AMERICAN RESOURCES POLICY NETWORK

AMERICAN RESOURCES POLICY NETWORK REPORT

THROUGH THE GATEWAY:

Gateway Metals and the Foundations of American Technology

DANIEL MCGROARTY & SANDRA WIRTZ
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AMERICAN RESOURCES POLICY NETWORK

The American Resources Policy Network serves as a hub for a collection of mining policy experts who offer commentary, analysis, and options for reducing our dependence on foreign mineral sources and improving exploration and development of American critical and strategic resources.

To this end, American Resources produces a quarterly report geared to policy makers, legislators, industry leaders and media providing detailed analysis and measurements of U.S. resource dependence. This report was created with the support of American Resources policy team members and subject-matter experts.

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Introduction

Dozens of metals and minerals used in high-tech applications have a special status in the natural resource world as by-products of base or industrial metals extraction. As economic analysts begin to recognize mining's deep connection to manufacturing, a failure to recognize the arcane realm of by-product metals is muddying much of the discussion. Put simply, access to many tech-metals is not through primary mining projects, but rather, through major metal mines that may or may not recover tech-metals as a by-product.

Many commentators have begun to understand the critical importance of the so-called "technology metals" which, according to American Resources expert Gareth Hatch's Tech Metal Research, are

> *"those generally-rare metals that are essential for the production of 'high tech' devices and engineered systems, such as:*
> - *The mass production of miniaturized electronics and associated devices;*
> - *Advanced weapons systems and platforms for national defense;*
> - *The generation of electricity using 'alternative' sources such as solar panels and wind turbines;*
> - *The storage of electricity using cells and batteries.* [1]"

As certain metals and minerals are not only critical to manufacturing in their own right, but as "gateway" elements that yield (or, in other words, "unlock") the tech metals increasingly critical to innovation and development, this ARPN quarterly report focuses on a group of five such "gateway metals:" [2]

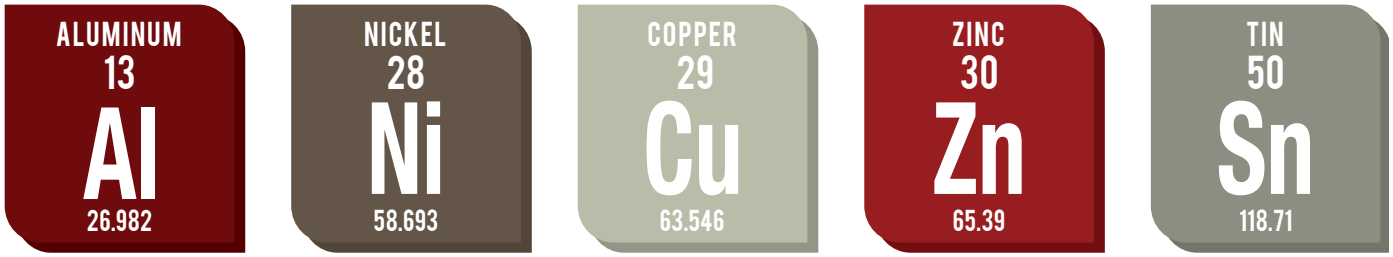
[1] http://www.techmetalsresearch.com/what-are-technology-metals/.

[2] In choosing our five "gateway metals," we consulted various studies and presentations, most notably the U.S. Geological Service's Mineral Commodity Summaries 2012, See also the report issued by C-Tempo, the think tank serving the Government of India's "Public Sector Undertakings," India's governent-controlled industrial entities:
http://www.c-tempo.org/studies/TECHNOLOGY%20METALS%20AND%20ENERGY%20CRITICAL%20ELEMENTS%20(ECEs).pdf;
http://www.insg.org/presents/Mr_Willis_Apr12.pdf

INSG, By-Product Metals of Nickel Production, Environmental and Economics Committee, Item 6, Lisbon, 27 September 2011, www.insg.org/presents/Mr_Stewart_Sep11.pdf

1.1 Gateway Metals hold the Key to Critical Tech Metals

In these pages, we will spotlight the tech metals each unlocks, and explore some of the associated economic implications and geopolitical challenges. [3]



THE KEY: GATEWAY METALS

Mainstay metals such as Aluminum, Copper, Nickel, Tin and Zinc are known to be industrial building blocks of the economy. Less widely recognized is the velocity at which technology is transforming the utility of by-product metals and minerals associated with mainstay metal mining. [4]

The following table provides a snapshot of the traditional uses of the gateway metals assessed in this report. It also lists the tech metals they unlock, and provides some contextual information on global and domestic resources, exploration and development – as well as the United States' degree of dependency on foreign sources of supply.

[3] The authors thank Dr. John Papp and his fellow experts at the United States Geological Survey, and American Resources expert and Tech Metal Research co-founder Gareth Hatch for valuable input.

[4] Precious metals are increasingly used in industrial and tech-intensive applications; mainstays like steel and aluminum are present in state-of-the-art tech applications; specialty metals used today in niche applications could well become foundation elements in industrial and information applications that will drive the 21st Century economy.

1.1 Gateway Metals hold the Key to Critical Tech Metals

COPPER
29
Cu
63.546

MAIN TRADITIONAL USES:

Refined copper and direct-melt scrap used in brass and rod mills, foundries, chemical plants; copper and copper alloy products primarily used in building construction, electric and electronic products, transportation equipment, consumer and general products, industrial machinery and equipment.

Unlocks the following Tech Metals	Molybdenum, Rhenium, Selenium, Tellurium, (REEs – in minimal amounts)
Global Reserves	690,000 (in thousand metric tons)
U.S. Reserves	Known total: 35,000 (in thousand metric tons) As Percentage of Global: 5.07%
U.S. Mine Production	Total: 1,120 (in thousand metric tons) As Percentage of U.S. Reserves: 3.2% As Percentage of Global Reserves: 0.16%
Dependency Degree	35%
Main Supplier Nations	Chile, Canada, Peru, Mexico

ZINC
30
Zn
65.39

MAIN TRADITIONAL USES:

Galvanizing, zinc-based alloys, brass and bronze. Compounds and dust used by agriculture, chemical, paint, and rubber industries.

Unlocks the following Tech Metals	Indium, Germanium, Cadmium
Global Reserves	250,000 (in thousand metric tons)
U.S. Reserves	Known total: 12,000 (in thousand metric tons) As Percentage of Global: 4.8%
U.S. Mine Production	Total: 760 (in thousand metric tons) As Percentage of U.S. Reserves: 6.33% As Percentage of Global Reserves: 0.3%
Dependency Degree	73%
Main Supplier Nations	Canada, Peru, Mexico, Ireland

1.1 Gateway Metals hold the Key to Critical Tech Metals

ALUMINUM
13
Al
26.982

MAIN TRADITIONAL USES:

Domestic consumption, transportation, building, electrical, machinery, consumer durables.

Unlocks the following Tech Metals	Gallium, Vanadium
Global Reserves	55,900 (year-end capacity in thousand metric tons)
U.S. Reserves	Known total: 3,200 (in thousand metric tons) As Percentage of Global: 5.72%
U.S. Mine Production	Total: 1,990 (in thousand metric tons) As Percentage of U.S. Reserves: 62.19% As Percentage of Global Reserves: 3.56%
Dependency Degree	13%
Main Supplier Nations	Canada, Russia, China, Mexico

TIN
50
Sn
118.71

MAIN TRADITIONAL USES:

Electrical, cans and containers, construction, transportation.

Unlocks the following Tech Metals	Indium, Scandium
Global Reserves	4,800,000 metric tons
U.S. Reserves	Known total: zero As Percentage of Global: zero
U.S. Mine Production	Zero
Dependency Degree	76%
Main Supplier Nations	Peru, Bolivia, Indonesia, China

1.1 Gateway Metals hold the Key to Critical Tech Metals

NICKEL
28
Ni
58.693

MAIN TRADITIONAL USES:

Stainless steel and alloy steel production, nonferrous alloys and superalloys, electroplating with end uses in transportation, chemical industry, electrical equipment, construction, fabricated metal products and petroleum industry.

Unlocks the following Tech Metals	Cobalt, Palladium, Rhodium, Scandium
Global Reserves	80,000,000 metric tons
U.S. Reserves	Known total: Zero As Percentage of Global: Zero
U.S. Mine Production	Total: Withheld
Dependency Degree	47%
Main Supplier Nations	Canada, Russia, Australia, Norway

THROUGH THE GATEWAY: CRITICAL TECH METALS

Tech metals fuel today's innovations and are critical components of high-tech devices. An example of this is CIGS solar panels (solar cells made from Copper, Indium, Gallium, and Selenium), which were considered so innovative that they made the list of Time Magazine's 50 Best Inventions of 2011. [5] We cannot hope to make America part of the transition to alternative energy if we fail to ensure access to the critical metals that are the precursor to alternative energy manufacturing. Over time, economic activity – and with it, jobs, GDP and Intellectual Property – will go where the metals are. Domestic resource development is the foundational floor for U.S. manufacturing capability in the technology age.

Indeed, almost all of the tech-metals fall into the category of "rare metals." As Gareth Hatch points out: *"The problem with the technology metals is that our supply of them, or more specifically our maximum rates of production of them, is critically dependent mostly upon our production of base metals."*

[5] Time Magazine, The Fifty Best Inventions of 2011, Nov. 28, 2011, http://www.time.com/time/magazine/article/0,9171,2099708-8,00.html. According to Clean Technica, the award-winning panels "are designed to integrate with limitless applications, transforming unused surface area into a source of clean, renewable energy." http://cleantechnica.com/2011/11/25/ascent-solars-flexible-cigs-solar-panels-one-of-times-50-best-inventions-of-2011/.

1.1 Gateway Metals hold the Key to Critical Tech Metals

CADMIUM

MAIN USES:
Alloys, coatings, nickel-cadmium batteries, pigments, and plastic stabilizers.

Unlocked by the following Gateway Metals	Zinc
Global Reserves	640,000 metric tons
U.S. Reserves	Known total: 39,000 metric tons As Percentage of Global: 6.09%
U.S. Mine Production	Total: 600 metric tons As Percentage of U.S. Reserves: 1.54% As Percentage of Global Reserves: 0.09%
Dependency Degree	Net Exporter
Main Supplier Nations	Mexico, Australia, Canada, Germany

COBALT

MAIN USES:
Superalloys, mainly in aircraft gas turbine engines, cemented carbides for cutting and wear-resistant applications, various other metallic applications; and a variety of chemical applications.

Unlocked by the following Gateway Metals	Nickel
Global Reserves	7,000,000 metric tons
U.S. Reserves	Known total: 33,000 metric tons As Percentage of Global: 0.47%
U.S. Mine Production	Total: Zero As Percentage of U.S. Reserves: Zero As Percentage of Global Reserves: Zero
Dependency Degree	75%
Main Supplier Nations	China, Norway, Russia, Canada

GALLIUM

MAIN USES:
Integrated circuits, optoelectronic services including laser diodes, light-emitting diodes, photodetectors and solar cells.

Unlocked by the following Gateway Metals	Aluminum (Zinc – only in Japan)
Global Reserves	Unknown, global production total is 216 metric tons
U.S. Reserves	Unknown, but occurs as byproduct of Bauxite, of which the U.S. has 20,000 metric dry tons
U.S. Mine Production	Zero
Dependency Degree	99%
Main Supplier Nations	Germany, Canada, United Kingdom, China

GERMANIUM

MAIN USES:
Fiber-optic systems, infrared optics, polymerization catalysts, electronics and solar electric applications, phosphors, metallurgy, infrared devices, and chemotherapy.

Unlocked by the following Gateway Metals	Zinc
Global Reserves	N/A
U.S. Reserves	Known total: 450,000 kilograms As Percentage of Global: N/A
U.S. Mine Production	Total: 3,000 kilograms As Percentage of U.S. Reserves: 0.67% As Percentage of Global Reserves: N/A
Dependency Degree	90%
Main Supplier Nations	China, Belgium, Russia, Germany

INDIUM

MAIN USES:
For electrically conductive purposes primarily in flat-panel devices, solders and alloys, compounds, electrical components and semiconductors.

Unlocked by the following Gateway Metals	Zinc, Tin
Global Reserves	Quantitative estimates of reserves are not available
U.S. Reserves	Quantitative estimates of reserves are not available
U.S. Mine Production	Zero
Dependency Degree	100%
Main Supplier Nations	China, Canada, Japan, Belgium

MOLYBDENUM

MAIN USES:
Iron and steel and superalloy production.

Unlocked by the following Gateway Metals	Copper
Global Reserves	10,000 (in thousand metric tons)
U.S. Reserves	Known total: 2,700 (in thousand metric tons) As Percentage of Global: 27%
U.S. Mine Production	Total: 64,000 metric tons As Percentage of U.S. Reserves: 2.37% As Percentage of Global Reserves: 0.64%
Dependency Degree	Net Exporter
Main Supplier Nations	Ferromolybdenum: Chile, China, Canada Ores and Concentrates: Mexico, Chile, Peru, Canada

PALLADIUM/RHODIUM (PLATINUM GROUP METALS)

MAIN USES:
Catalysts to decrease emissions in both light- and heavy-duty vehicles; in chemical sector as catalysts for manufacturing bulk chemicals such as nitric acid and in the production of specialty silicones; in the petroleum refining sector; and in laboratory equipment, electronics sector, glass manufacturing sector.

Unlocked by the following Gateway Metals	Nickel
Global Reserves (All PMGs)	66,000,000 kilograms
U.S. Reserves (All PMGs)	Known total: 900,000 As Percentage of Global: 1.36%
U.S. Mine Production	Total (for Palladium, no other data given): 12,500 As Percentage of U.S. Reserves: unclear as total is for all PMGs As Percentage of Global Reserves: unclear as total is for all PMGs
Dependency Degree	56% for Palladium
Main Supplier Nations	For Palladium: Russia, South Africa, United Kingdom, Norway

RHENIUM

MAIN USES:
Petroleum-reforming catalysts and in superalloys used in high-temperature, turbine engine components, in petroleum-reforming for the production of high-octane hydrocarbons used in the production of lead-free gasoline. Also in nickel-based superalloys. crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and other applications.

Unlocked by the following Gateway Metals	Copper
Global Reserves	2,500,000 kilograms
U.S. Reserves	Known total: 390,000 kilograms As Percentage of Global: 15.6%
U.S. Mine Production	Total: 6,300 kilograms As Percentage of U.S. Reserves: 1.62% As Percentage of Global Reserves: 0.25%
Dependency Degree	87%
Main Supplier Nations	Chile, Netherlands, Germany

SCANDIUM

MAIN USES:
Aluminum alloys for sporting equipment, metallurgical research, high-intensity metal halide lamps, analytical standards, electronics, oil well tracers, and lasers.

Unlocked by the following Gateway Metals	Tin, Nickel
World Mine Production and Reserves	Scandium was produced as byproduct material in China, Kazakhstan, Russia, and Ukraine. Foreign mine production data were not available. No scandium was mined in the United States in 2011. Scandium occurs in many ores in trace amounts, but has not been found in sufficient concentration to be mined for scandium alone. As a result of its low concentration, scandium has been produced exclusively as a byproduct during processing of various ores or recovered from previously processed tailings or residues.
Dependency Degree	100%
Main Supplier Nations	Mostly imported from China, though no definitive data listing import sources exist

SELENIUM

MAIN USES:
Glass manufacturing, catalysts, plating solutions, rubber compounding chemicals, electrolytic production, brass alloys, human and livestock dietary supplement, fertilizer, metallurgical additive to improve machinability of copper lead and steel alloys, certain solar cells.

Unlocked by the following Gateway Metals	Copper
Global Reserves	93,000 metric tons
U.S. Reserves	Known total: 10,000 As Percentage of Global: 10.75%
U.S. Mine Production	Data withheld
Dependency Degree	Net Exporter
Main Supplier Nations	Belgium, Germany, Canada, China

TELLURIUM

MAIN USES:
Alloying additive in steel and other metals, chemical industry, production of solar cells, photoreceptor and thermoelectric electronic devices.

Unlocked by the following Gateway Metals	Copper
Global Reserves (All PMGs)	24,000 metric tons
U.S. Reserves (All PMGs)	Known total: 3,500 metric tons As Percentage of Global: 14.58%
U.S. Mine Production	Data withheld
Dependency Degree	Data withheld
Main Supplier Nations	China, Canada, Philippines, Belgium

VANADIUM

MAIN USES:
Metallurgical use, primarily as alloying agent for iron and steel, and in catalysts.

Unlocked by the following Gateway Metals	Aluminum
Global Reserves	14,000 (in thousand metric tons)
U.S. Reserves	Known total: 45 (in thousand) metric tons As Percentage of Global: 0.32%
U.S. Mine Production	Data withheld
Dependency Degree	80%
Main Supplier Nations	Rep. of Korea, Canada, Austria, Czech Republic

1.1 Gateway Metals hold the Key to Critical Tech Metals

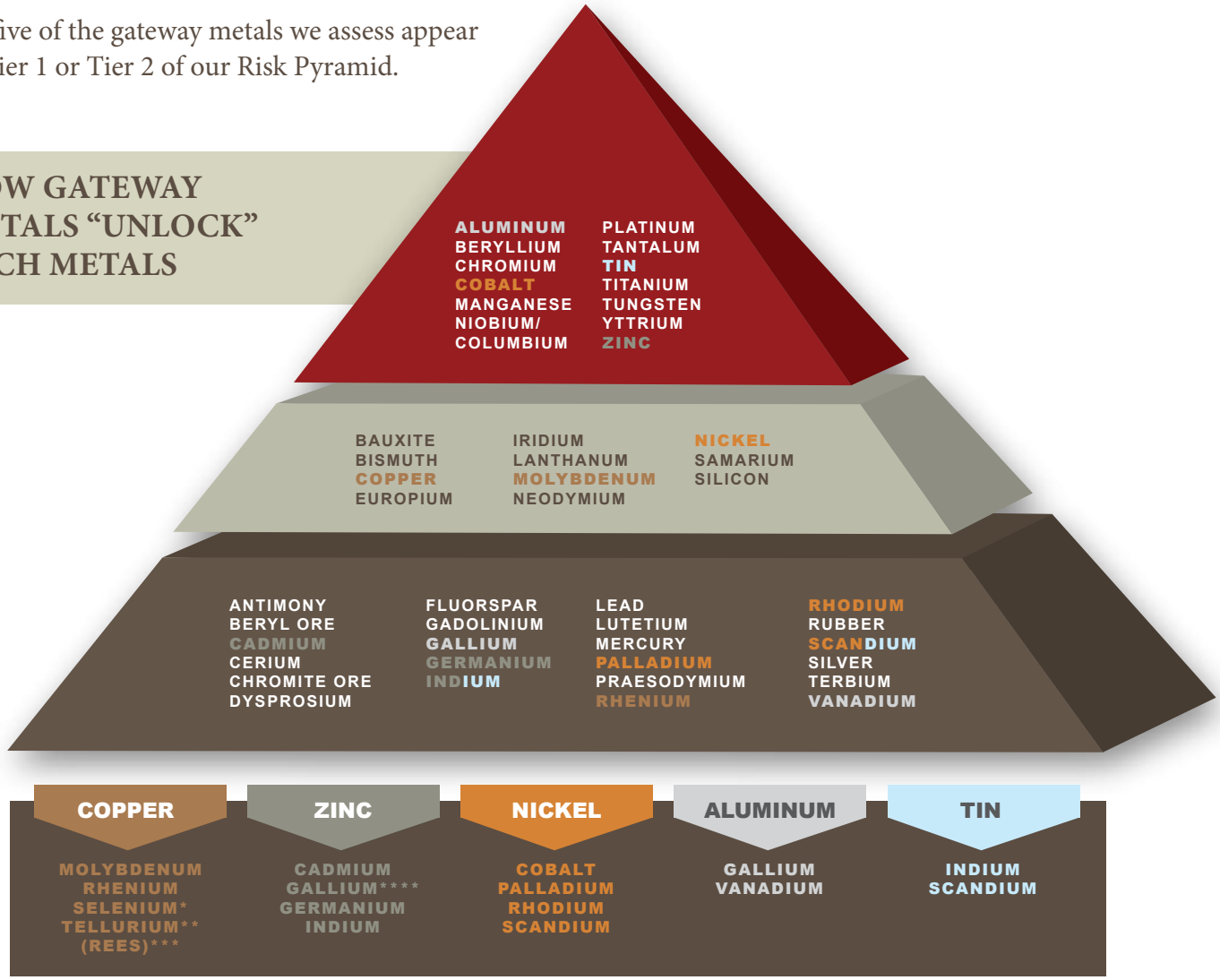
A VISUALIZATION

The following is a modification of the American Resources Risk Pyramid (June 2012),[6] which illustrated "Critical and Strategic Minerals in US Government Studies Relating to National Security," and captured what comes closest to a consensus among federal agencies on which elements may be deemed as "critical and/or strategic metals or minerals."

In its modified form, the graphic below depicts the correlation between certain gateway and tech metals against the background of the U.S. critical mineral strategic context.

All five of the gateway metals we assess appear in Tier 1 or Tier 2 of our Risk Pyramid.

HOW GATEWAY METALS "UNLOCK" TECH METALS



* SELENIUM IS NOT PART OF THE ARPN RISK PYRAMID, BUT MADE THE WATCH LIST, WHICH WAS EXCLUDED FROM THIS GRAPHIC FOR SPACE PURPOSES.
** TELLURIUM IS NOT PART OF THE ARPN RISK PYRAMID, BUT MADE THE WATCH LIST, WHICH WAS EXCLUDED FROM THIS GRAPHIC FOR SPACE PURPOSES.
*** REES ARE DERIVED FROM COPPER IN MINIMAL AMOUNTS.
****GALLIUM IS ONLY A BYPRODUCT OF ZINC PRODUCTION IN JAPAN.

[6] http://americanresources.org/wp-content/uploads/2012/06/ARPN_Quarterly_Report_WEB.pdf

1.2 Opportunity in the Face of Dependency

As both gateway and tech-metals are critical to U.S. commercial manufacturing, green-energy development, technological innovation, and advanced weapons systems, America cannot maintain its modern economy without a steady supply of these key metals and minerals. In a very real sense, these metals are the "gateway" to our future economic, technological and military strength.

To what extent can the U.S. reduce dependency by encouraging domestic production of the gateway metals? Here, we apply one of the screens used in our last report, "Reviewing Risk – Critical Metals & National Security." In our analysis of mineral supply dependencies, we screened for "Opportunity." We identified critical metals and minerals on our Risk Pyramid for which there exists documented U.S. resources, which – if developed – could lessen our resource dependency. [7] Applying our screen to the "gateway metals," we find that for three of the gateway metals assessed – Aluminum, Copper and Zinc – known U.S. reserves suggest that more could be done to reduce our resource dependency.

For Aluminum, which unlocks the tech metals Gallium and Vanadium, the U.S. possesses 5.72 percent of known global reserves. Here, at least, it can be argued that the U.S. lives up to its potential by mining more than 62 percent of its known reserve capacities. As a result, the U.S. is only 13 percent import dependent.

Meanwhile, for Copper – the gateway to Molybdenum, Rhenium, Selenium, Tellurium, and (in minimal amounts) Rare Earths – the U.S. is home to more than 5 percent of global reserves, but U.S. mine production only accounts for 0.16 percent of global reserves -- or 3.2 percent of U.S. reserves respectively. With high import dependency rates for at least Rhenium and Rare Earths, increasing development of the gateway metal would lead to reduced dependencies not only for Copper (import dependency 35 percent), but also its critical tech-metal by-products.

A similar scenario unfolds for Zinc. The U.S. accounts for 4.8 percent of global known reserves but mines only 0.3 percent of them -- 6.33 percent of U.S. reserves. As with Copper, increased exploration and development of the Zinc gateway could yield reduced dependency rates not only for Zinc itself (with U.S. manufacturers relying on foreign sources for 73 percent of their supplies), but also for Indium (for which the U.S. is 100 percent import-dependent at present) and Germanium (at a current resource dependency rate of 90 percent).

[7] For more on resource dependency and associated geopolitical risk, please see "Reviewing Risk. Critical Metals & National Security, http://americanresources.org/wp-content/uploads/2012/06/ARPN_Quarterly_Report_WEB.pdf.

For the gateway metals Nickel and Tin, the situation is entirely different. As we possess zero percent of global reserves for both metals, sourcing from other countries is our only option.

As American Resources indicated in our initial quarterly report, the metals and minerals we possess but fail to develop perpetuate a needless foreign dependence, exposing the U.S. to nations that may choose to use their resource leverage to America's disadvantage. As they hold the key to so many other strategic metals and minerals, gateway metals like Aluminum, Copper and Zinc can play an important role in improving our resource security – with all the benefits that brings to our economic strength, our technological advancement, and our national security.

REPORT FINDINGS

-- The exploration and development of the five gateway metals assessed here ultimately unlock 14[8] of the remaining 41[9] metals and minerals on our Risk Pyramid.

-- If the Rare Earths are counted individually, the 5 gateway metals alone (10 percent of the Risk Pyramid) unlock 25 of the remaining 41 metals – more than 60 percent.

-- Of the five, Copper, Zinc and Nickel lead the pack, each unlocking four tech metals. If we include the occasional instances where a Copper deposit presents with Rare Earths Elements, Copper is the lone gateway metal to unlock five tech metals.

-- In those instances where known U.S. resources exist (Aluminum, Copper and Zinc), focusing on Gateway metal development will reduce foreign dependency and improve U.S. critical metals and mineral access.

[8] 14 counting REEs as "one."
[9] 46 (excluding rubber) minus the 5 Gateways = 41.

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