Ukraine.[38]

The high-grade titanium market is very much a pull market based on end uses. Boeing and Airbus make up over 60% of the market today, and their percentage of market demand is expected to grow moving forward.[39] "Current and forecast supply is more than adequate to meet demand as there is some unused capacity overhanging the market."[40] With the increased demand in aerospace over the next 20 years, it appears that the market is right-sized from a capacity standpoint.

The threat of new entrants in titanium is low. The most likely new entrants would be in China. However, China has sufficient demand to consume the increased production, and the increased Chinese output would likely be in commercial grade titanium as opposed to an aerospace grade product.

Beryllium

	Beryllium (Be) Summary			
Properties	Corrosion resistant,			
Market Uses	Nuclear industry, aerospace industry, space industry, electronics[41]			
Five Forces Summary	Market Structure	Monopoly		
	Power of Suppliers	High	Power of Buyers	Low
	Threat of Substitutes	Low	Threat of New Entrants	Low

Table 5: Beryllium Summary

The United States is the world's largest producer of beryllium, and the only other countries that produce beryllium in any significant amounts are China and Mozambique.[42] In 2000, the only beryllium producer in the United States, Materion, closed their plant in Ohio due to equipment obsolescence and environmental concerns.[43] Materion simply did not generate enough revenue from sales to meet the capital investment cost, and the plant could no longer be safely operated. The Department of Defense awarded Materion a $73.26 million grant under the Defense Production Act (DPA), Title III to construct a new beryllium "Pebble" plant and return the production capability to the United States for critical defense applications.[44] Materion provided approximately $26.4M of its own funds towards the construction of the plant. Materion's 10K report clearly shows that the finances required for a full capital investment was clearly impossible as the highest return in the last four years was $46M in profit with a 2013 low of $19M. [45] Of this profit, only 5% was generated from beryllium sales.[46]

Rare Earth Elements (REEs)

	Rare Earth Elements (REE) Summary			
Properties				
Market Uses	Magnets, catalysts, alloys, clean energy technologies, batteries			
Five Forces Summary	Market Structure	Oligopoly		
	Power of Suppliers	ed	Power of Buyers	M ed
	Threat of Substitutes	ed	Threat of New Entrants	L ow

Table 6: Rare Earth Element Summary

Rare Earth Elements (REEs) are composed of the "lanthanides" (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium) and yttrium and scandium due to their common properties (though some sources exclude scandium).[47] The Department of Defense employs REEs in precision-guided munitions, lasers, and mine detection among many other uses.[48] The market model is not significantly different from any number of mineral and ore markets, but what makes it different than most is that the majority of the mining and refining capability for REEs resides in China (China supplied approximately 95% of all REEs in 2011).[49] This is in spite of the fact that China only has an estimated 50% of the world's reserves of REEs.[50] Chinese state-owned companies (e.g., Inner Mongolia Baotou Steel Rare-Earth Group Hi-Tech Co.) produce most REEs,[51] but price spikes have encouraged new entrants to explore the market (though high capital costs, particularly for beneficiation have slowed this effort), consumers to seek substitutes and some Asian and European companies have stockpiled REEs, as well.

The number one 'rule' that regulates the REE market on an international basis and has the biggest positive impact on global supplies, is the March 2014 World Trade Organization's (WTO) ruling that Chinese export restrictions on rare earths violate global trade rules by imposing export restrictions in the form of licensing, duties, pricing, and quotas. China's Ministry of Commerce has indicated that China is willing to abide by this WTO decision and the rulings appear to have had a stabilizing effect on the global REE market.[52] That being said, lower prices have made it difficult for new entrants to break into the market and remain viable.

A valid economics-based analysis of the REE mining sector is not practical due to Chinese dominance of the market and its associated misreporting of true REE supply. Financial data available for Chinese companies is suspicious. A valid economics-based analysis of the REE mining sector is not practical due to Chinese dominance of the market, and its associated misreporting of true REE supply. Financial data available for Chinese companies are suspicious. For example, as emphasized by author Tom Orlik in a 2013 article in Foreign Policy magazine titled: "Lies, Damned Lies, and Chinese Statistics – Who's Cooking Beijing's Books," Chinese economic figures and statements are "man-made" and considered unreliable.[53]

INDUSTRY OUTLOOK

Based upon research and interviews with industry experts, several significant industry trends were identified. First, the industry is driven by the broader economy; thus, future performance is directly related to the broader economy's performance. Next, in the search for additional profits, industry firms are pursuing a number of strategies like supply chain integration, consolidation, globalization, and productivity/efficiency gains. These trends are expected to continue and shape the future outlook for the industry.

Broader Economy

The best indicator of the Strategic Materials industry performance over the next five to ten years is the performance of the broader economy. As the economy expands, the fortunes of the industry follow. For example, during the 2000s, the industry experienced large growth rates as demand growth was extremely high, in large part due to strong growth in China. Large growth rates peaked in 2009 with the global recession, where some industry sectors saw revenue fall almost 35 percent. In 2010 and 2011 the global economy had an initial recovery, and the industry correspondingly rebounded.[54] Looking ahead there are both positive and negative signs for the global economy. On one hand, there's evidence the U.S. economy's expansion is taking hold.[55] On the other hand, the rest of the world's major economies appear headed for a slowdown.[56] Before making an overall assessment of industry growth the next five to ten years, the paper will explore whether its customer base is projected to grow.

Three primary customers of the industry are the steel industry (NAICS Code 33111), the aircraft industry (NAICS Code 33641A), and the oil and gas machinery industry (NAICS code 33313). The expected performance of these industries over the next five to ten years is a good indicator to how the Strategic Materials industry will perform. The steel industry has contracted over the past two years after rebounding from the 2009 recession. Specifically, in 2012 the demand for steel was basically unchanged from 2011, and in 2013 the demand dropped by 11 percent.[57] Demand is forecast to rebound as 2014 closes out with an increase of approximately 10 percent compared to 2013. *IBISWorld* estimates that demand will increase over the next five years at an annual rate of 3 percent, which is slow yet steady growth.[58] That level of growth does not translate into significant growth for the industry over the next five years.

The aircraft market has been booming since shortly after the 2009 Great Recession. The DoD portion of the market has shrunk since 2012, but the commercial market grew rapidly enough to compensate for the slowdown in defense spending.[59] Most signs indicate the aerospace industry will continue to grow over the next five years. Boeing currently has a backlog of 5,500 aircraft valued at $430 million.[60] Similarly, Airbus reported in November its backlog stands at just over 6,000 aircraft.[61] *IBISWorld* projects the aerospace industry will grow at an annual rate approaching 4% over the next five years.[62] The aerospace industry also relates to one of the industry's complements: aircraft engines. As the sale of aircraft grows, it also drives engine sales, and the industry provides several metals for these high performance engines.[63] The aerospace industry appears to be a bright spot that should drive growth in the Strategic Materials industry.

The oil and gas industry represents another sector customer that is forecast to grow steadily over the next five years. The past five years the oil and gas production index has increased 5.15 percent on average annually.[64] That growth is forecast to slow over the next five years but will still average almost 3 percent annually.[65] In summary, the oil and gas industry, like the steel industry, will have slight, yet steady growth over the next five years. That should benefit the strategic materials industry, albeit at a modest level.

Overall, it is difficult to accurately predict and aggregate the financial effects hitting this industry over the next five to ten years. The growing strength of the U.S. economy should help the industry grow. The preceding summary of customer growth projects relatively weak growth over the next five years. Against that backdrop, it is no wonder industry growth projections range from less than three to four percent over the next five years.[66]

Supply Chain Integration & Potential Consolidation

Given the market structure and environment, the firms within industry have developed strategies to position themselves for the future. Across the board, firms are positioned at the far left of the supply chain (i.e., delivery of basic materials). Integration backward is not a viable option as their suppliers operate in radically different industries (e.g., water, energy, mining equipment manufacturing). Forward integration offers an option that several companies have pursued. In attempting to forward integrate, firms are further refining and processing their materials to deliver items closer to end products. By doing so, these firms are pursuing value-added processes that may differentiate them from their competitors. For example, beryllium producer Materion has forward integrated into component manufacturing, which it is able to sell for higher prices than just beryllium metals.[67] Through forward integration, firms have attempted to control more of the supply chain thus differentiating their products and competing less on price.

Additionally, the large number of suppliers in the industry and the industry's projected modest growth over the next five years portends a potential period of consolidation and intense rivalry. Through our conversations with industry experts, companies will likely use mergers and acquisitions as a means to acquire new technologies, reduce overhead, and/or rebalance asset portfolios, and thus create a more financially prosperous industry. As firms are unable or struggle to recover from the 2009 recession, larger firms may acquire these lesser firms in hopes of increasing market share. At the same time, due to high barriers to entry, there is expected to minimal new entrants to the industry. IBISWorld projects a 2.1% decrease in the number of firms operating within the industry.[68]

Globalization

Another trend expected to continue is firms' pursuit of overseas operations with lower cost structures (e.g., lower regulation, wages, transportation costs) and potentially higher ore grades. This trend of moving mining operations overseas has been taking place for the past 50 years. The U.S. percentage of world mining hit a peak in the 1940s (approximately 39%) and has subsequently declined. Today, U.S. mining makes up less than 10% of world mining production. Foreign mining has greatly increased in that time period.[69] This trend is expected to continue as economic, easily accessible resources in the U.S., and Europe continue to decline, technology advances increase access to remote areas of the globe, and transportation costs remain low.[70]

Geographically, the trend toward globalization of the industry is expected to continue. For future growth potential, mining exploration budgets are a good indicator. According to SNL, a metals and mining research company, outlays for mining exploration have dropped considerably from $15.19B in 2013 to $11.36B in 2014—a 25% decrease. This is primarily due to firms still recovering from the 2009 recession. Firms are cutting back exploration budgets from growth-oriented spending of the 2000s and concentrating more on profit margins (i.e., cost cutting). In 2014, firms continued to pursue worldwide exploration in 124 countries. The leading exploration countries are Canada, Australia, United States, Mexico, and Chile. In 2011, the International Council on Mining & Metals (ICMM) predicted that Latin America, Africa, and Asia were the most likely future growth areas.[71] However, as indicated by SNL, these regions have seen larger than average reductions in exploration budgets. The impact of political and security stability is readily evident. For example, Argentina and Columbia had 46% and 42% decreases due political instability, and West Africa saw a decrease of 38% due to security concerns and the Ebola crisis.[72]

Increased Productivity & Efficiency

Across our discussions with industry experts, two major trends driving the industry are decreasing ore grades and increasing costs. Deloitte in their 2014 assessment, "*Mining Spotlight on: Sliding Productivity and Spiraling Costs,"* noted that between 2001 and 2012 the average quality of nickel ore dropped an unprecedented 40% and copper by almost 30%. Additionally, Deloitte reported that production costs continue to grow due to expenses associated with ports, roads, railways, water, electricity, labor, taxes, royalties, permitting fees and environmental compliance. This assessment further noted that in many areas, mining in the 21st century must increasingly absorb the rapidly escalating costs associated with local mandates for development of indigenous capabilities, stakeholder relations, reconstruction tolls and other consequences of rising resource nationalism.[73]

As a result of decreasing ore grades and increasing costs, industry faces significant pressure to increase the productivity and efficiency of its operations. The industry, with assistance from mining technology firms and academia, is pursuing technological advancements both in extraction and beneficiation that positively impact productivity and efficiency. These advancements have turned previously sub-economic deposits into economic ones. As a result, the industry is extending the life of older mines and pursuing deposits in more remote regions and at greater depths utilizing larger operations that can take advantage of economies of scale.[74]

ROLE OF GOVERNMENT IN STRATEGIC MATERIALS

The role of Government covers a multitude of activities. The role ranges from local, state and federal permitting to acts intended to ensure environmental compliance. Within the Department of Defense, there is a national stockpile created as a “hedge” for reconstitution of depleted minerals. The Berry Amendment stipulates what minerals or mineral products must be procured domestically and the Defense Production Act Title III funding is intended to insure the Department of Defense has the materials required for the defense of our nation. Finally, the Dodd-Frank Act lends transparency to mining operations.

Permitting and Environmental Regulation

The 1872 Mining Law is the primary regulation governing the operation of mines in the United States. It established the legal and financial framework that makes public land available for mining. The 1872 Mining Law has been updated over the past 140 years, but its core elements remain intact.[75] Environmental regulations associated with the mining industry and the broader Strategic Materials industry arose during the 1960s and 1970s. During that timeframe, federal and state governments implemented an environmental regime aimed at protecting the nation’s land, air, and water. The regulations broadened and became stricter over the past 40 years as policymakers learned more about environmental threats and as technology to mitigate environmental damage matured.[76]

The National Environmental Policy Act, the Clean Water Act, and the Clean Air Act are three commonly cited regulations impacting the Strategic Materials industry. The National Environmental Policy Act, or NEPA, was passed in 1969. It requires federal agencies consider environmental impacts of proposed development efforts and stipulates the information must be made available to the public for their input.[77] The Clean Water Act was passed to "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[78] Various aspects of mining potentially impact nearby surface water and groundwater sources including discharge from open pits and tailing ponds.[79] The final, significant regulation impacting the industry is the Clean Air Act. It was first legislated in 1955 to regulate air quality standards and was significantly broadened in 1970.[80] Today the law regulates emission limits on 187 dangerous effluents, and it’s most applicable to the processing and refining sectors of the Strategic Materials industry.[81] The Act includes language targeted at metal smelters.[82]

An industry trade group, Behre Dolbear, evaluated the global mining sector using seven criteria that examined a nation’s business climate. Its 2014 report noted that while the United States is blessed with minerals, a stable government, and generally favorable economic system, two specific areas deter investment. First, the nation does not support mining and metal processing due to social issues including environmental concerns. Second, the U.S. ranked almost last among 25 surveyed countries for permitting timelines. Environmental Impact Statement timelines are a big source of the industry’s permitting delays.[83] Behre Dolbear notes that it takes 7-10 years on average to successfully permit a new mine in the U.S.[84] That time delay leads to significant uncertainty and risk for companies thinking of investing in this industry.

The National Defense Strategic Stockpile

The stockpile was established as a hedge prior to World War II (WWII) to ensure the nation had sufficient supplies and materials for military operations throughout the world. National policy experts widely agree that it was the industrial might and access to raw materials (critical and strategic) that allowed the country to defeat the Axis powers during WWII.[85] Accordingly, the stockpile endures still today, although its requirements have changed to factor in civilian and industrial economy needs prior to, during and post conflict.

The Secretary of Defense is currently designated as the National Defense Stockpile Manager, and the Defense Logistics Agency (DLA) administers the stockpile on a day-to-day basis.[86] DLA is required by the Strategic and Critical Materials Stock Piling Act to provide a bi-annual assessment to Congress on the status of materials designated as strategic and critical.[87] The risk analysis provided in the report is based on a congressionally-mandated Defense Planning Scenario, known as the Base Case, to ultimately assess the health of the stockpile. The general requirements of the Base Case are included as part of Appendix D.

Title III Defense Protection Act (DPA) Funding:

The Defense Production Act (DPA) Title III was established in 1950 at the beginning of the Korean War in order to secure military production of needed equipment and supplies. The DPA Title III is intended to "create assured, affordable, and commercially viable production capabilities and capacities for items essential for national defense."[88] There are substantial direct and indirect, economic and technological benefits to the company and the Department of Defense to use DPA Title III funding.[89] The DPA Title III program is currently funding 26 projects totaling over $133 million dollars annually.[90] The 2010 venture with the Materion Corporation to produce a domestic supply of high quality Beryllium (previously discussed in Chapter 3 of this paper) is a successful example of DPA Title III.

Dodd-Frank Act:

The Dodd-Frank Act was signed into law on July 21, 2010 and enforces mining company reporting requirements through the Securities and Exchange Commission (SEC). The Dodd-Frank Act lends transparency to mining transactions and in particular brings awareness to any transactions that may involve conflict minerals.[91] Among other requirements, the Dodd-Frank Act imposes disclosure requirements on issuers that:

(1) are involved in resource extraction and/or purification, including mining, oil and gas exploration and oil refining;
(2) make use of "conflict minerals;"
(3) operate mines located within the U.S.[92]

Berry Amendment:

Items listed in the Berry Amendment (the list of items is periodically reviewed and changed), must be purchased 100% domestically. Section 2533b "prohibits the acquisition of a specialty metal that is not melted or produced in the United States and that is to be purchased directly by the Department of Defense or a prime contractor of the department, or end items, or components thereof, containing a specialty metal not melted or produced in the United States, including aircraft, missile and space systems, ships, tank and automotive items, weapon systems, or ammunition."[93]

MAJOR ISSUES

The report now turns to actionable policy recommendations that are focused on improving the health of the Strategic Materials industry and to mitigate current material risk to the domestic economy and national security. The recommendations follow a consistent format. A 'background' description frames each specific issue. A 'discussion' section talks through the key points, considerations, and interests for each issue, and then the 'recommendation' section offers one or more recommended policy fixes and a top-level implementation strategy.

Growing Dependence on Strategic Materials Imports

Background: The USGS reported in its most recent survey of mineral commodities that the nation is now 50 percent dependent on imports for the 40 key minerals. Of these 40, the U.S. is 100 percent dependent on imports for 19 of these minerals. By comparison, in 1978 USGS reported on the same 40 minerals, and at that time U.S. was 50 percent dependent on only 25 of the minerals and 100 percent dependent on imports for only seven.[94] Appendix E includes a visual summary of mineral production that is largely concentrated in foreign countries.

Discussion: Three examples of material supply disruption over the past ten years show how foreign dependence adds risk to the U.S. economy and national security. The most frequently referenced event occurred in late 2010, when the Chinese government stopped the shipment of all REEs to Japan after that nation detained a Chinese fishing boat captain operating in the vicinity of the disputed Senkaku Islands. The resulting REE shortage almost crippled Japan's magnet manufacturing industry.[95] In a separate example, the U.S. experienced a minor disruption of DoD repair parts during the invasion of Iraq in 2003. Switzerland's Swatch Group AG refused to ship components containing REEs and gallium required for precision air to surface munition guidance systems in protest of U.S. actions in Iraq.[96] DoD successfully procured an alternate supplier to manufacture the parts for a significantly increased cost following a brief delay.[97] Political crises can also disrupt supplies. In 2005 and 2006, the United States experienced a supply disruption in rhenium, triggered by a domestic dispute in Kazakhstan. Exports from Kazakhstan, which supplied 25 percent of the U.S. demand at that time, "were halted from the third quarter of 2005 until the fourth quarter of 2006."[98] "By early 2006 rhenium prices were rising precipitously just as demand was increasing for use in petroleum refining and, important for DoD, in jet engine production."[99]

Ultimately, if the United States wants to compete with China and other nations in the extraction, beneficiation and refining industry, it should look for solutions at home. China's main strength in several mineral industries (REEs, Tungsten, Tantalum) is not its domestic reserves, but its regulations that encourage development of those markets, particularly at the refining or beneficiation level. Hence, beneficiation is likely the best way for the U.S. to profit from strategic minerals, create jobs and provide a competitive advantage in any mineral market.[100]

Recommendation: *Federal and local governments should partner with industry to invest in beneficiation facilities near inexpensive electricity, abundant water and within close proximity of urban areas to pull appropriately skilled personnel.[101] The Tennessee River Valley near Oak Ridge National Laboratory would be an example of a location that might fit this bill. Congress should start implementing this recommendation by amending The American Minerals Security Act of 2015 to direct to the Department of Commerce, Department of Interior and Environmental Protection Agency to investigate potential sites for a federal "industrial beneficiation park". Once a site is identified, an overarching Environmental Impact Statement for the site and permitting should be pre-approved for beneficiation and smelting activities. Companies could then apply to* *construct beneficiation or refining facilities at the site for a fee to cover administrative costs of the federal government.*

Risk of Rare Earth Element Dependence in Defense Acquisitions

Background: The Department of Defense uses a relatively small portion (5%) of REE compared to the overall domestic consumption,[102] resulting in significant competition in meeting their demand in the REE market. DoD is at risk of supply disruptions because China controls such a large percentage of the rare earth element market. Dysprosium, a rare earth mineral used as an additive in neodymium-iron-boron magnets, is particularly concerning due to its use in precision-guided weapons. The material is also used in larger quantities in the automotive industry and clean energy technologies. The emerging emphasis on green technologies such as electric motors and turbines has resulted in concern about long-term dysprosium supply.[103]

Discussion: Two problems hinder DoD's ability to mitigate the use of REE in its weapons systems. First, its mitigation program has lacked proper focus. DoD's plan to address the risk of rare earth shortages is a three-pronged approach: diversification, substitutes, and recycling. However, DoD's 2014 report to Congress on the subject makes it clear that DoD is dependent upon the market and industry to do the heavy lifting, leveraging research performed by institutions like the DoE's Critical Materials Institute (CMI).[104] However, CMI is focused on technologies associated with clean energy which do not necessarily correlate to defense requirements. The F-35 Joint Strike Fighter provides an illustrative example of how REE supply constraints could impact DoD. Each F-35 contains 920 pounds of rare earth minerals and DoD currently plans to procure over 2,400 fighter aircraft.[105]

The second problem with DoD REE mitigation plans is the rigidity of military weapon system designs. The 2014 National Defense Authorization Act directed the Navy, in coordination with the Program Executive Office for the F-35, to submit a report on the potential for REE substitutes.[106] Congress directed the report because it foresaw sustainment costs increases due to unplanned qualification costs associated with introducing REE substitutes.[107] Similarly, although there is technology that eliminates or reduces REEs in the Joint Direct Attack Munition,[108] the weapon remains unchanged due to the long and arduous process required for DoD technology insertion. Once a weapon system design is established, the U.S. military is stuck with legacy hardware and sometimes-costly processes due to the onerous and ever growing acquisition regulations.

Recommendations:

1: The Under Secretary of Defense for Acquisition, Technology, and Logistics should develop a material substitution plan to ensure it's able to meet material needs of current and future weapon system designs. The REE portion of that plan should be coordinated and aligned with the DoE rare earth plan to take advantage of the higher REE demand associated with domestic clean energy investment.

2: DoD should further examine acquisition policy and process revisions that allow for timely material substitutions in weapon systems. The Under Secretary of Defense for Acquisition, Technology and Logistics should update the Better Buying Power initiative to include an initiative to reduce the substitution cycle times. This recommendation aligns with the current initiative to eliminate unproductive processes and bureaucracy, but broadens the initiative to include cycle time reductions from substitutions within the product life cycle. [109]

Strategic Materials Responsibilities Fractured within U.S. Government

Background: At least nine different government agencies[110] manage aspects of the Strategic Materials industry. Each one has its own unique agenda and purpose. As previously noted, Congress initially started a strategic materials management plan under the National Defense Stockpile program shortly before World War II.[111] Today, Congress, DoD, and parts of the Department of the Interior (USGS) play some role in the management of the National Strategic Stockpile.[112] Beyond the stockpile, other elements of government have jurisdiction over this industry. The Department of Interior (DoI - Bureau of Land Management)[113] and Department of Agriculture (Forest Service) are responsible for overseeing mining permits. The Department of Energy conducts Strategic Materials research and development to help the nation transition to clean energy.[114] Finally, USGS within the DoI has responsibility for conducting geologic research. It collects geologic and scientific information about the earth to include the location of natural resource deposits and the supply and demand of strategic materials.[115] Besides these primary agencies, the following group of secondary industries also share some role in managing this industry: the Environmental Protection Agency (EPA), the Department of Commerce, and the Department of State (DoS).[116]

Discussion: Distribution of responsibility for this industry throughout the government leads to uncoordinated and misaligned policy. Take mine permitting, for example. The Bureau of Land Management and Forest Service have different permitting and approval processes.[117] Look back at the difficulty in defining the Strategic Materials industry. Department of Defense and Department of Energy use different definitions and as a result they have different views of the industry. Finally, given the fractured government responsibility there's no single advocate for the industry. DoD advocates in the interest of national security; DoE advocates in the interest of clean energy; and DoI advocates in the interest of land ownership. Yet there's no single agency that looks at the industry as a whole.

Recommendation*: The Department of Commerce should be chartered to conduct a study on how government functions should be consolidated or realigned to manage this industry end-to-end. The study should consider and include the activities of DoI, DoE, DoD, and USDA to ensure that coherent policy and investment decisions are made to improve the health of the industry. The American Mineral Security Act of 2015 should be amended to include this study recommendation.*[118]

Human Capital: Strategic Materials Workforce Health

Background: "What is it that keeps you up at night?" we asked the CEO of a major metals processing company. The answer surprised us—his future workforce—not enough people graduating with the degrees in material science or metallurgy, and not enough technicians (welders, machinists, equipment operators) qualified or interested in working in the metals industry. This story was much the same through the industry,[119] both in the U.S. and in Chile.

The causes of this gap are partly explained by the impression of the industry as dirty and dangerous, a situation the National Mining Association is working hard to counter.[120] However, quantifying the emerging workforce gap has proven elusive. The National Research Council issued a very thorough review of workplace issues regarding mining and energy, projecting industry growth, but no particular gaps.[121] The main professional society for mining reports a 50% drop in accredited degrees in mining and mineral engineering,[122] yet the number of graduates has rebounded, as it is in metallurgy and material science.[123] The consensus view is that they will not fill the gap caused by 20 years of lack of hiring, though no one can quantify it.[124] Indeed, an expert panel concluded vaguely "U.S. mining finds itself with a predominantly senior workforce and an expanding need for labor to meet the increasing resource demand."[125,]

To fill this gap, industry leaders have well-funded foundations to "develop, improve or expand innovative instructional programs in science, technology, engineering and math (STEM)."[126] One company spends roughly $2 million per year in STEM outreach to kindergarteners to twelfth graders ("K-12"), including science fairs, teacher training, games, and kits for schools.[127] For smaller companies, the STEM outreach was more limited—educational materials on websites,[128] sponsorship of internships, and participation of individual employees in student outreach events. To increase the impact, smaller companies also leverage the STEM programs run through the Metals-related professional societies, though these overwhelmingly assist undergraduates already in these fields with scholarships and internships.

Meanwhile, Chile has formed a Mining Skills Council. Armed with much better data on the industry needs, this nascent group intends to "address the skills gap companies face in the Chilean mining industry by assessing skills shortages in the sector, defining profiles and career paths, and providing guidance to training institutions and potential workers."[129]

Discussion: The effectiveness of STEM outreach by companies and professional societies has proven very difficult to measure. This leads to problems when the federal government attempts to step in to replicate, coordinate, and leverage programs like those mentioned above. In the DoD, leadership in STEM is provided by an office in the Office of the Secretary of Defense (OSD) under the Deputy Assistant Secretary of Defense (DASD) for Research, who primarily look for best practices in the Services and Agencies.[130] Their tools are the same as industry's: K-12 outreach events, teacher training, and direct support scholarships (which only number in the hundreds across STEM disciplines). The K-12 outreach effectiveness has proven hard to measure without long-term tracking of kids to see how many who participated ended up at scientists and engineers. Programs up at the U.S. Government level increase the scope of the effort, bringing in other resources to tackle the problem, but with even vaguer impacts and recognition of much duplication of effort.[131] Given that federal money always require oversight and measurable impact, increasing this money always comes with a significant overhead cost

Recommendations:

1. The Mining industry and the professional societies to aggressively feed mining-related inputs into state and local STEM teacher training programs.

2. Mining professional societies and advocacy groups should quantify their specific need for Metals-related workers, and then look to the Chilean Mining Skills Council as an example for partnership with academia.

Environmental Challenges, Permitting and Mining R&D Investment

Background: Permitting for Strategic Materials industry projects has increased dramatically due to tighter environmental regulation. For example, in 2013 the National Association of Environmental Professionals reported that 197 Environmental Impact Statements were completed across all agencies of the federal government. On average the assessments took 1,675 days or 4.6 years to complete.[132] Unfortunately, the time delay in getting environmental impact statements approved has steadily increased since 1970. Data from 2000 to 2012 shows the timeline increased on average 35 days per year over that span.[133] That obviously adds considerable financial risk to any firm looking to initiate a new mining or processing capability.

Behre Dolbear evaluated the global mining sector of the industry using seven criteria that examined a nation's business climate. Its 2014 report noted that while the United States is blessed with minerals, a stable government, and generally favorable economic system, two specific areas deter investment. First, the nation does not support mining and metal processing due to social issues including environmental concerns. Second, the U.S. ranked almost last among 25 surveyed countries for permitting timelines and Environmental Impact Statement timelines are a big source of the industry's permitting delays.[134] Behre Dolbear notes that it takes 7-10 years on average to successfully permit a new mine in the U.S.[135]

Discussion: The cost and uncertainty associated with environmental regulations have negatively affected the domestic Strategic Materials industry over the past 30 years. Firms have gone out of business or moved overseas because they cannot afford to operate in market conditions created by the current environmental regime. The next logical question is how has the U.S. responded? Is the industry investing in more environmentally conscious technology and processes? Is the government doing research to help reduce the expense of environmentally safe mining and processing?

The government has done very little to invest in more environmentally conscious technologies to support the industry. The DoI is charged with managing mineral extraction on public lands, but it has not been an advocate for increased "green" mineral mining. The DoI's most recent Strategic Plan and its fiscal year 2015 budget request affirm the lack of research and development associated with environmentally friendly mining techniques.[136] The agency's budget request includes $140 million, which is primarily earmarked for land reclamation and clean energy initiatives.[137] The DoE spends the bulk of its research and development funding toward reducing dependence on specialized metals, in effect looking to reduce market demand for the mining and processing sectors of the industry. It highlights the fact the agency made "significant investments" in finding substitutes for critical materials.[138] For example, DoE spent $38.2 million on programs to find substitutes for rare earth elements in magnets and other applications.[139] The EPA spends some money on the Strategic Materials industry, but it's focused primarily on reclamation projects.[140] The DoD is the final federal agency with significant investment in the Strategic Materials industry. Through the previously mentioned DPA Title III program, DoD has invested in Strategic Materials firms, but not with the intent of driving innovation in environmentally responsible technology. The composite picture shows the government has not invested in the industry to help it operate in a sustainable manner.

Tracking industry investment in green mining and metal processing is difficult. Companies are always investing because environmental regulations are constantly changing, and companies must make capital investments to remain financially viable. Molycorp's Mountain Pass rare-earth element mine is a useful exemplar. Molycorp invested $1.55 billion on green-mining capabilities that enabled it to re-open Mountain Pass and mine rare earth elements. The green-mining investment dramatically cut water consumption, electricity costs, and virtually eliminated its environmental footprint.[141] However, the exorbitant capital expenditure coupled with low rare earth prices is now dragging the company toward bankruptcy.[142] The U.S. may be on the verge of, again, losing its only rare earth element source.

Recommendations: *This paper does not recommend lessening or removing environmental regulations. That's unrealistic, undesirable, and contrary to the environmental leadership position the United States has taken in the world.*

1: U.S. policymakers should implement a 30-month permit timeline for mining on federal land. Congress should pass The National Strategic and Critical Minerals Production Act to fix the timelines or amend the American Mineral Security Act of 2015 to include the 30-month timeline.

2: The U.S. should establish a research and development fund for environmentally sustainable mining and metal processing. The intent of the fund is to help mature the technologies so that *private firms do not bear the full burden of developing technology to comply with new environmental regulations. The fund does not necessarily require new revenue. Existing DoE and DoI funding could be redirected toward this effort. Finally, the investment in sustainable mining could take the form of direct investment, public-private partnerships, tax incentives, university grants, and other mechanisms.*

CONCLUSION

A healthy Strategic Materials industry benefits most other areas of the domestic economy and solidifies the defense industrial base. Unfortunately, over the past 30 years parts of the U.S. industry atrophied to the point the nation's economy and national security are at risk. For example, the U.S. is heavily dependent on China for rare-earth elements, tungsten, and tantalum. The dependence potentially jeopardizes the health of the U.S. economy, constrains U.S. geo-political activity, and increases the likelihood that materials will strain the nation's relations with other countries around the world.

This report showed some of the difficulties with analyzing this industry and developing effective policy to manage it. Each mineral or metal in the industry really operates as its own market. Narrowing even further, some sectors (e.g. extraction) of a mineral market may be healthy, whereas other sectors may be unhealthy. Thus, it's difficult to offer a composite assessment. However, 30 years of mineral dependence data does illustrate the domestic industry has atrophied.

The report offered three broad areas of recommendations that improve the health of the domestic industry to meet the nation's economic needs and preserve its national security. In the area of government oversight, the report offered recommendations to study better alignment of Executive Branch responsibilities for this industry, and a recommendation to improve DoD planning for material shortages. The report offers several recommendations associated with incentivizing Strategic Materials industrial parks, streamlining mining permits, and increasing the government's sustainable mining and metal processing research and development to reduce industry entry barriers. Finally, the report offers a two recommendations to improve Strategic Materials human capital to help ensure the nation maintains adequate skills for this industry.

APPENDIX

APPENDIX A
Acronyms and Abbreviations

CEO - Chief Executive Officer
DASD - Deputy Assistant Secretary of Defense
DIB - Defense Industrial Base
DLA - Defense Logistics Agency
DoD - Department of Defense
DoC - Department of Commerce
DoE - Department of Energy
DoS - Department of State
EPA - Environmental Protection Agency
HHI - Herfindahl-Hirschman Index
H.R. - House Resolution
NAICS - North American Industry Classification System
FARC - Revolutionary Armed Forces of Columbia
GAO - Government Accountability Office
ICMM - International Council on Mining & Metals
IDA - Institute of Defense Analysis
IP - Intellectual Property
NDS - National Defense Stockpile
OSD - Office of the Secretary of Defense
REE - Rare Earth Elements
REO - Rare Earth Oxides
SMPB - Strategic Materials Protection Board
STEM - Science, Technology, Engineering and Math
STATMAT - Strategic Materials
U.S.C. - United States Code
USG - United States Government
USGS - United States Geological Society
WTO - World Trade Organization

APPENDIX B

ORGANIZATIONS THAT PROVIDED REPRESENTATIVES TO BRIEF THE STRATEGIC MATERIALS INDUSTRY STUDY SEMINAR AY 2014-15

Congressional Research Service
Defense Logistics Agency Strategic Materials (National Defense Stockpile)
Department of Commerce
Environmental Protection Agency
J.A. Green and Company
National Intelligence University
National Mining Association
Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
Office of the Assistant Secretary of Defense for Research and Engineering
RAND Corporation
Resource Capital Funds
U.S. Army War College, Strategic Studies Institute
U.S. Geological Survey Mineral Resources Program
U.S. Geological Survey National Minerals Information Center

APPENDIX C
Michael Porter's Five Forces Model[143]

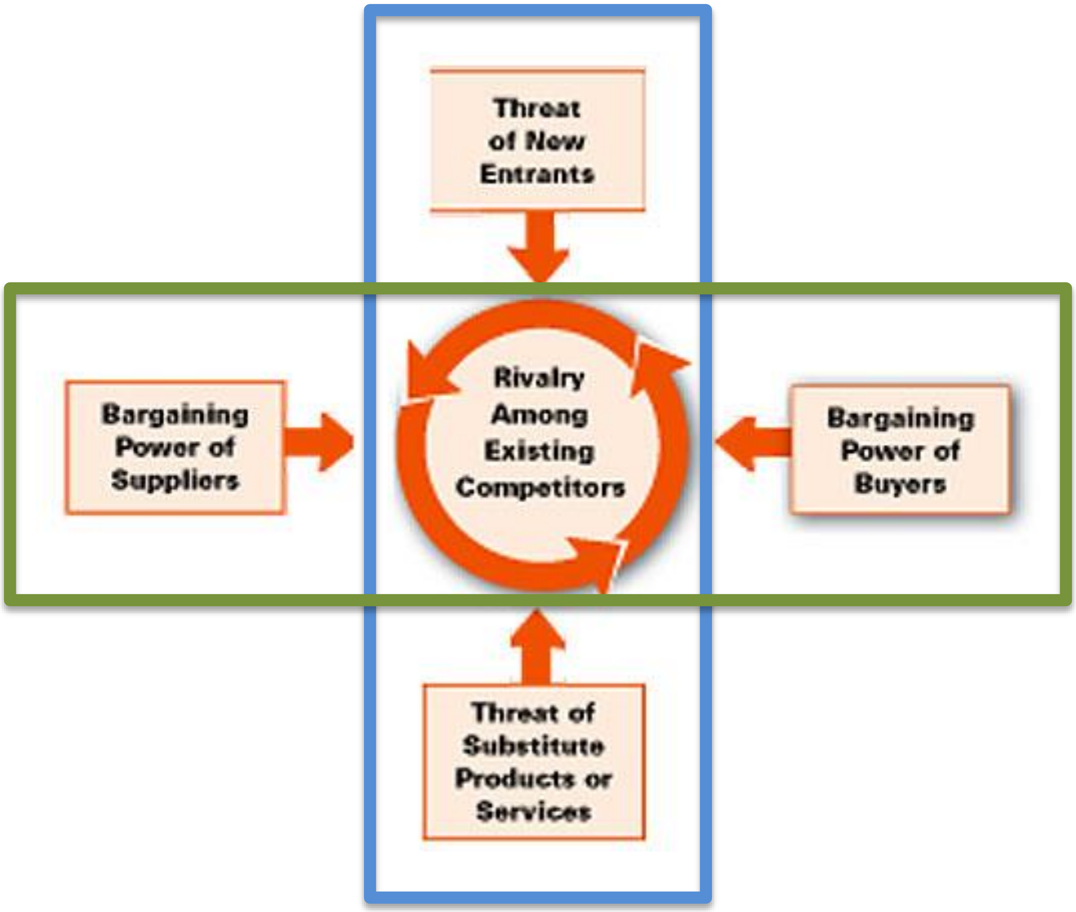


Figure source: Michael E. Porter, "The Five Forces that Shape Strategy," *Harvard Business Review;* Jan 2008, Vol. 86 Issue 1, p78-93

Michael Porter's Five Forces model is used to analyze the structural components of industry. The model begins with an assessment of how firms in the industry interact based on the value that's created in the industry (rivalry among existing competitors). The vertical axis of the model assesses how the value of the industry is divided: between suppliers, principal firms, and buyers. The vertical axis assesses how external players in the industry try to capture some of the industry value. Some scholars advocate two forces that should be included in a Five Forces analysis. The first is "complementors" which captures how other industries may impact the value of an industry. The second is the role of government which acts to ensure the industry structure is properly balanced.

The study group used the Five Forces model to assess a representative group of mineral markets. These assessments are by nature qualitative and subjective, so each was assigned a rating of low, medium, or high. "Low" indicates a minimal likelihood and consequence of the that has on the market, such as few reasonable, cost-effective substitutes for beryllium. "High" indicates a substantial likelihood and consequence of impact on the competitors in the market, necessitating concerted awareness and planning by the market players, such as the reliance of tungsten on the supply chain. Finally, "medium" (or "med") indicates likelihood and/or consequence in between these limits, necessitating some planning and action for the competitors.

APPENDIX D
National Strategic Stockpile Base Case Overview[144]

The Base Case of the National Strategic Stockpile is a planning scenario used by Congress and the Department of Defense to determine what raw materials are necessary to reconstitute military capability and the civilian economy. Specific requirements of the Base Case include:

- U.S. will be engaged in a 4 year protracted war, 1 year of conflict and three years of recovery regeneration;
- Materials necessary to replenish or replace, within three years of the end of the conflict all munitions, combat support items, and weapon system that would be required after such military conflict;
- All other essential military demands are met;
- All essential industrial and civilian sectors demands are met;
- Utilize level of forces included in latest National Defense Strategy;
- Multiple contingencies occur during conflict year (catastrophic attack in the U.S., deterring two regional aggressors; deterring and defeating a highly capable aggressor; responding to several significant counter-insurgency activities).

The Base Case is required to make assumptions for the supply and demand portions of the market. The Supply-Side assumptions for the Base Case include.[19]

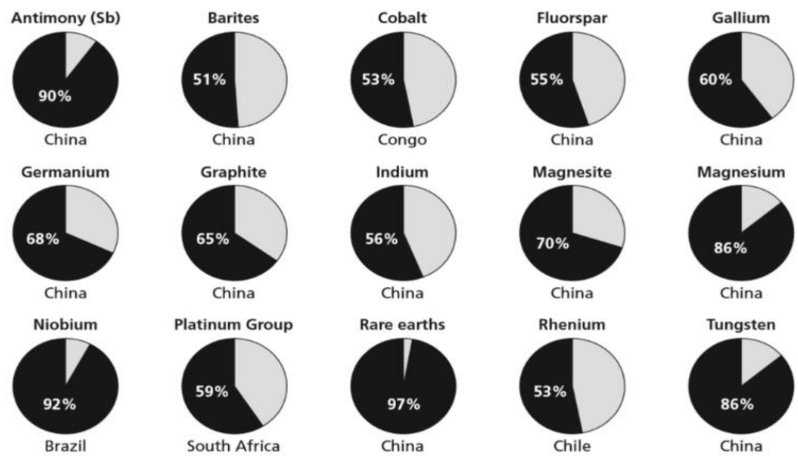
- U.S. material producers operating at full capacity within 6 months of mobilization, utilizing available material supply.
- Foreign material producers operating at full capacity within 6 months.
- Reprocessing capability (recycled material) will be utilized as secondary U.S. supply source.

The Demand-Side Assumptions for the Base Case include.[20]

- Essential goods and services are available to military, industrial, and civilian use.
- Economic growth will continue.
- Defense demands will continue to be apportioned within ongoing defense budget.
- Catastrophic attack will occur during the first year, recovery will replace assets will cost approx. 100 billion in government and private spending over a three year period.

APPENDIX E
RAND Summary of Mineral Production that is Highly Concentrated in Foreign States

Percentage of Global Production (Mining) of Key Materials Within a Single Country



SOURCE: U.S. Geological Survey, *Minerals Commodity Summaries*, Pittsburgh, Penn.: U.S. Government Printing Office, 2012; International Organizing Committee for the World Mining Congresses, *World Mining Data*, Vol. 26, 2011.

RAND *RR133-S.1*

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